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United States Department of Commerce

National Bureau of Standards

Miscellaneous Publication 280

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Hydraulic Research in the United States 1966

(Including Contributions from Canadian Laboratories)

Edited by Helen K. Middleton and Gershon Kulin

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PREFACE

The information contained in this publication was compiled from reports by the various hydraulic and hydrologic laboratories in the United States and Canada. The cooperation of these agencies is greatly appreciated. The National Bureau of Standards cannot assume responsibility for the completeness of this publication. We must depend upon reporting laboratories for the completeness of the coverage of their own programs, as well as upon new laboratories engaged in hydraulics to bring their activities to our attention.

Projects are numbered and the number once assigned is repeated for identification purposes until a project is completed. The numbers 5656 and above refer to projects reported for the first time. All projects are in active state, unless otherwise noted under (f).

The National Bureau of Standards does not maintain a file of reports or detailed information regarding the research projects reported by other organizations. Such information may be obtained from the correspondent listed under (c) or immediately following the title of the organization reporting the work. It is of course understood that any laboratory submitting reports on the work will be willing to supply information to properly qualified inquirers.

A similar bulletin, "Hydraulic Research", compiled and published biennially by the International Association for Hydraulic Research, contains information on hydraulic research being conducted in foreign countries. This bulletin is edited by IR H. J. Schoemaker, Director, Delft Hydraulics Laboratory, Delft, Netherlands, and Secretary of the International Association for Hydraulic Research. Copies are available to nonmembers of the International Association for Hydraulic Research from the Secretary at $7.50 each (postage included).

There is now available a Water Resources Research Catalog prepared by the Science Information Exchange of the Smithsonian Institution at the request of the Office of Water Resources Research, U. S. Department of Interior. Volume 1 is for sale by the Superintendent of Documents, U. S. Government Printing Office, in two parts: Part 1, Federally Supported Research in Progress, February 1965 - Price $2.50; Part 2, Non-Federally Supported Research in Progress, September 1965 - Price $1.00. Volume 2 is scheduled for publication during 1966.

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Key to Projects

(a) Number and title of project
(b) Project conducted for
(c) Correspondent
(d) Nature of project
(e) Description
(f) Present status (see Foreword)
(f) Results
(h) Publications

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UNIVERSITY OF ARIZONA.

(4625) CRITICAL TRACTIVE FORCE OF UNIFORM SANDS.

(b) Departmental.
(c) Dr. Emmett M. Laursen, Head, Dept. of Civil Engineering, Univ. of Arizona, Tucson, Arizona 85721.
(d) Analytical and laboratory investigation related to theory. Master's and doctor's theses.
(e) Analytic and experimental attempts to relate the average boundary shear to the incipient movement of sediment particles composing the boundary.
(g) The experimental data plot on a Shield's diagram as two parallel lines for the laminar and turbulent cases. Both cases extend over the range usually considered the transition between a laminar sub-layer and fully rough turbulent flow. An approximate analysis lends credibility to the experimental results.

(4626) SCOUR AT RELIEF BRIDGES.

(b) Departmental.
(c) Dr. Emmett M. Laursen; Department of Civil Engineering, Univ. of Ariz., Tucson, Ariz. 85721.
(d) Laboratory investigation.
(e) To find the effect of sediment size and velocity of flow on the limiting depths of clear-water scour in simple relief-bridge geometries. Long contractions and abrupt contractions will be studied. The experimental data will be compared to an approximate solution of the problem previously published by the principal investigator.

(4627) A STUDY OF PARTIALLY SATURATED FLOW IN SAND-EPOXY RESIN COLUMNS.

(b) Departmental.
(c) Professor Richard L. Sloane; Department of Civil Engineering, Univ. of Arizona, Tucson, Arizona 85721.
(d) Laboratory investigation related to theory; doctoral thesis.
(e) The flow of water through soils often takes place under conditions of partially saturated flow. The prediction of fluid distribution and pressure under conditions of partially saturated flow will make use of vertical columns made of sand grains cemented together with epoxy resin. The use of this type of sand columns will result in a model for which properties such as void ratio and particle arrangement will remain constant during a series of tests.

(4628) RADIOCARBON AS A TRACER IN GROUND WATER PROBLEMS.

(b) Research Corporation and State of Arizona.
(c) Prof. Paul E. Damon, Geology Dept. and Geochronology Lab., University of Arizona, Tucson, Arizona 85721.
(d) Laboratory and field research; doctoral thesis.
(e) The radiocarbon content of ground and surface waters is being used as a tracer to study surface and ground water movement. The data is being related to such ground water problems as the rate of laminar flow through aquifers, their permeability, the source, time and rate of recharge, radioactive contamination in water supplies and the waste disposal problem.
The increase in the carbon-14 content of the atmosphere, biosphere and hydrosphere due to Nuclear Technology is also being monitored.

(4630) MODELS FOR STUDY OF GROUND WATER MOVEMENT.

(b) National Science Foundation.
(c) Dr. J. W. Harshbarger, Project Director, University of Arizona, Tucson, Arizona, 85721.
(d) Laboratory investigation; design, development and operation.
(e) The development of two-dimensional hydraulic models simulating common geological skeletons in consolidated media have made possible demonstrations with actual ground water movement in systems which could be accurately depicted in two dimensions. As many ground water systems require study of the third dimension for full understanding, the development of a three-dimensional porous matrix flow system would permit the construction of three-dimensional ground water flow models. The effects of grain size, various lithologies, boundary conditions, recharge and discharge and well development on ground water movement will then be readily observable in the models.
The immediate objective of this project is to develop a three-dimensional transparent porous media system. The system will consist of a colorless porous media immersed in a colorless liquid with identical indices of refraction.
With the aid of such a system, it will be possible to (1) provide basic descriptions and explanations of three-dimensional laminar flow in unconsolidated porous media, and (2) demonstrate how grain size, lithologic fabric, structural features, hydraulic head and rock pressures are related to ground water movement.
(g) Experiments have been conducted to determine the most suitable solid and liquid media having the same indices of refraction. The media are being combined in a wide range of case designs for testing transparency under several light conditions. Tracer dyes are being developed which will produce the most distinct flow bands in the transparent model.

(5348) OPEN CHANNEL TRANSITIONS.

(b) Departmental.
(c) Dr. E. M. Laursen, Head, Dept. of Civil Engineering, Univ. of Arizona, Tucson, Arizona 85721.
(d) Laboratory investigation for development, master's thesis.
(e) Both contractions and expansions in canal sections are being studied, looking toward improvements in design methods. For the contractions various shapes ranging from the abrupt through circular ellipsoidal walls to the free stream line form will be used. Flow patterns, water surface profiles and head losses are being measured. For the expansion, standard warped sections veined expansions and other shapes are being studied. Flow patterns, water surface profiles and head losses will be measured.

(5349) EFFECT OF SILT LADEN WATER ON INFILTRATION IN ALLUVIAL CHANNELS.

(b) Departmental.
(c) Dr. Emmett M. Laursen, Head, Dept. of Civil Engrg., Univ. of Arizona, Tucson, Ariz. 85721.
(d) Laboratory and field investigation; doctoral thesis.
(e) In arid regions a large part of the natural recharge is through the bed of intermittent streams. A better understanding of the effect of silt content of the flow is needed in order to predict natural recharge and to evaluate works to promote recharge.
(g) The phenomenon is being studied in a 100-foot recirculating tilting flume with a porous bottom which permits infiltration through the bed. Although the infiltration is very dependent upon the past history of the channel, useable values have been obtained for the infiltration as a function of the velocity of flow and the suspended sediment load. The laboratory results

correlate reasonably well with field observations.

(5351) HYDRAULICS OF SURFACE IRRIGATION.

(b) Agricultural Experiment Station, University of Arizona.
(c) Mr. Charles D. Busch, Associate Agricultural Engineer, Dept. of Agricultural Engineering, Univ. of Arizona, Tucson, Ariz. 85721.
(d) Field studies; applied research.
(e) Previous research in surface irrigation hydraulics has developed a theoretical framework for the improvement of surface irrigation systems. This project will contribute through field research for the evaluation of mathematical models that were developed by earlier investigators. Field evaluation will consist of two phases. First, equipment will be perfected to measure and record electronically the advance and recession curves for border furrow irrigation. Second, the equipment will be used for field measurement and evaluation of a variety of surface irrigation systems.
The signal of a float-actuated potentiometer, modulated for a milli-volt recorder, will provide the desired record of water depth. Preliminary data indicate that advance and recession curves will require separate treatment in analysis.

(5354) PREDICTION OF WATER MOVEMENT IN UNSATURATED SOILS.

(b) U. S. Dept. of Agriculture and State of Arizona.
(c) Dr. D. D. Evans, Dept. of Agricultural Chemistry and Soils, Univ. of Arizona, Tucson, Arizona 85721.
(c) Theoretical and experimental; basic research.
(e) The flow of water and energy will be examined under conditions of simultaneous water potential and temperature gradients for the purpose of improving the prediction of flow to evaporative surfaces. Initially, flow will be restricted to one-dimensional steady-state flow to an evaporative soil surface when the water potential and temperature are held constant at the surface opposite the evaporative surface. Water potential and temperature gradients, quantity of flow and appropriate soil properties will be measured and the data used to evaluate different equations developed for predicting flow under those conditions.

(5869) ELECTRICAL ANALOGUE ANALYSIS OF THE TUCSON GROUNDWATER BASIN.

(b) University of Arizona.
(c) Mr. Dennis E. Peterson, Instructor, Geology (Hydrology Dept.), Univ. of Arizona, Tucson, Arizona 85721.
(d) Experimental and analytical.
(e) A lumped parameter resistance-capacitance model is being constructed to simulate the Tucson groundwater basin. The model is based on the analogies between Darcy's law and Ohm's law and between the groundwater and electrical forms of the diffusion equation.
When it is complete, the model will simulate the original steady-state groundwater conditions that existed until approximately 1910 and will duplicate the subsequent water level changes that have occurred due to pumping.
The next step will be to examine the response of the system, in the next 20 years, due to several hypothetical inputs (e.g., pumping due to projected population changes, changes in pumping waters, artificial recharge).

(5870) FLUID DISPERSION IN FLOW THROUGH NON-UNIFORM POROUS MEDIA.

(b) University of Arizona.
(c) Mr. E. S. Simpson, Dept. of Geology, Univ. of Arizona, Tucson, Arizona 85721.
(d) Experimental; basic research.
(e) Dispersion of a fluorescent dye, transverse to direction of flow, is measured by filter paper placed in flow field. After contact with dye, paper is removed and dried and concentration distribution of dye is measured in a fluorometer. A systematic series of experiments is planned to measure transverse dispersion of a dye stream moving across interfaces separating regions of differing permeability and at various angles to flow direction. Experimental data will be analyzed to better understand nature of dispersion in non-uniform media and to further develop theory.

(5871) UNSATURATED SOIL MOISTURE MOVEMENT IN PLANT ROOTS.

(b) Agricultural Research Service, Soil and Water Conservation Research Service.
(c) Prof. C. O. Stanberry, Univ. of Arizona, Tucson, Arizona 85721.
(d) Experimental; basic research.
(e) An idea of Japanese workers is being utilized to study water movement in soils. Water is "tagged" with chlorine and measured with time as it changes the color of potassium dichromate from a deep red color to white. Moisture movement is being studied in pressure-membrane chambers developed at Tucson, Ariz. First the soil is saturated with moisture. Then it is forced out of the soil by a given pressure. Using a sensitive gauge, the pressure is reduced, permitting water with chlorine to move into the soil again. A specially made apparatus is necessary to permit this taking place. The water film thickness is being studied in relation to the movement of the unsaturated moisture.

UNIVERSITY OF ARKANSAS, Agricultural Experiment Station.

(2255) GROUND WATER, RESOURCES AND RECHARGE, IN THE RICE GROWING AREA OF ARKANSAS.

(b) Arkansas Agricultural Experiment Station cooperative with U. S. Geological Survey and U. S. Corps of Engineers.
(c) Prof. Kyle Engler, Head of Agricultural Engineering Dept., University of Arkansas, Fayetteville, Arkansas.
(d) Basic and applied research.
(e) The straight 26-inch sand-packed recharge well has been tested for one year and results have not proved completely satisfactory. Main difficulties encountered arise in duplicating test condition under field situations. The sand packed well seemed to filter out plugging material but redevelopment proved more difficult than in the gravel packed well. Separan AP-30 was tried but proved unsatisfactory for conditions as encountered in this test. A slow gravel filter was constructed and tested as a means of clarifying recharge water during the winter and spring of 1960-61. The slow, gravel filter did not work under the conditions set up on this situation. Turbidity was slightly reduced but not enough to be practical and project was closed out.
(f) Discontinued.
(h) U. S. Geological Survey Water Supply Papers available from the Office of the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402: "Testing Procedures and Results of Studies of Artificial Recharge in the Grand Prairie Region, Arkansas," by R. T. Sniegocki, F. H. Bayley, 3rd, Kyle Engler and J. W. Stephens, 1615-G, 1965, 56 pp.

(4066) HYDRAULICS OF FURROW IRRIGATION.

(b) Arkansas Agricultural Experiment Station.
(c) Prof. Billy B. Bryan, Acting Head, Dept. Agricultural Engineering, University of Arkansas, Fayetteville, Arkansas.
(d) Experimental, field investigations; basic research.
(e) Investigation of fundamental hydraulic criteria involved in flow of water in irrigated furrows (shallow flow in small, open channels). Object is to develop equations for determining (1) rate of stream advance and recession; (2) depression storage; (3) stream size-storage relationships.
(g) Suspended.

(4067) SURFACE DRAINAGE IN BOTTOM LANDS AND TOPOGRAPHY.

(b) Arkansas Agricultural Experiment Station.
(c) Asst. Prof. Warren Harris, Dept. Agric. Engr., Univ. of Arkansas, Fayetteville, Arkansas.
(d) Experimental and field investigations; applied research.
(e) The purpose of this study is to define the physical requirements for adequate drainage of individual crop rows and of field-sized areas in the bottom land soils and topography of the Miss. River Delta. Shallow surface field ditches are the largest drainage structures considered. Findings are based on the assumption that larger drainage structures must be of a size that will not restrict drainage for undue periods of time.
(g) Depressions and restricted outlets have been found to be the basic causes of inadequate drainage in both individual rows and in shallow surface field ditches. Shallow ditches can be designed and constructed so that with a nominal amount of maintenance, they will form only minor obstructions to mechanized farming operations.
(h) "The Warped Surface Method of Land Grading," by Warren Harris, paper presented at joint Southeast and Southwest Regional Meeting of ASAE, Dallas, Texas, February 1,2,3, 1965.
"Field Drain Studies in the Delta," by Warren Harris, Arkansas Farm Research, Vol. XIV, No. 2, March-April, 1965.
"Trends and Construction Techniques for Land Grading in Arkansas," by Warren Harris, paper presented at National ASAE Meeting, Athens, Georgia, June 20-23, 1965.

BATELLE NORTHWEST LABORATORIES, Chemistry Department.

(5699) MATHEMATICAL MODEL ANALYSIS OF FLOW THROUGH PARTIALLY SATURATED HETEROGENEOUS POROUS MEDIA.

(b) Atomic Energy Commission, Division of Biology and Medicine.
(c) Mr. William A. Haney, Manager, Geochemical and Geophysical Research, Battelle-Northwest, P. O. Box 999, Richland, Washington 99352.
(d) Experimental and field investigation; applied research.
(e) The development of mathematical formulations and digital computer models is in progress for analyzing the movement of liquids (radioactive wastes in this instance) through the vadose zone. Interest is in three-dimensional analysis of liquid flow through saturated and unsaturated, heterogeneous soils for steady-state and transient conditions. Methods of measuring soil parameters, capillary pressure, conductivity and moisture content, needed as input data to computer programs are being investigated.
(g) A computer program (STEADY) was developed to analyze steady-state flow conditions in saturated or unsaturated heterogeneous soils. The program, in Fortran II, uses iteration techniques to solve one, two and three dimensional or axisymmetrical cases for up to 8,000 grid points using input data from as many as 15 soil types in the unsaturated system. Inputs are in the form of equations describing relationships between conductivity and pressure and/or moisture content and pressure for each soil type. Work towards transient case solution methods was started recently. An Am^{241} (low energy gamma ray) source technique is being used to make measurements of moisture content, conductivity and pressure simultaneously. Nonnuclear applications of programs are in analyzing seepage losses from irrigation canals, ponds, etc.
(h) "Methods for Solving Problems of Multidimensional Partially Saturated Steady Flow in Soils," A. E. Reisenauer, J. of Geophysical Research, Vol. 68, No. 20, pp 5725-33, October 15, 1963.
"Steady Darcian Transport of Fluids in Heterogeneous Partially Saturated Porous Media," "Part I - Mathematical and Numerical Formulations," R. W. Nelson, AEC Report HW-72335 - Pt. 1, June 1962.
"Part II - The Computer Program," A. E. Reisenauer, et al, AEC Report HW-72335 - Pt. 2, October 1963 (Parts I and II are available from Office of Technical Services, Department of Commerce, Washington, D. C.)
"Description of Soil Characteristics for Partially Saturated Flow," L. G. King, Soil Sci. Soc. Amer. Proc., Vol. 29, No. 4, pp. 359-362, July-Aug. 1965.

(5700) MATHEMATICAL MODEL ANALYSIS OF LARGE COMPLEX GROUND WATER FLOW SYSTEMS.

(b) Atomic Energy Commission, Division of Biology and Medicine.
(c) Mr. William A. Haney, Manager, Geochemical & Geophysical Research, Battelle-Northwest, Richland, Washington 99352.
(d) Experimental and field investigation; applied research.
(e) Work is directed towards the development of mathematical models and associated digital computer programs for accurate analysis of large, complex (heterogeneous soils) groundwater flow systems in three dimensions. Immediate application is in analyzing the movement of radioactive-wastes which might enter the saturated zone. Also, means for evaluating the effects of boundary condition changes on flow systems are under investigation. Methods desired will optimize use of available field input data: Ground-water potentials, boundary conditions in permeability, and flow system physical boundaries.
(g) Two digital-computer programs (GENORO and STREAM) were developed to permit accurate flow system analysis programs, which use ground water potentials in functional form rather than as tabular data, provide determinations of permeabilities, travel paths and travel times using potentials and boundary conditions in permeability as input data. Optimum fitting functions for measured potentials and physical boundaries are being sought. A third program (N-STEADY) is under development for determination of altered potentials due to boundary condition changes. Program testing showed no significant errors in using finite difference approximations. Additional applications are in water resources and petroleum reservoir analysis.
(h) "Stream Functions for Three-Dimensional Flow in Heterogeneous Porous Media," R. W. Nelson, Extract of Publication No. 64, International Association of Scientific Hydrology, Meeting held at Berkeley, California, 1963.
"Genoro, A General Data Fitting and Linear Functional Evaluation Computer Code for the IBM-7090," C. A. Oster, AEC report HW-76692, May, 1963. (Available from the Office of Technical Services, Department of Commerce, Washington, D. C.)
"A Sequence for Predicting Waste Transport by Ground Water," R. W. Nelson, AEC Report BNWL-63, April 1965.

BOLT BERANEK AND NEWMAN INC.

(5190) SOUND RADIATED FROM A TURBULENT BOUNDARY LAYER.

(b) Bureau of Ships Fundamental Hydromechanics Research Program Administered by the David Taylor Model Basin.
(c) Dr. J. E. Ffowcs Williams, Dept. of Mathematics, Imperial College, London, England.
(d) Basic theoretical research.
(e) The research is aimed at clarifying the exact role of a solid surface in determining the mechanism by which sound generated in a turbulent boundary layer is radiated. It is known that if the surface is very large, it merely acts like a passive reflector, and if it is small, it constitutes an additional dipole field. The intermediate size situation remains obscure and it is on this problem that the work is concentrated.
(f) Completed.
(g) The role of a responsive homogeneous surface of infinite extent has been studied. The main result of the analysis is that no fundamentally more efficient source of sound is introduced by the surface motion. The radiation remains quadrupole in character. The surface merely accounts for a reflection of the turbulence generated sound, with the reflection coefficient being identical to that for plane acoustic waves.
(h) Final Report "Theory of Boundary Layer Noise," BBN Technical Report 1301, 13 July 1965 obtainable from David Taylor Model Basin.

(5191) INTERACTION OF DISTRIBUTED SURFACE VIBRATIONS WITH AN ADJACENT BOUNDARY LAYER FLOW.

(b) Bureau of Ships Fundamental Hydromechanics Research Program Administered by the David Taylor Model Basin.
(c) Dr. Francis J. Jackson, Bolt Beranek and Newman Inc., 50 Moulton St., Cambridge, Mass. 02138.
(d) Basic theoretical and experimental.
(e) The program is aimed at studying the stability of a flow in contact with a non-rigid (responsive) wall. The effect of the wall response on the properties of the adjacent boundary layer flow are of special interest. Particular attention is being paid to the effects of actuating the wall motion by external means.
(f) Completed.
(g) An analysis of the Reynolds stress very close to the wall indicates that the direction of energy flux between the mean flow and the boundary layer disturbances (which may give rise to instability) depends upon the properties of the wall, and its response to the pressure fluctuations produced by the disturbance field.
In addition analysis of the interaction between a fluid flow and an adjacent boundary which is excited so as to produce a transverse wave at the fluid-solid interface has been carried out. An idealized treatment permits some conclusions to be drawn as to the conditions under which amplification of the induced boundary layer disturbances occurs as they are transmitted through the steady flow boundary layer.
(h) "Interaction of a Distributed Surface Vibration with an Adjacent Steady Fluid Flow," BBN Technical Report No. 1291, 13 Sept. 1965. Obtainable from David Taylor Model Basin.

POLYTECHNIC INSTITUTE OF BROOKLYN.

(5359) SCOUR TESTS OF NEW JERSEY DAM NUMBER 3.

(b) Hackensack Water Co.
(c) Dr. Chilton A. Wright, Polytechnic Inst. of Brooklyn, 333 Jay St., Brooklyn, New York 11201.
(d) Model study of a particular dam design.
(e) The dam is about 15 ft. high and will be built on a sand foundation. There is a movable gate on the crest. The model is constructed to a scale of 1 to 35 and set in a wooden flume 20 inches wide with a sand bed downstream. The purpose of the project is to study scour and performance of the model under various flows.
(f) Completed.

CALIFORNIA INSTITUTE OF TECHNOLOGY, Division of Engineering and Applied Science.

(1548) PROBLEMS IN HYDRODYNAMICS.

(b) Office of Naval Research, Dept. of the Navy.
(c) Prof. Milton S. Plesset, Calif. Inst. of Tech., Pasadena, California.
(d) Theoretical and experimental; basic research.
(e) Studies of cavitating and noncavitating flow; dynamic behavior of cavitation bubbles; theoretical studies of cavitation damage.
(h) "Stability of a Conducting Fluid Flowing Down an Inclined Plane in a Magnetic Field," by Din-Yu Hsieh, The Physics of Fluids, Vol. 8, No. 10, 1785-1791, 1965.
"Some Analytical Aspects of Bubble Dynamics," by Din-Yu Hsieh, presented at the June Meeting of the ASME, 1965 (in press).
"Effect of Exposure Time on Cavitation Damage," by M. S. Plesset and R. E. Devine, presented at the November Meeting of the ASME, 1965 (in press).

CALIFORNIA INSTITUTE OF TECHNOLOGY, W. M. Keck Laboratory of Hydraulics and Water Resources.

(3671) EVALUATION OF FORMULAS FOR THE TRANSPORT RATE OF SEDIMENT BY ALLUVIAL STREAMS.

(b) Laboratory project.
(c) Prof. Vito A. Vanoni, Calif. Inst. of Tech., Pasadena, Calif. 91109.
(d) Analytical research using published data.
(e) The sediment discharge calculated by several well-known formulas is compared with actual measured sediment discharges in natural streams. The results are presented as graphs of sediment discharge against water discharge.
(f) Project is continuing.

(4075) MECHANICS OF FLOW IN SAND-BED CHANNELS AT VERY LOW RATES OF SEDIMENT TRANSPORT.

(b) National Science Foundation.
(c) Prof. V. A. Vanoni or N. H. Brooks, Calif. Inst. of Tech., Pasadena, California 91109.
(d) Experimental and theoretical research.
(e) Studies are made (1) of the development of dunes with time on a sand bed with flows which produce low rates of sediment transport and of the resulting changes in flow resistance as the dunes grow and (2) on the mechanism of entrainment of sediment by flowing water and (3) of relations of geometric parameters of dunes and the frictional resistance to flow produced by the dunes with a view to predicting resistance from dune dimensions.
(h) "The Growth of Sediment Bed Forms from an Initially Flattened Bed," by Fredric Raichlen and John F. Kennedy, presented at XIth Int'l. Assoc. for Hyd. Research, Leningrad, Sept. 1965.
"Flow Resistance of Dunes in Alluvial Streams," by Li-San Hwang, Thesis, California Institute of Technology, June 1965.

(4561) DYNAMICS OF DENSITY-STRATIFIED RESERVOIRS.

(b) U. S. Public Health Service (research grant).
(c) Prof. Norman H. Brooks, Calif. Inst. of Tech., Pasadena, Calif. 91109.
(d) Basic theoretical and experimental research.

(e) (1) In reservoirs having density variation with depth, the pattern of flow toward an outlet may be quite different from the flow in a homogeneous reservoir. The withdrawal pattern has been studied experimentally in a laboratory tank of water having a linear density profile induced either by dissolved salt or heat. Application will ultimately be in management of water quality in rivers by selective withdrawal from reservoirs.
(2) Research is continuing on the problem of discharge into a stratified environment. When a buoyant jet (or plume) is generated from a point or line source in a stratified ambient fluid, it may rise only to some equilibrium level, then spread in a thin cloud.

(g) (1) At very low Reynolds numbers there is a distinct "withdrawal layer" extending upstream at the level of the outlet. Fluid above and below this layer is not withdrawn through the outlet. Research has been extended from line sinks to point sinks durthe past year with good agreement between theory and experiment. The theoretical analysis based on the laminar boundary layer equations and the diffusion equation for the substance causing density variation. An approximate integral theory, valid for somewhat larger flow rates, has also been developed for both the two-dimensional and axisymmetric cases.
(2) Integral type solutions for buoyant jets and plumes have been made following Morton's approach, with initial variables including mass flux, buoyancy flux, and the momentum flux vector.

(h) "A Free Streamline Solution for Stratified Flow into a Line Sink," by Timothy W. Kao, Journal of Fluid Mechanics (1965), Vol. 21, Part 3, pp. 535-543.
"Viscous Stratified Flow Towards a Sink," by R.C.Y. Koh, Journal of Fluid Mechanics, in press, 1965.
"Stability of Two-Layer Viscous Stratified Flow Down an Inclined Plane," by Timothy W. Kao, The Physics of Fluids, Vol. 8, No. 5, May 1965, pp. 812-820.
"Discharge of Sewage Effluent from a Line Source into a Stratified Ocean," by N. H. Brooks and R.C.Y. Koh, presented at XIth Congress of Int'l. Assoc. for Hydraulic Research, Leningrad, September 1965.

(5013) DYNAMICS OF DENSITY-STRATIFIED GROUND-WATER FLOW.

(b) U. S. Public Health Service (research grant).
(c) Prof. Norman H. Brooks, Calif. Inst. of Tech., Pasadena, Calif. 91109.
(d) Basic theoretical and experimental research.
(e) Slight density variations often affect groundwater flow patterns. Water which is recharged artificially may not mix readily with native waters but develops density stratification in the aquifer. Studies include problems such as overturning of unstably layered systems, flow due to sources of buoyancy and effects of density difference on fluid dispersion in flow through porous media.

(g) (1) Theory and experiments have shown it possible to have a more dense liquid in quasistable horizontal motion above a less dense liquid in a saturated porous medium.
(2) Lateral dispersion in saturated porous media has been shown experimentally to be dependent solely on the Peclet number provided the Reynolds number is low enough for laminar flow. At high Reynolds numbers the dispersion becomes independent of the Peclet number.

(h) "The Stability and Mixing of a Density-Stratified Flow in a Saturated Porous Medium," Ph.D. Thesis by E. John List, Calif. Institute of Technology, Pasadena, Calif, June 1965.
"A Quasi-Stable Density-Stratified Flow in a Saturated Porous Medium," paper presented to Second Australasian Conference on Hydr. and Fluid Mech., Auckland, New Zealand, December 1965.

(5014) WAVE INDUCED OSCILLATIONS OF SMALL MOORED VESSELS.

(b) Dept. of the Army, Corps of Engineers.
(c) Prof. Fredric Raichlen and Prof. Vito A. Vanoni, Calif. Inst. of Tech., Pasadena, Calif. 91109.
(d) Experimental and theoretical research.
(e) Serious ship and dock damage can be caused by wave induced oscillations of moored vessels. The ship and its mooring system constitute a dynamic system capable of resonant oscillations. The objective of this research is to investigate the motion of small boats moored to fixed or floating platforms in a standing wave environment. The study is directed toward an understanding of the problems of mooring small craft in marinas and to providing information that will assist in planning and operation of marinas.
(g) A wave basin with wave generator and measuring and recording equipment have been assembled and the research is proceeding actively. Some prototype measurements of the natural periods and damping characteristics of moored small craft have been made.
(h) "Wave-Induced Oscillations of Small Moored Vessels," F. Raichlen, KH-R-10, W.M. Keck Laboratory of Hydraulics and Water Resources, California Institute of Technology, Oct. 1965.
"Long Period Oscillations in Basins of Arbitrary Shapes," F. Raichlen, Proceedings of the Specialty Conference in Coastal Engineering, Santa Barbara, California, Oct.1965.

(5360) MECHANICS OF SLUG FLOW IN STEEP CHANNELS.

(b) Los Angeles County Flood Control District.
(c) Prof. Vito A. Vanoni and Mr. Richard Brock, Calif. Inst. of Tech., Pasadena, Calif. 91109.
(d) Experimental and theoretical research.
(e) Detailed laboratory observations are being made of slug flows (also called roll waves) with a view to checking the many theoretical studies of this problem and to evaluating problems arising from slug flows in the many high-velocity flood channels in Los Angeles County.

(5361) EXPERIMENTS ON TURBIDITY CURRENTS.

(b) Petroleum Research Fund.
(c) Dr. Gerard V. Middleton, McMaster Univ., Hamilton, Ontario, Canada.
(d) Experimental research.
(e) Comparative studies were made on the behavior of density underflows composed of salt solutions, clay suspensions, and coarse sediment suspensions. Particular attention was devoted to the movement of the head of the current, and to deposition of sediment from the current.
(f) The experiments have been completed and the report is being prepared.
(g) A report on the preliminary experiments is available on request.
(h) "Density Currents Experiments" (abstract). Program, Soc. Econ. Paleontologists and Mineralogists, New Orleans, April 1965.

(5773) LONGITUDINAL DISPERSION IN OPEN CHANNEL FLOW.

(b) U.S. Geological Survey and Laboratory Project.
(c) Prof. Norman H. Brooks, Calif. Inst. of Tech., Pasadena, Calif., 91109.
(d) Experimental and theoretical, laboratory and field; basic research for Ph.D. dissertation.
(e) Contaminants or tracers are dispersed longitudinally in flow in a channel by an interaction of the variable mean flow velocity in the cross section and the transverse turbulent mixing. The purposes of this project are: first, to test the existing theory and determine wherein it fails; second, to identify the dominant mechanisms responsible for dis-

persion in both laboratory and natural situations; and third, to establish a workable method whereby the dispersion characteristics of a natural system can be more closely predicted from a knowledge of the hydraulic characteristics. The project includes participation in a field study being carried out by the U. S. Geological Survey in the Duwamish River and Estuary in the State of Washington.

(g) Large values of dispersion coefficients in rivers are due to effect of horizontal velocity profile as well as vertical velocity profile.

(h) Discussion of "Time of Travel of Soluble Contaminants," by Thomas J. Buchanan, by Hugo B. Fischer, Journal of the San. Eng. Div., ASCE, Dec. 1964, p. 129-130.
Discussion of "Numerical Solution to a Dispersion Equation," by N. Yotsukura and M. B. Fiering, by Hugo B. Fischer, Journal of the Hyd. Div., ASCE, March 1965, pp. 402-407.
Discussion of "Estuarine Water Quality Management and Forecasting," by R. V. Thomann and M. J. Sobel, by Hugo B. Fischer, Journal of the San. Eng. Div., ASCE, June 1965, pp. 126-128.

CALIFORNIA INSTITUTE OF TECHNOLOGY, Hydrodynamics Laboratory.

(3378) HYDRODYNAMICS OF TURBOMACHINES.

(b) Fluid Dynamics Branch, Office of Naval Research.

(c) A. J. Acosta, California Institute of Tech., Pasadena, California.

(d) Experimental and theoretical investigation, basic reseach.

(e) The effort of the past year on this investigation of the hydrodynamics of turbomachines has been mainly devoted to an intensive experimental study of the cavitating flow in a cascade arrangement. It has been found possible to simulate the cascade effect in the High Speed Water Tunnel of the Hydrodynamics Laboratory. Fully wetted flow, partially cavitating and supercavitating flows were investigated under these conditions, using one simple profile shape (a plano-convex hydrofoil) and one basic stagger angle (45 degrees).

(g) The fully wetted and fully cavitating flows were in reasonably good agreement with theoretical predictions. Under conditions of partial cavitation, strong flow oscillations take place similar to those on isolated hydrofoils.

(h) "Cavitation in Cascade," by A. J. Acosta, Hydrodynamics Lab., Calif. Inst. of Tech., Film Report No. E-79.7, presented at ASME Winter Meeting, Chicago, Nov. 7-11, 1965.
"Investigations on Cavitating Hydrofoils," by R. B. Wade, PhD Thesis, Calif. Inst. of Technology, 1965.
"Experimental Observations on the Flow past a Plano-Convex Hydrofoil," by R. B. Wade and A. J. Acosta, Hydrodynamics Lab., Calif. Inst. of Tech., Report No. E-79.8; also appeared as ASME Paper No. 65-FE-3, 1965.
"Linearized Theory of a Partially Cavitating Plano-Convex Hydrofoil Including the Effects of Camber and Thickness," by R. B. Wade, submitted to Journal of Ship Research, 1965.

(5035) FORCES ACTING ON A BODY DURING WATER EXIT.

(b) Bureau of Weapons, Dept. of the Navy.

(c) Prof. A. T. Ellis and Dr. J. G. Waugh, Calif. Institute of Technology, Pasadena, Calif.

(d) Experimental and theoretical investigation. Basic research.

(e) To assess the validity of theories for determining added mass in the presence of a free surface and hydrodynamic effects on missiles in the neighborhood of, or approaching a free surface. To provide experimental data on surface effects on missiles of simple mathematical configuration under conditions of cavitating flow which might be used as a basis for further theoretical developments.

(g) The following studies were made in collaboration with the U. S. Naval Ordnance Test Station, Pasadena, Calif.:
(1) A series of tests was made to determine the added mass of a 1-inch-diameter steel sphere impulsively accelerated vertically upward from rest along the axis of Lucite cylinders filled with water and the results correlated with ideal fluid theory. No free surface effects were involved. The sphere was accelerated electromagnetically and the acceleration regime was sufficiently brief so that essentially potential frictionless flow obtained. Eight cylinders were used whose inside diameters ranged from 1.11 to 4.45 inches. The agreement between experiment and theory was very good.
(2) Further tests were made to determine the effect of water surface proximity on the added mass of a 1-inch-diameter steel sphere accelerated vertically upward from rest in open water and the results correlated with ideal fluid theory. Again, essentially frictionless potential flow obtained during the acceleration regime. The agreement between experiment and theory was very good and the results indicate that surface proximity has practically no effect on the added mass until the sphere center is about two diameters from the surface. For lesser depths, the added mass decreases with depth.
(3) Several techniques for metric photography were developed and used in the studies above. In the first, missile position-time data are obtained from measurement of photographs of the virtual image produced in a precision-ground sphere by a timed stroboscopic point-source lamp. In the second, a rotating circular film disk is covered with sector-shaped exposures using a timed stroboscopic lamp. In the third, the previously described techniques are combined to obtain data simultaneously.
(4) In addition to the above collaborative studies, an experimental and theoretical evaluation of the viscous drag forces acting on a sphere launched impulsively from rest along the axis of a cylinder in a viscous liquid was made at the California Institute of Technology.

(h) "The Variable-Atmosphere Wave Tank," by J. G. Waugh and A. T. Ellis. Published in Cavitation Research Facilities and Techniques, 1964. The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th St., New York, N. Y., pp. 114-117.
"Techniques for Metric Photography," by J. G. Waugh, A. T. Ellis and S. B. Mellsen. Submitted for publication in the Journal of Society of Motion Picture and Television Engineers.

(5770) EXPERIMENTAL STUDIES OF UNSTEADY CAVITY FLOW.

(b) Fluid Dynamics Branch, Office of Naval Research.

(c) A. J. Acosta, Calif. Inst. of Tech., Pasadena, California.

(d) Experimental and theoretical investigation. Basic research.

(e) The concern of this research program has been the measurement of non-steady forces on simple hydrofoil shapes due to a steady imposed heaving oscillation. A method and equipment for force measurement have been developed, and experiments have been conducted on several hydrofoils of aspect ratio unity in the Free Surface Water Tunnel. These include: a four percent thick, flat plate hydrofoil with sharp leading and trailing edges, a wedge with included angle of 8 degrees, and a plano-convex hydrofoil of 8 percent thickness.

(g) The fully wetted experiments are in reasonable agreement with theoretical experiments. Base vented hydrofoils act essentially the same as fully wetted hydrofoils. The flat

plate hydrofoils were also ventilated from the leading edge. The dynamic force coefficients were not in agreement with theories based on the assumption of a constant pressure within the cavity.

(h) "Some Preliminary Measurements of the Unsteady Forces on an Oscillating Hydrofoil," by A. J. Acosta and G. J. Klose, presented to Society of Naval Architects and Marine Engineers Panel on Hydroelasticity, Nov. 1965, Stevens Institute of Technology, Hoboken, New Jersey.

(5771) RESEARCH ON CAVITATING RING WINGS.

(b) Bureau of Naval Weapons and Office of Naval Research, Department of the Navy.
(c) A. J. Acosta, Calif. Inst. of Tech., Pasadena, California.
(d) Experimental and theoretical investigation. Basic research.
(e) Research covers an investigation of cavitating and ventilated ring wings in the Hydrodynamics Laboratory, including model construction, testing and analysis of results. The immediate objective of this work was to explore the feasibility of using partial ventilation to control vehicles equipped with ring tails and to evaluate a suitable design theory. This required systematic investigation of the effect of changes in chord diameter ratio, velocity, and cavitation number in both fully wetted and ventilated flows.
(h) "Measurements on Fully Wetted and Ventilated Ring Wing Hydrofoils," by A. J. Acosta, E. R. Bate, Jr., and T. Kiceniuk, Hydrodynamics Laboratory, Calif. Inst. of Tech., Report No. E-138.1, June 1965.

(5772) INVESTIGATIONS IN HYDRODYNAMICS OF UNDERWATER ORDNANCE.

(b) U. S. Naval Ordnance Test Station, Pasadena, California, (Bureau of Naval Weapons, Dept. of the Navy).
(c) A. J. Acosta, T. Y. Wu, T. Kiceniuk.
(d) Experimental and theoretical investigation. Basic research.
(e) Fundamental and design investigations in the field of hydrodynamics of underwater ordnance. These have included studies of the forces acting on underwater bodies when fully wetted and when cavitating.
(f) Discontinued.
(h) "Some New Measurements on the Drag of Cavitating Disks," by G. J. Klose and A. J. Acosta, Journal of Ship Research, Vol. 9, No. 2, p. 102, September 1965.
"Superventilated Flow Past Delta Wings," by T. Kiceniuk, Hydrodynamics Laboratory, Calif. Inst. of Tech., Rept. No. E-101.5, July 1964; also , "Experiments on Delta Wings in Superventilated Flow," by T. Kiceniuk, submitted for publication to the Journal of Ship Research, 1965.
"Experiments on Gravity Effects in Supercavitating Flow," by T. Kiceniuk and A. J. Acosta, in preparation.

UNIVERSITY OF CALIFORNIA, College of Agriculture, Department of Water Science and Engineering.

(23) HYDROLOGY OF IRRIGATION SUPPLIES IN CALIFORNIA.

(b) University of California.
(c) Prof. R. H. Burgy and Mr. D. C. Lewis, Dept. of Water Science and Engineering, Univ. of California, Davis, California.
(d) Experimental and field investigation; applied research.
(e) Hydrologic investigations of mountain watersheds are being conducted on pilot watersheds in three areas of the state. Measurements are being made of rainfall, surface runoff, erosion, and groundwater storage and outflow. The hydrologic effect of vegetative conversions on the watersheds is under long-range study. Various tracer techniques are used to study groundwater movement and sources of water for native vegetation water uptake. Moisture movement and storage above water tables in fractured rock mantles are measured with neutron scattering meters, combined with seismic and resistivity methods. Micrometeorological techniques and equipment are being tested to provide an independent evaluation of evapotranspiration from the study watersheds.
(h) "Water Use by Native Vegetation and Hydrologic Studies", by D. C. Lewis and R. H. Burgy, Annual Report No. 6, 1964-65, Dept. of Water Science and Engineering, Univ. of Calif., Davis, Calif. Jan. 1965.
"Hydrologic Balance From an Experimental Watershed," by D. C. Lewis and R. H. Burgy. Jour. of Hydrol. 2: 197-212, 1964. North Holland Publishing Co., Amsterdam.

(1819) DRAINAGE IN RELATION TO IRRIGATION.

(b) University of California.
(c) Dr. J. N. Luthin and Mr. J. Woerner, Univ. of California, Davis, California.
(d) Basic and applied research.
(e) The development of computer programs and solutions of problems involving surfaces of seepage, unsaturated flow above the water table and transient flow phenomena has continued with some success. A variety of problems have been solved including the steady-state rainfall equilibrium problems for sloping land.
The Hele-Shaw viscous flow model has been used for both steady-state and transient flow problems involving ditch and tile drains on lands of all slopes. In addition, it was used to test existing transient drain spacing theories.
(h) "Viscous Model Study of Drain Spacing on Sloping Land and Comparison with Mathematical Solution," by J. C. Guitjens and J. N. Luthin. Water Resources Res. 1:523-530. 1965.

(4086) MISCIBLE AND IMMISCIBLE FLUID DISPLACEMENTS IN RELATION TO SOLUTE MOVEMENT IN SOIL AND OTHER POROUS MATERIAL.

(b) University of California.
(c) Drs. J. W. Biggar and D. R. Nielsen, Dept. of Water Science and Engineering, Univ. of California, Davis, California.
(d) Theoretical and experimental; basic and applied.
(e) The simultaneous transport of fluids and solutes through porous media is under investigation. The mixing and spreading of the fluids in the medium, the interaction of the fluids with each other and the medium have been studied. The work will help define the nature of the porous structure of materials, and the coupling between velocity and diffusion in the dispersion process. Leaching phenomena, disposal of industrial and radioactive wastes, and the movement of pesticides in soil water depend upon the dispersion process.
(g) Transient water and salt conditions in columns of soil are currently under study. These conditions involve, among other complex processes, the hysteritic moisture content-pressure relation and the rate dependence of this relation. The mixing processes in unsaturated medium which have not been understood are als involved. Field experiments demonstrating the importance of mixing in saturated and unsaturated soils have been completed. A computer program for predicting leaching of salts has been improved to include a variable K and mixing processes.
(h) "Chloride Displacement in Panoche Clay Loam in Relation to Water Movement and Distribution," by R. J. Miller, J. W. Biggar and D. R. Nielsen. Water Resources Research 1:63-73, 1965.

(4088) IRROTATIONAL FLOW OVER A VERTICAL, SHARP-CRESTED WEIR.

(b) University of California.
(c) Dr. Theodor S. Strelkoff, Dept. of Water Science and Engineering, Univ. of California, Davis, California.
(d) Theoretical, basic research.
(e) A digital computer is used to carry out the approximate numerical solution of an exact integral equation, derived by conformal mapping and singularity distribution, and describing the two-dimensional flow over weirs ranging in height from zero to infinity. Effect of rotationality on an inviscid flow is studied by a relaxation solution of the Poisson equation in the stream function.
(g) A velocity distribution imposed as a boundary condition far upstream from a free overfall results more closely in accord with experiment than results of potential theory.
(h) "Inviscid Rotational Flow with a Free Surface and Gravity," by M. Moayeri. Ph.D. Dissertation, University of California, 1965.

(4857) USE OF WELLS IN AREA DEVELOPMENT.

(b) University of California.
(c) Dr. V. H. Scott, Department of Water Science and Engineering, Univ. of California, Davis, California.
(d) Theoretical and field research including doctoral thesis research.
(e) These studies are in progress: (1) Effect of well interference on discharge and drawdown of individual wells; (2) Evaluation of aquifer characteristics from transient well discharge tests; (3) Dimensional analysis approach to groundwater flow in confined and unconfined aquifers; (4) Optimum schedule for cyclic operation wells; (5) Hydrologic balance of a two-aquifer system under conjunctive use of imported surface and groundwaters; (6) Artificial recharge through injection wells into confined and unconfined aquifers; (7) The potential for groundwater recharge by trenches or down wells; (8) Groundwater recharge through a multiple well system along a coastal aquifer.
(g) (1) A study on the combined effects of well interferences, location of aquifer boundaries and variations in discharge on the piezometer water table and well yields was made; (2) Simple graphical procedures were developed for evaluating the hydraulic characteristics in a confined aquifer pumped at a gradually or stepwise changing discharge rate; (3) The relationships between drawdown, discharge and aquifer characteristics in confined and unconfined aquifers was analyzed and presented in dimensionless form; (4) Guidelines for determining a cyclic pumping schedule to obtain a constant residual drawdown after each completed cycle are under study; (5) A mathematical model of a confined aquifer overlain by an unconfined aquifer replenished by surface recharge is being formulated; (6) Numerical solutions for recharge into confined or unconfined aquifers are being determined by computer techniques and will be presented in dimensionless form; (7) A study on the comparative capacity and cost of recharge wells versus shallow ditches was performed; (8) General criteria are being sought for the optimization of recharge well location and recharge operations to prevent sea water intrusion in coastal regions.
(h) "Effects of Well Interference on Discharge and Drawdown in Individual Wells," by Y. M. Sternberg. Ph.D. Thesis, Univ. of California, Davis, 1965.
"Determination of Confined and Unconfined Aquifer Parameters by Dimensional Analysis," by G. J. Kriz. Ph.D. Thesis, Univ. of California, Davis, 1965.
"Simplified Solution for Decreasing Flow in Wells," by G. Aron and V. H. Scott. Jour. Hyd. Div., ASCE, HY5, pp. 1-12, 1965.
"Analysis of Data from Stepwise Throttle Pump Tests," by G. Aron and V. H. Scott. In press, ASCE, Hyd. Division.

(5142) VARIABLE FLOW UNDER A VERTICAL GATE.

(b) University of California.
(c) Dr. Theodor S. Strelkoff, Dept. of Water Science and Engineering, Univ. of Calif., Davis, California.
(d) Experimental, theoretical; basic research, for Ph. D. dissertation.
(e) Time-dependent flows under sluice gate moving vertically in its own plane are being studied in a laboratory flume. A numerical, quasi-steady, potential-flow analysis is being developed to complement the experimental investigation.
(g) The case of steady flow under a gate has been solved for gate-opening: total-head ratios of 0.1, to 0.53.

(5143) PROFILE OF A WETTING FRONT ADVANCING IN AN IRRIGATION BORDER.

(b) University of California.
(c) Dr. Theodor S. Strelkoff, Dept. of Water Science and Engineering, Univ. of Calif., Davis, California.
(d) Experimental, theoretical; applied research for Ph.D. dissertation.
(e) This is a special case of surge on a dry bed. Vegetation is simulated in a laboratory flume by an array of uniformly distributed vertical rods set into the bottom. Flow is introduced at the head end, and the passage of the wave through the rods is measured by electrical depth gauges. The unsteady flow is being analyzed by a numerical method related to the characteristic equations.

(5144) UNSTEADY FLOW IN OPEN CHANNELS.

(b) University of California.
(c) Dr. Theodor S. Strelkoff, Dept. of Water Science and Engineering, Univ. of California, Davis, California.
(d) Theoretical; basic research.
(e) A computer-implemented numerical solution is being developed for the one-dimensional continuity, momentum, and energy equations of unsteady flow in canals of arbitrary cross-sectional form. A method is sought which will permit automatic tracking of spontaneously formed shock-discontinuities in the profile. Under investigation are various finite-difference and integral methods.
(g) An effective computer program has been developed for gradually variable flow with surface profile discontinuities only at checks, siphons and pumping plants. Arbitrary initial and boundary conditions of depth, velocity and discharge are easily introduced. Computations have shown satisfactory agreement with field tests conducted in the Delta-Mendota Canal.
(h) "Gradually Varied Unsteady Flow in a Controlled Canal System," by Theodor Strelkoff and J. Amorocho. Presented at XI Congress of the International Association for Hydraulic Research, Lenigrad, September, 1965. (Will be published in Proc. of the Congress.)
"Hydraulic Transients in the California Aqueduct," by J. Amorocho, T. Strelkoff, W. E. Hart and A. Babb. W. S. and E. Paper 1002:1-73. June 1964.
"Hydraulic Transients in the California Aqueduct," Report No. 2. J. Amorocho and T. S. Strelkoff. W. S. and E. Paper 1008:1-76. June 1965.

(5145) GENERALIZED ANALYSIS OF SMALL WATERSHED RESPONSES.

(b) University of California.
(c) Professor J. Amorocho, Dept. of Water Science and Engineering, Univ. of Calif., Davis, Calif.
(d) Theoretical and experimental investigation; basic and applied research.
(e) (1) Studies on the mathematical theory of nonlinear systems with lumped and with distributed parameters. (2) Characterization of time- and space-variable rainfall dis-

tributions. (3) Development of methods for the establishment of nonlinear inflow-outflow relationships for natural catchments. (4) Laboratory and field application of (3) above.

(g) A method has been developed for the characterization of gage level precipitation patterns, which expresses the input to a hydrologic system in terms of the coordinates of a point in the catchment and time. This method has been applied to California watersheds and has led to the preliminary establishment of criteria for the design of precipitation networks for hydraulic analysis. New equipment is now under test for the simulation of special distribution of rainfall over a catchment.

(h) "Use of Laboratory Catchments in the Study of Hydrologic Systems," by J. Amorocho and W. E. Hart. Jour. of Hydrology 3:106-123, 1965. "The Characterization of Gage Level Precipitation Patterns," by J. Amorocho and A. Brandstetter. In press.

(5146) THE EFFICIENCY OF ENERGY DISSIPATORS.

(b) University of California.
(c) Dr. J. Amorocho, Dept. of Water Science and Engineering, Univ. of Calif., Davis, Calif.
(d) Theoretical and experimental investigation; applied research.
(e) Development of analytical criteria for the efficiency of energy dissipating structures in terms of the characteristics of the flow stream delivered and the shear stresses over the boundary of the receiving channels. Experimental evaluation of efficiencies from hydraulic model data.
(g) "Energy efficiency" and "shear efficiency" criteria have been developed as means of evaluating: (1) The effectiveness of a structure in dissipating energy; and (2) the scouring potential of the outflowing water. Experiments with a vortex-type energy dissipator, and with a classical open chute structure, illustrate application of these criteria for designs based on hydraulic model investigations. In the course of recent studies, a comprehensive investigation of velocity distributions in flow area where the boundary layer is not fully developed has been advanced.

(5861) THE MECHANICS OF OPEN CHANNEL FLOW SYSTEMS.

(b) University of California, Davis.
(c) Prof. J. Amorocho and Prof. T. S. Strelkoff, Dept. of Water Science and Engineering, Univ. of California, Davis, California.
(d) Theoretical and experimental investigations.
(e) Comprehensive analytical and experimental study of phenomena encountered in the operation of complex open channel systems with multiple controls. Development of mathematical models of the systems for steady and unsteady state operation.
(g) Preliminary models for the study of hydraulic transients in gated channels have been developed.
(h) "Hydraulic Transients in the California Aqueduct," W. S. and E. Paper 1008:1-76. June 1965.

(5862) BEHAVIOR OF LARGE PUMPING PLANT SIPHON-DISCHARGE LINES.

(b) University of California, Davis.
(c) Prof. J. Amorocho and Mr. A. Babb, Dept. of Water Science and Engineering, Univ. of California, Davis, California.
(d) Hydraulic model studies.
(e) Investigation of energy losses due to air entrapment at the crests of large pumping plant discharge siphons due to the release of air in solution from the water stream due to pressure reduction near siphon crests.

(5863) OVERFLOW AND UNDERFLOW DISCHARGE COEFFICIENTS FOR RADIAL GATES.

(b) University of California, Davis.
(c) Professor J. Amorocho and A. Babb, Dept. of Water Science and Engineering, Univ. of California, Davis, California.
(d) Experimental, applied research.
(e) Theoretical and experimental investigation of discharge coefficients of radial gates under steady and unsteady states for the cases of simultaneous gate overflow and underflow, and for siturations of flow reversal. The purpose of the study is to establish the theory and to obtain experimental data applicable to the analysis of surge problems in gate-controlled open channel systems in which flow reversal can be expected.

(5864) DEL VALLE DAM GLORY HOLE SPILLWAY.

(b) University of California, Davis.
(c) Prof. J. Amorocho and A. Babb, Dept. of Water Science and Engineering, Univ. of California, Davis, California.
(d) Model studies for design development.
(e) Study of glory hole spillway for a Calif. dam. Investigation of the effect of the asymmetrical flow field created by the topography of the reservoir in the immediate vicinity of the spillway on the overflow capacity. Effects of discharges from the river outlet into the spillway tunnel on the performance of the structure.

(5865) MIXING CHAMBER FOR WATERS OF DIFFERENT QUALITIES.

(b) University of California, Davis.
(c) Prof. J. Amorocho and Mr. A. Babb, Dept. of Water Science and Engineering, Univ. of California, Davis, California.
(d) Hydraulic model investigation for design development.
(e) Development of a mixing chamber for obtaining homogeneous quality in the mixture of two dissimilar water supplies. The optimization of this device is sought in terms of mixing qualities and minimum energy losses.

(5866) FLOW CONVEYANCE EFFICIENCY OF TRANSITIONS AND CHECK STRUCTURES IN A TRAPEZOIDAL CHANNEL.

(b) University of California, Davis.
(c) Prof. J. Amorocho and Mr. A. Babb, Dept. of Water Science and Engineering, Univ. of California, Davis, California.
(e) Investigation of the flow conveyance efficiency of transitions and check structures in the California Aqueduct. A detailed study of energy conversion effects was performed on a 1:16 scale model of structures with various inlet and outlet transition configurations.
(f) Completed.
(g) The design of the check structures was optimized; substantially smaller losses than those predicted by conventional design analysis were obtained. Data for detailed analysis of the flow field in the zones of separation were obtained.
(h) "Flow Conveyance Efficiency of Transitions and Check Structures in a Trapezoidal Channel (California Aqueduct)," by Alan Babb and J. Amorocho. Water Science and Engineering Paper 1007, Dept. of Water Science and Engineering, Davis, June 1965.

(5867) EFFECTS OF FOREBAY CONFIGURATIONS ON THE FORMATION OF VORTICES NEAR PENSTOCK ENTRANCES.

(b) University of California, Davis.
(c) Prof. J. Amorocho and Mr. A. Babb, Dept. of Water Science and Engineering, Univ. of California, Davis, California.
(d) Model studies for design development.
(e) Study of flow field parameters affecting the formation of vortices near power plant penstock inlets.
(f) Completed.

(g) A new design involving the construction of a skirt wall overhanging the penstock inlets, together with improvements in the inlet and approach channel configurations proved to be very effective in the total elimination of vortices created by unfavorable approach conditions.
(h) "Effects of Forebay Configurations on the Formation of Vortices Near Penstock Entrances," by J. Amorocho and A. Babb. Progress Report No. 1. Water Science and Engineering Paper 1009, Dept. of Water Science and Engineering. September 1965.

(5868) DEL VALLE DAM AND SPILLWAY.

(b) University of California, Davis.
(c) Prof. J. Amorocho and A. F. Babb, Dept. of Water Science and Engineering, Univ. of California, Davis, California.
(d) Model studies for design development.
(e) The study of a non-gated ogee-crested chute spillway including the effect of upstream geometry upon the flow configurations within the chute. Shock wave patterns in the spillway were studied in some detail. This configuration includes an auxiliary flood control outlet tunnel discharging through a large opening in the spillway floor which was tested for various combinations of flood control and spillway discharges.
(f) Completed.
(g) Shock wave patterns occurring in the open chute were compared with predicted patterns computed on the basis of conventional theory. Shock wave nodes were partially eliminated by modifications in the configuration of the chute.

UNIVERSITY OF CALIFORNIA, BERKELEY, Dept. of Civil Engineering, Fluid Mechanics Laboratory.

(1554) SEA WATER CONVERSION RESEARCH.

(b) State of California.
(c) Prof. Everett D. Howe, Coordinator, Saline Water Conversion Research, University of Calif., 1301 South 46th Street, Richmond, California.
(e) The purpose of this project is to discover whether there is available any method for the large-scale, low-cost demineralization of sea water. The project includes a number of investigations, of which the following have been active during 1964-65: (1) Multiple effect rotating evaporator; (2) evaporation by immiscible fluid heat transfer; (3) vacuum flash distillation (low temperature difference method); (4) solar distillation; (5) electrodialysis tests; (6) freeze-separation; (7) ion exchange; (8) biological studies; (9) capillary control of vapor transfer gaps; (10) reverse osmosis pilot plant; (11) thermodynamic and economic analysis; (12) experimental heat transfer studies; (13) transport phenomena near a liquid-vapor interface; and (14) fundamental studies of corrosion processes. Investigations are being carried on at the Berkeley, Los Angeles and San Diego Campuses.
(g) Detailed results may be obtained from the progress reports and publications listed under (h) below. This project has been active since 1951-52 and previous summaries have listed all reports prior to July 1964.
(h) The following reports and publications have been issued during the period since July 1964 and summarize the work to date:
UNIVERSITY OF CALIFORNIA AT LOS ANGELES:*
"Evaporation Experiments With Wiped and Falling Saline Water Films," R. Webb, W. Unterberg & W. Gregson, Department of Engineering Report No. 64-23, 123 pp., August 1964.
"Field Tests on Osmotic Desalination Membranes," S. Loeb & S. Manjikian, Dept. of Engineering Report No. 64-34, 28 pp., July 1964.
"Saline Water Research," Project Staff, Dept. of Engineering Report No. 65-1, 78 pp. January 1965.
"Appropriate Electrolytic Additives in Cellulose Acetate Casting Solutions for Reverse Osmosis Desalination Membranes," S. Loeb, Dept. of Engineering Rpt. No. 65-4, 175 pp. January 1965.
"Semipermeable Desalination Membranes From Organic Casting Solutions," S. Manjikian, Dept. of Engrg. Rpt. No. 65-13, 41 pp. Mar., 1965.
"Corrosion Studies-Part 1- Theory of Organic Corrosion Inhibitors. Adsorption and Linear Free Energy Relationships, Part II - Capacitance and Transient Techniques in the Polarization of Iron," F. M. Donahue & K. Nobe, Dept. of Engrg. Rpt. No. 65-17, 19 pp., April 1965.
"Gradients in Temperature Across a Vapor-Liquid Interface Undergoing Steady-State Evaporation," J.L. Dyer, R.L. Perrine, Dept. of Engrg. Rpt. No. 65-27, 59 pp., July 1965.
"Corrosion Studies-Pt. III-Anodic Polarization of Impure and Higher Purity Nickel in H_2SO_4, " R. R. Sayano, K. Nobe, Dept. of Engrg. Rpt. No 65-38, 35 pp. Sept. 1965.
"Corrosion Studies - Part IV - Kinetics of Uninhibited Iron," F. M. Donahue & K. Nobe, Dept. of Engrg. Rpt. No.65-39, 46 pp, Sept. 1965.
"Corrosion Studies - Part V - Kinetics of Consecutive Electrode Reactions on Iron," F. M. Donahue & K. Nobe, Dept. of Engineering Report No. 65-40, 25 pp., September 1965.
"Passivity of Inconel in Acidic Chloride Solutions," E. P. Koutsoukos & K. Nobe, Dept. of Engrg. Rpt. No. 65-41, 15 pp., Sept. 1965.
"Corrosion Studies-Part VII-Corrosion Inhibition of Iron With Aniline and Substituted Aniline Compounds," F.M. Donahue, A. Akiyama & K. Nobe, Dept. of Engrg. Rpt. No. 65-44, 44 pp., Sept. 1965.
UNIVERSITY OF CALIFORNIA, BERKELEY**
"Sea Water Entrainment in Low Temperature Flash Evaporators," by E. I. Ewoldsen, P. Dattani, A. F. Mills, E. M. Stocking, Sea Water Conversion Lab Rpt. No. 64-3, 41 pp., December 1964.
"1964 Progress Rpt., Berkeley & San Diego Campuses," E.D. Howe et al, Sea Water Conversion Lab. Rpt. No. 65-1, 47 pp., Feb.1965.
"Saline Water Softening By Fixed-Bed Ion Exchange Equilibrium-State Computation Method for Multicomponent Systems," by P. Pandya, G. Klein, & T. Vermeulen, Sea Water Conversion Lab. Rpt. No. 65-2, 40 pp., June 1965.
"Multicomponent Ion Exchange In Fixed Beds Operated Under Equilibrium Conditions-Part 1-General Properties of Uniformly Presaturated Beds Receiving Feed of Constant Composition," G. Klein, D. Tondeur & T. Vermeulen, Sea Water Conversion Lab. Rpt. No. 65-3, 59 pp., June 1965.
"Multicomponent Ion Exchange In Fixed Beds Operated Under Equilibrium Conditions - Part II - Constant-Separation-Factor Systems," by D. Tondeur, G. Klein & T. Vermeulen, Sea Water Conversion Laboratory Report No. 65-3, 59 pp., July 1965.
"Condensation On And Evaporation From Radially Grooved Rotating Disks," by L. A. Bromley, R. F. Humphreys & William Murray, Sea Water Conversion Lab. Rpt. No. 65-5, 25 pp. July 1965.
"Solar Distillation Problems in the Developing Countries," by E. D. Howe, ASME Paper No. 64-WA/SOL-7, presented at the Annual Meeting of the American Society of Mechanical Engineers in November 1964.
"Water Desalting," article by E. D. Howe, Annual Supplementary Volume of Encyclopedic Dictionary of Physics, Pergamon Press, Ltd.
"Ion Exchange Equilibrium Data in the Design of A Cyclic Sea Water Softening Process," by G. Klein, M. Villena-Blanco & T. Vermeulen, I & EC Process Design and Development, Vol. 3, p. 280, July 1964.
"Behavior of Various Permselective Membranes with Mixed Feeds," by S. A. Weiner, I & EC Process Design and Development, Vol. 4, Page

349, October 1965.
*Requests for copies should be directed to: Institute of Industrial Cooperation, Dept. of Engineering, University of California, Los Angeles, California.
**Requests for copies should be directed to: Sea Water Conversion Laboratory, University of California, 1301 South 46th Street, Richmond, California.

(2265) FORCES ON ACCELERATED CYLINDERS.

(b) Laboratory project.
(c) Prof. A. D. K. Laird, 109 Mechanics Bldg., Univ. of California, Berkeley, Calif. 94720.
(d) Experimental and theoretical, basic research.
(e) Measurement and prediction of drag coefficients and flow configurations about cylinders during accelerated motion in fluids as related to wave forces as cylinders including effects of support flexibility.
(h) "Hydroelastic Vibrations of Circular Cylinders," by G. L. Fritzler and A. D. K. Laird. Univ. of California IER Rept. HPS-64-2, August 1964.
"Behavior of a Flexibly Supported Cylinder in a Fluid Stream," by W. J. MacLean, A. D. K. Laird and J. W. Brewer, Univ. of California IER Rept. HPS-64-3, November 1964.

(2505) EFFECT OF SEDIMENT DISTRIBUTION IN STREAM CHANNELS.

(b) University project.
(c) Prof. H. A. Einstein, Dept. of Civil Engineering, Univ. of California, Berkeley, Calif. 94720.
(d) Experimental; basic research.
(e) Alluvial flows in channels with artificially secured banks are studied systematically for their tendency to meander as expressed by the development of alternate bars. It is the aim of this study to develop criteria for stability.
(f) Concluded.
(g) It was found empirically that it is pratically impossible to create the characteristic alternate bars based on reversing secondary currents in laboratory flumes with smooth vertical banks. Under the same average flow and sediment conditions in the same flumes the alternate bars appear if rough sloping banks are substituted. The bank friction is used to explain the creation of the bars.
(h) "A Study on Meandering in Straight Alluvial Channels," by H. A. Einstein and H. W. Shen, Journal of Geophysical Research, Vol. 69, No. 24, December 15, 1964, pp. 5239-47.

(3675) CLAY TRANSPORT.

(b) National Science Foundation and California State Water Resources Center.
(c) Prof. H. A. Einstein, Dept. of Civil Engineering, Univ. of California, Berkeley, Calif. 94720.
(d) Experimental, basic research.
(e) Determination of the friction factor of flocculated clay deposits using mud from San Francisco Bay.
(f) Terminated.
(g) The 1000-ft channel is used to measure the friction characteristics of mud deposited in flowing salt water. The mud surface is hydraulically smooth except in periods of active scour or deposition when the irregularities increase the friction up to twice the value of the smooth surface. No extraneous materials such as vegetation were considered on the bed.

(3677) ANNULAR NOZZLE GROUND EFFECT MACHINE.

(b) Office of Naval Research, Dept. of the Navy.
(c) Prof. R. L. Wiegel, Dept. of Civil Engrg., Univ. of Calif., Berkeley, California 94720.
(d) Experimental; applied research.
(e) Airborne vehicles supported by annular jets have a lift considerably in excess of that due to the jet momentum when operating in a region close to the ground. The dynamic lift, bending moment, wave resistance, base pressures, and intake pressures are being measured for such a vehicle operating over both calm water and water with surface gravity waves present.
(f) Completed.

(3678) OCEAN SEWER OUTFALLS.

(b) U. S. Public Health Service.
(d) Basic research.
(e) This study is concerned with the various phenomena involved in the diffusion of sewage at the discharge end of an ocean sewer outfall.
(f) Completed.
(g) Recent work has been done on the mixing of warm water jets being discharged horizontally at the surface of a body of water.

(4562) ANALYSIS OF NONLINEAR SYSTEMS.

(b) Laboratory project.
(c) Prof. J. A. Harder, Hesse Hall, Univ. of California, Berkeley, Calif. 94720.
(d) Theoretical; basic research.
(e) Given a sufficiently long record of the input and output of a stationary system that may include nonlinearities, the purpose is to develop a predictor for arbitrary inputs.
(g) Computer program is written that has enabled close prediction of the output of an experimental nonlinear system to a sine wave having an amplitude and frequency well within the limits of the random input used to develop the predictor.

(4565) MATHEMATICAL MODELS FOR FLOOD ROUTING.

(b) U. S. Corps of Engineers, Omaha District Office.
(c) Prof. J. A. Harder, Hesse Hall, Univ. of California, Berkeley, Calif. 94720.
(d) Theoretical; basic research.
(e) Various models are being fitted to experimental floods induced by spillway releases from reservoirs on the Missouri River.
(g) Principal limitation has been found to be accuracy of channel data.

(4930) COASTAL SAND MOVEMENT.

(b) Corps of Engineers, U. S. Army, Coastal Engineering Research Center.
(d) Experimental; laboratory and field.
(e) This investigation is concerned with the transportation of sand by both wind and waves.
(h) "Sand Loss from a Coast by Wind Action," by J. W. Johnson and A. A. Kadib, Proc. 9th Conf. on Coastal Engineering, 1964.
"Study of High Water Levels in San Francisco Bay," for Bay Area Rapid Transit Dist., November 1964, 15 pp., app. and figures, by J. W. Johnson.
"Sand Movement Near Point Reyes, California," by John Cherry, Shore and Beach, Vol. 33, No. 1, April 1965.

(4932) GROUND WATER BASIN MANAGEMENT.

(b) Laboratory project.
(d) Experimental and theoretical; applied research.
(e) Study of the physical conditions within a basin so that ground water levels at any point can be predicted for any future time for given recharge and discharge conditions. Subsequently, study of alternate methods for operating the basin to obtain an economically optimal system.

(4933) HYDRAULIC SYSTEMS ANALYSIS.

(b) California Department of Water Resources.
(c) Prof. J. A. Harder, Hesse Hall, Univ. of California, Berkeley, Calif. 94720.
(d) Experimental; applied research and design.
(e) Analog model and digital computer methods are being used to predict salinity, tidal amplitudes, tidal elevations, and fresh water flows in the Sacramento-San Joaquin Delta Region.

(4934) WAVE DIFFRACTION AND REFRACTION.

(b) Corps of Engineers, U. S. Army, Coastal Engineering Research Center, Washington, D. C.
(c) Prof. R. L. Wiegel, Univ. of California, Berkeley, Calif. 94720.
(d) Experimental; basic research.
(e) Determination by model tests the diffraction and refraction characteristics of wind waves. Also, model studies of the "Mach-stem" equivalent of water waves.
(g) A study is being made on the diffraction of waves over a channel dredged through a submerged reef.
(h) "Two Dimensional Spectrum of Wind Waves," by Ismail Mobarek, IER Tech. Rept. HEL 1-6, January 1965, 186 pp.
"A Non-Linear Problem in Surface Water Waves," by John A. Williams, IER Tech. Rept. HEL 1-5, October 1964, 246 pp.

(5435) SEAWALL OVERTOPPING BY WIND WAVES.

(b) Laboratory project.
(d) Experimental.
(e) The intensity of overtopping of a seawall by wind waves was investigated for various water depths in front of the seawall.
(f) Completed.
(h) "Overtopping of Wind Waves at a Sea Wall as Affected by Water Depth," by Paul W. Merkens, Shore and Beach, Vol. 32, No. 2, Oct. 1964.

(5436) BAR RESISTANCE IN DEGRADING CHANNELS.

(b) Laboratory research, supported by California State Water Resources Center.
(c) Prof. H. A. Einstein, Dept. of Civil Engrg., Univ. of California, Berkeley, Calif. 94720.
(d) Experimental, Ph.D. thesis.
(e) An equilibrium flow is established and measured. Then the same flow is repeated with reduced sediment feed and the effect on the flow is observed.
(f) Terminated.
(g) Only minor deviations have been observed, indicating that slowly degrading flows may be caluclated like equilibrium flows. Only few sediment conditions have been tested to date.

(5437) DEPOSIT OF SILT IN A GRAVEL BED BY WATER FLOWING OVER THE BED.

(b) U. S. Bureau of Reclamation.
(c) Prof. H. A. Einstein, Dept. of Civil Engrg., Univ. of California, Berkeley, Calif. 94720.
(d) Experimental, basic research.
(e) The rate at which fine sediment is deposited in artificial spawning grounds for salmon and other fish has been determined. The sediment carrying flow is recirculated over gravel beds in laboratory flumes.
(f) Terminated.
(g) The fine sediment deposits at a rate that is proportional to the concentration. The concentration decreases exponentially. The "half life" is proportional to the water depth and inversely proportional to the settling velocity.
(h) Final report to the U. S. Bureau of Reclamation under preparation.

(5438) SHAPE OF CROSS SECTIONS IN RIVER BENDS.

(b) Laboratory research, supported by the California State Water Resources Center.
(c) Prof. H. A. Einstein, Dept. of Civil Engrg., Univ of California, Berkeley, Calif. 94720.
(d) Experimental with statistical analysis, Ph.D. thesis.
(e) A circular flume has been constructed in which various flows are established and cross sections established. The cross sections are statistically described by a minimum of parameters and the change of these parameters established in terms of the flow and sediment parameters. River sections are equally analyzed.

(5439) WAVE FORCES.

(b) Corps of Engineers, U. S. Army, Coastal Engineering Research Center, Wash., D. C.
(c) Prof. R. L. Wiegel, Univ. of California, Berkeley, Calif. 94720.
(d) Experimental and theoretical; basic research.
(e) Determine by model tests the forces exerted by waves on coastal structures. Theoretical studies of statistical properties of wave forces.
(g) Forces exerted by bores on structures are being studied theoretically and experimentally.
(h) "Wave Forces on Piles: Tables and Graphs," by R. H. Cross and R. L. Wiegel, IER Tech. Rept. HEL 9-5, June 1965, 57 pp.
"A Statistical Theory for Hydrodynamic Forces on Objects," by Leon E. Borgman, IER Tech. Rept. HEL 9-6, Oct. 1965, 33 pp.

(5816) GROUND WATER FLOW IN THE CAPILLARY ZONE.

(b) Water Resources Center.
(c) D. K. Todd.
(d) Experimental; basic research.
(e) A sand model with steady ground water flow was employed to study flow in the capillary zone, its relative magnitude, and its importance in relation to flow in the saturated zone.
(h) Report in preparation.

(5817) SHIP WAVES IN NAVIGATION CHANNELS.

(b) Coastal Engineering Research Center.
(c) Prof. J. W. Johnson, Univ. of Calif., Berkeley, Calif.
(d) Theoretical, laboratory and field experimental basic research study.
(e) The characteristics of waves generated by ships moving at various speeds in shallow water are being investigated.

(5818) TRANSMISSION OF WAVE ENERGY THROUGH RUBBLE MOUNDS.

(b) Laboratory project.
(c) Prof. J. W. Johnson, Univ. of California, Berkeley, Calif.
(d) Experimental.
(e) The transmission of wave energy through three scale models of rubble structures was conducted with rubble size and wave characteristics as the principal variables.
(h) "Wave Transmission Through Rubble," by Hideo Kondo, M. S. Thesis in Engineering, Univ. of Calif., Sept. 1965.

(5819) WATER TABLE AND TOPOGRAPHY RELATIONS.

(b) Water Resources Center.
(c) D. K. Todd.
(d) Experimental; basic research.
(e) It is planned to study by hydraulic models the effect of various topographic configurations on the shape of the water table.

(5820) TRANSPORT OF SILT THROUGH POROUS MEDIA.

(b) National Science Foundation.
(c) Prof. H. A. Einstein, Dept. of Civil Engineering, Univ. of California, Berkeley, California.
(d) Experimental and theoretical basic research.
(e) Silt-carrying water is flowing at various directions through porous media. The deposition, transport and erosion of the silt are studied as a function of silt size,

concentration and density, and of the flow velocity.

(f) Literature survey shows very little information.

UNIVERSITY OF CALIFORNIA, Institute of Industrial Cooperation, Department of Engineering.

(5872) STUDY OF THE OPERATION OF FLOAT CONTROLLED VALVES FOR IRRIGATION DISTRIBUTION SYSTEMS.

(b) Laboratory project supported by the University of California's Water Resources Center.

(c) Prof. E. H. Taylor, Univ. of California, Dept. of Engrg., Los Angeles, Calif. 90024.

(d) The project was primarily experimental in that empirically determined characteristics were employed in the attempts at analysis. Project was the basis of a Ph.D. dissertation.

(e) The work is being done for the purpose of arriving at design criteria for float operated valves. An existing valve and float were tested for head loss characteristics buoyancy requirements and transient response properties. A theory of operation was developed and compared with observation. Agreement was encouraging.

(f) A first phase of the project is complete. Additional aspects are currently being explored.

(g) It has been possible to arrive at equations amenable to solution by digital computer to predict the behavior of a particular valve and float combination. The techniques are being refined in an effort to determine the necessary hydraulic and mechanical characteristics which will result in the design of a valve which will operate in a predetermined manner.

UNIVERSITY OF CALIFORNIA, BERKLEY, Dept. of Naval Architecture.

(4083) DYNAMIC INTERACTION BETWEEN SHIPS.

(b) Office of Naval Research, Dept. of the Navy.

(c) Prof. J. R. Paulling, Dept. of Naval Architecture, College of Engineering, University of California, Berkeley, California 94720.

(d) Theoretical and experimental.

(e) The linearized equations of motion for two ships operating on parallel courses are formulated. Coefficients appearing in these equations are being evaluated by captive model techniques. Analog and digital means of solving the equations are being studied.

(g) Rudder forces and moments, interaction forces and moments, and velocity and acceleration derivatives have been found experimentally for two models operating on parallel courses.

(4084) SHIPS OF MINIMUM RESISTANCE.

(b) Office of Naval Research, Dept. of the Navy.

(c) Prof. J. V. Wehausen, Dept. of Naval Architecture, College of Engineering, University of California, Berkeley, Calif. 94720.

(d) Theoretical applied research.

(e) The general aim of this work is to find computer designed ships of minimum "total" resistance, subject to various restraining conditions. Here "total" resistance means the Michell wave resistance plus the equivalent flat-plate frictional resistance.

(g) Computations reported earlier produced ships with rather wavy lines. Increasing the number of terms in the Fourier series describing the ship has produced smoother lines, which do not, however, 'smooth' the earlier ones. A model has been made and tested corresponding to Froude number 0.29.

(4570) PRESSURE DISTRIBUTION ON SEMI-SUBMERGED OSCILLATING BODIES.

(b) David Taylor Model Basin, Department of the Navy, continued under ONR.

(c) Prof. J. R. Paulling, Dept. of Naval Architecture, College of Engineering, University of California, Berkeley, California 94720.

(d) Experimental and theoretical.

(e) To determine the response of a floating body in a seaway, it is necessary to know the magnitudes and phases of hydrodynamic forces and moments acting on this body. In the linearized analysis the total pressure at any point takes the form of two terms: (a) exciting pressure dependent upon the waves only: (b) pressure dependent upon the geometry and motion of the body and independent of the waves. These two terms are being measured on: (1) A prolate spheroid; (2) A ship-like form.
First the models are attached rigidly to the dynamometers, towed in waves and the pressure distribution, total forces and moments measured. Then the models are oscillated sinusoidally in still water and again the pressure distribution, total force and moment measured. The results will be compared with theoretical calculations.

(g) Both the models have been tested in still water as well as in waves. The results indicate that the wave forces and moments follow the general trend as predicted by Krylov's Theory. For the oscillating models in still water, the longitudinal distribution of virtual mass and damping have been determined experimentally.

(h) "Measurements of Heave and Pitch Moments Acting on a Restrained Shiplike Model in Regular Waves," by Hou-Wen Huang. Univ. of Calif. IER Report No. NA-64-11, December 1964.
"Measurement of Pressures and Hydrodynamic Forces on a Shiplike Model Oscillating in a Free Surface," by Hou-Wen Huang. Univ. of Calif. IER Report No. NA-65-1, Jan. 1965.

(4971) SHIP RESISTANCE IN IRREGULAR WAVES.

(b) David Taylor Model Basin, Dept. of the Navy.

(c) Mr. O. J. Sibul, Dept. of Naval Architecture, College of Engineering, University of Calif., Berkeley, California 94720.

(d) Experimental; applied research.

(e) The previous resistance measurements of ship models in uniform waves will be used to predict the total added resistance in irregular waves of known spectral content. The predictions will be compared with experiments in irregular waves of various spectral contents and severity, combined with a number of model speeds.

(g) To test the validity of the linear theory for the prediction of resistance of ships in irregular seas, a wave, containing only two components of the uniform waves, was used. In the first set of experiments individual wave steepnesses were approximately 1:70. The resultant combined wave was rather severe and green water was washed over the deck. The measured resistances in the combined waves were higher than the addition of the measured resistances in the component waves predicted. On the second set of experiments the steepnesses of the individual waves were reduced to approximately 1:160. The measured resistances in the combined waves agreed well for the intermediate speeds, but were somewhat higher than predictions for low and high speeds.

(h) In preparation.

(5301) SHIP SLAMMING.

(b) U. S. Dept. of Commerce, Maritime Administration.

(c) Prof. H. A. Schade, Dept. of Naval Architecture, Univ. of Calif., Berkeley, Calif. 94720.

(d) Experimental and theoretical; applied re-

search.

(e) The purpose of the project is to investigate the impact loads (pressures) caused by slamming and the response of the ship structure to these loads. The capacity of the testing equipment is as follows: (a) 1/4 scale models; (b) total model weights up to 40,000 lbs; (c) drop height up to 10 ft. above the still water surface.

(g) Preliminary results for an extra stiff flat model indicate that: (a) For lower drop heights the peak pressure varies nearly as the square of the impact velocity; (b) the pressure is proportional to the deceleration (for the range 10 to 30 g). More experiments in preparation.

(h) Report in preparation.

(5774) HYDRODYNAMICS OF SHIP SLAMMING.

(b) University of California-Berkely and David Taylor Model Basin.

(c) Prof. J. V. Wehausen, Dept. of Naval Architecture, College of Engrg., Univ. of Calif., Berkeley, California 94720.

(d) Theoretical, experimental.

(e) Some experimental results suggest that air trapped under the flat bottom of the falling model, is cushioning the impact and reducing the peak pressures for slamming. A preliminary theory has been developed to take into consideration the entrapped air.

(g) Preliminary results indicate that the theory (under e) gives pressure-time curves that agree reasonably well with the experimental results. More detailed experiments are in preparation.

(h) "On the Cushioning of Water Impact by Entrapped Air," by G. Lewison and W. M. Maclean. (In preparation).

THE CATHOLIC UNIVERSITY OF AMERICA, Department of Civil Engineering.

(3030) TRANSIENT FLOW THROUGH POROUS INCOMPRESSIBLE MEDIA WITH VARIOUS BOUNDARY CONDITIONS.

(b) Experimental part was supported by the National Research Council of Canada.

(c) Dr. B. S. Browzin, Professor of Civil Engrg., The Catholic University of America, Wash., D. C. 20017.

(d) Experimental and theoretical; basic research.

(e) The unsteady laminar flow was reproduced by a highly viscous liquid flowing between closely spaced translucid plates on a number of models with geometric boundaries representing various types of earth dams on impervious foundations and earth massives crossed by open channels.
Experimental part concerning earth dams and earth massives on impervious foundations completed. The theoretical part of the research completed for the case of rapid drawdown in homogeneous dams. The theoretical research of cases of gradual drawdown, of non-homogeneous dams, of tailwater condition, and the drawdown in canals was continued for the reported period. It is intended to continue it farther for the coming year.

(g) An approximate function, relating by dimensionless parameters, the shape and the position of free surface of flow through the earth dam, following rapid reservoir drawdown, to the geometry of the dam, was obtained theoretically and confirmed by experiments.

(h) "Nichtstationare Sickerstromungen in homogenen Erddammen und Erdkorpern," pp. 280 Doctoral dissertation at the Rheinisch-Westfaelische Technische Hochschule Aachen, 1961. The book is available at the library of the National Research Council of Canada, Ottawa 2, Ontario, Cat. No. TC543-B88.

(3031) THE VARIATION OF HYDROLOGIC FACTORS AND THEIR INFLUENCE ON RIVER REGIMES IN THE GREAT LAKES-ST. LAWRENCE DRAINAGE AREA.

(b) Laboratory project.

(c) Dr. B. S. Browzin, Professor of Civil Engrg., The Catholic University of America, Wash., D. C. 20017.

(d) Basic research.

(e) Research is based on long range flow and meteorologic record. Flow and precipitation data on U.S. and Canada stations were statistically investigated in order to obtain river regime characteristics.

(f) Completed.

(g) Classified discharges for long range gauging stations are calculated. Characteristic parameters for river classification of the area are obtained, water-balance in the basin is calculated; average, maximum and minimum run-off for the period of available observations is analysed. Historical variation of flow and climatic factors were investigated.

(h) "Seasonal Variations of Flow and Classification of Rivers in the Great Lakes - St. Lawrence Basin". Proceedings of the 7th Conference on Great Lakes Research, Pub. No. 11, pp. 179-204, Ann Arbor, Mich., 1964. "Donnees Fondamentales sur l'Hydrologie des Rivieres dans le Bassin du Saint-Lauren", pp. 448. Dissertation of the "Doctorat d'Etat es Science" at the University of Grenoble. The book is available from the author.

(5258) ANALYTICAL METHODS OF CALCULATION OF THE UPLIFT ACTING ON GRAVITY DAMS BUILT ON PERVIOUS BASES.

(b) Laboratory project.

(c) Dr. B. S. Browzin, Professor of Civil Engineering. The Catholic University of America, Wash., D. C. 20017.

(d) Theoretical.

(e) Mathematical solution from recent foreign literature is collected, summarized and presented primarily for dam designers. Use of generally available tables of special functions is proposed to facilitate designers to apply in practice these highly efficient new methods.

(f) Completed.

(h) "Nouvelle Methode d'Application de Quelques Fonctions de la Variable Complexe aux Calculs des Sous-Pressions Agissant sous les Ouvrages de Retenue". La Houille Blanche, No. 7, Dec. 1964, pp. 803-814, Grenoble.

COLORADO STATE UNIVERSITY, Civil Engineering Section.

(55) SNOW COURSE MEASUREMENTS AND FORECAST ANALYSIS.

(b) Soil Conservation Service, Colorado Agric. Experiment Station.

(c) Mr. Jack N. Washichek, Snow Survey Supervisor, Agricultural Engineering Section.

(d) Field investigations; applied research.

(e) Systematic measurements of depth and water content of snow are being made at high elevations in Colorado and New Mexico mountain areas for the purpose of forecasting the runoff of the principal rivers in the interest of irrigation, power, domestic supplies, and other uses.
Investigation of the area at headwaters of the Fryingpan-Arkansas will be made to determine the need for additional snow courses. Additional installations may be necessary to forecast stream-flow for the project.

(g) Forecasts are now being issued at forty-four gaging stations in Colorado and New Mexico. As forecast procedures improve, additional streams will be forecasted and other areas of potential power and irrigation development will be investigated on the Colorado,

San Juan, Animas and Arkansas Rivers.

(h) Colorado Agricultural Experiment Station General Series Papers Nos. 817, 818, 819 and 820 covering monthly snow reports for all of Colorado and New Mexico. Nine small basin reports and one two-state bulletin covering the South Platte River watershed; Arkansas River watershed; Rio Grande watershed in Colorado; Rio Grande watershed in New Mexico; Dolores River watershed; San Juan and Animas River watershed; Gunnison River watershed; Colorado River watershed; Yampa, White and North Platte River watershed; Lower South Platte River watershed. Supplemental reports are issued January 1, May 15, and June 1. "Progress Report of Steamboat Project." "Second Progress Report of Steamboat Project."

(821) GROUND WATER FLUCTUATIONS AND THEIR RELATION TO PUMPING.

(b) Colorado Agricultural Experiment Station.
(c) Mr. M. M. Skinner, Assistant Civil Engineer and Mr. Harold R. Duke, Jr., Civil Engineer.
(d) Field investigation; applied research.
(e) Semi-annual measurements of the depth to the water table in approximately 635 observation wells are presently being obtained. The Ground Water Branch of the U. S. Geological Survey, Denver, Colorado are cooperating in furnishing measurements for about 130 wells. The observation wells are primarily existing irrigation wells in the South Platte and Arkansas River Basins, the High Plains area of eastern Colorado and the San Luis Valley. Electrical Power and Natural Gas Consumption data are compiled and estimates of groundwater pumpage made. The purpose of the project is to detect areas of ground-water depletion, to develop relationships between gross pumpage and respective ground-water reservoir storage volume changes, and acquire basic data for ground-water studies in the various areas of Colorado.
(g) Ground-water levels of the spring of 1965 are generally down as compared to the spring of 1964 in the South Platte and Arkansas River Basins and the San Luis Valley. Considerable ground-water pumpage is continuing in the High Plains area of eastern Colorado with some increase in pumping lifts resulting. Reported electrical power consumption by electrical pumping during 1963 in Colorado amounted to approximately 190,000,000 kilowatt hours for 9295 pumping units.
(h) "Colorado Ground-Water Levels - Spring 1965," CER65HRD-MMS29, by H. R. Duke and M. M. Skinner.

(2770) TURBULENCE STUDIES IN LIQUID USING ELECTROKINETIC PHENOMENON.

(b) National Science Foundation.
(c) Dr. J. E. Cermak.
(d) Experimental research; basic research, doctoral thesis.
(e) The primary objective of the study is to determine the interaction between velocity fluctuations produced by turbulence in the liquid flow and electrokinetic potential fluctuations generated at a liquid-solid interface. Knowledge gained by this study will be applied to developing techniques for measuring turbulence characteristics in luquids.
(g) Probes constructed with electrode pairs have been used to measure the distribution of turbulence intensities (three components) and the turbulent shear stress across a diameter of a circular pipe. The distribution measured in water agree with those obtained by Laufer in air using a hot-wire anemometer.
(h) "Streaming - Potential Fluctuations Produced by Turbulence," by G. J. Binder and J. E. Cermak, The Physics of Fluids, 6 (8), August 1963.

(2902) DEVELOPMENT IMPROVEMENT OF WATER MEASURING DEVICES.

(b) Northern Plains Branch, Soil and Water Conservation Research Division, ARS, USDA.
(c) E. Gordon Kruse, Agricultural Engineer.
(d) Experimental, laboratory investigation; applied research, operation and development.
(e) New and improved devices and techniques for measurement of irrigation water are being developed. Specific objectives are (1) Design, evaluation and calibration of trapezoidal measuring flumes, (2) Design and evaluation devices for combined water measurement and control, and (3) Development of a probe using the drag on a suspended wire to indicate total flows, velocity distributions and forces on sediment particles.
(f) Completed.
(g) The development of trapezoidal measuring flumes is continuing. Flumes with cross-sections corresponding to common slipform concrete ditches have been designed and calibrated.
Two shapes of broadcrested weirs were evaluated with respect to their ability to measure flows accurately under high degrees of submergence.

(3398) TURBULENT DIFFUSION IN SHEAR FLOW.

(b) National Institute of Health, Public Health Service, U. S. Dept. of Health, Education and Welfare, Washington, D. C.
(c) Dr. J. E. Cermak.
(d) Experimental research; basic research, doctoral thesis.
(e) The objective of this project is to determine the influence of geometrical factors (land surface roughness, topography, structures), and thermal and aerodynamical factors (turbulence intensity and scale) upon atmospheric diffusion of heat and mass. "Laws of modeling" or "similitude parameters" are sought by obtaining detailed data under various conditions in the wind tunnel and by comparing them with similar data now existing for the atmospheric prototype.
(g) Application of a hypothesis of Lagrangian similarity to particle motions in a turbulent shear flow near a solid boundary has yielded similarity parameters and relationships between them which correlate the wind-tunnel diffusion data and available diffusion data obtained in the atmospheric surface layer.

(3400) HYDRAULICS OF SUB-CRITICAL FLOW IN SMALL, ROUGH CHANNELS.

(b) Colorado Agricultural Experiment Station and Agricultural Research Service, U. S. Department of Agriculture.
(c) Dr. Norman A. Evans, Head, Dept. of Agricultural Engineering.
(d) Theoretical, laboratory experiment.
(e) Both laboratory and field studies have been conducted. A tilting flume was used in the laboratory, and a portable truss to carry a measuring carriage was used in the field. The purpose is to relate roughness in small channels to flow resistance.
(g) Resistance to flow in small channels does not follow the same relationships established for large channels. The standard deviation of peak to valley heights was found to be a significant parameter, and a spectral density description of roughness is being tested.

(3704) DEVELOPMENT AND USE OF COLORADO BENTONITE IN SEALING IRRIGATION CANALS AND RESERVOIRS.

(b) State of Colorado.
(c) R. D. Dirmeyer, Jr., Project Leader
(d) Field investigation; applied research and development.
(e) The work consists of three stages: (1) Inventory of clay deposits in Colorado with

emphasis on those potentially usable in sealing canals and reservoirs. (2) Laboratory evaluation of clays from (1) above. (3) Field trials in canals and reservoirs with best clays found in (1) and (2) and evaluation of sealing results (initial and with time).

(f) Completed.

(g) Inventory and Testing -- A total of 321 samples of Colorado clays were collected and tested in the laboratory. Development of Deposits and Field Trials -- Eight deposits have been developed commercially. Clays from these deposits were used in 132 trials in canals and ponds during the three year project.

(4099) WAKE CHARACTERISTICS FOR BODIES OF REVOLUTION WITH MOMENTUM ADDITION.

(b) David Taylor Model Basin.

(c) Dr. L. V. Baldwin, Acting Dean of Engineering.

(d) Experimental, theoretical; basic research.

(e) Turbulent and mean flow characteristics of wakes formed behind axisymmetric and eliptical bodies have been studied experimentally in a wind tunnel using hot-wire anemometers. Theoretical studies have lead to explanations of all observed phenomena.

(f) Completed.

(h) "Decay of Turbulence in Axisymmetric Wakes", N. H. C. Hwang and L. V. Baldwin, Paper accepted for publication in ASME Transactions (early 1965).
"Three Dimensional Turbulent Wakes," by Y. H. Kuo, Ph.D. Dissertation, Colorado State University, August 1965.
"The Formation of Elliptic Wakes," by Y. H. Kuo and L. V. Baldwin, paper submitted to Journal of Fluid Mechanics (1965).
"The Diffusion and Decay of Turbulent Elliptic Wakes," by Y. H. Kuo and L. V. Baldwin, paper submitted to AIAA Journal, (1965).
"Instrument for Measuring the Intermittency of Quasi-Steady Signals," by C. Finn and V. A. Sandborn, CSU Fluid Mechanics Paper No. 3 (1964).

(4100) INVESTIGATION OF RAINFALL AND RUNOFF SEQUENCES.

(b) National Science Foundation.

(c) Dr. V. M. Yevdjevich, Professor of Civil Engineering.

(d) Theoretical; basic research.

(e) The study of fluctuations of river flow and precipitation has been contined.

(g) The time dependence models of annual values and monthly values have been determined for samples of several hundreds of river flow and precipitation stations.

(h) Hydrology Paper No. 6, "Inter-station Correlations in Annual Precipitation and in Annual Effective Precipitation," by James E. Caffey, June 1965.
Hydrology Paper No. 8, "Probability Functions of Best Fit to Distributions of Annual Precipitation and Runoff," by Radmilo D. Markovic, August 1965.
Hydrology Paper No. 9, "Similitude for Non-Steady Drainage of Partially Saturated Soils," by G. L. Corey, A. T. Corey and R. H. Brooks, August 1965.
Hydrology Paper No. 10, "The Application of Surplus, Deficit, and Range in Hydrology," by Vujica M. Yevdjevich, September 1965.
Hydrology Paper No. 11, "The Analysis of Range with Output Linearly Dependent Upon Storage," by Mirko J. Melentijevich, September 1965.
Hydrology Paper No. 12, "Conditional Probabilities of Wet and Dry Years Over Large Continental Areas," by Subin Pinkayan, November 1965.

(4101) UNSTEADY FREE SURFACE FLOW IN A LARGE STORM DRAIN.

(b) U. S. Bureau of Public Roads and U. S. Public Health Service.

(c) Dr. V. M. Yevdjevich, Professor of Civil Engineering, A. H. Barnes, Assoc. Prof. of Civil Engineering and G. L. Smith, Asst. Prof. of Civil Engineering.

(d) Experimental and theoretical; basic research.

(e) A 825-ft long, 36-in. diameter conduit, movable on 43 supports on a hillside, is used as the main experimental facility to simulate and record free surface waves in pipes. The same waves are computed by using a digital computer and then a comparison is made. The ultimate purpose is a development of a set of routing methods to suit the desired accuracy and the quality of the initial and boundary data. The experimental part of the hydraulic study has progressed sufficiently during 1964 so that the analysis of data is underway.

(g) The analytical study for directing the research is being completed.

(h) "Predictability of Free-Surface Profiles for Steady Non-Uniform Flow In a Circular Cross-Section," by A. H. Barnes, Ph.D. Dissertation, Colorado State University, August 1965.

(4106) GROUND-WATER RESERVOIR MANAGEMENT.

(b) Colorado Agricultural Experiment Station.

(c) Mr. R. A. Longenbaugh, Junior Civil Engineer and M. W. Bittinger, Associate Civil Engineer.

(d) Theoretical and field investigation; applied research.

(e) It is the purpose to study the operating characteristics of ground water reservoirs in Colorado. Specific studies include (1) natural recharge from ephemeral streams, (2) electric analog study of High Plains aquifer, (3) evaluation of natural recharge to High Plains aquifer, and (4) development of a general mathematical model, for solution on a digital computer, that can be adopted to particular ground water aquifers to relate the effect of the various parameters on the aquifer.

(g) (1) Kiowa Creek data analysis reveals influence of ephemeral stream flow on irrigation wells. (2) Electric analog model has provided preliminary estimates on the quantity of water that can be pumped from the High Plains Aquifer. (3) Mathematical models have shown importance of priority of rights, aquifer characteristics, ground water pumping and consumptive demand on management of an integrated surface-ground water system.

(h) "Geologic Control of Ground Water in the Kiowa-Wolf-Comanche Creek Area in Central Adams County, Colorado," by John Romero, M. S. Thesis, Colorado State University, August 1965.

(4108) WATERSHED HYDROLOGY.

(b) Colorado Agricultural Experiment Station.

(c) Dr. V. M. Yevdjevich, Prof. of Civil Engineering, and Dr. Brian M. Reich, Asst. Professor.

(d) Theoretical and experimental; basic research.

(e) The research is concerned with floods from small watersheds. It is being pursued in three phases: (1) Assembly of research data from actual floods on small watersheds, (2) physical experimental studies on a large rainfall-runoff simulation area, and (3) theoretical studies of the relation between flood hydrographs and the rainfall and catchment factors that affect them.

(f) Phase one is active, data collection having progressed well; Phase Two is active in the planning stages, and Phase Three is active in the initial stage.

(g) The leads to stream flows and rainfall data, that have been established, will be carried to the conclusion of punching all the information onto cards. The programs developed thus far will be improved so that the observed and theoretical hydrographs can be

obtained at maximum speed from an x-y-plotter. Additional multi-variate analyses on such items as total runoff volumes, peak rates of runoff will be completed. Theoretical considerations of runoff, and probability approaches will be pursued.

(h) "Rapid Flood Peak Determination on Small Watersheds," by Brian M. Reich. Paper No. 64-709 ASAE Winter Meeting, New Orleans, December 1964.

(4110) TURBULENT AIR MOTION IN THE HIGH ROCKIES IN RELATION TO THE WATER YIELD OF UPPER WATERSHEDS.

(b) Colorado Agricultural Experiment Station.
(c) Dr. Herbert Riehl, Professor of Atmospheric Science.
(d) Field, basic and applied.
(e) The structure of the turbulent wind eddies, which produce the exchange of momentum between atmosphere and ground in the high mountains, is unknown. Yet these have sufficient force for the most part to blow the snow away from the mountain slopes above timberline. This snow in part drifts into high-altitude basins where it accumulates in depth augmenting the summer water supply; in part it drifts on slopes where it readily evaporates. Much interest has been shown in the possibility of channeling the drift so that a substantially higher fraction goes into the basins. Technologically this appears to be feasible. But any construction is dependent on knowledge of the turbulence spectrum, especially on the first day following snowfall. In order to determine this spectrum, a first installation containing electronic wind and temperature measuring instruments have been established above timberline in the Central Colorado Rockies.

(4112) THE DISCHARGE OF MAJOR WESTERN RIVERS IN RELATION TO THE GENERAL CIRCULATION OF THE ATMOSPHERE.

(b) Office of Naval Research, Department of the Navy.
(c) Dr. Herbert Riehl, Professor of Atmospheric Science.
(d) Basic research.
(e) The discharge of major western rivers (Colorado, Columbia, Sacramento, Rio Grande) has fluctuations with the order of magnitude of the mean annual discharge itself. These fluctuations are brought about mainly by variations in precipitation yield and by variable evaporation. Heavy precipitation may result from seasonal conditions favorable for the recurrence of cyclones over headwater areas. High evaporation, requiring weeks of abnormally dry and warm conditions, must be a manifestation of general circulation anomalies of longer duration. The objective of the study is (1) to separate the "systematic" and "random" components of the precipitation, and (2) to determine the controls for the systematic anomalies of precipitation and evaporation.
(f) Completed.

(4606) STRUCTURE OF TURBULENCE IN TURBULENT SHEAR FLOW.

(b) Department of the Army.
(c) Dr. J. E. Cermak, Prof. of Engineering Mechanics and Civil Engineering, Mr. E. J. Plate, Assoc. Professor, and Mr. V. A. Sandborn, Associate Professor; Dr. H. Chuang, Asst. Prof., Dr. G. J. Binder, Asst. Prof., and Dr. R. M. Meroney, Asst. Prof., Engineering Department, CSU.
(d) Experimental research; basic research, doctoral theses.
(e) The effects of surface roughness and surface heating or cooling upon the structure of turbulence in boundary layer flow will be determined. The flows investigated will be those existing on the heated or cooled floor of a wind-tunnel test section 6 x 6 ft in cross section and 80 ft long. Space-time correlations, joint probability densities, spectra and intensities of the turbulent velocities and temperatures will be obtained by hot-wire techniques and special analog computers employing magnetic tape input.
Efforts are being made to determine the diffusion characteristics for instantaneous point and line sources of heat and mass located within the turbulent boundary layer. This work is another way in which the effect of vertical temperature gradients and the turbulent boundary layer effect the turbulence structure.
(g) A 2.5 x 10 inch diameter, 90% platinum-10% rhodium wire was evaluated as a resistance thermometer. From steady state evaluation of the wire physical properties the transient response of the wire was predicted. The predictions agree well with measured time constants for the wire. The bare wire with a detection current of 0.1 milliamps will have a sensitivity of approximately .07 millivolts per F. The frequency response of the wire in still air is 3200 cycles per second and this increased to approximately 6000 cycles in a moving air stream of 100 feet per second.
The recent measurements of spectra within the neutral turbulent boundary layer over the roughened floor of the wind tunnel show very close agreement with turbulent spectra reported for water flow in an ocean tidal channel and for air flow of the sea surface.
(h) "A Resistance Thermometer for Transient Measurements," J. L. Chao & V. A. Sandborn, Fluid Mechanics Paper No. 1, CSU, 1964.
"Instrument for Measuring the Intermittency of Quasi-Steady Signals," by C. L. Finn and V. A. Sandborn, Fluid Mechanics Paper No. 3, Colo. State University, 1964.
"A Three-Dimensional Single Roughness Element in a Turbulent Boundary Layer," by H. W. Tielemand and V. A. Sandborn, Fluid Dynamics and Diffusion Laboratory, CSU, April 1965.
"Evaluation of the Turbulent Energy Dissipation From the Time Derivative Measurements," by C. Y. Liu and V. A. Sandborn, Fluid Dynamics and Diffusion Laboratory, CSU, April 1965.
"Vertical-Velocity Fluctuations in Thermally Stratified Shear Flows," by J. E. Cermak and H. Chuang, Proceedings of International Colloquium on Fine Scale Structure of the Atmosphere, Moscow, USSR, June 1965.

(4608) TURBULENCE DATA ANALYSIS SYSTEM.

(b) Department of the Army and National Center for Atmospheric Research.
(c) V. A. Sandborn, Associate Professor.
(d) Laboratory development.
(e) The system employing magnetic tape input is designed to yield the following information: (1) spectra (10^{3} to 10^{4} cycles/second), (2) joint probability densities, (3) root-mean-squares, and (4) space-time correlation.

(4612) TRANSPORT OF PARTICLES THROUGH UNSATURATED SOILS.

(b) Department of Health, Education, and Welfare, Bureau of State Service.
(c) Dr. A. T. Corey, Prof. of Agricultural Engrg.
(d) Applied; experimental.
(e) The objective of this research is to determine to what extent the transport of solid particles by water flowing through soil may be affected by the degree of saturation of soil. The term "soil" is interpreted broadly as including sands and gravels as well as agricultural soils. The solid particles to be considered in this study will be of sizes and shapes corresponding to that of viruses.
(f) Active, continuing.
(g) A considerable amount of data has been

accumulated which show that soils (and even sand) have a considerable capacity to adsorb virus-like particles. If, however, a continuous supply of these particles are supplied over a period of time, sand will eventually lose its capacity to retain additional particles. Under the latter conditions virus-like particles may be transmitted for considerable distances through sands (even fine sands). Soils having even a small amount of clay can retain a vastly greater quantity of virus particles than clean sands. The mechanism is apparently physical adsorption rather than entrapment.

(4617) MECHANICS OF LOCAL SCOUR.

(b) Department of Commerce, Bureau of Public Roads, Hydraulic Research Division.
(c) Mr. S. S. Karaki, Associate Professor and Dr. H. W. Shen, Assoc. Professor.
(d) Theoretical and experimental; basic research.
(e) A theoretical study of the mechanics of local scour is under way to develop basic equations for determining local scour. Basic experiments will be undertaken simultaneously to assist theoretical development.
(h) "Time Variation of Bed Deformation Near Bridge Piers," by H. W. Shen, Y. Ogawa and S. S. Karaki, International Assoc. for Hydraulic Research Eleventh International Congress, Leningrad, U.S.S.R., Sept. 1965.

(5161) CHANGE IN QUALITY OF DRAINAGE EFFLUENT FROM IRRIGATION PROJECTS USING A VISCOUS FLOW ANALOGY MODEL.

(b) U. S. Bureau of Reclamation.
(c) Mr. M. W. Bittinger, Assoc. Civil Engineer, Colo. State Univ., Fort Collins, Colo.
(d) Experimental.
(e) The study is designed to determine quality change (with time) of tile drainage effluent under various aquifer and geometry conditions.
(g) Results - Dimensionless curves have been prepared relating quality of effluent to time, permeability, porosity, tile spacing, and distance above impermeable layer, and recharge rate for uniform aquifers. Additional studies are being conducted on layered aquifers.

(5164) FLOW MEASUREMENT.

(b) Colorado Agricultural Experiment Station, Civil Engineering Section and Northern Plains Soil and Water Conservation Research Division, ARS, USDA.
(c) Dr. H. J. Koloseus, Assoc. Prof. of Civil Engineering, Colorado State Univ., Fort Collins, Colorado.
(d) Experimental laboratory and basic research which involves staff and graduate student participation leading to M.S. and Ph.D. degrees.
(e) This project has the general objective of developing and improving devices and techniques for the measurement of irrigation water. The present activity includes: (1) The further development of the semiconductor strain gage method of measuring velocity in pipes and open channels and its utilization to measure the velocity distribution above and very close to both smooth and rough boundaries in open channels, and (2) continued studies of the trapezoidal measuring flumes, control structures for alluvial channels and other metering devices.
(g) A suspension wire probe involving use of semiconductor strain gages has been developed to measure average velocity in pipes and essentially point velocities in open channels. The probe is being further modified to measure velocity very close to boundaries. Also, a pipe insert flow meter is being developed.
(h) "Pipe Insert Flow Meter," by M. S. Abadallah and D. B. Simons, Nov. 1965, (final report).

(5165) HYDRAULICS.

(b) Colorado Agricultural Experiment Station and Civil Engineering Section.
(c) Dr. D. B. Simons, Associate Dean for Research, Colorado State Univ., Fort Collins, Colo.
(d) Basic hydraulic research.
(e) This research is in hydraulics oriented toward agriculture and irrigation. The principal areas under study include, fall velocity, sediment transport, resistance to flow in alluvial channels with limited research on rigid boundary hydraulics including loss in bends and the mechanics of flow in alluvial channels.
(g) A study has been completed on the fall velocity of gravel size particles. Reports are in preparation on resistance to flow in open channels, bed material transport in open channels, and design of stable channels.
(h) "Sedimentary Structures Generated by Flow in Alluvial Channels," by D. B. Simons, E. V. Richardson and C. F. Nordin, Aug. 1965.
"Unsteady Movement of Ripples and Dunes Related to Bed-Load Transport," by D. B. Simons, E. V. Richardson and Carl F. Nordin, Jr., 1965.
"Behavior of Geometric Particles Falling in Quiescent Viscous Fluids," by Glen E. Stringham. Aug. 1965.
"Analysis of Change in Size of Bed Material Along Alluvial Channels," by Tariq Rafay, 1964.

(5393) MANAGEMENT OF GROUND WATER RESERVOIRS - SURFACE WATER SUPPLIES.

(b) Colorado Water Conservation Board.
(c) M. W. Bittinger, Associate Professor.
(d) Theoretical and experimental; and applied research.
(e) A study of operation and management of ground water reservoirs which are in hydraulic connection with appropriated stream flow. It is the purpose of this study to develop practical conjunctive-use plans so as to alleviate water right conflicts, increase beneficial use and stablize water supplies for junior appropriators.
(f) Completed.
(g) Systems analysis studies have been completed on simple hypothetical stream-aquifer systems.

(5394) ECONOMICS OF WATER TRANSFER: AN INSTITUTIONAL APPRAISAL.

(b) State of Colorado Experiment Station - Western Regional Project W-81.
(c) L. M. Hartman, D. A. Seastone and R. L. Anderson.
(d) Theoretical, field investigation, basic research and applied research.
(e) The study was set up to investigate and compare various organizations and procedures, which control the use of water in terms of their respective acheivement of allocative efficiency. Also, to investigate and estimate demand functions for water in various uses and investigate complimentary and competative relationships between uses, with emphasis on the implications of these relationships for organizational arrangements.
(g) The project has just been initiated and present accomplishments include a rather comprehensive study of the organization of the Northern Colorado Conservancy District.

(5395) WATERSHED MANAGEMENT PRACTICES AFFECTING WATER SUPPLIES ON IRRIGATION PROJECTS.

(b) U. S. Bureau of Reclamation.
(c) R. E. Dils and J. R. Meiman.
(d) Field investigation; applied research.

(e) The objectives of this study are: (1) to evaluate the use of dye solutions as a method of determining water yields from watershed subdivisions, (2) to test snow surface additives for the suppression of evaporation and control of snow melt and (3) to study such additional watershed management measures as are suggested by the work and which offer promise of successful application to Bureau projects.

(5396) EXPERIMENTAL ARTIFICIAL RECHARGE STUDY-ARICKAREE RIVER.

(b) Colorado Ground Water Commission.
(c) Mr. Robert A. Longenbaugh, Assistant Research Engineer, CSU.
(d) Experimental; applied research, design and operation.
(e) The purpose of this study is to determine the feasibility and practicality of artificial ground water recharge with Eastern Colorado ephemeral-stream flood flows using temporary low-cost structures. The project will include the design and evaluation of several different types of recharge structures.
(g) Structures were designed and constructed on two artificial recharge sites. Data were collected for two floods in June prior to the destruction of the project by the July 24 flood. Analyses of data and consideration on reconstruction of the project are underway.
(h) Progress Report #PR170 - Artificial Ground Water Recharge on the Arickaree River Near Cope. July 1965.

(5397) PUMPING PLANT EFFICIENCY STUDIES.

(b) KC, Highline and YW Rural Electric Associations, Kansas-Nebraska and Plateau Natural Gas Companies, and Colorado Farm Power Council.
(c) Mr. R. A. Longenbaugh, Assistant Research Engineer, Colorado State University, Fort Collins, Colorado.
(d) Field investigation and operation.
(e) This is a part of an interdepartmental study that is being conducted to determine the pumping costs for the deep well turbine irrigation pumps in Eastern Colorado. Both Natural Gas and Electric pumping plants will be evaluated. Efficiency data will also be used to calculate the total quantity of water pumped from the aquifer.
(g) Efficiency data has been collected on 68 wells in 1964 and 235 in 1965. These wells use deep well turbine pumps in Eastern Colorado using electricity, natural gas, and liquid petroleum gas for power.
(h) Final report on observed efficiencies of the 303 wells and a discussion of the causes of low-efficiencies will be published by January 1, 1966.

(5398) ELECTROKINETIC-POTENTIAL-FLUCTUATION METHOD FOR INVESTIGATION OF TURBULENT FLOW.

(b) National Science Foundation.
(c) J. E. Cermak, Professor of Engineering Mechanics in charge of Fluid Mechanics Program, Civil Engineering Section, Foothills Campus, CSU.
(d) Experimental and basic research.
(e) A systematic study is being made of the response of electrode probes to electrokinetic fluctuations produced by turbulence in flowing water. An effort is being made to determine directional sensitivity of the probes and to optimize their design for use in measuring turbulence characteristics in water. Work in the effect of dissolved salts and different electrode materials on response of the probes is underway.
(h) "Measurement of Turbulence in Water by Electrokinetic Transducer," by J. E. Cermak and L. V. Baldwin, Fluid Mechanics Paper No. 2, Colorado State University, April 1964. "Turbulence Measured by Electrokinetic Transducer," by H. Chuang and J. E. Cermak, Journal Hydraulic Division, ASCE 91 (2) 1965.

(5399) TURBULENT DIFFUSION OF GASES.

(b) U. S. Army Electronics Material Agency.
(c) J. E. Cermak, Professor of Engineering Mechanics in charge of Fluid Mechanics Program, Civil Engineering Dept., Foothills Campus, CSU, and E. J. Plate, Associate Professor, Civil Engineering Dept., Foothills Campus, CSU.
(d) Experimental and basic research.
(e) Turbulent diffusion of tracer gas in the turbulent boundary layer is being studied. Two main problems are being studied; (1) turbulent diffusion downstream from a 2-dimensional "hill" and (2) diffusion over and in a simulated vegetated region. In both cases the boundary layer is stratified by either heating or cooling.
(h) "Modeling of Velocity Distribution Inside and Above Tall Crops," by E. J. Plate and A. A. Quvaishi, Journal of Applied Meteorology, Volume (3), June 1965.
"The Velocity Distribution Downstream From a Two-Dimensional Model Hill," Part I, by E. J. Plate and C. W. Lin, Fluid Dynamics and Diffusion Laboratory, CSU, April 1965.

(5400) CHEMICAL SEALING OF WATER CONVEYANCES.

(b) State of Colorado.
(c) Mr. R. D. Dirmeyer, Jr.
(d) Experimental and field investigation; applied research and development.
(e) The purpose of this project is to develop practical, fast and low-cost design procedures for utilizing chemicals, such as NaCl and NaCO, for pond sealing purposes. The work is including laboratory evaluations and field trials.
(g) Three field trials have been installed and are being evaluated.

(5401) DIFFUSION IN SHEAR FLOWS.

(b) Health, Education and Welfare, State Services.
(c) Dr. J. E. Cermak, Professor of Engineering Mechanics and In-Charge of Fluid Mechanics Program, and Dr. L. V. Baldwin, Acting Dean, College of Engineering.
(d) Experimental; basic research.
(e) A study of turbulent diffusion in turbulent boundary layers with varying degrees of thermal stability is being conducted in the micrometeorological wind tunnel. One specific goal is to determine the effect of molecular diffusivity of a diffusing gas upon the overall diffusion rate.

(5402) RESEARCH INITIATION - MEANDERING IN STRAIGHT ALLUVIAL CHANNELS.

(b) National Science Foundation.
(c) H. W. Shen, Associate Professor.
(d) Experimental and theoretical; basic research.
(e) This is to study the generation of secondary currents between the smooth and rough boundaries in an open channel. The development of secondary currents in the flow is the cause of forming alternating scour holes (commonly known as meander pattern) on the alluvial channel bed.
(f) Temporarily discontinued.
(g) The generation of secondary currents in open channel was found to be associated closely with both the presence of rough boundaries and the unsteadiness of the main flow.
(h) Under preparation.

(5403) SLOT JET INVESTIGATION.

(b) Kalium Chemical Limited.
(c) V. M. Yevdjevich, Professor.
(d) Experimental; basic research.

(e) The diffusion of submerged circular and two-dimensional jets have been well studied. This investigation refers to slot jet deflection, with various width-length ratio of slots. The time-average velocity distributions, as well as flow rate, momentum and energy changes with distance from the orifice are investigated.
(f) Completed.
(g) The distribution of velocities as function of length-width ratio of slot jets have been determined. As a result of the research on the project, Slot Jet Investigation, the following paper was published: "Diffusion of Slot Jets with Finite Orifice Length-Width Ratios," by V. M. Yevdjevich, Dec. 1965, CSU, Hydraulics Paper No. 2.

(5404) REMOTE SNOW MEASURING DEVICE.

(b) Jointly with Soil Conservation Service, Forest Service and U. S. Bureau of Reclamation.
(c) Jack N. Washichek, Supervisor, USDA and SCS.
(d) Field investigation; operation and development.
(e) This device is a 12-foot diameter pillow filled with antifreeze which indicates water content of the snow at the site. This is achieved by the use of a manometer indicating pressure on the pillow. This data can be recorded on standard A-35 or F Recorder or telemetered to any area for reception. Purpose is to develop some instrument to gather continuous data relating to snow pack in the mountainous areas. It will also indicate duration, and intensity of each snow storm. This equipment could be installed in unaccessible areas. Six more remote sentinels will be installed in the Steamboat Springs area. These will be capable of telemetrying the information to Steamboat Springs.
(g) The remote snow measuring device installed at Berthoud Pass last year accurately measured the water content of the snow at the site. Some problems encountered, generally were attributed to the expansion of the methanol. This year a closed system will be used to eliminate the diurnal change.
(h) "History of Snow Pillow at Berthoud Pass," by Jack N. Washichek, Sept. 1965.

(5405) GROUND WATER IN HIGH PLAINS OF COLORADO.

(b) Plateau Natural Gas Company.
(c) M. W. Bittinger, Associate Professor, Civil Engineering Section.
(d) Thesis.
(e) A study of ground water management problems and needs in the High Plains of Colorado.
(f) Completed.
(g) Natural ground water recharge is negligible to potential development and sound management is needed, based on physical, legal and economic considerations.

(5406) EVALUATING STREAM POLLUTION IN THE SOUTH PLATTE RIVER NEAR DENVER, COLORADO USING AERIAL PHOTOGRAPHY.

(b) Civil Engineering Section, Engineering Research Center, Colorado State University, Ft. Collins, Colorado.
(c) M. M. Skinner.
(d) Field investigation and applied research.
(e) Four film types (black and white, black and white infra-red, color and color infra-red) have been used to photograph a stretch of the South Platte River in the vicinity of Denver, Colorado. The purpose of the study is to (1) Detect the location of outfalls; (2) observe the photographic impression of pollution in the stream; (3) determine film types most suitable for detecting stream pollution; and (4) develop photo interpretive techniques applicable to stream pollution studies in general.
(f) Completed.

(5407) WATERSHED ENVIRONMENT AND MICROBIAL DYNAMICS.

(b) Public Health Service, Water Pollution.
(c) S. M. Morrison, Colorado State Univ., Dept. of Microbiology.
(d) Experimental, basic research.
(e) A study of the effects of physical and biological environmental factors upon the microbial dynamics of mountain water sources with emphasis upon improved laboratory and field methods. To gain information on the subject of surface water pollution by comprehensive study of the physical, chemical, and biological factors which affect the growth, survival, and distribution of bacterial organisms that are potential enteric pathogens or that are potential indicators of water pollution. Study area in field is the Cache LaPoudre River at elevation 6000/9000 ft. Laboratory studies include refrigerator water-bath similator of the microbial environment.
(g) An improved membrane filter--enrichment medium technique developed for detecting (enteric bacteria) and urea utilizing organisims. Patterns of relationship between total bacterial counts and Escherichia coli and the relationship of the organisms to the physical environment have been determined.
(h) "Behavior of Selected Enteric Bacteria in Varying Quality Natural Water," by C. W. Hendrics and S. M. Morrison. Bacteriological Proceedings, 1965, p. 12.
"Effect of Stream Flow on the Coliform and Total Bacterial Content of a Mountain Stream," by S. M. Morrison and J. F. Fair. Bacteriological Proceedings, 1965, p. 12-13.
"Stream Environment and Microbial Dynamics," by J. F. Fair and S. M. Morrison. Hydrology Monograph Series, Colorado State University, No. 13, 1965 (In press).

(5408) GEOLOGIC FACTORS CONTRIBUTING TO THE DEVELOPMENT AND HYDROLOGIC CHARACTERISTICS OF MOUNTAIN BOGS AND MEADOWS.

(b) Rocky Mountain Forest and Range Experiment Station.
(c) B. C. Goodell.
(d) Field investigation and thesis.
(e) The basic objectives of this study are: (1) To map bedrock of study area(s); (2) to log the overlying regolith(s); (3) interpret the information obtained in terms of geologic history and current characteristics of water recharge, storage, and discharge; and (4) to conduct limited tests of these interpretations with tracer techniques.
(g) (Field data collected - analysis in progress.)

(5409) PHYSICAL CHARACTERISTICS-SEDIMENT YIELDS, AND STORM HYDROLOGY OF TWO SMALL COLORADO FRONT RANGE WATERSHEDS.

(b) Colorado Game, Fish, and Parks Dept.
(c) E. E. Farmer.
(d) Field investigation and Thesis.
(e) The major objectives of this study are to: (1) Determine present watershed use and conditions contributing to sediment production and movement and depressed water quality; (2) determine stream bank, channel, and stream discharge conditions contributing to sediment production and movement and depressed water quality; and (3) determine present water quality as related to flow regime. These studies are being conducted on selected tributaries of the North Fork of the Cache LaPoudre watershed.

(5410) WATER UTILIZATION STUDY - ARKANSAS RIVER BASIN-COLORADO.

(b) State of Colorado.
(c) M. M. Skinner, Asst. Civil Engineer, Civil Engineering Section Foothills Campus, Colorado State Univ., Fort Collins, Colo.
(d) Field investigation and applied research.
(e) A water resource inventory (ground water and surface water) and water utilization study for a 15-county area in South Eastern Colorado. Summary of potential water users to benefit from a new trans-mountain water diversion project and alternate plans for use. Summary of future water needs. Compilation to be used for planning new developments in the area.
(f) Completed.
(g) A summary of historic ground and surface water uses in the Arkansas Valley consisting of Appendices listing historic records is included in the final report with a brief discussion of future needs and possible development.
(h) Water Utilization Study Project No. Colorado P-30/Arkansas Valley Region. CER65MMS20.

(5411) FACTORS INFLUENCING THE FLOW OF SUBSOIL WATER IN THE IMMEDIATE PROXIMITY OF AND INTO DRAINAGE FACILITIES.

(b) Colorado Agricultural Experiment Station.
(c) Dr. A. T. Corey.
(d) Experimental and theoretical; applied research.
(e) The work underway in Colorado is for the purpose of perfecting techniques of porous media modeling. When these techniques have been perfected sufficiently a laboratory model of a large field installation will be constructed in the Hydraulics Laboratory. Work to date has established what soil parameters need to be taken into account when a model media is selected. The theory has been tested by comparing laboratory models of different sizes and materials and found to be valid.
(g) Using the techniques developed, it will be possible to solve many problems associated with flow into drains that are much too complex for analytical solutions.
(h) "Properties of Porous Media Affecting Fluid Flow," by R. H. Brooks and A. T. Corey. A manuscript prepared for publication in Transactions of the ASCE.

(5412) HYDROMETEOROLOGY OF WESTERN RIVER BASINS.

(b) Office of Naval Research.
(c) H. Riehl and J. Rasmussen.
(d) Experimental; basic research.
(e) The purpose of this project is to find relationships between the large-scale circulation features of the atmosphere as they affect precipitation over large western watersheds. The study covers daily precipitation and longer period precipitation extending to months and seasons. Computations of daily precipitation minus evaporation from moisture flux computations are being computed with the purpose of obtaining estimates of the evaporation over the basin. The watersheds studied are the Colorado River Basin and the Sacramento River Basin.
(g) The precipitation regimes of the Colorado river basin have been determined and some circulation features associated with wet and dry periods have been found and the results published in reports listed below.

(5413) IMPACT OF LAND USE ON WATER QUALITY WITHIN A FORESTED MOUNTAIN WATERSHED.

(b) Experiment Station, McIntyre-Stennis.
(c) James R. Meiman.
(d) Field investigation; basic research.
(e) The objectives of this study are to assess present water quality characteristics within a forested mountain watershed at varying natural flow regimes under land use conditions of limited development to non-use, and to measure the effects of multiple land use management--including road construction, logging, recreational developments, and grazing--on water quality.

(5876) HYDRAULIC OPERATING CHARACTERISTICS OF LOW GRADIENT BORDER CHECKS IN THE MANAGEMENT OF IRRIGATION WATER.

(b) Colorado Agricultural Experiment Station and Office of Water Resources Research; Agricultural Research Service (Cooperator).
(c) Dr. Norman A. Evans, Head, Agricultural Engineering Dept.
(d) Field investigation and applied research.
(e) Determine water application efficiencies for low gradient border checks. Determine the limitations of border checks under different cropping practices. Determine effectiveness of automation on low gradient border checks. Develop design criteria for low gradient border checks.
(g) The project began on July 1, 1965 and as yet no significant results have been obtained.

(5877) FLOW OF SUBSOIL WATER IN PROXIMITY OF DRAINAGE FACILITIES.

(b) Colorado Agricultural Experiment Station.
(c) Dr. Norman A. Evans, Head, Agricultural Engineering Department.
(d) Experimental, theoretical, basic research, and applied research.
(e) To develop methods for the construction and operation of laboratory models of systems involving flow from soils into drains.
(g) Criteria of similitude for flow in partially saturated soils have been developed theoretically and tested experimentally. The tests have shown these criteria of similitude to be valid.
(h) CSU Hydrology Paper No. 9.

(5878) DEVELOPMENT OF MATHEMATICAL METHODS OF EVALUATION OF RESULTS OF ATMOSPHERIC WATER RESOURCES PROGRAMS.

(b) U. S. Bureau of Reclamation, U. S. D. I.
(c) Dr. V. M. Yevdjevich.
(d) Theoretical and applied research.
(e) The objectives of this research are: (1) to develop criteria for selecting mountainous drainage basins for general and experimental weather modification procedures; (2) to evaluate the hydrologic characteristics of river flows from basins selected for experimental weather modification purposes; and (3) to develop mathematical and statistical techniques for evaluating the attainments of experimental weather modification programs.
(g) Research still in progress.

(5879) WATER STORAGE MANAGEMENT.

(b) Office of Water Resources Research, U.S.D.I.
(c) Dr. V. M. Yevdjevich.
(d) Theoretical and basic research.
(e) The objective of this research is to determine the optimum method of water storage for any selected watershed or region on the basis of climatic, geomorphic, ecologic and other characteristics.
The term storage is here taken to mean the beneficial retention of water by impounding reservoirs, groundwater recharge, snow accumulation, and/or watershed management practices. The optimum method of storage is that which achieves the most economic balance between the value of water lost from beneficial use by evaporation or other causes and the cost of storage utilization.
(f) Discontinued.
(g) Project replaced by Project 5881, on which research is still in progress.

(5880) STUDY OF CHANGES IN WATER QUALITY IN A GROUND WATER RESERVOIR.

(b) Office of Water Resources Research.
(c) Robert A. Longenbaugh, Asst. Research Engineer, CSU.
(d) Field investigation operation and applied research.
(e) A field study was conducted near Severance, Colorado, to determine the extent and cause of their ground water quality problem. Development of research techniques and experience in ground water quality investigations was one of principal goals.
(g) Ground water quality in the Severance area of Colorado is influenced by geology, fertilizer practices, feedlot contamination, oil field brine disposal and individual influences can not be differentiated.

(5881) WATER STORAGE MANAGEMENT.

(b) Office of Water Resources Research, U.S.D.I.
(c) Dr. V. M. Yevdjevich.
(d) Theoretical and basic research.
(e) The objective of this research is to determine the optimum method of water storage for any selected watershed or region on the basis of climatic, geomorphic, ecologic and other characteristics.
The term storage is here taken to mean the beneficial retention of water by impounding reservoirs, groundwater recharge, snow accumulation, and/or watershed management practices. The optimum method of storage is that which achieves the most economic balance between the value of water lost from beneficial use by evaporation or other causes and the cost of storage utilization.
(g) Research still in progress (continuation of Project (5879).

(5882) EVALUATION OF THE TOTAL WATER RESOURCES OF THE KIOWA-BIJOU BASINS OF COLORADO.

(b) Colorado Water Conservation Board.
(c) Robert A. Longenbaugh and Harold R. Duke, Research Engineers, CSU.
(d) Field investigation and applied research.
(e) All available data will be analyzed to evaluate the total ground water and surface water resources of the Kiowa-Bijou watersheds. Analyses will be made on the required accuracy of the data and suggestions made for the collection of the required data for management of the water resources.
(g) Quantities of water in storage, present pumping rates, annual natural recharge and projected pump withdrawals have been computed for the Kiowa-Bijou Basin.

(5883) USE OF RADIOISOTOPES IN MAKING ACCURATE DISCHARGE MEASUREMENTS IN PIPELINES.

(b) U. S. Bureau of Reclamation.
(c) Robert W. Filmer and Jack C. Schuster.
(d) Experimental, theoretical and applied research.
(e) To study the turbulent diffusion of a solute injected into a pipeline so that the accuracy of indirect flow measurements can be predicted.

(5884) DESIGN FLOODS FOR SMALL WATERSHEDS IN ARID AND SEMI-ARID WEST.

(b) Bureau of Land Management, Dept. of the Interior.
(c) Dr. Brian M. Reich.
(d) Theoretical and applied research.
(e) Knowledge is sought of floods in arid and semi-arid regions, their probability, hydrographs and relation to rainfall and basin parameters.

(5885) HYDRAULIC INVESTIGATION OF FLEXIBLE TUBES.

(b) Kalium Chemicals Limited.
(c) Mr. B. P. Edmonds, Kalium and Dr. A. H. Barnes, CSU.
(d) Experimental, development and applied research.
(e) The purpose of this study is to develop a nozzle of such a geometry that the hydrodynamic forces produced thereby will deploy a flexible hose under a free water-surface. The study is (1) to determine the hydrodynamic properties of various nozzle geometries; and (2) to determine the hose diameter-discharge relationships for a stable hose position.
(g) Nozzle geometries have been determined to produce predictable forces on the end of a hose. Additional field tests are proposed to be made.

(5886) DEVELOPMENT OF TELESCOPING TUBES FOR USE IN SOLUTION MINING.

(b) Kalium Chemicals Limited.
(c) George L. Smith (CSU); B. P. Edmonds, Mining Manager (Kalium Chemical Limited).
(d) Experimental, theoretical; applied research, design; development.
(e) The purpose of this study is to design, construct and test a telescoping tube with a reactive head at the discharge outlet. The telescoping tube to have an O.D. range from 3-1/4 to 1 in., and to be tested under various conditions of discharge and buoyancy.
(g) Development of telescopic tubes and theoretical curves for determining maximum length of the nested tubes for given t/D = thickness/diameter-and submergence conditions of fluids of different specific gravities. Maximum deflection of the pipes for given lengths and fluid characteristics has been determined also.
(h) Preliminary report in preparation.

(5887) STUDY OF THE HYDRAULICS OF FLOW THROUGH SOLUTION CAVITIES.

(b) Kalium Chemicals Limited.
(c) Dr. E. P. Helvingston, Kalium and Dr. A. H. Barnes, CSU.
(d) Experimental and basic research.
(e) This is a basic observational study to (1) determine the characteristics of the fluid motion within a solution cavity; and (2) to identify those parameters relating geometry, discharge rate and specific gravity of the effluent brine from a solution cavity. Two experimental facilities have been constructed to observe the phenomena. Each represents an 18° cylindrical sector of an assumed solution cavity. One approximately 8 inches high by 24 inches long and the larger 5 feet high by approximately 15 feet long. The ultimate purpose will be to better understand the physical process of solution mining as it applies to water-soluble salts.
(g) Preliminary quantitative studies have indicated the general pattern of circulation as predicted. Certain anomilies are attributed to the character of the salt blocks (livestock) used. Natural rock salt blocks will be used to observe whether or not the same phenomena exists.

(5888) STUDY OF RIPPLES AND RIPPLE BED STRATIFICATION WITHOUT AND WITH SUPERPOSED WIND-GENERATED WAVES.

(b) Marathon Oil Company, Littleton, Colorado.
(c) Dr. D. B. Simons, Associate Dean for Research, Colorado State University, Fort Collins, Colorado.
(d) Experimental and basic research.
(e) A study of the characteristic stratifications of ripples generated at the sand-water interface in alluvial channels with and without wind generated water waves at the air-water interface.

(5889) STABLE ALLUVIAL CHANNELS.

(b) National Science Foundation.
(c) H. W. Shen, Associate Prof. and D. B. Simon,

Professor.
(d) Experimental, basic research.
(e) The objectives of this project are to study: (1) The shear distribution on the rigid boundary of channels with different cross section shapes. (2) The effects of sediment load; seepage force, flood plain material and hydraulic conditions on the ultimate stable channel cross section based on the variation of shear distributions along the boundary.

(5890) CHANGES IN THE PHYSICAL AND BIOLOGICAL CHARACTERISTICS OF GROUND WATER RESERVOIRS AND ADJACENT SURFACE WATERS.

(b) The Office of Water Resources Research, Dept. of the Interior.
(c) S. M. Morrison, Prof. of Microbiology, Colorado State University.
(d) Experimental, basic research.
(e) The objectives of the research are (1) to determine the chemical and biological relationships between ground water and adjacent surface flows under laboratory conditions and (2) to determine the changes in physical and biological characteristics of ground water reservoirs as a result of man's activities in a specified natural location.
Laboratory studies will be done in models of a ground-water surface flow system with known chemical agents and bacteria used as markers to study flow, movement and adsorption. The field studies will be at selected sites adjacent to a stream to study ground water movement and quality as related to the geology and man made structures.

(5891) DIFFUSION OF ENTRAPPED GASES IN RESPONSE TO INTERFACIAL ENERGY.

(b) National Science Foundation.
(c) A. T. Corey, Dept. of Agr. Eng., Colorado State University, Fort Collins, Colorado.
(d) Experimental, theoretical and basic research.
(e) A study of the process whereby a gas in isolated pockets (surrounded by liquid) diffuses from porous media under the influence of interfacial energy. The object is to develop and to test equations describing the rate of diffusion of entrapped gas from porous media.

(5892) FLOW INTO SUB-SOIL DRAINS.

(b) CSU, Agricultural Experiment Station.
(c) A. T. Corey, Dept. of Agricultural Engrg., Colorado State University, Fort Collins, Colorado.
(d) Experimental, theoretical, applied research and development.
(e) Development of techniques for modeling systems involving drainage from soils.
(g) A theory of similitude for flow in partially saturated porous media (and applicable to drainage from soils) was developed. The criteria of similitude resulting from this theory were tested experimentally and found to be valid.
(h) CSU Hydrology Paper Number 9.

UNIVERSITY OF COLORADO, Department of Civil Engineering.

(5701) STUDIES OF BRANCHED OPEN-CHANNEL FLOW.

(b) Laboratory project.
(c) Dr. W. W. DeLapp, Department of Civil Engrg., University of Colorado, Boulder, Colo. 80304.
(d) Laboratory investigation; applied research.
(e) Study of the division of flow in an open channel as influenced by the angle of the branch, the Froude number upstream, the ratio of the width of the branch to the width of the main channel for sub-critical flow.
(h) Master's thesis will be completed early in 1966 and will be available on loan from University of Colorado library. "Studies of Branched Open-Channel Flow," by Barada Sarma.

(5702) REGIONAL ENVIRONMENTS ON THE EAST SLOPE OF THE COLORADO FRONT RANGE.

(b) Army Research Office.
(c) Dr. John W. Marr, Director of Arctic and Alpine Research, Univ. of Colorado, Boulder, Colorado 80304.
(d) Field investigation; applied research.
(e) A continuing project started in 1951 with measurements of air and soil temperature, relative humidity, precipitation, wind, snow depth and soil moisture at four stations ranging from 7,000 to 12,300 feet elevation. Solar radiation measurements started in 1964.
(g) A master's thesis on the relationship of geographic parameters and storm movement to precipitation is now being completed by Civil Engineering graduate student.
(h) The thesis by Donald Richard Minges will be available in 1966 on loan from University of Colorado library.

(5703) ENGINEERING-HYDROLOGIC ANALYSIS OF WATER RIGHTS.

(b) Office of Water Resources Research, Dept. of the Interior.
(c) Dr. J. Ernest Flack, Dept. of Civil Engrg., University of Colorado, Boulder, Colo. 80304.
(d) Field investigations; applied research.
(e) A case stream is being studied in detail to identify the physical quantities of water described in the legal water rights as to priority, yield and timing of the diversions. These are being correlated with stream flow to determine the inter-relation of legal and hydrologic definitions of the rights.
(g) Preliminary results include evaluation of the effect of urbanization on downstream irrigation withdrawals. Low flow analysis of the case stream at various locations and with different end-of-season dates have been made.

(5704) ANALYSIS OF TOTAL WATER USE.

(b) Office of Water Resources Research, Dept. of the Interior.
(c) Dr. J. Ernest Flack, Dept. of Civil Engrg., University of Colorado, Boulder, Colo. 80304.
(d) Field investigation.
(e) The goal of this study is the determination of total water use of selected municipalities and industries. Total water use includes withdrawals, consumptive use and return flow. The effects of price and climate on water consumption will be considered.
(g) Water consumption by categories of users--residential, industrial and commercial--have been determined for Boulder, Denver and Colorado Springs, Colorado and Monterrey, Mexico. The effects of metering and climatic factors on water use have been investigated. Changes in water use and revenue from water sales overtime have been investigated and some conclusions regarding projections have been made.
(h) "Analysis of Total Water Use by Selected Cities and Industries," by Fortunato Martinez. M. S. thesis published through cooperation of the Natural Resources Center, Colorado State University.

(5705) STABILITY OF STONES IN OPEN CHANNEL FLOW.

(b) Laboratory project.
(c) Dr. J. Ernest Flack, Dept. of Civil Engrg. University of Colorado, Boulder, Colo. 80304.
(d) Experimental, basic research, for Master's thesis.
(e) This study is an experimental investigation of the scour of stones subjected to high velocity flow in an open channel. The loss

of material from the test section is being correlated with parameters such as the mean velocity of flow, the bed velocity, the note of flow, depth of flow, slope of channel, and diameter and weight of the stones.

(f) Suspended.

(g) Empirical relationships have been developed correlating the scour of the stones with various flow and geometry characteristics. No specific results have been obtained but some general conclusions regarding scour of stones have been made.

(h) "Stability of Stones Under Flowing Water," by Nazir Joonejo. M. S. thesis, now in preparation, will be available on loan from the University of Colorado library, Boulder, Colorado.

UNIVERSITY OF CONNECTICUT, School of Engineering.

(5489) BOUND-ROCK EROSION PROTECTION FOR HIGHWAY DRAINAGE DITCHES.

(b) Connecticut State Highway Department and Institute of Water Resources.

(c) Prof. C. J. Posey, Box U - 37, Univ. of Conn., Storrs, Conn. 06268.

(d) Experimental, applied.

(e) Develop application of scientific erosion-protection method to highway ditches. Experiments will provide necessary design data and develop construction methods for low-cost installations.

(5490) RECOVERY OF DEPTH OF SCOUR FLOATS RELEASED DURING FLOODS.

(b) Department of Civil Engineering.

(c) Prof. C. J. Posey, Hydraulics Research Laboratory, Box U - 37, Univ. of Conn., Storrs, Conn. 06268.

(d) Field investigation; for master's thesis.

(e) Floats devised by W. B. Moeller were released in Connecticut and Willimantic Rivers during spring 1964 peak flows. Floats were brightly marked and had instructions and a return postcard visible from the outside. A float capable of reporting by radio is now being designed.

(f) Design of reporting floats temporarily suspended: probable subject of doctoral thesis.

(g) M . S. Thesis available on loan from Wilbur Cross Library, University of Connecticut, Storrs, Connecticut 06268. "Depth of Scour by Detection of Release of Buried Floats" by W. G. Moeller, 1965. See also Rocky Mountain Hydraulic Laboratory item 5488.

(5491) FLOW IN A WIDE FLAT TRIANGULAR CHANNEL.

(b) Laboratory project.

(c) Prof. C. J. Posey, Box U - 37, Univ. of Conn., Storrs, Conn. 06268.

(d) Experimental, basic.

(e) Measurement of water-surface configuration approaching drop-off at the end of a smooth channel with horizontal grade line.

(f) Suspended.

(g) Importance of lateral components is evident but unaccounted for in presently available theories. Turbulence intensity seems uniform over entire width.

(5492) DISCHARGE FROM CIRCUMFERENTIAL WEIRS.

(b) Department of Civil Engineering.

(c) Prof. C. J. Posey, Box U - 37, Univ. of Conn., Storrs, Conn. 06268.

(d) Experimental; master's thesis.

(e) Head measurements and nappe measurements for water flowing out of vertical pipes and spilling out over their horizontal peripheries.

(f) Completed.

(g) M. S. Thesis available on loan from Wilbur Cross Library, University of Connecticut, Storrs, Conn. 06268. "Discharge Over a Circumferential Weir," by Chao Song Shu, 1965.

(5737) REDUCTION OF RIVER HEAT POLLUTION BY TURBULENCE STIMULATION.

(b) Institute of Water Resources.

(c) Prof. V. E. Scottron, Civil Engineering Dept, Box U-37, Univ. of Conn., Storrs, Conn. 06268.

(d) Experimental; applied research for master's and doctoral theses.

(e) The objective of this work is to break up stratification of heated river flows by generation of heavy turbulence. The laboratory program will investigate a variety of turbulence generating devices, including systematic roughness, in low-speed air flows.

(5738) STUDY OF DISTURBANCE ON THE FREE SURFACE OF ROTATING FLUIDS.

(b) Laboratory project.

(c) Dr. J. D. Lin, Civil Engrg. Dept., Box U-37, Univ. of Conn., Storrs, Conn. 06268.

(d) Experimental and theoretical; basic research for both master's and doctoral theses.

(e) A theoretical and experimental study of the scattering of the disturbance generated on the free surface of rotating fluids. A rotating tank of 5' in diameter and 3' in depth is used for the experiments.

(5739) A STUDY OF VISCOUS FLOW PAST A SHIP.

(b) David Taylor Model Basin, Navy Department.

(c) Dr. J. D. Lin, Dept. of Civil Engineering, Box U-37, University of Conn., Storrs, Conn. 06268.

(d) Theoretical, basic and doctoral thesis.

(e) Calculation of Potential Flow over the hull of a ship generated by singularity distribution. Calculation of the boundary layer along the streamlines on the hull. Investigation of the wake and wave resistance of the hull form.

(g) Only intermediate results available.

(h) Quarterly progress reports since January 1965.

(5769) FILTER EROSION PROTECTION.

(b) Water Resources Institute.

(c) Prof. C. J. Posey, Box U-37, Univ. of Conn., Storrs, Conn. 06268.

(d) Basic research, experimental.

(e) To determine whether finest-grained non-cohesive and/or cohesive materials can be protected by Terzaghi-Vicksburg inverted filter.

(f) In progress.

CORNELL AERONAUTICAL LABORATORY, INC.

(5193) THEORETICAL STUDY OF HYDROFOIL FLUTTER CHARACTERISTICS.

(b) David Taylor Model Basin, Office of Naval Research, Dept. of the Navy.

(c) Dr. Irving C. Statler, Head, Applied Mechanics Dept., Cornell Aeronautical Laboratory, Inc., P. O. Box 235, Buffalo, New York 14221.

(d) Applied research (theoretical).

(e) The purpose of this investigation was to formulate the two-degree-of-freedom flutter determinant of a two-dimensional hydrofoil near the free surface and, then, to compute flutter boundaries for various values of system parameters.

(f) Completed.

(g) Despite large effects of the free surface on hydrodynamic loading, systems having two-degrees of freedom (pitching and plunging) have flutter characteristics nearly independent of submergence depth. A foil free only to pitch may experience serious instability due to proximity of a free surface, however.

(h) "Flutter Analysis of a Hydrofoil Near A Free Surface," by P. Crimi and J. M. Grace. Cornell Aeronautical Laboratory Report No. BB-1629-S3. August 1965.

(5194) THEORETICAL INVESTIGATION OF FORCES AND MOMENTS ON AN OSCILLATING HYDROFOIL WITH AN OSCILLATING FLAP.

(b) Bureau of Ships, Dept. of the Navy.
(c) Dr. Irving C. Statler, Head, Applied Mechanics Dept., Cornell Aeronautical Laboratory, Inc., P. O. Box 235, Buffalo, New York 14221.
(d) Applied research (theoretical).
(e) The objective of this study is to compute the lift, total moment and hinge moment for a fully-wetted oscillating hydrofoil with an oscillating flap from the exact, linearized, two-dimensional potential solution. The solution to be used takes full account of the surface waves caused by the hydrofoil.
(f) Completed.
(h) "Forces and Moments on an Oscillating Hydrofoil with an Oscillating Flap," by J. M. Grace and I. C. Statler, Cornell Aeronautical Laboratory Report No. BB-1798-S-1, January 1965.

(5363) UNSTEADY FORCES AND MOMENTS ON A TWO-DIMENSIONAL FULLY CAVITATED HYDROFOIL.

(b) Bureau of Ships, Dept. of the Navy.
(c) Dr. Irving C. Statler, Head, Applied Mechanics Dept., Cornell Aeronautical Laboratory, Inc., P. O. Box 235, Buffalo, New York 14221.
(d) Applied research (theoretical).
(e) The purpose of the project is to determine the steady and unsteady forces and moments on a fully cavitated hydrofoil operating near a free surface. The approach being taken to this general problem is to use linearized flow theory to examine the forces and moments on a fully cavitating flat plate executing either steady or harmonic motion near a free surface. Full account is taken of the gravity waves generated by the motion of the foil-cavity system and cavitation numbers greater than or equal to zero are considered.
(f) Suspended.
(h) "A Note on the Problem of an Oscillating Supercavitated Hydrofoil Near a Free Surface," by J. M. Grace and I. C. Statler, Cornell Aeronautical Laboratory Report No. BB-1935-S-1 in preparation.

(5364) AN EXPERIMENTAL AND THEORETICAL STUDY OF SCATTERING FROM WATER WAVES.

(b) Office of Naval Research, Dept. of the Navy.
(c) Dr. James W. Ford, Head, Applied Physics Dept., Cornell Aeronautical Laboratory, Inc., P. O. Box 235, Buffalo, N. Y. 14221.
(d) Applied research (experimental).
(e) The purpose of this research was to investigate certain aspects of microwave scattering from water waves. In particular, relationships were sought between characteristics of the waves and their Doppler spectra for backscattering. The program included experimental and analytical work. In the experiments a forty-foot wave tank was used for producing gravity and capillary waves with a wide range of characteristics, and a small X-band CW Doppler radar provided the radar measurements. The analytical work included a study of wave kinematics and the analysis of several possible mechanisms of scattering by water surfaces.
(f) Completed.
(g) A formulation of the physical optics theory applicable to microwave scattering from water surfaces has been developed. The special case of backscattering from simple gravity waves has been investigated, and expressions obtained for the scattering amplitudes from both smooth waves and rough waves. A simple model based on the assumptions that individual area elements of the water surface scatter independently with a Lambert's law distribution, and that the power scattered from an element is Doppler shifted in accord with the fluid velocity at the element has been considered in detail. Applications of this model to trochoidal waves have been made using expressions for particle trajectories and velocities derived from the theory of hydrodynamics.
(h) "Project WAVE: An Experimental and Theoretical Study of Scattering from Water Waves," by H. G. Camnitz and R. R. Rogers, Cornell Aeronautical Laboratory Report No. RM-1933-P-1, March 10, 1965.

(5775) THEORETICAL STUDY OF FREE-SURFACE EFFECTS ON APPARENT-MASS, QUASI-STEADY, AND WAKE CONTRIBUTIONS TO HYDROFOIL LOADS.

(b) David Taylor Model Basin, Office of Naval Research, Department of the Navy.
(c) Dr. Irving C. Statler, Head, Applied Mechanics Dept., Cornell Aeronautical Laboratory, Inc., P.O. Box 235, Buffalo, New York 14221.
(d) Applied Research (Theoretical).
(e) The purpose of this study was to evaluate the relative contributions to the lift and moment of apparent-mass, quasi-steady, and wake-induced loadings for a hydrofoil oscillating near a free surface, using the exact linearized potential solution for determining the flow.
(f) Completed.
(h) "Free-Surface Effects on the Apparent-Mass, Quasi-Steady, and Wake Contributions to Hydrofoil Loads," by J. M. Grace and I.C. Statler, Cornell Aeronautical Lab. Report No. BB-1629-S-2, August 1965.

(5776) THEORETICAL INVESTIGATION OF HYDROFOILS RUNNING UNDER SINUSOIDAL SURFACE WAVES.

(b) David Taylor Model Basin, Office of Naval Research, Department of the Navy.
(c) Dr. Irving C. Statler, Head, Applied Mechanics Dept., Cornell Aeronautical Lab., Inc., P. O. Box 235, Buffalo, New York 14221.
(d) Applied Research (Theoretical).
(e) This study is directed to computing the oscillatory lift and moment experienced by a two-dimensional hydrofoil running under sinusoidal surface waves, using the exact linearized potential solution for the flow.

CORNELL UNIVERSITY, School of Civil Engineering.

(4531) SECONDARY CURRENTS IN NON-CIRCULAR CONDUITS.

(b) National Science Foundation.
(c) Dr. J. A. Liggett, Hollister Hall, Cornell Univ., Ithaca, New York.
(d) Theoretical and experimental.
(e) Those secondary currents caused by Reynold's stresses in straight, non-circular conduits are being studied. A triangular open channel is being used. Measurements are to be taken by the hot-film anemometer.
(g) A quantitative theory has been developed and is being tested.
(h) "Secondary Currents in a Corner," by J. A. Liggett, C. L. Chiu, and L. S. Miao, Journal of the Hyd. Div., ASCE, Vol. 91, No. HY6, November 1965, p. 99.

(5039) PRESSURES DUE TO SUDDEN DRAWDOWN IN EARTH EMBANKMENTS.

(b) Laboratory project.
(c) Dr. J. A. Liggett, Hollister Hall, Cornell Univ., Ithaca, N. Y.
(d) Theoretical and experimental; basic and applied research.
(e) The equations for unsteady flow in porous media are being solved to find the pressures and free surface shape resulting from sudden drawdown in a porous media. Both analytical and numerical techniques are being used. Experimental work is conducted on a Hele-Shaw model.
(f) Suspended.
(h) "Initial Motion Problem in Porous Media," by

J. A. Liggett and Christos Hadjitheodorou, Journal of the Hyd. Div., ASCE, Vol. 91, HY3, May 1965, p. 61.

(5040) FRICTIONAL EFFECTS IN RIVERS AND WATERWAYS.

(b) Laboratory project.
(c) Dr. W. H. Graf, Hollister Hall, Cornell Univ., Ithaca, N. Y.
(d) Applied research.
(e) Under study are different American, English, Indian, Swiss and Austrian rivers and waterways. The data investigated are furnished by the different governmental offices.
(g) A theory has been put forward to calculate the frictional effect (Manning's n).
(h) "Gesetze der turbulenten Geschwindigkeitsverteilung in geschlossenen Rohren und offenen Gerinnen," by Schweizer Bauzeitung, 82. Jg., No. 53 (1964).
"Manning's Roughness Determination in Navigable Waterways," XXIst International Navigation Congress; PIANC: Stockholm, June 1965.

(5041) VARIATION OF KARMAN'S K-VALUE IN PIPES CARRYING SUSPENSIONS.

(b) Laboratory project.
(c) Dr. W. H. Graf, Hollister Hall, Cornell Univ., Ithaca, N. Y.
(d) Theoretical.
(e) A study of the Karman "K" value, as it appears in the logarithmic velocity distribution equation in an open channel shows considerable variation of its value dependent on the concentration. Under investigation in this research project is a closed pipe with varied concentration of sediment pumped through. Data are already obtained.
(f) Suspended.

(5302) SETTLING VELOCITIES OF SUSPENDED SOLIDS IN A TURBULENT ENVIRONMENT.

(b) U. S. Public Health Service.
(c) Dr. J. A. Liggett or Dr. W. H. Graf, Hollister Hall, Cornell Univ., Ithaca, N. Y. 14850.
(d) Theoretical and experimental; basic and applied research.
(e) The research concerns the effect of turbulence on suspended solids and the rate of settlement of suspended solids.

(5303) RECESSION HYDROGRAPHS OF IDEALIZED UNCONFINED AQUIFERS.

(b) Laboratory project.
(c) Dr. W. H. Brutsaert, Hollister Hall, Cornell Univ., Ithaca, N. Y. 14850.
(d) Experimental and theoretical.
(e) A Hele-Shaw model has been constructed to study the different parameters affecting drainage from large unconfined geological formations into stream channels. The obtained ground water recession hydrographs are compared with those derived from previous theoretical, but approximate, solutions. New theoretical analyses are being developed.
(h) "Inflow Hydrographs from Large Unconfined Aquifers," by H. A. Ibrahim and Wilfried Brutsaert, Journal of the Irrigation and Drainage Division, ASCE, Vol. 91, JR2, June 1965, p. 21.

(5304) INVESTIGATIONS ON TWO-PHASE FLOW PROBLEMS.

(b) College of Engineering, Cornell University.
(c) Dr. W. H. Graf, Hollister Hall, Cornell Univ., Ithaca, N. Y. 14850.
(d) Experimental and theoretical research.
(e) Various problems encountered in solid-liquid mixture transport are under investigation. Measuring devices for water solid mixtures will be developed.
(h) "Experimental Apparatus Studies Sediment Transport in Closed Conduit," by J. A. Liggett and H. A. Einstein, ASCE, Civil Engineering, 1963.
"The Loop System for Measuring Sand-Water Mixtures," by J. A. Liggett and H. A. Einstein, ASCE, Journal of Hydraulics, Jan. 1966.

(5305) THE PHYSICAL PHENOMENA INVOLVED IN PAN EVAPORATION.

(b) Laboratory project.
(c) Dr. W. H. Brutsaert, Hollister Hall, Cornell Univ., Ithaca, N. Y. 14850
(d) Theoretical and experimental.
(e) Evaporation is being measured from a number of insulated shallow pans of different sizes and colors. These experimental results and simultaneous climatological data will be used to check and extend some theoretical models of the hydrodynamics--and also of the energy budget aspects of pan evaporation and evaporation in general.

(5306) THE HYDRAULICS OF POROUS MEDIA.

(b) Laboratory project.
(c) Dr. W. H. Brutsaert, Hollister Hall, Cornell University, Ithaca, N. Y. 14850
(d) Theoretical and experimental.
(e) An analysis is being made of moisture characteristic curves of porous media to describe the pore size distribution by mathematical equations. These distributions are used to calculate hydraulic properties of the media.

(5307) MECHANICS OF INFILTRATION.

(b) Laboratory project.
(c) Dr. W. H. Brutsaert, Hollister Hall, Cornell Univ., Ithaca, N. Y. 14850.
(d) Theoretical.
(e) The micro hydrological equations of unsaturated flow in porous media are being investigated and solved for different boundary conditions. The results of the mathematical analysis are extended to develop infiltration equations for larger areas or for an entire watershed.

(5308) END-DEPTH STUDIES IN CHANNELS WITH MILD SLOPE.

(b) Laboratory project.
(c) Dr. W. H. Graf, Hollister Hall, Cornell Univ., Ithaca, N. Y. 14850.
(d) Applied research.
(e) The ultimate scope is to find end-depth relationship for channels with different geometrics.
(g) M. S. Thesis is being written at the moment.

(5873) STEADY AND TRANSIENT FLOWS IN RIVERS CONNECTING TWO RESERVOIRS.

(b) U. S. Dept. of the Interior.
(c) Dr. W. H. Graf or J. A. Liggett, Hollister Hall, Cornell University, Ithaca, New York.
(d) Theoretical and field investigation.
(e) The effects of friction, reservoir level, and transients on the flow profile, velocities and discharge.

(5874) MATHEMATICAL FLOW ANALYSIS.

(b) U. S. Dept. of the Interior.
(c) Dr. J. A. Liggett, Hollister Hall, Cornell University, Ithaca, New York.
(d) Theoretical.
(e) The equations of continuity and momentum are being solved on a digital computer in order to analyze unsteady flow over surfaces and in channels.

(5875) REGIONAL VARIATION OF STATISTICAL PARAMETERS OF STREAM FLOW.

(b) Laboratory project.
(c) Dr. D. A. Woolhiser, Hollister Hall, Cornell University, Ithaca, New York 14850.
(d) Theoretical, master's thesis.
(e) Stream flow records have been selected from

what would, a priori, appear to be a relatively homogeneous region with respect to the infiltration characteristics of the soils. This region also has a very low groundwater storage capacity. Log-One serial correlation coefficients for monthly, seasonal and annual periods have been calculated. Regression techniques are being used to relate these coefficients to measurable physical properties of the basins, or to climatic variations.

UNIVERSITY OF DELAWARE, Fluid Mechanics Laboratory Section, Dept. of Civil Engineering.

(4123) STUDIES ON MECHANICS OF FLUID FLOW.

(b) Laboratory and U. S. Army's Harry Diamond Laboratory Projects.
(c) Dr. K. P. H. Frey, Prof. of Engrg. Mech., Dept. of Civil Engrg., University of Delaware, Newark, Delaware 19711.
(d) Experimental, applied research.
(e) Verification of theoretical concepts of cusp devices and other abrupt enlargements using two- and three-dimensional models in the flume and the wind tunnel. Slotted guide vanes were used in two-dimensional models. Flow visualization in water and air, measurements (in air) of fields of static heads and degree of turbulence for large ratios of length over inlet width, 20, were done. The initial degree of turbulence was less than 1% (facility reported under 5366, 1965). The potential vortex motion theory, the Bernoulli equation, and the impulse momentum theorem were used for comparison.
(f) Completed at projected scope.
(g) The potential vortex motion theory is somewhat applicable during the very first phase of flow. The steady state of flow for all models, including cusp devices and application of guide vanes seems to be well described by the impulse-momentum theorem if sufficient length is available. The length over inlet width ratio should be larger on future tests. The static head and the degree of turbulence development are interrelated. The physical assumptions for the application of the impluse-momentum theorem seem to be reasonably met by the consideration of the drop of static head downstream from the inlet. In efficient methods of flow control there is a rapid increase of static head. Then, the static head remains constant throughout a large value of length over width. In total, a sudden enlargement without and with flow control at the inlet results in approximately same, maximum, head increase. The degree of turbulence at approximately 20 units of length over inlet width does not vary substantially for the various models.
(h) "Flow Stability for Two-Dimensional Cusp Devices," by K.P.H. Frey and N.C. Vasuki (paper No. 5).
"New Comprehensive Studies on Sudden Enlargements," by K.P.H. Frey, N. C. Vasuki and P. Trask (paper No. 6).
Proceedings of the (Third) Fluid Amplification Symposium of the U.S. Army's Harry Diamond Laboratory, Fluid System Branch, Washington, D.C., October 1965, Volume 1, pp. 111-118 (paper No. 5), pp. 119-137 (paper No. 6).
More information in "Detached Flow and Control," Chapters 4 and 8, and Appendix B, by K.P.H. Frey in collaboration with N.C. Vasuki (may be obtained through K. Frey, 96 E. Main Street, Newark, Del. 19711).

UNIVERSITY OF FLORIDA, The Engineering and Industrial Experiment Station, Coastal Engineering Laboratory.

Inquiries concerning projects should be addressed to Dr. Per Bruun, Head, Coastal Engineering Laboratory, University of Florida, Gainesville, Florida 32603.

(3413) INLET STUDIES.

(b) Laboratory project.
(d) Field investigation; applied research.
(e) Study of the stability of coastal inlets.

(4127) FLUORESCENT TRACING OF SEDIMENT IN COASTAL AREAS.

(b) National Institute of Health, Department of Health, Education and Welfare.
(d) Field investigation; basic and applied research.
(e) Tracing of sediment drift on beach and offshore bottoms by means of injected fluorescent material.
(g) Statistical sampling methods, rapid measurement fluorescent tracer concentration by electronic scanners, a new longshore current theory and a statistical approach to littoral transport mechanism are being developed at the laboratory.
(h) "Quantitative Tracing of Littoral Drift," by P. Bruun, published by Federal Inter Agency Sedimentation Conference, Proceedings, Jackson, Mississippi. Miscellaneous Publication No. 970, U. S. Department of Agriculture, 1965.

(4128) FLUX OF WAVE ENERGY PERPENDICULAR TO THE DIRECTION OF WAVE PROPAGATION.

(b) National Science Foundation.
(d) Basic research.
(e) Experiments to determine flux of wave energy perpendicular to the direction of wave propagation.
(f) Discontinued.
(h) "Wave Attenuation on a Channel with Roughened Sides," by J. A. Battjes, Engineering Progress at the University of Florida, Vol.XIX, No. 7, July 1965. Paper of same title presented at the Coastal Engineering Specialty Conference of Santa Barbara, California, October 1965.

(4129) INFLUENCE OF SEA LEVEL RISE ON EROSION.

(b) Laboratory project.
(d) Basic research.
(e) To determine the influence of short-term as well as long-term fluctuation of sea level on erosion and shoreline movements.
(f) Tracer experiment being undertaken on transversal drift in connection with other field projects.

(4474) COASTAL ENGINEERING STUDY AT SOUTH LAKE WORTH INLET, FLORIDA.

(b) South Lake Worth Inlet District Commission.
(c) South Lake Worth Inlet District Commission, c/o K. C. Mock and Associates, 2930 Okeechobee Road, West Palm Beach, Florida.
(d) Experimental field and applied research.
(e) To study distribution of inlet currents, improvement of entrance jetties, and navigation channels and measures against beach erosion. Also study the effect of proposed landfills in the bay.
(f) Completed.
(g) Report submitted to sponsor.
(h) Publication in print.

(4475) COASTAL ENGINEERING STUDY AT HILLSBORO INLET, FLORIDA.

(b) Hillsboro Inlet Improvement and Maintenance District, City of Pompano Beach and Trustees of the Internal Improvement Fund.
(c) Director, Trustees, Internal Improvement Fund, Capitol Bldg., Tallahassee, Florida.
(d) Experimental, field and applied research.
(e) To study methods for inlet stabilization, navigation improvement, and sand bypassing across the inlet.
(f) Completed.
(g) Report submitted to sponsor.
(h) Publication in print.

(4479) REVIEW OF BEACH EROSION AND COASTAL PROTECTION IN FLORIDA.

(b) Engineering and Industrial Experiment Sta.,

University of Florida.
(d) Field investigation; applied research.
(e) Review of the erosion and protection situation in Florida.
(f) Research continued.
(h) "Withdrawn Dykes and Preservation Lines," by P. Brunn. Shore and Beach, Journal of the American Shore and Beach Preservation Association, October, 1964. "Offshore Dredging - Influence on Beach and Bottom Stability," The Dock and Harbour Authority, London, England, Vol. XLV, No. 530, December 1964, p.7, by P. Bruun. "Revetments for Coastal Protection - Review of Some Different Types," Dock and Harbour Authority, Vol. XLIV, No. 520. February 1964. "Modern Trend in Revetment Design," by P. Brunn. Consulting Engineer, February 1964. "Coastal Protection Procedures," Bulletin No. 118, 1964, Vol. XVIII, No. 12, Florida Engineering and Industrial Experiment Station. "Revetments for Coastal Protection," by P. Brunn. The Journal of the Institution on Engineers in Australia, Vol. 37, No. 1-2, March 1965, pp. 17-20.

(4482) EXPERIMENTAL STUDY OF MECHANICS OF DUNE BUILDING AT CAPE HATTERAS NATIONAL SEASHORE AREA.

(b) Cape Hatteras National Seashore, National Park Service, Manteo, North Carolina.
(c) Cape Hatteras National Seashore, National Parks Service, Manteo, North Carolina.
(d) Experimental and field research.
(e) Study of mechanics of dune building by various types of sand fences and other sand catchment devices under controlled conditions is underway in a laboratory wind tunnel to be later correlated with field tests.

(4895) SAND TRANSPORT BY WIND & MECHANICS OF DUNE BUILDING.

(b) National Science Foundation, Washington, D. C.
(d) Experimental and theoretical; basic research.
(e) To study the basic mechanics of sand transport by wind under dry and humid conditions, with and without vegetation, uniform and gusty winds and with and without solid and permeable vertical fences.

(4896) HYDRAULIC MODEL TESTS FOR SUCTION WELL DESIGN FOR MIAMI RIVER WELL TREATMENT PLANT, DAYTON, OHIO.

(b) F.M.C. Corporation, Hydrodynamic Division, Peerless Pump, Indianapolis, Indiana.
(d) Experimental & applied research.
(e) To determine the most optimum compatible location and design of suction well baffling for the field treatment plant.
(f) Completed.
(h) Report submitted to sponsor.

(4897) COASTAL ENGINEERING STUDY OF SEBASTIAN INLET, FLORIDA.

(b) Sebastian Inlet, District, Melbourne, Florida.
(d) Experimental and applied research.
(e) To conduct field survey and model study of the inlet for least shore erosion and best navigable inlet conditions.
(f) Completed.
(g) Report submitted to sponsor.

(4898) BASIC RESEARCH ON LITTORAL DRIFT BY WAVE AND CURRENT ACTION.

(b) National Science Foundation, Wash., D. C.
(d) Experimental and basic research.
(e) A laboratory basic research project on friction coefficients and sediment transport by currents and waves running with or against each other and running perpendicular to each other.

(4899) HYDRAULIC MODEL STUDY OF BURNS WATERWAY HARBOR, INDIANA.

(b) Indiana Port Commission, State of Indiana, Indianapolis, Indiana.
(d) Experimental and applied research.
(e) Laboratory model study of the effects of diffraction, siltation, and harbor surging on the proposed harbor.
(f) Completed.
(g) Report submitted to sponsor.

(5281) TRACING OF LITTORAL DRIFT AT CAPE KENNEDY.

(b) Field project.
(c) Atomic Energy Commission.
(d) Basic applied research.
(e) Special tracer project on transversal drift in bottom and beach profile.

(5282) PROTECTION FOR DREDGE OPERATION IN NEW YORK BAY.

(b) Laboratory project.
(c) Gahagan Dredging Co., Pacific, Atlantic, and Gulf Dredging Co.
(d) Applied.
(e) To arrange proper protection for dredging operation at Staten Island, N. Y.
(f) Completed.
(h) Report submitted to sponsor.

(5283) SCRAPER OPERATION, JUPITER ISLAND.

(b) Field project.
(c) Coastal Engineering Research Center and Coastal Engineering Laboratory Cooperative project.
(d) Applied and basic.
(e) To check on operation of offshore scraper dragging sand in from 800 ft. from shore at 12-15 ft. depth.

(5284) SAND FENCES.

(b) Laboratory project.
(c) Coastal Engineering Research Center, Wash., D. C.
(d) Applied.
(e) To test various sand fences.

(5684) SIMILARITY OF BED LOAD TRANSPORT BY CURRENTS.

(b) National Science Foundation, Washington, D. C.
(c) Mr. J. A. Battjes, Dept. of Coastal Engrg., Univ. of Florida, Gainesville, Florida.
(d) Theoretical and experimental development research.
(e) A study of the feasibility of applying specially developed artificial roughness elements in movable bed models.

(5685) STUDY OF LONG WAVE PENETRATION IN DEEP NARROW FIORDS (ICELAND).

(b) Office of Naval Research, Washington, D. C.
(c) Office of Naval Research, Washington, D. C.
(d) Basic research.
(e) Research on low frequency ocean waves and their penetration in narrow fiords.

(5686) COASTAL ENGINEERING STUDY OF MACQUARIE HARBOUR INLET (TASMANIA).

(b) Pickands Mather & Co., Cleveland, Ohio.
(c) Pickands Mather & Co., Cleveland, Ohio.
(d) Experimental, theoretical and field investigation, applied research.
(e) Stability computations for the proposed navigation channel study methods to arrive at a minimum of maintenance dredging.

GRUMMAN AIRCRAFT ENGINEERING CORP.

(5195) THE EFFECTS OF GAS BUBBLES IN LIQUID SHEAR FLOWS.

(b) Laboratory project.
(c) Dr. Richard A. Oman, Head of Gas Dynamics Group, Research Dept., Plt. 25, Bethpage, New York 11714.
(d) Experimental and theoretical; basic research.

(e) This program is aimed at determining how a suspension of gaseous bubbles perturbs a liquid flow field. Bubbles can change the effective viscosity, introduce compressibility effects, and by convection through the liquid can transport momentum. These effects may have varying degrees of influence, depending on the type of flow. We have numerically solved for the boundary layer on a flat plate and on a rotating blade where the major perturbation is through viscous interaction between bubbles and liquid. We have also solved for a linearly accelerating flow, where the pressure gradient drives bubble convection. In these studies, unsteady bubble growth and collapse have been neglected and the bubble-liquid interactions have been described by Stokes' drag equation for a sphere. This work is being extended to include other effects, and to include propulsive flow systems. A small two-phase flow apparatus will provide experimental data on viscosity coefficients, bubble distributions, and flow patterns.

(g) Numerical solution for a liquid flat plate boundary layer containing a dilute suspension of small gas bubbles indicates reduced skin friction and increased thickness, the latter by more than the displaced volume of the bubbles.

UNIVERSITY OF HAWAII, Hawaii Institute of Geophysics, Department of Civil Engineering.

(5893) LABORATORY STUDY OF LONG WAVE AMPLIFICATION AT SMALL CIRCULAR ISLANDS.

(b) Conducted as a part of the Hawaii Institute of Geophysics Tsunami Research Program, Dr. W. M. Adams; Principal Investigator.

(c) Dr. John A. Williams, Center for Engineering Research, College of Engineering, University of Hawaii.

(d) The project is experimental and of an applied research nature.

(e) The project is a model study to determine the amplification of long waves on cylindrical islands which have circular "sea mounts" as bases, i.e.,

$$h = h_o \left(\frac{r}{b}\right)^q$$

where h_o is the water depth for all $r \geq b$
h is the water depth for $a \leq r < b$
(a is radius of cylindrical island), and q is an exponent which may vary over the range $0<q<2$. Wave heights at r = a are observed and compared with predicted values based on linear, long wave theory.

(f) The experiments are being conducted at present with completion of the laboratory work expected by March 31, 1966, and a report completed by June 30, 1966.

(g) The results to date concern only cylindrical islands with no base slope, i.e., a/b = 1. Both essentially deep water waves, i.e., $\lambda/D \leq 2.5$ and long waves, i.e., $\lambda/D \geq 22$, were used in these runs with the amplification at the cylinder showing reasonably good agreement with the theoretical predictions. The straight cylindrical island tests, conducted mainly as pilot runs to check out the experimental setup, are currently being followed by runs on islands with q's of .5, 1.0, and 1.5, where $0 \leq a/b \leq .357$ for each q.

(h) The particular theoretical results with which this model study is concerned are those of Drs. David Webster and Byrne Perry (as yet unpublished), who carried out their work in support of the H.I.G. Tsunami program.

UNIVERSITY OF HAWAII, J. K. K. Look Laboratory of Oceanographic Engineering, Civil Engineering Dept.

(5894) HILO HARBOR, HAWAII SEICHING STUDY.

(b) Laboratory project, in conjunction with Hawaii Institute of Geophysics.

(c) Jan M. Jordaan, Jr., Asso. Prof. of Civil Engrg., Univ. of Hawaii, Honolulu, Hawaii.

(d) Experimental, model and field data.

(e) Determination of Seiching periods and modes of harbor in present and future planned states, due to tsunamis and storm surges. Continuation study by Univ. of Hawaii on existing 1:600 Hor. 1:200 Ver. model of Hilo Bay of U. S. Army Corps of Engineers (See No. 3903 in 1965 Issue of Hydraulic Research in the United States under W.E.S., Vicksburg, U. S. Army Corps of Engineers.

(5895) HILO HARBOR, HAWAII, BEACH EROSION AND RESTORATION STUDY.

(b) Laboratory project, in conjunction with Hawaii Institute of Geophysics.

(c) Jan M. Jordaan, Jr., Assoc. Prof. of Civil Engrg., Univ. of Hawaii, Honolulu, Hawaii.

(d) Experimental, model and field data.

(e) Determination of feasibility of restoring bathing beach along Hilo Bayfront under present and future planned states of harbor. Utilize existing model, see above under (e).

(5896) RUN-UP AROUND COASTLINE OF OAHU, HAWAII.

(b) Laboratory project, in conjunction with Hawaii Institute of Geophysics.

(c) Jan M. Jordaan, Jr., Assoc. Prof. of Civil Engrg., Univ. of Hawaii, Honolulu, Hawaii.

(d) Experimental, model and field data.

(e) Determination of wave amplification and run-up potential, of tsunamis arriving from various directions, at points around the principal islands of the Hawaiian chain, starting with a model of Oahu, on a 1:250,000 scale.

UNIVERSITY OF IDAHO, Engineering Experiment Station.

(3056) TELEMETERING HYDROLOGIC DATA FROM MOUNTAIN LOCATIONS.

(b) Laboratory project; in cooperation with federal agencies and power companies.

(c) Prof. G. A. McKean, Elec. Engr. Dept., Univ. of Idaho, Moscow, Idaho 83848.

(d) Laboratory and field investigation; basic and applied operational research.

(e) A complete system for reporting six or more hydrologic data is being studied and basic parameters of snow melt are being studied for conversion into time delay circuits for transmission by radio.

(g) Prototype unit is being tested on Moscow Mountain; elements of measurement transducers are being studied both in the field and in the laboratory.

(h) "Telemetering Hydrologic Data from Mountain Locations," K. E. Waltz. Univ. of Idaho Engr. Exp. Station. Progress Report No. 7.

(3057) CONSERVATION OF WATER FOR RANGE STOCK.

(b) Laboratory project; in cooperation with Bureau of Land Management and ranchers.

(c) Prof. C. C. Warnick, College of Engineering, Univ. of Idaho, Moscow, Idaho 83843.

(d) Field investigation; applied operational research.

(e) Field investigation; applied operational research. Field investigation to study hydrology of small desert watersheds, evaporation under field conditions and occurrence of impermeable earth materials has been made. Several small ponds have been constructed using various manufactured lining materials and the effectiveness of evaporation retardants under field conditions has been investigated. It

is proposed to construct several small ponds in naturally impermeable sites or lined with local impermeable earth materials in 1966.

(g) Performance of various manufactured lining materials and effectiveness of evaporation retarding chemicals under field conditions has been evaluated. Some criteria for estimate of evaporation losses in range areas have been developed. Studies of the occurrence of impermeable sites and earth materials and the correlation of the occurrence of such material with geomorphology, vegetation and air-photo appearance have been undertaken.

(h) A progress report discussing asphalt and glass fibre pond linings was issued in 1964. A general report summarizing all aspects of the project will be presented in 1966.

(5167) TOTAL HYDROELECTRIC RESOURCES IN IDAHO AND DEVELOPMENT PROBLEMS ON IDAHO STREAMS.

(b) Laboratory project.
(c) Prof. Paul Mann, Elec. Engr. Dept., Univ. of Idaho, Moscow, Idaho 83843.
(d) Experimental, applied research for master's thesis.
(e) A study of streamflow data is being made to determine full water resource capability. The study is designed to develop estimating constants which may give a 90 percent accuracy. New ideas for stream-to-stream diversion will be investigated.

(5170) CORRELATION FOR THE DISPERSION OF LIQUIDS FLOWING THROUGH PACKED BEDS USING MODIFIED RANDOM WALK MODELS.

(b) Laboratory project.
(c) Dr. R. R. Furgason, Chem. Engr. Dept., Univ. of Idaho, Moscow, Idaho 83843.
(d) Theoretical and experimental, basic research for doctor thesis.
(e) The random walk equations were used as a model for the horizontal liquid distribution in a packed bed. A study was made of the effect of the liquid properties (surface tension and viscosity) on the horizontal dispersion of the liquid and the horizontal step sizes. A proposed mechanism for liquid flow through packed beds, consisting of a series of pools and vertical steps was evaluated by comparing the residence time for a tracer in the liquid with the apparent residence time for the liquid itself.
(f) Completed.
(g) The dispersion of a liquid in a packed bed was found to be affected by both surface tension and viscosity. A decrease in surface tension caused an appreciable decrease in the horizontal dispersion coefficient while an increase in viscosity caused a lesser decrease for any given size of packing.
(h) A Ph.D. thesis will be completed in 1966.

(5368) GROUND WATER MOVEMENT IN HIGHWAY LANDSLIDES.

(b) Laboratory project; cooperative with Idaho Dept. of Highways and Idaho Bureau of Mines and Geology.
(c) Prof. J. J. Peebles, College of Engineering, Univ. of Idaho, Moscow, Idaho 83843.
(d) Experimental and field investigation; applied research and development with master's thesis.
(e) To study the flow characteristics of ground water movement in landslides and to ascertain sources of the water. Tracing techniques are being studied using dyes and isotopes as well as other pressure measuring devices. This is an attempt to predict and identify slide behavior in places where slides are apt to occur.
(g) Various dyes have been experimented with in several locations in Northern Idaho.
(h) Master's thesis will be completed in early 1966.

(5897) FACTORS INFLUENCING THE FLOW OF SUBSOIL WATER IN THE IMMEDIATE PROXIMITY OF AND INTO DRAINAGE FACILITIES.

(b) Western Regional Research Project.
(c) Dr. G. L. Corey, Dept. of Ag. Engr., Univ. of Idaho 83843.
(d) Experimental basic.
(e) To develop a dimensionless nomograph for vertical free drainage from various soils.

(5898) TWO AND THREE-DIMENSIONAL DIFFUSION ANALYSIS OF UNSTEADY FLOW INTO POROUS MEDIA.

(b) Laboratory project.
(c) Dr. G. L. Corey, Ag. Engr. Dept., Univ. of Idaho, Moscow, Idaho 83843.
(d) Experimental basic.
(e) To determine quantity and rates of advance of flow into porous materials with various initial capillary pressures.

(5899) PHYSICAL STATE PROPERTIES OF PRECIPITATION.

(b) Office of Water Resources Research.
(c) Prof. G. A. McKean, Electrical Engr., Univ. of Idaho, Moscow, Idaho 83843.
(d) Experimental and field investigation, basic research for master's thesis.
(e) Precipitation state (i.e. rain or snow) is a useful parameter for application in watershed management and flood control. The objective of this project is to ascertain precipitation state properties which would permit actual determination of the state. Various properties of rain and snow such as optical reflectance, acoustic, energy and momentum and electrostatic properties will be investigated.

(5900) MOVEMENT OF WATER FROM CANALS TO A GROUND WATER TABLE.

(b) Office of Water Resources Research.
(c) Dr. G. L. Bloomsburg, Ag. Engr. Dept., Univ. of Idaho, Moscow, Idaho 83843.
(d) Experimental and field investigation, applied research for master's thesis.
(e) The movement of water from canals will be studied and new experimental tools such as a nulltensiometer for field conditions will be developed. An attempt to develop a procedure for obtaining permeability capillary pressure relationships in the field will also be made.

(5901) HYDROLOGY OF FROZEN GROUND FLOODS.

(b) Office of Water Resources Research.
(c) Prof. A. C. Robertson, Ag. Engr. Dept., Univ. of Idaho, Moscow, Idaho 83843.
(d) Experimental and field investigation, basic and applied research.
(e) Relationships between soil moisture, frozen ground temperatures, runoff water temperatures and infiltration rates will be investigated to develop parameters for use in estimating design discharges to expect from frozen ground floods.

(5902) TRANSITION BETWEEN LAMINAR AND TURBULENT FLOW IN POROUS MEDIA.

(b) National Science Foundation.
(c) Dr. G. L. Bloomsburg, Ag. Engr. Dept., Univ. of Idaho, Moscow, Idaho 83843.
(d) Theoretical and experimental basic research for master's thesis.
(e) A theoretical and experimental investigation will be conducted to develop an index of laminar or turbulent flow. This will be a modified Reynolds number which will better reflect the effect of pore size and tortuosity on the type of flow than the Reynolds numbers that have been used in the past.

(5903) EFFECT OF EXTERNAL AIR PRESSURE ON LIQUID FLOW THROUGH POROUS MEDIA.

(b) Laboratory project.
(c) Dr. G. L. Bloomsburg, Ag. Engr. Dept., Univ. of Idaho, Moscow, Idaho 83843.
(d) Experimental and theoretical, basic research.
(e) The effect of changes in external air pressure on flow of a liquid through a porous

media containing trapped air will be investigated in laboratory columns.

IIT RESEARCH INSTITUTE.

(5196) TURBULENT FLOW TRANSITION NEAR SOLID AND FLEXIBLE BOUNDARIES.

(b) BuShips Fundamental Hydromechanics Research Program administered by David Taylor Model Basin.
(c) Mr. Henry B. Karplus, Research Physicist, 10 West 35th St., Chicago 16, Ill.
(d) Experimental basic research.
(e) Transition to turbulence is investigated in a water channel having walls with adjustable rigidity. It is intended to obtain a better understanding of the effect of resilience and damping of the walls on the build up of turbulence in boundary layers. The ultimate objective is the reduction of drag of vessels and the reduction of boundary layer noise in hydrophone domes.
(f) Completed.
(g) Transition to turbulence is affected by wall resilience. Flexible walls may delay turbulence onset over limited flow rate regions.
(h) Interim Technical Report No. IITRI 1205-4.

(5538) STUDY OF VIBRATIONS INDUCED IN THIN-WALLED PIPES BY FLUID FLOW.

(b) N.A.S.A. , George C. Marshall Space Flight Center, Contract NAS8-11248.
(c) Mr. J. M. Clinch, IIT Research Institute, 10 West 35th Street, Chicago, Illinois 60616.
(d) This work involved an experimental and theoretical investigation of the vibrational response of thin-walled pipe sections to the wall pressure field applied by fully developed turbulent water flow within them.
(e) Experimental measurements were made of the turbulent wall pressure field in a 20' long 6" diameter pipe section, and of the vibrational response which it induces. Results are presented for a Reynolds number range from 5×10^5 to 2×10^6 . The measured pipe response is found to be in good agreement with that predicted theoretically using random vibration analysis.
(f) This work is to be extended to consider the effects of bends and elbows in the fluid line.
(g) See (e) above.
(h) "Study of Vibrations Induced in Thin-Walled Pipes by Fluid Flow," J. M. Clinch, Final report on NASA Contract No. NAS8-11248, September 1965.

(5904) OPTICAL MEASUREMENTS WITH HIGH TEMPORAL AND SPATIAL RESOLUTION.

(b) N.A.S.A., George C. Marshall Space Flight Center, Contract NAS8-11258.
(c) Mr. M. J. Fisher, IIT Research Institute, 10 West 35th Street, Chicago, Illinois 60616.
(d) The aim of this project is the development of a technique for measuring the local turbulent properties of shear layers while avoiding the insertion of probes into the flow.
(e) An experimental technique is being developed with the aid of which estimates of local turbulent properties of shear layers may be obtained without the necessity of inserting probes into the flow field. The probe is replaced by two beams of radiation, which pass through the entire flow field in two mutually perpendicular directions. It has been shown that, although each beam independently measures only an integral of the flow properties along the entire light path between the source and detector, the covariance of the two detected signals does yield local turbulent information.
Although the technique is primarily aimed at supersonic or hot turbulent flows a verification study has been performed using a subsonic jet. Good agreement with published hot wire data has been obtained.
(f) This work is currently being extended to supersonic jet exhausts.
(g) See (e) above.
(h) "A Technique for the Measurement of Local Turbulent Properties of Supersonic Shear Layers," M. J. Fisher and F. R. Krause, Proc. Fifth International Congress on Acoustics,1965. "Optical Integration over Correlation Areas in Turbulent Flows," F. R. Krause and M. J. Fisher, Proc. Fifth International Congress on Acoustics, 1965.

(5912) STUDIES ON TWO-DIMENSIONAL TURBULENT JETS (THE RECEIVER NOISE PROBLEM).

(b) Sponsored by the Harry Diamond Laboratories of the U.S. Army Materiel Command, Conn. and Van Ness Sts., Washington, D. C.
(c) Mr. Dennis W. Prosser, Research Engineer, IIT Research Institute, 10 West 35th Street, Chicago, Illinois 60616.
(d) Experimental and theoretical; basic research.
(e) The object of this program was to study the "noise" problem associated with the operation of single-stage proportional fluid amplifiers. The word "noise" refers to the undesirable momentum fluctuations which turbulence superimposes on the mean "signal" measured at the entrance of a receiver placed in the fluid jet.
(f) Completed.
(g) Main results were: (1) With a receiver held stationary in the power jet the noise to signal ratio is minimized by keeping the center of the receiver on the center line of the power jet. (2) When the receiver moves relative to the power jet the ratio of noise to change in genuine signal is minimized by keeping the receiver away from the center line of the power jet.
(h) "Studies on Two Dimensional Jets (the Receiver Noise Problem)," D. W. Prosser and M. J. Fisher, Sept. 21, 1965, final report prepared for the Harry Diamond Laboratories under Contract No. DA-49-186-AMC-192(D). Contact HDL for copies of report.

(5913) NOISE TRANSMISSION IN FLUID AMPLIFIERS.

(b) Sponsored by the Harry Diamond Labs. of the U. S. Army Materiel Command, Conn. and Van Ness Streets, Washington, D. C.
(c) Mr. Dennis W. Prosser, Research Engineer, IIT Research Institute, 10 West 35th Street, Chicago, Illinois 60616.
(d) Experimental and theoretical.
(e) The objective of this program is to determine the relative importance of stage-produced noise and transmitted noise in two-stage proportional fluid amplifiers, and subsequently to investigate the basic geometric and flow parameters associated with the larger of these two contributors to noise.
(g) Started January 1966.

ILLINOIS STATE WATER SURVEY DIVISION.

A list of publications is available upon request; write to Illinois State Water Survey, Box 232, Urbana, Illinois 61802.

(1865) HYDRAULIC DESIGN OF DROP-INLET SPILLWAY STRUCTURES FOR SMALL RESERVOIRS.

(b) Laboratory project, in cooperation with Agricultural Research Service, Soil Conservation Service, and Illinois Agricultural Experiment Station.
(c) Mr. H. W. Humphreys, Illinois State Water Survey, Box 232, Urbana, Ill. 61802.
(d) Experimental; generalized applied research for development and design.
(e) To determine the most desirable proportions and shapes of drop-inlet spillway structures that have unique flow characteristics and to develop anti-vortex devices. To provide

the necessary information on flow relations and discharge coefficients so that these structures may be economically designed. Experimental apparatus and tests conducted on the complete spillway. Information is being obtained on discharges, vortex effect on discharge, pressures, head loss coefficients, a flat plate anti-vortex device, and flow conditions.

(g) Model tests were performed on a drop-inlet spillway to determine whether or not a metal grating deck placed above the inlet can control vortices. The results of the tests show that gratings do not prevent or control strong vortices.

(h) Report of Investigation in preparation covering circulation effects, flat plate anti-vortex device effect, and vortex effect on model spillway performance.

(2535) FILTERING THROUGH COARSE MATERIALS.

(b) Laboratory project.
(c) Mr. Ralph L. Evans, Peoria Laboratory, Illinois State Water Survey, Box 717, Peoria, Illinois.
(d) Experimental; basic research.
(e) Small, coarse media (1/4 - to 3/4-inch) filters are operated at rates comparable to those achieved in field practice. Purpose is to study the effects of coarse media on physical, chemical, and bacteriological properties of recharged water and to evaluate the function of coarse media in protecting aquifer materials.
(g) Results of former field tests of various sizes of materials are reported in State Water Survey Bulletin 48. Program of specially controlled laboratory test runs initiated in 1962 under grant from U. S. Public Health Service.

(4135) CORROSION PREVENTION BY $CaCO_3$.

(b) Laboratory project.
(c) Dr. T. E. Larson or H. W. Humphreys, Illinois State Water Survey, Box 232, Urbana, Ill.
(d) Experimental.
(e) To determine chemical requirements and velocity requirements to provide protective coating in water pipes.

ILLINOIS DIVISION OF WATERWAYS, Springfield.

(1863) EROSION CONTROL, ILLINOIS SHORE OF LAKE MICHIGAN.

(b) State of Illinois.
(c) Mr. John C. Guillou, Chief Waterway Engr., Div. of Waterways, Dept. of Public Works and Buildings, 201 West Monroe Street, Springfield, Illinois 62706.
(d) Field investigation; applied research.
(e) To obtain and correlate basic data on the several forces and factors involved in erosion processes along the Illinois Shore of Lake Michigan to the end that future efforts toward the prevention of erosion might be founded upon a more definite and factual basis with a consequent greater degree of assurance that the works will serve the intended purposes.

(5548) SOLDIER CREEK CHANNEL MODEL.

(b) State of Illinois.
(c) Mr. John C. Guillou, Chief Waterway Engr., Div. of Waterways, Dept. of Public Works and Buildings, 201 West Monroe Street, Springfield, Illinois 62706.
(d) Experimental applied research.
(e) A hydraulic model study is being conducted to determine the practicability of increasing the channel capacity of Soldier Creek thru Kankakee by enlarging, realining and concrete lining the rock channel in order to reduce damaging flood stages.
(f) Completed and discontinued.

(5549) ILLINOIS RIVER.

(b) State of Illinois.
(c) Mr. John C. Guillou, Chief Waterway Engr., Div. of Waterways, Dept. of Public Works and Buildings, 201 West Monroe Street, Springfield, Illinois 62706.
(d) Experimental applied research.
(e) A hydraulic model study is being conducted to determine the effects, on the Upper Illinois River, of various flood relief measures proposed for the Illinois Waterway and Chicago Sanitary and Ship Canal.

(5656) KINKAID CREEK DAM.

(b) State of Illinois.
(c) Mr. John C. Guillou, Chief Waterway Engineer, Division of Waterways, 201 West Monroe St., Springfield, Illinois 62706
(d) Experimental; applied research.
(e) A hydraulic model study is being conducted to assist in the design of the spillway and stilling basin for a proposed reservoir to be constructed in Jackson County, Ill.

UNIVERSITY OF ILLINOIS, Soil and Water Conservation Engineering Lab., Department of Agricultural Engrg.

Inquiries concerning the following projects should be addressed to Prof. B. A. Jones, 100 Agricultural Engineering, University of Illinois, Urbana, Ill.

(2316) RUNOFF FROM SMALL AGRICULTURAL AREAS IN ILLINOIS.

(b) Laboratory project cooperative with ARS, U. S. Department of Agriculture.
(d) Experimental and field investigation; basic research.
(e) To determine frequencies of peak rates and total amounts of runoff from agricultural watersheds of 25 to 1,500 acres; to determine maximum rates of runoff from agricultural watersheds in different soil association areas in Illinois; to compare runoff from agricultural watersheds under accepted soil conservation practices with watersheds cultivated without soil conservation practices. Watersheds of 45.5, 63, 82, and 390 acres near Monticello, Illinois are covered with a rain gage network, and runoff is measured at weirs and spillway structures by water level recorders. Maximum stage recorders are installed at field structures on 8 watersheds in Champaign, Piatt, Vermillion, and Ford Counties on watersheds ranging in size from 45 to 1,400 acres. Model studies and field calibrations are made on the field structures.
(g) A computer program for the IBM 7094 has been developed to analyze and summarize rainfall data. Precipitation amounts are summarized for each storm, month, and year, and maximum intensities are tabulated for eleven duration ranges.
(h) Fortran II Program for Precipitation Data Analysis. J. Kent Mitchell, Agricultural Engineering Research Report, Illinois Agricultural Experiment Station, University of Illinois Urbana.

(2789) LABORATORY MODEL STUDIES OF CONSERVATION AND DRAINAGE STRUCTURES.

(b) Laboratory project.
(d) Experimental investigation in the laboratory; applied and basic research.
(e) To investigate the performance of soil and water conservation structures by means of hydraulic model studies, to study water flow patterns into surface drains and to determine the cause of failures and remedial measures of certain conservation structures under flood conditions.

(g) A model study of channel scour immediately upstream from a drop spillway is nearing completion. Preliminary analysis of scour location, rate, depth and volume data indicates that scour can be controlled by designing the weir and channel wide enough to maintain the depth and velocity of flow below scour threshold values.

(3424) A STUDY OF RAINFALL ENERGY AND SOIL EROSION.

(b) Laboratory project cooperative with ARS, U. S. Dept. of Agriculture.
(d) Experimental; basic research.
(e) Natural rainstorms are photographed with a raindrop camera so that the number of raindrops, their size and size distribution, and the kinetic energy of a rainstorm may be calculated. Physical measurements will be made of the soil to determine the effect of the kinetic energy of the rainstorm on soil loss. The nature and properties of rainstorms that occur in this area of Illinois will also be studied.
(f) To be completed by June 30, 1966.

(4986) WATER INFILTRATION RATE METHODS AND DETERMINATIONS ON SOILS.

(b) Laboratory project.
(d) Field investigation, basic research.
(e) To field test practical methods for determining and predicting relative infiltration rates of soils during irrigation and during rains. To determine infiltration rates for specific soil types under various management practices.
(f) Completed June 30, 1965.
(g) To be reported by North Central Region, Agricultural Experiment Station Bulletin.
(h) "Artificial Rainfall Used to Measure Infiltration Rates on Illinois Soils," by G. D. Bubenzer and B. A. Jones, Jr., Ill. Res. 8-1. In press (copies may be obtained from the authors).

(4987) THE EFFECT OF GYPSUM AND DRAINAGE ON SOLONETZIC SOILS (SLICK-SPOTS) IN ILLINOIS.

(b) Laboratory project in cooperation with Dept. of Agronomy.
(d) Experimental field investigation.
(e) To test the feasibility of replacing and removing excess sodium from solonetzic soils under field conditions with (a) different methods and rates of applying gypsum (calcium sulphate), (b) different degrees of disturbing the subsoil, and (c) different spacings of tile drains.
Twenty plots were established in a random pattern to compare 3 positions for the application of gypsum and 3 spacings of tile drains with check plots. The tile effluent is measured by recording equipment to determine the rate and volume of flow. Also samples will be taken to determine the amount of sodium in the leachate.

(5369) HYDROLOGIC CHARACTERIZATION OF SMALL WATERSHEDS.

(b) A laboratory project.
(d) Experimental and theoretical; basic research.
(e) The objective is to select a method for integrating the partial differential equations which will form a part of the mathematical model for watersheds.
(g) The computer programs developed in 1964 were used with new input data to analyze channel conditions leading to both sub-critical and super-critical flow upstream from a free overfall. The non-converging solutions previously reported for the sub-critical case did not appear when flow was super-critical, apparently because there was no longer a discontinuity in the depth and velocity derivative at the overfall.
(h) Discussion "Computer Analysis of Overland Flow," by R. N. Fenzl Proceedings ASCE, 91:HY6. 224-227. November 1965.

(5808) SURFACE DRAINAGE OF SLOWLY PERMEABLE SOILS OF SOUTHERN ILLINOIS.

(b) Laboratory project in cooperation with Dept. of Agronomy; SCS, U. S. Dept. of Agriculture; and M and W Gear Company.
(c) Same as listed earlier.
(d) Experimental field investigation.
(e) To determine a recommended spacing for a uniform system of surface drainage channels on slowly permeable soils of southern Illinois.
A field experiment will be conducted with four treatments replicated a minimum of three times. The treatments will be no drainage and parallel surface channels spaced 660, 990 and 1320 feet apart. Each treatment channel will drain approximately 1320 feet to a collection ditch. The no drainage area will be smoothed and the area between channels will be crowned to provide a uniform slope to all the channels. Likewise all channel grades to the collection ditches will be uniform.
The effectiveness of each treatment will be determined by sampling crop yield on grid line perpendicular to the channels and the collection ditches.

(5809) DEVELOPMENT OF DRAINAGE ASSESSMENT PROCEDURES BASED ON PHYSICAL FEATURES IN ILLINOIS.

(b) Laboratory project in cooperation with the Dept. of Agronomy and Dept. of Agricultural Economics.
(c) Theoretical and field investigation.
(e) To formulate an assessment procedure based upon measurable physical features of the land in Illinois.
The first phase will be to determine the over-all benefits that accrue to the land as a result of drainage. This will be based primarily upon the increase in land value or increase in return.
The second phase will be to develop an empirical equation giving consideration to the influence of selected physical features on benefits accruing to drainage. This equation will be tested on existing drainage districts which have assessment roles accepted by the land owners and approved by the courts.

UNIVERSITY OF ILLINOIS, Hydraulics and Water Resources Laboratory, Department of Civil Engrg.

Inquiries concerning all projects should be addressed to Dr. V. T. Chow, Prof. of Hydraulic Engineering, University of Illinois, Urbana, Ill., 61803, unless otherwise indicated.

(4538) WATER DISTRIBUTION SYSTEMS-ANALYSIS CRITERIA.

(b) N. I. H. Research Grant.
(c) Prof. M. B. McPherson, Dept. of Civil Eng., Univ. of Ill., Urbana, Illinois.
(d) Numerical; development.
(e) Exploitation of previously developed generalized relations describing network head losses in a concise analytical form makes possible comprehensive system analyses, balancing pump-network-storage characteristics for optimization of a composite system design.
(g) The feasibility and comparative cost of various operating options have been determined. Using a computer, system parameter combinations for given demand schedules have been studied, and results have been succinctly defined in simple representations. Simple analogous demand schedules, such as sine distributions, are being studied so that results can be completely generalized. More complex hydraulic cases will also be

investigated. Mathematical proofs and practical limitations of basic network and system parameters are being developed. Using statistical techniques, the possibility of simulating future demand schedules for general use in analysis, design, and operation will be studied.

(h) "A Study of Distribution System Equalizing Storage Hydraulics," by M. B. McPherson and R. Prasad, Univ. of Ill. Civil Engrg. Studies Series No. 6, March 1965.
"A Study of the Applicability of Generalized Distribution Network Head Loss Characteristics," by R. A Wiseman and M. B. McPherson, Univ. of Ill. Civil Engrg. Studies Series No. 7, June 1965.
"A Study of Power Consumption for Equalizing Storage Operating Options," by M. B. McPherson and R. Prasad, Univ. of Ill. Civil Engrg. Studies Series No. 8, June 1965.
"An Analysis of Distribution Demand Variations," by Gordon Gracie, Univ. of Ill. Engrg. Studies Series No. 9, June 1965.

(4541) VARIATION OF TRACTIVE FORCE IN SEWERS AND DRAINS.

(b) Laboratory project.
(d) Experimental and theoretical.
(e) To study the distribution of boundary shearing stress, or tractive force in a circular conduit flowing partially full and to determine the relationship between the shearing-stress distribution and the velocity distribution.
(g) The solution of the problem is based on the assumption that a turbulent flow in the channel has a uniform velocity distribution modified by boundary effects and turbulent mixing. The boundary effects are further considered to consist of two additive components, namely, viscous effects and the secondary effects caused by the restraint of the turbulent fluctuations at the walls and the surface. The velocity of flow normal to the channel cross section is therefore expressed as the weighted sum of two functions of the Poisson equation type. The relative influence of the two functions of the total flow is defined experimentally for the relationship of the weighted coefficient to channel geometry and roughness.
The experimental determination of the coefficient is accomplished by using a smooth copper pipe and a rough steel pipe. The tractive force distribution is determined by a "law-of-the-wall" method and with the Preston technique using Pilot tubes calibrated in place. The equations are solved by the finite-differences method using the digital computer to evaluate the weight coefficient in the Poisson equations for both smooth and rough pipes. The relations developed from this investigation compare favorably with some published velocity distributions including those obtained by Bazin.
(h) "Tractive Force Distribution in Open Channels," by John A. Replogle and Ven Te Chow, Proceedings ASCE, Journal of the Hydraulics Division, 91: HY8 (1965).

(4543) WATER RESOURCES SYSTEM ANALYSIS

(b) Laboratory project for R. W. Drucker's special problem.
(d) Theoretical; basic research
(e) Operations research techniques are used to optimize water resources systems for the planning and development of water projects. Convenient use is made of mathematical models and simulation. Optimization is made by deterministic and stochastic linear programming and dynamic programming considering various types of constraints including economic efficiency and budgetal limitations. For mathematical simulation, both random sampling and systematic sampling are considered, and additional hydrologic data are generated sequentially by means of Monte Carlo methods and Markov-chain models. Study of the reservoir design is made by using queueing theory through the use of the sequentially generated stochastic input flow information.
Additional research during the year was made to investigate the similarity between rail transport system and water resources system. Beginning with the nature of inputs and the physical formation of the systems, the comparable structures in two systems were studied. To each system, basic components, such as the dams and reservoirs in the water resources system and the yards in the railroad system, were identified and their uses were compared. The nature of flow in the systems, particularly the different types of flow, was also investigated. Finally modifications and assumptions were discussed in order to equate the two systems for purposes of comparative analysis.

(4905) WATER WAVE AND STRUCTURE INTERACTION.

(b) Laboratory project supported by the NSF undergraduate research grant and University of Illinois Research Board.
(c) Prof. J. P. Murtha, Dept. of Civil Engineering, Univ. of Illinois, Urbana, Illinois.
(d) Experimental; basic research.
(e) To study the time variation of forces produced by gravity waves on coastal and offshore structures and to evaluate the subsequent structural motion. The effort involves laboratory studies of wave-structure interaction as well as analytical investigations.
(g) During the past year, laboratory equipment for small-scale investigations has been constructed, and experimental data relating to type of disturbance and subsequent wave characteristics have been obtained.

(4906) BASIC INVESTIGATION ON WATERSHED HYDRAULICS.

(b) National Science Foundation research project.
(d) Experimental and theoretical; basic research.
(e) To investigate the basic laws governing the flow of surface water over drainage basins by controlled experiments on geometric basins. By controlling the various factors involved in the mechanics of flow, the experimental data so obtained can be more amenable to theoretical analyses for the determination of the basic laws. In addition to the shape of the geometric basin, other characteristics including slope, size, surface roughness, channel storage, channel density, etc., will be studied. The input rainfall excess is to be simulated by electronically controlled sprinkling systems composed of a large number of modules so that different patterns of rainfall supply and even the effect of the movement of rain-making clouds can be produced artifically. The output discharge from the basin is to be measured by electronic sensing devices which can automatically be digitized for the computer to construct the hydrographs of outflow.
(g) During the year, the hydraulic system as well as the electronic system were designed, constructed, and tested for experimental use.
(h) "Artificial Raindrops for Lab. Watershed Experimentation," Trans. American Geophysical Union, 45:4(1964), p. 611. "Raindrop Production for Laboratory Watershed Experimentation," by Ven Te Chow and Terence E. Harbaugh, Jour. of Geophysical Research, December 15, 1965.

(4908) THE FORCES CAUSED BY WAVES BREAKING AGAINST VERTICAL IMPERVIOUS RIGID WALLS.

(b) Laboratory project for a doctoral thesis by W. J. Garcia, Jr., under the direction of Prof. V. T. Chow cooperative with U. S. Army Engineers Waterways Experiment Station.
(d) Experimental and analytical; basic research.
(e) To formulate relations which will enable one to determine pressures on impervious rigid walls due to breaking waves with sufficient

accuracy to afford an economical and safe design for sea walls and breakwaters; also to investigate the variation of pressure on the wall with respect to time and spacial distribution.

(g) During the year the experimental data were analysed and a final report is in preparation.

(4909) A STUDY OF THE EFFECT OF BASIN STORAGE ON SURFACE RUNOFF HYDROGRAPHS.

(b) Laboratory project.
(d) Theoretical; basic research.
(e) To study the drainage basin taken as a lumped hydrologic system.
(g) Assuming a general nonlinear equation for the basin storage and combining it with the equation of continuity, a differential equation for the system is formulated. The equation is quasi-linearized by assuming that the coefficients are functions of the average inflow and outflow of the sytem. Solution of the resulting equation produces four possible conceptual system models depending on the nature of the roots of the equation. Storms and the corresponding outflow hydrographs over six natural drainage basins varying from 7.16 to 1,141 square miles are analyzed by the proposed equation and theory. From the results of the analysis it is seen that three coefficients of the proposed equation vary with the outflow, thus indicating nonlinearity, while the remaining two coefficients do not change much and can be assumed constant. A study of the variation of the three coefficients seems to indicate that they decrease exponentially with the peak runoff. The storage equation derived in this study is shown for use in flood routing and it is proposed also for use in infiltration analysis.

(4910) PROBABILITY AND SYNTHETIC HYDROLOGY APPROACH TO THE ANALYSIS OF RAINFALL-RUNOFF FREQUENCY RELATIONSHIP.

(b) Laboratory project.
(d) Theoretical; basic research.
(e) To treat the inflow into a basin as a stochastic input, the basin as a linear system, and the outflow as the response of the basin to the input and to investigate the stochastic behavior of the system by sequential generation and simulation techniques.
(h) "Sequential Generation of Rainfall and Runoff Data," by Ven Te Chow and S. Ramaseshan, Proceedings, Journal of Hydraulics Div., 91:HY4 (July 1965) pp. 205-223.

(5289) STOCHASTIC HYDRODYNAMIC ANALYSIS OF OCEAN WAVE ACTIONS ON MOORED PLATFORM FOR UNDERWATER MISSILE LAUNCHING.

(b) Laboratory project for a doctoral thesis by B. J. Muga, under the direction of Prof. V. T. Chow cooperative with U. S. Navy Civil Engineering Laboratory.
(d) Experimental and analytical; basic and applied research.
(e) To analyze the motions and forces induced by irregular waves on a construction type platform as moored in the open Pacific Ocean.
(g) Prototype and model tests are conducted on the platform, named "Fishook," which is of the catamaran design, having a displacement of 850 tons. It is spread-moored by four 2 1/2-inch stud link chains in 165 feet of water. Water level fluctuations, ship rotations and accelerations, mooring forces, and wind speed and directions are measured. Both prototype and model tests data are analyzed in the form of amplitude response operations by the spectrum and cross-correlation analyses of the complex time series histories. The results are compared with the linear theory of ship's motion. Equations of motion of the system for sinusoidal waves are formulated on the basis of the slender body theory for 6 degrees of freedom, taking into account both hydrostatic and hydrodynamic effects. The excitation functions and the various coefficients in the equations are obtained for surges, heaves, pitches, sways, rolls, and yaws. Solutions are also given to the forces in the mooring cables and the horizontal force components and the yawing moment induced by the mooring system on the platform.

(5657) HYDROLOGIC ANALYSIS BY ANALOG COMPUTERS.

(b) Laboratory project.
(d) Direct and indirect analog computers are used for the analysis of hydrologic problems on surface and ground water. In the analysis of surface water problems, the EAI PACE computer of the Analog Computer Laboratory was employed to route floods through linear as well as non-linear reservoirs. For the analysis of ground water, resistance networks were designed and analysed for a number of ground water regions. The results will be recommended for use in the design and planning of water resources systems.
(h) "Applications of Electronic Computers in Hydrology," by V. T. Chow, Section 29, "Handbook of Applied Hydrology" ed. by V. T. Chow, McGraw-Hill Book., Inc., New York, 1964.

(5658) NONLINEAR SYSTEM PARAMETERS OF SURFACE RUNOFF HYDROGRAPHS.

(b) Laboratory project for Ph.D. thesis by R. Prasad directed by Prof. M. B. McPherson.
(d) The determination and correlation of generalized parameters defining the hydrograph of surface runoff for natural drainage basins in central Illinois using a lumped nonlinear system approach are being studied. Involved are hypotheses relating to rainfall--storage--runoff relations and to a simulated basin reservoir routing. An attempt will be made to delineate the contribution of system nonlinearities. The bulk of the computations will be performed on a digital computer, complemented with work on an electronic analog computer.
(h) Discussion of "Nonlinear Instantaneous Unit Hydrograph Theory," by R. Prasad, Proceedings ASCE, 90:HY5, Paper 4050 (Sept. 1964), pp. 287-292.

(5659) FLOW IN A TWO-DIMENSIONAL 90° CLOSED BEND.

(b) Laboratory project for Ph. D. thesis by W. H. Huang directed by Profs. J. M. Robertson and M. B. McPherson.
(d) To approximate turbulent flow in two-dimensional closed bends for various bend-radius to approach-width ratios at different Reynolds numbers, using frozen vorticity fluid flow analysis.
(e) As a prelude to the turbulent case, numerical and analytic solutions for potential flow were achieved, together with exploratory numerical solutions for simulated wholly viscous conditions using the frozen vorticity concept. Velocity and pressure fields generated from the turbulent flow simulation analyses will be used in an attempt to explain general flow phenomena.

(5660) MICROSCOPIC DETERMINATION OF TRACTIVE FORCE DISTRIBUTION IN FREE-SURFACE WATER CONVEYANCES.

(b) Office of Water Resources Research Grant.
(c) Profs. V. T. Chow and H. G. Wenzel, Jr., Dept. of Civil Engrg., Univ. of Illinois, Urbana, Illinois.
(d) Experimental and basic research.
(e) Tractive forces of flow in conveyances tremendously affect the economy of water supply systems in water resources planning and development. The present knowledge of tractive force in flow lacks precision because it is based largely on a few empirical formulas using simplified analytical solutions. As a

result, water projects can easily be overdesigned or underdesigned. The present research is to investigate the tractive force distribution in water supply conveyances of various cross-sectional shapes carrying turbulent free-surface flow. Once the distribution is determined, it will be possible to apply this knowledge to channel proportioning and design.

(g) Investigation will involve the use of a newly invented high-power microscope equipped with light condensers to examine the velocity in the conveyance. By focusing the microscope onto the very proximity of the boundary, photographs can be taken by a high-speed motion camera. From these microscopic velocity measurements within the laminar boundary sublayer, it will be possible to establish the velocity gradient and thus to determine the tractive force developed on the boundary. The basic knowledge gained can be profitably incorporated in engineering design procedures.

(5661) INFLUENCE OF TURBULENCE ON SURFACE REAERATION.

(b) Office of Water Resources Research Grant.
(c) Prof. E. R. Holley, Dept. of Civil Engrg., University of Illinois, Urbana, Illinois.
(d) Experimental and basic research.
(e) Turbulence effects on surface reaeration rates are being studied from at least two aspects: (1) What is the turbulence condition near the free surface of turbulent water, i.e., in the region of the "surface film"? (2) What is the mechanism by which turbulence influences the rate of reaeration?

(g) An effort will be made to combine the theories of molecular diffusion and turbulent diffusion to describe the way that oxygen, which has been absorbed at the free surface, penetrates into turbulent eddies for subsequent transport away from the surface. The initial phase of the experimental work centers around measurement of turbulence conditions near the free surface, the gross rate of oxygen absorption, and the gradients of dissolved oxygen for some analogous substance near the free surface. It is planned to make these initial measurements in a turbulence mixing vessel. Later, it is hoped that similar measurements can be made in open channel flow.

(5662) SCOUR PROTECTION FOR CULVERT OUTLETS.

(b) National Science Foundation undergraduate research for D. D. Meredith.
(c) Prof. M. B. McPherson, Dept. of Civil Engrg., Univ. of Illinois, Urbana, Illinois.
(d) Analytical study.
(e) Analysis of all classes of energy dissipators which may be suitable for culverts, and development of new devices for optimum over-all hydraulic performance, are the ultimate goals of this study.
(f) Completed.
(g) An analysis and experimental investigation of the U. S. Bureau of Reclamation Basin VI energy dissipator used in conjunction with a box culvert has been completed. Criteria for classification and evaluation of energy dissipators for culverts have been established.
(h) "Energy Dissipators for Spillways and Outlet Works," by M. McPherson, with Task Force, Task Force Report, Proceedings ASCE, Journal of the Hydraulics Division, 90:HY1 (1964), pp. 121-147. Closure to discussion by Task Force, Proceedings ASCE, Journal of the Hydraulics Division, 91:HY2 (1965), pp. 292-300.

UNIVERSITY OF ILLINOIS, Fluid Mechanics and Hydraulics Laboratory.

Inquiries concerning Project No. 2083 should be addressed to W. M. Lansford, 219 Talbot Laboratory, University of Illinois, Urbana, Illinois, and for Projects Nos. 2536, 3427, 4142, 4558,5777 and 5778, to Professor J. M. Robertson, 125 Talbot Laboratory, University of Illinois, Urbana, Illinois 61803.

(2083) VELOCITY DISTRIBUTION IN AN OPEN CHANNEL HAVING A TRIANGULAR CROSS-SECTION.

(b) Laboratory project.
(d) Basic research.
(e) Data being obtained from a channel artificially roughened.
(f) Investigation reactivated, additional data being taken with new improved instruments, one of which is a hot wire probe.

(2536) STUDY OF HOMOLOGOUS TURBULENCE.

(b) Laboratory project, formerly National Science Foundation.
(d) Basic research.
(e) The nature of turbulence (its production and dissipation) is being studied in the simplest possible shear flow-plane Couette flow where the shear is constant and the turbulence homogeneous but not isotropic. Mean-flow studies essentially complete.
(f) Reactivated.

(3427) STRUCTURE OF TURBULENCE NEAR ROUGH SURFACES.

(b) Bureau of Ships Fundamental Hydromechanics Research Program.
(d) Basic research; experimental.
(e) Information on mean-flow and turbulence structure near roughnesses being studied in an 8-inch "natural roughness" pipe and in 3-inch sand-roughened pipe.
(f) Completed.
(g) Temporal-mean velocity and frictional results agree with Nikuradse for sand and Colebrook for natural roughness. Pipe factor correlation on same basis establishes another Nikuradse "shift." Turbulence intensity in terms of shear velocity is found to be similar to that in smooth pipe and to be nearly constant with Reynolds number. Spectral energy measurements evidence an inertial subrange at high enough turbulence Reynolds number when taken not too near conduit wall.
(h) "A Study of Turbulent Flow in Rough Pipes," by J. M. Robertson, T. H. Burkhard and J. D. Martin, T&AM Report No. 279, May 1965.

(4142) TURBULENT BOUNDARY-LAYER FLOW TOWARDS A NORMAL STEP.

(b) Laboratory project.
(d) Basic research.
(e) An analytical and experimental study is being made of upstream separation, i.e., the real fluid behavior (separation, mixing, reattachment) in front of a normal step projecting inward from a plate along which fluid is flowing with a turbulent boundary layer. Air is fluid medium being used.
(f) Investigation in process.
(g) First phase of study completed; in one case rather good agreement was found between theoretical solution and experimental observation of separation streamline.

(4143) HEMODYNAMICS SIMILITUDE STUDY OF AN ARTERIAL DISTRIBUTION SYSTEM.

(b) Public Health Service, National Institutes of Health, Research Grant No. HE08330-02.
(c) Prof. M. E. Clark, 123 Talbot Laboratory, University of Illinois, Urbana, Illinois.
(d) Basic research; experimental.
(e) The flow of blood in the Circle of Willis--the arterial distribution system for the brain--is to be studied utilizing large-sized models. Present goal is to fabricate a model which will simulate in as many ways as possible the prototype and its flow.
(f) Investigation in process.
(g) Fabrication and model-prototype verification of first-stage model essentially complete. Studies being initiated in the pulsatile flow aspects of flow in flexible conduits;

in particular, the wave reflections at bifurcations, the impedance characteristics of fluid Helmboltz resonators, and the velocity distributions in pulsatile flow as depicted by hydrogen bubble techniques.

(h) "The Circle of Willis as Simulated by an Engineering Model," by W. A. Himwich, F. M. Knapp, R. A. Wenglarz, J. D. Martin and M. E. Clark, Archives of Neurology, Vol. 13, 164-172, August 1965.
"Engineering Analysis of the Hemodynamics of the Circle of Willis," by M. E. Clark, J. D. Martin, R. A. Wenglarz, W. A. Himwich and F. M. Knapp, Archives of Neurology, Vol. 13, 173-182, August 1965.

(4558) EFFECT OF TURBULENT NORMAL STRESS ON DRAG EVALUATION BY WAKE MOMENTUM METHOD.

(b) Laboratory project.
(d) Basic research.
(e) Conventionally the evaluation of the drag of bodies from wake transverses ignores normal stresses in wake. Experimental measurements one half a chord length behind a fineness-ratio 3.5 strut indicates a contribution of some 2 percent. Further studies including finer bodies are planned.
(f) Suspended.

(4559) FLOW STABILITY AND HEAD LOSS IN BRANCHED TUBES.

(b) Public Health Service, National Institute of Health, Research Grant No. HE08330-02.
(c) Prof. M. E. Clark, 123 Talbot Laboratory, Univ. of Illinois, Urbana, Illinois.
(d) Basic research; experimental.
(e) In conjunction with a model study of the Circle of Willis--the arterial distribution system for the brain--a need was felt for a better understanding of the stability of viscous flows through certain types of junctions as well as the amount of head loss which occurs. A series of bifurcations and fusions of rigid, circular tubes are being studied to gain this understanding.
(f) Investigation in process.

(5777) THREE DIMENSIONAL EFFECTS IN TURBOMACHINERY.

(b) Caterpillar Tractor Co.
(d) Basic research, experimental and analytical, for Ph.D. thesis.
(e) Radial outward and inward flow systems are being studied in terms of base flow, boundary layer and secondary flow occurrences.
(f) Study initiated.

(5778) BODY DRAG AT LOW REYNOLDS NUMBERS.

(b) Laboratory project.
(d) Basic analytical and experimental research.
(e) Except for flat plate, analytical drag relations are available only in the creeping motion and boundary layer regimes. Experimental data is available only for a few other bodies in the intermediate (Navier-Stokes) range. Objective of study is to help fill this gap.

(5779) UNIQUE ASYMPTOTIC EXPANSIONS IN THE THEORY OF HYDRODYNAMIC STABILITY.

(b) National Science Foundation.
(c) Leland K. Shirely, 314 Talbot Laboratory, University of Illinois, Urbana, Illinois 61803.
(d) Theoretical, basic research.
(e) Asymptotic approximations of certain functions which occur in hydrodynamic stability theory are being studied with reference to their uniqueness; error bounds for such approximations are being studied also.
(g) Have obtained explicit representations for functions which satisfy the differential equations pertinent to the stability theory and which have asymptotic approximation indextially equal to zero.

IOWA INSTITUTE OF HYDRAULIC RESEARCH, University of Iowa.

(66) HYDROLOGIC STUDIES, RALSTON CREEK WATERSHED.

(b) Cooperative with the Agricultural Research Service and the U.S. Geological Survey.
(c) Prof. J. W. Howe, Department of Mechanics and Hydraulics, University of Iowa, Iowa City, Iowa.
(d) Field investigation; applied research, and M. S. theses.
(e) Study being made of relation between rainfall and runoff over a small area. Discharge from a 3-square-mile area measured by U. S. G. S.; rainfall records at five automatic recording stations collected by Agricultural Research Service. Continuous records since 1924 of precipitation, runoff, groundwater levels, and vegetal cover.
(g) Yearly records available for examination at Iowa Institute of Hydraulic Research.
(h) Reports prepared annually since 1924 available in files at the Iowa Institute of Hydraulic Research. Summary of 33-year record published as Bulletin 16 of the Iowa Highway Research Board in 1961; available upon request from Iowa Highway Commission, Ames, Iowa.

(67) COOPERATIVE SURFACE-WATER INVESTIGATIONS IN IOWA.

(b) Cooperative with U. S. Geological Survey.
(c) District Engineer, U. S. Geological Survey, Iowa City, Iowa.
(d) Field investigation; collection of basic stream-flow data.
(e) Stream-flow and sediment measuring stations maintained throughout the State of Iowa cooperatively on a continuous basis. Records collected by standard methods of U. S. G. S.
(g) Records of stream-flow and sediment discharge computed yearly.
(h) Records contained in Water-Supply Papers available through offices of the Geological Survey.

(68) HYDROLOGIC STUDIES, RAPID CREEK WATERSHED.

(b) Cooperative with U. S. Geological Survey.
(c) District Engineer, U. S. Geological Survey, Iowa City, Iowa.
(d) Field investigation; applied research.
(e) Study being made of relation between rainfall and runoff over a small area. Discharge from a 25-square-mile area measured and flood runoff on main subbasins determined by U. S. Geological Survey; rainfall ecords at four automatic recording stations collected by U. S. Weather Bureau. Continuous records since 1941 of precipitation, runoff, and ground-water levels.
(g) Rainfall records published in Weather Bureau Climatological Bulletins and surface runoff and ground-water levels published in Geological Survey Water-Supply Papers.

(73) MEASUREMENT OF TURBULENCE IN FLOWING WATER.

(b) Cooperative with Office of Naval Research, Department of the Navy.
(c) Dr. Philip G. Hubbard, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
(d) Experimental and theoretical; basic and applied research.
(e) Instruments, primarily electrical in operation are being developed to measure the characteristics of turbulent flow over a wide range of laboratory and field conditions. Both sensing and computing elements are involved.
(g) Additional studies on the stability of heat transfer over periods of several hours have shown that there is an "aging" effect. After a period of several hours of operation, the heat transfer is much more nearly constant.

(78) CAVITATION.

(b) Cooperative with Office of Naval Research, Department of the Navy.
(c) Dr. Hunter Rouse, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
(d) Experimental and theoretical; basic research and graduate theses.
(e) Basic information is sought on cavitation for systematically varied boundary conditions. Studies of cavitation in abrupt conduit expansions are now being pursued.
(h) "Fluctuation of Pressure in Conduit Expansions," H. Rouse and V. Jezdinsky, Proceedings, XI Congress IAHR, Leningrad, 1965.

(1875) CHARACTERISTICS OF STABLE EDDIES.

(b) Laboratory project, partially supported by Office of Naval Research, Department of the Navy and U. S. Army Research Office (Durham).
(c) Dr. Hunter Rouse, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
(d) Experimental and analytical; basic research.
(e) Distributions of velocity, pressure, and turbulence have been investigated throughout the vicinity of separation zones produced by abrupt changes in flow section, to the end of establishing the primary eddy characteristics as functions of the boundary geometry.
(g) Analytical evaluations are now being carried out for a two-dimensional and an axisymmetric boundary expansion.
(h) "Characteristics of Separation at Conical Afterbodies," S. Narasimhan, Ph.D. Dissertation, Univ. of Iowa, June 1965, (available on loan).

(2091) RESEARCH ON SHIP THEORY.

(b) Cooperative with Office of Naval Research and David Taylor Model Basin, Department of the Navy.
(c) Dr. Louis Landweber, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
(d) Experimental and theoretical; basic research.
(e) To determine the laws governing the forces, moments, and motions of ships. Work is under way on the following problems: (1) Development of procedure for computing potential flow about ship forms. (2) Determination of hydrodynamic images, forces, and moments for a spheroid in an arbitrary potential flow. (3) Effect of tank size on ship-model resistance. (4) Resolution of viscous and wave drag by means of wake and surface-profile measurements. (5) Effect of a free surface on separation. (6) Vibration of ships.
(h) "Free-Surface Effects on Turbulent-Boundary-Layer Separation," S. K. Chow, IIHR Report, March 1965.
"Experimental Study of Methods of Determining Wavemaking Resistance by Means of Surface-Profile Measurements," H. E. Kobus, IIHR Report, March 1965.
"Verification of Method of Determining the Viscous Drag of a Ship Model," Kenneth Key, M.S. Thesis, Univ. of Iowa, January 1965, (available on loan).
"Effect of Screens on Damping of Currents and Resistance of a Model in a Towing Tank," Y. K. Chung, M. S. Thesis, Univ. of Iowa, June 1965, (available on loan).
"Analytical and Experimental Study of Egger's Relationship between Transverse Wave Profiles and Wave Resistance of a Modified Ogive in a Channel," H. E. Kobus, Ph.D. Dissertation, Univ. of Iowa, August 1965, (available on loan).
"Induced Drag Due to Bilge Keels," Gabriel Echavez, M. S. Thesis, Univ. of Iowa, Feb. 1966, (available on loan).
"Effect of Channel Walls on Base Pressure and Flow about a Blunt Body," Clark An-ching Lin, M.S. Thesis, Feb. 1966,(available on loan).
"Added Masses of Two-Dimensional Forms by Conformal Mapping," L. Landweber and M. Macagno, IIHR Report, October 1965.

(2328) INVESTIGATION OF SURFACE ROUGHNESS.

(b) Cooperative with U. S. Geological Survey, Office of Naval Research, and Waterways Experiment Station.
(c) Dr. Hunter Rouse, Iowa Institute of Hydraulic Research, University of Iowa, Iowa City, Iowa.
(d) Experimental; basic research.
(e) Apparatus for measuring drag on individual roughness elements and element groups is now in use.
(h) "Critical Analysis of Open-Channel Resistance," Hunter Rouse, ASCE Journal of the Hydraulics Division, HY4, 4387, July 1965.
"Resistance to Flow over Boundaries with Small Roughness Concentrations," E. M. O'Loughlin, Ph.D. Dissertation, Univ. of Iowa, August 1965, (available on loan).

(2541) DEVELOPMENT OF INSTRUMENTS FOR USE IN ANALYZING APERIODIC SIGNALS.

(b) Cooperative with Office of Naval Research, Department of the Navy.
(c) Dr. John R. Glover, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
(d) Experimental; applied research.
(e) The purpose is to improve the analysis of turbulent velocity and pressure fluctuations, especially where long-period fluctuations are significant.
(g) An improved analog multiplier which utilizes the square-law relationship associated with heat-transfer elements is under development. An intermittency circuit, sensitive to the instantaneous amplitude and derivative of the amplitude of signals representing flow variables, has been developed. The analysis of unsteady-flow variables by digital techniques is actively being investigated from the point of view of real-time analysis. The utilization of matched silicon semiconductors for linearization of nonlinear flow variable-voltage relationships has been investigated and found to be most successful.
(h) "Techniques for Detecting and Analyzing Unsteady-Flow Variables," J. R. Glover, Ph.D. Dissertation, Univ. of Iowa, June 1965, (available on loan).

(3074) WAKE OF ZERO MOMENTUM FLUX.

(b) Cooperative with Office of Naval Research, Department of the Navy.
(c) Dr. Eduard Naudascher, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
(d) Experimental; basic research.
(e) Mean flow and turbulence characteristics are being measured and the energy transformation is being analyzed in the field of flow past a bluff, axisymmetric body with a centrally located jet for the particular condition of zero momentum flux.
(f) Completed.
(h) "Flow Behind a Point Source of Turbulence," by H. Wang, Ph.D. Dissertation, Univ. of Iowa, August 1965, (available on loan).
"Flow in the Wake of Self-Propelled Bodies and Related Sources of Turbulence," E. Naudascher, Journal of Fluid Mechanics, Vol. 22, Part 4, 1965.

(3428) MECHANICS OF BANK SEEPAGE IN NATURAL STREAMS DURING FLOOD FLOWS.

(b) Laboratory project in cooperation with U. S. Geological Survey.
(c) Prof. J. W. Howe, Dept. of Mechanics and Hydraulics, University of Iowa, Iowa City, Iowa.
(d) Field investigation; basic research for Ph. D. thesis.
(e) Observations taken on transverse profile of ground-water levels during rise and recession of hydrographs. Sections on Missouri, Des Moines, Boone, Iowa, and English Rivers, Clear Creek and Rapid Creek. Permeability tests made by pumping wells.
(f) Continuing.
(g) Early results indicate substantial flow into

banks during period of rise, thus showing a negative groundwater contribution to the flow in this period.

(3739) EDUCATIONAL FILMS ON THE MECHANICS OF FLUIDS.

(b) National Science Foundation.
(c) Dr. Hunter Rouse, Iowa Institute of Hydraulic Research, Iowa City Iowa.
(e) Six 20-minute sound films in color are planned to cover following material: (1) An introduction to the subject, stressing its great breadth of coverage, the necessarily close tie between theory and experiment, the role of the scale model in engineering analysis and design, and methods of flow measurement in laboratory and field. (2) The source and significance of the fundamental principles of continuity, momentum, and energy, and their application to typical problems in many professional fields. (3) Gravitational phenomena, including jets, nappes, channel transitions, waves, surges, and effects of density stratification. (4) Effects of viscosity, examples of laminar flow, characteristics of fluid turbulence, and problems of surface resistance. (5) Form drag and lift, and their application to propulsion and fluid machinery. (6) Compressibility effects - water hammer, submarine signaling, gravity-wave and sound-wave analogies, and supersonic drag.
(g) First five films of series, "Introduction to the Study of Fluid Motion," "Fundamental Principles of Flow," "Flow in a Gravitational Field," "Characteristics of Laminar and Turbulent Flow," and "Form Drag, Lift, and Propulsion," now available from Audiovisual Center, Univ. of Iowa, Iowa City, Iowa. Sixth film, "Effects of Fluid Compressibility," in preparation.

(3740) HYDRODYNAMICS OF FLUIDS UNDER CONDITIONS OF RAPID ACCELERATION.

(b) Rock Island Arsenal, U. S. Army.
(c) Dr. Enzo O. Macagno, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
(d) Theoretical and experimental; basic research.
(e) Analytical techniques which are applicable to systems involving rapid acceleration of fluids through constrictions or of solids through fluids. Results will be expressed as lumped-constant parameters similar to those used for steady-flow phenomena.
(g) Field tests have shown that errors are reduced by an order of magnitude if the volume changes due to compressibility are considered. As shown by analysis of simplified model, pressure waves may also require consideration in the presence of extremely short impulses.
(h) "Analysis of the XM37 Recoil Mechanism," A. D. Newsham, E. O. Macagno and P. G. Hubbard, Final Report to the Rock Island Arsenal, July 1965.

(4145) INTERFACIAL EFFECTS IN FLUID FLOW WITH DENSITY STRATIFICATION.

(b) Cooperative with U. S. Army Research Office (Durham).
(c) Dr. Enzo O. Macagno, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
(d) Experimental; basic research and graduate theses.
(e) Instability and mixing of two fluid layers of different densities flowing in the same direction. Effect of stratification on turbulent mixing of two fluid layers.
(f) Completed.
(g) Experiments on disturbances in the zone of establishment of a two-layer stratified flow have been compared with results obtained with a discretized computational model of the Navier-Stokes equations. Experimentally observed disturbances were successfully simulated for moderately long periods of time.
(h) "The Stability of a Stratified Flow in the Region of Flow Establishment," J. B. Hinwood, Ph.D. Dissertation, Univ. of Iowa, Feb. 1966, (available on loan).

(4148) MEAN-FLOW AND TURBULENCE CHARACTERISTICS OF RIVER BENDS.

(b) Supported by the National Science Foundation.
(c) Dr. E. M. O'Loughlin, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
(d) Experimental; basic research for Ph.D. dissertation and M.S. thesis.
(e) To determine the mean-flow and turbulence characteristics of flow in a model river bend
(g) Phase I: Through an approximate theoretical solution and experiments in a meandering fixed-bed channel of trapezoidal cross section, the influences of the Froude number and the width-depth ratio of subcritical flow have been determined.
Phase II: Stable channels have been established in cohesionless material between fixed boundaries for three width-depth ratios and three Froude numbers. Measurements of longitudinal and transverse velocity, bed shear, turbulence intensity, and surface elevation have been made for one configuration of the stabilized channel.
(h) "Characteristics of Subcritical Flow in a Meandering Channel," Ben-Chie Yen, IIHR Report, June 1965.

(4149) DRAG OF SUPERCAVITATING BODIES OF REVOLUTION.

(b) Bureau of Ships, Office of Naval Research.
(c) Dr. Louis Landweber, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
(d) Theoretical; applied research.
(e) An approximate method of computing pressure distributions on supercavitating bodies of revolution has been developed. Equipment for measuring drag of nose forms with air-simulated supercavitating flow in a towing tank has been constructed and experiments are under way.
(h) "The Effect of the Free Surface on the Drag of Super-Cavitating Bodies," A. D. Newsham, IIHR Report, December 1965.

(4974) TURBULENCE CHARACTERISTICS OF THE WAKE OF A BODY OF REVOLUTION.

(b) Cooperative with David Taylor Model Basin, Dept. of the Navy.
(c) Dr. Philip G. Hubbard, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
(d) Experimental basic research.
(e) Measurements are being made of the turbulence near the stern of an ellipsoid mounted in an air tunnel. Specially designed instruments are used to respond correctly to the low-frequency, high-intensity components.
(g) Data on the pressure, velocity, components of turbulence, and turbulent shear are at hand for a zero angle of attack.

(4976) EFFECT OF LIFTING BEAMS ON GATE VIBRATION.

(b) Cooperative with Tennessee Valley Authority.
(c) Dr. Eduard Naudascher, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
(d) Experimental; applied research.
(e) The effect of the lifting-beam geometry upon the fluctuating hydrodynamic force acting on a multiple-leaf gate during overflow and underflow is being investigated.
(f) Completed.
(g) Due to interference of the wakes behind lifting beam and gate, downpull fluctuations contain high- and low-frequency components with amplitudes greatly affected by geometry.
(h) "Effect of Lifting-Beam Geometry on the Vibration of Multiple Leaf Gates," C. Farell, M.S. Thesis, Univ. of Iowa, June 1965, (available on loan).
"Effect of Interacting Periodic Wakes on the Vibration of Multiple-Leaf Gates," E. Naudascher, Proceedings XI Congress IAHR, Leningrad, 1965.

(5320) DISCHARGE COEFFICIENTS OF SKEWED PIPE ORIFICES.

(b) Laboratory project.
(c) Prof. J. W. Howe, Dept. of Mechanics and Hydraulics, Univ. of Iowa, Iowa City, Iowa.
(d) Experimental; for M.S. Thesis.
(e) Effect of inclination of orifice plate to pipe centerline for orifices of the same projected diameter.
(f) Completed.
(g) Discharge coefficients proved proportional to the ratio of the actual to the projected area of the orifice, indicating that flow is normal to the orifice plate even though the ratio of orifice diameter to pipe diameter is large.
(h) "Discharge Characteristics of a Skewed Orifice," Pai Chuan Lin, M.S. Thesis, Univ. of Iowa, Feb. 1966, (available on loan).

(5321) PRESSURE FLUCTUATIONS AT GATED OUTLET WORKS.

(b) Cooperative with U. S. Army Corps of Engrs.
(c) Dr. Eduard Naudascher, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
(d) Experimental, basic research.
(e) Effects of shear-layer instability on the spectral distribution and the intensity of pressure fluctuations that may induce gate vibrations are being investigated for various gate and conduit geometries, including effects of cavitation and hydroelastic control.
(h) "A Preliminary Investigation of the Pressure Fluctuations in the Vicinity of Normal Walls," F. A. Locher, M.S. Thesis, Univ. of Iowa, Jan. 1965 (available on loan).

(5905) RESISTANCE TO FLOW OVER RIPPLED SAND BOUNDARIES.

(b) Laboratory project.
(c) Dr. E. M. O'Loughlin, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
(d) Experimental and analytical; Ph.D. dissertation.
(e) To evaluate the roughness of rippled sand boundaries as a function of the ripple geometry and the flow parameters.

(5906) SCALE EFFECTS IN MODEL TESTS OF ROCK-PROTECTED STRUCTURES.

(b) Iowa Highway Research Board.
(c) Dr. E. M. O'Loughlin, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
(d) Experimental; applied research.
(e) To define quantitatively the influence of the viscous forces which result in imperfect similarity between the behavior in the model and in the prototype of rock protection around structures.

(5907) SELF-PRESERVATION TENDENCY IN TURBULENT SHEAR FLOWS.

(b) Cooperative with Office of Naval Research, Department of the Navy.
(c) Dr. Eduard Naudascher, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
(d) Analytical; basic research.
(e) Shear flows not exhibiting self-preservation in the conventional sense are analyzed on the basis of a new self-preservation concept.

(5908) EFFECTS OF TURBULENCE AND CURVILINEARITY ON STRATIFIED FLOW.

(b) Supported by the National Science Foundation.
(c) Dr. Enzo O. Macagno, Iowa Institute of Hydraulic Research, Iowa City, Iowa.
(d) Experimental and theoretical; basic research and graduate theses.
(e) The effects of introducing turbulent disturbances and of curving an otherwise stable density-stratified flow are being investigated experimentally. A layer of fresh water and a layer of salt water are used in the first case, and a continuous stratification in the second. Work is also being done on improving an electrical probe to detect density variations.
(g) Preliminary results have been obtained for the effects of turbulence and curvilinearity on stratified flow.

(5909) ENERGY TRANSPORT AND DISSIPATION IN VISCOUS FLOW.

(b) Laboratory project.
(c) Dr. Enzo O. Macagno, Institute of Hydraulic Research, Iowa City, Iowa.
(d) Analytical; basic research and graduate theses.
(e) Analysis of laminar steady and unsteady flows from the viewpoint of the energy transport and dissipation.
(g) Analysis of basic equations of viscous fluid flow in vectorial form has shown the advantage of introducing a Bernoulli vector associated with the Bernoulli sum, and a Navier vector associated with the viscous-stress tensor. A number of classical cases of viscous flow have already been studied to determine their transport and energy-dissipation functions.
(h) "Transfer and Dissipation of Energy in Laminar Flow," Carlos E. Quevedo, M.S. Thesis, Univ. of Iowa, Feb. 1966, (available on loan).

(5910) STUDY OF DYNAMIC FORCES ON FLASHBOARDS.

(b) Laboratory project.
(c) Prof. J. W. Howe, Dept. of Mechanics & Hydraulics, Univ. of Iowa, Iowa City, Iowa.
(d) Analytical.
(e) Analysis of results of various previous investigations.

(5911) EFFECT OF TURBULENCE CHARACTERISTICS UPON REGISTRATION OF THE PRICE CURRENT METER.

(b) Laboratory project.
(c) Prof. J. W. Howe, Dept. of Mechanics & Hydraulics, Univ. of Iowa, Iowa City, Iowa.
(d) Experimental.
(e) Correlation of turbulence characteristics with variation of current meter registration.

IOWA STATE UNIVERSITY, Department of Agricultural Engineering.

Inquiries concerning projects 2330, 2331 and 2334 should be addressed to Dr. H. P. Johnson, Dept. of Agricultural Engineering, Iowa State University, Ames, Iowa. Projects 4913, 5707 and 5708 should be addressed to Dr. C. E. Beer, Dept. of Agricultural Engineering, Iowa State University, Ames, Iowa 50010.

(2330) DEPTH, SPACING AND HYDRAULICS OF TILE DRAINS.

(b) Laboratory project.
(d) Theoretical and field investigation; basic and applied research; master's and doctor's thesis.
(e) Analytical and experimental approach is being studied to determine depth and spacing of tiled drains by analyzing soil characteristics and geometry of systems. Work is cooperative with Dr. Kirkham, Soil Physics Department of Agronomy. Studies of the relationship of hydrologic and applied hydraulic problems of field tile systems being made.
(g) Field studies of flow through the spacing between individual tile for saturated conditions have been completed. A study of the effect of the geometry at the junction of individual drain tile is being made. A study of the probability of the water level being greater than a given elevation for a given time has been completed. The study was based on point rainfall records, climatological records, soil characteristics and tile depth and spacing.
(h) "Flow Into Tile at Joints," by D. W. DeBoer and

H. P. Johnson. Agricultural Engineering 45: 494-498. 1965.

(2331) SURFACE RUNOFF FROM AGRICULTURAL WATERSHEDS.

(b) Laboratory project.
(d) Theoretical; applied research; M. S. and Doctoral thesis.
(e) A study comparing predicted volumes of storm runoff to measured runoff for small agricultural watersheds is being made. A second study is being conducted in which the relationship of surface storage in relatively level, recently glaciated watersheds on the storm discharge is being evaluated. A study has been completed in which runoff records from 11 Iowa watersheds under 50 sq. mi. in area were analyzed. The yearly yields were related to climatic, hydrologic and agronomic factors by multiple regression.
(h) "Runoff Prediction from Point Rainfall Data by Application of the Digital Computer," by D. B. Palmer and H. P. Johnson. Transactions of ASAE, 7:424-426. 1964.
"Unit Hydrographs Compared," by T. L. Hanson and H. P. Johnson. Transactions of ASAE, 7:448-451. 1964.

(2334) RUNOFF FROM SMALL WATERSHEDS.

(b) Laboratory project.
(d) Field investigation; applied research; design.
(e) Measurements of rainfall, surface runoff, soil moisture, water table levels, and evaporation being made on six small agricultural watersheds under a single cover crop. Two additional agricultural watersheds are being gaged for rainfall and surface runoff.

(4913) QUANTITATIVE EVALUATION OF GULLY EROSION.

(b) Laboratory project.
(d) Field investigation; applied research.
(e) A study where multiple regression has been used to relate gully growth to a series of independent variables. Initial equation developed from 20 year history has been checked from data collected during established 2-year sequence of gully measurement. Study includes two watersheds with continuing measurement of gully growth, precipitation, surface runoff, sediment production and recording of land use.

(5707) EVALUATION OF FLOOD DAMAGE TO CORN FROM CONTROLLED DEPTH AND FREQUENCY OF FLOODING.

(b) Laboratory project.
(d) Field investigation; applied research.
(e) A study initiated to determine yield reduction and observe physiological effects on corn plants from controlled flooding at different growth stages.

(5708) SEDIMENT YIELD IN DEEP LOESS HILLS LAND RESOURCE AREA.

(b) Cooperative with the Soil Conservation Service and Agricultural Research Service of the U.S.D.A.
(d) Field investigation; applied research; design.
(e) Sedimentation surveys have been made on a total of 27 reservoirs in Western Iowa and Missouri. The rate of deposition will be related to watershed, hydrologic and topographic variables by statistical procedures.

IOWA STATE UNIVERSITY, Department of Agronomy.

(3079) MOVEMENT OF WATER IN SOILS.

(b) Laboratory project.
(c) Dr. Don Kirkham, Department of Agronomy, Iowa State University. 50010.
(d) Theoretical and applied research; Doctor's thesis.
(e) Theoretical work done on the movement of ground water in soil, particularly in the saturated phase continues. Mr. John C. Corey is continuing isotope work on water movement in the unsaturated state (miscible displacement) in cooperation with the Iowa State University Institute for Atomic Research.
(h) "Miscible Displacement of N-15 Tagged Nitrate and Tritiated Water in Water-saturated and Water-unsaturated Soil," John Corey and Don Kirkham. Proceedings of the International Atomic Energy Agency's Symposium on the Use of Isotopes and Radiation in Soil-Plant Nutrition Studies at Ankara, Turkey, June 28, 1965 (in press).
"The Stream Function for Potential Flow in Axial Symmetry," Dan Zaslavsky and Don Kirkham. Amer. J. Physics 33: 677-679 1965.

(4592) MOVEMENT OF WATER FROM WASTE RECHARGE INSTALLATIONS.

(b) U. S. Department of Health, Education, and Welfare, Public Health Service, National Institute of Health.
(c) Dr. Don Kirkham, Department of Agronomy, Iowa State Univ., Ames, Iowa 50010.
(d) Theoretical and field investigation; basic and applied research; master's and doctor's thesis.
(e) The purpose of this project is to discover laws which predict, from the geometry of the waste recharge installation, and from the physical properties of the soil about it, how fast, and how far at certain times, water will move from the installation. This will be accomplished by (1) obtaining empirical laws governing seepage of water from an idealized scaled model (2) testing by full-scale field experiments to see if the empirical laws found in (1) above need to be modified when applied to field conditions, and (3) formulating rational relations between the water movement, the geometry of the system and the soil conditions, by setting up and solving the appropriate seepage differential equations and checking the result against the experimental data from (1) and (2) above.
(h) "Some Recent Land Drainage Investigations at Iowa State University of Science and Technology, Ames, Iowa, U. S. A." Proc. Sodic-soils Symposium, Aug. 9-16 Hungarian Academy of Science. Supplement TOM 14: 229-234 1965.
"Two-dimensional Infiltration and Wetting Fronts," Sadik Toksoz, Don Kirkham and E. Robert Baumann. Proc. Am. Soc. of Civ. Engr. 91: 65-79 1965.

(5706) MOISTURE MOVEMENT TO VERTICAL SINKS IN WATER-SATURATED SOIL.

(b) Iowa State Water Resources Research Institute.
(c) Dr. Don Kirkham, Agronomy Dept., Iowa State University, Ames, Iowa 50010.
(d) Theoretical and applied research; Doctor's Thesis.
(e) Differential equations for the flow of water into vertical sinks such as soil cracks, plant roots, and vertical worm holes will be derived and solved either analytically or by finite differences with the aid of a digital computer. Laboratory soil columns will then be used to test the mathematical theory.
(f) Initiated July 1, 1965.

THE JOHNS HOPKINS UNIVERSITY, Applied Physics Lab.

(2335) APPLICATION OF SWITCHING TECHNIQUES TO HYDRAULIC CONTROL SYSTEMS.

(b) Bureau of Weapons, Department of the Navy.
(d) Theoretical and experimental; applied development and design.
(e) Study the dynamic qualities of an acceleration switching hydraulic servomechanism

while operating in a closed loop under the presence of various loads and environmental conditions on the transfer valve, actuator and feedback transducer.

(g) The operation of a broad bandpass servomechanism driving a low resonant frequency linkage has resulted in radial design compromises to prevent instability. Extension of acceleration switching techniques without any mechanical modifications has permitted closed loop operation with bandpasses equal to or exceeding the linkage characteristics.

(h) "Design of a Hydraulic Servo with Improved Bandpass Characteristics When Driving a Resonant Mechanical Load," APL/JHU CM-962, by W. Seamone.

(3436) ADAPTIVE ELECTRO HYDRAULIC SERVOMECHANISMS.

(b) Bureau of Weapons, Department of the Navy.
(d) Theoretical and experimental.
(e) Techniques have been developed for designing linear servomechanisms with a limit cycle instability about a relay type non-linearity. The closed loop characteristics of this servomechanism becomes invariant to any pure gain changes occurring in the linear elements. This servomechanism, categorized as a self-oscillating control servomechanism, appeared to be an evolutionary improvement over the acceleration switching hydraulic servomechanism.

(g) A self-oscillating rate servomechanism has been operated with the loop closed around the valve spool position. Predictable self-oscillation frequency was achieved and dynamic performance bandpass was independent of hydraulic supply pressure between 500 and 2000 psi. The bandpass of both servomechanisms exceeded 60 cycles per second with the latter operating a complex mechanical load system.

THE JOHNS HOPKINS UNIVERSITY, Department of Environmental Engineering Science, School of Engineering.

Inquiries concerning the following projects should be addressed to Dr. John C. Geyer, Chairman, Dept. of Environmental Engineering Science, The John Hopkins University, Baltimore, Maryland 21218.

(856) HYDROLOGY OF STORM DRAINAGE SYSTEMS IN URBAN AREAS.

(b) Baltimore City, Baltimore County, Maryland State Roads Commission, and the U. S. Bureau of Public Roads.
(d) Field investigation; basic research and design.
(e) Study of rainfall and runoff relationships as affected by various drainage area parameters. At present, runoff from 6 urban areas ranging in size from 10 to 150 acres are gaged, 5 by stage instruments and 3 by Parshall Flumes. Three recording systems which simultaneously record rainfall and runoff from 12 inlet areas provide good opportunity for detailed study. About 11 years of rainfall records now exist for a network of 14 recording gages covering an area of 100 square miles.

(g) Work has been done on the synthesis of the hydrograph of runoff from impervious portions of a drainage area, knowing only the rainfall pattern and the geometry of the area. Correlation between the synthesized hydrograph and the actual storm hydrographs, for the same area and same rainfall, has been excellent. This method is now being expanded to apply to pervious drainage areas as well as impervious.

(h) Technical Report No. 2, John W. Knapp, Dept. of Environ, Eng'g. Sci., The Johns Hopkins Univ., Baltimore, Maryland.
Technical Report No. 3, John C. Schaake, Jr., Dept. of Environ. Eng'g. Sci., The Johns Hopkins University, Baltimore, Maryland.

(3437) RESIDENTIAL WATER USE RESEARCH PROJECT.

(b) Federal Housing Administration and 16 participating Water Utilities.
(d) Field investigation; applied research and design.
(e) This project is directed toward obtaining data on maximum hourly demands and water use patterns in residential areas having varying populations and located in various climatic regions throughout the country. It also is directed toward obtaining information on the effect of lawn sprinkling and other large water uses on maximum demands. The purpose of the project is to obtain a rational design criteria for water distribution systems, to provide a basis for evaluating water rate structures and a basis for improving system operation.
(f) Field data collection completed as of October 1, 1965.

(g) Water use patterns and demand rates imposed on distribution systems have been measured in forty-one residential study areas throughout the United States during the period between July 1, 1963 and October 1, 1965. The major factors influencing residential water use have been evaluated, and a mathematical model to represent the phenomenon has been derived.
The study shows that in an area with a large number of consumers, the expected sprinkling demand during dry periods approximately equals the evapotranspiration rate from the overall irrigable area. Thus, area-wide sprinkling demands do not depend on the frequency, duration, or magnitude of the demands of individual services. When no precipitation occurs, all evapotranspiration is met by sprinking from the water system, and, thus, lack of precipitation considerably increases lawn sprinkling. The normal domestic or household use depends primarily on economic level.
Residential water use is influenced also by whether consumers are metered or on a flat-rate basis, and whether they utilize septic tanks for sewage disposal. Peak demands in flat-rate areas are more than double those in metered areas because of high sprinkling demands. Domestic use is significantly lower in metered areas with septic tanks.

(h) "Report II on Phase Two of the Residential Water Use Research Project," F.P. Linaweaver, Jr., Dept. of Environ. Eng'g. Sci., The Johns Hopkins Univ., 62 pages, (June 1965). A limited number of copies are available upon request.

(5171) GROUND WATER STORAGE PROJECT.

(b) National Institutes of Health Research Grant.
(d) Field investigation, applied research.
(e) Application of gravity meter to study of change of storage of ground water in water budget of 38 acre drainage basin.
(g) Commencing collection of data.

(5914) COOLING WATER DISCHARGES PROJECT RP49.

(b) Edison Electric Institute, New York 17, N. Y.
(c) Dr. John C. Geyer, Chairman, Dept. of Environ. Eng'g. Sci., The Johns Hopkins Univ., 513 Ames Hall, Balto., Md. 21218.
(d) The project is a combination of theoretical development and field investigation, and can be classed as applied research. Work on this project is applicable to Masters essays and Doctoral theses.
(e) The purpose of the project is to develop techniques for predicting water temperatures in water bodies receiving the condenser cooling water discharges of thermal electric generating stations. The first phase of the project, extending from March 1963 to June 1965, was an investigation of existing theory related to water temperature prediction, and an assembly of existing knowledge on the relationship between water temperatures

and the ecology of water bodies. The present second phase is concerned with developing field studies necessary to evaluate water temperature prediction techniques.

(f) Presently in Phase II, "Field Studies."

(g) Results of Phase I have been reported in publications given in item (h).

(h) "Water Temperatures and Aquatic Life," C. E. Renn and C. Wurtz, Edison Electric Institute Publication No. 65-901, 70 pages, June 1965. Available from Edison Electric Institute, 750 3rd Ave., New York, N. Y. 10017. Price $2.00.
"Heat Exchange in the Environment," J. E. Edinger and J. C. Geyer, Edison Electric Institute Publication No. 65-902, 253 pages, June 1965. Available from Edison Electric Institute, 750 3rd Ave., N. Y., N. Y. 10017. Price $2.50.
"Heat Exchange in the Enviroment - A Study of the Physical Principles Relating to Condenser Cooling Water Discharges," J. E. Edinger, Doctoral Thesis, 197 pages, The Johns Hopkins Univ. June 1965.
"Final Report on Cooling Water Discharges Project - RP49," J. E. Edinger, EEI Bulletin, August 1965, Vol. 33, No. 7.

UNIVERSITY OF KANSAS, Dept. of Mechanics and Aerospace Engineering.

Inquiries concerning the following projects should be addressed to Dr. Y. S. Yu, Dept of Mechanics and Aerospace Engineering, Univ. of Kansas, Lawrence, Kansas 66045.

(4151) SEPARATION OF FLOW AT INTERIOR CORNERS.

(b) Kimberly-Clark Corporation, Neenah, Wis.
(d) Theoretical and experimental; basic research.
(e) The separation of laminar flow at interior corners is studied to determine experimentally and mathematically the flow pattern and the geometry of the zone of separation.
(f) Suspended.
(g) A study of the spatial characteristics of the zone of separation for laminar and transitional flows past an interior corner has been made. The locations of flow separation and reattachment have been determined experimentally for corner angles of 90, 60, 45, and 30 degrees and contraction-ratios of 0.75, 0.50 and 0.25. The values of the Reynolds number based on the maximum main-stream velocity, the duct height, and kinematic viscosity of the fluid ranged from 2×10^3 to $4.t \times 10^4$.
(h) "Separation of Laminar and Transitional Flows at an Interior Corner," by Mack H. Gray, III, M. S. Thesis, 1965. (Available on loan at the Engineering Library, The University of Kansas.)

(4944) SOLUTION OF POTENTIAL FLOW WITH FREE STREAMLINES BY INTEGRAL EQUATION METHOD.

(b) University research grant.
(d) Theoretical; M.S. thesis.
(e) The integral-equation method developed in the previous study is extended to include the effect of gravity.

(4945) SECONDARY MOTIONS IN A "DRAIN-HOLE" VORTEX.

(b) Laboratory project.
(d) Theoretical and experimental basic research for doctoral thesis.
(e) The secondary motions in a steady "drain-hole" vortex flow are being studied to determine the mechanics of its formation and the effects of rotational speed of the tank and the water depth on the secondary motions.
(f) Completed.
(g) An approximate solution to the boundary-layer equations for the flow adjacent to the flow of the vortex container is obtained. The computed velocity profiles within the boundary layer agree within 10 percent with the measurements. The radial inflow within the boundary layer is found to be greater than that outside the boundary layer. This excess radial inflow probably causes the formation of the large torus-shaped secondary vortices in the vertical flow.
(h) "A Theoretical and Experimental Study of a Laminar Vertical Flow," by P. R. Smith, Ph.D. Thesis (in preparation).

(5709) WALL-PRESSURE FLUCTUATIONS IN A CAVITATING TURBULENT SHEAR FLOW.

(b) Tennessee Valley Authority.
(d) Experimental; basic research for doctoral thesis.
(e) The purpose of this study is to investigate the formation of cavitation pockets and the associated pressure fluctuations downstream from an abrupt expansion.
(f) Completed.
(g) An experimental study of wall-pressure fluctuations in a cavitating turbulent shear-flow at a two-dimensional abrupt expansion in a conduit was performed. Four cavitation regimes were observed. Root-mean-square values and frequency spectra of wall-pressure fluctuations were obtained for non-cavitating, incipiently cavitating, and fully cavitating flow with different expansion ratios of the conduit.
(h) "Wall-pressure Fluctuations in a Cavitating Turbulent Shear Flow," by Svein Vigander, Studies in Engineering Mechanics, Report No. 21, June 1965.

(5710) INSTABILITY OF NON-NEWTONIAN HELICAL FLOW.

(b) Laboratory project.
(d) Theoretical and experimental; basic research for doctoral thesis.
(e) The Taylor-Gortler instability of a power-law fluid in an annulus between two rotating coaxial cylinders with and without axial flow is studied both experimentally and theoretically.

LEHIGH UNIVERSITY, Department of Civil Engineering.

Inquiries concerning the following projects and requests for reprints and technical reports should be addressed to Dr. J. B. Herbich, Professor, Chairman, Hydraulic & Sanitary Division, Fritz Engineering Laboratory, Lehigh University, Bethlehem, Pa. 18015.

(2543) STUDY OF CONDUIT EXIT PORTALS.

(b) Laboratory Project.
(d) Experimental: M. S. Thesis.
(f) General pressure-distribution study completed.
(g) Tests of square and circular conduit with free-jet, horizontal apron, and three different wall flares, have been completed.

(3084) STUDY ON IMPROVING DESIGN OF A HOPPER DREDGE PUMP.

(b) District Engineer, U.S. Army Engineer Dist., Marine Division, Philadelphia, Corps of Engineers.
(d) Applied and Basic Research.
(e) The immediate purpose of the study is to improve design of a hopper dredge centrifugal pump for pumping silt-clay water mixtures. The long-term objective is to determine the effect of Bingham Body-type of fluid on pumping characteristics. The project has been divided into four phases: (1) Model test of existing dredge pump; (2) recommendations for design changes of the dredge pump; (3) model investigation of the modified design of the dredge pump; and (4) analysis of the investigation and final recommendations. Phase 1 involved installation in the hydraulic laboratory of a 1:8

scale model of the dredge pump now used on the U.S. Corps of Engineers dredge ESSAYONS. Water as well as silt-clay-water mixtures (Bingham Body-type of fluid) were pumped and complete characteristics of the pump obtained for capacity of 0 to 1200 gallons per minute, speed of 1150 to 1900 revolutions per minute, and liquid concentrations of 1000 and 1380 grams per liter. Phases 2 and 3 involve modifications in the shape of vane and changes in the exit vane angle of the impeller. Experimental tests indicate considerable improvement in pump efficiency. Analysis of the experimental data resulted in recommendations for changes in pump design.

(f) 1, 2, 3 and 4 completed.
(g) Considerable improvement in pump efficiency has been achieved.

(3085) STUDY OF SCALE EFFECT BETWEEN MODEL AND PROTOTYPE SPILLWAYS.

(b) Laboratory project.
(d) Graduate students' project.
(e) A 1:100 scale two-dimensional model built of Chief Joseph Dam. Prototype crest pressures compared with the data obtained on the model.
(f) Completed.
(g) Very good correlation obtained between the model and prototype.

(3086) INVESTIGATION OF DESIGN CRITERIA OF SPUR DIKES.

(b) Modjeski and Masters, Consulting Engineers, Harrisburg, Pa., Lehigh University Inst. of Research.
(d) Analytical and experimental.
(e) The project has been divided into four phases: (a) Literature survey; (b) analytical study; (c) experimental study in a fixed-bed model to determine the desired lengths and shapes of spur dikes to provide uniform velocity distribution in the waterway between bridge abutments; (d) experimental study in a movable-bed model to verify findings in part c. A spur dike has been defined as a projection extending upstream from the bridge abutments.
(f) Phases (a), (b) and (c) completed; phase (d) active.
(g) Preliminary investigation indicates that a properly designed spur dike can produce a fairly uniform velocity distribution between the abutments.
(h) "Hydraulics of Bridges," - by J. W. Delleur, D. E. Schneible and H. J. Tracy, Joint Highway Research Project, American Society of Civil Engineers Task Force, Purdue University, Lafayette, Indiana.

(3441) STUDY OF SCALE EFFECT BETWEEN MODEL AND PROTOTYPE 270 DEGREE BENDS FOR FLOW OF SILT-CLAY-WATER MIXTURES.

(b) Laboratory project.
(d) M. S. Thesis.
(e) Four-, six-, and eight-inch diameter 90 degree elbows assembled to form 270 degree bends. Head loss measurements obtained for various flows and concentrations of silt-clay-water mixtures. Prediction equations have been investigated.
(f) Completed.
(g) No evidence of appreciable scale effect observed.

(3442) SUGGESTED DESIGN CHANGES FOR A CENTRIFUGAL PUMP IMPELLER HANDLING DREDGED MUD.

(b) Research report requirement of master's degree.
(d) Theoretical.
(e) Design changes in centrifugal pump impeller for handling mud are suggested on basis of past research and theoretical considerations.
(f) Completed.

(3746) ANALYSIS OF FLOW PATTERN IN VOLUTE OF A CENTRIFUGAL PUMP.

(b) Research report requirement of master's degree. District Engineer, U. S. Army Engineer District, Marine Division, Phila. Corps of Engineers.
(d) Experimental
(e) High-speed movies of flow taken through a transparent plexiglas volute casing were analyzed. Velocity distribution as well as distribution of the exit angle between the impeller vanes as fluid leaves the impeller were determined.
(f) Completed.

(3747) FRICTION HEAD LOSSES IN CIRCULAR PIPES FOR A BINGHAM-BODY FLUID.

(b) Laboratory project.
(d) Experimental and theoretical.
(e) The object of the study is the determination of the pipe flow characteristics of slurries of various concentrations. The slurries do not behave as fluids of constant viscosity so that it is not possible to use conventional methods for prediction of head losses in pipes conveying them. Tests are being conducted in 6-inch, 3-inch, and 2-inch pipelines with velocities from less than 1 fps to over 30 fps.
(f) Suspended.

(4154) DREDGE PUMP DESIGN.

(b) National Bulk Carriers, Inc.
(d) Experimental.
(e) The objective of the investigation is to obtain the efficiency and head-capacity curves, to check the effect of the reduced vane exit angle, and to determine the efficiency of a model dredge pump while pumping silt-clay-water mixture of specific gravity equal to 1.17. The experimental tests were carried out on a 1/8 model pump of the National Bulk Carriers Hopper Dredge, S. S. Zulia.
(f) Completed.
(h) Report in preparation.

(4155) WAVE RUN-UP ON COMPOSITE BEACHES.

(d) Graduate students' project. Experimental, applied research for design.
(e) The main object of the study is to verify existing equations for determining the height of wave run-up and obtain the limits of application of the equation for long beach berms.
The study is conducted in a 67 ft. long, 2 ft. wide and 2 ft. deep wave channel equipped with pendulum-type wave generator and efficient absorbers.

(4156) MULTIPLE DREDGE PUMP SYSTEMS.

(b) National Bulk Carriers, Inc.
(d) Experimental and theoretical.
(e) The study is conducted to determine the effect on total production of dredge pumps with separate discharges and a combined discharge. The investigation is divided into two parts: (a) One pair of pumps is handling a mixture of water and solids, the other is pumping only water. It is required to determine what percentage of its normal output will the dredge pump passing the mixture attain. (b) If one of a pair of dredge pumps, both handling water-solids mixtures, is revolving slower than the other one, how does the total discharge compare to the total if the discharges were not combined?
(f) Completed.

(4644) STUDY OF THE GRAVITY WAVE REFLECTIONS FROM FLOATING RECTANGULAR BODIES.

(b) Research report requirement of master's degree.

(d) Experimental.
(e) The object of the study is to determine the magnitude of wave reflections from rectangular floating bodies. Tests are being conducted in a 67-ft. long, 2 ft.-wide and 2 ft.-deep wave channel equipped with pendulum-type wave generator and efficient absorbers.
(f) Completed.

(4645) EFFECT OF LENGTH AND SPACING OF SPUR DIKES.

(b) Laboratory report.
(d) Experimental and theoretical; M.S. Thesis.
(e) The object of the study is to determine the effect of length and spacing of spur dikes on the magnitude of scour in uniform flow. The experiments are conducted in a 10-ft. wide, 35-ft. long open channel with movable sand bed. Scour patterns are observed and analyzed.

(5172) MEASUREMENT OF SLURRY FLOW BY USE OF 90° ELBOW METER.

(b) National Bulk Carrier Inc., New York, N. Y.
(d) Applied and Basic Research.
(e) A four-inch 90° elbow meter was calibrated against a magnetic flow meter. A flow range of from 0-1100 gpm was effected in the calibration. Water and fine concentrations of silt-clay-water mixtures are included in the calibration tests. The basic theory of the "elbow meter" is discussed and an emperical mathematical relation between liquid concentration, differential head, and pipe velocity is presented and discussed. The feasibility of use of the elbow meter for flow measurement of slurry type flow is highly possible, but calibration of meter in place is recommended. Also, the viscous properties of the material metered are believed to play an important role in the meter's performance.

(5173) SUCTION DREDGING LITERATURE SURVEY.

(b) Ellicott Machine Corp., Baltimore, Maryland.
(d) Applied and basic research.
(e) This report is a brief review and summary of selected literature pertaining to equipment and methods associated with dredging practice and laboratory studies of dredge pumps. It consists of four parts: (1) Summary and discussion section. (2) Selected abstracts. (3) Annotated bibliography. (4) Bibliography. The discussion section consists of two parts. Part 1 discusses dredging equipment and dredging in general. Part 2 discusses dredge pumps.

(5174) PERFORMANCE STUDY OF A 1:6 MODEL DREDGE PUMP.

(b) Ellicott Machine Corporation, Baltimore, Md.
(d) Applied and basic research.
(e) Performance tests were made on five 1:6 scale model impellers. Each impeller was tested at four constant speeds over a wide range of heads and discharges. Water and two concentrations of a typical dredging mud were tested with each impeller at all four speeds. Various graphs and design application curves were developed for making similarity studies and designs in the homologous series of pumps.

(5550) CAVITATION STUDIES ON A MODEL DREDGE PUMP.

(b) Ellicott Machine Corp., Baltimore, Md.
(d) Applied and basic research.
(e) Effect of various pump design parameters on cavitation is being investigated. Water and two concentrations of a typical dredging mud are being used as dredging material in the laboratory. Other variables, in addition to geometric characteristics of the pump, include pump speed and rate of flow.
(h) "Effect of Impeller Modifications on Cavitation Characteristics," by J. T. Cassan, Fritz Engineering Laboratory Rpt. No. 301.4, 1965.

(5551) EFFECT OF LIQUID VISCOSITY ON CAVITATION OF A MODEL DREDGE PUMP.

(b) Laboratory project.
(d) Experimental and theoretical.
(e) Research requirement of Master's degree.
(f) Completed.
(g) Cavitation tests were performed on three impellers in a model dredge pump. It was found that the impeller with the highest efficiency rating demonstrated the best cavitation performance. Tests of the impellers in silt-clay-water mixtures of various densities indicated that the viscosity of the liquid had a negligible effect on cavitation inception. The impeller rotative speed appeared to have no effect on the discharge at which cavitation began for constant head conditions.

(5552) SCOUR OF FLAT SAND BEACHES DUE TO WAVE ACTION.

(b) Laboratory project.
(d) Experimental and theoretical.
(e) Research requirement of Master's degree.
(g) Stability of a horizontal sand bed deposited in shallow water in front of an impervious, smooth seawall under conditions in which the waves have not yet begun to break was investigated. Experimental studies have been performed in a two-dimensional wave channel in an effort to determine the rate, extent, and ultimate amount of scour of the flat sand bed for different conditions of water depth, wave height and length, and slope of sea wall.
(h) "Beach Scour Due to Wave Action on Seawalls," by B. Van Weele, Fritz Engineering Report No. 293.3, Lehigh University 1965.

(5821) WAVE REFLECTION AND TRANSMISSION FOR CYLINDRICAL PILE ARRAYS.

(b) Laboratory project.
(d) Experimental.
(e) Master's Thesis.
(g) The purpose of the investigation is to determine the relationship between wave reflection and transmission and several pile-group configurations. A total of 16 circular piles were used in different rectangular arrays and one random pattern. In the rectangular arrangements both the spacings transverse to the oncoming wave and the spacings longitudinal to the oncoming wave were investigated. The experimental studies were performed in a two-dimensional wave channel.
(h) "Wave Reflection and Transmission for Cylindrical Pile Arrays," by B. Van Weele, Fritz Engineering Laboratory Report No. 293.4, Lehigh University, 1965.

(5822) GAS REMOVAL SYSTEMS ASSOCIATED WITH DREDGE PUMPS.

(b) District Engineer, U. S. Army Engineer District, Marine Division, Philadelphia, Corps of Engineers.
(d) Applied and basic research.
(e) The overall purpose is to study the effect of gas removal systems on centrifugal dredge pumps. This consists of a program of studies, tests, analysis and reports dealing with ways and means for efficiently removing entrained and dissolved gases from the effluents of dredging with centrifugal pumps in rivers and harbors. The project has been divided into four (4) phases. (a) Literature Search and Formulation of a Test Program, (b) Formulation of Specific Test Setup and Schedule of the Tests with Water, (c) Experimental Study and Analysis of Test Results, (d) Experimental Study with Solid-Water Mixtures (mud) and Analysis of Test Results.
(f) Phases (a) and (b) are completed; phase (c)

is active.

(h) "Gas Removal Systems, Part I: Literature Survey and Formulation of Test Program," by W. P. Isaacs and J. B. Herbich, Fritz Engineering Laboratory Report No. 310.3, 1965. "Gas Removal Systems, Part II: Development of Facility Layout and Formulation of Test Program," by A. Shindala, Fritz Engineering Laboratory Report No. 310.7, 1965.

LOUISIANA STATE UNIVERSITY AND A AND M COLLEGE, Agricultural Engineering Department.

(5915) FACTORS AFFECTING RUNOFF ON SMALL AGRICULTURAL WATERSHEDS IN LOW, FLAT, ALLUVIAL AREAS.

(b) Louisiana Agricultural Experiment Station, Louisiana State University, Baton Rouge, Louisiana 70803, Dr. Doyle C. Chambers, Dir.
(c) Dr. Jerry Chesness, Assoc. Prof. Agricultural Engrg. Dept., Louisiana State Univ., Baton Rouge, Louisiana, 70803.
(d) Field investigation.
(e) Runoff is being gauged on a 50 acre watershed with 0 to 5% slopes on the Mississippi River alluvial flood plain. A study is being conducted to measure the effect of land use and vegetative cover on volume and rate of runoff.
(g) Double peak hydrographs are often obtained. Surface detention appears to be highly influential on outflow rate.

LOUISIANA STATE UNIVERSITY AND A AND M COLLEGE, Louisiana Water Resources Research Institute.

(5711) FRESH WATER STORAGE IN SALINE AQUIFERS.

(b) Louisiana Water Resources Research Institute.
(c) Dr. Oscar K. Kimbler, Associate Professor, Dept. of Petroleum Engineering, Louisiana State University, Baton Rouge, La. 70803.
(d) Theoretical and experimental; basic research.
(e) To determine whether it is theoretically feasible to store fresh water in saline aquifers: injecting fresh water, then removing it from storage. The relative effects of diffusion, dispersion and differences in specific gravity are being studied mathematically and by means of models. The ultimate importance of the work to cities located in flat marshland areas lacking in surface-water storage sites that are underlain by saline aquifers is readily appreciated.

(5713) STUDY OF MEASURES TO BE TAKEN TO ACCOMPLISH PROTECTION OF THE GROUND-WATER SUPPLY OF THE BATON ROUGE AREA FROM DEGRADATION DUE TO SALINE WATER INTO AREA OF OFFTAKE-ENGINEERING ASPECTS.

(b) Louisiana Water Resources Research Institute.
(c) Professor R. G. Kazmann, Dept. of Civil Engrg., Louisiana State Univ., Baton Rouge, La. 70803.
(d) Field invesitigation and theoretical study; applied research and design.
(e) Evaluate engineering solutions for providing permanent ground-water supply for Baton Rouge area. Make preliminary feasibility studies of most promising projects; coordinate work with that being done in aspects 1-3.
(g) Project started July, 1965. Tentative date of publication, February 1966.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Department of Civil Engineering, Hydrodynamics Laboratory.

Requests for reprints and Technical Reports should be addressed to Dr. Arthur T. Ippen, Professor of Civil Engineering, Hydrodynamics Laboratory, Mass. Inst. of Technology, Cambridge, Mass. 02139.

(1609) STUDY OF BEACH PROCESSES IN THE INSHORE AND FORESHORE ZONES.

(b) Coastal Engineering Research Center, U.S. Army Corps of Engineers.
(c) Professor P. S. Eagleson, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Experimental and theoretical; basic research. (S.M. thesis, Ph.D. thesis).
(e) Study of the surface profile and internal kinematics of a shoaling oscillatory wave up to and beyond the breaker.
(g) The theoretical phase seeks a finite amplitude, irrotational solution in water of gradually varying depth. The experimental phase involves the development of an instrument package for measuring orbital velocities, static pressure and wave profile.
(h) "An Instrument Package for the Laboratory Study of the Kinematics of Shoaling Waves," by M. M. Kolpak, S. M. Thesis, MIT Dept. of Civil Engineering, June 1965 (Unpublished). "Theoretical Study of Longshore Currents on a Plane Beach," by P. S. Eagleson, MIT Dept. of Civil Engineering, Hydrodynamics Laboratory Report No. 82, Sept. 1965.

(2801) INTERACTION OF WAVES WITH SUBMERGED AND FLOATING BODIES.

(b) Office of Naval Research, Dept. of the Navy.
(c) Prof. A. T. Ippen, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Theoretical and experimental; basic research (ScD. thesis).
(e) The purpose of the study is to determine the wave reflecting and transmitting characteristics of different types of structures. Applications are made to floating or moored breakwaters and to wave transformation in variable geometry channels.
(g) (1) Tubular Breakwater. Experiments on a tubular breakwater covered a series of tests on various lengths and number of tubes for a wide range of wave lengths and wave steepness.
The effects of these variables on the transmission and reflection coefficients and on the wave power loss and on the forces on the breakwater are thus defined. (2) Effect of a Gradual Change of Depth and Width on Wave Transformation. A theory has been developed which is applicable to long waves encountering a gradual change in depth. These investigations are made in connection with a more general study on the transformation of long waves in the presence of submarine obstructions. A systematic investigation is now conducted to extend this work analytically and experimentally to the following phases: (a) Reflection and transmission characteristics for gradual changes in depth. (b) Reflection and transmission characteristics for gradual changes in width. (c) Combinations of (a) and (b).

(2802) EXPERIMENTAL STUDY OF WAKE MECHANICS.

(b) Laboratory project.
(c) Professor P. S. Eagleson, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Experimental and theoretical; basic research (S.M. thesis).
(e) A study of the effect of trailing edge geometry and flow-induced body vibration on spanwise correlations of instantaneous wake structure for flat plates.
(f) Suspended.
(g) Spanwise spatial correlations of total head fluctuations as obtained from cross power spectrum indicate the feedback from vibratory motion to forcing moment to result primarily from increasing spanwise wake coherence.
(h) "The Effect of Transverse Body Vibration on the Spanwise Correlation of Instantaneous Wake Structure for Flat Plates," by J. J. Turner, R. L. Warters and P. S. Eagleson, MIT Dept. of Civil Engineering Hydrodynamics Laboratory Report No. 81, July 1965. "Maximum Negative Damping in the Flutter of

Flat Plates in Water," by P. S. Eagleson and W. J. Shack, Proc. Eleventh Congress of IAHR, Lenigrad, 1965, Paper No. 415.

(3443) COMPUTER SIMULATION OF THE COMPLETE TRANSIENT PROBLEM IN A HYDRO-POWER PLANT.

(b) U. S. Army Corps of Engineers, Missouri River Division.
(c) Professor A. T. Ippen, Professor P. S. Eagleson.
(d) Theoretical, field tests; applied research.
(e) Development of a digital computer program of general utility and proven validity for performing design analyses involving the response of hydro-power plant systems to load fluctuation.
(f) Completed.
(g) Digital computer programs have been written which for a wide range of hydraulic geometries will yield the time variation of the important hydraulic and mechanical variables for an arbitrary time variation in electrical load under the assumption of an isolated system. The results of these programs compare well with field test measurements. Final reports and a user's manual have been prepared.
(h) "Hydro-Power Plant Transients Part IV: Computer Program User's Manual," by F. E. Perkins, Hydrodynamics Laboratory TN No. 9, June 1965.

(3444) EFFECTS OF BASIN GEOMETRY AND VISCOUS DAMPING ON THE AMPLITUDE OF RESONANT OSCILLATIONS IN HARBORS.

(b) Office of Naval Research, Dept. of the Navy.
(c) Prof. A. T. Ippen, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Theoretical and experimental; basic research.
(e) Investigation of the response of a harbor to waves incident on the harbor opening, with open ocean conditions simulated in a basin of finite size.
(f) Suspended.
(g) The response of a rectangular harbor connected to the open sea was studied both analytically and experimentally. Solutions were obtained for the harbor response to wave incident from the ocean. Experiments were conducted on fully-open as well as partially-open harbors of different geometrical properties. It was found that the theoretical solutions accurately predict the resonant periods of the harbor. Good understanding was also reached regarding the "harbor paradox." Investigations revealed its relation to viscous damping and to the response of a harbor to waves of a continuous power spectrum. Experiments revealed that particular resonant modes could be eliminated by the introduction of partial barriers along modal lines, however, these introduced new and sometimes more severe resonances.

(3748) DISPERSION IN POROUS MEDIAN AND WASTE WATER RECHARGE.

(b) U. S. Public Health Service, Division of Water Supply and Pollution Control
(c) Professor D. R. F. Harleman, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Theoretical and experimental; basic research (doctoral thesis).
(e) A numerical analysis to determine the amount of dispersion between miscible fluids of differing quality in radial, confined flow through a porous medium has been completed. An investigation of dispersion arising from the injection of a contaminant through a recharge well and the withdrawal of fresh water through a pumping well, both pumping at the same rate, in an infinite, confined aquifer is being carried out currently. Results will be important to engineering projects in the recharging of aquifers with reclaimed waste water.
(f) Completed.
(g) A general correlation has been made of known measurements of the longitudinal and lateral dispersion coefficients, using the correct dimensionless representation. Measurements have been made of the amount of dispersion (mixing) that occurs when a single well, pumping at a steady rate, discharges reclaimed waste water into an infinite, homogeneous, isotropic aquifer. A numerical solution of the governing differential equation has been obtained. This solution is compared with several approximate methods of solution to the differential equation and to some known field and experimental results. In the final phase, the problem of two-dimensional dispersion, arising from the steady injection of a contaminant through a recharge well and the steady withdrawal of fresh water by a pumping well (both pumping at the same rate), is being investigated experimentally and numerically. A sand model of this two-well flow problem has been constructed.
(h) "Waste Water Recharge and Dispersion in Porous Media," by John A. Hoopes, PhD, MIT, June 1965.
"Waste Water Recharge and Dispersion in Porous Media," by J. A. Hoopes and D.R.F. Harleman, TR 75, MIT Hydrodynamics Lab.

(3750) WAVE FORCES ON STRUCTURES.

(b) Laboratory project.
(c) Prof. D. R. F. Harleman, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Theoretical and experimental; applied research (PhD. thesis).
(e) The objective is the development of design information for wave forces on immersed objects. Included in the investigation is an analysis that will predict the response statistics of a pile supported offshore structure when it is subjected to a random wave train characterized by a narrow banded spectrum. Refinements in the analysis of such structures subjected to harmonic waves are also being investigated.
(g) Analytical procedures have been developed to determine the variation with time of the lateral forces developed on a vertical cylinder due to eddy shedding. Experiments are being run to determine the magnitude of the lateral forces as a function of cylinder diameter and wave characteristics. The phasing of the vortex shedding forces is being correlated with the wave motion. An analysis has also been made of a one degree of freedom system consisting of a nearly massless vertical cylinder, fixed at the base, loaded with a concentrated mass, subjected to a random wave train. Experiments are being run to verify the analysis.

(4159) INSTRUMENTATION SYSTEM FOR THE ANALYSIS OF COMPLEX WAVE FORMS.

(b) National Science Foundation.
(c) Prof. A. T. Ippen, Prof. P. S. Eagleson.
(d) Basic research facility.
(e) Selection and assembly of an analog computer for the calculation and plotting of correlation and spectrum functions. Design and construction of a mechanical time delay mechanism.
(f) Suspended.
(g) Data are acquired on a portable, multichannel FM tape transport. A second transport permits frequency multiplication through rerecording and provides a 120-foot tape loop capability for the repetitive analysis of short records. Matched filters allow the determination of cross power spectral densities as well as the power spectral density of a single signal. Output of all operational modes is through an x-y plotter.

(4160) MOTION OF SUBMERGED BODIES BELOW A FREE SURFACE.

(b) Office of Naval Research, Dept. of the Navy.
(c) Prof. J. F. Kennedy, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Experimental and theoretical; basic research (S.M. thesis).
(e) An investigation of the turbulent wakes generated by two- and three-dimensional bodies moving beneath the free surface. The effects of density stratification are central to the study.
(g) Velocity distributions have been measured at various distances behind a two-dimensional body moving at different depths of submergence in a homogeneous fluid, and at the interface of a two-layered density-stratified fluid. The turbulent mixing between the two layers has been measured by measuring concentration profiles of the tracer, initially present in only the lower, heavier layer, at various distances behind the body. The vertical-diffusion coefficient has been found to decrease significantly with increasing density difference between the two fluid layers. The density stratification also causes the wake width to decrease with increasing distance behind the body after attaining a maximum value at a moderate distance behind the body. The velocity profiles in the stratified fluid are of the exponential, similar type, but cannot be predicted using the methods developed for homogeneous fluids, because of the collapse of the wake. Experiments are now being performed to map the concentration configuration in the wake of a 4 1/2 -inch diameter, self-propelled, three dimensional body moving in a fluid with continuous (nearly linear) density stratification.
(h) "Turbulent Wakes in Density Stratified Fluids of Finite Extent," by E. A. Prych, F. R. Harty, Jr., and J. F. Kennedy, Hydrodynamics Lab., TR No. 65, July 1964.

(4648) MECHANICS OF AERATION AND DISPERSION IN RIVER AND ESTUARY POLLUTION.

(b) Public Health Service, Division of Water Supply and Pollution Control.
(c) Prof. D. R. F. Harleman, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Experimental and theoretical; basic research (doctoral thesis).
(e) (1) A basic study of estuary dispersion in an oscillating flow with throughflow superimposed. Extension of Taylor analysis of longitudinal mixing in estuary type flows. Study of similitude of distorted estuary models in regard to distribution of pollutants in fresh water region of the estuary.
(2) A study of the basic mechanism of oxygen transfer from the atmosphere into turbulent water.
(f) Completed.
(g) (1) Experimental and analytical investigations were conducted on mixing in a pipeline with oscillating plus throughflow. It was found that incorrect logitudinal concentration distributions may be obtained if one-to-one ratio is assumed for concentrations in model and prototype. Exact solutions to the dispersion equation were found for both instantaneous and continuous injection of pollutants into an estuary-type flow and both were verified experimentally. It was found that the equation representing the concentration distribution of a continuously injected pllutant must include the tidal or oscillating velocity. If it does not, the values of the dispersion coefficient found will be much too high.
(2) Turbulence was produced with oscillating screens in a shallow tank of initially deaerated water, and the dissolved oxygen was measured as a function of time and depth by means of an electro-chemical probe. One of the objectives is to separate the effects of turbulence on oxygen transfer across the surface from the effects of turbulent diffusion within the body of the fluid.
(h) "Dispersion of Pollutants in Estuary-Type Flows," by E. R. Holley, Jr., ScD. thesis, September 1964.
"The Significance of Longitudinal Dispersion in the Analysis of Pollution in Estuaries," by D. R. F. Harleman, Proc. 2nd Int. Conf. on Water Pollution Research, Tokyo, Sec. I, paper No. 13, Pergamon Press, Inc., Aug. 1964.
"Dispersion of Continuously Injected Pollutants in Estuary Type Flow," by W. C. Huber, M. S. Thesis, Dept. of Civil Engineering, Mass. Inst. of Technology, June 1965.

(4649) TURBULENT TRANSFER MECHANICS OF FLUID SUSPENSIONS OF SOLID PARTICLES.

(b) Pioneering Research Program, Institute of Paper Chemistry.
(c) Professor J. F. Kennedy, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Experimental; basic research S. M. and Ph.D. theses.
(e) Basic investigation of turbulent transfer mechanics of liquid flows with suspended particles.
(g) Velocity profiles and friction factors have been measured for concentrated suspensions of almost-neutrally-buoyant plastic particles in water flowing in a two-inch tube in a special flow facility. Measurements were made with both spherical and non-spherical particles. The friction factor is generally greater for suspensions then for clear water at the same flux, and decreases with decreasing concentration and increasing particle size, becoming slightly less than the clear water value for the coarser (0.13 inch) particles at larger Reynolds numbers. Experiments performed to measure the velocities of the particles and of the fluid have revealed that the particles move 10 to 15% faster than the fluid. The total head tubes used to measure velocity profiles in earlier experiments were calibrated in flowing suspension using a special nozzle. The coefficients of the probes were found to be 4 ro 5% higher for the suspensions than for clear water.
(h) "Flow of Suspensions of Rigid Non-Spherical Particles," by Antonio Barrera, S. M. Thesis, June 1965.

(4654) A NEW METHOD FOR THE SYSTEMATIC INVESTIGATION OF SEDIMENT TRANSPORT.

(b) National Science Foundation.
(c) Prof. A. T. Ippen, Prof. L. W. Gelhar, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Theoretical and experimental; basic research.
(e) A research program to develop the general characteristics of the flow of fluid-sediment mixtures and of the interaction of fluid flow with movable boundaries.
(g) A study of sediment transport by shear flow in the annulus between two rotating drums rather than by flow in a channel has been initiated. A new experimental apparatus which replaces the commonly employed longitudinal channel by an annular channel between two rotating drums has been designed and built. The normal gravitational field is replaced by a centrifugal force field. With the cylindrical drums rotating at different relative speeds a large variety of flow conditions can be established in the "endless" annular channel, covering a wide range of tractive forces on the sediment deposited on the wall of the outer drum under various modes of relative motion. Mean velocities and turbulence characteristics are being measured in the annulus using homogeneous fluids. The structure of the mean velocity profiles indicates that the flow is influenced by secondary motions. A theoretical description of the secondary motion in the annulus is being developed.
(h) "The Development of a Rotating Endless

Channel for Hydraulic and Sedimentary Studies," by P. A. Drinker, L. W. Gelhar and W. Schriek, Tech. Report 83, Hydrodynamics Lab., Dept. of Civil Engineering, MIT.

(5114) ROUTING UNSTEADY FLOWS FROM HYDROELECTRIC PLANTS FOR OPTIMIZATION OF NAVIGATION AND PEAK POWER PRODUCTION.

(b) Tennessee Valley Authority.
(c) Prof. R. T. McLaughlin, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Analytical; applied research.
(e) Theoretical analysis of rapid changes of discharge in open-channels and the use of mathematical models of such flows in digital and analog computers.
(f) Completed.
(g) A method of characteristics especially suitable for large and rapid changes of discharge has been applied to a channel having quite general geometry, and a program for carrying out the computations has been completed.
(h) "Numerical Analysis of Open-Channel Transients from Hydro-Power Operation," by Christian Kim, S. M. Thesis, February 1965.

(5115) SYSTEMS METHODOLOGY FOR WATER-RESOURCE PLANNING IN A REGIONAL DEVELOPMENT CONTEXT.

(b) M.I.T. Inter-American Program in Civil Engineering.
(c) Prof. R. T. McLaughlin, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Theoretical and analytical; basic research.
(e) Research on the use of mathematical models and systems analysis in planning for comprehensive development of water resources in river basins or other hydrologic units. The relationship of such developments to the social and economic activity of the region in which the unit is located is also being considered.
(g) An existing mathematical model for simulating a single multi-purpose reservoir is being modified for more sophisticated handling of operating decisions during the simulation. Simplified mathematical models are being investigated for possible use in obtaining approximate answers in the early stages of a planning study. The results of the simplified models are being checked against results of simulation.

(5116) DEFINITION OF WATER-RESOURCE PROBLEMS IN LATIN AMERICA.

(b) M.I.T. Inter-American Program in Civil Engineering.
(c) Prof. R. T. McLaughlin, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Area survey; for problem identification.
(e) General study of water-resource problems of Latin America to define specific and significant problems that seem to be areas of fruitful research.
(f) Completed.
(h) "On the Water-resource Problems of Latin America," by J. W. Bulkley, R. T. McLaughlin and F. Ibanez. Hydrodynamics Laboratory T. R. No. 87, Oct. 1965.

(5117) ANALYSIS AND SYNTHESIS OF HYDROLOGIC SYSTEMS.

(b) M.I.T. Inter-American Program in Civil Engrg.
(c) Prof. P. S. Eagleson, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Experimental and theoretical; basic research (Ph.D. thesis).
(e) Development of improved analytical techniques for the prediction of the time variation in stream flow at some point in a drainage basin due to a given temporal and areal distribution of precipitation. Development of the means for synthesizing these predictors in the absence of long term hydrologic records.
(g) The similarity relationships governing surface runoff have been derived and from these the useful range of operation of model catchments has been determined. Instrumentation for a model catchment has been designed and is being built.
(h) "Similarity Criteria in the Surface Runoff Process," by R. A. Grace and P. S. Eagleson, MIT Dept. of Civil Engineering, Hydrodynamics Laboratory Report No. 77, July 1965.
"Optimum Discrete Linear Hydrologic Systems with Multiple Inputs," by J. C. Ochoa-R. and P. S. Eagleson, MIT Dept. of Civil Engineering, Hydrodynamics Laboratory Report No. 80, August 1965.
"The Computation of Optimum Realizable Unit Hydrographs from Rainfall and Runoff Data," by P. S. Eagleson, R. Mejia and F. March, MIT Dept. of Civil Engineering, Hydrodynamics Laboratory Report No. 84, Sept. 1965.

(5118) MECHANICS OF SEDIMENT RIPPLES AND DUNES AND THEIR EFFECT ON CHANNEL ROUGHNESS.

(b) Agricultural Research Service, U. S. Dept. of Agriculture.
(c) Prof. J. F. Kennedy, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Theoretical; basic research (Master's and Doctor's thesis).
(e) The formation of sediment ripples and dunes by uniform free-surface flow, uniform infinite flow, and oscillating flow has been investigated as a stability problem by using a potential flow solutions for fluid motion over a small-amplitude wavy bed and a sediment transport law in which the transport rate at any point is proportional to a power of the velocity near the bed at some distance upstream. The kinematics of the resulting sediment motion are used to determine the conditions for which the bed waves will grow, and the behaviour of the resulting bed features.
(g) Formulas for the wave length, velocity of movement, and amplitude of ripples and dunes have been developed, and the conditions for formation bed waves have been delineated. The investigation is now being directed toward development of a method for predicting the friction factor of uniform flows over sand beds in alluvial channels. The friction factor is being related to the flow quantities that have been shown by the theoretical analysis to govern the geometry of the bed configuration. An extensive body of laboratory and field data has been placed on computer cards and computer programs have been developed to evaluate new methods of predicting channel roughness and compare them with existing methods.
(h) "Wave-Generated Sediment Ripples," by John F. Kennedy and Marco Falcon, MIT Dept. of Civil Engineering, Hydrodynamic Laboratory Technical Report No. 86, Aug. 1965.

(5119) TIDAL, SALINITY AND SEDIMENTATION PROBLEMS IN LAKE MARACAIBO CHANNEL, VENEZUELA.

(b) M.I.T. Inter-American Program in Civil Engrg.
(c) Prof. A. T. Ippen, Prof. E. Partheniades, Prof. J. F. Kennedy and Prof. D. R. F. Harleman, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Theoretical and experimental; basic research and field investigation (S.M.Thesis).
(e) Purpose of basic research: Investigation of flow variables and soil properties controlling infiltration and rates of erosion and deposition of fine cohesive sediment in a flow field. Purpose of field investigation: To determine the sources and motion of sediment and the time and special salinity distribution within the Maracaibo estuary in Venezuela. Also to utilize this information for designing remedial works in order to re-

duce shoaling in the Maracaibo Navigable Channel and control salt water intrusion into Lake Maracaibo.

(g) Basic research: the special apparatus developed consists of an annular rotating channel and a counterrotating annular ring placed in the channel and in contact with the water surface. The relative motion of channel and ring generates a uniform turbulent flow field. Experiments with kaolinite clay suspensions have revealed two important properties: (1) The existence of a critical flow velocity for clay deposition. (2) For a given flow, the equilibrium concentration is a constant percentage of the initial sediment concentration in the channel. Field investigations: Results point out that most of the sediment comes from the Gulf of Venezuela transported near the bottom by tidal and salinity currents. Also a bottom layer at high salinity has been found to exist all the way to the entrance to the Lake throughout the year.

(h) "A Summary of the Present Knowledge of the Behavior of Fine Sediments in Estuaries," by E. Partheniades, Hydrodynamics Laboratory, Technical Note No. 8, June 1966.
"Erosion and Deposition of Cohesive Soils," by E. Partheniades, Journal of Hydraulics Division, A.S.C.E. Vol. 91, No. HY 1 Proc. Paper 4204, pp. 105-139, Jan. 1965.
"Stratified Flow in Estuaries and its Influence on Sedimentation in Navigable Channels," (in Spanish) by E. Partheniades, to be published in the Review of Hydraulic Engineers of Venezuela.
"A Laboratory Apparatus for the Study of Transport of Cohesive Sediment in a Flow Field," by R. J. Etter and R. P. Hoyer. M. S. thesis, Dept. of Civil Engrg., MIT, June 1965.

(5120) THE FEASIBILITY OF ROTATING MODELS IN THE STUDY OF CIRCULATION PATTERNS IN LARGE LAKES.

(b) Laboratory project.
(c) Prof. D. R. F. Harleman, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Theoretical and experimental; basic research.
(e) A study of the feasibility of small scale models in which similitude with respect to gravity and Coriolis forces is obtained. Velocity and time scales are obtained from Frondian conditions for a distorted model. Model is rotated to obtain effect of Coriolis acceleration.

(g) Surface current patterns on a small model of Lake Michigan have been obtained for a constant wind field both with and without rotation of the model. The effect of a vertical density stratification on current patterns has been studied. The production of a thermocline by infrared heating of the model surface has also been investigated. Results indicate that rotation of the model produces marked differences in circulation patterns when compared to non-rotating model having the same wind pattern over the surface. A small model of Lake Maracaibo (Venezuela) has been constructed for the purpose of studying the peculiar pattern of salinity distribution which exists in the lake. Results indicate that pattern is produced by interaction of wind generated currents and Coriolis effect.

(5539) FREE SURFACE FLOW OVER THE WAVY BED.

(b) Laboratory project.
(c) Prof. J. F. Kennedy, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Experimental and theoretical; basic research (Master's thesis).
(e) An investigation of a free surface flow of a real fluid over a small-amplitude sinusoidal bed in a rectangular-cross-section channel.
(g) Velocity profiles upward from the bed and outward from the vertical side walls have been measured at various locations along a rectangular-cross-section open channel with a sinusoidal-shaped wavy bed, and along an isolated sinusoidial hump in the channel bottom for a supercritical flow. It has been found that the displacement thickness of the straight vertical walls varies periodically along the length of the channel with the same period as the wavy bottom. This undulation in the displacement thickness generates diagonal free-surface waves which criss-cross the flume, a new wave being generated by each wave on the channel bottom. Pressure and velocity measurements indicate that the perturbation in the displacement thickness is caused by secondary currents resulting from the interaction of the boundary layers of the vertical side walls and the distortion of the vertical and lateral pressure gradients caused by the curvature of the bed. The orientation of the diagonal wave is in good agreement with that predicted using small-amplitude wave theory. The form of the vertical velocity-profiles vary markedly along the channel, being sharpest in the troughs (n=4 in the power-low velocity distribution) and bluntest at the crest (n=17 to 19).
(h) "Free Surface Flow over a Wavy Bed," by Luc Robillard, S.M. Thesis, Feb. 1965.

(5540) MINIMUM-COST DESIGN OF PIPE NETWORKS.

(b) Unsponsored laboratory project.
(c) Professor R. T. McLaughlin, Mass. Inst. of Technology, Cambridge, Mass. 02139.
(d) Analytical, design (Master's thesis).
(e) Marginal analysis by means of a digital computer is used to find the pipe network that delivers prescribed amounts of water at fixed points with a minimum cost of network and pumping.

(5542) CAVITATION NEAR SURFACES OF DISTRIBUTED ROUGHNESS.

(b) U.S. Army Research Office - Durham.
(c) Prof. A. T. Ippen, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Experimental and theoretical (Ph.D. thesis).
(e) The influence of various distributions of roughness height on cavitation inception in a turbulent boundary layer. Boundary layer and roughness parameters and the role of free stream and boundary layer turbulence will be correlated with cavitation inception. An attempt will be made to determine any advantages of roughness in cavitation design.

(5543) DISPERSION OF POLLUTANTS IN HETEROGENEOUS AND ANISOTROPIC AQUIFERS.

(b) Public Health Service, Div. of Water Supply and Pollution Control.
(c) Prof. D. R. F. Harleman, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Analytical and experimental (Doctoral thesis).
(e) Study of the dispersion and mixing in miscible fluid displacement in heterogeneous and anisotropic porous media. First phase dealt with dispersion in layered formations. The current phase deals with numerical solutions to the convective-dispersion equations. These results will be applied to problems in layered and anisotropic formations.
(g) Analytical solution for longitudinal dispersion in flow perpendicular to the layers, and lateral dispersion in flow along the layers have been obtained. These solutions have been verified experimentally. The numerical solutions are aimed at obtaining a general and efficient computer program with which a large variety of problems may be solved.
(h) "Dispersion and Adsorption in Porous Media," Discussion by D. R. F. Harleman and U. Shamir, by R. B. Banks and Iqbal Ali, Proc. ASCE Vol. 91, No. HY3, May 1965, pp. 330-333.

(5544) TECHNIQUES OF MODELLING THE SOLAR POND IN THE LABORATORY.

(b) Laboratory project.
(c) Prof. D. R. F. Harleman, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Experimental and analytical (Doctoral thesis).
(e) The solar pond is used to store solar energy by absorption of radiation in a dense layer at the bottom of a pond. The object of the research is to (1) find an analytic prediction for the temperature distribution in a pond with and without a black body absorber at the bottom for a specified radiation at the surface, and verify the analytic predictions experimentally. (2) Seek methods of obtaining prescribed temperature distributions for distorted models.

(5823) TURBULENCE STRUCTURE OF FLOW IN ROUGH CONDUITS.

(b) National Science Foundation.
(c) Professor J. F. Kennedy, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Experimental; basic research S.M. and Ph.D. theses.
(e) Measurement of the turbulence structure for pipe flow in the fully rough regime. Particular attention is being directed to the region near the boundary.
(g) An air flow facility with a ten-inch diameter test section is being constructed. The working section can be opened, and 0.13 inch diameter spheres are being cemented to the pipe to give a rough surface. The turbulence structure will be measured using a hot wire anemometer. The goal is to gain more insight into the process of particle entrainment by a turbulent flow by examining the turbulent component of velocity near the bed.

(5824) URBAN HYDROLOGIC SYSTEMS.

(b) Commonwealth of Mass., Dept. of Public Works.
(c) Prof. P. S. Eagleson.
(d) Theoretical and data analysis (S.M. thesis).
(e) Representation of urban drainage basins as optimum linear systems.
(f) Suspended.
(h) "Linear Synthesis of Urban Hydrographs," by F. March, S. M. thesis, MIT Dept. of Civil Engrg., Sept. 1965 (unpublished).
"Approaches to the Linear Synthesis of Urban Runoff Systems," by F. March and P. S. Eagleson, MIT Dept. of Civil Engrg., Hydrodynamics Lab. Report No. 85, Sept. 1965.

(5825) OPTIMAL DESIGN OF SEWER AND DRAINAGE SYSTEMS.

(b) U. S. Public Health Service.
(c) Prof. R. T. McLaughlin, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Theoretical and analytical; basic research.
(e) Unsteady flow in systems of open channels is being analyzed numerically using a digital computer and dynamic programming is being applied to the optimal design of such systems.

(5826) MECHANICS OF VISCOUS STRATIFIED FLOW.

(b) MIT, Sloan Basic Research Grant.
(c) Prof. L. W. Gelhar, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Theoretical and experimental, basic reserch (master's thesis).
(e) General studies of viscous effects in density stratified flows. The present study deals with slow flow of a non-diffusive fluid.
(g) A mathematical model for slow viscous non-diffusive flow has been developed. The resulting ordinary differential equation is being integrated numerically for a number of flow problems including flow toward a line sink and the developing shear layer between stratified fluids moving at different velocities.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Department of Mechanical Engineering.

(4490) BASIC RESEARCH ON COOLING OF HIGH-PERFORMANCE ELECTROMAGNETS.

(b) M.I.T. National Magnet Laboratory.
(c) Prof. Arthur Bergles, M.I.T., Cambridge, Mass. 02139.
(d) Experimental and theoretical; basic and applied research; bachelor's, master's, and doctor's theses.
(e) This project has been concerned with the prediction of heat transfer and pressure drop under conditions simulating those encountered in high-performance electromagnets. Nonboiling and boiling heat transfer with water are being studied. Techniques of augmenting heat transfer are being considered.
(g) Data have been taken and correlations proposed for the prediction of heat transfer, pressure drop, and burnout for forced-convection surface boiling. The conditions for stability in parallel-channel systems have been defined. Investigations of the effects of fluid vibrations, additives, and swirl flow have been performed.
(h) "A Study of System-Induced Instabilities in Forced-Convection Flows with Subcooled Boiling," J. S. Maulbetsch and P. Griffith, M.I.T. Engineering Projects Lab. Tech. Report 5382-35, April 1965.
"Effects of Upstream Compressibility on Subcooled Critical Heat Flux," by R. S. Daleas and A. E. Bergles, ASME Paper No. 65-HT-67, 1965.
"The Influence of Ultrasonic Vibrations on Heat Transfer to Water Flowing in Annuli," by A. E. Bergles and P. H. Newell, Jr., Int. J. Heat Mass Transfer, Vol. 8, No. 10, pp. 1273-1280, 1965.

(4498) USE OF ELECTROCHEMILUMINESCENCE IN FLOW VISUALIZATION AND THE MEASUREMENT OF MASS TRANSFER RATES.

(b) Laboratory project.
(c) Mr. George S. Springer, Asst. Prof., M.I.T., Cambridge, Mass. 02139.
(d) Experimental, applied research, Master's thesis.
(e) To study the process of electrochemiluminesce and investigate its usefulness in flow visualization and mass transfer measurements.
(f) Suspended.
(g) The technique shows separation in laminar flow. It can be used to measure mass transfer rates to solid surfaces in laminar flow.
(h) "Use of Electrochemiluminescence in the Measurement of Mass Transfer Rates," by G. S. Springer, The Rev. Sci. Instruments 35, 1277-1280, 1964.
"Flow Visualization with the Technique of Electrochemiluminescence," by B. Howland, G. S. Springer, M.G. Hill. J. of Fluid Mechanics. In print.

(4982) FUNDAMENTAL INVESTIGATION OF HEAT TRANSFER AND FLUID FLOW INSIDE A HORIZONTAL TUBE EVAPORATOR.

(b) American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc, Research Grant RP 47.
(c) Prof. S. William Gouse, Jr., Assoc. Prof. of Mechanical Engineering, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Basic research; experimental and theoretical.
(e) To conduct a visual and quantitative study of the fluid mechanics of a horizontal tube evaporator in order to clarify the confusion which presently exists in the interpretation

of experimental results as concerns heat transfer mechanisms.

(h) "Heat Transfer and Fluid Flow Inside a Horizontal Tube Evaporator," by S. W. Gouse, Jr., and others. Presented at the Boiling and Two-Phase Flow Symposium at the ASHRAE National Meeting, Portland, Oregon, July 7, 1965, Trans. ASHRAE, Part II, 1965.
"Heat Transfer and Fluid Flow Inside a Horizontal Tube Evaporator-Phase II," by S. W. Gouse, Jr., A. J. Dickson, M.I.T., Engineering Projects Laboratory Report DSR 9649-2, November 1965.

(4983) DETERMINATION OF THE STATE OF THE ART IN TWO-PHASE GAS-LIQUID FLOW PHENOMENA.

(b) Office of Naval Research (Nonr-1841(73)).
(c) S. William Gouse, Jr., Associate Prof. of Mechanical Engineering, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Literature search and review.
(e) Conduct a world wide search of the literature on various aspects of two-phase gas-liquid flow, index the literature and review the state of the art in various problem areas.
(h) "An Index to the Two-Phase Gas-Liquid Flow Literature, Part III," by S. W. Gouse, Jr., M.I.T., Engineering Projects Laboratory Report DSR 8734-6, December 1965.
"The Evaporator Tube-State of the Art," by S. W. Gouse, Jr., A. J. Dickson, M.I.T. Engineering Projects Laboratory Report DSR 8734-7, December 1965.

(5554) TWO-PHASE DIFFUSER FLOW STUDIES.

(b) M.I.T. Solar Energy Fund.
(c) S. William Gouse, Jr., Associate Prof. of Mechanical Engineering, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Basic research; experimental and theoretical.
(e) Analytical and experimental investigation of decelerating two-phase gas-liquid flows.

(5555) WAVE PROPAGATION IN FLEXIBLE TUBES.

(b) National Institutes of Health.
(c) Prof. A. H. Shapiro, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Experimental and theoretical, basic research; master's and doctoral theses.
(e) Pulsatile flow, with reference to the human vascular system. Studies of wave propagation, non-linear effects, flow patterns, effects of local changes in tube wall properties.
(h) Report is now in preparation.

(5557) MOMENTUM FLUXES IN TWO PHASE (GAS-LIQUID) FLOW.

(b) U. S. Atomic Energy Commission.
(c) Prof. Peter Griffith, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Experimental. Direct measurement of momentum fluxes made for air-water and steam-water in a round pipe. Applied research - doctoral.
(e) A two-phase mixture is turned through 90° and the force on the turning tee is measured.
(g) Homogeneous momentum fluxes are closest to the truth.
(h) "The Momentum Flux in Two-Phase Flow," by Gerry B. Andeen, P. Griffith. Technical Report No. 4547-38, AEC Code: Report MIT 3496-1, October 1965. M.I.T., Cambridge, Mass. 02139.

(5780) ANALYTICAL AND EXPERIMENTAL INVESTIGATION OF FLOW OSCILLATIONS IN A CLOSED LOOP WITH TRANSPARENT, PARALLEL, VERTICAL, HEATED CHANNELS.

(b) Office of Naval Research (Nonr-3963(15)).
(c) S. William Gouse, Jr., Associate Prof. of Mech. Engrg., Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Basic research, analytical and experimental.
(e) Examine the details of two-phase gas-liquid flow oscillations with the object of identifying mechanisms and predicting stable operating conditions.

(5781) AERODYNAMIC DRAG IN TUNNELS.

(b) U. S. Department of Commerce.
(c) S. William Gouse, Jr., Associate Prof. of Mechanical Engineering, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Basic research, analytical and experimental.
(e) By means of similitude experimentally determine the aerodynamic drag characteristics of vehicles moving along guideways of varying degrees of enclosure.

(5782) OPTIMIZATION OF AIR-CYCLE COOLING SYSTEMS FOR SUPERSONIC AIRCRAFT.

(b) Laboratory project.
(c) John S. Maulbetsch, Asst. Prof. of Mechanical Engineering, Room 1-112, M. I. T., Cambridge, Mass. 02139.
(d) Analytical, Applied Research (Master's Thesis).
(e) The project constitutes an attempt to systemtize and computerize air-cycle cooling system calculations which presently involve tedious trial-and-error calculations. This may be done on three levels of complexity: (1) off-design calculations for a system already designed. (2) optimization of components at the design part for a situation where the general cycle configuration has been decided. (3) choice of optimum cycle configuration from a specification only of the system loads and the mission profile for the aircraft.

(5783) HYDRAULIC ANALOGY STUDY OF COMPRESSIBLE WAVES IN TUNNELS.

(b) Project Transport - Dept. of Commerce.
(c) Prof. Mikio Suo, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Experimental applied research, master's thesis.
(e) The formation and initial propagation of compressible waves in high speed train tunnels is being studied. The hydraulic analogy to compressible fluid flow is being used as a tool in this study.

(5784) TRANSITION FROM TURBULENT TO LAMINAR FLOW IN COOLED LIQUID FLOWS.

(b) Laboratory project.
(c) Prof. Mikio Suo, Mass. Inst. of Tech., Cambridge, Mass. 02139.
(d) Experimental basic research, master's thesis.
(e) A liquid which is at a low turbulent Reynolds number in a pipe may become laminar if it is cooled sufficiently. The nature of this transition is being investigated.

UNIVERSITY OF MASSACHUSETTS, School of Engineering.

(2561) HYDROLOGY STUDIES OF MASSACHUSETTS.

(b) Cooperative with the U. S. Geological Survey, the U. S. Soil Conservation Service and the Massachusetts Water Resources Commission.
(c) Assoc. Prof. G. R. Higgins, Engineering Research Institute, University of Massachusetts, Amherst, Mass. 01003.
(d) Experimental; Field and Laboratory; for hydrologic information for the Commonwealth to better assess the water resources potential and for design of future works.
(e) Mass curves, flow duration curves, and recurrence interval curves have been prepared for nearly all the gaged streams in Mass. through the water year 1962. Preliminary investigations to determine factors that affect base flow have been conducted. These included studies of soil types, drainage density, surface cover, and others deemed pertinent. Present emphasis is concerned with evaporation studies to determine the effect of evaporation on reservoir yield.
(g) A 250 page report entitled "Hydrology Studies in Massachusetts" was completed for the Mass.

Water Resources Commission in 1964. Copies are available upon request.

(h) Progress reports were submitted to the Research Council of the University of Mass. in 1959 and 1960. A report for the Water Resources Research Center is in preparation.

(5371) A PHOTOMICROSCOPIC INVESTIGATION OF NON-NEWTONIAN FLOWS AT LOW REYNOLDS NUMBERS.

(b) David Taylor Model Basin.
(c) Dr. Charles E. Carver, Jr., Prof. of Civil Engrg., Univ. of Mass., Amherst, Mass. 01003.
(d) Experimental; basic research.
(e) Laminar velocity profiles have been determined from photomicrographs of the motion of polystyrene latex spheres 0.557 microns in diameter dispersed in distilled water and three different aqueous solutions of non-Newtonian additives flowing in a lucite channel of cross-section 13 x 1.5 mm at a channel Reynolds number of 0.92.
(g) Velocity profile for distilled water agrees within 2% with the theoretical parabolic distribution for laminar flow between parallel flat plates. Profiles for the additives at both concentrations of 0.125% and 0.25% were indistinguishable from that of distilled water except near the boundaries, from 20-50 microns, where the velocity was measureably higher. Experiments are to be repeated for turbulent flow using high speed cinemamicrophotography.
(h) "Measurement of Laminar Velocity Profiles with Non-Newtonian Additives," in preparation.

(5373) EFFICIENCY OF SPRAY AERATION.

(b) National Institutes of Health, U. S. Public Health Service.
(c) Dr. Charles E. Carver, Jr., Prof. of Civil Engrg., Univ. of Mass., Amherst, Mass. 01003.
(d) Experimental; basic research.
(e) Overall oxygen transfer coefficients have been measured for deaerated water droplets falling through the atmosphere as a function of drop size and drop distance. The experiments are repeated with a synthetic detergent added to the water. Transfer coefficients are also measured from fully aerated water droplets falling through a pure nitrogen atmosphere as a function of drop size and drop distance and these experiments are repeated with a synthetic detergent added.

UNIVERSITY OF MICHIGAN, Department of Civil Engrg.

(4858) WATER HAMMER: RESONANCE IN TRIPLEX PUMP SUCTION AND DISCHARGE LINES.

(b) Union Pump Company.
(c) Prof. V. L. Streeter, Prof. of Hydraulics, Dept. of Civil Engrg., College of Engrg., Univ. of Mich., Ann Arbor, Mich. 48104.
(d) Theoretical and experimental; basic research.
(e) Theoretical determination of resonance-free suction lines and experimental study of actual transients.

(4859) PULSATILE FLOW THROUGH ARTERIES.

(b) National Institutes of Health.
(c) Prof. V. L. Streeter, Prof. of Hydraulics, Dept. of Civil Engrg., College of Engrg., Univ. of Mich., Ann Arbor, Mich. 48104.
(d) Theoretical and experimental; basic research.
(e) Computer simulation of portions of the arterial tree; experimental studies of energy dissipation in pulsatile flow through distensible tubes.

(4862) WATER HAMMER, LIQUID COLUMN SEPARATION.

(b) National Science Foundation.
(c) Prof. V. L. Streeter, Prof. of Hydraulics, Dept. of Civil Engrg., College of Engrg., Univ. of Mich., Ann Arbor, Mich. 48104.
(d) Theoretical and experimental; basic research for doctoral thesis.
(e) Study of shape of separated liquid free surface in a horizontal pipe.

(4946) RESONANCE IN PIPELINES.

(b) Horace H. Rackham School of Graduate Studies, The University of Michigan, Ford Foundation, National Science Foundation.
(c) Prof. V. L. Streeter, Prof. of Hydraulics, Dept. of Civil Engrg., College of Engrg., Univ. of Mich., Ann Arbor, Mich. 48104.
(d) Theoretical and experimental.
(e) Study of geometry of pipelines and the frequencies for which resonance could occur. Effect of friction in damping resonance.
(h) "Resonance in Pressurized Piping Systems," E. B. Wylie, ASME paper No. 65-FE-6 Applied Mechanics/Fluids Engineering Conf., Wash., D.C., June 7-9, 1965.
"Resonance in Bersimis No. 2 Piping Systems," E. B. Wylie, V. L. Streeter, ASME paper No. 65-FE-10 Applied Mechanics/Fluids Engrg. Conf., Wash., D.C., June 7-9, 1965.
"Resonance in Governed Hydro Piping Systems," V. L. Streeter and E. B. Wylie, ASME Symposium "Waterhammer in Pumped Storage Projects" Nov. 8-10, 1965, Winter Annual Meeting, Chicago.
"Computer Solution of Surge Problems," V. L. Streeter, Symposium on Surges in Pipelines, Inst. of Mechanical Engineers, London, Nov. 2-3, 1965.

(5558) THE EFFECT OF URBANIZATION ON THE RUNOFF PROCESS.

(b) National Institute of Health.
(c) Dr. E. F. Brater, Prof. of Hydraulic Engineering, Dept. of Civil Engineering, Ann Arbor, Michigan 48104.
(d) Analysis of field data, basic research.
(e) Rainfall and runoff data from six watersheds are being analyzed. Some watersheds are rural, others are urbanized and others are in the process of urbanization. The ultimate goal of the research is the prediction of storm runoff on watersheds in various stages of urbanization.
(g) More than 50 flood hydrographs from six drainage basins were analyzed for shape and timing with respect to rainfall and volume of surface runoff.

(5916) RAINFALL-RUNOFF RELATIONS ON URBAN AND RURAL AREAS.

(b) National Institutes of Health.
(c) Dr. E. F. Brater, Prof. of Hydraulic Engrg., Dept. of Civil Engrg., Ann Arbor, Mich. 48104
(d) Analysis of field data, basic research.
(e) Investigations will be made of rainfall and runoff for 27 small watersheds located in southwestern Michigan in order to determine basic relationships between flood discharge and rainfall and watershed characteristics.
(g) Research is in preliminary stages.

(5917) VALVE STROKING TO CONTROL WATERHAMMER.

(b) National Science Foundation.
(c) Prof. V. L. Streeter, Prof. of Hydraulics, Dept. of Civil Engrg., College of Engrg., Univ. of Mich., Ann Arbor, Mich. 48104.
(d) Theoretical and experimental.
(e) Development of theoretical equations for motion of a valve so that the transient ceases the instant the valve motion ceases; confirmation on 4,000 ft. line with servo-operated valve.

UNIVERSITY OF MISSOURI, Dept. of Civil Engineering.

(5259) HYDRAULIC CHARACTERISTICS AND SELF-CLEANING CHARACTERISTICS OF HIGHWAY GRATE INLETS.

(b) Rowland Engineering Co. and Univ. of Missouri, Engineering Experiment Station.

(c) Dr. John J. Cassidy, Civil Engineering Dept., University of Missouri, Columbia, Mo. 65202.
(d) Experimental; applied.
(e) Several commonly used geometric types of grate inlets are being investigated in order to generalize the hydraulic characteristics of the grates, and hence provide a rational means of comparison of individual efficiencies.
(f) Completed.
(g) Efficiency of a grate has been shown to a function of the Froude number and depth of the gutter flow. Grates with vane-shaped bars were found to be more efficient for large Froude numbers than were grates formed from flat bars. Self-cleaning characteristics of the grate appeared to vary with the thickness of the grate bars.
(h) Results have been submitted for publication at the Highway Research Board Meeting in Washington, D. C., Jan. 17, 1966.

(5260) IRROTATIONAL FLOW THROUGH A SPILLWAY BUCKET OF GIVEN SHAPE IN A GRAVITY FIELD.

(b) U.S. Army Corps of Engineers Waterways Experiment Station.
(c) Dr. John J. Cassidy, Dept. of Civil Engineering, University of Missouri, Columbia, Mo. 65202.
(d) Analytical; basic research.
(e) An analytical method is being devised for the determination of free-surface profiles, pressure distributions, and velocity distributions for irrotational flow through a curved spillway of given shape in a gravity field.
(f) Completed.
(g) A FORTRAN program was written for the analysis of flow through a curved spillway bucket. Input to the program included the total head, bucket radius, coordinates of the center of curvature, and the slope of the approaching channel. Output from the program includes pressures on the solid boundary and free-surface coordinates.
(h) "Analytical Study of Flow Characteristics For Flow Over a Curved Spillway Bucket," Contract No. DA-22-079-CIVENG-64-83, by John J. Cassidy, obtainable from the Engrg. Experiment Station, Univ. of Mo., Columbia, Missouri 65202.

(5261) THE CELERITY OF SOLITARY WAVES OF CONSTANT FORM.

(b) Laboratory project.
(c) Dr. Charles Lenau, Dept. of Civil Engineering, Univ. of Missouri, Columbia, Mo. 65202.
(d) Analytical; basic.
(e) The celerity of solitary waves with large amplitudes is being investigated through numerical solution of a nonlinear integral equation under the assumption that the flow is potential. The wave of maximum amplitude is of particular interest.
(f) Completed.
(g) A solution was obtained for the form of a large solitary wave of constant form. The maximum amplitude and the celerity were obtained as part of the solution.
(h) Results have been submitted for publication in the Journal of Fluid Mechanics.

(5827) EFFECT OF AQUATIC GROWTHS ON THE RESISTANCE TO FLOW IN PIPES.

(b) Missouri State Water Pollution Board.
(c) Dr. John J. Cassidy and Dr. Darrel L. King, Civil Engrg. Dept., Univ. of Mo., Columbia, Missouri 65202.
(d) Experimental, basic; M. S. thesis.
(e) Nutrients are being added to water in order to grow algae and other organisms on the walls of pipes through which the water is being pumped. Change in the resistance coefficient with time is being measured.

(5828) SPILLWAY DISCHARGE COEFFICIENTS AND PRESSURE DISTRIBUTIONS AS A FUNCTION OF SPILLWAY SHAPE.

(b) Univ. of Missouri, Engrg. Experiment Station.
(c) Dr. John J. Cassidy, Civil Engrg. Dept., Univ. of Missouri, Columbia, Mo. 65202.
(d) Experimental, basic, M. S. Thesis.
(e) Discharge coefficients and pressure distributions are being determined experimently for spillways with varying crest shapes.

(5829) DISCHARGE MEASUREMENT IN TWO-DIMENSIONAL FLOWS.

(b) Laboratory study.
(c) Dr. Henry Liu, Civil Engrg. Dept., Univ. of Missouri, Columbia, Missouri 65202.
(d) Experimental, applied.
(e) A new method of discharge measurement is being studied. The method involves the release of lighter-than-water particles on or near the floor of a channel, and the measurement of the horizontal distance traversed during their rise to the surface.

UNIVERSITY OF MISSOURI AT ROLLA, Dept. of Civil Engrg.

(319) WEIR STUDIES.

(b) Laboratory project.
(c) Prof. E. W. Carlton, Civil Engrg. Dept., University of Missouri at Rolla, Rolla, Missouri 65401.
(d) Experimental; basic research for master's thesis.
(e) Tests on rectangular weirs were made to determine effect of velocity of approach on the relation between crest depth and critical depth of an imaginary open channel having same dimensions as the weir opening.
(f) Completed.
(g) Study produced a simple, accurate and quick solution for plotting of M function. Relationship between the M function, and the critical depth is logarithmic. This greatly simplifies determination of critical flow where the critical depth is known or vice versa. A relationship exists between M function of channels of same shape but different dimensions. The velocity of approach does not affect the relationship between physical depth and crest depth.

(3775) VERTICAL WATER JET IMPACTING UPON A STILLING BASIN.

(b) Laboratory project.
(c) Prof. V. A. C. Gevecker, Civil Engineering Department, Univ. of Missouri at Rolla, Rolla, Missouri 65401.
(d) Experimental; basic research for master's thesis.
(e) Tests being conducted on the terminal effect of a 3/8 inch water jet on a cylindrical stilling basin to determine side and bottom pressures, velocities and energy dissipated.
(f) Completed.
(g) It was found that the hydraulic behavior of the free jet impacting on a stilling basin can be determined to a degree which may be considered accurate for practical purposes. It was also shown that given the free jet velocity, the magnitudes of the velocities at the critical points inside the stilling basin can be computed by menas of the equations presented.
(h) "Velocity Distribution Induced by Free Jet Impact on A Stilling Basin" by Sedat Ozkol, Master's Thesis, Missouri School of Mines, 1962.

(4169) INVESTIGATION OF VERTICAL INTERNAL SPILLWAYS.

(b) Laboratory project.
(c) Prof. C. D. Muir, Assoc. Prof. of Civil Engineering, Univ. of Missouri at Rolla, Rolla, Missouri 65401.
(d) Experimental; basic research for master's thesis.

(e) A scale model rockfill dam containing a vertical internal spillway was studied to determine factors affecting stage-discharge relationships.
(f) Completed.

(4661) A COMPUTER STUDY OF BACKWATER COMPUTATIONS.

(b) Laboratory project.
(c) Prof. C. D. Muir, Associate Professor of Civil Engineering, Univ. of Missouri at Rolla, Rolla, Missouri 65401.
(d) Experimental; basic research for master's thesis.
(e) The effect of some approximations used in backwater calculations on the resulting surface profile were studied by use of a digital computer. Also, several methods of backwater computations were compared.
(f) Completed.
(g) The results of this study indicated that the use of approximations is feasible for curves above critical depth but are dependent on flow regime.

(4662) HYDROLOGY OF SMALL MISSOURI WATERSHEDS.

(b) Laboratory project.
(c) Prof. C. D. Muir, Associate Professor of Civil Engineering, Univ. of Missouri at Rolla, Rolla, Missouri 65401.
(d) Experimental; basic research for master's thesis.
(e) This study was for the purpose of correlating basin characteristics and mean annual flood for Missouri watersheds having a drainage area of less than ten square miles.
(f) Suspended.
(g) It was found that mean annual floods could be predicted and correlated to known data from forty-five Missouri watersheds by use of a shape factor (AL^2) and basin index ($AL^2S^{1/2}$).

(4663) FLOW THROUGH A ROCKFILL DAM.

(b) Laboratory project.
(c) Prof. P. R. Munger, Assistant Professor of Civil Engineering, Univ. of Missouri at Rolla, Rolla, Missouri 65401.
(d) Experimental; basic research for master's thesis.
(e) Model studies are being conducted on a rockfill dam with a sloping internal spillway to determine the characteristics of flow through such dams.
(f) Suspended.
(g) Preliminary results indicate a relation exists between flow rate, head, core height and rock size.

(5468) INVESTIGATION OF HIGH VELOCITY JETS ON HYDRAULIC JUMP.

(b) Laboratory project.
(c) Prof. Paul R. Munger, Dept. of Civil Engrg., Univ. of Missouri at Rolla, Rolla, Missouri 65401.
(d) Experimental; basic research for master's thesis.
(e) Investigation of tailwater depth, length, and wave formation properties of hydraulic jump due to introduction of high velocity jets from apron.
(f) Suspended.
(g) Test results indicate: (a) the quantity of water flowing through the submerged jets is a primary factor in determining the specific energy of the water leaving the hydraulic jump, (b) submerged jets can be more effective than baffle piers in reducing the length of the hydraulic jump, (c) submerged jets are not as effective as baffle piers in reducing the wave formation properties of a jump.
(h) "The Effect of Submerged Jets on the Hydraulic Jump," by Harvey E. Jobson, Master's Thesis, Univ. of Missouri at Rolla, 1965.

(5469) VELOCITY AND KINETIC ENERGY DISTRIBUTION OF A SUBMERGED JET.

(b) Laboratory project.
(c) Prof. V. A. C. Gevecker, Dept. of Civil Engrg., Univ. of Missouri at Rolla, Rolla, Missouri 65401.
(d) Experimental; basic research for master's thesis.
(e) Tests conducted to determine the effect on velocity and kinetic energy by submerging a jet below the surface of a stilling basin.
(f) Suspended.
(g) The entraining effect of the submerged jet is of an order of ten or more times the discharge of the jet itself at the section of the jet opening. The major energy dissipation effects occur in the region of the jet itself. The kinetic energy decreases not linearly but exponentially with depth of penetration.

(5740) DISCHARGE CHARACTERISITICS OF SIDE WEIRS.

(b) Laboratory project.
(c) Prof. V. A. C. Gevecker, Civil Engineering Dept., University of Missouri at Rolla, Missouri 65401.
(d) Experimental, basic research for Master's thesis.
(e) An investigation of the division of flow of water in a flume of rectangular cross-section when the flume is provided with a side weir.
(f) Suspended.
(g) An equation is derived so that the quantity of water flowing over the side weir compared to the quantity of water flowing in the main channel can be predicted. This ratio is acceptable only within the ranges of heads, velocities, and weir lengths imposed by the geometry of the system tested.
(h) "Discharge Characteristics of Side Weirs," by Edgar Snowden IV, Master's Thesis, Univ. of Missouri at Rolla, 1965.

MONTANA STATE COLLEGE, Agricultural Experiment Station.

(4664) EFFICIENT APPLICATION OF IRRIGATION WATER BY SURFACE FLOODING METHODS.

(b) Laboratory project.
(c) Prof. C. C. Bowman, Head, Agricultural Engineering Dept. Montana State College, Bozeman, Montana 59715.
(d) This is a study to develop design criteria for more efficient application of irrigation water by flooding method. This is basic research at the present time, but will be applied research immediately upon completion of the first phase.

UNIVERSITY OF NEBRASKA, Hydrodynamics Laboratory, Dept. of Engineering Mechanics.

(3776) VORTEX FORMATION AND DRAG IN UNSTEADY FLOW PAST BLUFF BODIES.

(b) National Science Foundation.
(c) Prof. T. Sarpkaya, Dept. of Engineering Mechanics, Bancroft Hall 219, University of Nebraska, Lincoln, Nebraska 68508.
(d) Experimental and theoretical study of drag and inertia in unsteady flow. Basic research for master's and Ph.D. thesis.
(e) Primary objects of the research are: To determine the growth and motion of vortices behind two dimensional bluff bodies subjected to unidirectional unsteady flow; to determine the various components of corresponding resistance; and to correlate a particular vortex configuration with the instantaneous resistance.
(g) The forces predicted on the basis of the moving and growing vortices are comparable in magnitude to forces which are observed. Resistance to

unsteady flow is not to be thought of as a mere juxtaposition of resistances to steady flow augmented by an inertial force.

(h) "Unsteady Flow Over Bluff Bodies", by T. Sarpkaya, Developments in Mechanics, Pergamon Press, Oxford, England, pp. 45-68, 1964.

(3782) INDUCED MASS OF CONFINED FLUIDS.

(b) Laboratory project.
(c) Prof. T. Sarpkaya, Bancroft Hall 219, University of Nebraska, Lincoln, Nebr. 68508.
(d) Theoretical basic research; for master's thesis.
(e) When a confined fluid is suddenly accelerated through an opening, initial average acceleration is determined by the induced mass of the fluid system. Since the equation of the elastic wave propagagion cannot be solved for the boundary conditions imposed, solution of Laplace's equation is joined to that obtained from the wave equation through the application of the Schwartz-Christoffel transformation and electrical analogy.
(g) The effect of induced mass is most pronounced particularly for short conduits. Average times necessary for the reflection of an elastic wave from a given reservoir is determined.

(4893) COUNTER VORTEX OSCILLATOR.

(b) Diamond Ordnance Fuze Laboratories, Wash., D. C.
(c) Dr. T. Sarpkaya, Bancroft Hall 219, Univ. of Nebraska, Lincoln, Nebraska 68508.
(d) Theoretical and experimental and for master's thesis.
(e) To determine the intensity of pressure fluctuations and frequency of the instability created by two vortices rotating in opposite directions in two vortex chambers connected by a circular tube.
(g) Frequency and intensity of pressure fluctuations are determined as a function of fluid properties and the geometry of the system. The counter vortex oscillator unit proved to be usable together with a pneumatic amplifier in controlling the momentum of the power jet.
(h) "Characteristics of a Vortex Device and the Vortex-Breakdown Phenomenon", by T. Sarpkaya, Proceedings of the Fluid Amplification Conference, Vol. II, pp. 245-268, 1965.

(5263) VORTEX-RATE SENSOR.

(b) Harry Diamond Laboratories.
(c) Dr. T. Sarpkaya, Bancroft Hall 219, Univ. of Nebraska, Lincoln, Nebraska 68508.
(d) Theoretical and experimental for M. S. thesis.
(e) To use the vortex-sink flow to provide a signal proportional to rate of rotation.
(g) Boundary layer development in vortex-sink flow has been analyzed theoretically. The units built provide sufficiently large signals for very low rates of rotation.
(h) "A Theoretical and Experimental Investigation of the Vortex-Sink Angular Rate Sensor", by T. Sarpkaya, Proceedings of the Fluid Amplification Conference, Vol. II, pp. 301-329, 1965.

(5264) SEPARATED FLOW ABOUT LIFTING BODIES.

(b) Laboratory project partly supported by NSF and ONR.
(c) Dr. T. Sarpkaya, Bancroft Hall 219, Univ. of Nebraska, Lincoln, Nebraska 68508.
(d) Experimental and theoretical.
(e) Cross-flow drag and normal-force coefficients are determined for slender bodies at high angles of attack within subsonic to moderately supersonic range.
(g) Cross-flow drag coefficient is about 25% larger near the point of separation than that for steady flow at the same Reynolds number past a circular cylinder. Results indicate that Schwabe's data for cylinders set in motion impulsively from rest may be in error.
(h) "Separated Flow about Lifting Bodies and Impulsive Flow about Cylinders", by T. Sarpkaya, Journal of the American Institute of Aeronautics and Astronautics, No. 65-395, July 1965.

(5265) DYNAMICS OF A BISTABLE FLUID AMPLIFIER WITH A LATCHING VORTEX.

(b) Harry Diamond Laboratories, Washington, D. C.
(c) Dr. T. Sarpkaya, Bancroft Hall 219, Univ. of Nebraska, Lincoln, Nebraska 68508.
(d) Theoretical and experimental, M. S. thesis.
(e) To determine the response of a bistable fluid amplifier with a latching vortex to various types of input.
(g) Latching vortex increases the power and pressure-recovery factors but it also increases the noise level of the amplifier.
(h) "Steady and Transient Behavior of a Bistable Amplifier with a Latching Vortex", by T. Sarpkaya, Proceedings of the Fluid Amplification Conference, Vol. II, pp. 185-205, 1965.

(5670) EVOLUTION OF SMALL DISTURBANCES IN THE TRANSITION REGION OF HAGEN-POISEUILLE FLOW.

(b) National Science Foundation.
(c) Dr. T. Sarpkaya, Bancroft Hall 219, Univ. of Nebraska, Lincoln, Nebraska 68508.
(d) Theoretical and experimental basic research.
(e) The purpose of the project is to study the stability of pipe flow to small upstream disturbances.

(5671) A THEORETICAL AND EXPERIMENTAL STUDY OF THE FLUID MOTION ABOUT A FLAT PLATE ROTATED IMPULSIVELY FROM REST TO A UNIFORM ANGULAR VELOCITY.

(b) David Taylor Model Basin.
(c) Dr. T. Sarpkaya, Bancroft Hall 219, Univ. of Nebraska, Lincoln, Nebraska 68508.
(d) Theoretical and experimental basic research.
(e) To determine the characteristics of the time-dependent flow and the torque acting on the flat plate.

NEW YORK UNIVERSITY, Department of Chemical Engrg.

(5560) THEORETICAL STUDY OF SUSPENSION VISCOSITY: BY MEANS OF A MODEL OF THE SLOW MOTION OF SPHERES AND A VISCOUS FLUID THROUGH A CYLINDER.

(b) Laboratory project.
(c) Prof. J. Happel, Dept. of Chem. Engr., New York Univ., Univ. Heights, Bronx, N. Y. 10453.
(d) Theoretical; basic research for doctoral thesis.
(e) The slow translational and rotational motion of particles moving through a viscous fluid subjected to the influence of cylindrical boundaries is being studied. This will ultimately enable a theoretical prediction of the frictional drag, rotational moment, permanent pressure drop caused by the presence of these particles in the original Poiseuillian field of flow, and suspension viscosity.
(g) The method of reflections technique for solving boundary value problems is applied to the slow translational and rotational motion of a particle subjected to the influence of cylindrical boundaries. Expressions were obtained for the frictional drag, rotational moment, permanent pressure drop and suspension viscosity.

NEW YORK UNIVERSITY, School of Engineering and Science, Department of Civil Engineering.

(4988) MECHANISM OF GAS ABSORPTION BY TURBULENT LIQUIDS.

(b) Laboratory project.
(c) Dr. William E. Dobbins, Prof. of Civil Engineering, New York University, School of

Engineering and Science, University Heights New York 10453.
(d) Theoretical and experimental; basic research (doctoral thesis).
(e) A study of the mechanism by which gases are transferred across a turbulent gas-liquid interface, with particuar emphasis on the process as it occurs in natural streams.
(f) Suspended.
(g) A mathematical model for the transfer process has been developed. Experimental work using several gases of varying diffusivities indicates an acceptability of the mathematical model. The present phase is concerned with the effect of impurities in the liquid.

(5951) TILTING CHANNEL.

(b) Laboratory project.
(c) Dr. Erick R. Gidlund, Ass't. Professor of Civil Engineering, New York School of Engrg. and Science, Univ. Heights, New York, New York 10453.
(d) Development of research facilities.
(e) The channel is 65 feet long, 3 feet wide and 2 feet deep, glass walled and glass bottomed. It has a tilting capacity of +1 percent to -2 percent. It is designed as a general purpose facility for studies in open channel and estuary flow problems including dispersion, sediment transport and wave interaction studies.

NEW YORK UNIVERSITY, Department of Meteorology and Oceanography.

(3120) OFFICE OF NAVAL RESEARCH ATMOSPHERE INTERACTION AND WAVE PROJECT.

(b) Geophysics Branch, Office of Naval Research, Department of the Navy.
(c) Prof. Gerhard Neumann, Prof. of Oceanography and Prof. Willard J. Pierson, Prof. of Oceanography, New York University, New York 53, New York.
(d) Experimental and theoretical; basic and applied research.
(e) Study of wave generation and propagation in deep water; nonlinear properties of capillary and gravity waves in both Eulerian and Lagrangian form. Observations of temperature, humidity, and wind over the sea surface. Albedo measurements. Wind stress over the water surface. The prediction of large scale oceanic circulations. Equatorial current systems in the Atlantic Ocean. Theoretical and observational studies of turbulence in water. Diffusion studies.
(g) Analysis of data obtained during Equalant I-III expeditions has proved the existence of the Atlantic Equatorial Undercurrent all across the ocean. Detailed studies of the termination of this current in the Bay of Guinea indicate a direct relationship to the African SW-Monsoon.
(h) "Observations of the Equatorial Undercurrent in the Atlantic Ocean at 15 W during Equalant I," J. Geophys. Res., Vol. 79, no. 2, pp. 297-304.
"Oceanography of the Tropical Atlantic," Proc. of a Symposium on the Oceanography of the Western South Atlantic, Rio de Janeiro, Brazil, 1964.

(5470) U. S. NAVAL OCEANOGRAPHIC OFFICE ATLANTIC AND PACIFIC WAVE HINDCASTING PROJECT.

(b) U. S. Naval Oceanographic Office.
(c) Professor Willard J. Pierson, Jr., Prof. of Oceanography. New York University, New York, New York 10453.
(d) Experimental and theoretical, basic and applied research.
(e) Development of ways to hindcast waves by spectral techniques on an oceanwide basis. The North Atlantic has been completed, and the North Pacific is first being started.
(f) Will run for two years. A file of magnetic tape containing wave spectra for every 6 hours at 519 points on the North Atlantic for 15 months is available.
(h) "A Proposed Spectral Form for Fully Developed Wind Seas Based on the Similarity Theory of S. A. Kitaigorodskii," W. J. Pierson and L. Moskowitz, J. Geophys. Res., Vol. 69, no. 24, 1964.
"The Interpretation of Wave Spectrums in Terms of the Wind Profile Instead of the Wind Measured at a Constant Height," W. J. Pierson, J. Geophys. Res., Vol. 69, no. 24, 1964.
"The Accuracy and Potential Uses of Computer Based Wave Forecasts and Hindcasts for the North Atlantic," Proc. Second Symp. on Military Oceanography, pp. 69-82.

NORTH CAROLINA STATE OF THE UNIVERSITY OF NORTH CAROLINA, Department of Engineering Research.

(4667) UNSTEADY FREE SURFACE FLOWS.

(b) Laboratory project.
(c) Dr. M. Amein, Department of Civil Engrg., North Carolina State of the Univ. of No. Carolina, Raleigh, N. C. 27607.
(d) Experimental and theoretical; basic research.
(e) An experimental investigation on translatory motions with irregular profiles, on bore formations and on the propagation of unsteady motions through non-uniform flows is made in a glass-walled channel. The channel is 14 ft. long, 2 ft. wide with adjustable variable slope. The experimental results are analyzed by the nonlinear shallow water theory. The objective of the project is to seek improvements to the prevalent techniques for the computation of unsteady flows and to provide experimental data for further theoretical investigations.

(4668) STUDY OF VORTEX MOTION IN WAKE FLOWS.

(b) Laboratory project.
(c) Prof. Paul Harrawood, Department of Civil Engineering, North Carolina State of the Univ. of No. Carolina, Raleigh, North Carolina 27607.
(d) Experimental and theoretical; doctoral thesis.
(e) An investigation of the eddy motions present in the wakes of bluff bodies in a streaming fluid, with particular attention given to the periodicity of eddy motions and to vortex strength.

(4669) AN INVESTIGATION OF THE STABILITY OF FLOW IN CIRCULAR SEDIMENTATION BASINS.

(b) Laboratory project.
(c) Professor Charles Smallwood, Jr., Dept. of Civil Engrg., North Carolina State of the Univ. of No. Carolina, Raleigh, North Carolina 27607.
(d) Experimental; master's thesis.
(e) A semi-circular center-fed model basin was built with a transparent back for visual examination of the flow pattern. A uranine dye tracer was used to determine flow through waves for the basin. Stability was measured by the reproducibility of the time-effluent dye concentration waves. In an attempt to stabilize the flow radial baffles were placed in the basin to reduce the angle of divergence and to provide solid boundaries in the divergent flow.
(f) Completed.
(g) The baffles had no detectable effect. The flow pattern was characterized by a short-circuit along the tank bottom and a back-flow in the upper portion of the tank.

NORTH DAKOTA STATE UNIVERSITY, Agricultural Engrg. Dept.

(3121) PREFABRICATED DITCH LININGS.

(b) Laboratory project.
(c) Prof. Harold Holmen, Assistant Agricultural Engineer, Agricultural Engineering Dept., North Dakota State University, Fargo, N. Dak.
(d) Experimental; applied research.
(e) A field study of the durability and usefulness of black polyethylene for lining farm irrigation ditches.
(f) Completed.
(h) "Polyethylene Linings for Irrigation Ditches," Harold Holmen. North Dakota Farm Research, Vol. 23, No. 11, pp. 11-16, May-June 1965. Reprint No. 627.

(4175) WATER INTAKE RATES AND PHYSIOCHEMICAL PROPERTIES OF IRRIGABLE SOILS.

(b) Joint laboratory project between Department of Agricultural Engineering and Department of Soils.
(c) Prof. Harold Holmen, Assistant Agricultural Engineer, Agricultural Engineering Dept., North Dakota State University, Fargo, N. Dak.
(d) Experimental, basic research, and Master's thesis.
(e) Infiltration tests were made in the field on 8 inch, 16 inch, and 33 inch double ring infiltrometers. Various sized buffer rings were used ranging from no buffer ring to a buffer ring measuring 5 times the inner ring diameter.
(g) Infiltration rate generally decreased as the size of the outer ring was increased.

(5471) CONCRETE DITCH LINING AND PIPE FOR IRRIGATION SYSTEMS.

(b) Laboratory project.
(c) Prof. Harold Holmen, Assistant Agricultural Engineer, Agricultural Engineering Dept., North Dakota State Univ., Fargo, N. Dak.
(d) Experimental; applied research and Master's thesis.
(e) Soil moisture content and temperature measurements were made in the soil profile adjacent to concrete lined farm irrigation ditches and 12 inch buried concrete pipe during various periods of the past 12 months. The alignment and elevation of the ditch and pipe is also recorded. The study is being conducted to predict the behavior of these conduits under North Dakota conditions.
(g) Pipe and ditch linings have not shown appreciable deterioration after one year of use.

NORTHWESTERN UNIVERSITY, The Technological Institute.

(3476) FLOOD WAVE ROUTING.

(b) Northwestern Technological Institute.
(c) Prof. W. S. Hamilton, Dept. of Civil Engrg., Northwestern University, Evanston, Ill. 60201.
(d) Theoretical and analytical for doctoral and masters theses.
(e) The purpose is to calculate the movement of flood waves in prismatic and natural channels. Finite difference equations based on the method of characteristics have been programmed and solved on a digital computer for the case of a non-prismatic channel. The effect of ignoring certain terms in the basic equations is to be studied next.
(g) Problems of instability have been avoided and reasonable hydrographs obtained.
(h) "Solution of the Non-Linear Equations Governing Flood Waves in Natural Channels by the Method of Characteristics," Ph.D. dissertion, A. G. Fletcher, August 1965. Paper in preparation.

(3799) FORCES ON SUBMERGED BODIES IN UNSTEADY MOTION.

(b) National Science Foundation.
(c) Prof. Lyle F. Mockros, Technological Institute, Northwestern University, Evanston, Ill. 60201.
(d) Theoretical and experimental, basic research, M. S. and Ph.D. theses.
(e) Investigation of the forces on solid spheres accelerating along a rectilinear path through incompressible viscous fluids. The investigation includes (1) experiments that will be compared with a numerical evaluation of theoretical linear solutions, (2) experiments on the general case of large motions, and (3) a study of the effect of the velocity pattern on added mass.
(g) The complex theoretical solution for the creeping motion case has been put into graphical form. This theoretical solution has been used to study the dispersion of particles in a turbulent fluid. Experiments on large motion oscillations have been performed and the data correlated in terms of velocity (drag), acceleration (added mass) and history coefficients.
(h) Discussion "Accelerated Motion of a Sphere in a Viscous Fluid," L. Mockros and A. Hjelmfelt, Jl. Hyd. Div. ASCE, Vol. 90, p. 367, 1964. "Motion of Discrete Particles in a Turbulent Fluid," A. Hjelmfelt and L. Mockros. (Submitted for publication.) "Behavior of a Sphere Accelerating in a Viscous Fluid," A. Hjelmfelt and L. Mockros. (Submitted for publication.)

(5472) WIND-DRIVEN CIRCULATION IN LAKE MICHIGAN.

(b) National Science Foundation.
(c) Asst. Professor G. E. Birchfield, Engineering Sciences, Northwestern University, Evanston, Ill. 60201.
(d) Two year grant, theoretical study; funds for research assistant, undergraduate assistant; primarily basic research.
(e) Develop mathematical methods for predicting response of lake to varying wind conditions. Study forces which generate lake currents, effect of shore lines on currents. Together with recent observational studies, construct better picture of general circulation in lake, than at present.
(g) Results are available for some simple analytical models of wind-driven circulations. Edited tape of current data and wind data completed.

(5473) DYNAMIC FLOW CHARACTERISTICS OF VENTRICLE PUMPS.

(b) National Heart Institute and Bio-Medical Engineering Center, Northwestern Technological Institute.
(c) Prof. Lyle F. Mockros, Technological Institute, Northwestern Univ., Evanston, Ill. 60201.
(d) Experimental and theoretical; basic and applied research, M.S. thesis.
(e) Investigation of the dynamics of pumping fluid out of a flexible chamber by pneumatically squeezing the chamber.
(g) The static collapse, dynamic pressure transfer, and dynamic collapse characteristics have been determined for a range of wall thickness to diameter ratios. The effect of liquid viscosity and tube length also has been determined.
(h) "The Mechanics of a Collapsing Tube Heart Pump," M. Weissman and L. Mockros, (submitted for publication).

(5474) PHYSICAL ENVIRONMENT OF EXTRACORPOREAL CIRCULATION.

(b) National Heart Institute.
(c) Prof. Lyle F. Mockros, Technological Institute, Northwestern Univ., Evanston, Ill. 60201.
(d) Experimental, basic and applied research, Ph.D. thesis.
(e) Investigation of the geometry and fluid dynamics favorable to the circulation of blood outside the animal body. Purpose is to obtain design criteria for heart lung machines.
(g) The functional dependence of red cell lysis and

plasma denaturation on fluid dynamic parameters have been determined. Further work is indicated. The gas transfer to blood flowing in tubes has been theoretically studied using numerical techniques.

(5475) NOISE SPECTRA GENERATED BY FLOW OF A LIQUID THROUGH VARIOUS ORIFICES.

(b) Bio-Medical Engineering Center, Northwestern Technological Institute.
(c) Prof. W. S. Hamilton, Dept. of Civil Engrg., Northwestern Univ., Evanston, Illinois 60201.
(d) Experimental; applied research, thesis.
(e) Purpose is to identify characteristic flow generated noise in an abnormal heart. The noise spectra generated by steady and pulsating flow through rigid and flexible orifices is being investigated. Water is pumped through aortic valves of sheep's hearts. The flaps are partly sewn together to restrict the opening.
(g) The noise spectra for steady flow through rigid orifices as reported in the literature has been verified for water flows. The technique of testing natural heart valves is reasonably well developed.

(5714) YIELD OF A NON-LINEAR ELASTIC AQUIFER.

(b) Northwestern Technological Institute.
(c) Prof. W. S. Hamilton, Dept. of Civil Engrg., Northwestern Univ., Evanston, Ill. 60201.
(d) Analytical and experimental for M. S. and Ph.D. theses.
(e) The drawdown of an elastic artesian aquifer is being studied analytically and with a sponge rubber model. The permeability and yield coefficients both are functions of the drawdown. The purpose is to find whether the unsteady state solution using average values differs significantly from a solution that includes the variation of the coefficients.
(g) Compression and permeability tests have yielded preliminary values of the coefficients. The test apparatus for time-dependent measurements is partly constructed.

(5715) LIGHT EMISSION FROM HYDRODYNAMICALLY INDUCED CAVITATION.

(b) Laboratory project.
(c) Prof. Thomas P. Anderson, Assoc. Prof., Dept. of Mechanical Engineering and Astronautical Sciences, Northwestern Univ., Evanston, Illinois 60201.
(d) Experimental investigation of the fundamental phenomenon for doctoral research requirements.
(e) The light emission produced from collapsing cavitation bubbles in water is being spectrally analyzed as related to various dissolved gases. It is anticipated that these results will provide insight into the basic characteristics of the collapse mechanisms.

OHIO AGRICULTURAL RESEARCH AND DEVELOPMENT CENTER, Department of Agricultural Engineering.

(5033) DRAINAGE INVESTIGATIONS FOR AGRICULTURAL LANDS.

(b) Ohio Agricultural Research and Development Center in cooperation with Agricultural Research Service.
(c) Dr. G. O. Schwab, 2073 Neil Ave., The Ohio State University, Columbus, Ohio 43210.
(d) Field investigation; applied research.
(e) Tile flow, surface runoff, water table levels, and crop yields are measured to evaluate various types of drainage systems and to develop improved engineering design criteria.
(g) Fifteen years of tile flow data, partial analysis completed; corn (3 years) and soybean (1 year) yields evaluated from various methods of drainage.
(h) "Tile Spacing Prediction Based on Drain Outflow," Glenn J. Hoffman and G. O. Schwab. Am. Soc. Agr. Eng. Trans. 7(No. 4): 444-447, 1964.
"Research on Plastic-Lined Mole Drains in the United States," J. L. Fouss and G. O. Schwab. VIth International Congress of Agricultural Engineers Proc., Vol II, Sect. 1, pp. 150-158, 1964.
"Drainage," Chapter 5, G. O. Schwab, Corn Congress Proceedings, Delavan, Wisc., Oct. 1964, In press.
"Crop Response from Tile and Surface Drainage," G. O. Schwab, G. S. Taylor, J. L. Fouss and E. Stibbe. ASAE Paper No. 65-217, June 1965.

(5293) FLOW OF COLLOIDAL SUSPENSIONS IN POROUS MEDIA.

(b) Laboratory project with partial support by National Science Foundation.
(c) Dr. R. Bruce Curry, Assoc. Prof. Dept. of Agricultural Engineering, Ohio Agricultural Research and Development Center.
(d) Theoretical and experimental; basic research.
(e) To investigate the fundamental principles underlying the flow of colloidal suspensions into or through porous media.
The scope of this study will include the use of several granular materials and suspensions of colloidal materials. Initially, carborundum will be used as the porous media and Wyoming bentonite as the suspended material in order that there will be continuity between the present work and past studies. Materials to be used later will include chemically active materials such as zeolite, natural occurring materials, such as soils and filter sands. The natural occurring materials will be used to tie this basic study to practical applications in the field.
Both the porous media and the suspended materials will be characterized completely by determination of various physical and chemical properties.
The granular material will be placed in a permeameter for testing. The actual test procedure will involve three phases: (1) Initial flow of de-aired; de-ionized water through the porous media in the permeameter; (2) followed by the introduction of the suspension into the permeameter; (3) finally the de-aired, de-ionized water will be reintroduced into the permeameter in order to determine the effect of the suspension flow on the system.
(g) A system has been developed to determine the amount of clay deposited from suspension during flow through a porous media using a radioactive tracer. Data obtained are being used to test a mathematical model of suspension flow in porous media. The electrokinetic properties of both the suspension and the media have been measured using electrophoresis and streaming potential techniques, respectively.
(h) "The Interrelationships of Physical and Chemical Properties Involved in the Flow of Colloidal Suspensions in Porous Media," by R. B. Curry, G. L. Barker and Z. Strach, Trans. ASAE, Vol 8, No. 2, 1965.
"Scandium as a Tracer of the Movement of Clay Suspensions in Columns of Porous Media," by R. Bruce Curry, Trans. ASAE, Vol. No 3, 1965.

(5294) HYDROLOGIC CHARACTERIZATION OF SMALL WATERSHEDS.

(b) Laboratory project.
(c) Dr. R. Bruce Curry, Assoc. Prof. Dept. of Agricultural Engineering, Ohio Agricultural Research and Development Center, Wooster, Ohio 44691.
(d) Theoretical; basic research.
(e) To investigate the use of mathematical, electrical, and hydraulic models to study hydrologic phenomena of watersheds.

(a) To investigate statistical models as a means of identifying and evaluating the pertinent variables in the runoff process.
(b) To use these variables together with a mathematical model to predict behavior of a small watershed.
The behavior of small watersheds will be investigated to identify the pertinent variables using the statistical theory. These variables will be combined with the underlying physical and biological phenomena to develop a mathematical model which will permit statements to be made about probable watershed behavior. Data from existing watersheds and runoff plots will be used to test the validity of the model.

(g) Present activity centers around the application of nonequilibrium thermodynamics to the runoff process.

(5672) ELECTROKINETIC REMOVAL OF COLLOIDS FROM SUSPENSION.

(b) Laboratory project with partial support by National Science Foundation.
(c) Dr. R. Bruce Curry, Assoc. Prof., Dept. of Agricultural Engineering, Ohio Agricultural Research and Development Center, Wooster, Ohio 44691.
(d) Theoretical and experimental; basic research.
(e) The objectives of the study are (1) to improve present theory or to develop new theoretical relationships regarding the electrokinetic removal of colloidal material from water suspensions and (2) to determine the limitations and conditions under which a laboratory pilot model will operate most efficiently.
The purposes of this research are to develop basic theoretical relationships regarding the electrokinetic removal of colloids from water suspensions and to verify this theory with a pilot model in the laboratory. The limitations and conditions for efficient removal will involve measuring the characteristics of the colloids, selecting suitable physical arrangements for the electrodes, and determining the optimum field strength, current, temperature, and flow rate through the system. Migratory velocity, conductivity, and electrical charge of the colloids are important properties to be determined. Kaolin and bentonite clays will be considered initially, but the principle may have application for the removal of bacteria and other microorganisms, as well as chemical contaminates, such as pesticides.
(g) Present activity is devoted to (1) the formulation of a theory for the movement of charged clay colloids in a flowing medium with an electric field impressed on the system by considering the entire ensemble of particles rather than a single particle. A probabilistic approach based on diffusion theory is being considered. The Langevin, Fokker-Planck and Smoluchowski equations and turbulent diffusion equations provide background for these considerations. And (2) the verification of this theory experimentally.
(h) "Electrokinetic Removal of Colloids from Suspension," by E. A. Hiler, R. B. Curry, and G. O. Schwab, Trans. ASAE, Vol. 8, No. 1, pp. 79-82, 1965.

(5716) HYDROLOGIC INVESTIGATIONS OF SMALL WATERSHEDS IN OHIO.

(b) Water Resources Center, Ohio State Univ. in cooperation with Office of Water Resources Research, U. S. Dept. Interior.
(c) Dr. E. Paul Taiganides, Assoc. Prof., Agricultural Engrg. Dept., Ohio State Univ. Columbus, Ohio, 43210.
(d) Experimental; design research.
(e) The application of mathematical models as a means of identifying and evaluating the pertinent variables in rainfall-runoff relationships for small watersheds, 7,000 to 50,000 acres, will be investigated. Nearly 30 years of runoff, rainfall data on the Little Mill Creek Watershed located within the province of the Coshocton, Ohio, Hydrologic Research Station will be used to test the model and relate flood peaks and volumes to climatic and physical parameters. The effect of strip mining on water yield will also be studied.

OHIO STATE UNIVERSITY, Department of Agronomy.

(5176) SOIL CHARACTERISTICS AND SUBSURFACE DRAINAGE.

(b) Ohio Agricultural Experiment Station.
(c) Prof. George S. Taylor, Dept. of Agronomy, Ohio State Univ., Columbus, Ohio 43210.
(d) Experimental investigation, applied research.
(e) Numerical analysis solutions of soil moisture flow problems in subsurface drainage are made with digital computers. Steady-state and transient analyses are studied for various parameters of size, depth, and spacing of tile and ditch drains and of soil hydraulic conductivity. Similar studies were initiated in 1965 to analyze water table drawdown around a pumped well. Hillside seepage problems are also evaluated. Field evaluations of hydraulic conductivity are made with the aid of lysimeter-type installations. The principal objective is to interrelate the above factors in rational design of subsurface drainage systems.
(g) Characteristics of water flow into tile drains have been studied for layered soils. An analysis of hillside seepage into open ditches was made. Agreement between analytical and numerical analysis techniques was established.
(h) "Soil Stratification and Ponded Flow into Subsurface Drains," William Burke and George S. Taylor, Ohio Agricultural Experiment Station Research Circular 138, 3-23, Mar., 1965.
"Septic Tank Effluent Percolation Through Sands Under Laboratory Conditions," Joe H. Jones and George S. Taylor, Soil Science, 99: 301-309, Apr. 1964.
"Drainage Characteristics of Toledo and Hoytville Soils," George S. Taylor, Truman Goins and N. Holowaychuk, Ohio Agricultural Experiment Station Research Bulletin 876, 3-23, May 1961.

OKLAHOMA STATE UNIVERSITY, Agricultural Engineering Department.

(2365) HYDROLOGIC STUDIES ON SMALL GRASS-COVERED WATERSHEDS.

(b) Oklahoma Agricultural Experiment Station, cooperative with Agricultural Research Service, U. S. Dept. of Agriculture.
(c) Prof. F. R. Crow, Okla. State Univ., Dept. of Agricultural Engrg., Stillwater, Okla. 74075.
(d) Field investigation; applied research.
(e) Measurements are being made to provide hydrologic data on total watershed runoff and peak rates of runoff from three small grass-covered watersheds (17 to 206 acres) in north central Oklahoma. Highway culverts, modified by the addition of weir sills, are being used as runoff measuring devices. The moisture content of the soil profile on each of the watersheds is determined weekly.
(g) Thirteen year record of rainfall and runoff record is available. Frequency distributions of runoff rates and amounts have been determined. An analysis of the effect of stock water ponds on total water yield of small watersheds has been completed.

(2828) THE EFFECTIVENESS OF MONOMOLECULAR FILMS FOR REDUCING EVAPORATION FROM RESERVOIRS.

(b) Oklahoma Agricultural Experiment Station, cooperative with U. S. Bureau of Reclamation.
(c) Prof. F. R. Crow, Oklahoma State Univ., Dept. of Agricultural Engineering,

Stillwater, Oklahoma 74075.
(d) Experimental; applied research.
(e) Two paired plastic lined ponds, designed for evaporation research, are being used to study various aspects of evaporation reduction by monomolecular films. Apparatus has been developed for automatic application of hexaoctadecanol slurry. Current research relates the energy budget to the water budget when the test reservoir is covered with a chemical monolayer.
(g) Evaporation reductions of 25 to 40% have been obtained in long duration tests using slurry method of applying films. Curves have been developed relating wind speed and required film application rate. A system of floating barriers has been used to confine the monolayer to reduce frequency of application. Various height/spacing ratios have been tested.

(5177) AUTOMATION OF CUT-BACK FURROW IRRIGATION.

(b) Oklahoma Agricultural Experiment Station.
(c) Dr. James E. Garton, Oklahoma State Univ., Dept. of Agricultural Engineering, Stillwater, Okla. 74075.
(d) Experimental and field investigation; applied research and design for thesis.
(e) The development of a system of cut-back furrow irrigation using level furrow outlet tubes with hooded inlets. The system will irrigate through the furrows at a design initial flow, cut-back to a design cut-back flow, and shut off by the simple removal of sheet-metal check dams. The purpose of the method is to improve the uniformity of furrow irrigation and to drastically reduce the high labor requirement.
(g) Discharge characteristics of various lengths, and diameters of short, level, galvanized pipe with hooded inlets have been determined. Design procedures for applying the system to a particular design situation have been developed. Operating characteristics of a designed system have been calculated. A prototype system has been constructed. The system is completely automated utilizing a time clock control, solenoid operated latches and automated gates. The labor requirement is about one to two per cent of that for conventional systems in the area.

(5918) REDUCTION OF WATER APPLICATION LOSSES THROUGH IMPROVED DISTRIBUTION CHANNEL DESIGN.

(b) Oklahoma Water Resources Research Institute.
(c) Dr. J. E. Garton, Oklahoma State Univ., Dept. of Agricultural Engrg., Stillwater, Oklahoma 74075.
(d) Experimental, applied research for theses.
(e) The determination of Boussinesq and Coriolis coefficients and retardance values for a slip form lined concrete irrigation channel, with and without siphon tubes is being conducted. Values obtained will be used to develop relationships for spatially varied flow water surface profiles. Design procedures will be developed to apply the results to irrigation distribution channel designs.
(g) A comprehensive computer analysis of the problem has been made.
(h) "Spatially Varied Flow in an Irrigation Distribution Ditch," James E. Garton and Albert L. Mink. Paper presented at 1964 Annual Winter Meeting of ASAE, New Orleans, Louisiana.

(5919) WATER YIELD AS INFLUENCED BY WATERSHED CHARACTERISTICS AND SMALL UPSTREAM RESERVOIRS.

(b) Oklahoma Water Resources Research Institute.
(c) Dr. J. E. Garton, Oklahoma State Univ., Dept. of Agricultural Engrg., Stillwater, Oklahoma 74075.
(d) Experimental and field investigation.
(e) Meager information on the hydrology of small watersheds is available. This project plans to instrument three upstream reservoirs with 0.6 to 3.0 sq. mile watersheds. The objectives are to measure the percent and total volume change in water yield caused by various sizes of upstream reservoirs, and to relate the volume and peak rate of runoff from the watershed to rainfall and watershed characteristics. Rainfall will be measured by a network of recording rain gages. Outflow through the spillway will be determined by flood routing techniques. The percent reduction in flow due to the reservoirs will be computed for monthly and annual time periods. Correlative procedures will be used to relate peak rates and volumes of runoff to rainfall, soil texture, plant cover, and soil moisture characteristics.

(5920) THE MECHANISM OF DIRECT SURFACE RUNOFF FROM RAINFALL.

(b) Oklahoma Water Resources Research Institute cooperative with Agricultural Research Service, U. S. Dept. of Agriculture.
(c) Dr. J. E. Garton, Oklahoma State Univ., Dept. of Agricultural Engrg., Stillwater, Okla. 74075.
(d) Experimental; applied research.
(e) Now in its initial phase, the ultimate goal of this project is to route rainfall through the sheet flow phase of runoff; through terrace channels, grassed waterways, detention structures, and spillways to the principal outlet of a small watershed using prediction equations based on known laws of fluid behavior. The objectives of the study are: (1) To develop prediction equations for water surface profiles of overland flow from rainfall by finite increment computer solutions of the partial differential equations of momentum and continuity for spatially varied unsteady sheet flow. (2) To develop procedures of routing various rainfall rates, through the sheet flow phase and into channel flow phase of surface runoff from rainfall using rational equations.

OREGON STATE UNIVERSITY, Department of Civil Engineering.

(3805) INVESTIGATION OF SUPERCRITICAL FLOW CHANNEL JUNCTIONS.

(b) U. S. Dept. of Commerce, Bureau of Public Roads.
(c) Prof. C. E. Behlke, Dept. of Civil Engrg., Oregon State University, Corvallis, Oregon (on leave); Director of Institute of Water Resources, University of Alaska, College, Alaska.
(d) Theoretical and experimental; applied research.
(e) Wave effects resulting from the junction of two supercritical, open channel flows are being studied to determine the magnitude and the location of the wave pile up on the channel walls.
(f) Completed.
(g) The prediction of wall pile-up.
(h) "An Investigation of Supercritical Flow Channel Junctions," by C. E. Behlke, Oregon State University Engineering Experiment Station, December 1964.
"Design of Supercritical Flow Channel Junctions," by C. E. Behlke submitted for publication to Highway Research Board, January 1966.

(5300) HYDRAULIC INVESTIGATION OF BAFFLED, PIPE TYPE FISH LADDERS.

(b) State of Oregon Fish Commission.
(c) Prof. C. E. Behlke, Dept. of Civil Engrg., Oregon State Univ., Corvallis, Oregon (on leave); Director of Institute of Water Resources, University of Alaska, College, Alaska.
(d) Experimental; applied research.
(e) High energy dissipation, enclosed fish ladders are being studied. Purpose is to

develop relatively short, inexpensive fish ladders for small streams. Prototypes will be constructed and tested with adult salmon by the sponsoring agency.

(f) Completed.

(g) Baffles have been developed which can be placed in pipes to yield large energy dissipation. In a 36-inch pipe, with a fish passage area of 15" by 15", the head loss is 0.55 ft. per foot of pipe, with a mean velocity of 4.5 ft/sec through the fish passage area.

(5785) COMPLEX NUMERICAL INTEGRATION TO FIND STREAM VELOCITY.

(b) Laboratory project.

(c) Asst. Prof. L. S. Slotta, Dept. of Civil Engineering, Oregon State University, Corvallis, Oregon.

(d) Theoretical; basic research for Ph.D. thesis.

(e) Complex numerical integration of the Schwartz-Christoffel transformation and application to potential flow.

(f) Completed.

(g) By applying real numerical integration jointly on the real and imaginary parts of the complex integral, this thesis extends the principles and formulas of real numerical integration to include complex analytic functions with a finite number of singularities. The principles of complex numerical integration are then shown to be applicable to problems of potential flow which require a Schwartz-Christoffel mapping. A generalization of the Schwartz-Christoffel transformation is made to include curved corners. Computational examples and streamline plots of potential flow over irregular boundaries are included.

(h) Ph.D. thesis by Dr. Robert Henry Wassmuth in Dept. of Mathematics is completed. Paper in preparation.

(5786) MANIFOLD STUDIES.

(b) Laboratory project.

(c) Asst. Prof. L. S. Slotta, Dept. of Civil Engineering, Oregon State University, Corvallis, Oregon.

(d) Experimental; applied research for M. S. thesis.

(e) Study of the effect of the diameter and spacing of manifold outlets on manifold flow.

(f) Completed.

(g) Magnitude of spacing parameter is a function of the lateral diameter ratio as well as the lateral spacing. The results obtained using a two inch lateral ($D_L/D = 0.4$) agree well with data obtained by Yanes and indicate for a spacing exceeding 20 conduit diameters no inter-lateral interference occurs. However, for larger diameter ratios ($D_L/D > 0.5$), a spacing exceeding the 15 to 20 conduit diameters predicted by previous investigators is necessary before inter-lateral interference is not present.

(h) M.S. thesis by Michael D. Coleman.

(5787) FACTORS INFLUENCING STREAM TEMPERATURES.

(b) U.S.P.H.S.

(c) Asst. Professors John Seaders and L. S. Slotta; Dept. of Civil Engineering, Oregon State Univ., Corvallis, Oregon.

(d) Experimental and field investigation; basic research for M. S. and Ph.D. thesis.

(e) The aims of this research project are: to determine the evaporation from turbulent surfaces; the radiation to and from natural water surfaces; and the effect of turbudity on evaporation and heat rates.

(g) Model evaporation and radiation studies are designed, instrumented and in progress. Field instrumentation has been tested in a preliminary field evaporation study. Full scale experiments are to follow.

(h) "Factors Influencing Stream Temperatures," Progress Report No. 1, Engineering Experiment Station, Oregon State University, Corvallis, Oregon. February 1965.

THE PENNSYLVANIA STATE UNIVERSITY, Hydraulics Laboratory, Department of Civil Engineering.

Inquiries concerning the following projects, should be addressed to Prof. Sam Shulits, Head, Hydraulics Laboratory, 212 Sackett Building, The Pennsylvania State University, University Park, Penna. 16802.

(5181) ROUGHNESS COEFFICIENTS OF COBBLE-STREWN STREAMS.

(b) Laboratory project..

(d) Experimental; applied research; doctoral thesis.

(e) To provide a quantitative means of determining Manning's "n" or the coefficient K in $V=KR^{2/3}S^{1/2}$ in cobble-strewn streams, particularly for use in the slope-area method of computing flood discharge. In a lucite-walled tilting flume, 1 ft wide, 1.5 ft deep, and 25 ft. long, roughness patterns are created with small wooden cubes, 1.09 inches on a side. Maximum discharge approximately 2 cfs.

(g) Previous work revealed systematic relationships among the roughness coefficient, Reynolds and Froude numbers, and a quantitative parameter of the roughness pattern. See "Large-Scale Roughness in Open-Channel Flow," J. B. Herbich and S. Shulits, Journal, ASCE Hydraulics Div., Vol. 90, No. HY6, Proc. Paper 4145, Nov. 1964. Whereas the latter dealt with low flows in which the water surface was slightly higher or lower than the 6 or 4 inch cubes, the current research treats the condition of high flows in which the height of the small wooden cubes is a small fraction of the water depth. The similitude between the large blocks and the tiny ones was checked experimentally. Experimental work has been completed, and the search for relationships between Manning's "n" and various hydraulic parameters is now under way.

(5182) TRANSITIONS IN SUPERCRITICAL FLOW.

(b) Pennsylvania Department of Forests and Waters.

(d) Experimental; applied research, design.

(e) See Abstract in (g)

(f) Completed.

(g) Transitions of three different shapes were tested for Froude numbers varying from 1.2 to 3.0, representing test flows of 0.56 to 5.27 cfs. Each transition connected an upstream trapezoidal channel with a downstream rectangular channel, all three parts lying on one straight center line and having constant and continuous invert slopes. One transition type had warped walls. The other two effected the transition with plane walls: one with a vertical surface above a sloping one, and the other with a sloping surface above a vertical one. The experiments with each of the three shapes covered combinations of five transition lengths with three depths in the trapezoidal approach channel. Twenty-eight different transitions were investigated. Tables and charts summarize the variation of the water surface caused by the wave patterns due to supercritical flow, along the channel wall and the center line. Not only do these tables and charts give a picture of the complex wave patterns, but they are a basis for the design of transitions of the three tested shapes. A guide is offered for the application of the extensive data to actual design.

(5183) EXNER EQUATIONS OF RIVER FORM.

(b) Laboratory project.

(d) Theoretical; basic research.

(e) Felix Exner's simple erosion postulates of the 1920's result in equations which produce rather closely dune, bed and bank forms of real rivers. The accuracy of his equations and charts of river forms are being verified so that the concept embodied in the postulates can be extended and applied to the

prediction of river development.

(g) Two equations have been verified; namely, one dealing with dune growth and the other with bankline development. The third equation is concerned with fixed banks and movable bed or, actually, the condition of a revetted contraction with a movable bed. As there seems to be some doubt about the accuracy of Exner's final equation, his work is being checked much more carefully than was originally intended.

(5921) RIPRAP BANK PROTECTION OF SMALL STREAMS.

(b) Pennsylvania Dept. of Forests and Waters.
(d) Experimental; applied research, design.
(e) The design of riprap protection of the banks of small streams is still a doubtful procedure. Existing design criteria often yield results which the designer finds difficult to accept: the computed protection is either inadequate or excessive on the basis of his experience. This program will be preceded by a literature search which will result in a report containing an annotated bibliography and a critical evaluation of current design methods. The preceding step will permit a better formulation of a useful experimental program.

THE PENNSYLVANIA STATE UNIVERSITY, Institute for Science and Engineering, Ordnance Research Laboratory, (Dr. John C. Johnson, Director), and Department of aeronautical Engineering, (Dr. George F. Wislicenus, Department Head). Work done under Dr. George F. Wislicenus, Director of the Garfield Thomas Water Tunnel and Head, Department of Aeronautical Engineering.

(2832) MEASUREMENT OF FORCES ON A MODEL IN A WATER TUNNEL.

(b) Laboratory project sponsored by the Bureau of Naval Weapons.
(c) Mr. George B. Gurney, Ordnance Research Laboratory, University Park, Penna. 16802.
(d) Experimental; developmental.
(e) The problem concerns the measurement of forces on models in a water tunnel over a velocity range up to 80 feet per second, pressure ranges of 3 to 60 pounds per square inch absolute.
(g) Two four component (lift, axial force, pitching and rolling moment) balances for use in water tunnels utilizing strain gaged pre-tensioned flexure beams as the force sensing devices have been in successful operation for four years. A Planar Motion Mechanism capable of imparting pitching and heaving motions to models is now under construction and should be in operation in March of 1963. The balance assoicated with this mechanism will measure all the hydrodynamic stability coefficients required in the equations of motion for a submerged body with four (4) degrees of freedom. These equations include the static, damping and acceleration derivatives. A balance which will measure unsteady forces on propulsors has been developed and successfully tested.

(3143) REDUCTION OF SKIN FRICTION DRAG.

(b) Joint program of investigation with the General Electric Company, the United States Rubber Company and the Northrop Corporation sponsored by the Bureau of Naval Weapons.
(c) Dr. John Lumley, Dr. Thomas E. Peirce and Mr. John McMahon, Ordnance Research Laboratory, University Park, Pennsylvania 16802.
(d) Experimental, basic research; theoretical and applied research.
(e) Investigations into the application of boundary layer control through suction and compliant surfaces for underwater bodies.
(g) Several axisymmetric models employing discrete slots have been experimentally investigated, both in the field and in the laboratory. Experimental measurements of boundary layer transition and thickness aft of the transition have been made for a number of flat plates, which were covered with a compliant surface.

(3486) TURBULENCE MEASUREMENTS IN WATER.

(b) Laboratory project sponsored by the Bureau of Naval Weapons.
(c) Dr. John Lumley, Ordnance Research Lab., University Park, Pennsylvania. 16802.
(d) Experimental.
(e) Using a constant temperature probe, some turbulent flows at high Reynolds numbers will be investigated with particular attention to homogeneous grid-produced turbulence and turbulent dispersion in a shear flow.
(g) Measurements have been taken in a small water tunnel settling section determining the effect of various screens and honeycombs on turbulence.

(3807) INVESTIGATION OF THE CAVITATION CHARACTERISTICS OF A FEW SIMPLE LIQUIDS.

(b) Laboratory project sponsored by NASA.
(c) Dr. J. William Holl, Ordnance Research Lab., University Park, Pennsylvania. 16802
(d) Experimental, analytical; basic research.
(e) To investigate experimentally the cavitation characteristics of a few simple (as regards to vapor pressure and handling) liquids under conditions occurring in space and aircraft pumping machinery, and analyze the results so that a reliable basis for theory applicable to these conditions can be formulated.
A small high speed water tunnel having test section velocities of 370 feet per second, pressures to 1000 pounds per square inch, temperatures to 300 degrees Fahrenheit, has been constructed and has been in operation since April of 1962.
(g) Investigations of desinent cavitation at very high velocities on 1/4 inch diameter ogive noses indicates that the desinent cavitation number approaches the minimum pressure coefficient. Studies of cavitation hysteresis on ogive noses show that the cavitation delay time is a random function and is of significant duration e.g. 3 to 4 minutes.

(4180) UNSTEADY FLOW INVESTIGATIONS AROUND AN ELLIPSOID OF REVOLUTION.

(b) Laboratory project sponsored by Bureau of Naval Weapons.
(c) Dr. Maurice Sevik, Ordnance Research Lab., University Park, Pennsylvania 16802.
(d) Experimental and theoretical.
(e) A study of unsteady forces acting on an ellipsoid of revolution over a range of Reynolds numbers and body attack angles.
(f) Completed.
(g) A theoretical and experimental investigation of the lift and moment on an 8/1 ellipsoid of revolution performing small oscillations in a direction normal to the free stream has been carried out. The maximum circulatory lift coefficient is about half that obtained in steady flow. A phase lag of 20 degrees in build-up of lift was observed. The maximum pitching moment is reduced by 16 percent from that predicted by potential theory.

(4181) DETERMINATION OF EFFECT OF TUNNEL BOUNDARIES ON THE FORCES ACTING ON A MODEL.

(b) Laboratory project sponsored by Bureau of Naval Weapons.
(c) Dr. Thomas Peirce, Ordnance Research Lab., University Park, Pennsylvania 16802.
(d) Theoretical and experimental.
(e) Investigation of the errors introduced by the physical boundaries of tunnel walls

on the measured forces on large models. The investigation covers both the axially symmetric case and when the models are at low angles of attack. Establishing the means for correcting these errors is also a part of this investigation.

(g) A method has been developed for the prediction of errors in drag caused by water-tunnel wall deviations. It is shown that small deviations in contour can cause a significant error in model drag measurements. Tunnel wall interference effects on model pitching moment have been investigated and a correction procedure established for models of low attack angle and diameters up to 1/3 tunnel diameter.

(4677) THE INVESTIGATION OF TWO-DIMENSIONAL UNSTEADY CAVITY FLOWS ABOUT FIXED SYMMETRIC BLUFF BODIES.

(b) Laboratory project sponsored by Bureau of Naval Weapons.
(c) Dr. J. William Holl, Ordnance Research Laboratory, University Park, Penna. 16802.
(d) Experimental and theoretical.
(e) An investigation of the wake region behind supercavitating, two-dimensional wedges at zero degrees angle of attack is in progress with the purpose of determining the wake characteristics, in particular the Strouhal number as a function of Reynolds number, cavitation number and wedge apex angle.

(4678) HYDRAULIC SERVOMECHANISM FOR AN UNDERWATER MISSILE.

(b) Laboratory project sponsored by the Bureau of Naval Weapons and conducted under Mr. C. L. Key, Asst. Director, Ordnance Research Laboratory.
(c) Messrs. H. M. Jensen and R. E. Kershaw, Ordnance Research Laboratory, University Park, Pennsylvania 16802.
(d) Experimental, applied development and design.
(e) A high-performance hydraulic servomechanism for control of rudders and elevators in an underwater missile system. Specific design problems were instability caused by a resonant linkage and high-frequency oscillation of the servovalve.
(g) Stability was achieved by increasing the resonant frequency of the linkage, providing hydraulic damping with a bypass orifice, and lag-lead phase compensation in the servo amplifier. The high-frequency oscillation was eliminated by increasing the diameter of activator ports.

(5106) INVESTIGATION OF TENSIONS IN LIQUIDS.

(b) Laboratory project sponsored by NASA.
(c) Dr. J. William Holl, Ordnance Research Laboratory, University Park, Penna. 16802.
(d) Experimental and theoretical.
(e) Investigation of liquid tensions for a variety of liquids under a range of conditions employing a non-flow apparatus. Results will be compared to those obtained in a flowing system.

(5107) INVESTIGATION OF THE KUTTA CONDITION IN UNSTEADY FLOW.

(b) Laboratory project sponsored by Bureau of Naval Weapons.
(c) Dr. Maurice Sevik, Ordnance Research Laboratory, University Park, Penna.
(d) Experimental, theoretical; basic research.
(e) The validity of the Kutta-Joukowski criterion is being investigated for the prediction of control surface hinge moments in steady flow, or instantaneous forces on rapidly oscillating air and hydrofoils.

(5108) JET INSTABILITY IN MERCURY.

(b) Laboratory project sponsored by National Science Foundation.
(c) Dr. David P. Hoult, Ordnance Research Laboratory, University Park, Penna. 16802.
(d) Experimental and theoretical; basic research.
(e) The study involves the stability of a jet of mercury into mercury in the presence of a magnetic field. The magnetic field acts to stabilize the jet and thus control the rate of amplification of unstable oscillation. The experimental findings are then to be compared with appropriate small disturbance theory in an effort to further understand the instability of jets.

(5590) INVESTIGATION OF SHED WING VORTICES AND THEIR DECAY.

(b) Laboratory project sponsored by the Army Research Office, Durham, North Carolina.
(c) Dr. Barnes W. McCormick, Jr., Ordnance Research Laboratory, University Park, Penna. 16802.
(d) Experimental; analytical; basic research.
(e) The vortex sheet shed by a wind tunnel mounted, semi-span lifting wing has been investigated at various angles of attack and free-stream velocities. The vortex core has been studied by mapping the downstream flow field at distances up to 20 chord lengths. Tangential velocities of vortices have been determined by integrating the vorticity through the vortex core. The local vorticity is measured by a pitchless, cruciform vane which rotates in rotational flow. Rotational speeds of 40,000 rpm have been measured. Similar investigations will be conducted by mounting the vortex probe behind the wing of a full-scale flight test airplane. Qualitative characters of shed vortices have been studied by flying an airplane adjacent to a large tuft grid and photographing the motion of the tufts as the vortex moves across the grid.
(g) It is believed that after completion of the investigations it will be possible to predict the vortex geometry of an arbitrary aircraft as a function of the airplane configuration and distances downstream.

(5591) BOILING BOUNDARY LAYER.

(b) Laboratory project sponsored by the Bureau of Naval Weapons.
(c) Dr. David P. Hoult, Department of Aeronautical Engineering, The Pennsylvania State Univ., University Park, Pa. 16802.
(d) Theoretical.
(e) Theoretical investigation of the boiling boundary layer on a flat plate.

(5592) EXPERIMENTAL INVESTIGATION OF SECONDARY FLOW IN AXIAL FLOW INDUCERS.

(b) Laboratory project sponsored by NASA.
(c) Dr. George F. Wislicenus and Dr. B. Lakshminarayana, Dept. of Aeronautical Engineering, The Pennsylvania State Univ., University Park, Pa. 16802.
(d) Experimental and theoretical.
(e) A three-foot diameter model of an axial flow inducer for a pump was built and will be tested with air, using smoke for direct observation of secondary motions in long and narrow vane passages. In addition, approximate measurements of the velocity distribution at inlet and discharge will be made to obtain at least a qualitative picture of the fluid motions under the predominant influence of viscous fluid friction.

(5593) INVESTIGATION OF LAMINAR BOUNDARY LAYER AND TRANSITION IN THE VICINITY AND BETWEEN SUCTION SLOTS.

(b) Laboratory project sponsored by the Bureau of Naval Weapons and the Office of Naval Research.
(c) Dr. Thomas E. Peirce and Mr. Charles F. Holt,

Ordnance Research Laboratory, University Park, Pa. 16802.
(d) Experimental and theoretical.
(e) This project will examine the characteristics of the flow at the entrance to suction slots and determine the effect the suction slots have on the laminar boundary layer flowing into each slot. This investigation will be limited to plane radial slots and the effect that variations in slot shape have on the laminar boundary layer.

(5594) GRID TURBULENCE IN DILUTE POLYMER SOLUTIONS.

(b) Bureau of Naval Weapons and the Office of Naval Research.
(c) Dr. John L. Lumley and Mr. Andrew G. Fabula, Dept. of Aeronautical Engineering, The Pennsylvania State Univ., University Park, Pa. 16802.
(d) Experimental and basic research for Ph.D. thesis.
(e) Turbulent velocity measurements will be made behind a grid in a 48-foot towing tank filled with dilute polymer solution. Experimental spectra and correlation functions will be compared with previous measurements in Newtonian fluids and with theory, in order to investigate possible explanations of the Toms effect (the friction reduction in turbulent flow produced by extremely low concentrations of very high molecular weight polymers).

(5595) TURBULENCE MEASUREMENTS IN THE VISCOUS SUBLAYER.

(b) Bureau of Naval Weapons and the Office of Naval Research.
(c) Dr. John L. Lumley and Mr. Henry Bakewell, Ordnance Research Laboratory, The Pennsylvania State University, P. O. Box 30, State College, Pa. 16801.
(d) Experimental, basic research for Ph.D. thesis.
(e) u-u space-time correlations will be taken in the viscous sublayer under a turbulent boundary layer in glycerin. The sublayer thickness is such that a $y^+ = 5$ corresponds to 0.25 inches. It is hoped that these measurements will shed light on the dynamics of the sublayer, in particular on the translation velocities of disturbances there.

(5596) THEORETICAL INVESTIGATION OF TURBULENCE FLOW OF NON-NEWTONIAN MEDIA.

(b) Office of Naval Research.
(c) Dr. John L. Lumley and Mr. Kirtan Singh, Dept. of Aeronautical Engineering, The Pennsylvania State University, University Park, Pa. 16802.
(d) Theoretical, basic research for Ph.D. thesis.
(e) Machine calculations will be made of the initial effect on the energy budget resulting from a sudden change in the constitutive relation (from Newtonian to any of several non-Newtonian types) of a fluid in isotropic, homogeneous turbulent motion. It is hoped that the investigation will provide insight into the mechanism by which low concentrations of high molecular weight additives markedly change the skin friction in turbulent shear flows (the Toms effect).

PRINCETON UNIVERSITY, School of Engineering and Applied Science.

(5184) FALL OF A SPHERE IN A HORIZONTALLY OSCILLATING FLUID.

(b) Laboratory project.
(c) Prof. Lucien M. Brush, Jr., Departments of Civil and Geological Engineering, Princeton University, Princeton, N. J.
(d) Analytical and experimental, basic research, master's thesis.
(e) The purpose of this research is to predict the temporal mean fall velocity of a spherical particle falling in a horizontally oscillating fluid. An analytical solution was derived for particles with a small (0.1) Reynolds number. A numerical solution is possible for large Reynolds numbers. Experimental verification of the appropriate equations is the purpose of the study. The results will be applicable to problems involving turbulent diffusion of sediment.
(h) Original study completed, manuscript in preparation.

(5185) DYNAMIC STORAGE OF GROUNDWATER.

(b) Laboratory project.
(c) Dr. Roger J. De Wiest, Professor, School of Engineering and Applied Science, Princeton, N. J.
(d) Analytical and experimental, basic research, master's thesis.
(e) Purpose of the research is to investigate the dynamic behavior of a groundwater basin intersected by streams and from which water is withdrawn at a time dependent rate. An electric analog model (R-C) will be constructed.
(g) An electric analog was constructed for the steady case with free boundary and leakage into aquifer. Master's thesis available.

(5186) MEASUREMENT OF UNSTEADY PRESSURES.

(b) Laboratory project.
(c) Prof. C. P. Kittredge, Dept. of Aerospace and Mechanical Sciences, Princeton University, Princeton, N. J.
(d) Theoretical and experimental, M.S. thesis.
(e) The differential equations of motion for a simple manometer system with non-linear damping have been programmed for an IBM 7094 data processing system. An experimental program is in progress to check the computation.
(g) Preliminary experimental results have been in qualitative agreement with the computer solutions for the case of a sinusoidal driving function. A report in the form of a Master's thesis is scheduled for June 1966.

(5480) INERTIAL EFFECTS IN TURBULENT SUSPENSIONS.

(b) National Institute of Health, Public Health Service.
(c) Prof. Lucien M. Brush, Jr., Departments of Civil and Geological Engineering, Princeton, N. J.
(d) Theoretical and experimental; basic research.
(e) The purpose of this research is to examine the inertial lag between particle motion and fluid motion in a turbulent suspension. A turbulence tank consisting of an oscillating three-dimensional grid will be used for the experiment. Measurements are to be made of the energy contribution to the system as a result of collisions between particles and the grid. By varying the frequency of oscillation, grid spacing and size, and particle density, an attempt will be made to describe the detailed particle motion and the sediment diffusion coefficient.

(5952) UNSTEADY FLOW BETWEEN OVERLYING PARALLEL AQUIFERS.

(b) Laboratory project.
(c) Dr. Roger J. De Wiest, Prof., School of Engrg. and Applied Science, Princeton Univ., Princeton, N. J.
(d) Analytical and experimental, basic research, Ph.D. thesis.
(e) Purpose is to investigate the flow pattern when overlying parallel aquifers are tapped by several wells.

PURDUE UNIVERSITY, Department of Agricultural Engineering.

(2596) THE USE OF A RAINFALL SIMULATOR FOR SOIL AND WATER CONSERVATION MANAGEMENT STUDIES.

(b) Soil and Water Conservation Research Div., Agricultural Research Service, USDA and Purdue University. (See Agricultural Research Service, Corn Belt Branch, Project No. 4276).
(c) Dr. L. Donald Meyer, ARS-SWC, Agricultural Engineering Department, Purdue University, Lafayette, Indiana 47907.
(d) Field investigation; applied research.
(e) The rainfall simulator is used on runoff plots for comparison of treatments which effect erosion and infiltration. Research includes studies of tillage methods, crop residue management, slope, soil type, crop rotations, and intensity histograms.
(h) "Simulation of Rainfall for Soil Erosion Research," by L. D. Meyer, Trans. ASAE 8(1), 1965.
"Effect of Minimum Tillage for Corn on Infiltration and Erosion," by J. V. Mannering, L. D. Meyer, and C. B. Johnson, Soil Sci. Soc. Amer. Proc. 30(1), 1966.

(2837) TREATMENT OF SURFACE WATERS FOR DOMESTIC USE ON THE FARM.

(b) Laboratory project.
(c) Dr. E. J. Monke, Agricultural Engineering Department, Purdue University, Lafayette, Indiana 47907.
(d) Field investigation; applied and basic research.
(e) The treatment of pond water by use of slow sand and diatomaceous earth filters is being evaluated. Improved designs are under investigation. The effects of algae growth and coagulation-sedimentation methods on filtration processes are being studied.
(f) Completed.
(g) Diatomaceous earth filtration provides a safe and effective treatment process for pond water. With equipment available, however, some supervision of the filtration operation may be needed. A small automated diatomite filter system which was specifically designed for single family operation is being evaluated. This system has proved to be effective and with minor changes could be manufactured and installed in individual homes at a relatively low cost.
(h) "Diatomaceous Earth Filtration of Pond Water for Domestic Use," by E. J. Monke, H. R. Wilke, L. G. Laudenschlager, and K. J. Albrecht, Trans. ASAE 7, 1964.
"Pond Water Treatment Research on the Southern Indiana Forage Farm," by D. M. Edwards and E. J. Monke, Research Progress Report 173, Agr. Exp. Sta., Purdue Univ., 1965.

(3490) INVESTIGATION OF FLOW CHARACTERISTICS IN DRAIN TILE AND THE RELATIONSHIP OF THESE FLOW CHARACTERISTICS TO SEDIMENTATION.

(b) Laboratory project.
(c) Mr. L. F. Huggins, Agricultural Engineering Department, Purdue Univ., Lafayette, Indiana 47907.
(d) Experimental; basic research.
(e) A 60 - foot model drain capable of recirculating sediment-laden flow has been constructed. Drain slopes at which incipient deposition occurs are being investigated.
(g) The percentage of sediment (100 to 400 microns) in the total discharge at which incipient deposition occurred appears to be a simple function of the slope of the drain. Particle shape (very angular to smooth) and size (100 to 400 microns) did not have an observable effect on the slope attained.
(h) "Sediment Transport Capacity of Circular Drains," by C. T. Haan, L. F. Huggins and E. J. Monke, ASAE Paper No. 65-723, 1965.

(3808) DEVELOPMENT AND REFINEMENT OF METHODS FOR ESTIMATING FIELD RUNOFF AND SOIL LOSS.

(b) Soil and Water Conservation Research Div., USDA, and Purdue University. (See Agri. Research Service, Corn Belt Branch, Project No. 4274).
(c) Mr. Walter H. Wischmeier, ARS-SWC, Agric. Engineering Dept., Purdue Univ., Lafayette, Indiana 47907.
(d) Experimental; development.
(e) The relationships of numerous rainstorm characteristics, topographic features, soil characteristics and surface conditions to field runoff and soil erosion are being evaluated from plot data obtained under natural and/or simulated rainfall. Basic plot and small watershed data on an individual storm basis have been assembled in an ARS central runoff and soil-loss data lab. at Purdue Univ., from 24 states. The data represent results of cooperative research studies over the past 32 years at 47 locations.
(g) A broadly applicable equation for field soil-loss prediction to help guide farm planning for soil and water conservation has been developed and published. Data for locality evaluations of the equation's factors were disseminated in ready-reference form. Present emphasis is on analysis of surface runoff in relation to physical and management factors.
(h) "Predicting Rainfall-Erosion Losses from Cropland East of the Rocky Mountains - Guide for Selection of Practices for Soil and Water Conservation," by W. H. Wischmeier and D. D. Smith, Agr. Handbook No. 282 (47 pages), U. S. Gov. Printing Office, 1965.
"Relation of Field-plot Runoff to Management and Physical Factors," by W. H. Wischmeier, Soil Sci. Soc. Amer. Proc. 30(1), 1966.

(4182) THE MECHANICS OF EROSION BY RAINFALL AND RUNOFF.

(b) Soil and Water Conservation Research Div., Agricultural Research Service, USDA and Purdue University, (See Agricultural Research Service, Corn Belt Branch, Project No. 4275.)
(c) Dr. L. Donald Meyer, ARS-SWC, Agricultural Engineering Department, Purdue University, Lafayette, Indiana 47907.
(d) Experimental; basic research.
(e) The influence of slope inclination, slope length, particle size, particle shape, and wind velocity on the resulting splash and runoff erosion are being investigated in the laboratory. Methods for simulating rainfall, slope length, soil and wind have been developed. This study is providing an understanding of the mechanics of the process involved in erosion and the basic relationships of the above variables.
(h) "Effect of Particle Roughness on Soil Erosion by Surface Runoff," by G. D. Bubenzer, L. D. Meyer, and E. J. Monke, ASAE Paper No. 65-227, 1965.
"Simulation of Rainfall and Soils for Laboratory Research," by G. D. Bubenzer and L. D. Meyer, Trans. ASAE 8(1), 1965.
"Resume: Mathematical Relationships Governing Soil Erosion by Water," by L. D. Meyer, Jour. Soil and Water Cons. 20(4), 1965.

(4183) SUBSURFACE DRAINAGE OF BLOUNT SILT LOAM.

(b) Laboratory project.
(c) Dr. E. J. Monke, Agricultural Engineering Department, Purdue University, Lafayette, Indiana 47907.
(d) Field investigation; applied research.
(e) Various spacings between parallel subsurface

drains are under investigation to determine their effectiveness in water removal and crop response. Continuous records of tile discharge are being made and crop yields are determined at harvest time.

(5481) EVALUATION OF THE PARALLEL DITCH SYSTEM FOR SURFACE DRAINAGE ON CLERMONT SOIL.

(b) Laboratory project.
(c) Mr. D. R. Sisson, Agricultural Engineering Dept., Purdue Univ., Lafayette, Indiana 47907.
(d) Field investigation; applied research.
(e) A parallel ditch system of surface drainage is being compared to the conventional drainage practices on Clermont silt loam.
(f) Completed.
(h) "Surface Drainage on Clermont Silt Loam," by D. R. Sisson and H. M. Galloway, Research Progress Report 159, Agr. Exp. Sta., Purdue Univ., 1964.

(5810) TREATMENT OF WATER FROM SMALL RESERVOIRS FOR DOMESTIC CONSUMPTION.

(b) Laboratory project.
(c) Dr. E. J. Monke, Agricultural Engineering Dept., Purdue Univ., Lafayette, Ind. 47907.
(d) Applied and basic research.
(e) The purpose of the project is to study electrophoretic control as an aid for filtration of raw water supplies and to investigate methods for reducing the adverse effects of aquatic weed residues on water treatment processes and water quality.

(5811) EFFECT OF PESTICIDE RESIDUES AND OTHER ORGANO-TOXICANTS ON THE QUALITY OF SURFACE AND GROUND WATER RESOURCES.

(b) Laboratory project.
(c) Dr. E. J. Monke, Agricultural Engineering Dept., Purdue University, Lafayette, Indiana 47907.
(d) Field investigation, applied and basic research.
(e) The purpose of the project is to study the mechanisms by which organo-toxicant materials are held by the mineral and organic fractions in the soil, to determine the fate of organo-toxicant materials in water storage reservoirs, to evaluate the effect of organo-toxicants on terrestrial and farm pond invertebrates and farm pond vertebrates, to determine the role of microorganisms in the elimination of organo-toxicants from surface and ground waters, and to effect control and removal methods for reducing or eliminating organo-toxicant residues from reservoir water supplies.

PURDUE UNIVERSITY, Department of Agronomy.

(4679) FLOW LAWS FOR THE MOVEMENT OF WATER IN SOIL.

(b) Laboratory project.
(c) Dr. Dale Swartzendruber, Department of Agronomy, Purdue Univ., Lafayette, Indiana.
(d) Experimental and theoretical; basic research.
(e) The validity of basic equations for water relationships in soil, such as Darcy's proportionality and Buckingham's capillary potential function, is being tested under various circumstances. Revised equations and mathematical solutions for deviating behavior are also being sought.
(g) Experimental measurements of steady-state water flow in unsaturated soils indicate that Darcy-type proportionality between flow velocity and hydraulic gradient does not hold at a constant soil-water suction. Instead, the flow velocity increases more than proportionally with gradient, in a manner qualitatively similar to what has been reported for water-saturated materials containing clay. A study has also been made on the mathematical solution of the nonlinear diffusion equation applied to horizontal water absorption by a uniform, semi-infinite column of soil. An additive type of variable separation is used to show that a recent proposed solution in the literature is in error. A product-type of variable separation, however, does solve the problem, and is shown to be the equivalent of the classical Boltzmann transformation, which in turn is seen to be a consequence of the governing partial differential equation and the boundary condition, rather than as an additional assumption in need of separate justification.
(h) "Comments on paper by J. M. Davidson, J. W. Biggar, and D. R. Nielsen, 'Gamma-radiation attenuation for measuring bulk density and transient water flow in porous materials'," by D. Swartzendruber, J. Geophys. Res. 69: 1676-1677, 1964.
"Variables-separable Solution of the Horizontal Flow Equation with Nonconstant Diffusivity," by D. Swartzendruber, in press Soil Sci. Soc. Amer. Proc. 30, Jan.-Feb., 1966.

(5788) CHARACTERIZATION OF THE RATE OF WATER INFILTRATION INTO SOIL.

(b) Agricultural Experiment Station and Office of Water Resources Research, U.S. Dept. of the Interior.
(c) Dr. Dale Swartzendruber, Dept. of Agronomy, Purdue University, Lafayette, Ind. 47907.
(d) Experimental, theoretical, and field measurements; basic and applied research.
(e) Theoretical and experimental means of describing water-transport properties of soil relevant to the infiltration process are being sought, along with a means of predicting the infiltration rate from these transport properties, the water content of the soil profile, and the crusting properties of the soil. The predicted values will be validated with field measurements obtained from several types of plot-size infiltrometers. Development of a successful prediction scheme would provide a useful new tool for analyzing the hydrology of a watershed.
(g) Preliminary analysis of infiltration rates into laboratory columns of sand-silt mixtures has been initiated. Results indicate that the relationship between water infiltration rate and volume of water absorbed cannot be described on the basis of the classic Darcy and Buckingham water-transport functions. However, the experimental results can be accommodated quite well by assuming that the water-flow process is non-Darcy of a type previously reported in the literature for water-saturated porous materials.
(h) "The Applicability of Darcy's Law," by D. Swartzendruber. Presented before Divisions S-1 and S-6, Soil Science Society of America, Columbus, Ohio, Nov. 3, 1965.

PURDUE UNIVERSITY, Automatic Control Laboratory, School of Mechanical Engineering.

(4197) FLUID LINE DYNAMICS.

(b) Laboratory project.
(c) Prof. Rufus Oldenburger, School of Mech. Engineering, Purdue Univ., Lafayette, Ind. 47907.
(d) Theoretical and experimental project; Master's and Doctor's Thesis Research.
(e) Mathematical models in use for systems with significant fluid lines are generally so complicated as to make design with such models impractical. In this investigation models are sought which are as simple as possible but which still adequately describe the response of the system to the class of disturbances of interest. Using infinite product expansions of transcendental functions satisfactory results have been obtained for single conduits terminating in lumped elements. Viscosity, boundary effects and line vibration are being considered in the analytical work. Frequency response runs to verify the theory are being made to determine

the range for which solutions obtained are applicable. The theoretical and experimental approaches are being extended to systems with two or more lines. Rational approximations to the transfer functions of such systems are sought where the accuracy of the approximation can be seen directly from the approximation, as is the case where infinite products have been applied. Studies so far have been restricted to medium and large diameter lines. They are being extended to very small lines in the capillary class. The rate of dispersion of a pressure wave in a single line of constant cross section is also under study and the reinforcement of such a wave traveling back and forth in conduit closed at both ends.

(g) Theory and tests show that for a wide range of operation encountered in practice flow through bends may be treated as flow through straight conduits. Mathematical models developed for straight fluid lines describe their response to high frequency. However, if resonance effects are to be included a certain complication of the model is necessary, beyond which further simplification is not possible.

(h) "Dynamic Response of Hydraulic Lines," R. Oldenburger and R. E. Goodson. Automatic Control, Vol. 8, No. 5, pp. 324-326, 1961, Tokyo, Japan.
"Hydraulic Line Dynamics," R. Oldenburger and R. E. Goodson. Proceedings of the Congress of the International Federation of Automatic Control, Basle, Switzerland, Aug. 27-Sept. 4, 1963.
"Dynamic Response of Fluid Lines,"R. Oldenburger and A. F. D'Souza. Transactions of the American Society of Mechanical Engineers, Journal of Basic Engineering, Vol. 86, Series D, No.3, pp. 589-598, September 1964.
"Simplification of Hydraulic Line Dynamics by Use of Infinite Products," R. Oldenburger and R. E. Goodson. Transactions of the American Society of Mechanical Engineers, Journal of Basic Engineering, Vol. 86, Series D, No. 1, pp. 1-10, March 1964.

PURDUE UNIVERSITY, School of Electrical Engineering.

(4499) ANALYSIS AND DESIGN OF PULSE-WIDTH-MODULATED HYDRAULIC CONTROL SYSTEMS.

(b) Laboratory project.
(c) Dr. David E. Boddy, Oakland University, Rochester, Michigan 48063.
(d) Experimental and theoretical, basic research for doctoral thesis.
(e) The purpose of this investigation was to determine the characteristics of a PWM hydraulic servo and to develop analytical tools and design procedures for treating the PWM hydraulic servo. Theoretical considerations were correlated to measured system performance.
(f) Completed.
(g) A straight-forward design procedure for PWM hydraulic servos was obtained. Analytical methods based on method of Tsypkin were developed for treating closed loop PWM systems. An analog computer study was carried out and the results compared to the physical system performance.
(h) "Analysis and Design of Pulse-Width-Modulated Hydraulic Control Systems," David E. Boddy, Ph.D. thesis, Purdue University, Jan. 1966.

PURDUE UNIVERSITY, Jet Propulsion Center.

(2374) MASS TRANSFER IN ANNULAR, TWO-PHASE FLOW IN A VERTICAL TUBE.

(b) National Science Foundation.
(c) Dr. M. J. Zucrow, Jet Propulsion Center, Purdue University, Lafayette, Indiana 47907.
(d) Experimental and theoretical; basic research for Master's and Ph.D degrees.
(e) The problem concerns the analytical and experimental study of mass transfer from an annular liquid film on the inside wall of a vertical circular tube to a concurrent gas flow in the core of the tube. Systematic experiments have been conducted with air and water for determining the effect of the rates of flow of gas and liquid, the length of the tube, and the temperature difference between gas and liquid upon the rate of mass transfer from the liquid film. Characteristics of the gas-liquid interface, including surface area, wave velocity, and liquid film thickness have been measured.
(f) Completed.
(g) The mass transfer data were satisfactorily correlated employing equations for the local rates of heat and mass transfer. The liquid flow rate then had no effect on the dimensionless mass transfer coefficient. There was a negligible (less than 0.1 per cent) increase in surface area due to the presence of waves on the surface of the liquid film.
(h) "Measurements of Mass Transfer and Pressure Drop in Annular, Two-Phase Flow," R. S. Mezey, Report No. TM-65-4, Jet Propulsion Center, Purdue University, Lafayette, Indiana, March 1965 (available from Purdue University).
"Mass Transfer in Annular, Two-Phase Flow in a Vertical Tube," G. R. Schneiter, Report No. F-65-2, Jet Propulsion Center, Purdue Univ., Lafayette, Indiana, December 1965 (available from Purdue University).

PURDUE UNIVERSITY, School of Mechanical Engineering.

(5712) AN INVESTIGATION OF THE RADIAL FLOW BETWEEN TWO PARALLEL, NARROWLY SPACED DISKS.

(b) Laboratory project.
(c) Dr. E. J. Wellman, Associate Professor of Mechanical Engineering, Purdue University, Lafayette, Indiana.
(d) Analytical and experimental basic research for doctoral thesis.
(e) Existing literature on investigations of the radial flow between two parallel narrowly spaced disks was examined and the results analyzed. The studies for compressible choked flow were found to be inconsistent. An experimental and analytical investigation of this flow was carried out.
Pressure measurements were obtained for outward radial flow of air between two 5-inch diameter disks with spacings ranging from 0.005 to 0.030 inches and initial pressures of from 5 to 40 psig. A sliding pressure tap permitted continuous pressure readings. Calculated pressure distributions were obtained by numerical integration of the momentum equations.
(f) Completed.
(g) The existence of compression shock was clearly shown by the pressure measurements and also by visual (schlieren) observations. The experimental and calculated results indicated very good agreement for the shock location. Pressure distributions were also in very good agreement except for a small region immediately preceding the shock where a preliminary pressure rise indicated an upstream effect of the shock which was apparently due to a shock-boundary layer interaction.
(h) "An Investigation of the Radial Flow between Two Parallel, Narrowly Spaced Disks," Somchob Chaiyavej, Ph.D. Thesis, January 1966. (available on loan)

(5741) A STUDY OF ROTATING FLUIDS BETWEEN PARALLEL DISKS.

(b) Purdue Research Foundation.
(c) Dr. E. J. Wellman, Associate Prof. of Mechanical Engineering, Purdue Univ., Lafayette, Indiana.
(d) Analytical and experimental basic research for doctoral thesis.
(e) From analytical studies of similar solutions and

existing experimental results a rotating system is being designed for an experimental study of the flow of liquids between parallel, rotating disks.

ROCKY MOUNTAIN HYDRAULIC LABORATORY.

(5488) RELIABILITY OF RELEASE OF BURIED FLOATS TO DETERMINE DEPTH OF SCOUR.

(b) Laboratory project.
(c) Prof. C. J. Posey, Director, Rocky Mountain Hydraulic Laboratory, Allenspark, Colorado 80510.
(d) Experimental; master's thesis.
(e) Scour model studies were conducted to determine the reliability of release of floats which were either buried or placed through casing jetted to desired depths.
(f) Completed.
(g) Except for the shallower-placed jetted floats breaking loose as soon as their tops were exposed, all floats remained in place until more than half uncovered, regardless of relative buoyancy, lack of soil cohesion, and vibration to which the nearby pier was subjected.
(h) "Experiments with Buried Floats to Determine Depth of Scour," by W. G. Moeller, R.M.H.L. Report No. 35, 1965. Condensed from M. S. Thesis. (See item 5490, page 24.)

(5768) COMPARISON OF ROCK EROSION-PROOFING WITH AND WITHOUT AN INVERTED FILTER BASE.

(b) Laboratory project.
(c) Prof. C. J. Posey.
(d) Experimental, applied.
(e) Preparation of motion-picture comparison of erosion of overflow chute with various combination of protection features.
(f) Active during summers.

ST. ANTHONY FALLS HYDRAULIC LABORATORY, UNIVERSITY OF MINNESOTA.

Inquiries concerning Projects 2144, 3153, 3502, 3824, 4201, 4209, 4700, 5493, 5494, 5495, 5496, 5497, 5498, 5500, 5501, 5502, 5504, 5505, 5506 and 5792 to 5807, inclusive should be addressed to the Director, St. Anthony Falls Hydraulic Laboratory, Mississippi River at Third Avenue S. E., Minneapolis, Minnesota, 55414.

Inquiries concerning Projects 111, 1168, and 2386, which are conducted in cooperation with the Agricultural Research Service, should be addressed to Mr. Fred W. Blaisdell, Hydraulic Engineer, Soil and Water Conservation Research Division, Agricultural Research Service, St. Anthony Falls Hydraulic Lab., Mississippi River at Third Avenue S. E., Minneapolis, Minnesota, 55414.

Inquiries concerning Project No. 194, which is conducted in cooperation with the Corps of Engineers and the U. S. Geological Survey, should be addressed to Engineer in Charge, Mr. John V. Skinner, Federal Inter-Agency Sedimentation Project, St. Anthony Falls Hydraulic Laboratory, Mississippi River at Third Avenue, Minneapolis, Minnesota, 55414.

(111) CLOSED CONDUIT SPILLWAY.

(b) Agricultural Research Service, U. S. Dept. of Agriculture, in cooperation with the Minnesota Agricultural Expt. Station and the St. Anthony Falls Hydraulic Laboratory.
(d) Experimental; generalized applied research for development and design.
(e) A square drop inlet having a hood barrel entrance is being tested to determine entrance loss coefficients for various drop inlet sizes and heights and various barrel slopes. Previous tests have evaluated the performance of this type of inlet. The elbow and transition between the two-way drop inlet and the barrel is being studied to determine the pressures and the best form to minimize the possibility of cavitation.
(g) The theory of closed conduit spillways has been developed, verified, and published. Results of tests on many forms of the closed conduit spillway entrance have been published. Pipe culverts laid on steep slopes may flow completely full even though the outlet discharges freely. Generalized methods for analysis and reporting of the results have been developed. The use of air as the model fluid has been verified by comparing test results with those obtained using water as the model fluid.
The drop inlet with the horizontal anti-vortex device causes the spillway to act as a self-regulating siphon when the headpool level approximates the anti-vortex plate elevation. The height of the anti-vortex plate above the drop inlet crest and the overhang of the anti-vortex plate determine the effectiveness of the plate as an anti-vortex device. For one form of the inlet, tests have been made to determine the crest loss coefficient, the barrel entrance loss coefficient, the pressures on the plate and the drop inlet, the general performance of the inlet, minimum and maximum permissible plate heights, and the head-discharge relationship for plate control. Variables have been the length of the drop inlet, the barrel slope, the height and overhang of the anti-vortex plate, and the sidewall thickness.
Tests on the hood drop inlet have shown that the hood barrel entrance can be used to reduce the minimum required height of the drop inlet. Minimum sizes of drop inlet and anti-vortex devices have been determined.
Tests of low-stage orifices in the two-way drop inlet have shown that improper location and improper proportioning of the orifices can prevent priming of the spillway. The proper location and size of the orifices have been determined.
To supplement the experiments, potential flow methods have been used to determine the theoretical coefficient of energy loss at the crest of the two-way drop inlet.
(h) "Tests of a Splitter-Type Antivortex Wall for a Hood Drop Inlet to a Closed Conduit Spillway," by Charles A. Donnelly, Agricultural Research Service Report ARS 41-92, November 1964.
"Test of an Antivortex Wall for a Rectangular Drop Inlet to a Closed Conduit Spillway," by Charles A. Donnelly, Agricultural Research Service Report ARS 41-96, December 1964.
"A Digital Point Gage Recorder," by Fred W. Blaisdell and Scott D. Crist, Agricultural Research Service Report ARS 41-102, Feb. 1965.
"Hydraulic Efficiency in Culvert Design," by Fred W. Blaisdell, ASCE Transportation Engineering Conference Preprint 212, May 1965.

(1168) A STUDY OF CANTILEVERED OUTLETS.

(b) Agricultural Research Service, U. S. Dept. of Agriculture, in cooperation with the Minnesota Agricultural Expt. Station and the St. Anthony Falls Hydraulic Laboratory.
(d) Experimental; generalized applied research for design.
(e) Pipe outlet conduits for small spillways are frequently cantilevered beyond the toe of the earth dam. Attempts will be made to determine quantitatively for the size of the scour hole to be expected under various field conditions.
The present phase of the study is on rectangular cantilever outlets with a deflector at the exit to throw the water away from the structure and move the scour hole further downstream.

(2144) EXPERIMENTAL AND ANALYTICAL STUDIES OF HYDROFOILS.

(b) Office of Naval Research, Department of the

Navy.
(d) Experimental and analytical; basic research.
(e) Investigation of the unsteady flow characteristics of ventilated hydrofoils of finite span in the vicinity of a free surface.
(g) Unsteady force characteristics were investigated for a ventilated foil undergoing sinusoidal heaving motions near a free surface. Lift and drag forces were measured for various heave amplitudes and frequencies. Fair agreement has been obtained with unsteady, linearized theory. Force measurements are also being made on a restrained foil with an oscillating trailing edge flap.

(2386) GENERALIZED DESIGN OF TRANSITIONS FOR SUPERCRITICAL VELOCITIES.

(b) Agricultural Research Service, U. S. Dept. of Agriculture, in cooperation with the Minnesota Agricultural Experiment Station and the St. Anthony Falls Hydraulic Lab.
(d) Experimental; generalized applied research for development and design.
(e) Studies will be made to develop a transition and to determine the rules for its design. The transition will be used to change the flow cross section from circular to rectangular when the velocities are supercritical.

(3153) FLOW ABOUT BODIES AT SMALL CAVITATION NUMBERS.

(b) Office of Naval Research, Department of the Navy.
(d) Experimental and analytical; basic research.
(e) A flat plate and a cambered hydrofoil are tested in a free-jet tunnel under supercavitating conditions. The unsteady flow due to the oscillation of a trailing flap as influenced by one or two free surfaces is being studied.
(h) "Performance of Supercavitating Hydrofoils with Flaps, with Special Reference to Leakage and Optimization of Flap Design," by R. Oba, St. Anthony Falls Hydraulic Laboratory Technical Paper No. 51, Series B, May 1965. "Supercavitating Flat-Plate with Oscillating Flap at Zero Cavitation Number," by C. S. Song, St. Anthony Falls Hydraulic Laboratory Technical Paper No. 52, Series B, November 1965. "A Note on the Supercavitating Flat-Plate with Leak through Flap Hinge," by C. S. Song, St. Anthony Falls Hydraulic Laboratory Technical Paper No. 53, Series B. (In preparation). "On the Existence of Zero Form-Drag and Hydrodynamically Stable Supercavitating Hydrofoils," by R. Oba, St. Anthony Falls Hydraulic Laboratory Technical Paper No. 54, Series B. (In preparation).

(3502) MANGLA SPILLWAY STUDIES.

(b) Harza Engineering Company, Chicago; Binnie and Partners, London; Government of Pakistan.
(d) Experimental; design and operation.
(e) A 1:300 scale section model consisting of half the control structure and basin and a 1:150 scale comprehensive model for study of all important hydraulic features. A 1:216 scale section model consisting of two control structure gates for study of pressures and gate calibration. A 1:300 scale comprehensive approach model for study of flow conditions in approach. Two 1:150 scale section models, one a detailed study of pressures and forces on baffle blocks, one a detailed study of waves on the basin side walls. Typical dimensions of earth fill dam spillway include a drop in water level of 330 ft, and a design discharge of 900,000 cfs through a two-stage stilling basin energy dissipator.
(g) Model studies for design are completed and a final report is being prepared.

(3824) SURFACE CHARACTERISTICS OF AIR ENTRAINED FLOW IN STEEP CHANNELS.

(b) Laboratory project.
(d) Analytical and experimental investigation of the air concentration, velocity distribution, and surface roughness of water flow in steep open channels, Ph.D. thesis.
(e) Experimental investigation was carried out on the SAF high velocity channel for slopes up to 53 degrees. Velocities were measured by means of a pitot tube and high speed photography. Air concentration was measured by the SAF concentration meter. The surface elevation was measured by a device which measures the average time the surface is above a given elevation.
(f) Experimental work completed.

(4201) GURI HYDROELECTRIC PROJECT MODEL STUDIES.

(b) Harza Engineering Company, Chicago, Corp. Venezolano de Guayana.
(d) Experimental, design and operation.
(e) Study for the design of the Guri Hydroelectric development on the Caroni River, Venezuela using a 1:394 comprehensive spillway model, 1:197 spillway section model, and a 1:197 comprehensive model. Studies include spillway design, channel closure, and cofferdam studies.
(g) Model studies for design are completed and a final report is being prepared.

(4209) THE INFLUENCE OF ELECTROKINETIC PHENOMENA ON THE HYDRAULIC AND ELECTROOSMOTIC PERMEABILITY OF UNIFORM VERY FINE SANDS.

(b) Laboratory project.
(d) Experimental and theoretical; Ph.D. thesis.
(e) Accurately sized, narrow range, angular quartz particles and spherical glass beads were tightly placed in a permeameter with reversible silver-silver chloride electrodes at the ends of the test section. Streaming potential, streaming current, electrical resistivity of low conductivity liquid, and filter velocity were precisely measured. Studies include: (1) Flow retardation from return electroosmosis; (2) analysis of electroosmotic permeability factors with respect to particle characteristics and hydraulic permeability, and (3) comparisons of streaming current and filter velocity at varying Reynolds numbers.
(g) It has been found that the streaming current-potential varies linearly with hydraulic gradient to a slightly higher Reynolds number than the filter velocity. Lack of complete deaeration causes a larger reduction in the filter velocity than the streaming. When "boiling" action takes place anomalous relations between the filter velocity and streaming current occur.
(h) Thesis in preparation.

(4700) OSCILLATORY LIFT AND DRAG FORCES ON VENTILATED HYDROFOILS IN REGULAR WAVES.

(b) Office of Naval Research, Department of the Navy.
(d) Experimental; basic research.
(e) Investigation of the force characteristics of a restrained, naturally ventilated hydrofoil moving through regular waves.
(g) Flow visualization studies were conducted to determine the regions of boundary layer separation on hydrofoils with a sharp leading edge near the free surface. The length of the separation bubble was found to vary with velocity, angle of attack, and aspect ratio. Variation of the leading-edge thickness on wedge profiles had little influence on the separation bubble.
(h) "Measurement of the Leading-Edge Separation Bubble for Sharp-Edged Hydrofoil Profiles," by J. M. Wetzel and K. E. Foerster. (In preparation).

(5493) BIG SIOUX CROSSING RIVER BRIDGE MODEL STUDY.

(b) Iowa State Highway Commission and South Dakota State Highway Dept.

(e) Model studies to simulate condition of failure of highway bridge due to scour and to determine method of protection and to establish procedure for prevention of scour and bank subsidence. Experiments carried out on 1:75 movable bed model.
(f) Completed.
(h) "Studies of the Stabilization of the Big Sioux River at the Interstate 29 Bridge Crossing," by Alvin G. Anderson, St. Anthony Falls Hydraulic Laboratory Project Report No. 78, May 1965. (Not available for distribution).

(5494) THERMAL POLLUTION STUDIES OF ST. CROIX RIVER.

(b) Northern States Power Company.
(d) Experimental applied research.
(e) In a first phase of the project, thermal density currents created by the discharge of heated condenser water from a steam power plant into a broad, deep river were studied in a model and isotherm surfaces were calculated. On the basis of the results obtained from this model, a permit to use the river water for condenser cooling was granted. A second phase of the model is now under way, studying the outlet channel between the plant and river with a view to discharging the warm water in as thin a layer as possible at the river surface. The scale of this model is 1:40.
(f) First phase completed, second phase under way.
(g) The initial study showed that it would be possible to discharge the warm water as a relatively thin layer on the river surface, thereby obtaining maximum heat dissipation to the atmosphere. Probable temperature limits on the water were determined.
(h) "Effects of Condenser Cooling Water Discharge from Projected Allen S. King Generating Plant on Water Temperatures in Lake St. Croix," by Edward Silberman and Heinz G. Stefan, St. Anthony Falls Hydraulic Laboratory Project Report No. 76, December, 1964. (Not available for distribution.)

(5495) A STUDY OF IMPACT CAVITATION DAMAGE.

(b) David Taylor Model Basin and Office of Naval Research, Dept. of the Navy.
(d) Experimental applied research.
(e) Development and tests of a cavitation damage facility utilizing repeated single liquid drop impacts on a target moving at high speed in a vacuum.
(f) Completed.
(g) Weight loss damage tests yield findings very similar to those for cavitation damage tests. Enhanced ability to control impact conditions permits detailed study of the mechanics of failure.
(h) "A New Facility for Evaluation of Materials Subject to Erosion and Cavitation Damage," by J. F. Ripken, J. M. Killen, S. D. Crist, and R. M. Kuha, St. Anthony Falls Hydraulic Laboratory Project Report No. 77, 23 pages, March 1965. (Not available for distribution.)

(5496) STRUCTURE OF TURBULENCE OF NON-NEWTONIAN FLOWS.

(b) David Taylor Model Basin, Dept. of the Navy.
(d) Experimental, basic research.
(e) The experiment consists of the measurements of Taylor vortices in a non-Newtonian fluid placed between two concentric cylinders when the inner cylinder is rotating.
(h) Report in preparation.

(5497) A STUDY OF FLOW NOISE IN A NON-NEWTONIAN FLUID.

(b) David Taylor Model Basin, Dept. of the Navy.
(d) Experimental.
(e) An experimental investigation of the influence of a non-Newtonian additive on the flow noise in the boundary layer of a rotating cylinder is proposed.
(f) Experimental work in progress.

(5498) A STUDY OF SURFACE SEALANTS TO REDUCE CAVITATION DAMAGE.

(b) David Taylor Model Basin, Dept. of the Navy.
(d) Experimental applied research.
(e) A determination of materials or techniques which will serve to seal cavitating surfaces to either reduce the amount of caviation or the damage resulting therefrom.
(f) Completed.
(g) Gaseous evolution observed from metallic surfaces but various sealants were unable to withstand erosion under standard ASME vibratory cavitation exposure.
(h) Report in preparation.

(5499) INFLUENCE OF MICRO BUBBLES ON FLOW NOISE.

(b) David Taylor Model Basin, Dept. of the Navy.
(d) Experimental.
(e) An experimental investigation of the flow noise intensity and spectra in the boundary layer of a rotating cylinder with the addition of free gas bubble is contemplated.
(f) Experimental work in progress.

(5500) HYDRODYNAMIC FLUTTER OF SUPERCAVITATING HYDROFOILS.

(b) David Taylor Model Basin, Dept. of the Navy.
(d) Experimental, basic research.
(e) Flat-plate hydrofoils are tested in a free-jet water tunnel at supercavitating conditions to determine the critical velocity as a function of the mass density ratio and other variables. The main purpose is to check the existing theories.

(5501) AN ELECTROMAGNETIC VELOCITY PROBE.

(b) A laboratory thesis study.
(d) Experimental; M.S. thesis.
(e) The study involves the construction, calibration and demonstration of an electromagnetic velocity probe designed for use in the measurement of the axial component of the turbulent velocity in water flow. The magnetic field is provided by permanent magnets placed outside the flow system, which is a 3/4 in. ID lucite pipe. The probes are constructed of .010 in. platinum wire with an electrode gap of .050 in. A total head tube is used in conjunction with the electromagnetic probe in order to obtain mean velocities.

(5502) A STUDY OF BOUNDARY WALL PIEZOMETER TAP ERRORS.

(b) A laboratory thesis study.
(d) Analytical and experimental applied research; M.S. thesis.
(e) A determination of the relation between the piezometer tap shape characteristics, flow boundary layer characteristics and the pressure measuring errors.
(f) Completed.
(g) Tap errors were found to vary as a function of velocity tap depth-diameter ratio, pipe diameter - tap diameter ratio, and back up diameter - tap diameter ratio.
(h) "A Study of the Influence of boundary Layer Properties and Hole Dimensions on the Accuracy of Pressure Measurements at a Boundary," by Shih-Weng Chiang, M. S. Thesis, University of Minnesota, December 1964. (Available on Inter-Library Loan from University of Minnesota Library.)

(5504) BUBBLE AERATION STUDIES.

(b) A laboratory thesis study.
(d) Analytical and experimental applied research; M.S. thesis.
(e) A determination of the oxygen transferred to undersaturated water by rising clouds of submerged bubbles. Studies include variation of bubble size, bubble concentration, water depth and oxygen deficiency.
(f) Completed.
(g) Transfer found to vary with decreasing bubble

Reynold's number, tank depth air flow rate, bubble size and mixing.

(h) "An Experimental Study of the Effects of Air Flow Rate, Bubble Size and Rise Velocity, and Depth on the Efficiency of the Diffusion Aeration Process," by S. A. LaBella, M. S. Thesis, University of Minnesota, March 1965. (Available on Inter-Library Loan from University of Minnesota Library.)

(5505) A STUDY OF THE WAVE ATTENUATION CHARACTERISTICS OF WATER-FILLED SPHERICAL BAGS EMPLOYED AS A FLOATING BREAKWATER.

(b) A laboratory thesis study.
(d) Analytical and experimental applied research; M.S. thesis.
(e) A determination of the attenuation of gravity waves by rafts of water-filled spherical elastic bags floating at a free surface.
(f) Completed.
(g) Attenuation shown to be a function of relative breakwater length, sphere pattern, sphere size, percentage of sphere fill, and anchorage location.
(h) "Wave Attenuation Employing Submerged Spheres," by R. P. Stehly, M.S. Thesis, University of Minnesota, December 1964. (Available on Inter-Library Loan from University of Minnesota Library.)

(5506) TWO-DIMENSIONAL, INCOMPRESSIBLE, ROTATIONAL FLOW OVER A WEDGE ON THE BOTTOM OF A CHANNEL UNDER FREE SURFACE.

(b) A laboratory thesis study.
(d) Theoretical; Ph.D. thesis.
(e) To investigate the rotational effect on the cavity and drag characteristics of the above flow over a wedge. The flow is assumed to be rotational with constant vorticity. The method is to solve the mixed boundary value problem on the upper half of the semi-infinite plane using complex variable technique.
(f) Completed.
(g) A linearized theory was developed which was compared with experimental results of supercavitating flow over wedges in the boundary layer.
(h) "A Linearized Theory for Potential and Rotational Supercavitating Flow over a Wedge in a Two-Dimensional Open Channel," by Kesavarao Yalamanchili, Ph.D. Thesis, University of Minnesota, May 1965. (Available on microfilm from University Microfilms, Ann Arbor, Mich.)

(5792) ITTC HEADFORM STUDY.

(b) David Taylor Model Basin, Dept. of the Navy.
(d) Experimental applied research.
(e) Determination of the inception cavitation conditions for a standardized headform in the 6-in. closed jet water tunnel of the Laboratory. Results are to be compared with those in other water tunnels. Comparisons being made by International Towing Tank Conference.
(f) Completed.
(g) Value of inception sigma found to diminish with tunnel speed and gas content of water.
(h) "Cavitation Inception Evaluation of the ITTC Modified Ellipsoidal Head Form," by F. R. Schiebe, J. M. Killen, and J. F. Ripken, St. Anthony Falls Hydraulic Laboratory Memo No. M-103, November 1965. (Not available for distribution.)

(5793) TANK FOR OCEANOGRAPHIC CURRENT METER CALIBRTION.

(b) U. S. Navy Oceanographic Office.
(d) Theoretical and experimental, basic research.
(e) A study was made to determine the feasibility of constructing a calibration facility for very low speed ocean current meters (0.01 to 1 knot.)
(f) Completed.
(g) A facility in the form of a low-speed jet from a nozzle was recommended.
(h) "A Feasibility Study of a Calibration Tank for Ocean Current Meters," by Edward Silverman, St. Anthony Falls Hydraulic Laboratory Memo No. M-104, October 1965. (Not available for distribution.)

(5794) JET FLAP STUDIES.

(b) David Taylor Model Basin, Dept. of the Navy.
(d) Experimental basic research.
(e) The utility of a trailing-edge jet flap on ventilated hydrofoils in the vicinity of a free surface is to be investigated. The tests are to be primarily conducted in the towing tank facility, and are an extension of previous work carried out in the Laboratory free-jet water tunnel.

(5795) NON-NEWTONIAN BOUNDARY LAYER.

(b) David Taylor Model Basin, Dept. of the Navy.
(d) Experimental and anlytical investigation.
(e) Study of boundary layer structure of laminar, transition and turbulent flows with homogeneous non-Newtonian fluids and Newtonian fluids with injected non-Newtonian additives.

(5796) IMPACT CAVITATION DAMAGE II.

(b) David Taylor Model Basin and Office of Naval Research, Dept. of the Navy.
(d) Experimental and analytical applied research.
(e) Utilization of facility described under (5495) to clarify fundamental mechanics of failure of solids by impact of liquid drops.

(5797) TUNNEL FEASIBILITY STUDY.

(b) David Taylor Model Basin, Dept. of the Navy.
(d) Analytical design study.
(e) Clarification of fluid dynamic problems which might be encountered in providing a new alternate two-dimensional test section for a large existing water tunnel.
(f) Completed.
(g) Limits of feasibility established.
(h) "A Feasibility Study of a High-Speed Two-Dimensional Test Section for the DTMB 36-Inch Water Tunnel," by J. F. Ripken and C. S. Song, St. Anthony Falls Hydraulic Laboratory Memo No. M-102, July 1965. (Not available for distribution.)

(5798) FLOW CONDITIONS IN SOILS AND FILTERS.

(b) National Institutes of Health.
(d) Project is primarily experimental with some theoretical work; applied research.
(e) A study of the flow of water through unsaturated porous media is being conducted. The variation of the seepage coefficient, K, with the characteristics of the porous media and the degree of saturation is being investigated. Knowledge of the variation in the seepage coefficient with porous media characteristics and degree of saturation will aid in the determination of the pressure gradient as a function of velocity and saturation necessary to maintain a given flow rate through filters, natural soil and capillary flow from groundwater tables to the surface.

(5799) REVIEW AND ANALYSIS OF PRECIPITATION AND RUNOFF DATA FOR SELECTED WATERSHEDS IN MINNESOTA.

(b) USDI - Water Resources Research.
(c) Professor C. E. Bowers, University of Minnesota, St. Anthony Falls Hydraulic Laboratory, Minneapolis, Minnesota 55414.
(d) Analytical; basic research.
(e) Project involves an analysis of precipitation, infiltration and runoff from selected watersheds in Minnesota. The objective of the study will be the procurement of information on peak rates of runoff and infiltration rates for selected storms in the watersheds. An attempt will be made to correlate results with various hydrologic parameters and basic characteristics.

(5800) A STUDY OF THE RELATIONSHIP BETWEEN EROSION AND SOIL PROPERTIES FOR COHESIVE SOIL.

(b) National Science Foundation.
(d) Experimental applied research.
(e) The soil properties and the erosion characteristics of a series of cohesive soil samples are being obtained. A relationship between the erosion characteristics and the soil properties is being obtained.

(5801) MINNESOTA FLOOD STUDY.

(b) Division of Waters, Dept. of Conservation, State of Minnesota.
(d) Applied Research - Field Investigation.
(e) Project involved motion picture records of the April 1965 flood on the Minnesota River plus the computation of data on discharges, water content of snow and rainfall during the critical runoff period.
(g) Of primary interest is the procurement of photographic records of the flood.
(h) A 1600 ft sound, color motion picture entitled "Flood: The Minnesota River, April 1965," is being assembled.

(5802) STUDIES OF FLOATING OIL TANKS.

(b) Chicago Bridge and Iron Company.
(d) Experimental and analytical, applied research.
(e) Tanks for storing oil from wells under the continental shelf would be floated and moored near the wells. The objective of the project is to determine ideal shapes for the tanks to minimize mooring problems during storms.
(f) Suspended.
(g) A first experimental phase of the project has been completed in which mooring forces in shallow water waves created by hurricanes have been measured on several 1 to 48 scale models.

(5803) WATER JET INLET STUDY.

(b) The Boeing Company, Seattle, Washington.
(d) Experimental applied research.
(e) Determination of performance-limiting cavitation characteristics of the inlet system for a jet propelled high speed hydrofoil boat.

(5804) STUDY OF FLOW TUBES.

(b) Automatic Control Company, St. Paul, Minnesota.
(d) Experimental and analytical development.
(e) Development of new forms of conduit flow meters of the differential pressure type.

(5805) GRIT DISTRIBUTION IN GRIT REMOVAL CHANNELS OF SEWAGE TREATMENT PLANT.

(b) Toltz, King, Duvall, Anderson, and Associates, Consulting Engineers and Minneapolis-St. Paul Sanitary District.
(d) Experimental model study, applied research.
(e) The model study will be directed at determining causes of uneven distribution of grit among several presently operating removal channels. It will also be used to assist in planning future grit channels and in improving operation of the present channels. A 1 to 12 model scale is in use.

(5806) VELOCITY PROFILES IN AN ENCLOSED BODY OF WATER DUE TO WIND ACTION.

(b) A Laboratory thesis study.
(d) Experimental, theoretical, M. S. Thesis.
(e) The project involves an experimental study of the velocity profile in an enclosed body of water due to wind blowing over the water. Of interest will be the equations for the velocity distribution and an evaluation of the effective surface roughness.

(5807) HYDROGRAPH LINEARITY IN AN ELEMENTARY CHANNEL.

(b) A Laboratory thesis study.
(d) Experimenta, M. S. Thesis.
(e) The condition of increasing spatially-varied flow in a channel was used to generate hydrographs that would occur in a first order stream in a natural basin with rapid overland flow. Tests were performed in a laboratory channel 80 ft long with uniform lateral inflow along the length of channel with various durations and intensities of lateral inflow.
(f) Completed.
(g) For hydrographs of equal duration of inflow the times of occurrence of peak discharges decreased with increasing inflow. The magnitude of peak discharges for hydrographs of equal duration of inflow were greater than the linear behavior assumed by unit hydrograph theory. The departure from linear behavior was most significant in tests where channel storage was greatest.
(h) "Hydrograph Linearity in an Elementary Channel," by A. F. Pabst, M. S. Thesis, University of Minnesota, December 1965. (Available on Inter-Library Loan from University of Minnesota.)

INTER-AGENCY SEDIMENTATION PROJECT IN COOPERATION WITH ST. ANTHONY FALLS HYDRAULIC LABORATORY.

(194) A STUDY OF METHODS USED IN MEASUREMENT AND ANALYSIS OF SEDIMENT LOADS IN STREAMS.

(b) Subcommittee on Sedimentation, Inter-Agency Committee on Water Resources, Personnel of the U. S. Army Corps of Engineers and the U. S. Geological Survey are actively engaged on the project.
(c) Engineer in Charge, Mr. John V. Skinner, Federal Inter-Agency Sedimentation Project, St. Anthony Falls Hydraulic Laboratory, Mississippi River at Third Ave., S. E., Minneapolis, Minnesota. 55414.
(d) Experimental; applied research and development.
(e) Drawings and specifications are available to facilitate the manufacture of suspended-sediment and bed-material samplers, particle-size analyzers, and associated laboratory equipment. Approved designs for the measurement of suspended sediment include a single-stage sampler, 4-,22-, and 62- pound depth-integrating samplers, and electrically operated point-integrating samplers weighing 100, 200, and 300 pounds. Samplers for the measurement of bed material include a piston-type hand-operated sampler, a 30-pound hand-line sampler, and a 100-pound sampler for cable suspension. Additional items are a sediment sample splitter, a bottom-withdrawal sedimentation tube for size analysis, and visual-accumulation sedimentation tubes with recording equipment for particle size analyses of sands. The primary objective of the current program is the development of an instrument to automatically record suspended-sediment concentrations in flowing streams.
(g) Field and laboratory tests have been continued on intermittent pumping-type samplers, turbidimeters and electrical and nuclear sensing devices. Field testing of the nuclear density probe was terminated. Preparation of a report on Laboratory Investigation of Pumping Sampler Intakes, designated Progress Report T, and the initial draft of a report on Turbidity Method for Suspended-Sediment Analysis are in progress. The report on the Use of the Sediment Density Probe was revised to include the period 1958 through 1964.
(h) "Electronic Sensing of Sediment," Report R, Progress Report, 80 pages, December 1964. For sale by the District Engineer, St. Paul District Corps of Engineers, 1217 U. S. Post Office and Custom House, St. Paul, Minnesota 55101. Price is 75 cents per copy.

SCRIPPS INSTITUTION OF OCEANOGRAPHY, University of California, San Diego.

(4500) A STUDY OF INTERNAL WAVES IN THE OCEAN.

(b) Laboratory project.
(c) Dr. Charles S. Cox, The Scripps Institution of Oceanography, La Jolla, California 92038.
(d) The project is theoretical, including field investigation and is basic research.
(h) "On Coherent Electric and Magnetic Fluctuations in the Sea," Charles Cox, Toshihiko Teramoto, and Jean Filloux, Studies on Oceanography (Hidaka Anniversary Volume), pp. 449-457 (1964).

(5922) MECHANICS OF SEDIMENT TRANSPORT BY WAVES AND CURRENTS.

(b) Coastal Engineering Research Center and Office of Naval Research.
(c) Dr. D.L. Inman and Mr. A.J. Bowen, Scripps Institution of Oceanography, La Jolla, California 92038.
(d) Field and experimental; basic research.
(e) (1) To measure the thresholds of sand motion and suspension under wave action. (2) To measure and compare the sediment transported with measurements of basic parameters such as orbital velocity and longshore currents. (3) To investigate the behavior of granular media under shearing stresses.
(g) Techniques have been established for photographically recording the movement of the sand and water over the ocean floor, using SCUBA divers. These results have then been compared with the pressure recordings taken at the same site and the wave height record above the site.
(h) Coastal Engineering Research Center Quarterly Progress Reports 1 through 9 covering the period 1 August 1963 to 30 September 1965. Office of Naval Research Progress Reports for the years 1962 to 1965.
"Flume Experiments on Sand Transport by Waves and Currents," D. L. Inman and A. J. Bowen, Proc. Eighth Conf. Coastal Engineering, pp. 137-150, 1963.

(5923) THE CIRCULATION OF WATER ON BEACHES.

(b) Laboratory project, Office of Naval Research.
(c) Mr. A. J. Bowen and Dr. D. L. Iman, Scripps Institution of Oceanography, La Jolla, Calif. 92038.
(d) Experimental, theoretical, and field; basic research for Ph.D. thesis.
(e) Field and laboratory study of waves and wave-induced currents on beaches. Theoretical work to study the reasons for the existence of rip currents and their influence on the nearshore regime.
(h) Office of Naval Research Progress Reports for the years 1963 to 1965.

(5924) INSTRUMENTATION IN THE NEARSHORE REGIME.

(b) Coastal Engineering Research Center.
(c) Mr. W. A. Koontz and Dr. D. L. Inman, Scripps Institution of Oceanography, La Jolla, Calif. 92038.
(d) Experimental and field; applied research.
(e) The development of a multi-purpose data acquisition system for use in all phases of study in the nearshore region. A multi-channel recorder contains both an analog output channel for immediate appraisal of data and also a digital read-out on magnetic tape. The tape can be input to the CDC-3600 computer for extensive analysis.
(h) Coastal Engineering Research Center Quarterly Progress Reports 1 through 9 covering the period 1 August 1963 to 30 September 1965. "A Multi-Purpose Data Acquisition System for Field and Laboratory Instrumentation of the Nearshore Environment," W. A. Koontz and D. L. Inman (in press).

(5925) WAVE ATTENUATION.

(b) Office of Naval Research.
(c) Dr. Walter H. Munk, Associate Director and Frank E. Snodgrass, Research Engineer, Institute of Geophysics and Planetary Physics University of California, San Diego, Calif. 92038.
(d) A field investigation to measure attenuation of ocean waves over very large distances.
(e) Wave stations were occupied for three months at six points along a great circle between New Zealand and Alaska. On the basis of a spectral analysis of these records the attenuation was studied.
(f) Completed.
(g) The observed attenuation is not inconsistent with the effect of nonlinear interactions between waves generated within the storm area.
(h) "Propagation of Ocean Swell Across the Pacific," F. E. Snodgrass, G. W. Groves, K. F. Hasselmann, G. R. Miller, W. H. Munk and W. H. Powers, Phil. Trans. Roy. Soc. (in press) 1965.

(5926) TIDE PREDICTION.

(b) U. S. Coast & Geodetic Survey.
(c) Dr. Walter H. Munk, Associate Director, Institute of Geophysics and Planetary Physics University of California, San Diego, Calif. 92038.
(d) Theoretical.
(e) Application of modern time series methods to prediction of tides.
(g) For stations with relatively small shallow water tides the method gives better predictions with fewer station constants.
(h) "Tidal Spectroscopy and Prediction," W. H. Munk and D. Cartwright, Phil. Trans. Roy. Soc. (in preparation) 1965.

(5927) DEEP SEA TIDES.

(b) Office of Naval Research.
(c) Dr. Walter H. Munk, Associate Director and Frank E. Snodgrass, Research Engineer, Institute of Geophysics and Planetary Physics University of California, San Diego, Calif. 92038.
(d) Field investigation.
(e) A self recording instrument package is dropped freely to the sea bottom and records, in situ, pressure, temperature and currents to a high degree of precision. The instrument is acoustically recalled from a surface vessel, typically after one month.

UNIVERSITY OF SOUTH CAROLINA, College of Engineering, Department of Civil Engineering.

Inquiries concerning the following projects should be addressed to Dr. Harold Flinsch, Civil Engrg. Department, University of South Carolina, Columbia, South Carolina 29208.

(4) THE DEVELOPMENT OF SURFACE WAVES BY WIND.

(b) Laboratory project.
(d) General theoretical, experimental, and field research.
(e) Research on the theories of surface wave origin and growth, on measurements in the laboratory and in nature, and on the comparative results of theory and measurement. Equipment has been assembled for telemetering and recording wave height, period, and direction.
(g) A lake shore receiving and recording station is under construction.

(1631) THE EFFECT OF WAVES ON BEACHES.

(b) Laboratory project.
(d) General theoretical, experimental, and field research.
(e) Research on beach slopes and contours, in the laboratory and in nature.
(g) Eight-directional wave tank has been completed.

(1907) SHIP STABILITY AND ROLLING PERIOD.

(b) Laboratory project.
(d) General theoretical, experimental, and field research.
(e) Rolling and pitching period and metacentric height relationships are studied for stationary and moving ships, in still water and under wave action.
(g) Model experiments have been assembled in a brief report.

(4701) THE EFFECT OF TIDES ON HARBORS, BAYS, AND ESTUARIES.

(b) Laboratory project.
(d) General theoretical, experimental, and field research.
(e) A study of the scouring or shoaling effect of tidal currents in South Carolina harbors and estuaries.

SOUTHWEST RESEARCH INSTITUTE, Department of Mechanical Sciences.

(4216) STUDIES OF FUEL SLOSHING.

(b) National Aeronautics and Space Admin., Marshall Space Flight Center.
(c) Dr. H. N. Abramson, Director, Department of Mechanical Sciences, Southwest Research Institute, 8500 Culebra Road, San Antonio, Texas 78206.
(d) Theoretical and experimental; applied research.
(e) Studies of forces and moments in missile fuel tanks resulting from sloshing motions of fuel.
(f) Completed.
(h) Eleven SwRI technical reports have been issued under this project; six of these have been published in technical journals of AIAA.

(4217) LIQUID DYNAMIC BEHAVIOR IN ROCKET TANKS.

(b) National Aeronautics and Space Administration, Washington, D. C.
(c) Dr. H. N. Abramson, Director, Department of Mechanical Sciences, Southwest Research Inst., 8500 Culebra Road, San Antonio, Texas 78206.
(d) Theoretical and experimental; applied research.
(e) Current interest is concerned with nonlinear aspects of lateral sloshing.
(f) Completed.
(h) "Some Studies of Nonlinear Lateral Sloshing in Rigid Containers," by H. N. Abramson, W. H. Chu, and D. D. Kana, Journal of Applied Mechanics (ASME), in press.

(4702) HYDRODYNAMICS OF SHIP ANTI-ROLL TANKS.

(b) Bureau of Ships, Department of the Navy (DTMB technical supervision).
(c) Mr. John F. Dalzell, Senior Research Engineer, Department of Mechanical Sciences, Southwest Research Institute, 8500 Culebra Road, San Antonio, Texas 78206.
(d) Theoretical and experimental; applied research.
(e) Studies of forces and damping effects in passive anti-roll stabilization tanks for ships.
(h) Two SwRI technical reports.

(4704) VIBRATION OF HYDROFOIL STRUCTURES.

(b) Bureau of Ships, Department of the Navy (DTMB technical supervision).
(c) Mr. Jack T. Irick, Senior Research Engineer, Department of Mechanical Sciences, Southwest Research Institute, 8500 Culebra Road, San Antonio, Texas 78206.
(d) Theoretical and experimental; applied research.
(e) Study of the vibration characteristics of hydrofoil-type structures.
(f) Completed.
(h) Two SwRI technical reports; "Vibration Characteristics of Representative Hydrofoil Configurations" by J. T. Irick, Proceedings First Conference on Ship Vibration, pp. 195-208, January 1965.

(4927) LIQUID DYNAMIC BEHAVIOR IN TANKS UNDER AXIAL OSCILLATION.

(b) National Aeronautics and Space Administration, Marshall Space Flight Center.
(c) Dr. H. N. Abramson, Director, Dept. of Mechanical Sciences, Southwest Research Institute, 8500 Culebra Road, San Antonio, Texas 78206.
(d) Theoretical and experimental; applied research.
(e) Studies of nonlinear liquid motions in rigid and elastic tanks undergoing axial oscillations.
(h) Four Southwest Research Institute technical reports.

(5266) HYDROELASTIC STUDIES OF SUPERCAVITATING HYDROFOILS.

(b) Bureau of Ships, Dept. of the Navy.
(c) Dr. H. N. Abramson, Director, Dept. of Mechanical Sciences, Southwest Research Institute, 8500 Culebra Road, San Antonio, Texas 78206.
(d) Theoretical and experimental; applied research.
(e) Design, construction, and testing of dynamic supercavitating hydrofoil models to obtain data on unsteady hydrodynamic lift and moment for a variety of operating conditions.

(5267) MONOGRAPH ON LIQUID DYNAMIC BEHAVIOR IN ROCKET PROPELLANT TANKS.

(b) National Aeronautics and Space Administration, Washington, D. C.
(c) Dr. H. N. Abramson, Director, Dept. of Mechanical Sciences, Southwest Research Institute, 8500 Culebra Road, San Antonio, Texas 78206.
(d) Theoretical; applied research.
(e) Preparation of a monograph on stated subject.

(5663) MONOGRAPH ON HYDROELASTIC PROBLEMS OF HYDROFOIL CRAFT.

(b) Bureau of Ships, Department of the Navy (DTMB technical supervision).
(c) Dr. H. N. Abramson, Director, Dept. of Mechanical Sciences, Southwest Research Institute, 8500 Culebra Road, San Antonio, Texas 78206.
(d) Theoretical; applied research.
(e) Preparation of a monograph on stated subject.

STANFORD UNIVERSITY, Department of Civil Engineering.

(1946) HYDROLOGIC SYNTHESIS.

(b) National Science Foundation.
(c) Prof. Ray K. Linsley and N. H. Crawford, Dept. of Civil Engineering, Stanford Univ., Stanford, Calif. 94305.
(d) Theoretical and field research.
(e) Detailed digital computer synthesis models are used to investigate the interaction of physical variables in the hydrologic cycle.
(g) A simplified mathematical treatment of non-equilibrium overland flow has been developed. Digital computer programs to simulate non-equilibrium overland and channel flow in rivers and streams have been developed. A statistical analysis of soil-moisture frequency has been completed. Synthesis models which calculate continuous streamflow from rainfall, temperature, and potential evapotranspiration data have been developed and application of these models to ungaged

areas is being studied together with related applications for engineering design.

(3507) STUDY OF INFILTRATION.

(b) U. S. Public Health Service.
(c) Prof. Joseph B. Franzini, Dept. of Civil Engineering, Stanford University, Stanford, California 94305.
(d) Theoretical investigation; laboratory and field studies; basic research; Ph.D. theses.
(e) An attempt is being made to develop relations between soil parameters and infiltration capacities. Investigation is being extended to unsteady unsaturated flow through soils as experienced in capillary rise, drainage, and infiltration situations.
(g) An analytic approach to the solution of unsteady unsaturated flow in soils has been developed. If the initial moisture condition and the hydraulic and capillary characteristics of the soil are known, the method permits prediction of the future disposition of soil moisture. Experiments using a gamma source for moisture content have been conducted. Some effects of trapped air on infiltration have been investigated. An analytical method for the solution of unsteady, unsaturated flow from a cylindrical source has been developed, and currently, the effect of a substantial initial pressure head on such flows is under investigation.
(h) "Unsteady and Unsaturated Flow in soils in Two-Dimensions," by Rameshwar Singh, Technical Report No. 54, Dept. of Civil Engrg., Stanford University, 1965.

(4219) SUPERCAVITATING HYDROFOIL THEORY.

(b) David Taylor Model Basin, Bureau of Ships, Navy Department.
(c) Professors R. L. Street and B. Perry, Dept. of Civil Engrg., Stanford Univ., Stanford, Calif. 94305.
(d) Theoretical, basic research for Ph.D. theses and post-doctoral research.
(e) Examination is being made of forces acting on fully cavitating bodies. Effects of free surfaces, gravity, angle of attack, rotation, etc. are being studied. Linearized, non-linearized and finite-difference numerical analyses are conducted.
(g) Rotation, gravity, free surface and tandem interference effects between bodies have been shown to have important roles in fully cavitating flows.
(h) "A Note on Gravity Effects in Supercavitating Flow," by R. L. Street, J. Ship Research, V. 8, No. 4, Mar. 1965.
"A Nonlinear Theory for Symmetric, Supercavitating Flow in a Gravity Field," by C. W. Lenau and R. L. Street, J. Fluid Mech., V. 21, No. 2, 1965.
"Tandem Interference Effects of Supercavitating Struts," by T. Green, III, and R. L. Street, Ingenieur-Archiv, Band 34, Heft 4, 1965.
"A Riemann-Hilbert Problem for Nonlinear, Fully Cavitating Flow," by B. E. Larock and R. L. Street, to appear J. Ship Research, 1965.

(4916) DISPERSION OF POLLUTANTS IN FLOW THROUGH POROUS MEDIA.

(b) Laboratory project.
(c) Prof. E. Y. Hsu and R. L. Street, Dept. of Civil Engrg, Stanford Univ., Stanford, Calif. 94305.
(d) Basic experimental and theoretical research for Ph.D. thesis.
(e) Study of hydrodynamic dispersion in porous media. Complex variable analysis of flow fields is combined with a convective dispersion equation to define time-space history of pollutant concentrations. Effects of channel boundary shapes and free streamlines on dispersion are to be studied also.
(g) Theoretical and experimental analyses in progress.

(4917) MECHANISMS INVOLVED IN WIND-GENERATED WAVES.

(b) Fluid Mechanics Branch, Math. Sci. Div., Office of Naval Research.
(c) Prof. E. Y. Hsu and R. L. Street, Dept. of Civil Engrg., Stanford Univ., Stanford, Calif. 94305.
(d) Experimental and theoretical basic research for doctoral theses.
(e) Examination, experimental verification, and extension of available theory are the purpose of this project. A steady flow model of the wind-wave problem is being constructed in the laboratory.
(g) Miles' wave generation theory has been verified for moving wavy boundary in a shear flow.

(5453) STUDIES OF LARGE WAVES.

(b) Field Projects Branch, Earth Sciences Div., Office of Naval Research.
(c) Prof. R. L. Street, Dept. of Civil Engrg., Stanford Univ., Stanford, Calif. 94305.
(d) Experimental investigation; master's and Ph.D. project.
(e) Study of and verification of theory regarding characteristics of large waves-breaking, shoaling, and run-up. Wave-shore interaction. Facility under construction.

(5454) STUDIES ON WIND-WAVE INTERACTIONS.

(b) National Science Foundation.
(c) Prof. E. Y. Hsu, Dept. of Civil Engrg., Stanford Univ., Stanford, Calif. 94305.
(d) Experimental; Ph.D. theses.
(e) The experiments include pressure, velocity, wave form, and spectral measurements in the region of, and at, the interface. They are designed to study the mechanism of energy transfer between the air and the water.
(h) "A Wind, Water-wave Research Facility," by E. Y. Hsu. Technical Report No. 57, October 1965, Dept. of Civil Engrg., Stanford Univ.

STEVENS INSTITUTE OF TECHNOLOGY, Davidson Laboratory.

(3516) INVESTIGATION OF HULL BENDING MOMENTS IN WAVES.

(b) Ship Structure Committee.
(c) Mr. Edward Numata, Davidson Laboratory, Stevens Institute of Tech., 711 Hudson St., Hoboken, N. J. 07030.
(d) Experimental; applied research.
(e) A model of the cargo ship WOLVERINE STATE will be instrumented to measure vertical and lateral wave bending moments at the same location used aboard ship for strain gage measurements during actual voyages. Model will be run at a range of headings to regular waves with a range of lengths. Prediction of ship bending moments in realistic seas will be made for correlation with bending moment data collected aboard ship.
(h) "Further Investigation of Bending Moments within Midship Half-Length of a Mariner Model in Extreme Waves," N. M. Maniar and E. Numata (in preparation).

(4226) INVESTIGATION OF SURFACE-PIERCING FULLY VENTILATED DIHEDRAL HYDROFOILS.

(b) Office of Naval Research, Department of the Navy.
(c) Mr. P. Ward Brown, Chief of High Speed Craft Division, Davidson Laboratory, Stevens Inst. of Tech., 711 Hudson Street, Hoboken, New Jersey 07030.
(d) Experimental and theoretical; applied research.
(e) A continuing investigation aimed at providing basic design information on three-dimensional hydrofoils operating near a water surface, under conditions of either fully wetted or fully ventilated flow. To date the forces and moments on a

series of surface piercing dihedral hydrofoils have been measured and the dynamics of systems employing such foils has been studied, including the problem of a hydrofoil impacting on the water surface and the stability of hydrofoil craft, and their response in waves.

(g) Analytical expressions for the forces and moments on surface piercing fully wetted and fully ventilated dihedral hydrofoils, including the effect of flaps, have been obtained and confirmed experimentally. Unsteady problems including those of stability, impact and ventilation of such foils have also been dealt with. The conventional linearized supercavitating foil theory has been extended to cover the entire angle of attack range with simplicity and precision. The response of surface piercing hydrofoil systems in irregular waves has been analyzed and techniques developed and proved experimentally for making predictions of the time history of motion response in irregular waves.

(4227) SMOOTH WATER BEHAVIOR OF SURFACE-PIERCING HYDROFOIL VESSEL.

(b) Office of Naval Research, Fluid Dynamics Branch, Navy Dept.

(c) Dr. A. Strumpf, Head Underwater Weapons Div., Davidson Lab., Stevens Inst. of Tech., 711 Hudson St., Hoboken, N. J. 07030.

(d) Theoretical and experimental; applied research.

(e) The aim of the study made of the smooth water operation of a 110-ton craft supported by a tandem set of surface piercing hydrofoils is to develop the motion equations and determine the hydrodynamic data necessary to predict the motions of such craft in six degrees of freedom. Many of the necessary hydrodynamic coefficients were obtained from rotating-arm experiments, and many of the coefficients also were predicted using formulations based on available theory. Reasonable agreement was obtained between the predictions and measurements. The motions of the craft under the action of the rudder and its stability in six degrees of freedom were determined numerically using the UNIVAC 1105 computer at Stevens Institute of Technology.

(g) A technical report is in preparation. The experimental phases of this report have been completed.

(4229) THE BOUNDARY LAYER UNDER PROGRESSIVE AND STANDING WAVES.

(b) Office of Naval Research, Dept. of the Navy.

(c) Dr. S. J. Lukasik, Chief, Fluid Physics Division, Davidson Laboratory, Stevens Inst. of Tech., 711 Hudson St., Hoboken, N. J. 07030.

(d) Experimental, theoretical, and field investigations; basic research.

(e) The purpose of this work is to study energy loss processes in shallow water waves. Theoretically, this is of interest because unsteady viscous flows have received relatively little attention, particularly the case of an oscillatory flow with no mean flow. Analytical and numerical solutions of the non-linear Navier-Stokes equations are under investigation. Laboratory measurements in the Stevens shallow water wave channel have been made of the wave attenuation coefficient of a progressive wave, the bottom shear stress under a progressive wave, and the time decay of standing waves. Field measurements of the bottom pressure and bottom velocity in 40 foot depths have been made off Block Island, R.I. These field measurements provide the possibility of determining the applicability of the laboratory measurements and the theoretical studies to the geophysical problem of the energy loss by ocean waves in shallow coastal waters.

(g) Direct measurement of the wave attenuation coefficient both at Stevens and MIT indicated that the energy dissipation in a shallow water gravity wave exceeded that which would be expected from a linearized laminar solution of the Navier-Stokes equation valid in the bottom boundary layer. Several hypotheses have been examined in order to reconcile the discrepancy. It appears that the cause of the excess attenuation lies in the fact that the finite amplitude nature of the wave potential flow must be considered when formulating the boundary layer problem. For small deviations from infinitesimal amplitude theory, the Stokes approximation is valid. The attenuation theory, when revised to include the effect of the first two harmonics as well as the fundamental frequency, is then in much better agreement with the laboratory measurements of the attenuation. Oceanographic studies to relate the theory and laboratory work on the attenuation of gravity waves to the case of ocean swell are continuing.

(5058) UNSTEADY LOADS ON TEED HYDROFOILS IN OBLIQUE SEAS.

(b) Bureau of Ships, Dept. of the Navy.

(c) Dr. S. Tsakonas, Head of Fluid Dynamics Div., and Mr. Charles J. Henry, Research Engineer, Davidson Lab., Stevens Institute of Tech., 711 Hudson St., Hoboken, N. J. 07030.

(d) Experimental and theoretical; basic research.

(e) To investigate the forces and moments acting on hydrofoil struts and foils while operating in oblique regular waves.

(f) At the stage of completion.

(g) A theoretical method has been evolved for the evaluation of the loading distribution on a hydrofoil of finite aspect ratio for arbitrary orientation and various free surface conditions when operating in an unsteady flow field. A numerical program has been developed for the case of the fully submerged foil operating in unsteady and steady-state flow. Systematic experiments have been conducted for the cases of hydrofoil and strut alone and for combinations in the form of teed hydrofoils operating in irregular sea conditions at various headings.

(h) Davidson Laboratory Report 1118.

(5060) UNSTEADY LIFTING SURFACE THEORY FOR A MARINE PROPELLER OF AN ARBITRARY PITCH ANGLE WITH CHORDWISE LOADING DISTRIBUTION.

(b) David Taylor Model Basin, Bureau of Ships, Dept of the Navy.

(c) Dr. S. Tsakonas, C. Y. Chen and W. R. Jacobs, Davidson Lab., Stevens Inst. of Tech., 711 Hudson St., Hoboken, New Jersey 07030.

(d) Theoretical; applied research.

(e) To solve the surface integral equation relating the unknown loading distribution on the propeller blade lying on a helicoidal surface of an arbitrary pitch with the known velocity distribution induced by the presence of a hull, by utilizing the first term of the Birnbaum chordwise distribution in conjunction with the Glauert lift operator, and without resorting to any mathematical simplification in treating the helicoidal surface.

(f) Completed.

(g) Assuming that the helicoidal surface may be treated as a "staircase" function is workable in contrast to the simplification of the directional derivatives. The staircase function approximation eliminates the deterrent to a closed-form evaluation of the kernel function.

(h) Davidson Laboratory Report 1117.

(5062) EFFECT OF PLANFORM VARIATIONS ON HYDROFOIL FLUTTER.

(b) Bureau of Ships, Dept. of the Navy.

(c) Mr. Charles J. Henry, Research Engineer, Davidson Lab., Stevens Institute of Tech., 711 Hudson St., Hoboken, N. J. 07030.

(d) Experimental and theoretical; basic research.

(e) Measurements of flutter speed were obtained

for a two degree of freedom system including the effects of sweep, taper and aspect ratio. The results were compared with predictions using two-dimensional stripwise theory and will be compared with three-dimensional lifting surface theory.

(f) Completed.

(g) Two-dimensional strip theory prediction of flutter speed did not agree with measured values for a 15° swept foil nor for two tapered foils with taper ratios of 2/3 and 1/3. The asymptotic behavior of flutter speed at low density ratio remains in the two degree of freedom system even with sweep and/or taper and is not accurately predicted by two-dimensional strip theory. The measured flutter speed on a foil with rectangular planform increased with decreasing aspect ratio.

(h) "Hydrofoil Flutter Phenomenon and Airfoil Flutter Theory - Volume III: Sweep and Taper," C. J. Henry and M. R. Ali, to be published as Davidson Laboratory Report. "Hydrofoil Flutter Phenomenon and Airfoil Flutter Theory - Volume IV: Finite Aspect Ratio," C. J. Henry and M. R. Ali, to be published as Davidson Laboratory Report.

(5064) INVESTIGATION OF SHIP MOTIONS.

(b) U. S. Naval Training Devices Center, Dept. of the Navy.

(c) Prof. Earl M. Uram, Staff Scientist, Davidson Laboratory, Stevens Inst. of Tech., 711 Hudson St., Hoboken, N. J. 07030.

(d) Theoretical and experimental; basic research.

(e) Development of equations of motion of ships in very low speed maneuvering condition to be applied to a simulator for training.

(g) Analysis of general linearized motion equations including terms of importance at very low speeds. Experimental model and full scale program to determine static and dynamic derivatives of importance for inclusion in computer programs for calculating responses to bridge commands.

(5309) ESTIMATION OF STABILITY DERIVATIVES AND INDICES OF VARIOUS SHIP FORMS, AND COMPARISON WITH EXPERIMENTAL RESULTS.

(b) David Taylor Model Basin, Office of Naval Research, Dept. of the Navy.

(c) Miss Winnifred R. Jacobs, Research Engr., Davidson Laboratory, Stevens Institute of Technology, 711 Hudson Street, Hoboken, N. J. 07030.

(d) Theoretical; applied research.

(e) An analytical method is devised for estimating stability derivatives which combines Albring's empirical modifications of simplified flow theory with aerodynamic wing theory. The method is then checked by comparing calculated derivatives with those computed from experimental data obtained in rotating-arm tests.

(f) Completed.

(g) Comparison with experimental results in 35 cases, including two families of hulls of 8 members each, show that the stability derivatives and indices determined by the analytical method are of the right order of magnitude and indicate correct trends. The method can predict relative effects of changes in ship form geometry and effects of changes in skeg and rudder area.

(h) "Estimation of Stability Derivatives and Indices of Various Ship Forms and Comparison with Experimental Results," W. R. Jacobs, Davidson Laboratory Report 1035, September 1964. To be published in the Journal of Ship Research.

(5310) ACOUSTIC PROPERTIES OF BUBBLES IN PRESSURE FIELDS.

(b) David Taylor Model Basin, Bureau of Ships.

(c) Professor E. M. Uram, Staff Scientist, Davidson Laboratory, Stevens Institute of Tech., 711 Hudson Street, Hoboken, New Jersey 07030.

(d) Experimental; basic research.

(e) Study of the sound produced by a single gas bubble in the presence of boundaries generating a varying pressure field in the flow direction.

(5311) STRUCTURE OF TURBULENT WAKES WITH ASYMMETRIES.

(b) David Taylor Model Basin, Bureau of Ships.

(c) Prof. E. M. Uram, Staff Scientist, Davidson Laboratory, Stevens Institute of Technology, Castle Point Station, Hoboken, N. J. 07030.

(d) Experimental; basic research.

(e) Determination of turbulent structure of wakes very near bodies of revolution with systematically varied asymmetries. Particular attention to distortion imposed by asymmetries and circumferential eddy structure.

(5312) INVESTIGATE GAIN IN WATER SPEED OBTAINED BY COUPLING AMPHIBIOUS CRAFT.

(b) Office of Naval Research, Dept. of the Navy.

(c) Mr. Howard Dugoff, Chief, Vehicle Research Division, or Mr. Robert L. Van Dyke, Research Engineer, Davidson Laboratory, Stevens Institute of Technology, Castle Point Station, Hoboken, N. J. 07030.

(d) Experimental investigation; applied research.

(e) Towing tank scale model tests are being conducted to determine the hydrodynamic drag reduction attainable through coupling of amphibious vehicles in train configuration. Limited tests of directional behavior in waves also have been made.

(g) Results to date are extremely encouraging; total resistance for a train of five LVTP-5 amphibians is less than twice as great as the resistance of a single vehicle. Assuming that propulsive efficiency is unaffected by coupling, this represents a potential speed gain of almost 50%. Insofar as performance at sea is concerned, the tests to date indicate that resistance of the train to broaching is no worse than the very stable single LVTP-5.

(5313) HYDRODYNAMIC TRACK PROPULSION.

(b) Office of Naval Research.

(c) Mr. Howard Dugoff, Chief, Vehicle Research Division or John A. Mercier, Research Engr., Davidson Lab., Stevens Institute of Tech., Castle Point Station, Hoboken, N. J. 07030.

(d) Experimental and theoretical investigations; applied research.

(e) The purpose of the study is to investigate the mechanism by which floating land vehicles propel themselves through water by use of their tracks only. Towing tank tests are being conducted using a non-operating track section. A theoretical performance analysis of the test configuration is also being made for comparison with the experiments. The results of this initial program are intended to provide data for the optimum design of an operating track model to be built and tested in a subsequent study.

(g) The most promising prospect for improving the efficiency of the track propulsion appears to be the application of the Voith-Schneider propeller principle to the track, i.e., the use of cams to vary the attitude of the track cleats as they rotate. It is now proposed to build an operating model track incorporating this principle for evaluation of its feasibility. The results of the tests with the static model indicate that the cleat spacing should be made as small as practical and that the influence of their aspect ratio is not great.

(5314) HYDRODYNAMIC WHEEL PROPULSION OF FLOATING LAND VEHICLES.

(b) U. S. Army Tank Automotive Center.

(c) Mr. Howard Dugoff, Chief, or H. M. Parekh,

(e) The fluid dynamic mechanism by which a floating land vehicle can propel itself through water by spinning its fully submerged wheels is being investigated. Studies are being conducted on two related yet essentially distinct aspects of the problem:
Phase 1-Hydrodynamic Studies of Spinning Disk. Tests are being conducted to determine the thrust force which acts on a disk rotating about an axis parallel to a plane boundary. The experiments are being performed for comparison with a proposed theoretical solution, reported on in the 1964 issue (reference number 5067), intended to provide an insight into the basic elements of the wheel propulsion phenomenon.
Phase 2-Tests on Scale Model of Floating Cargo Truck. Towing tank tests of self-propelled scale model of a five ton army cargo truck are being conducted in an effort to develop a scale model technique for studying the hydrodynamic performance of wheel-propelled vehicles.
(g) Phase 1-The experimental results follow the trends predicted by the theory. In general, however, the measured values of thrust are lower than the theoretical predictions. It is felt that this may be due primarily to deficiencies inherent in the available apparatus and in the test setup employed. Thus additional tests with an improved setup are planned.
Phase 2-Attempts are being made to circumvent the inability to attain total dynamic similarity (due to the familiar Reynolds No. - Froude No. incompatibility), by use of some empirical distortion factors in conjunction with tests under partially similar conditions. To date, no satisfactory procedure has been developed, but work is still in progress.

(5928) ROUGH WATER TAKE-OFF RESISTANCE OF HYDROFOIL SHIP HULLS.

(b) David Taylor Model Basin.
(c) Mr. Edward Numata, Davidson Lab., Stevens Inst. of Tech., 711 Hudson St., Hoboken, New Jersey 07030.
(d) Experimental; applied research.
(e) A systematic study of the rough water resistance of hull forms suitable for use with hydrofoils, as a function of wave steepness, and frequency of encounter, with and without a range of foil restoring and damping forces and moments.

(5929) THE OSCILLATION OF A FLAT PLATE IN A STREAM OF VISCOUS LIQUID.

(b) Laboratory project.
(c) Prof. T. V. Davies, Davidson Lab., Stevens Inst. of Tech., 711 Hudson St., Hoboken, New Jersey 07030. Senior Visiting Scientist from Univ. College of Wales, Aberystwyth.
(d) Theoretical; applied research.
(e) The longitudinal and transverse oscillations of a flat plate in a stream of viscous liquid is being solved on the basis of Oseen's equations. The problem is reduced to solving coupled integral equations.
(g) The longitudinal oscillation problem is completely solved and closed expressions for the drag in terms of Reynolds number k and reduced frequency ω have been found in the case of large and small Reynolds numbers.

(5930) PUBLICATION OF AMPHIBIAN RESEARCH STUDIES.

(b) Office of Naval Research, Dept. of the Navy.
(c) Mr. Howard Dugoff, Chief, Vehicle Research Div., or Mr. I. O. Kamm, Asst. Manager, Transportation Research Group, Davidson Lab., Stevens Inst. of Tech, Castle Point Station, Hoboken, New Jersey 07030.
(d) Applied research.
(e) The object of this program is to organize, review, and publish the results of a comprehensive study of wheeled amphibious vehicles performed earlier (1956-59) by the Davidson Lab. under a contract with the U. S. Army Ordnance Tank-Automotive Command. The comprehensive study was halted shortly before its completion, when cognizance over amphibious vehicle development was transferred from the sponsor.

(5931) MODEL STUDY OF DOCKING CHARACTERISTICS OF LARC AMPHIBIANS.

(b) U. S. Army Mobility Equipment Center.
(c) Mr. Howard Dugoff, Chief, Vehicle Research Div., Davidson Lab., Stevens Institute of Tech., Castle Point Station, Hoboken, N. J. 07030.
(d) Experimental; applied research and development.
(e) Scale model tests have been conducted to determine methods for improving the docking performance of the LARC V amphibian by changing the rudder shape, stern configuration, rudder post location, and mooring line attachment location. Full scale tests are also being conducted by the Army to verify the model results. Davidson Lab. personnel are cooperating in these tests, and also are continuing the model studies in an attempt to extend the present results from the point of view of general applicability to amphibious vehicle design.
(g) It was found in the model tests that the lateral force available to hold the LARC V at dockside could be increased materially, without modification to the hull, by use of a new rudder in the shape of a truncated pyramid with a vertical center plate. The tests also demonstrated that a change in the mooring line attachment location would improve operational performance significantly.

(5932) HYDROPLANING OF AIRCRAFT TIRES.

(b) National Aeronautics & Space Administration.
(c) Mr. Howard Dugoff, Chief, Vehicle Research Div., Davidson Lab., Stevens Inst. of Tech., Castle Point Station, Hoboken, N. J. 07030.
(d) Experimental and theoretical; applied research.
(e) A systematic experimental study is being made of the various parameters affecting hydroplaning of pneumatic aircraft tires. Model tests are being conducted on the Davidson Laboratory rolling road facility; tires may be mounted above this rolling road so that with the tire mount stationary, the tire behavior may be studied and the tire loads measured as functions of rolling speed. The model tires are fabricated of polyurethane foam, whose density is varied to simulate variations in pneumatic tire inflation pressure. Static and dynamic tests of these models indicate that they are geometrically similar to the prototype pneumatic tires as they deform under load. A quantitative theoretical description of the hydroplaning phenomenon also is being sought.
(g) No quantitative experiments have been conducted to date. The results of exploratory qualitative tests, however, have been quite encouraging; hydroplaning of model tires has occurred at speeds predictable by the currently accepted empirical theory. On the theoretical end, equations have been developed to describe dynamic (non-viscous) hydroplaning phenomena in three dimensions. An approximate solution to these equations has been effected which provides agreement in trend, but not magnitude, with test data.

(5933) STUDY OF 1/4-TON TRUCK FLOATING CONCEPTS.

(b) U. S. Army Tank-Automotive Center.
(c) Mr. Howard Dugoff, Chief, or Mr. George M. Worden, Research Engineer, Vehicle Research Div., Davidson Lab., Stevens Inst. of Tech., Castle Point Station, Hoboken, N. J. 07030.
(d) Experimental and theoretical; applied research and development.

(e) This program has two main objectives: (1) To evaluate specific proposed 1/4-ton truck concepts relative to their performance in crossing water obstacles, and (2) to develop general methods for evaluating such vehicles on an objective basis. Specific evaluations will include consideration of expected water speed, rough water characteristics, and water entrance and exit problems.

(5934) INVESTIGATION OF SWIMMING PERFORMANCE OF A PROPOSED 1 1/2-TON MARGINAL TERRAIN VEHICLE.

(b) U. S. Army Tank-Automotive Center.
(c) Mr. Howard Dugoff, Chief, or Mr. H. M. Parekh, Research Engineer, Vehicle Research Div., Davidson Lab., Stevens Inst. of Tech., Castle Point Station, Hoboken, N. J. 07030.
(d) Experimental development.
(e) The object of this program is to optimize the swimming capabilities of a proposed 1 1/2-ton marginal terrain vehicle currently under development for the U. S. Marine Corps by the contractor. To this end, experiments are to be made with a working scale model of one of the vehicle's air-bag type tracks, in the proximity of a model hull simulator. Parameters to be investigated include bag diameter, bag spacing, bag aspect ratio, bag air pressure, track speed, depth of submergence, and entrance and exit angles.

(5935) UNSTEADY LOADS ON DUCTED PROPELLERS AND NOZZLES.

(b) David Taylor Model Basin, Bureau of Ships, Dept. of the Navy.
(c) Dr. S. Tsakonas, Head, Fluid Dynamics Div., and Mr. J. Mercier, Research Engineer, Davidson Lab., Stevens Inst. of Tech., 711 Hudson St., Hoboken, N. J. 07030.
(d) Theoretical; applied research.
(e) To develop a method of determining the unsteady and steady loading on a ducted propeller and its enshrouding nozzle operations in a three-dimensional non-uniform flow field. The present phase is concerned with derivation of the pair of surface integral equations governing the interaction problem and their reduction to a pair of corresponding line integral equations by the mode approach and lift operator technique.

(5936) PROPELLER-SINGING PHENOMENON AS A SELF-EXCITED VIBRATION SYSTEM.

(b) David Taylor Model Basin, Bureau of Ships, Department of the Navy.
(c) Dr. S. Tsakonas, Head of Fluid Dynamics Div., Davidson Lab., Stevens Inst. of Tech., 711 Hudson St., Hoboken, N. J. 07030.
(d) Theoretical; applied research.
(e) To improve the mathematical model introduced in the previous study at Davidson Lab. for the propeller singing phenomenon as a self-excited vibration system and to develop expressions for the acoustic signal produced by the propeller at the singing stage.

(5937) PROPELLER-RUDDER INTERACTION.

(b) David Taylor Model Basin, Bureau of Ships, Department of the Navy.
(c) Dr. S. Tsakonas, Head of Fluid Dynamics Div., and Miss W. R. Jacobs, Senior Research Engr., Davidson Lab., Stevens Institute of Tech., 711 Hudson St., Hoboken, N. J. 07030.
(d) Theoretical; applied research.
(e) To evaluate theoretically the loading distribution on a rudder of finite aspect ratio in the presence of a propeller operating in three-dimensional non-uniform flow and to determine the rudder torque and side force.

(5938) UNSTEADY LOADS ON A MARINE PROPELLER.

(b) David Taylor Model Basin, Bureau of Ships, Department of the Navy.
(c) Dr. S. Tsakonas, Head of Fluid Dynamics Div., and Miss W. R. Jacobs, Senior Research Engr., Davidson Lab., Stevens Inst. of Tech., 711 Hudson St., Hoboken, N. J. 07030.
(d) Theoretical; applied research.
(e) To determine the loading distributions and vibratory thrust and torque on a rotating propeller operating in a non-uniform three-dimensional flow. The resulting integral equation is solved by the mode approach in conjunction with the Glauert lift operator.

(5939) BOUNDARY LAYER BEHAVIOR ON ROUGH SURFACES.

(b) Commercial Ship Operator.
(c) Prof. E. M. Uram, Staff Scientist, Davidson Lab., Stevens Inst. of Tech., 711 Hudson St., Hoboken, New Jersey 07030.
(d) Experimental, theoretical; basic research.
(e) Study of boundary layer growth and turbulence structure on rough surfaces. Includes various geometrically regular roughness elements and distributions and random roughness typical of ship hull plates.

ROBERT TAGGART INCORPORATED.

(4863) DIMENSIONAL EFFECTS ON HYDROPHONE OUTPUT IN THE NEAR FIELD.

(b) David Taylor Model Basin, Department of the Navy.
(c) Robert Taggart, President. Robert Taggart Incorporated, 3930 Walnut Street, Fairfax, Virginia 22030.
(d) Experimental; applied research.
(e) Measurements were made of the outputs of two cylindrically shaped hydrophones, 5/8" and 2" diameter, whose bases formed the active area. The hydrophones were mounted in a closed trunk over a flat flexible plate forming part of the wall of a rectangular water tunnel. The distances between the active face and the plate were 1/8", 1/4", 1/2", 1", 2" and 4", while the flow velocities through the main pipe ranged from 6 to 13 kts. These tests were conducted to determine whether a "distance" effect, previously noted, could be reproduced in a laboratory facility.
(f) Completed.
(g) It was found that a relation did exist between output levels and distance, the higher level occurring at the closest position. During the process of reducing the data, there was some evidence of an "area" effect also, at least for the two closest positions of the hydrophones.

(4864) SEA-CHEST STRAINER PLATE SUCTION.

(b) Bureau of Ships, Department of the Navy.
(c) Robert Taggart, President, Robert Taggart Inc. 3930 Walnut Street, Fairfax, Virginia 22030.
(d) Experimental; applied research.
(e) An experiment was performed in a 2" x 8" plastic water tunnel, to determine the acoustic effects of a fully developed turbulent boundary layer sucked through a model strainer plate. The plate is flush-mounted in the lower tunnel wall and contains 1100 holes 1/16" diameter. Flow through the plate is by gravity and all throttling and flow control is by pinch-type Flex valves. Flush-mounted hydrophones and accelerometers provide a measure of the boundary layer pressure fluctuations and the acoustic radiation at several locations near the strainer plate. The ratio of suction velocity through the plate to the maximum velocity across the plate is varied.
(f) Completed.
(g) The model experiments show that the source of noise in such a configuration is definitely related to the suction through the strainer plate holes. This source is seen to be broadband in nature resulting from the combination of a large series of discrete frequencies comprising jet-tones originating

in each of the openings.

(5189) ACOUSTIC EXCITATION OF FLAT PLATES BY TURBULENT FLOW.

(b) David Taylor Model Basin, Dept. of the Navy.
(c) Robert Taggart, President, Robert Taggart Inc., 3930 Walnut St., Fairfax, Virginia 22030.
(d) Experimental; applied research.
(e) Tests were carried out in a rectangular water tunnel in which various thin flat plates were mounted flush with the tunnel wall. (1) Using a 1/16" thick stainless steel plate, the investigation was directed toward correlation of the boundary layer characteristics with the pressure spectra of a flush-mounted pencil-end hydrophone and an accelerometer located on the quarter diagonal point of the plate surface. (2) Experiments were conducted to determine the dimensional effects of cylindrical hydrophones located in a water-filled trunk above the plate. The height above the plate was varied for two hydrophones of different sensitive areas. (3) The effect of damping on the acoustic pressure was examined for two aluminum and two fiberglass plates. Comparison is made between the four plates (damped and undamped) at a maximum flow velocity of 20 ft./sec. Acceleration levels were measured.
(f) Completed.
(g) (1) It is demonstrated that unsteady flow excitation from a turbulent boundary layer on a thin flat surface, causes vibration of the plate at many natural modes. Chladni figures are shown for a frequency range cps. (2) Both the area of a hydrophone and its distance above a vibrating plate have considerable effect on the dimensionless pressure spectra. (3) Measurements on the four damped plates show that the acoustic response of aluminum plates is lowered more than that of fiberglass plates. The ratio of the thickness of the damping material to the plate thickness is 2.

(5812) EFFECT OF NATURAL ROUGHNESS ON THE PRESSURE FLUCTUATIONS IN A TURBULENT BOUNDARY LAYER.

(b) Office of Naval Research, Dept. of the Navy.
(c) Mr. Matthew Stevenson, Hydrodynamicist, Robert Taggart Inc., 3930 Walnut Street, Fairfax, Virginia 22030.
(d) Experimental; applied research.
(e) Studies are being conducted concerning the generation of noise by a turbulent boundary layer. The investigation is directed toward measuring the two-point correlations (transverse and longitudinal) of the pressure fluctuations on both smooth and rough walls. It is also planned to determine the effect of hydrophone size by using two or three larger diameter transducers.

TEXAS A AND M UNIVERSITY, Department of Oceanography and Meteorology.

(4866) MODIFICATION OF TWO-DIMENSIONAL LONG WAVES OVER VARIABLE BOTTOM TOPOGRAPHY.

(b) Coastal Engineering Research Center, DA-49-055-CIV-ENG-63-9.
(c) Prof. R. O. Reid, Texas A and M Univ., College Station, Texas.
(d) Theoretical applied research.
(e) The objective is to investigate the modification of free gravity waves in variable depth, including reflection and transmission ects, with particular attention being given to the interaction of tsunamis with islands. The analysis employs numerical methods.
(g) Studies to date include: (1) The development of modified long-wave equations to allow for vertical acceleration and dispersive character of the waves. (2) The development of a computing system for generating an orthogonal coordinate system for an island of general configuration to be employed in numerical wave diffraction studies. (3) The development of a numerical program for evaluating the diffraction of long waves by islands of general configuration using the special coordinate system. The above system has been tested for several cases of simple geometry where the analytical solution is known.
(h) "Orthogonal Coordinates for the Analysis of Long Gravity Waves Near Islands," by R. O. Reid and A. C. Vastano, submitted ASCE for publication in proceedings of specialty conference on coastal engineering (Oct. 1965).

TEXAS A & M UNIVERSITY, Water Resources Institute.

Inquiries concerning the following projects should be addressed to Dr. Ernest T. Smerdon, Director, Water Resources Institute, Texas A and M University, College Station, Texas.

(5477) THE MECHANICS OF EROSION BY FLOWING WATER.

(b) Texas A & M University.
(d) Experimental; basic and applied.
(e) The study is to determine relationships between water erosion of soils and the hydraulic characteristics of the flowing water, to develop quantitative relationships between specific soil properties and an acceptable erosion index, and to develop design data by which the erosion hazard can be adequately considered in the design of water control and management systems.
(g) Laboratory research has been carried out in the research flume on channel erosion and sediment transport with shallow flow, both with and without simulated rainfall. The effects of soil compaction on soil erosion have been studied in the flume. Chemical and mineralogical data are available on the soils. In addition, a rotating shear apparatus has been constructed and tests performed to measure the erosion character of soils in this laboratory device under carefully controlled conditions. The effect on erosion resistance of changing the cations on the clay are being studied in this apparatus.

(5478) WATER POLLUTION FROM ERODED SEDIMENTS.

(b) U. S. Public Health Service.
(d) Experimental; basic and applied.
(e) The laboratory study is designed to obtain data on the initial transport of eroded sediments from the point of detachment to streams of appreciable size. This transport path considered, which may be only a few hundred feet to a few miles, is that portion of the flow path which is sufficiently shallow to be significantly affected by the existence of rainfall energy on the flow. This stream size limit is unknown but will be determined and related to rainfall energy and other factors affecting the flow and sediment transport capability of the flow.
(g) Rainfall superimposed on shallow open channel flow reduces the sediment transport capacity of the streams. This is caused by at least two effects which are being studied further, i.e., changes in vertical velocity distribution in the flow and changes in settling characteristics of suspended sediments.
(h) "The Effect of Rainfall on the Velocity Distribution in Shallow Channel Flow," L. J. Glass. Tech. Rept. No. 1, Water Resources Institute, Texas A & M Univ., Jan. 1965. "Flume Studies of Sediment Transportation in Shallow Flow with Simulated Rainfall," F. M. Nail. Tech. Rept. No. 3, Water Resources Inst., Texas A & M Univ., Jan. 1966.

(5479) EFFECT OF SURFACE IRRIGATION HYDRAULICS ON EFFICIENT APPLICATION OF WATER.

(b) Texas A&M University.
(d) Laboratory and field investigation.
(e) The objectives are to determine the effect of irrigation stream size, slope and shape of irrigated surface, hydraulic roughness of irrigated surface, and water intake characteristics of soil on irrigation system design for most efficient application of water by surface irrigation methods; and to correlate results into design procedures, using hydraulic factors of surface irrigation as criteria for design.
(g) The results indicate that it may be possible to integrate the differential equation for the advance and recession curves by single graphical means (rather than by lengthy and cumbersome numerical calculations or using computers). This will make specific design practical for individual farms and soil conditions instead of so-called "rule-of-thumb" designs so often used now.
(h) "Surface Irrigation Water Distribution Efficiency Related to Soil Infiltration," E. T. Smerdon and L. J. Glass. Trans. of ASAE, Vol. 8, pp. 76-78, 82, 1965.
"A Solution of the Irrigation Advance Problem," O. C. Wilke and E. T. Smerdon. Jour. of Irr. and Drain. Div., ASCE, Vol. 89, No. IR3, pp. 23-34, Sept. 1965.

(5940) RESEARCH ON THE MORPHOLOGY OF PRECIPITATION AND RUNOFF IN TEXAS.

(b) Water Resources Institute, Texas A&M Univ.
(c) Dr. Robert A. Clark, Dept. of Meteorology, Texas A&M Univ., College Station, Texas 77843.
(d) Field and laboratory investigation; applied research.
(e) An investigation of the rainfall-producing mechanism and associated hydrologic regime in Texas. Data obtained from a dense network of recording and non-recording rain gages will be correlated with that obtained from a dual-frequency radar system. This information will then be related to actual data on surface runoff. The network of rain gages is located over the East Yegua Creek drainage basin, 243 sq mi, which is approximately 30 to 45 mi west of the radar system. In addition, a network of 40 rain gages in an urban area of 7 sq mi will be used to study precipitation variation within a small area and the effects of urbanization on surface runoff.
(g) Installation of precipitation networks will be completed by February 1966. Collection and analysis of data from these networks should begin at that time.
(h) "An Investigation of 3.2 -cm Attenuation of Sub-Tropical Precipitation Through Use of a Dual-Frequency Equi-Volume Radar System," Donald B. Hodges, M. S. Thesis, Texas A&M Univ., Jan. 1966.
"Techniques for Hydrograph Synthesis Based on Analysis of Data from Small Drainage Basins in Texas," Michael D. Hudlow, M. S. Thesis, Texas A&M Univ., Jan. 1966.

UNIVERSITY OF TEXAS, Department of Civil Engineering.

Inquiries concerning Projects Nos. 2162, 2397, 3524, 4234, 4235, 5456 and 5457 should be addressed to Dr. Walter L. Moore, Department of Civil Engrg., Univ. of Texas, Austin, Texas 78712.

(2161) CHARACTERISTICS OF A HYDRAULIC JUMP AT AN ABRUPT CHANGE IN BOTTOM ELEVATION.

(b) University of Texas Research Institute and Bureau of Engineering Research.
(c) Dr. Carl W. Morgan, Assoc. Prof. of Civil Engrg., Univ. of Texas, Austin, Texas 78712.
(d) Experimental.
(e) Experimental determinations were made of the flow characteristics at two-dimensional channel drops and rises. The velocity distribution and surface profile were determined throughout the length of the jump for various relative changes in bottom elevation. The longitudinal location of the jump in relation to the change in bottom elevation was varied over a broad range in contrast with previous related investigations in which relative location of the jump was held constant.

(2162) HYDROLOGIC STUDIES, WALLER CREEK WATERSHED.

(b) Cooperative with U. S. Geological Survey.
(d) Field investigation; applied research.
(e) Measurements of rainfall and runoff for a 4 square mile and a 2 square mile portion of the Waller Creek watershed are being made to provide basic information for estimating runoff from small urban watersheds in the Southwest area. Two stream flow stations and a rain gage net are in operation. Studies of the correlation between runoff, rainfall, and the characteristics of the drainage basin are being made by various proposed methods to serve as a base for comparison with the data as it is collected from the stream.
(g) The records are now long enough to begin comparing with peak discharge estimates previously given at least for short recurrence intervals. A start is being made on this analysis.
(h) "Hydrologic Data of Waller Creek, Colorado River Basin, Texas, 1961, 1962, 1963." Geological Survey - Water Resources Division, Surface Water Branch, Austin District, Austin, Texas.
"Compilation of Hydrologic Data, Waller and Wilbarger Creeks, Colorado River Basin, Texas, 1964." Geological Survey - Water Resources Division, Austin, Texas.

(2397) EFFECT OF UPSTREAM DEVELOPMENT ON THE RUNOFF FROM SMALL WATERSHEDS IN THE SOUTHWEST.

(b) Laboratory project.
(d) Field investigation (thesis).
(e) For selected watersheds rainfall runoff relations are being developed on a storm by storm basis. Multiple correlation diagrams, based on data before changes in the watershed, have been developed and used to compute runoff for later periods. Comparison of these computed runoff values with measured values is taken as an index of the effect of watershed development.
(g) The first results were not conclusive because of random error in the computed values. Further studies are being made on another watershed with an improved method which better accounts for the spacial variation of rainfall.

(2874) AN INVESTIGATION OF THE SCOUR RESISTANCE OF COHESIVE SEDIMENTS.

(b) The University of Texas Research Institute.
(c) Dr. Frank D. Masch, Department of Civil Engineering, The University of Texas, Austin, Texas 78712.
(d) Analytical and experimental (laboratory).
(e) Exploratory tests have been made with two different schemes, one with radially outward flow between a circular disc and the soil sample, and one with a submerged vertical circular jet impinging on a horizontal soil surface. With the first scheme it was not possible to obtain the necessary precision of measurement at low scour rates, but with the second scheme satisfactory measurements were obtained. A correlation based on dimensional analysis gave consistent results in evaluating the relative scour resistance of several materials. Apparatus has been fabricated for a new test which permits direct evaluation of the shear stress at the soil

surface. In this test a cylindrical soil sample is submerged in a transparent concentric cylinder which can be rotated at a controlled speed to generate a shear stress on the soil surface. Attempts are being made to relate the scour resistance to other measurable soil properties, and finally to interpret the results in relation to field observations.

(g) Using test procedures previously developed, a series of tests have been run to determine the effect of moisture content on the critical shear stress for Taylor Marl. Tests have been run at nearly constant degree of saturation.

(h) "Measurements of the Shear Resistance of Cohesive Sediments," F. D. Masch, W. H. Espey and W. L. Moore, Proceedings, Federal Inter-Agency Sedimentation Conference, 1963, Agricultural Research Service Miscellaneous Publication No. 970, June 1965.

(3522) LONG TIME FLUCTUATIONS IN STREAM RUNOFF.

(b) Laboratory project.
(c) Dr. Carl W. Morgan, Dept. of Civil Engrg., Univ. of Texas, Austin, Texas 78712.
(d) Analytical and field study.
(e) Values of runoff from selected drainage areas in the lower Mississippi River Basin and in basins of the rivers emptying directly into the Gulf of Mexico were studied. Variations in the runoff values for each stream were considered and these trends compared with solar variations. The relative sunspot numbers were used as the measure of solar variations and were correlated with the mean annual runoff. Further correlations are being made with different "lag" periods between solar activity and surface runoff.

(g) The gradual shifting of the centers of runoff excess and deficiency is consistent rather than random and appears to represent a gradual cyclic change in the runoff pattern. It appears that the locations of the centers of runoff deficiency are following roughly the same path that they did some 22 to 24 years previously. Correlation coefficients of plus 0.2 to plus 0.5 are obtained for selected rivers in Mississippi, Alabama, Georgia, and Arkansas when sunspot numbers in the 11-year sunspot cycle are correlated with runoff. Texas streams do not give significant correlation with the 11-year sunspot cycle but give better correlation if runoff is compared with the double sunspot cycle in which sunspot numbers are assumed as negative in alternate cycles.

(3524) GROUND WATER FLOW AND SEEPAGE IN NON-HOMOGENEOUS, NON-ISOTROPIC SEDIMENTS.

(b) Laboratory project.
(d) Theoretical, basic.
(e) A relaxation solution for the Laplace equation has been developed which is applicable across a boundary between two regions of different permeabilities. It is believed that the method can be expanded to apply to any specified non-homogeneous and non-isotropic condition. It is intended that the solution be set up for computation on an electronic computer and that selected numerical solutions be checked against those from an electrolytic tank.

(4234) EVAPORATION REDUCTION BY CONTROL OF ADVECTED ENERGY.

(b) Partial sponsorship by the Lower Colorado River Authority of Texas.
(d) A Master's thesis involving theoretical and field investigation.
(e) Measurements have been made to determine the temperature field in Lake Travis for the 1962-63 season. A method was developed to estimate the effect of withdrawing water from near the lake surface. Monthly estimates of the resulting temperature field and reduction in evaporation were made.

(4235) TWO-PHASE FLOW IN CONDUITS.

(b) Laboratory project.
(d) Experimental master's thesis.
(e) It is apparent that for a two-phase flow system with a liquid and gas, many different types of flow are possible. This investigation explored the use of sound measurements to detect the type of flow present, in a metal pipe. Various types of flow were established in a thin-walled aluminum pipe, 1.66 I.D., with a transparent plastic section at each end. Records of the sound pattern were made with different pick-ups and correlated with the visual observation of the flow type. Magnetic tape records of the sound were also made.

(g) Study of the recorded sound patterns revealed some identifiable characteristics related to the type of two-phase flow in the line. Additional work is needed to refine techniques and try other sound pick-up and recording methods.

(4716) DRAG FORCES IN VELOCITY GRADIENT FIELDS.

(b) David Taylor Model Basin, Dept. of the Navy.
(c) Dr. Frank D. Masch and Dr. Walter L. Moore, Department of Civil Engineering, The Univ. of Texas, Austin, Texas 78712.
(d) Theoretical and experimental; basic research.
(e) The investigation is being conducted to determine the effect of a velocity gradient on the local and conventional drag coefficients for cylinders of varying L/D ratio and at different Reynolds Numbers. The study will be extended to other shapes.

(g) Studies have demonstrated that the velocity gradient along a cylinder affects the drag coefficient. The local drag coefficient decreases along the cylinder in the direction toward the end of the cylinder where the velocity is high. The reduction in drag coefficient is related to a dimensionless measure of the velocity gradient along the cylinder. The angle at which separation occurred was found to increase near the bottom of the cylinder where the free stream velocity is low.

(h) "The Influence of Secondary Flows on Drag Forces," Charles Dalton and Frank D. Masch, Hydraulic Engineering Lab. Technical Rept. No. HYD 04-6503, The University of Texas, July 1965.

(4717) TWO-FLUID FLOW IN A POROUS MEDIUM.

(b) Bureau of Engineering Research, Univ. of Texas.
(c) Dr. L. R. Mack, Department of Engineering Mechanics, Univ. of Texas, Austin, Texas 78112.
(d) Theoretical; basic research for masters thesis.
(e) The velocity distribution within and the shape of the interface between two immiscible fluids of different densities flowing through a uniform isotropic porous medium toward a well is sought. This problem is of interest in both petroleum engineering and ground-water hydrology.

(g) It has been shown that the method of solution set forth (for the special case when the upper fluid has zero density) by Kirkham (J. Geophys. Res., Vol. 69, pp. 2537-2549, June 1964) will not yield meaningful numerical results.

(h) "Critical Investigation of Kirkham's Theory of Determining the Shape of Water Table Near a Well," Tish-Chun Chang, M. S. Thesis, Univ. of Texas, August, 1965.

(4990) WAVE CHARACTERISTICS IN SHOALING WATER.

(b) Coastal Engineering Research Center, Corps of Engineers.

(c) Dr. Frank D. Masch, Dept. of Civil Engrg., The Univ. of Texas, Austin, Texas 78712.
(d) Theoretical; basic and applied research; Master's thesis.
(e) This study is to develop a workable method for computing water wave characteristics in shoaling water using cnoidal wave theory. The method involves evaluating the power transmission for a wave train in shallow water from cnoidal theory and using the concept of constant power between orthogonals on a refraction diagram. The study has been expanded to include computation of velocity, acceleration and pressure fields.
(g) Integrals of the cnoidal functions have been evaluated in terms of elliptic integrals and computer programs have been developed to solve the resulting equations.
(h) "Cnoidal Waves in Shallow Water," Frank D. Masch, Chapter I, Proceedings of Ninth Conference on Coastal Engineering, American Society of Civil Engineers, Lisbon, Portugal, June 1964.

(4991) LOCAL SCOUR IN CHANNELS.

(b) Laboratory project.
(c) Dr. Frank D. Masch and Dr. Walter L. Moore, Dept. of Civil Engrg., The Univ. of Texas, Austin, Texas 78712.
(d) Theoretical and experimental; basic and applied research.
(e) This project is designed to investigate the characteristics of the three dimensional flow patterns at channel obstructions and to study the extent to which these flows affect local scour. It is believed that a more thorough understanding of the fundamentals of the flow at an obstruction would provide the basis to devise methods for controlling scour. The nature of scour at culverts is also under consideration with efforts being devoted to develop methods for dissipating energy and reducing local scours.
(h) "The Influence of Secondary Flows in Local Scour at Obstructions in Channels," W. L. Moore and Frank D. Masch, Proceedings, Federal Inter-Agency Sedimentation Conference, 1963, Agricultural Research Service, Miscellaneous Publication No. 970, June 1965.

(5455) HYDROLOGY OF SMALL URBAN WATERSHEDS.

(b) Bureau of Engineering Research, Texas Water Commission.
(c) Dr. Carl W. Morgan, and Dr. Frank D. Masch, Dept. of Civil Engineering, The Univ. of Texas, Austin, Texas 78712.
(d) Field investigation, basic research.
(e) Data from selected watersheds have been collected. These are being studied to evaluate the effects of urbanization on the hydrologic characteristics of the watersheds.
(g) For the Waller Creek Watersheds, Austin, Texas preliminary results indicate that because of approximately twice as high percent of impervious cover in the lower part it produced yields per unit area approaching twice that of the upper area.
(h) "A Study of Some Effects of Urbanization on Storm Runoff from a Small Watershed," W. A. Espey, Jr., Ph. D. Dissertation, The Univ. of Texas, August 1965.
"A Study of Some Effects of Urbanization on Storm Runoff from a Small Watershed," W. A. Espey, Jr., C. W. Morgan and F. D. Masch, Hydraulic Engineering Laboratory Technical Report No. HYD 07-6501, The University of Texas, July 1965.

(5456) MATHEMATICAL MODELS FOR RELATING RUNOFF TO RAINFALL.

(b) Laboratory project.
(d) Doctoral thesis based on computer analysis of field data.
(e) The study is presently aimed at determining the runoff hydrograph from the rainfall data for individual storms. A computer solution to a multiple correlation method is used to obtain the amount of runoff for successive time intervals for individual sub areas of the watershed, and a modified unit hydrograph approach is used to obtain the runoff hydrograph at the lower end of the watershed. Preliminary results indicate that the method will be useful to estimate storm hydrographs where rainfall data are available for a long time, and flow records are available for only a short period. It is hoped that additional correlations can be developed for base flow making it possible to build up continuous runoff hydrographs based on rainfall records.
(g) Preliminary results indicate good success in predicting runoff hydrographs for individual storms.
(h) "The Synthesis of Storm Runoff Hydrographs from Unsteady Non-Uniform Rainfall," C. L. Smith, Ph. D. Dissertation, The University of Texas, 1965.

(5457) A NEW TYPE ENERGY DISSIPATOR FOR CULVERT OUTLETS.

(b) Texas Highway Dept. and U. S. Bureau of Public Roads.
(d) Experimental and theoretical doctoral thesis.
(e) A study is being made of a culvert energy dissipator based on the use of a sector of a circular hydraulic jump. Apparent advantages of the device are the stability of the jump over a range of discharge and tailwater conditions and the opportunity to spread the culvert discharge back to the original stream width. Problems of practical geometry need to be explored to see what compromises can be made and still achieve satisfactory energy dissipation performance.

(5458) SEDIMENTATION IN GALVESTON-TRINITY BAYS.

(b) Texas Parks and Wildlife Commission and Department.
(c) Dr. Frank D. Masch, Dept. of Civil Engrg., Univ. of Texas, Austin, Texas 78712.
(d) Experimental, field; applied research.
(e) Field investigation to determine the currents, sources of sediment, and sediment movement in Galveston and Trinity Bays, and to determine the effect they may have on the dredging of mudshell, oysters and oyster production.
(h) "Progress Report on Current and Sediment Movement in Galveston-Trinity Bays," Frank D. Masch, Hydraulic Engrg. Lab. Rept. No. HYD 06-6501, The Univ. of Texas, January 1965.

(5459) FINITE-AMPLITUDE GRAVITY WAVES.

(b) Laboratory project.
(c) Dr. L. R. Mack, Dept. of Engrg. Mechanics, Univ. of Texas, Austin, Texas 78712.
(d) Theoretical, basic research for master's thesis and doctoral dissertation.
(e) In order to obtain better quantitative agreement with the experimental frequency determinations of Fultz and of Edge, the analytical solutions for both two-dimensional standing waves and axi-symmetric standing waves are being carried to the fifth order in amplitude. Velocity distribution, free-surface configuration, and frequency of oscillation are being obtained.
(g) The two-dimensional solution has been carried through the fifth order. Surface configuration, frequency of oscillation, maximum amplitude, and the division of energy have been investigated. For a certain range of depths the oscillation exhibits "hard-spring" behavior for small amplitudes and soft-spring behavior for larger amplitudes. Close correlation is noted between soft-spring behavior of the frequency and the mean poten-

tial energy being greater than the mean kinetic energy.

(h) "Bessel-Function Identities Needed for the Theory of Axisymmetric Gravity Waves," Lawrence R. Mack, Mathematics of Computation, Vol. 19, pp. 654-657, October 1965. "Periodic Gravity Waves of Finite Amplitude," Donald F. Sattler, M. S. Thesis, Univ. of Texas, January 1966.

(5460) WIND WAVE OVERTOPPING OF SHORELINE STRUCTURES.

(b) Bureau of Engineering Research, Univ. of Texas, Austin, Texas 78712.
(c) Dr. Frank D. Masch, Dept. of Civil Engrg., Univ. of Texas, Austin, Texas 78712.
(d) Experimental, thesis.
(e) This study is designed to compare overtopping from wind waves with that predicted from criteria based on uniform wave trains. Overtopping is being measured under varying wind and wave conditions. Particular study is being given to beach geometry immediately in the front of the structure and its effect on overtopping rates.
(g) Results obtained to date show that the greater the depth of water at the wall, the greater the overtopping rates. The offshore beach profiles appear to have little or no effect on overtopping from wind generated waves.

(5461) ANALYSIS OF UNIT HYDROGRAPHS FOR SMALL WATERSHEDS.

(b) Laboratory project.
(c) Dr. Carl W. Morgan, Dept. of Civil Engrg., The Univ. of Texas, Austin, Texas 78712.
(d) Field investigation, thesis.
(e) Characteristic, two-hour unit hydrographs were determined for each of three selected watersheds. The derived dimensionless hydrograph shapes were compared with two widely-used empirical hydrographs. Techniques were studied for using the S-curve hydrograph as an aid in estimating the correct duration of rainfall excess by selecting that duration which caused the least fluctuation in the S-curve.
(g) The dimensionless 2 hour unit hydrographs developed in this study indicate that the falling limbs of the Commons and Mockus hydrograph shapes may need revision in order to be applied to watersheds of less than 100 square miles in area. However, these differences are only minor suggesting that an average dimensionless graph and reliable estimates of only two parameters, period of rise and peak discharge may be sufficient to define the shape of the unit hydrograph. Results indicate the S-curve can be used to estimate by trial and error the rainfall excess duration if rainfall data is not available.

(5953) MIXING AND DISPERSION OF CONTAMINANTS IN RESERVOIRS.

(b) U. S. Public Health Service.
(c) Dr. Frank D. Masch, Dept. of C. E., Univ. of Texas, Austin, Texas 78712.
(d) Basic and applied research; field investigation.
(e) This investigation has been undertaken to study the mixing and dispersion of contaminants in inland fresh waters. The study includes an investigation of the effects of currents, turbulent wave action, and periodic overturning on the disposition of waste materials discharged into reservoirs and lakes. The stability effects of temperature and density gradients within the receiving waters are also being determined. Mixing processes in both deep and shallow water reservoirs are being studied in the field.

(5954) PHYSICAL EXCHANGE CHARACTERISTICS OF TEXAS BAYS.

(b) Center for Research in Water Resources Project.
(c) Dr. Frank D. Masch, Dept. of C. E., Univ. of Texas, Austin, Texas 78712.
(d) Analytical; field investigation; applied research.
(e) To evaluate the assimilative capacity of Texas Gulf Coast Bays, studies are being carried out to determine a mathematical model which is descriptive of the mixing, dispersive and exchange characteristics of these bays. Preliminary analysis has proceeded on the basis of a modified tidal prism exchange model. Steps are now under way to improve this type model.

(5955) PERFORMANCE OF CIRCULAR CULVERTS ON STEEP GRADES.

(b) Texas Highway Department.
(c) Dr. Frank D. Masch, Dept. of C. E., Univ. of Texas, Austin, Texas 78712.
(d) Experimental and theoretical research.
(e) This study is concerned with the behavior of the hydraulic jump in circular broken-back culverts. Of particular concern are the conditions under which a jump will form in the culvert. The study is also concerned with methods to insure that the jump forms in the culvert.

(5956) SPILLWAY MODEL STUDIES - TOLEDO BEND DAM.

(b) Forrest and Cotton Consulting Engineers.
(c) Dr. Frank D. Masch, Dept. of C. E., Univ. of Texas, Austin, Texas 78712.
(d) Applied research; laboratory investigation.
(e) Model studies on the spillway section of the Toledo Bend Dam were carried out for the purposes of determining the hydraulic performance characteristics of the spillway section of the dam including stilling basin effectiveness, flow behavior in the upstream and downstream channels, and gate operating sequence for a range of discharges including the normal flood, the design flood, and the maximum probable flood.
(h) "Model Studies - Toledo Bend Dam," Walter L. Moore and Frank D. Masch, Hydraulic Engrg. Lab. Tech. Rept. No. HYD 08-6501, The Univ. of Texas, October 1965.

THERM ADVANCED RESEARCH, INC.

(5197) SPECIAL PROBLEMS IN FLUID DYNAMICS.

(b) Office of Naval Research, Dept. of the Navy.
(c) Dr. A. Ritter, President, Therm Advanced Research, Inc., 100 Hudson Circle, Ithaca, N. Y.
(d) Theoretical basic research.
(e) This is a continuing project of analytical studies which to date have consisted of: (1) The Hydrodynamics of Free-Surface Crossings, concerned with predicting the hydrodynamic forces acting on bodies in vertical motion crossing an air-water interface, and includes examination of the accuracy of the standard assumptions of infinite Froude number and small disturbances; and (2) The Jet-Flap Hydrofoil Near a Free Surface, a study which will provide expressions for the forces and moments acting on a two-dimensional jet-flap hydrofoil in close proximity to a free surface as well as determining the depth of submergence at which free-surface effects may be neglected.
(f) (e) 1. Completed, 2. Active.
(g) A second-order, small-perturbation theory for the water-exit and -entry of slender symmetric bodies, including Froude number and air-density effects, has been developed. The effect of a nearby free surface on a two-dimensional jet-flapped hydrofoil is found to

be negligible, for practical purposes, at submergence depth-to-hydrofoil chord ratios greater than unity for infinite Froude number.

(h) "On the Samll-Perturbation Theory of Water-Exit and -Entry," by John P. Moran and Keith P. Kerney, Developments in Mechanics, S. Ostrach, Editor, Pergamon Press, Oxford, pp. 478-506, 1965.
"On the Hydrodynamic Theory of Water-Exit and -Entry," by John P. Moran, Therm Advanced Research, Inc., TAR-TR 6501, March 1965.

(5198) LOW-ASPECT-RATIO JET-FLAP CONTROL SURFACES.

(b) David Taylor Model Basin, Dept. of the Navy.
(c) Mr. Gary R. Hough, Staff Scientist, Therm Advanced Research, Inc., 100 Hudson Circle, Ithaca, N. Y.
(d) Theoretical basic research.
(e) The objective of this project is to develop a theory which will predict satisfactorily the forces and moments acting on a fully wetted, low-aspect-ratio jet-flap control surface.
(g) Previous studies in this area found that the application of the conventional Jones low-aspect-ratio approximation was unsatisfactory for treating control surfaces of rectangular planform and/or deflected jet blowing. During the present contract, the improved low-aspect-ratio approximation of Lawrence is being employed to obtain a solution.

(5789) PREDICTION OF SHIP SLAMMING LOADS.

(b) David Taylor Model Basin, Dept. of the Navy.
(c) Dr. M. Greenberg, Staff Scientist, Therm Advanced Research, Inc., 100 Hudson Circle, Ithaca, N. Y.
(d) Theoretical basic research.
(e) The object is to develop computer codes for the accurate prediction of the pressures and forces on ship sections of arbitrary shape during slamming. Finite air density will be retained to avoid the unrealistic impact singularity predicted by simplified theory, in contrast with the water-compressibility artifice which is often employed. The analysis is based upon a discrete vortex representation of the body and water surface, and proceeds in finite time increments. The free surface conditions are linearized only in the calculation of the starting values, when the body is sufficiently far above the water.

UTAH STATE UNIVERSITY, College of Engineering.

(3183) DYNAMICS OF FLOW IN STEEP, ROUGH, OPEN CHANNELS.

(b) Laboratory and field projects; National Science Foundation.
(c) Dr. Dean F. Peterson, Dean of Engineering, Utah State University, Logan, Utah 84321.
(d) Experimental, theoretical, field investigation; basic research for doctoral theses.
(e) A basic study of relationships involved in flow in steep, rough channels where the roughness is relatively an appreciable part of the depth, and where channels are sufficiently steep or steeper than a slope such that supercritical flow can occur in connection with contractions caused by the roughness. The work is basic, however, it will have application to steep mountain streams and to hydraulic structures. The objective of the work is to relate descriptive parameters describing the size and configuration of the bed roughness to slope, depth and discharge of channels of this class. Studies began using simple bar and cube elements and have progressed through the use of beds formed by gluing natural gravel elements of various size, gradation and intensity to the bed. Nineteen field sites have been installed in streams, principally in northern Utah in the Wasatch Mountains, but also in New Mexico and Colorado. Piezometric type stilling wells have been installed at thirteen sites and discharge and depth measured. Bed element distribution and size have been studied at all sites. Collection of field data has been completed and analysis is continuing. A laboratory flume study using natural gravel elements glued to the bed, with water as the fluid, was completed. The flume study is being continued using the same beds only in a mirrored effect to eliminate the free surface influence, with air as the fluid.
(g) In the flume studies, discharge and slope were varied and depth was measured for each of the ten beds. Two sizes of material with five different spacings for each size were used. Experimental results show a continuous change in relative dominance of the factors of gross velocity variation and turbulent mixing as the kineticity and relative depth changes. Six flow zones defined by Froude number and relative depth were suggested. It was not practical to develop a single equation to describe a conductance coefficient, $C/g^{\frac{1}{2}}$, to cover all ranges of flow, but one equation for each zone is proposed. C is from Chezy's equation and is based on a roughness spacing parameter, roughness, height, and depth of flow. A measure for describing spacing was developed and a method of field application is also discussed.
(h) "Flume Study of the Effect of Concentration and Size of Roughness Elements on Flow in High-Gradient Natural Channels," by Mohamed Wafaie Abdelsalam. Ph. D. dissertation, Utah State University, Logan, Utah, 1965, p. 182.

(3185) HYDRAULICS OF SURFACE IRRIGATION.

(b) Public Health Service.
(c) Dr. Vaughn E. Hansen, Director, Utah Water Research Laboratory, Utah State Univ., Logan, Utah 84321.
(d) Experimental, theoretical; basic research; Doctoral dissertation.
(e) Hydrodynamic and field study of movement of water over a porous surface when intake varies with time. The free surface and the rates of advance are defined.
(f) Completed.
(g) Differential equations have been developed which define the free surface and rates of advance. High speed computers have been used to obtain typical solutions which have been compared with field measurement of the rate of advance. The results are within ten percent of field observations. A dimensionless plot has been constructed which will predict the advance for any given set of known soil conditions. A companion study is based upon utilizing empirical relationships as a foundation for subsequent development of rate of advance functions. The results compare well with measured values.
(h) "Hydrodynamics of Unsteady Open-Channel Fluid Flow Over a Porous Bed Having a Variable Infiltration Rate," by Edwin C. Olsen, III, Ph. D. dissertation, Utah Water Research Laboratory, Logan, Utah. June 1965.

(3528) THE EFFECT OF SEDIMENT PROPERTIES ON THE ATTENUATION OF AN ULTRASONIC PLANE WAVE.

(b) National Science Foundation.
(c) Dr. Gordon H. Flammer, Civil and Irrigation Engineering Department, Utah State Univ., Logan, Utah 84321.
(d) Theoretical and experimental; basic research.
(e) Some theoretical and experimental work has been performed on the attenuation of an ultrasonic plane wave passing through a sediment suspension. However, experimental work is still very limited in scope, particularly over certain loss regions. This study uses a standard pulse technique to investigate a wide range of natural and manufactured sediments over the various loss

ranges. Of primary concern is the effect of the various sediment properties on the attenuation.

(f) Completed.

(g) Natural sediments have been completed and an MS thesis has been prepared giving the results. Manufactured sediments of known properties have been tested, and a PhD dissertation has been completed and is available at the Utah State University Library.

(3530) WATER REQUIREMENTS OF MARSHLANDS.

(b) Utah State Fish and Game Dept.

(c) Prof. Jerald E. Christiansen, Professor of Civil and Irrigation Engineering, Utah State Univ., Logan, Utah. 84321.

(d) Field investigations; applied research, Master's theses.

(e) Large areas of marshy lands adjacent to Great Salt Lake have been developed and improved by the State Fish and Game Dept., and the Federal Wildlife Service, as Migratory Bird Refuges. Available stream flow from several of the major streams flowing into these areas where the water is impounded behind dikes to create habitat suitable for nesting, feeding and resting of water fowl. Millions of ducks and geese utilize this area each year during their migratory flights.

(f) Completed.

(g) The basic purpose of the study was to determine the quantities of water necessary for marshlands in order to maintain them in a productive state.

(h) Eight progress reports have been written. Three MS theses and one PhD dissertation have been completed.

(3845) WATERSHED MODEL STUDIES.

(b) Agricultural Research Service, U. S. Dept. of Agriculture.

(c) Dr. Jay M. Bagley, Utah Water Research Lab., Utah State University, Logan Utah 84321.

(d) Experimental; basic research for Master's and Doctoral theses.

(e) The purpose is to establish techniques and model-prototype laws so that watersheds can be intensively studied in a laboratory. A small watershed has been modeled. A rainfall simulator has been constructed for which design or actual rainfall events can be programmed to occur automatically over the model. The dominant factors influencing the characteristic shape of the run-off hydrography are being studied. Initial efforts have been aimed at determining effect on modeling relationships resulting from changes in the physical properties of water-chemical mixtures used in the rainfall simulator. Test runs are being made using a physical model with an impervious surface. Subsequent tests will incorporate the relationship between infiltration and run-off by providing for permeability changes in the model.

(g) Satisfactory mechanical performance and electronic control has been achieved. Verification tests to date are highly encouraging. Experimental tests are continuing.

(h) "Construction, Instrumentation, and Preliminary Verification of a Physical Hydrologic Model," by Donald L. Chery, Jr. Utah Water Research Laboratory and Agricultural Research Service, U. S. D. A., 152 pp., July 1965.

(5129) CALIBRATION OF IRRIGATION HEADGATES BY MODEL ANALYSIS.

(b) D.M.A.D. Irrigation Companies, Delta, Utah.

(c) Mr. Gaylord V. Skogerboe, Asst. Research Engineer, Utah Water Research Laboratory, Utah State Univ., Logan, Utah 84321.

(d) Experimental; applied research.

(e) The D.M.A.D. Irrigation Companies have approximately 600 of these headgates in their distribution system and would like to use the headgate as a measuring device. Standards for the installation of such a headgate will be developed along with flow rate curves and tables.

(f) Completed.

(g) A general method of analysis was developed for rating submerged gates. The coefficient of dischrge of the system was markedly affected by the degree of relative submergence. Also, the location of the gate guide angles, whether facing upstream or downstream, affected the coefficient of discharge by 12 percent.

(h) "Rating Submerged Gates for Flow Measurement in Open Channels," by Gaylord V. Skogerboe. Transactions, American Society of Agricultural Engineers, Vol. 8, No. 1, pp. 101-102, 1965.

(5130) FARM IRRIGATION STRUCTURES.

(b) Laboratory project.

(c) Mr. Gaylord V. Skogerboe, Asst. Research Engineer, Utah Water Research Laboratory, Utah State Univ., Logan, Utah 84321.

(d) Library research.

(e) A compilation of the material pertaining to the design of small irrigation structures that would be found on a farm. Will also determine gaps in information which will require additional research.

(5131) A STUDY OF THE STRUCTURE AND EDDY DIFFUSIVITY OF TURBULENT SHEAR FLOWS IN ROUGH OPEN CHANNELS.

(b) Laboratory project.

(c) Dr. Calvin G. Clyde, Civil Engineering Dept., Utah State Univ., Logan, Utah 84321.

(d) Experimental and theoretical; basic research for Ph.D. Thesis.

(e) The objectives of the project are: (1) To describe the structure of the turbulent shear flows in rough open channels; (2) To see if local isotropy exists in the turbulence under study; and (3) To investigate the relationship of the structure of the turbulence to the process of diffusion in the flow. Work on (1) and (2) is mostly completed and is continuing on (3). The experimental studies have been conducted in a 3 foot flume artificially roughened on the bottom with expanded metal mesh. A total head tube with barium titanate as the piezoelectric sensor has been used to measure turbulent velocity fluctuations in the direction of the mean flow. The signal was analyzed with a random signal indicator and correlator, a delay line, and a spectrum analyzer. Measurements were made at a section where the boundary layer growth had reached the free surface and the flow was essentially two dimensional. A hot wire system is being developed so that all components of velocity can be measured.

(f) Continuing.

(g) In the outer region of fully developed turbulent flow in the rough open channel, the wave number at which the transition between locally isotropic and anisotropic turbulence occurs is independent of Reynolds Number, but varies inversely with the depth of flow. Even in fully developed turbulent flow, local isotropy does not exist near the bed in the presence of steep mean velocity gradients. Hence, the concept of local isotropy is inadequate for obtaining the distribution of the rate of dissipation of energy, notwithstanding its use to evaluate the local rate in the outer region. The structure of the turbulence in the flows studied has been described in terms of longitudinal macroscale and microscale, relative intensity, and energy spectrum. The channel roughness has only an indirect influence on the structure of turbulence by transforming the flow into fully developed turbulent flow at a lower Reynolds Number. A procedure has been developed for estimating the statistical characteristics of the turbulence in fully developed turbulent shear flow in channels

from a knowledge of the mean flow quantities.

(h) "A Study of the Structure of Shear Turbulence in Free Surface Flows," by M. V. Rao, Ph. D. Thesis, Utah State University, Logan, Utah. Sept. 1965.

(5132) TECHNIQUES OF AERIAL APPLICATION OF EVAPORATION-REDUCING MATERIALS TO LARGE LAKES AND RESERVOIRS.

(b) U. S. Bureau of Reclamation.
(c) Dr. Vaughn E. Hansen, Director, Utah Water Research Laboratory, Utah State Univ., Logan, Utah 84321.
(d) Experimental; applied research and development.
(e) Development of equipment and techniques for the aerial application of monolayer-forming materials.
(f) Completed.
(g) The performance of the equipment has been very satisfactory. Techniques have been developed for the use of alcohols in molten form and the use of powdered alcohols. Further research and development will be concerned only with powdered alcohols.
(h) "Economics of Aerial Application of Evaporation Retardants to Water Surfaces," by Vaughn E. Hansen and Gaylord V. Skogerboe. Agricultural Aviation 7(4), 1965.

(5133) UTAH STATE UNIVERSITY STILLING BASIN FOR PIPE TO OPEN CHANNEL FLOW.

(b) Laboratory project.
(c) Dr. Gordon H. Flammer, Assoc. Prof. Civil and Irrigation Engr. Dept., Utah State University, Logan, Utah 84321.
(d) Experimental research for M. S. Theses.
(e) The objective of this study is to find an economical and effective means of energy dissipation at the transition of pipe flow to open channel flow.
(f) Continuing.
(g) An effective design has been found involving a short dissipator pipe placed on the opposite wall of the stilling basin from the inflow pipe. The best ratios have been found for: the dissipator pipe diameter to inflow pipe diameter, length of dissipator pipe to inflow pipe diameter, slit width to inflow pipe diameter, and center line offset to the inflow pipe diameter. The second MS thesis is studying the effect of changing the inlet pipe diameter and the inlet pipe velocity on the most efficient design described above.
(h) An MS thesis has been completed and research toward the second MS thesis is being actively pursued.

(5134) FREE SURFACE EFFECTS ON THE DRAG OF A HEMISPHERE ON A BOUNDARY, IN VELOCITY GRADIENT FLOW.

(b) National Science Foundation Project.
(c) Dr. Gordon H. Flammer, Professor of Civil Engineering, Utah State University, Logan, Utah 84321.
(d) Theoretical and experimental work leading to a doctoral dissertation.
(e) The objectives of this study were to: (1) study the relative effects of the Froude number and the Reynolds number for various relative submergences of an isolated hemisphere in open channel flow; (2) to correlate the total drag coefficient with the Froude number and Reynolds number with calculations based upon flow conditions measured with the hemisphere in place, and with the hemisphere removed; (3) correlation of wave drag coefficient with Froude number for flow conditions measured as in part 1 involving evaluation of the wave drag and the wave drag coefficient in correlation of the wave drag with the Froude number; and (4) analysis of the overall wave patterns and their effect on the drag.
(g) The experimental analysis has been completed and the doctoral dissertation is being written. It should be published by June 1966. It will be available at the Utah State University Library and its author will be James P. Tullis.

(5135) LIFT FORCES ON A HEMISPHERE IN A VELOCITY GRADIENT FIELD WITH FREE SURFACE EFFECTS.

(b) National Science Foundation grant.
(c) Dr. Gordon H. Flammer, Professor, Civil Engineering Department, Utah State Univ., Logan, Utah 84321.
(d) Experimental and theoretical research leading to a doctoral dissertation.
(e) Lift forces on a hemisphere attached to a boundary will be studied for the following conditions: (1) an infinite uniform flow field; (2) a semi-infinite non-uniform flow field; (3) a finite uniform flow field without free surface; (4) a finite non-uniform flow field without free surface; (5) a finite uniform flow field with free surface; and (6) a finite uniform flow field with a free surface.

(5137) DRAG ON A HEMISPHERE IN A THREE-DIMENSIONAL FINITE FLOW FIELD WITH FREE SURFACE EFFECTS.

(b) National Science Foundation Project.
(c) Dr. Gordon H. Flammer, Professor of Civil Enginrg., Utah State Univ., Logan, Utah 84321.
(d) Experimental and theoretical research toward a PhD dissertation.
(e) The objectives are to study and compare drag on a hemisphere attached to a boundary for: (1) A three-dimensional infinite non-uniform flow field where viscous forces are important; (2) a semi-infinite non-uniform flow field where viscous forces and shape of the velocity profile are important; (3) a finite uniform flow field without free surface where viscous forces, and relative submergence are important; (4) a finite non-uniform flow field without free surface where viscous forces, relative submergence and velocity profile shape are important; (5) a finite uniform flow field with a free surface where viscous forces, relative submergence and Froude number are important; and (6) a finite non-uniform flow field with a free surface where viscous forces, relative submergence, Froude number and velocity profile shape are important.
(f) This project was completed January 1, 1965.
(g) The objectives stated in item (e) have been realized.
(h) A doctoral dissertation has been published and is available at Utah State University Library. It is entitled, "Analysis of Drag Forces on a Hemisphere With Free Surface Effects," by Earl S. Mason, 1965.

(5138) STATE WATER PLAN INVESTIGATIONS.

(b) Dr. Jay M. Bagley, Utah Water Research Laboratory, Utah State University, Logan, Utah 84321.
(c) Dr. Jay M. Bagley, Civil Engrg. Dept., Utah State University, Logan, Utah 84321.
(d) Field investigation, applied research.
(e) Water supply and use determinations and projections. Frequency analyses of various kinds of hydrologic data.
(g) Hydrologic inventories of major study area of state completed.
(h) "Effects of Competition on Efficiency of Water Use," by Jay M. Bagley, Proceedings of Am. Soc. of Civil Eng., IRl, March 1965, 9 pp.

(5139) HYDROLOGY OF THE GREAT SALT LAKE.

(b) Dr. Jay M. Bagley, Utah Water Research Lab., Utah State University, Logan, Utah 84321.
(c) Dr. Jay M. Bagley, Civil and Irrigation Engineering Dept., Utah State Univ., Logan, Utah 84321.
(d) Field investigation, applied research.
(e) Attempting to develop an adequate description of the sources, amounts and regimen of water inflow into the lake from precipitation, surface flows, and subsurface flows. This

will provide the basis on which to predict the effect of future development so that alternative resource use patterns for the lake and its tributary system can be evaluated.
(f) Completed.
(g) Water budget for lake and tributary areas has been completed. Mean annual inflow to Great Salt Lake is calculated to be: Bear River drainage, 910,000 a.f.; Weber River drainage, 480,000 alfl; Jordan River drainage, 270,000 a.f.; other tributaries, 30,000 a.f.; Total surface and groundwater inflow, 1,690,000 a.f. Report in process.

(5140) ELECTRONIC ANALOG MODEL STUDIES OF RIVER BASINS.

(b) Dr. Jay M. Bagley and Prof. Duane G. Chadwick, Utah Water Research Laboratory, Utah State University, Logan, Utah 84321.
(c) Dr. Jay M. Bagley, Assoc. Prof., Civil Engineering Dept. and Prof. D. L. Chadwick, Asst. Prof. Electrical Engineering Dept., Utah State Univ., Logan, Utah 84321.
(d) Experimental.
(e) An electronic analog model of a river basin is being constructed. The basic hydrologic processes of precipitation, snowmelt, surface and subsurface runoff, groundwater storage and movement, evapotranspiration, streamflow, etc. have been modeled electronically. Model will be used to predict performance of various parts of hydrologic system resulting from proposed water management and development changes.
(f) Model completed. Continuing liaison in the operation and utilization.
(g) Completed model being effectively utilized in the Sevier River Basin Investigations of the Soil Conservation Service. Final report in process.

(5440) EVALUATION OF EVAPORATION RETARDANTS FOR AERIAL APPLICATION.

(b) The Proctor and Gamble Company.
(c) Dr. Vaughn E. Hansen, Director, Utah Water Research Laboratory, Utah State Univ., Logan, Utah 84321.
(d) Applied research and field investigations.
(e) Evaluate various chemical compositions and particle size gradations of evaporation retardants to determine their suitability for aerial application techniques. Particular emphasis will be given to the longer chain fatty alcohols, C_{20} and C_{22}.
(f) Suspended.

(5441) NEW CONCEPTS OF HYDROLOGIC INSTRUMENTATION.

(b) Laboratory project.
(c) Professor Duane G. Chadwick, Utah Water Research Labortory. Utah State University, Logan, Utah 84321.
(d) Experimental and field investigation; applied research and design.
(e) The aerial measurement of evaporation, evapotranspiration, and sublimation is being attempted by the application of new electronic, sonic, and optical techniques.

(5442) EVAPORATION AND CLIMATIC STUDIES.

(b) Laboratory project.
(c) Professor Joel E. Fletcher, Utah Water Research Laboratory, Utah State Univ. Logan, Utah 84321.
(d) Experimental; applied research.
(e) Evaporation from land, snow, and water surfaces constitutes the principal losses of water to the United States. The investigation of factors which affect the quantity, quality, and timing of these losses from a climatic standpoint are being investigated in order to assist in the more precise formulation of plans of water utilization.
(g) On the basis of dendroclimatic records, it appears that many of Utah's irrigation projects have been designed on the basis of a short, wet cycle.

(5443) MICROCLIMATIC HYDROLOGY.

(b) Laboratory project.
(c) Professor Joel E. Fletcher, Utah Water Research Laboratory, Utah State Univ., Logan, Utah 84321.
(d) Experimental and field investigation; applied research.
(e) Methods for evaluating and measuring the microclimatic factors associated with water supply and use are being investigated.

(5444) DESIGN AND CALIBRATION OF A SUBMERGED RECTANGULAR FLUME.

(b) D.M.A.D. Irrigation Companies, Delta, Utah.
(c) Mr. Gaylord V. Skogerboe, Asst. Research Engineer, Utah Water Research Laboratory, Utah State Univ., Logan, Utah 84321.
(d) Design; applied research.
(e) A rectangular flume was designed to operate under submerged flow conditions throughout the entire range of discharges between 20 and 500 cfs. The flume is to be calibrated in place.
(f) Completed.
(g) The flume has been constructed and field calibration data obtained.
(h) "Design, Operation, and Calibration of the Canal A Submerged Rectangular Measuring Flume," by Gaylord V. Skogerboe, W. Roger Walker, and Lawrence R. Robinson. Report PR-WG24-3, Utah Water Research Laboratory, Utah State University, Logan, Utah, March 1965.

(5445) TRAPEZOIDAL MEASURING FLUMES.

(b) Laboratory project.
(c) Mr. Gaylord V. Skogerboe, Asst. Research Engineer, Utah Water Research Laboratory, Utah State University, Logan, Utah 84321.
(d) Design; applied research.
(e) A proposed trapezoidal measuring flume with a design discharge of 300 cfs has been modeled in the laboratory. The purpose of this investigation is to arrive at a proper design and also to determine the feasibility of using this type of flume with both critical depth and submerged flow.
(f) Completed.
(g) Testing program has been completed. Results to date look very promising regarding the use of this type of flume for discharge measurement under submerged flow conditions.
(h) "Design, Calibration, and Evaluation of a Trapezoidal Measuring Flume by Model Study," by M. Leon Hyatt. M. S. thesis, Utah State University, Logan, Utah, March 1965. "Submerged Trapezoidal Measuring Flumes," by Calvin G. Clyde, Gaylord V. Skogerboe, and M. Leon Hyatt. Transactions, American Society of Agricultural Engineers (publication pending).

(5446) THEORY OF INFILTRATION AND FLUID MOVEMENT IN UNSATURATED POROUS MEDIA.

(b) Laboratory project.
(c) Dr. Yu-Si Fok, Utah Water Research Laboratory. Utah State Univ., Logan, Utah 84321.
(d) Theoretical, experimental; basic research, applied research.
(e) To develop mathematical relationships expressing the phenomena of infiltration. Primary interest is the infiltration of water into the soil. Further development is to extend the developed theory to other fluid and media.
To develop mathematical relationships expressing the fluid movement in unsaturated porous media. Primary interest is the movement of water in unsaturated soil.
To evaluate the validity and applicability of the relationships developed from the mathematical analysis by field and laboratory tests.
(g) Improvements have been made on the developed equations and the solutions.

(5449) HYDRAULICS AND EFFICIENCY OF IRRIGATION APPLICATION.

(b) Laboratory project.
(c) Dr. A. Alvin Bishop, Dept. of Civil and Irrigation Engineering, or Dr. Yu-Si Fok, Utah Water Research Laboratory, Utah State University, Logan, Utah 84321.
(d) Theoretical with field investigation; applied research.
(e) To develop basic mathematical relationships expressing the hydraulics of surface irrigation.
To evaluate the validity and reliability of the relationships which have been developed from mathematical analysis by field and laboratory tests.
To develop the nomographs for use with equations developed.
To develop the relationships for application efficiency and distribution efficiency with regard to the intake rate, advance rate, and the ratio of the required irrigation time to the required water advance time to cover the whole length of a field.
(g) Improvements have been made on the developed equations.
(h) "Analysis of Water Advance in Surface Irrigation," by Yu-Si Fok and A. Alvin Bishop. Journal of the Irrigation and Drainage Division, American Society of Civil Engineers, paper No. 4259, March 1965.

(5450) ELECTROKINETIC POTENTIAL IN SOIL CAPILLARIES.

(b) Laboratory project.
(c) Dr. Calvin G. Clyde, Civil Engineering Department, Utah State University, Logan, Utah 84321.
(d) Experimental and theoretical; basic research for PhD dissertation.
(e) Purpose of the project is to investigate the relationships between the streaming potential in a porous media flow and the soil parameters, the fluid parameters and the flow rate. Experimental equipment has been built and the experimental and theoretical work is being done.

(5451) SEEPAGE FLOW THROUGH DUNES IN ALLUVIAL CHANNELS.

(b) Laboratory project.
(c) Dr. Gary Z. Watters, Assistant Professor of Civil Engineering, College of Engineering, Utah State University, Logan, Utah 84321.
(d) Experimental and theoretical, basic research for M. S. Thesis.
(e) Experiments are being conducted to determine the permeability of the undisturbed dune structures occurring in alluvial channels. These results will be used to compute seepages through dunes, both in the direction of flow along the channel and vertically downward. This is done to determine the effect of dune movement on the permeability and seepage characteristics of the bed materials.
(f) Completed.
(g) Differences in permeability in horizontal and vertical directions appear to exist. However, measurement techniques were not satisfactory and results were widely scattered. Calculations were made to determine seepage through idealized (triangular-shaped) dunes. This was done for the linearized case - plane bottom but with varying potential - and the idealized dune shape - 45° dunes with equal upstream and downstream slopes. Conformal-mapping techniques were used.

(5452) HYDRODYNAMICS OF FREE SURFACE FLOW OVER HYDRAULIC STRUCTURES.

(b) Laboratory project.
(c) Dr. Gary Z. Watters, Assistant Professor of Civil Engineering, College of Engineering, Utah State University, Logan, Utah 84321.
(d) Theoretical and experimental, theoretical and applied.
(e) An approximation to real-fluid flow over simple hydraulic structures is being attempted by using a rotational ideal fluid. It is hoped that eddies and separation patterns will be somewhat similar locally to those of a real fluid. The theoretical results will be compared with the actual flows.
(g) A change in the direction of the project has resulted in order to attempt to duplicate more closely real-fluid flows.

(5747) APPLICATION OF ELECTRONIC ANALOG DEVICES TO SOLUTION OF HYDROLOGIC AND RIVER BASIN PLANNING PROBLEMS.

(b) Office of Water Resources Research.
(c) Dr. Jay M. Bagley and Prof. Duane G. Chadwick, Utah Water Research Lab., Utah State Univ., Logan, Utah 84321.
(d) Experimental, design, and development.
(e) Comprehensive study and new development of hydrologic relations employed in current model. Design improvements will be made in order to handle a greater range and variety of problems with more flexibility, reliability, and speed of operation.

(5748) SEQUENTIAL WATER USE WITHIN A HYDROLOGIC COMPLEX.

(b) Dr. Jay M. Bagley, Utah Water Research Lab., Utah State University, Logan, Utah 84321.
(c) Public Health Service, Dept. of Health, Education, and Welfare.
(d) Field investigation, applied research.
(e) The study will utilize data from the Little Bear River Basin in developing guides to the improved administration and management of water in a complex system of sequential uses. The prototype information will provide basis for development and testing of analytical methods of analyzing a variety of sequential water use problems.

(5749) OPTIMIZING CONJUNCTIVE USE OF SURFACE AND GROUND WATERS.

(b) Laboratory project.
(c) Dr. Calvin G. Clyde, Prof. of Civil Engrg., Utah Water Research Lab., Utah State Univ., Logan, Utah 84321.
(d) Theoretical, applied research, for Ph.D. dissertation.
(e) Past studies of conjunctive use of surface and ground waters have usually involved a selection of the best alternative among a number of different plans. The purpose of this project is to develop a true optimization methodology for conjunctive use systems utilizing operations research and involves the following steps: (1) General definition of the problem. (2) Development of the mathematical model of the hydrologic system. (3) Selection of the optimization technique. (4) Detailed statement of the parameters, equations, and constraints. (5) Use of a digital computer for the actual optimization.

(5750) ATMOSPHERIC WATER RESOURCES IN UTAH.

(b) United States Bureau of Reclamation.
(c) Prof. Joel E. Fletcher, Utah Water Research Lab., Utah State Univ., Logan, Utah 84321.
(d) Project is experimental and could be classed as both basic and applied research.
(e) Cloud seeding is to be done along the Wasatch Front to determine the feasibility of increasing water supplies, delineating the areas affected by individual generators, and determining the unique characteristics of the water producing storm systems.

(5751) EVALUATION OF REMOTE ELECTRO-MAGNETIC SENSORS FOR DETECTING TRANSPIRATIONAL WATER USE BY PLANTS SUBJECTED TO VARIOUS FOLIAR CHEMICAL TREATMENTS DESIGNED TO REDUCE TRANSPIRATIONAL LOSSES.

(b) Utah Center for Water Resources Research.

(c) Research Engineer, Frank W. Haws, Utah Water Research Laboratory, Utah State University, Logan, Utah 84321.
(d) Experimental, applied research, development, master's thesis.
(e) Objects on the earth, both living and lifeless, are selective absorbers or reflectors of the electro-magnetic energy emitted by the sun. The presence of water in some of these substances such as plant tissue or soils changes the spectral reflectance or absorption characteristics of the substance. It is the purpose of this project to identify these changes and to determine if spectral differences can be detected by remote sensors in such a manner that transpirational water use by native forest vegetation can be measured. Various photographic methods, including film-filter combinations, and image-forming devices using infra-red detectors will be investigated. Field plots have been established on the forest in order to manipulate the vegetation and measure the resulting alteration of transpiration.

(5752) OVERLAND FLOW.

(b) Laboratory project.
(c) Dr. Cheng-lung Chen, Utah Water Research Lab., Utah State Univ., Logan, Utah 84321.
(d) Theoretical; basic research.
(e) The general differential equation for overland flow describes a great variety of practical problems such as surface irrigation, the hydrologic analysis of basins and the spreading of water over infiltration areas for groundwater recharge. The objective of this research is to determine the general solution to the equation by finite difference methods and illustrate the dependence of the solution on the parameters involved by presenting the important phases of the solution in dimensionless form.
(g) Preliminary and simplified studies of the equation reveal that the solution is strongly affected by the inflow and outflow conditions as well as the roughness and slope of the channel.

(5753) RESISTANCE TO SEDIMENT-LADEN TURBULENT FLOW OVER SCHEMATIC DUNES.

(b) Laboratory project.
(c) Dr. Cheng-lung Chen, Utah Water Research Lab., Utah State Univ., Logan, Utah 84321.
(d) Theoretical and experimental; basic research.
(e) Sediment-laden turbulent flows in alluvial streams are the complex flow phenomena in which the flow and the bed interact to deposit and scour the sediments thereby shaping a variety of movable beds. This research is to apply the principles underlying the theory established to describe a steady uniform flow over a rigid boundary to the problem of flow in an alluvial channel.
(g) A preliminary analysis has indicated that the contributions to the resistance from bed-surface roughness, bed configuration, instability of free surface waves, and interference of the suspended sediments are so interrelated that any study of the individual effect will not entirely describe the trends in the variation of the universal constant in the Karman-Prandtl logarithmic velocity law and the Darcy-Weisbach friction coefficient, f.

(5754) ULTRASONIC MEASUREMENT OF THE SIZE DISTRIBUTION AND CONCENTRATION OF NATURAL SEDIMENTS IN SUSPENSION.

(b) Engineering Experiment Station Project, Utah State University.
(c) Dr. Gordon H. Flammer, Prof., Civil Engrg. Dept., Utah State Univ., Logan, Utah 84321.
(d) Experimental study; applied research.
(e) One of the most difficult problems in the study of sediment mechanics is that of instrumentation. This study applies the ultrasonic technique to the measurement of sediment size distribution and concentration for suspended sediments.
(g) The results of the National Science Foundation Project entitled "The Effect of Sediment Properties on the Attenuation of an Ultrasonic Plane Wave" have been applied to the measurement technique for natural sediments. An M.S. thesis has been prepared giving the results. The results of the thesis show suprisingly good accuracy in the measurement of both size distribution and concentration.
(h) "Ultrasonic Measurement of the Size Distribution and Concentration of Natural Sediments in Suspension," by Ernest Yu-Shih Liu, M.S. Thesis, Utah State University, Logan, Utah, 1965.

(5755) PRESSURE, SHEAR AND VELOCITY DISTRIBUTION AROUND A HEMISPHERE ON A BOUNDARY IN A FINITE THREE-DIMENSIONAL FLOW FIELD WITH FREE SURFACE EFFECTS.

(b) National Science Foundation grant.
(c) Dr. Gordon H. Flammer, Prof. of Civil Engrg., Utah State University, Logan, Utah 84321.
(d) Experimental and theoretical research leading to a doctoral dissertation.
(e) The objectives of this study are to determine the flow characteristics in the immediate vicinity of a hemisphere located on a boundary in a finite three-dimensional flow field with free surface effects. Such flow characteristics as the velocity distribution, the pressure distribution, the shear stress distribution and boundary layer development and separation patterns will be studied.
(f) This project will be completed by January 1, 1967.

(5756) TURBULENCE CHARACTERISTICS OF FLOW AROUND A HEMISPHERE IN A VELOCITY GRADIENT FIELD WITH FREE SURFACE EFFECTS.

(b) National Science Foundation Project.
(c) Dr. Gordon H. Flammer, Prof., Civil Engrg. Dept., Utah State University, Logan, Utah 84321.
(d) Experimental and Theoretical research leading to a doctoral dissertation.
(e) To study such instantaneous properties of the flow field in the near vicinity of the hemisphere as: the measurement of turbulence intensity, space correlations, cross correlations, the auto correlation curve, the instantaneous lift and drag forces on the hemisphere as related to turbulence characteristics near the hemisphere, the effect on the structure of the free stream turbulence of the hemisphere placed in the flow upstream, and to deduce the law of decay of turbulence behind the hemisphere, also, to compare the intensity of turbulence near the hemisphere for the semi-infinite non-uniform flow field, the finite non-uniform flow field without a free surface, and a finite non-uniform flow field with a free surface.

(5757) TURBULENCE CHARACTERISTICS OF FLOW AROUND AN ISOLATED CUBE IN A VELOCITY GRADIENT FIELD IN A FREE SURFACE EFFECTS.

(b) National Science Foundation Project.
(c) Dr. Gordon H. Flammer, Prof., Civil Engrg. Dept., Utah State Universty, Logan, Utah 84321.
(d) The project is experimental and theoreticalin nature leading to a doctoral dissertation.
(e) To study the instantaneous properties of the flow field in the near vicinity of the cube such as intensity of turbulence, space correlations, cross correlations, auto correlation curves, instantaneous drag and lift forces correlated with the turbulence characteristics of the hemisphere wake turbulence decay; and to compare the intensity of turbulence near the hemisphere for (1) a semi-infinite non-uniform flow field; (2) the finite non-uniform flow field without a free surface; and (3) a finite non-uniform flow field with a free surface.

(5758) ANALYSIS OF LIFT AND DRAG FORCES ON A CUBE IN A VELOCITY-GRADIENT, FINITE FLOW FIELD WITH FREE SURFACE EFFECTS.

(b) National Science Foundation.
(c) Dr. Gordon H. Flammer, Prof., Civil Engrg. Dept., Utah State University, Logan, Utah 84321.
(d) The project is experimental and theoretical in nature leading to a doctoral dissertation.
(e) This project is to determine the laws governing the lift and drag forces on a cube in (1) and infinite uniform flow field; (2) a semi-infinite non-uniform flow field; (3) a finite uniform flow field without a free surface; (4) a finite non-uniform flow field without a free surface; (5) a finite uniform field with free surface; and (6)a finite non-uniform flow field with a free surface.

(5759) ENERGY DISSIPATION IN HIGH GRADIENT OPEN CHANNELS WITH SEMI-CIRCULAR DISK ROUGHNESS ELEMENTS OF SIZE ORDER EQUIVALENT TO THE DEPTH OF FLOW.

(b) Laboratory project.
(c) Dr. Gordon H. Flammer, Prof. of Civil Engrg., Utah State University, Logan, Utah 84321.
(d) Experimental and theoretical research for a M. S. Thesis.
(e) This study was made to gain further information on flow characteristics around semi-circular roughness disks of the order of the depth in high gradient channels. This information will be of value in design of energy dissipators and in better understanding of the laws governing flow in high gradient streams such as mountain streams. The friction factors were to be studied and also the effects of spacing, size and distribution of the roughness elements on the flow characteristics. Also, the flow regimes were noted, both as defined by Dean Peterson and by Morris.
(h) "Energy Dissipation in High Gradient Open Channels With Semi-Circular Disk Roughness Elements of Size Order Equivalent to the Depth of Flow," by Robert McAllister, M. S. Thesis, Utah State Univ. Logan, Utah, 1965.

(5760) DRAG COEFFICIENTS AND PRESSURE DISTRIBUTION FOR SEMI-CIRCULAR DISK ROUGHNESS ELEMENTS FOR VARIOUS ROUGHNESS PATTERNS AND FLOW CONDITIONS.

(b) Laboratory project.
(c) Dr. Gordon H. Flammer, Prof. of Civil Engrg., Utah State University, Logan, Utah 84321.
(d) Experimental and theoretical research for M. S. Thesis.
(e) The objectives of this study were: to determine drag coefficients on individual roughnesses using various roughness patterns and flow conditions; and to determine the friction factor for each roughness pattern and flow condition in order to correlate these results with those of previous studies carried on at Utah State University; and further to determine the pressure distribution around a semi-circular disk using various roughness patterns and flow conditions.
(g) Semi-circular disk roughness elements were used as large roughnesses in four different patterns. An empirical equation was developed to relate the friction factor, the roughness density and the drag coefficient. A theoretical equation was also derived and compared with the empirical. Close agreement was found to exist.
(h) "Drag Coefficient and Pressure Distribution for Semi-Circular Disk Roughness Elements for Various Roughness Patterns and Flow Conditions," by German Uzcategui-Briceno, M. S. Thesis, Utah State University, Logan, Utah, 1965.

(5761) DRAG AND SURFACE WAVE CHARACTERISTICS FOR THE ISOLATED SEMI-CIRCULAR DISK IN A FINITE THREE-DIMENSIONAL FLOW FIELD WITH FREE SURFACE EFFECTS.

(b) National Science Foundation Project.
(c) Dr. Gordon H. Flammer, Prof., Civil Engrg. Dept., Utah State Univ., Logan, Utah 84321.
(d) Experimental and theoretical leading to Ph.D. dissertation.
(e) To study the drag on an isolated disk on a boundary for (1) an infinite uniform flow field; (2) a semi-infinite non-uniform flow field; (3) a finite uniform flow field without a free surface; (4) a finite non-uniform flow field without a free surface; (5) a finite uniform flow field with a free surface; and (6) a finite non-uniform flow field with a free surface. The surface wave characteristics will be studied for items (5) and (6).

(5762) SUBMERGED OPEN CHANNEL FLOW MEASUREMENT STRUCTURES.

(b) Office of Water Resources Research, U. S. Department of Interior.
(c) Mr. Gaylord V. Skogerboe, Asst. Research Engineer, Utah Water Research Laboratory, Utah State University, Logan, Utah 84321.
(d) Experimental; applied research.
(e) A hydraulic model study is being undertaken to provide calibration curves. An experimental model is being designed and constructed wherein the lengths of the entrance, throat, and exit may be varied; the width of the throat may be varied; the sides of the model can be placed in various positions to form either rectangular or trapezoidal shapes; and the degree of convergence and divergence may be varied. In addition to the above variable quantities, the effects of conditions in the channel both upstream and downstream from the flume, the scale factor, and roughness of the flume walls and floor will be evaluated.

(5763) SUBMERGED PARSHALL FLUMES.

(b) Laboratory project.
(c) Mr. Gaylord V. Skogerboe, Asst. Research Engineer, Utah Water Research Lab., Utah State University, Logan, Utah 84321.
(d) Experimental; applied research.
(e) An approach previously developed for analyzing submerged flow in rectangular and trapezoidal measuring flumes will be verified in the laboratory for Parshall flumes. In addition to the laboratory tests, existing data reported by Parshall and other investigators will be analyzed.
(g) The method of analyzing submerged flow previously developed has been found valid for Parshall flumes.
(h) "Submerged Parshall Flumes of Small Size," by G. V. Skogerboe, M. L. Hyatt, J. R. Johnson and J. D. England. Report PR-WR6-1, Utah Water Research Laboratory, Utah State Univ., Logan, Utah, July 1965.
"Submergence in a Two-Foot Parshall Flume," by G. V. Skogerboe, M. L. Hyatt, J. D. England and J. R. Johnson. Report PR-WR6-2, Utah Water Research Laboratory, Utah State Univ., Logan, Utah, August 1965.
"Measuring Water with Parshall Flumes," by G. V. Skogerboe, M. L. Hyatt, J. D. England, J. R. Johnson and R. E. Griffin. Bulletin published jointly by Utah Water Research Lab. and Utah Cooperative Extension Service, Utah State University, Logan, Utah, November 1965.
"Evaluation of Free and Submerged Flow Data for Large Parshall Flumes," by M. L. Hyatt and G. V. Skogerboe. Report PR-WR6-4, Utah Water Research Lab., Utah State University, Logan, Utah, December 1965.

(5764) MODIFICATIONS TO GATE-PARSHALL FLUME STRUCTURE.

(b) Utah Highway Department.
(c) Mr. Gaylord V. Skogerboe, Asst. Research Engineer, Utah Water Research Laboratory, Utah State University, Logan, Utah 84321.
(d) Experimental; applied research.
(e) Twin turnout structures have been constructed from the Davis-Weber Canal which employ a gate followed by a four-foot Parshall flume four feet deep. The flow passing through the flume is supercritical. Modifications to the turnout structures will be studied with a prototype structure constructed in the laboratory.

(5765) THE EFFECT OF SEEPAGE ON THE HYDRODYNAMIC FORCES ACTING ON NON-COHESIVE BED PARTICLES IN A FLOWING CHANNEL.

(b) Laboratory project.
(c) Dr. Gary Z. Watters, Asst. Prof. of Civil Engrg., College of Engrg., Utah State Univ., Logan, Utah 84321.
(d) Experimental and basic research.
(e) This project is to investigate the effect of seepage flow on the pressure forces (shear forces are negligible) acting on one of a number of hemispheres on a flowing stream bed. The change in the forces, namely, the lift and drag, is to be noted and the gross effect on the flow pattern past the hemispheres will be observed. These hemispheres are to represent qualitatively the natural bed material.
(f) Completed.
(g) Seepage was found to have an effect on the lift and drag forces. The dynamic forces (in addition to buoyancy) were found to decrease up to 40% for seepage from the bed into the flow. However, for seepage from the flowing channel into the porous bed, no measurable change in lift or drag was noted.

VANDERBILT UNIVERSITY, Dept. of Civil Engineering.

(5687) SINGLE PHASE FLUID FLOW THROUGH POROUS MEDIUMS.

(b) Laboratory project.
(c) Dr. Donald Dean Adrian, Assist. Prof. of Sanitary and Water Resources Engineering, Box 1625-Station B, Vanderbilt University, Nashville, Tenn. 37203.
(d) Basic research of a theoretical nature using published experimental data.
(e) This work is being carried out to better understand the flow of fluids through a porous medium in the presence of air. The air is assumed to remain stationary. The soil moisture diffusivity and a pore size distribution factor, called the "randomicity" function are evaluated from published experimental data.
(g) The diffusivity varies over several orders of magnitude with changes in the moisture content. The randomicity function follows a similar variation. Calculations using these functions are subject to instabilities due to the large changes which occur with small changes in the moisture content.
(h) "The Influence of Capillarity on the Flow of Water and Air in Porous Mediums," Donald Dean Adrian, Technical Report No. 38, Civil Engrg. Dept., Stanford Univ. 159 pages, June 1964.

(5688) TURBULENT DIFFUSION AND RIVER WASTE ASSIMILATIVE CAPACITY.

(b) Division of Water Supply & Pollution Control, U. S. Public Health Service.
(c) Dr. Peter A. Krenkel, Assoc. Prof. and Director of Sanitary and Water Resources Engineering, Box 1670-Station B, Vanderbilt University, Nashville, Tenn. 37203.
(d) Field and laboratory observations are used to verify theoretical considerations of the relation between turbulence and gas absorption. The investigations involve basic and applied research and both Master's and Ph.D. theses will result from the studies.
(e) The project objectives are: To determine the applicability of the mathematical models describing turbulent diffusion to river flow, to examine laboratory and field methodology for determination of the various mixing coefficients in the laboratory and field under controlled conditions, utilizing pulse testing techniques, to develop frequency response characteristics of various streams under differing hydraulic conditions, and to correlate turbulent diffusion characteristics of natural streams to the reaeration capacity and thus the waste assimilative capacity.
(g) Observations of the mixing coefficients and reaeration characteristics have been made in several TVA rivers and in the laboratory. A new mathematical model describing the exchange of tracer material with "dead zones" has been found to partially account for the discrepancies in theoretical and observed "flow-thru" curves and preliminary relationships have been proposed between the various mixing coefficients.
(h) "Turbulent Diffusion and River Waste Assimilative Capacity," Peter A. Krenkel. Tech. Rep. No. 3, Sanitary & Water Resources Engineering, Vanderbilt University. "Application of Frequency Response Techniques to the Analysis of Turbulent Diffusion Phenomenon," J. R. Hays, K. B. Schnell, P. A. Krenkel. Proc. Purdue Ind. Wastes Conf., May 1964. "Turbulent Diffusion and Reaeration," E. L. Thackston, P. A. Krenkel. Proc. 14th Southern Municipal & Ind. Wastes Conference, April 1965. "The Significance of Longitudinal Mixing in the Analysis of Estuaries," Discussion to paper by DRF Harleman, P. A. Krenkel, Proc. 2nd Int'l. Conf. on Water Pollution Research, Tokyo, 1964. "BOD and Oxygen Relationships in Streams," Discussion to paper by W. E. Dobbins, Proc. Journ. San. Engr. Div., Amer. Soc. of Civ. Engrs., February 1965, E. L. Thackston and P. A. Krenkel.

(5689) EFFECT OF IMPOUNDING RESERVOIRS ON WATER QUALITY.

(b) Laboratory project, The Mead Corp.
(c) Dr. Peter A. Krenkel, Asso. Prof. and Director of Sanitary and Water Resources Engineering, Box 1670-Station B, Vanderbilt University, Nashville, Tenn. 37203.
(d) Field investigations which may be classified as applied research. Studies have resulted in several M. S. theses.
(e) The causes and effects of stratified flow, and its relation to water quality changes are being investigated by field observations and surveys. The effects of flow modifications on waste assimilative capacity and water treatment facilities are being investigated.
(g) It has been demonstrated that the changes in flow regime on a particular river have caused an 80% reduction in waste assimilative capacity. Stratified flow has been shown to cause difficulties in the mixing of waste effluents into the receiving water and also significant increases in iron and manganese.
(h) "The Effects of Heat on Water Quality," B. C. Dysart and P. A. Krenkel, Proc. 20th Purdue Ind. Wastes Conf., May 1965. "The Effects of Impoundments on River Waste Assimilative Capacity," P. A. Krenkel, W. A. Cawley and V. A. Minch, Journ. Water Pollution Control Fed., October 1965. "The Effect of Modification of the Flow Regime on the Waste Assimilative Capacity of Rivers," E. E. Driver and P. A. Krenkel, Tech. Rep. No. 5, San. & Water Resources Engr., Vanderbilt Univ. May 1965. "Stratified Flow, Causes and Effects," E. E. Driver and P. A. Krenkel, Proc. 15th Oklahoma Ind. Wastes Conf., November 1964.

(5690) JET DISCHARGE INTO A STRATIFIED FLOW REGIME.

(b) E. I. du Pont de NeMours, Inc., laboratory project.
(c) Dr. Peter A. Krenkel, Assoc. Prof. and Director of Sanitary and Water Resources Engineering, Box 1670-Station B, Vanderbilt University, Nashville, Tenn. 37203.
(d) Applied research for M. S. thesis.
(e) An investigation of the jet discharge of a bouyant fluid into a stratified flow regime with differing velocities in the upper and lower layers.

VIDYA DIVISION, Itek Corp.

(5199) THE EFFECT OF FLOW SEPARATION FROM THE HULL ON THE STABILITY OF A HIGH SPEED SUBMARINE.

(b) Office of Naval Research, David Taylor Model Basin (jointly) under the BuShips Fundamental Hydromechanics Program.
(c) Mr. S. B. Spangler, Vidya Division, 1450 Page Mill Road, Palo Alto, Calif. 94304.

(d) Theoretical; applied research.
(e) The previous work on hull flow separation and the vortex interference on the hull and stern control surfaces due to the lift on the fairwater and fairwater planes is being extended to the case of steady pitching and yawing angular motions of the submarine. The purpose of this work is to obtain methods for predicting the variation, particularly the nonlinear portion, of forces and moments with angular rates.
(g) Results for low angular pitching and yawing rates at zero angles of attack and sideslip indicate that forward appendage interference effects are significant for the steady yawing angular velocity case, due to the fairwater load distribution, but are not significant for the steady pitching case.

(5200) INTERFERENCE BETWEEN A HULL AND A STERN-MOUNTED DUCTED PROPELLER.

(b) Dept. of the Navy, Bureau of Ships Fundamental Hydrodynamics Research Program.
(c) Dr. A. R. Kriebel, Staff Engineer, Vidya Division of Itek Corp., 1450 Page Mill Road Palo Alto, Calif. 94304.
(d) Theoretical investigation; applied research.
(e) A hydrodynamic analysis is made of an underwater hull and a stern-mounted ducted propeller in steady axially symmetric flow. Singularity distributions are used to represent a typical hull, the hull wake, a thin cambered duct, and a propeller which adds a uniform velocity to the slipstream. The pressure distribution and boundary layer of the duct are predicted along with the interference forces between the hull, duct, and propeller versus the length, thrust, loading distribution, and Reynolds number of the duct. The purpose of the analysis is to determine how much thrust can be carried by a duct. A highly loaded duct might reduce the sound generated by both the pressure field rotation with the propeller and the induced vibration of the hull.
(f) Discontinued.
(g) Duct camber lines are chosen to minimize duct leading-edge suction, hull-duct interference, and separation of the duct boundary layer. For the assumed conditions, computed results show that the duct can carry only about 7 percent as much thrust as the propeller without flow separation from the outer duct surface. Boundary layer control appears to be required to obtain more duct thrust.
(h) "Interference Between a Hull and a Stern-Mounted Ducted Propeller," A. R. Kriebel and M. R. Mendenhall. Vidya Rept. No. 204, October 30, 1965.

(5941) PREDICTED AERODYNAMIC COEFFICIENTS AND DYNAMIC DERIVATIVES FOR DUCTED PROPELLERS.

(b) Bureau of Naval Weapons, Dept. of the Navy.
(c) Dr. A. R. Kriebel, Staff Engineer, Vidya Div. of Itek Corp., 1450 Page Mill Road, Palo Alto, California 94304.
(d) Theoretical investigation; applied research.
(e) The main purpose of the current analysis is to express the previous theoretical results (1965 Reference Number 5201) in terms of an arbitrary ducted-propeller configuration. The aerodynamic characteristics of the duct have been predicted previously in terms of the thrust coefficient of the propeller with the assumption of uniform blade loading. The extended analysis will predict the inflow to the propeller, radial and azimuthal variations of blade loading, and the effect of these variations on the duct force and moment. The previous analysis of the aerodynamic interference between a pair of ducted propellers is also being extended, and a duct stall criterion is being developed.
(g) Preliminary results indicate that the effects of azimuthal variations of propeller loading are small. Radial variations of propeller loading appear to have little effect upon the duct thrust, but the duct lift force increases rapidly when the propeller blade loading is shifted toward the blade tips.

VIRGINIA POLYTECHNIC INSTITUTE, Dept. of Civil Engineering.

(5533) USE OF LARGE ROUGHNESS ELEMENTS FOR HYDRAULIC ENERGY DISSIPATION.

(b) Virginia Council of Highway Investigation and Research and U. S. Bureau of Public Roads.
(c) Dr. H. M. Morris, Professor and Head, Dept. of Civil Engineering, Virginia Polytechnic Institute, Blacksburg, Va. 24061.
(d) Analytical and experimental, supplemented by field studies; basic and applied research.
(e) Studies are being made to develop general design criteria for flow regimes and energy dissipation in steep channels with large roughness elements. The characteristics of the "tumbling-flow" regime are of special interest. Design applications for chutes, culverts, and other highway drainage structures are in view.
(g) Two progress reports have been issued.
(h) "Use of Roughness Elements for Energy Dissipation in Highway Drainage Channels," J. S. Jones, H. M. Morris and L. M. Younkin. Paper presented at annual meeting of Highway Research Board, Washington, D. C. Jan. 1966.

(5534) HYDRAULIC EFFECTS OF BOUNDARY ROUGHNESS.

(b) Laboratory project.
(c) Dr. H. M. Morris, Professor and Head, Dept. of Civil Engineering, Virginia Polytechnic Institute, Blacksburg, Va. 24061.
(d) Analytical and experimental; basic research, for Ph.D. thesis.
(e) Systematic studies are being made to delineate the various regimes of turbulent flow in rough pipes in terms of each dimension of the boundary roughness geometry, with the aim of attaining comprehensive quantitative criteria for all regimes.
(g) Experimental work completed. Turbulent flow regimes have been delineated and quantitative criteria for recognition established.

(5535) SEPARATION OF SOLIDS AND LIQUIDS AT FLOW TRANSITION BOUNDARIES.

(b) National Science Foundation.
(c) Dr. H. R. Bungay, Prof. of Civil Engineering, Virginia Polytechnic Institute, Blacksburg, Va. 24061.
(d) Analytical and experimental; basic research.
(e) A study was made of the hydraulic characteristics of "clear zones" (zones of clear liquid appearing in suspensions) as produced in vessels filled with a fluid suspension set in motion by stirring action and in flow of the fluid suspensions around obstacles in a channel.
(f) Completed.
(g) Characteristics of the clear zones have been studied and a suggested theoretical analysis has been developed, based on the migration of particles across laminar flow streamlines induced by unequal Bemoulli pressures. Applications to sediment transport, flow of blood corpuscles, flow of disease bacteria, and the handling of fibers as in papermaking seem to be indicated.
(h) "Relative Motion of Cells and Medium," H. R. Bungay and J. M. Wiggert, Biotechnology and Bioengineering, Vol. VII, No. 2, 1965, p.322.

(5536) HYDRAULIC DISRUPTION AND RE-ENTRAINMENT OF FROTH.

(b) Division of Water Supply and Pollution Control, U. S. Public Health Service, and Virginia Engineering Experiment Station.
(c) Dr. W. A. Parsons, Prof. of Civil Engineering, Virginia Polytechnic Institute, Blacksburg,

Va. 24061.
(d) Analytical and experimental; basic and applied research; Ph.D. Thesis
(e) Studies are being made to develop methods to disrupt froth generated in aerobic fermentation processes; hydraulic methods are desired in order to avoid use of bioresistant chemical antifoams which would retard oxygen transfer.
(f) Completed.
(g) Experimental measurements have been completed.

(5957) SURGE AND ROLL WAVE PHENOMENA IN STEEP, ROUGH CHANNELS.

(b) Laboratory project, supported in part by Virginia Council of Highway Investigation and Research in cooperation with U. S. Bureau of Public Roads.
(c) Dr. H. M. Morris, Professor and Head, Dept. of Civil Engineering, Virginia Polytechnic Institute, Blacksburg, Virginia 24061.
(d) Analytical and experimental; basic research; Ph.D. thesis.
(e) Unsteady flow phenomena in the form of surges and roll waves are experienced under some conditions in steep channels with rough beds. The characteristics of these phenomena and criteria for their formation are being studied.
(g) Experimental studies are in progress, using a large tilting flume with various bed roughness geometries and electronic recording equipment for the transient phenomena.
(h) "Roll Waves in a Steep, Rough Channel," Eugene Y. T. Koo, unpublished M. S. Thesis, Virginia Polytechnic Institute, 1963.

(5958) VELOCITY DISTRIBUTIONS IN OPEN CHANNELS WITH LARGE BED ROUGHNESS.

(b) Laboratory project, supported in part by Virginia Council of Highway Investigation and Research in cooperation with U. S. Bureau of Public Roads.
(c) Dr. H. M. Morris, Professor and Head, Dept. of Civil Engineering, Virginia Polytechnic Institute, Blacksburg, Virginia 24061.
(d) Analytical and experimental; basic research; Ph.D. Thesis.
(e) Velocity and pressure distributions are directly related to loss coefficients and surface phenomena in open channels, but very little information is available of this sort for hyper-rough beds. Detailed flow profiles are being obtained and analyzed for the tranquil, tumbling and rapid regimes in such channels.
(g) Experimental studies are in progress, using a large tilting flume and pitot traversing equipment; data are programmed for processing on digital computer.
(h) "Velocity Distribution in Steep, Rough Channel," Tsung-ting Chiang. Unpublished M. S. Thesis, Virginia Polytechnic Institute, 1963.

VIRGINIA POLYTECHNIC INSTITUTE, Dept. of Mechanical Engineering.

(5537) FLUID JET CONTROL.

(b) National Science Foundation (Grant GK 34).
(c) Dr. Robert A. Comparin, Assoc. Prof. of Mechanical Engineering, Virginia Polytechnic Inst., Blacksburg, Virginia 24061.
(d) Analytical and experimental study in part for Master's thesis.
(e) This project is a study of jet reattachment phenomena at low Reynolds numbers. The study will include both parallel and inclined walls and the effects of aspect ratio, offset, and wall angle.
(g) Data have been obtained for reattachment distance as a function of Reynolds number for an inclined wall at various angles. Significant three-dimensional effects have been noted with an aspect ratio of ten.
(h) "Jet Reattachment to an Inclined Wall at Low Reynolds Numbers," by Robert Brent Moore, Jr., M.S. thesis, Virginia Polytechnic Institute, September 1965.

WASHINGTON STATE UNIVERSITY, The R. L. Albrook Hydraulic Laboratory.

Inquiries concerning the following projects should be addressed to Dr. E. Roy Tinney, Head, The R. L. Albrook Hydraulic Laboratory, Division of Industrial Research, Washington State University, Pullman, Washington 99163.

(1689) STUDY OF FLUID FLOW IN PIPE NETWORKS.

(b) Personnel responsible for the design and/or operation of water and gas distribution systems.
(d) Analyses by analogue and digital computers.
(e) Flow distributions have been made with the McIlroy Analyzer for over 50 cities, several gas systems, an air system, a generator cooling system, and several other unique systems. Losses throughout the system are obtained. Engineers use the analogue to design system pumps, tanks, and piping additions or revisions.

(3848) CALIBRATION OF FLOW METERING FLUMES.

(b) Agricultural Research Service, Boise, Idaho.
(d) Experimental, development.
(e) A standard weir design is being studied to determine whether or not calibration curves can be developed for specific stream gaging stations without requiring extensive field or laboratory experimental calibration.
(g) Data analysis indicates that gaging site condition and flume size do not influence the discharge characteristics of the flume at discharges less than a certain percentage of the design capacity. Upstream bed slope and flume orientation affect these characteristics at larger flows if these parameters are greater than given magnitudes.
(h) "The Drop-Box Weir for Sediment Laden Flow Measurement," by Clifton W. Johnson, Howard Copp and E. Roy Tinney. Paper submitted to Hyd. Div. ASCE, Nov. 4, 1965.
"Stream gaging Weirs for Reynolds Creek Experimental Watershed," by Howard D. Copp. Bulletin 295, Wash. State University, College of Engrg. Research Division, Pullman, Wash., in preparation.

(4721) MODEL CALIBRATION OF ROCK ISLAND SPILLWAY.

(b) Public Utility District of Grant Co., Washington.
(d) Experimental; analytical.
(e) A 1:50 scale model of the west section of the Rock Island Dam spillway was constructed. Tests were made to determine the discharge coefficients for each bay as they may be influenced by adjacent and nearby bays, tailwater and apron elevations, and distribution of flow approaching the spillway discharges. Accurate discharge ratings were required in connection with power losses due to tailwater encroachment at Rock Island by the Wanapum pool.
(f) Complete.
(g) A technique was developed to compute discharge through the western section of the spillway. Effects of upstream topography, tailwater elevation, and spillway gate opening are noteworthy.
(h) "Spillway Discharge Coefficients for Rock Island Dam," Claud C. Lomax, Journal of the Hydraulics Division (ASCE), Vol. 91, May 1965.

(4724) WELLS COMPREHENSIVE MODEL.

(b) Bechtel Corporation.
(d) Experimental; design.

(e) A 1:78 model of the Wells Hydrocombine has been constructed to study potential erosion, wave action, passage of migratory fish, spillway capacity, and construction sequences. Since the power house and spillway are combined into one structure, several unique problems in design and operation must be investigated. The model is 44 feet wide and 66 feet long and will pass the equivalent of 1,300,000 cfs.
(f) Completed.
(g) Tests on project layout and operation provided a sound basis for modifying original plans. Additional stream channel protection was required to prevent undue erosion. A rather unusual fish attraction system including several stratigically placed, high-velocity jet streams was developed. Downstream, geologic formations will permit the spillway flow to scour its own escape channel thereby reducing costly machine excavation.
(h) "Wells Hydroelectric Project - Vol. I Comprehensive Model Studies," John S. Gladwell, Howard D. Copp and E. Roy Tinney. Bulletin 289, Washington State Inst. of Tech., Pullman, Washington.

(5519) SOUND SUPPRESSOR-HYDRAULIC MODEL TESTS.

(b) George C. Marshall Space Flight Center, NASA.
(d) Experimental, development.
(e) Development of a vane system to produce uniformly distributed flow around a clover-shaped weir was studied. Surges produced by the rocket exhaust at ignition were investigated with a simulated vacuum chamber.
(h) "Sound Suppressor Hydraulic Model Tests,"by Claud C. Lomax and E. Roy Tinney, Research Report No. 64/9-127, Washington State Inst. of Tech., Pullman, Washington, Dec. 1964. "Supplementary Hydraulic Model Tests of the Sound Suppressor Inlet," Edited by E. Roy Tinney, Research Report No. 65/9-92, Washington State University, Division of Industrial Research, Pullman, Washington, June 1965.

(5521) HELLS CANYON HYDROELECTRIC PROJECT.

(b) Idaho Power Company.
(d) Experimental; applied research.
(e) A 1:60 scale comprehensive hydraulic model was utilized to study fish attraction flows for the fish transportation facilities.
(f) Complete.
(g) A simulated barge above the draft tubes of the powerhouse provides attraction flow through a weir and jet combination.
(h) "Hydraulic Model Studies of the Hells Canyon Hydroelectric Project," by R. A. Sutherland and E. R. Tinney, Washington State University, College of Engineering, Research Division, Pullman, Washington, November 1965.

(5522) FLOW AROUND SHARP BENDS.

(b) Laboratory project.
(d) Theoretical, experimental, applied research.
(e) Project is being conducted to determine the optimum geometry of channel bends to minimize flow losses. Hydrodynamic theory is being developed to consider flow near the inside curve.
(h) Paper in preparation.

(5523) MECHANISMS OF MASS DISPERSION AND ENERGY DISSIPATION IN FREE LAMINAR AND TURBULENT LIQUID SHEETS.

(b) Laboratory project.
(d) Theoretical, experimental, basic research.
(e) Two laminar or turbulent jets, colliding from opposite directions, form a thin expanding sheet or water-bell. G. I. Taylor's equation for the shape of a water-bell has been extended to include gravitational force. Possible mechanisms for mass dispersion and energy dissipation in these sheets are being investigated.
(h) "On the Behavior of Liquid Sheets Formed by the Collision of Jets," by Chao-Piao Huang, Bulletin 292, Washington State University, College of Engineering Division of Research, Pullman, Washington, 1965.

(5524) HYDRAULIC MODEL STUDIES FOR THE ROCK ISLAND FISH ATTRACTION FACILITIES.

(b) Public Utility District of Grant County, Washington.
(d) Experimental.
(e) The purposes of the model study were, (a) to develop a gate opening and closing sequence to facilitate the passage of anadromous fish through the center and right bank fishladder, and (b), to document flow patterns and velocities in the tailrace region under encroachment conditions caused by the construction of Wanapum Dam.
(f) Completed.
(g) The gate operating sequence appears to be adequate under field conditions.
(h) "Hydraulic Model Studies of the Rock Island Fish Attraction Facilities," by David A. Ward, Research Report 65/9-43, Vol. I & II, Wash. State Inst. of Tech., Pullman, Washington, March 1965.

(5529) EVALUATION OF THE PULLMAN-MOSCOW GROUND WATER SITUATION BY TRITIUM AND CARBON-14 DATING TECHNIQUES.

(b) City of Pullman, City of Moscow, Washington Department of Conservation, Washington State University, University of Idaho.
(d) A field and laboratory study involving both applied and basic research.
(e) Ground-water samples are being collected from specific aquifers throughout the Pullman-Moscow basin. These samples are being analyzed for their tritium and carbon-14 contents in the attempt to determine recharge conditions and localities of natural recharge.
(f) Project is continuing.
(g) Current information indicates that ground waters have been in storage for thousands of years and that recharge is minor.
(h) "New Techniques of Water Sampling for Carbon-14 Analysis," by J. W. Crosby, III, and Roy M. Chatters, Journal of Geophysical Research, Vol. 70, No. 12, June 15, 1965.

(5742) CAVITATION AND BUBBLE FORMATION IN NEARLY SATURATED WATER FLOW.

(b) Laboratory project.
(d) Experimental, theoretical.
(e) The purpose of this project was to determine, if possible, the relationship between the scale of an object and the size of the bubble which forms behind it in the flow of water which is very close to its separation temperature.
(h) "Cavitation and Bubble Formation in Nearly Saturated Water Flow," by Richard W. Crain Jr. and John H. Lienhard, Washington State University, College of Engineering Research Division, Pullman, Washington, Oct. 1965.

(5743) FLUID MECHANICAL FORCES PRODUCING VIBRATION IN TRANSMISSION LINE CONDUCTORS.

(b) Bonneville Power Administration.
(d) Experimental, theoretical, master's thesis.
(e) This model study was conducted to investigate the fluid forces which produce vibration in electric transmission line conductors.
(h) "Theoretical and Experimental Studies of the Fluid Mechanical Forces Producing Vibration in Transmission Line Conductors," by J. H. Lienhard, Research Report 65/5-136, Washington State University, College of Engineering Research Division, Pullman, Washington, Oct. 1965.

(5744) HYDRAULIC MODEL STUDIES OF THE IRON GATE DAM.

(b) Bechtel Corporation.
(d) Experimental-Applied Research.
(e) Hydraulic Model studies were utilized to determine the hydraulic characteristics of a side-channel spillway, chute, and terminal structure.
(f) Complete.
(h) "Hydraulic Model Studies of the Iron Gate Side-Channel Spillway," David A. Ward, Washington State University, College of Engineering Research Division, Pullman, Washington, November 1965.

(5745) HYDRAULIC MODEL STUDIES OF POWERDALE DAM.

(b) Pacific Power and Light Company.
(d) Experimental - Applied Research.
(e) The model study was performed to evaluate various hydraulic characteristics of the Powerdale Dam.
(f) Complete.
(h) "Hydraulic Model Studies of Powerdale Dam," by Kannson T. H. Liu and E. Roy Tinney, Research Report No. 65/9-118, College of Engineering Research Division, Washington State University, Sept. 1965.

(5746) HYDRAULIC MODEL STUDIES OF SULLIVAN CREEK DAM AND HEAD WORKS.

(b) Pend Oreille County PUD No. 1, Washington.
(d) Experimental - Applied Research.
(e) A hydraulic model study was performed to verify estimated spillway capacity, investigate performance of spillway tunnel entrance, and investigate stilling basin efficiency.
(f) Completed.
(h) "Hydraulic Model Studies of the Sullivan Creek Dam Headworks and Stilling Basin," by John F. Orsborn, Research Report 65/9-99, Washington State University, College of Engineering Research Division, Pullman, Washington, August 1965.

UNIVERSITY OF WASHINGTON, Fisheries Research Inst.

(3535) EFFECTS OF LOGGING ON PINK SALMON IN ALASKA.

(b) Bureau of Commercial Fisheries, Auke Bay, Alaska.
(c) Dr. Ernest O. Salo, Fisheries Research Inst., University of Washington, Seattle, Wash. 98105.
(d) Determination of effects of logging on water quality of Alaska streams, field investigation, applied and basic research.
(e) Determination of rate of flow and quality of water in salmon spawning beds. Purpose of recording the effects of logging on water quality, hence salmon ecology.
(g) The relationships of (1) rate of flow, (2) dissolved oxygen and (3) permeability of spawning bed gravel and salmon embryo survival has been established.
(h) "Frequency of Digging Movements of Female Pink Salmon Before and After Egg Deposition," W. L. Sheridan. Animal Behaviour 8 (3-4): 228-230, 1960.
"Temperature Relationships in a Pink Salmon Stream in Alaska," W. L. Sheridan. Ecology. 42 (1): 91-98, 1961.
"Waterflow Through a Salmon Spawning Riffle in Southeastern Alaska," W. L. Sheridan, USFWS Special Scientific Report. Fisheries No. 407, 20 pp, 1962.
"Red Superimposition and Egg Capacity of Pink Salmon Spawning Beds,"W. J. McNeil. J. Fish. Res. Bd. Canada 21 (6): 1385-1395,1964.
"A Method of Measuring Mortality of Pink Salmon Eggs and Larvae," W. J. McNeil. USFWS Fishery Bulletin 63 (3): 575-588, 1964.
"Sedimentation in a Salmon Stream," S. Philip Shapley and Daniel M. Bishop. J. Fish. Res. Bd. Canada. 22 (4): 919-928, 1965.

(5959) ESTUARINE ECOLOGY.

(b) National Institutes of Health, U. S. Public Health Service.
(c) Dr. Donald E. Bevan, Associate Dean, College of Fisheries, Univ. of Wash., Seattle, Wash. 98105.
(d) This is a field investigation project encompassing both basic and applied research. Student trainees are employed.
(e) Study includes determining the dynamics of water and waste water under estuarine influence. Computer simulation techniques are being employed to assist in forecasting physical and chemical occurrences in the estuarine environment.
(g) New project, initiated June 1965.

UNIVERSITY OF WASHINGTON, Charles W. Harris Hydraulics Laboratory.

(4725) SALT WATER ENTRAINMENT FOR DILUTION IN SEWER OUTFALLS.

(b) U. S. Department of Health, Education, and Welfare-Public Health Service.
(c) Prof. R. E. Nece, Dept. of Civil Engineering, University of Washington, Seattle, Wash., 98105.
(d) Experimental; basic and applied research.
(e) The mechanism of the entrainment of a fluid from an infinite region of ambient fluid through discrete ports into a conduit flowing full is to be studied experimentally and analytically. One possible application is for pre-dilution in marine sewer outfalls.
(g) Data have been obtained for a range of single circular ports of varying sizes for zero and small density differentials between conduit and entrained fluids. Multi-port data have been obtained for the zero density difference case. Annular port data are being obtained.
(h) Three M. S. theses completed (available on loan).

(5530) A STUDY OF INFILTRATION BENEATH A FOREST FLOOR.

(b) State of Washington Water Research Center.
(c) Professor Thomas H. Campbell, Dept. of Civil Engineering, Univ. of Washington, Seattle, Washington 98105.
(d) Field laboratory investigation.
(e) Instrumentation permits continuous recording of flow past points in unsaturated flow field. Moisture content is also monitored by neutron probe. Transpiration is prevented and evaporation inhibited. Flow data obtained at various plan locations and at various depths can be displayed as hydrographs. Data is being obtained for a number of rainfall events.
(g) Small anomolies in soil structure are proving to cause major anomolies in the soil moisture flow pattern.
(h) "Infiltration Beneath a Forest Floor," Thomas H. Campbell, (progress report), submitted as abstract for publication in Journal of Geophysical Research.

(5531) HYDRAULICS OF FLOW OVER AN INCLINED, POROUS PLATE.

(b) Laboratory project.
(c) Prof. E. P. Richey, Dept. of Civil Engrg., Univ. of Washington, Seattle, Wash. 98105.
(d) Experimental; basic research.
(e) Flow distribution, surface profile determined as depending upon bed slope and porosity.
(f) Completed.

(5532) BED SHEAR AS AN INDEX OF HYDRAULIC JUMP EFFICACY.

(b) Laboratory project.
(c) Prof. R. E. Nece, Dept. of Civil Engrg., Univ. of Washington, Seattle, Wash. 98105.
(d) Experimental; basic research.

(e) Boundary shear stresses are used as an index of determining energy dissipation efficiencies of hydraulic jump in rectangular stilling basins; the procedure provides another description of the effective length of the jump as that within which the bed shear is reduced to safe limits.
(g) Data have been obtained for jumps on a horizontal floor and with jumps having approach slopes of 1 in 5, 1 in 3, and 1 in 1.5. Limited shear data are available for two basin configurations containing end sills and baffle piers.
(h) One M.S. thesis completed (available on loan).

(5697) FLUID MECHANICS OF DOWNSTREAM FISH PASSAGE STRUCTURES.

(b) State of Washington Water Research Center.
(c) Professor E. P. Richey, Dept. of Civil Engrg., Univ. of Wash., Seattle, Washington 98105.
(d) Experimental, applied research; Master's thesis.
(e) Certain wedge-shaped obstructions in an open channel have been observed to provide a degree of guidance to small, migrant fish. A laboratory experiment is being designed to determine the role of convective acceleration and other hydraulic parameters in the guidance phenomenon.

(5698) EFFECT OF DAM CONSTRUCTION ON DOWNSTREAM WATER TEMPERATURE.

(b) Office of Water Resources Research, and State of Washington Water Research Center.
(c) Prof. R. E. Nece, Dept. of Civil Engrg., Univ. of Washington, Seattle, Wash. 98105.
(d) Field investigation; applied research.
(e) The objective of this study is to correlate downstream water temperatures before and after dam construction with topographical, hydrological, and meteorological parameters of the drainage basin. Such data would provide a "model" for future dam development effects on certain aspects of water quality in comparable areas of the Pacific Northwest.
(g) Instrumentation being installed.

WEBB INSTITUTE OF NAVAL ARCHITECTURE.

(5202) DETERMINATION OF SHIP WAVE RESISTANCE.

(b) David Taylor Model Basin, Bureau of Ships, Dept. of the Navy.
(c) Dr. Lawrence W. Ward, Prof. of Engineering, Webb Institute of Naval Architecture, Glen Cove, Long Island, New York 11542.
(d) Experimental and theoretical; basic research.
(e) Investigation of means for direct experimental determination of ship wave resistance from measurements of the wave pattern during a model test. Purpose includes improvement in scaling model test results to full size as well as basic understanding of nature of ship resistance.
(g) Method utilizing forces exerted by the wave pattern on a long vertical cylinder has been developed and tests run. Results are encouraging and in agreement with other investigators. Experimental wave resistance when added to estimated skin friction is less than measured total resistance. New method utilizing wave slope records being investigated.
(h) "Wave Resistance Surveys on A Ship Model of Minimum Resistance," Lawrence W. Ward, Webb Institute, August 1965.
"Experimental Determination of Ship Wave Resistance from the Wave Pattern," Lawrence W. Ward, Webb Institute, November 1964.

(5203) ASSESSMENT OF SEAKEEPING CHARACTERISTICS OF SHIPS.

(b) Society of Naval Architects & Marine Engineers, Panel H-7 of Hydrodynamic Committee.
(c) Prof. Edward V. Lewis, Research Prof. of Naval Architecture, Webb Institute of Naval Architecture, Glen Cove, L. I., N. Y. 11542.
(d) Theoretical application of available experimental results and confirmation by model tests; applied research.
(e) Application of available knowledge of ship model behavior in regular waves to the prediction of trends of ship performance in realistic irregular wave patterns. Experimental confirmation by means of model tests in waves. Purpose is to provide the ship designer with guidance in the selection of hull characteristics.
(f) Theoretical work is completed; experimental phase is active.
(g) The advantage of a high length/draft ratio in permitting higher speeds before shipping water forward is clearly shown. A corresponding disadvantage in terms of likelihood of slamming is found, requiring a balance to be made in selecting optimum ship characteristics.
(h) "Applying Results of Seakeeping Research," E. V. Lewis, Fifth Symposium on Naval Hydrodynamics, Bergen, Norway, September, 1964. (To be published by Office of Naval Research, Washington 25, D.C.)
"Assessment of Seakeepability," Norman Hamlin and Roger Compton, Webb Institute, June 1965.

(5942) MODEL STUDIES OF SHIP SLAMMING IN WAVES.

(b) American Bureau of Shipping.
(c) Prof. Walter Maclean, Prof. of Engrg., Webb Inst. of Naval Architecture, Glen Cove, Long Island, New York 11542.
(d) Experimental study making use of ship models in waves; applied research.
(e) Two 5-foot models, jointed at amidships for measurement of wave bending moments, are being run in waves to determine the conditions for bottom slamming to occur and to compare with theoretical predictions.

THE WESTERN COMPANY, Research Division.

(5291) EFFECT OF POLYMER COILING ON DRAG REDUCTION.

(b) David Taylor Model Basin, Fundamental Hydromechanics Research Program.
(c) Dr. H. R. Crawford, The Research Div. of The Western Company of North America, 1171 Empire Central, Dallas, Texas 75247.
(d) Experimental; basic research.
(e) Turbulent friction loss of dilute solutions of polymers in various solvent systems are being determined to relate the degree of polymer coiling to the turbulent drag reduction.

(5960) TURBULENT HEAT TRANSFER CHARACTERISTICS OF VISCOELASTIC FLUIDS.

(b) NASA Physics of Fluids Branch.
(c) Dr. H. R. Crawford, The Research Division of The Western Company of North America, 1171 Empire Central, Dallas, Texas 75247.
(d) Experimental; basic research.
(e) Turbulent heat transfer coefficients are being determined for viscoelastic solutions of various polymers in distilled water, to allow prediction of turbulent heat transfer characteristics for this type of fluid.

(5961) EFFECT OF MOLECULAR WEIGHT AND SEGMENTAL CONSTITUTION ON DRAG REDUCTION.

(b) David Taylor Model Basin, Fundamental Hydromechanics Research Program.
(c) Dr. H. R. Crawford, The Research Div. of The Western Co. of North America, 1171 Empire Central, Dallas, Texas 75247.
(d) Experimental; basic research.
(e) The turbulent drag reduction of dilute water solutions of various polymers were determined to relate drag reduction to the molecular

dimensions of the molecule.
(f) Completed.
(g) A correlation between molecular dimensions and drag reduction is presented in the report.
(h) "Effect of Molecular Weight and Segmental Constitution on the Drag Reduction of Water Soluble Polymers," G. T. Pruitt and H. R. Crawford DTMB Rpt. Nonr 4306(00), (Apr. 1965).

UNIVERSITY OF WISCONSIN, Hydraulics and Sanitary Laboratories.

(956) ENERGY LOSS IN LIQUID FLOW IN PIPES AND FITTINGS UNDER HIGH PRESSURE.

(b) Laboratory project in cooperation with the Ladish Company, Cudahy, Wisconsin, and the Wisconsin Alumni Research Foundation.
(c) Dr. J. R. Villemonte, Director, Hydraulics and Sanitary Laboratories, Univ. of Wisconsin, Madison, Wisconsin 53706.
(d) Theoretical and experimental; applied research and design for B.S., M.S. and Ph.D. theses.
(e) Energy loss measurements in straight pipes and fittings have been completed on sizes 1/4 inch to 2 inches. Pressure range 0-2500 psi, temperature range 60 to 120 °F. Reynolds number range 50 to 150,000.
(f) Completed.
(g) If viscosity, density, and temperature relations are known, the standard pipe friction theory applies at high pressures. The fitting loss constants for laminar flow are about 3 times those for turbulent flow when N = 2000. The loss gradually reduces to zero at NB = 150.

(1181) VORTEX FLOW FROM HORIZONTAL THIN-PLATE ORIFICES.

(b) Laboratory project.
(c) Dr. J. R. Villemonte, Director, Hydraulics and Sanitary Laboratories, Univ. of Wisconsin, Madison, Wisconsin 53706.
(d) Theoretical and experimental; basic research for M.S. and Ph.D. theses.
(e) The effects of vorticity on orifice discharge are being studied over a wide range of vorticity, head, orifice size, and fluid viscosity.
(g) A new parameter, the vortex number, was developed as the ratio of inertial and centrifugal forces. A general correlation procedure was also developed for estimating discharge rates through orifices with varying degrees of vorticity.
(h) "The Effects of Viscosity on Vortex-Orifice Flow," P. B. Zielinski, Ph.D. thesis, 1965, University of Wisconsin (in preparation).

(3539) DISTURBED LAMINAR AND TURBULENT FLOW.

(b) Wisconsin Alumni Research Foundation.
(c) Dr. J. R. Villemonte, Director, Hydraulics and Sanitary Laboratories, Univ. of Wisconsin, Madison, Wisconsin 53706.
(d) Theoretical and experimental; basic research for M.S. and Ph.D. theses.
(e) The equation of motion has been applied to several situations of disturbed laminar and turbulent flow and compared with experimental results. Flows are disturbed using orifices and screens. Turbulence is measured by a newly developed magnetohydrodynamic probe in conjunction with analog and digital computers to give the turbulence energy spectra.
(g) New equations have been developed for estimating losses due to combined and divided flow as well as losses due to other disturbances. Turbulence energy spectra have been developed for a wide variety of boundary configurations. The new probe permits the observation of the distribution of turbulent energy across the section of flow.
(h) "Liquid Turbulent Investigation with an Electro-Magnetic Probe," H. J. Day and J. R. Villemonte, Proceedings 9th Midwestern Mechanics Conference, 1965, University of Wis.

(3540) MODEL STUDIES OF PUMP INLET STRUCTURES (see page 106).

(3541) HYDRAULIC CHARACTERISTICS OF GRAVITY SEPARATION BASINS (see page 106).

(3854) REACTION JET INLET FOR OIL-WATER SEPARATORS.

(b) The American Petroleum Inst.
(c) Prof. G. A. Rohlich and Dr. J. R. Villemonte Hydraulics and Sanitary Laboratories, Univ. of Wisconsin, Madison, Wisc. 53706.
(d) Experimental; basic research and design for master's and doctoral theses.
(e) Studies were conducted in a transparent basin 5 ft wide, 10 ft long and 3 ft deep. Investigations were made using various sizes and spacings of a reaction jet at the entrance to the basin to determine the effects of jet inflow on the hydraulic characteristics.
(f) Completed.
(g) Hydraulic characteristics for rectangular basins with Reaction Jet inlet devices were observed using a wide range of flows.

(4251) CHANNEL DYNAMICS ABOVE GULLY CONTROL STRUCTURES.

(b) U.S. Department of Agriculture, Agricultural Research Service.
(c) Dr. Arno T. Lenz, Chairman, Dept. of Civil Engineering, University of Wisconsin, 1513 University Ave., Madison, Wisconsin 53706.
(d) Theoretical study and field investiagtion of basic research in channel dynamics for Ph.D. thesis.
(e) Data from field surveys of 44 gully control structures in Southwestern Wisconsin have been analyzed to develop procedures for estimating quantitatively the dynamic changes in channel profiles which occur when a gully control or sediment detention structure is built.
(f) Completed.
(g) An equation has been developed for the ratio of the average deposition slope to the original channel slope as a function of past and present hydraulic and sediment parameters.

(4252) CHARACTERISTICS OF A DENSITY STRATIFIED FLUID.

(b) U. S. Public Health Service and Laboratory Project.
(c) Dr. P. L. Monkmeyer, 1261C Engineering Bldg., Univ. of Wisconsin, Madison, Wisc. 53706.
(d) Theoretical; basic research for Ph.D. thesis.
(e) Dynamic characteristics of density-stratified fluids are being investigated. Particular emphasis is being placed on a study of the mechanics of Langmuir Vortices, in an effort to explain the phenomenon of foam lines on lakes. Steady flow problems relating to standing internal waves are also under investigation.
(g) Linearized equations for steady, inviscid, compressible flow in atmospheres with various density distribution have been developed and solved for simple boundary configurations.

(4732) UNIT HYDROGRAPH VARIATION WITH STORM HYDROGRAPH SHAPE.

(b) Laboratory project.
(c) Dr. Arno T. Lenz, Chairman, Department of Civil Engineering, 1513 University Avenue, Madison, Wisconsin 53706.
(d) Theoretical study and field investigation of the unit hydrograph. Basic research for Ph.D. thesis.
(e) A general one-hour dimensionless unit hydrograph derived from 16 Illinois basins was used successfully to derive 92 one-hour unit hydrographs for four midwestern basins of 22 to 77 square miles in area for storms of 1 to 13 hours duration. Computations were made

using IBM 1620 and CDC 1604 computers.
(f) Ph.D. thesis by Dr. Donald L. Bender completed.
(g) Unit hydrographs needed to reproduce single-peak storm hydrographs varied with peak discharge, shape, and volume of the storm hydrographs. Shapes can be described by a dimensionless parameter the ratio of the hydrograph peak to the flow in a rectangular hydrograph of equal runoff volume and unit time base.
(h) Paper for A.G.U. in preparation.

(4733) THE TRANSFORMATION OF RAINFALL ON THREE BASINS IN NORTH CENTRAL WISCONSIN.

(b) Laboratory project.
(c) Dr. A. T. Lenz, Chairman, Dept. of Civil Engineering, University of Wisconsin, 1513 University Avenue, Madison, Wisconsin 53706.
(d) Experimental and theoretical with field investigation; basic research for Ph.D. thesis.
(e) This study is to determine the relationships existing between rainfall, stream runoff, infiltration, groundwater, and evapotranspiration with respect to three drainage basins in North Central Wisconsin which have both similar and dissimilar soil types and aquifers, based on published data.
(h) Ph.D. Thesis by Dr. John F. Orsborn completed. Paper in preparation.

(4734) FLOW BETWEEN CONCENTRIC ROTATING CYLINDERS.

(b) Wisconsin Alumni Research Foundation and Fairbanks Morse Co.
(c) Dr. P. L. Monkmeyer, 1261C Engineering Bldg., Univ. of Wisconsin, Madison, Wisconsin 53706.
(d) Theoretical and experimental; basic research for Ph.D. thesis.
(e) This study is concerned with the characteristics of turbulent flow in an annulus, with rotating inner cylinder. Theoretical prediction and experimental confirmation of shearing stresses, torque, pressure gradients, and frictional resistance are being sought.
(g) A theory has been developed to predict the frictional resistance to turbulent flow in a rotating annulus. Experimental confirmation has been obtained over a limited range of flow conditions.
(h) "Turbulent Helical Flow in an Annulus," Ph.D. thesis by L. W. Gelhar, 1964. A paper is in preparation.

(4735) MODEL STUDY OF A PROPOSED BARRAGE AT MUSCODA, ON THE WISCONSIN RIVER.

(b) Muscoda Advancement Corporation, Muscoda, Wisconsin.
(c) Dr. J. R. Villemonte and Dr. P. L. Monkmeyer, Hydraulics and Sanitary Laboratories, Univ. of Wisconsin, Madison, Wisconsin 53706.
(d) Experimental; applied research and design for M.S. thesis.
(e) A comprehensive study is under way to determine the possible effects of constructing a barrage, at Muscoda, on the Wisconsin River. The study includes construction of three models to determine downstream scour patterns, dam stability and overflow characteristics. Backwater effects are also being studied.
(g) Scour and stability data have been predicted from the results of two model studies. Predictions of upstream backwater levels have been made using the digital computer.
(h) Three unpublished theses and project reports have been prepared.

(4736) UNSTEADY FLOW IN POROUS MEDIA.

(b) Wisconsin Water Resources Center.
(c) Dr. P. L. Monkmeyer, 1261C Engineering Bldg., Univ. of Wisconsin, Madison, Wisconsin 53706.
(d) Theoretical and experimental; basic and applied research for Ph.D. thesis.
(e) The following problems in unsteady flow through a porous medium are under investigation: use of sound waves to determine permeability; effect of stream bank clogging on unsteady flow of ground water; unconfined, unsteady flow of groundwater toward a surface stream.
(g) A theory, predicting the behavior of sound waves transmitted through a porous medium, has been developed and verified experimentally. The theory, based on an extension of Darcy's Law for unsteady flow, may be used to determine permeability. A theoretical description of flow from an aquifer to a surface stream whose banks are less pervious than the aquifer has been developed using a heat flow analogy. Field data is used to confirm the theory.
(h) "Permeability of Porous Media to Transient Flow," Ph.D. thesis by H. C. Misra, 1965. "The Effect of Stream Perimeter Clogging on Unsteady Ground Water Flow Toward a Surface Stream," Ph.D. thesis by A. G. Law, 1965. Papers are in preparation.

(5011) HYDRAULIC CHARACTERISTICS OF CYLINDRICAL SLOT ORIFICES.

(b) W. A. Kates Company.
(c) Dr. J. R. Villemonte, Director, Hydraulics and Sanitary Laboratories, Univ. of Wisconsin, Madison, Wisconsin 53706.
(d) Experimental; design.
(e) The effects of viscosity, head, and slot type and shape on the coefficient of discharge are being studied.

(5597) HYDRAULIC CHARACTERISTICS OF DROP INLETS.

(b) U. S. Department of Agriculture, Agricultural Research Service and Laboratory Project.
(c) Dr. J. R. Villemonte, Director, Hydraulics and Sanitary Laboratories, Madison, Wisconsin 53706.
(d) Experimental; applied research for M. S. Theses.
(e) Model studies will be made of a drop inlet structure located in the head waters of the Kickapoo River Valley, Cashton, Wisconsin. The objective is to determine operating characteristics for several types of crest configurations.

(5598) CHARACTERISTICS OF GRAVITY WAVES.

(b) U. S. Army Mathematics Research Center.
(c) Dr. P. L. Monkmeyer, 1261C Engineering Building, Univ. of Wisconsin, Madison, Wisconsin 53706.
(d) Theoretical; basic research.
(e) Higher order theories for finite height gravity waves are under study.
(g) A higher order non-linear theory for deep water waves of finite amplitude has been developed.
(h) "A Higher Order Theory for Deep Water Waves," by P. L. Monkmeyer and J. E. Kutzbach, Proceedings of the Coastal Engineering Conference, Santa Barbara, 1965.

(5790) DISPERSION AND RE-CHARGE IN GROUND WATER FLOW.

(b) University of Wisconsin Alumni Research Foundation and the University of Wisconsin Water Resources Center.
(c) Dr. J. A. Hoopes, 1212 Engineering Building, University of Wisconsin, Madison, Wisc. 53706.
(d) Theoretical and Experimental; Basic Research.
(e) Dispersion of a tracer in flow through non-homogeneous porus media is under study. Theoretical predictions, coupled with experimental confirmation for different patterns of non-homogeneity are being sought.

(5791) CIRCULATION AND MIXING PROCESSES IN LAKES.

(b) University of Wisconsin Water Resources Center.
(c) Dr. R. A. Ragotzkie, 425 Science Hall, Univ. of Wisconsin, Madison, Wisconsin 53706; Dr. J. A. Hoopes, 1212 Engineering Building,

University of Wisconsin, Madison, Wisc. 53706.
(d) Experimental; Applied Research.
(e) This investigation deals with field and laboratory model studies of the current and temperature profiles of Lake Superior. These studies will be integrated and combined with mathematical models in an effort to understand and predict motions within the lake and the resulting distribution of substances introduced at various points in the lake.

WOODS HOLE OCEANOGRAPHIC INSTITUTION.

(4737) HYDRODYNAMICS OF ROTATING LIQUIDS.

(b) Office of Naval Research, Dept. of the Navy.
(c) Dr. Alan Ibbetson, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts 02543.
(d) Experimental and theoretical; basic research.
(e) Hydrodynamics of rotating liquid systems having variable depth, including blocking action by bottom topography ("Taylor columns") and measurements on Rossby waves in an open rotating basin.
(g) Measurements on Rossby waves in liquid annulus, including dispersion relationship, damping coefficient, reflection properties.
(h) "The Construction of a One-Meter Diameter Rotating Table," A. Ibbetson and R. E. Frazel, Woods Hole Oceanographic Institution unpublished report, Reference 65-41, August 1965. "An Experimental Study of "Taylor columns,"" R. Hide and A. Ibbetson. To appear in "Icarus."

WORCESTER POLYTECHNIC INSTITUTE, Alden Hydraulic Laboratory.

Inquiries concerning the following projects should be addressed to Professor Leslie J. Hooper, Director, Alden Hydraulic Laboratory, Worcester Polytechnic Institute, Worcester, Mass. 01609.

(1963) METER CALIBRATIONS.

(b) Foxboro, Company, Foxboro, Mass.
(d) Experimental, for design.
(e) Calibration of various sizes of magnetic flow tubes (1" to 36" diameter) and a variety of nozzle and orifice plate assemblies.
(f) Tests in progress.

(3859) METER CALIBRATIONS.

(b) B-I-F Industries, Providence, R. I.
(d) Experimental, for design.
(e) Calibration of open flow nozzles and flow tubes up to 48" in diameter. Tests performed in standard test loop and also in mock-up of particular field installations.
(f) Tests in progress.

(4255) METER CALIBRATIONS.

(b) Penn Meter Company, Philadelphia, Pa.
(d) Experimental; for design.
(e) Calibration of open flow nozzles and flow tubes from 2" to 48" in diameter in the standard test loop. In addition, tests have been performed to determine operating characteristics in a variety of field installation mock-up include a number of pipe surface finishes.
(f) Tests in progress.

(4740) CHONG PYONG HYDROELECTRIC PROJECT.

(b) Stone and Webster Engineering Corp., Boston, Mass.
(d) Experimental, for design.
(e) A 1/75 scale model of a reach of the North Han River in the Republic of Korea was constructed for the Korea Electric Company. The model included the spillway and powerhouse as well as river topography up and downstream of the development. Studies were made of a number of changes designed to improve spillway and powerhouse operation. In addition a number of schemes for the different river diversions and construction planning were studied.
(f) Completed.
(h) Report completed and on file with clients.

(4741) CORNWALL PUMPED STORAGE DEVELOPMENT.

(b) Uhl, Hall and Rich, Boston, Mass.
(d) Experimental, for design.
(e) A 1/80 scale model of the intake at the upper reservoir was constructed including local topography at the intake. The studies involved the flow patterns and possible surface disturbances in the reservoir and also the flow in the first few diameters of the vertical shaft of the intake.
(f) Tests completed.
(h) Report completed and on file with clients.

(4746) METER CALIBRATIONS.

(b) Hagan Chemicals and Controls, Inc., Pittsburgh, Penn.
(d) Experimental, for design.
(e) Calibration of a variety of sizes and designs of flow nozzles and flow nozzle assemblies.
(f) Tests in progress.

(5020) CARDINAL STEAM PLANT.

(b) American Electric Power Service Corp., New York, N. Y.
(d) Experimental, for design.
(e) A 1/120 by 1/40 distorted scale model of a section of the Ohio River upstream and downstream from the Cardinal Plant of the Ohio Power Co. The plant inlets and outlets for condenser cooling water were installed for both the present unit and three future units. The studies were performed on the hot water flow patterns in order to insure a minimum of hot water from either the old or the new units reentering the cooling water system. In addition bed load movement of the river and barge handling techniques were studied over a range of river stages.
(f) Additional tests completed during 1965.
(h) Report in preparation.

(5021) MUDDY RUN PUMPED STORAGE DEVELOPMENT.

(b) Philadelphia Electric Co., Philadelphia, Penn.
(d) Experimental, for design.
(e) A 1/35.3 scale model of the intake structure, the immediate topography in the reservoir and a section of the vertical tunnel below the intake were modeled to study the flow characteristics and evaluate the losses in both the pumping and generating cycles.
(f) Work completed.
(h) Report completed and on file with clients.

(5022) DYNAMIC EFFECTS IN FLOW METER COEFFICIENT PREDICTION.

(b) Laboratory project.
(d) Experimental, for M.S. thesis.
(e) A number of differential producer type flow meters are being studied under different Reynolds Number levels with the same volume flow rate. It is planned to evaluate the dynamic effects on the discharge coefficient.
(f) Suspended.

(5023) VELOCITY DISTRIBUTION INFLUENCE ON BEND LOSSES.

(b) Laboratory project.
(d) Experimental for M.S. thesis.
(e) An experimental and theoretical study of the variation in energy loss in a 90 pipe bend

was carried out and evaluation of the loss set up in terms of the upstream velocity distribution.
(f) Work completed.
(h) Masters Thesis by Tumkur B. Puttaswamy dated June 1964 on file in Worcester Polytechnic Institute Library.

(5024) CORNWALL PUMPED STORAGE DEVELOPMENT.

(b) Uhl, Hall and Rich, Boston, Mass.
(d) Experimental, for design.
(e) A 1/56 scale model of the manifold and penstock sections was constructed of plexiglass and PVC pipe in the appropriate diameters. The sections varied in diameter (full scale) from 40' for the manifold to 10' for the penstocks at the powerhouse. Measurements of pressure head at each change in section and alignment were made to evaluate the loss coefficients in both the generating and pumping situations.
(f) Tests completed.
(h) Report completed and on file with clients.

(5268) LITTLE GYPSY STEAM POWER PLANT.

(b) Ebasco Services, Inc., New York.
(d) Experimental, for design.
(e) A 1/12 scale model of the condenser cooling water intake of the plant of the Louisiana Power Co., including the sump and vertical pump bell mouth was constructed. The studies included various modifications to insure a uniform velocity distribution at the pump intake for the required flows.
(f) Tests completed.
(h) Report completed and on file with clients.

(5269) CABIN CREEK PUMPED STORAGE DEVELOPMENT.

(b) Stone and Webster Engineering Corp., Boston, Mass.
(d) Experimental, for design.
(e) A 1/100 scale model of the upper reservoir of the development of the Public Service Corp. of Colorado was constructed. The model included the reservoir, upper face of the dam and the water intake to the tunnel. The studies involved the flow patterns in the reservoir for various phases of operation including both pumping and generating. A qualitative study of ice flows in the reservoir under the influence of wind was conducted. Treatment of intake location and flow at the intake was evaluated.
(f) Test completed.
(h) Report completed and on file with clients.

(5270) KASTRAKI HYDROELECTRIC DEVELOPMENT.

(b) Ebasco Services Inc., New York.
(d) Experimental, for design.
(e) A 1/100 scale model of the Kastraki development of the Public Power Corp. on the Acheloos River was constructed. The model included a section of the reservoir, the gravity dam, spillway, powerhouse and river bed downstream including the confluence with the Zervas Torrent. The studies include the approach conditions to the side spillway, the supercritical flow in the spillway chute and the conditions in the tailrace area.
(f) Tests completed.
(h) Report in preparation.

(5271) CAMPBELL STEAM POWER PLANT.

(b) Commonwealth Associates Inc., Jackson, Michigan.
(d) Experimental, for design.
(e) A 1/10 scale model of the intake at the Campbell Plant of the Consumers Power Co. on Lake Michigan was constructed. The local lake section was duplicated in a steel head box and the intake structure was mounted outside to allow viewing of flow patterns through the transparent wall. Studies were aimed at reducing the head loss and disturbed flow in the screenhouse and gate structure.
(f) Tests completed.
(h) Report completed and on file with clients.

(5272) INDIAN POINT STEAM PLANT.

(b) Consolidated Edison Co., New York.
(d) Experimental, for design.
(e) A 1/60 horizontal by 1/40 vertical scale model was constructed of the Indian Point Atomic Power Plant on the Hudson River. A section of the river either side of the intake and including the intake and its allied docking facilities was modeled. The capability to model the hot condenser effluent was incorporated to facilitate the study of recirculation, mixing and allied density current effects.
(f) Tests in progress.

(5273) CICEROZ HYDROELECTRIC DEVELOPMENT.

(b) Ebasco Services Inc., New York.
(d) Experimental, for design.
(e) The 1/70 scale model was constructed of the Ciceroz development of the Electric Power Generating Co. of Turkey. The model included the streamabove and below the site, the arch dam, spillway and the powerhouse and allied water passages. The studies were involved with the approach flow to the spillway and powerhouse intake and the flow results in the tailrace for a variety of flow conditions. Penstocks were fabricated of clear plastic to allow observation of flow in various sections.
(f) Tests completed.
(h) Report completed and on file with clients.

(5274) KEBAN HYDROELECTRIC DEVELOPMENT.

(b) Ebasco Services Inc., New York.
(d) Experimental, for design.
(e) A 1/100 scale model of the project on the Euphrates River was constructed for the Electric Power Generating Co. in Turkey. Included in the model was the river above the dam, the dam, water intakes, spillway, fuse plug, penstocks, spillway chute, powerhouse and a section of river downstream including the tailrace. The studies involved intake operation, spillway and gates, fuse plug performance, spillway chute and wall design and tailrace flow patterns.
(f) Test completed.
(h) Report completed and on file with clients.

(5275) PETERSBURG STEAM POWER PLANT.

(b) Stone and Webster Engineering Corp., Boston, Mass.
(d) Experimental, for design.
(e) A 1/120 by 1/40 vertical scale model of a section of the White River has been constructed for the Indianapolis Power and Light Co. The model represents a section of the river above and below the Pittsburgh plant. Studies are being conducted on bed load movement necessary protective works at the intake, and possible recirculation of hot condenser cooling water.
(f) Tests completed.
(h) Report completed and on file with clients.

(5276) HOLYOKE POWER DEVELOPMENT.

(b) Holyoke Water Power Co., Holyoke, Mass.
(d) Experimental, for design.
(e) A 1/15 scale sectional model of the gate house structure at the canal entrance was constructed in the 3 foot glass sided flume. Studies were made of forces on various sections including gates and flow and velocity patterns were studied. The experimental work involved representatives of Stone and Webster, Holyoke Water Power and Alden Hydraulic Laboratory.
(f) Tests completed.
(h) Report completed and on file with clients.

(5278) METER CALIBRATIONS.

(b) Potter Aeronautical Corp., Union, N. J.
(d) Experimental, for design.
(e) Calibration of turbine type flow meters from 2" to 24" in diameter of both the volume and mass flow design have been calibrated. Piping arrangements include standard loop tests and variations such as tandem mounting.
(f) Tests in progress.

(5279) METER CALIBRATIONS.

(b) ITT General Controls, Warwick, R. I.
(d) Experimental, for design.
(e) Calibration of flow tubes in a range of sizes from 6" to 48" has been carried out. Field piping as well as standard test loop installation have been used.
(f) Tests in progress.

(5962) METER CALIBRATIONS.

(b) Bailey Meter Company, Wickliffe, Ohio.
(d) Experimental, for design.
(e) Calibration of flow nozzles and flow meters in standard as well as particular metering and piping configurations for a range of sizes from 1" to 16" diameter.
(f) Tests in progress.

(5963) METER CALIBRATIONS.

(b) Fischer and Porter Company.
(d) Experimental for design.
(e) Calibration of various sizes of magnetic flow tubes from 2" to 48" diameter.
(f) Tests in progress.

(5964) BRUNNER ISLAND STEAM POWER PLANT.

(b) Ebasco Services, Inc., New York.
(d) Experimental for design.
(e) A 1/10 scale model of the cooling water intake of the development on the Susquehanna River was modeled for Pennsylvania Power and Light Co. The model in addition to the intake structure included some topography at the inlet and the pump bell mouths. Measurements of velocity were obtained at a number of sections in the structure and in the pumps. Photographs and observations of dye patterns in the flow were made during the program.
(f) Tests completed.
(h) Report in preparation.

(5965) KANAWHA RIVER STEAM POWER PLANT.

(b) Union Carbide Co., Niagara Falls, New York.
(d) Experimental for design.
(e) A distorted model (1/100 horizontal and 1/50 vertical) of a section of the Kanawha River at Alloy, West Virginia was constructed. This model included river topography from approximately three miles above the plant to one mile below the plant as well as the plant intake (with flow) and other pertinent structures. Possible variations in the intake structure were studied in order to reduce the amount of bed load and suspended material drawn into the plant during operation. Water soaked sawdust and fine sand were used as materials to reproduce the foreign material during the studies. Velocity measurements at a number of sections on the model were also made during the studies.
(f) Tests completed.
(h) Report completed and on file with clients.

(5966) SUPERCRITICAL BOILER STUDY.

(b) Riley Stoker Co., Worcester, Massachusetts.
(d) Experimental for design.
(e) A 1/10 scale model of the boiler representing the tubular walls with clear lucite was constructed. The study was initiated to study flow patterns and residence time in boiler for a variety of fuel burner locations and combinations. Flow patterns were determined using dye and plastic balls while residence time was obtained from continuous counts of plastic particles.
(f) Tests completed.
(h) Report completed and on file with clients.

(5967) TWO PHASE FLOW STUDIES.

(b) M. W. Kellog, Co., New York.
(d) Experimental for design.
(e) A full scale mock-up of the piping was installed with clear plastic sections in a number of critical pipe sections. Air and water were used as to two fluids in the study and a variety of combinations of flows and pressures were studied. Oscillographic records of pressures at 12 stations were obtained in addition to visual and photographic observation of flow at the clear plastic sections. The effects of different combinations of elbows, tees and valves were evaluated during the program.
(f) Tests completed.
(h) Report completed and on file with clients.

(5968) MILLSTONE STEAM POWER PLANT.

(b) Bechtel Corp., Gaithersburg, Maryland.
(d) Experimental for design.
(e) A distorted model (1/3000 horizontal and 1/400 vertical) was constructed of a section on Long Island sound in the vicinity of Millstone Point. Approximately 12 miles of the Conn. shore was reproduced and tidal variations in this area were simulated. The study resulted in flow patterns over the area covered and allowed evaluation of dilution and distribution of effluent from Millstone Point.
(f) Tests completed.
(h) Report in preparation.

(5969) CHALK POINT STEAM POWER PLANT.

(b) Potomac Electric Power Co., Washington, D.C.
(d) Experimental for design.
(e) A 1/10 scale model of the water box and tube banks of a steam condenser have been modeled in clear plastic. The model also included the water passages upstream of the water box beyond the two 90° bends toward the pumps. The study involved determing flow patterns in the water box and velocities and velocity distribution in the tubes.
(f) Test in progress.

(5970) WILLOW GLEN STEAM POWER PLANT.

(b) Stone and Webster Engineering Corp.
(d) Experimental for design.
(e) A 1/21.8 scale model was constructed for the Gulf States Utility Co. The model included the discharge flume, stilling basin and river topography in the immediate area of the stilling basin. The studies involve evaluation of the effectiveness of the stilling basin for present loads plus future projected loads. Velocity measurements and water surface elevations as well as indications of scour in the river beyond the stilling basin have been recorded.
(f) Tests in progress.

(5971) WILLOW GLEN STEAM POWER PLANT.

(b) Stone and Webster Engineering Corp.
(d) Experimental for design.
(e) A 1/12 scale model of the proposed circulating water pump intake has been constructed for the Gulf States Utility Company. The model studies are to evaluate the alternative designs for the intake and water passages. Velocities and flow distribution will be measured and other critical phenomena near the pump inlets will be observed.
(f) Tests in progress.

UNIVERSITY OF MICHIGAN, Ship Hydrodynamics Lab.

(5375) LARGE BULBOUS BOWS ON FULL SHIP FORMS.

(b) Laboratory project.
(c) Prof. R. B. Couch, Ship Hydrodynamics Lab., Univ. of Mich., Ann Arbor, Mich. 48104.
(d) Experimental; applied research.
(e) Investigation of the effects on resistance and on flow of large bulbous bows on a full ship hull model. Variables are size, shape and position of bulb as well as displacement and trim of the model.
(g) Significant reductions in form and wave resistances are possible with proper combination of bulb, displacement and trim.
(h) To be published by the Society of Naval Architects and Marine Engineers.

(5376) SCALE EFFECT ON RESISTANCE AND SELF-PROPULSION FACTORS OF MERCHANT SHIP FORMS.

(b) Maritime Administration, Dept. of Commerce.
(c) Prof. R. B. Couch, Ship Hydrodynamics Lab., Univ. of Mich., Ann Arbor, Mich. 48104.
(d) Experimental; basic research.
(e) Ship models of Series 60 forms and variations and corresponding propeller models of varying size are being tested for resistance and propulsion characteristics to investigate effects of scaling. More accurate full scale predictions are sought.
(g) Full scale predictions of propulsion factors from tests of 17 ft. long models of conventional cargo ship forms are sufficiently free of scale effects as to be of desirable accuracy.
(h) "Resistance and Propulsion Scale Effect Investigation on Two C_B = 0.60 Merchant Hull Forms," R. B. Couch and J. L. Moss, The University of Michigan Ship Hydrodynamics Laboratory Report 06290-1-F. To obtain report, contact Prof. R. B. Couch.

(5377) BLOCKAGE CORRECTION IN A SHIP MODEL TOWING TANK.

(b) Maritime Administration, Dept. of Commerce.
(c) Prof. F. C. Michelsen, Dept. of Naval Architecture and Marine Engrg., Univ. of Michigan, Ann Arbor, Michigan 48104.
(d) Experimental and theoretical; basic research.
(e) The restricted channel effect is being investigated both theoretically and experimentally, the latter by geosim series towing tests of models in The University of Michigan tank and by comparison with tests from other tanks.
(g) A semi-empirical formula has been developed for normal merchant ship forms and is being refined.

(5378) DETERMINATION OF VISCOUS DRAG OF SHIP MODELS BY WAKE SURVEY.

(b) Maritime Administration, Dept. of Commerce.
(c) Prof. F. C. Michelsen, Dept. of Naval Architecture and Marine Engrg., Univ. of Michigan, Ann Arbor, Michigan 48104.
(d) Theoretical and experimental; basic research.
(e) A five-hole spherical pitot tube is used to determine the wake velocity field. Momentum considerations allow calculation of the viscous drag taking into account the free surface.
(g) Test data being analyzed by high speed analog to digital conversion techniques.
(h) "Experimental Techniques for Determination of Viscous Resistance Using the High Response Five-Hole Pilot Tube," J. C. Gebhardt, F. C. Michelsen and J. L. Moss, 1965 American Towing Tank Conference, for copies contact authors at above address.

(5379) DEVELOPMENT OF A LOW-RESISTANCE, HIGH DISPLACEMENT-LENGTH RATIO MERCHANT HULL FORM.

(b) Maritime Administration, Dept. of Commerce.
(c) Prof. F. C. Michelsen, Dept. of Naval Architecture and Marine Engrg., Univ. of Michigan, Ann Arbor, Michigan 48104.
(d) Theoretical and experimental; applied research.
(e) To develop a minimum wave resistance hull form of higher than generally designed displacement-length ratio from theoretical considerations and model tests.
(g) Utilization of transom stern and large bulbous bow yield powering requirements generally lower than otherwise comparable hull forms.
(h) Final report in preparation.

(5972) HYDRODYNAMICS OF SEA-GOING BARGES.

(b) Society of Naval Architects and Marine Engrs.
(c) Prof. R. B. Couch, Ship Hydrodynamics Lab., Univ. of Michigan, Ann Arbor, Mich. 48104.
(d) Experimental, applied.
(e) Determination of resistance and directional stability of pushed and towed barges is sought to provide design tool and recommended hull form and proportions. Experimental model studies and computer regression techniques are used.
(g) On the basis of data from tests of unrelated forms it is possible to predict performance of an arbitrary barge.
(h) Final report in preparation.

PURDUE UNIVERSITY, School of Civil Engineering.

(2841) HYDROLOGY OF SMALL WATERSHEDS IN INDIANA.

(b) Purdue Water Resources Research Center, (since June 1965) State Highway Department of Indiana and Indiana State Flood Control and Water Resources Commission (prior to June 1965).
(c) Dr. J. W. Delleur, Hydromechanics Laboratory, School of Civil Engineering, Purdue Univ., Lafayette, Ind. 47907.
(d) Analysis and field investigation for Ph.D. thesis.
(e) The purpose of the research is to study the hydrology of watersheds less than 200 square miles throughout the State of Indiana to improve the existing methods for estimating the runoff from these watersheds.
(g) Peak discharges were analyzed statistically and a correlation was obtained between the 25 year peak discharge and geomorphological characteristics of the watersheds. Peak discharges for other frequencies may also be obtained. A synthetic design hydrograph was developed on the basis of the instantaneous hydrograph theory. The hydrograph is determined by two parameters which have been related statistically to geomorphological characteristics of the watershed. The theory of overland flow has been investigated from a hydrodynamics standpoint.
(h) "Design Hydrographs for Small Watersheds in Indiana," I. P. Wu, ASCE, Journal of the Hydraulics Division, Vol. 88, 1963. "Hydrology of Small Watersheds in Indiana and Hydrodynamics of Overland Flow," Joint Highway Research Project, Report No. 15, July 1963.

(4191) MEANDER FLOOD PLAIN MODEL.

(b) Purdue Water Resources Research Center; Lab. Project.
(c) Dr. G. H. Toebes, Hydromechanics Laboratory, School of Civil Engineering, Purdue Univ. Lafayette, Ind. 47907.
(d) Analytical and experimental research for Ph.D. thesis.
(e) A meander-flood plain model is being constructed to replace 5' x 30 model used in first phase of project. Also data collection equipment is being improved to obtain greatly increased efficiency. Experimental and analytical study of three-dimensional flow patterns in meandering channel with adjacent flood plains. Collection of energy loss data and study of distribution of shear stress and scour. Work applicable to channel pro-

tection and flood routing questions, and to problems involving flood plain utilization. Statistical studies of meander geometry are being made for White River system in Indiana.

(g) Energy losses for the geometry considered are larger than the sum of the separate losses in the meandering channel and the flood plains. During overbank flows helicoidal currents are reversed compared to inbank flow conditions. During high floods the river tends to straigthen its course.

(h) "The Flow in a Meander-Flood Plain Geometry," A. A. Sooky, Ph.D. thesis (1963).
"The Hydraulics of Meandering Rivers with Flood Plains," G. H. Toebes and A. A. Sooky, Hydromechanics Laboratory, Purdue University, Technical Report No. 10. (1964).

(5110) HOT-WIRE PHYSICS IN LIQUIDS.

(b) Purdue Research Foundation.
(c) Dr. J. W. Delleur, Hydromechanics Laboratory, School of Civil Engineering, Purdue Univ., Lafayette, Ind. 47907.
(d) Theoretical and experimental for Ph.D. thesis.
(e) The purpose of this research is to investigate the heat transfer characteristics of hot wires in liquids, to determine their sensitivity to fluctuations of velocity, temperature and flow direction, and to arrive at an understanding of the physical causes of their limitations.
(g) System response equations have been formulated. Heat transfer from hot-wires and cylindrical hot films has been measured in deionized water and in ethylene glycol.

(5111) FLUIDELASTIC OPERATORS FOR UNDER-STREAM LINED STRUCTURES.

(b) National Science Foundation.
(c) Dr. G. H. Toebes, Hydromechanics Laboratory, School of Civil Engineering, Purdue Univ., Lafayette, Ind. 47907.
(d) Experimental and analytical for M.Sc. and Ph.D. theses.
(e) Analytic and experimental study aimed at correlating the hydroelastic loading of structural components and the turbulent structure of the generated wake and separating boundary layers; study of energy transfer between fluid and structure.
(g) Force, displacement and wake turbulence measurements are being made for variety of cylindrical components and plate-like structures. Reduction of data by means of spectrum analysis equipment.
(h) "Fluidelasticity," G. H. Toebes, Proc. XI Congress IAHR-Leningrad USSR (1965).
"Flow Induced Structural Vibrations," G. H. Toebes; ASCE, Journal of Eng. Mech., Vol. 91 - EM 6 (1965).

(5112) TURBULENCE MEASUREMENTS IN LIQUIDS.

(b) David Taylor Model Basin, Dept. of the Navy.
(c) Dr. G. H. Toebes, Hydromechanics Lab., School of Civil Engrg., Purdue Univ., Lafayette, Ind. 47907.
(d) Theoretical and experimental; for Ph.D. theses.
(e) Analytic and experimental investigations aimed at optimization of turbulence measurements in liquids using hot-wire anemometer equipment and to compare performance characteristics of hot-wire equipment with hot-film thermistor, electro-magnetic and pressure transducers. Dynamic calibration of hot-wire probes.
(g) Collecting of liquid anemometry data is in progress. Special calibration and test equipment has been built. Spectrum analysis equipment has been adapted for above studies. Special recirculation equipment for laboratory water supply has been built.
(h) "Turbulence Measurements in Liquids," T. R. 12, Hydromechanics Lab., Purdue Univ. (1965).

(5482) URBAN HYDROLOGY FOR SELECTED SITES IN INDIANA.

(b) Indiana Flood Control and Water Resources Commission.
(c) Dr. J. W. Delleur, Hydromechanics Laboratory, School of Civil Engineering, Purdue Univ., Lafayette, Ind. 47907.
(d) For M.S. Thesis.
(e) Rainfall-runoff relationships are studied for selected sites in Indiana in order to test scientific methods of estimating the surface runoff and to obtain design criteria that can be used by practicing engineers.
(g) An urban watershed is being instrumented in West Lafayette, Indiana.
(h) "Hydrologic Study of an Urban Watershed in West Lafayette, Indiana," E. Vician. M. S. Thesis, January 1966.

(5484) DESIGN OF INSTRUCTIONAL EQUIPMENT FOR LABORATORY DEMONSTRATIONS IN FLUID MECHANICS.

(b) Engineering Experiment Station, National Science Foundation, Purdue University.
(c) Dr. J. W. Delleur and Dr. G. H. Toebes, Hydromechanics Laboratory School of Civil Engineering, Purdue University, Lafayette, Ind. 47907.
(d) Developmental, M.S. Theses.
(e) Evaluation of the various means of conducting an undergraduate laboratory course in Hydromechanics; evaluation of the subject matter to be investigated, and design of specific equipment.
(g) The design of the following apparatuses have been completed: Manometers, rotating cylinder apparatus, radial flow apparatus, small wind tunnel, unsteady flow apparatus, cavitation apparatus, pressure measurement apparatus, viscous flow apparatus.
(h) "Aspects of the Distribution System of the Purdue Hydromechanics Laboratory," G. Sherwin, M. S. Thesis, June 1965.
"Selected Experiments in Fluid Mechanics," M. K. Householder, M. S. Thesis, Aug. 1965.

(5485) TURBULENT DIFFUSION OF AEROSOL DROPLETS.

(b) National Science Foundation.
(c) Dr. V. W. Goldschmidt, Hydromechanics Laboratory, School of Civil Engineering, Purdue Univ., Lafayette, Indiana 47907.
(d) Theoretical and experimental for Ph.D. Theses.
(e) To determine the relationship of a suspended particle's diameter and the turbulent structure of the carrier stream to the corresponding particle turbulent diffusion. The work has a direct application to problems related to air pollution, dispersion of contaminants in lakes, rivers and oceans, transport of suspended particles and the kinematics of erosion.
(h) "Measurement of Aerosol Concentrations with a Hot Wire Anemometer," Victor W. Goldschmidt, Journal of Colloid Science, Vol. 20, pp. 617-634, August 1965.

(5830) INSTRUCTIONAL FLUID MECHANICS LABORATORY DEVELOPMENT.

(b) National Science Foundation, Purdue Univ.
(c) Dr. V. W. Goldschmidt, Mr. W. Fite.
(d) Developmental.
(e) Curriculum improvement in undergraduate fluid mechanics is sought in part by the use of free hand experiments in which small groups of students are allowed to select, plan, instrument, execute and present the results of a small scale investigation under the counsel of the instructor.
(g) Equipment is being acquired to implement the objectives of the program.

(5831) PERFORMANCE CHARACTERISTICS OF LARGE SCALE HYDROMECHANICS LABORATORY EQUIPMENT.

(b) Purdue University, NSF (Fellowship).
(c) Dr. G. H. Toebes, Hydromechanics Laboratory, School of Civil Engineering, Purdue Univ.
(d) Design, theoretical, experimental; for Ph.D. thesis.
(e) Completed are a 35' x 1.5' x 3' and a 90' x 6'

x 3' tilting glass-lined flumes. The largest flume will accommodate sediment recirculation. A number of design problems is being studied in the equipment. The main problems are: uniformity of inflow from headbox; residual turbulence in inflow; the boundary layer development in free surface flow and the length of flow establishment.

(g) Data collection systems for flumes have been completed and are being tested. Equipment designed for connection with central hybrid computer facility, is aimed at greatly increasing both the accuracy and the speed of data collection.

(5832) MEAN VELOCITY VECTOR MEASUREMENTS.

(b) Laboratory project.
(c) Dr. G. H. Toebes, Hydromechanics Laboratory, School of Civil Engrg., Purdue University.
(d) Experimental, for M.Sc. thesis.
(e) Optimization of velocity meter based on Pitot-sphere principle and associated read out equipment.
(g) Probe construction completed. Calibration is being pursued. Digital data reduction progress nearly complete.

(5833) WIND TUNNEL DEVELOPMENT.

(b) Laboratory project.
(c) Dr. V. W. Goldschmidt, Hydromechanics Lab., School of Civil Engrg., Purdue University.
(d) Theoretical & experimental for M.S. thesis.
(e) Under separate work insight into the turbulent and convective dispersion of contaminants in the atmosphere and ocean is sought. Under this project a wind tunnel is being designed to provide the flow conditions for the necessary experimental studies.

ADDENDUM

UNIVERSITY OF WISCONSIN, Hydraulics and Sanitary Laboratories.

See page 99 for other projects of the Univ. of Wis.

(3540) MODEL STUDIES OF PUMP INLET STRUCTURES.

(b) Wisconsin Alumni Research Foundation in cooperation with the Government of West Bengal, India.
(c) Dr. J. R. Villemonte, Director, Hydraulics and Sanitary Laboratories, University of Wisconsin, Madison, Wis. 53706.
(d) Experimental; design for M.S. thesis.
(e) A 1/16-scale model of the inlet structure for one of four axial flow pumps at the Uttarbhag Pumping Station (Sonarpur, India) has been made. Studies of inlet flow patterns and pressure coefficients for a wide variety of flow situations are being made for the purpose of reducing the cavitation threshold.
(f) Completed.
(g) Pressure coefficients were computed at 37 points on the model over a wide range of flows.
(h) "Model Study of Pump Inlet Conditions at Uttarbhag, India," C. K. Sarkar, J. R. Villemonte and S. Kar, Indian Journal of Power and River Valley Development, Univ. of Wisconsin Engineering Experiment Station Reprint No. 666.

(3541) HYDRAULIC CHARACTERISTICS OF GRAVITY SEPARATION BASINS.

(b) National Institutes of Health, Wash., D. C.
(c) Drs. J. R. Villemonte and G. A. Rohlich, Hydraulics and Sanitary Laboratories, Madison, Wisconsin 53706.
(d) Experimental; basic research and design for M. S. and Ph.D. theses.
(e) Hydraulic characteristics of the model circular basins and one model rectangular basin are being studied using a wide range of flow and types of inlet and outlet design, using the fluorescent tracer technique and the automatic recording of dimensionless dispersion curves.
Field tests on actual basins are also being undertaken where dispersion curves and removal efficiencies are being observed simultaneously, so that correlations can be studied.
The principles of similitude which apply to gravitation separation basins are also being studied in the laboratory and in the field.
(g) Hydraulic characteristics have been determined for a wide range of overflow rates and basin types both in the laboratory and field using newly developed criteria.
Comparison of actual removal efficiencies and those derived from a new rational approach has been made of several lab. and field basins.
(h) "Hydraulic and Removal Efficiencies in Sedimentation Basins," J. R. Villemonte, G. R. Rohlich, and A. W. Wallace. Accepted for publication by 3rd International Conference on Water Pollution Research, Munich, Germany 1966.

U. S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Soil and Water Conservation Research Division.

CORN BELT BRANCH, 108 Soils Building, University of Minnesota, St. Paul, Minn., Dr. C. A. Van Doren, Branch Chief.

(66) HYDROLOGIC STUDIES, RALSTON CREEK WATERSHED.

See Iowa Institute of Hydraulic Research, page 37.

(1723) THE HYDRAULICS OF CONSERVATION STRUCTURES.

See St. Anthony Falls Hydraulic Laboratory Projects Nos. 111, 1168, and 2386. See also U. S. Department of Agriculture, Agricultural Research Service, Soil and Water Conservation Research Div., Southern Plains Branch, Project No. 4335, and Illinois State Water Survey Division Project No. 1865.

(b) Cooperative with the Minnesota Agricultural Experiment Station, the St. Anthony Falls Hydraulic Laboratory, and the Illinois State Water Survey.

(c) Mr. Fred W. Blaisdell, Hydraulic Engineer, St. Anthony Falls Hydraulic Laboratory, 3rd Ave. S. E., at Mississippi River, Minneapolis, Minnesota 55414.

(d) Experimental; applied research for development and design.

(e) Research dealing with the design, construction, and testing of structures for conserving and controlling soil and water are carried out. Cooperation with and co-ordination of the tests at the Stillwater, Oklahoma, Outdoor Hydraulic Laboratory and the Illinois State Water Survey are maintained.
A square drop inlet having a hood barrel entrance is being tested to determine entrance loss coefficients for various drop inlet sizes and heights and various barrel slopes. Previous tests have evaluated the performance of this type of inlet.
The elbow and transition between the two-way drop inlet and the barrel is being studied to determine the pressures and the best form to minimize the possibility of cavitation.
The transition between a circular pipe and a rectangular cantilevered outlet is being studied to determine the best form of the transition. Studies are also being conducted on a rectangular cantilevered outlet with a deflector at the exit to throw the water away from the structure and move the scour hole further downstream.

(g) If the anti-vortex plate is too low, undesirable orifice flow will control the discharge. If the anti-vortex plate is too high, harmful vortices will form under the plate. Rules for determining acceptable plate heights have been determined. The overhang of the plate must be greater than a certain minimum to insure satisfactory performance. The action of the two-way drop inlet is that of a self-regulating siphon. The tests using air agree with the results obtained from the water tests and are much easier to perform. Air is used as the model fluid only for the condition of full conduit flow.
Tests on the hood drop inlet have shown that the hood barrel entrance can be used to reduce the minimum required height of the drop inlet. Minimum sizes of drop inlet and anti-vortex devices have been determined. Tests of low-stage orifices in the two-way drop inlet have shown that improper location and improper proportioning of the orifices can prevent priming of the spillway. The proper location of the orifices and the sizes of the orifices for satisfactory spillway performance have been determined.
To supplement the experiments, potential flow methods have been used to determine the theoretical coefficient of energy loss at the crest of the two-way drop inlet.

(h) "Tests of a Splitter-Type Ativortex Wall for a Hood Drop Inlet to a Closed Conduit Spillway," Charles A. Donnelly, Agricultural Research Service Report ARS 41-92, Nov. 1964.
"Tests of an Antivortex Wall for a Rectangular Drop Inlet to a Closed Conduit Spillway," Charles A. Donnelly, Agricultural Research Service Report ARS 41-96, Dec. 1964.
"A Digital Point Gage Recorder," Fred W. Blaisdell and Scott D. Crist, Agricultural Research Service Rept. ARS 41-102, Feb. 1965.
"Hydraulic Efficiency in Culvert Design," Fred W. Blaisdell, ASCE Transportation Engrg. Conference Preprint 212, May 1965.
"Straight Drop Spillway Stilling Basin," Charles A. Donnelly and Fred W. Blaisdell, ASCE Proc. 4328, Vol. 91 (HY3), May 1965.

(2316) RUNOFF FROM SMALL AGRICULTURAL AREAS IN ILLINOIS.

See University of Illinois, Department of Agricultural Engineering, page 32.

(4264) HYDROLOGIC STUDIES ON AGRICULTURAL WATERSHEDS IN WISCONSIN.

(b) Laboratory project, cooperative with the Wisconsin Agricultural Experiment Station and the Wisconsin Valley Improvement Co.

(c) Mr. N. E. Minshall, Hydraulic Engineer, P. O. Box 4248, Madison, Wisconsin 53711.

(d) Field investigation and office analysis.

(e) Various records of runoff, ground water, precipitation and climatic factors, soil moisture, land use, and agricultural conditions and practices are maintained for 50 agricultural watersheds ranging in size from 23 to 88,000 acres in the vicinity of Fennimore, Colby and at other locations in southwestern Wisconsin. Analyses are made to evaluate the factors affecting flood flows, hydrograph characteristics, and the yield of stream flow.

(h) "New Type Weir Construction for Small Watersheds," N. E. Minshall and R. G. Spomer, Journal of Irrigation and Drainage Division, Proceedings Paper 4243, A.S.C.E. March 1965.
"Interflow in Claypan Soils," N. E. Minshall and V. C. Jamison, A.G.U. Water Resources Research, Vol. 1, No. 3, pp. 381-390. Third Quarter 1965.

(4265) PRECIPITATION CHARACTERISTICS INFLUENCING RUNOFF FROM AGRICULTURAL WATERSHEDS ON THE UNGLACIATED ALLEGHENY PLATEAU.

(b) Laboratory project, cooperative with Ohio Agricultural Experiment Station.

(c) Mr. L. L. Harrold, Supervisory Hydraulic Engineer, North Appalachian Experimental Watershed, USDA, ARS-SWC, Coshocton, Ohio 43812.

(d) Field investigation and office analysis.

(e) To develop methods of characterizing watershed precipitation related to runoff rates and volumes and to evaluate "normalcy" of sample periods.

(g) In 24 years of record, storm sizes ranged from 0.01 to 2.30 inches. About half of the storms were 0.10 inch or less in amount. Less than 0.5 percent of the number of storms were over 2.00 inches. The rate of sampling of these severe storms is slow, yet their influence in floods and water yield is highly important. Dense network of tube rain gages over a four-county area along with U.S.W.B. radar pictures has proven valuable in defining the extent of local, severe thunderstorms. One small area has experienced two "rare" storms in two successive years. Over 4.5 inches of rain fell in each of these two events.

(h) "Role of Storm Surveys in Small Watershed Research," J. L. McGuinness and L. L. Harrold. Water Resources Research, Vol. 1, No. 2, pp. 219-222. Second Quarter 1965.

(4266) SURFACE RUNOFF AND INTERFLOW STUDIES IN THE UNGLACIATED ALLEGHENY PLATEAU.

(b) Laboratory project, cooperative with the

Ohio Agricultural Experiment Station.

(c) Mr. L. L. Harrold, Supervisory Hydraulic Engineer, North Appalachian Experimental Watershed, USDA, ARS-SWC, Coshocton, Ohio 43812.

(d) Field investigation and office analysis.

(e) To evaluate the factors affecting the volume of storm surface runoff and interflow from various combinations of upland watershed soil, cover, and treatment, and to study the basic factors affecting the hydrograph of these flows under various soil-cover combinations.

(g) Work is continuing on these studies. Interflow occurred when the soil was quite wet and its volume generally exceeded those of surface flow. Interflow hydrographs showed sharp rises and recessions. Sprinkler plots have been instrumented with tensiometers, piezometers, and soil moisture devices in order to detect systems.

(4267) STUDIES OF RUNOFF FROM COMPLEX WATERSHEDS IN THE UNGLACIATED ALLEGHENY PLATEAU.

(b) Laboratory project, cooperative with the Ohio Agricultural Experiment Station.

(c) Mr. L. L. Harrold, Supervisory Hydraulic Engineer, North Appalachian Experimental Watershed, USDA, ARS-SWC, Coshocton, Ohio 43812.

(d) Field investigation and office analysis.

(e) To determine how flows from incremental areas combine to produce hydrographs of stream flow on larger complex watersheds; determine the effects of climate and watershed characteristics on rates and amounts of runoff; and develop methods for predicting the magnitude and frequency of flows from ungaged watersheds.

(g) Work is continuing on these studies. Preliminary analysis showed that flood runoff volume on a 4,580-acre watershed was equivalent to the moisture saturation deficit in the 6- to 7-inch soil depth. Pore space in the soil at greater depth was not available quickly enough to retain more of the storm rainfall. Maximum monthly flood peaks as shown by 24 years of record from a 4,580-acre watershed are most likely to occur in June. The amount of rain falling at rates in excess of 1.0 inch per hr. was the greatest in June. July rainfall was about the same as that for June, but its peak flood flows were 60% less than those for June.

(h) "Role of the Soil in Upland Water Supply and Floods," L. L. Harrold and F. R. Dreibelbis. Jour. Soil and Water Conservation, Vol. 20, No. 4, pp. 179-180, July-August 1965. "Experimental Watersheds for Research on Upstream Surface Waters," L. L. Harrold and J. C. Stephens, Bul. I.A.S.H. Symp. de Budapest, Vol. 1, Pub. No. 66, 1965.

(4268) STUDIES IN SUBSURFACE HYDROLOGY IN THE UNGLACIATED ALLEGHENY PLATEAU.

(b) Laboratory project, cooperative with the Ohio Agricultural Experiment Station.

(c) Mr. L. L. Harrold, Supervisory Hydraulic Engineer, North Appalachian Experimental Watershed, USDA, ARS-SWC, Coshocton, Ohio 43812.

(d) Field investigation and office analysis.

(e) To evaluate ground-water and interflow contributions to stream discharge of agriculture watersheds and the recharge to aquifers under various watershed and climatic conditions.

(g) Geologic studies showed that secondary features of the rock such as joints and fractures appear to influence subsurface flow more than their physical characteristics. As rock strata near their outcrop are fractured more extensively than those farther beneath the hill, the outflow versus water table relationship of the former is much better defined than that of the latter.

(h) "Geologic and Hydrologic Significance of Springs and Seeps in Eastern Ohio," J. B. Urban. Jour. Soil and Water Cons. Vol. 20, No. 4, pp. 179-180, July-Aug. 1965.

(4269) MOISTURE REGIMES OF SOILS IN THE UNGLACIATED ALLEGHENY PLATEAU.

(b) Laboratory project, cooperative with the Ohio Agricultural Experiment Station.

(c) Mr. L. L. Harrold, Supervisory Hydraulic Engineer, North Appalachian Experimental Watershed, USDA, ARS-SWC, Coshocton, Ohio 43812.

(d) Field investigation and office analysis.

(e) To maintain the soil moisture inventory of agricultural watersheds; to evaluate the effect thereon of soil, land use, and climate, to develop methods of estimating soil moisture quantities under various land use and climatic conditions; and to determine the influence of frozen soil and frost structure on water movement.

(g) Nuclear soil-moisture equipment is now providing good data on soil moisture down to 90-inch depths. They show material variations in moisture within a small watershed. Presently, methods of evaluating watershed soil moisture are being studied. Effect of vegetation of different rooting depths on soil moisture is being evaluated. Deep-rooted crops extract moisture to depths unaffected by shallow-rooted crops. In dry seasons, the former consumes more water than the latter, resulting in less percolation to ground water reservoirs. Lysimeters, 8 feet deep and 1/500 acre area of undisturbed soil record weight changes and percolation.

(h) "How much Topsoil Moisture is Availabe to your Crops?" F. R. Dreibelbis and C. R. Amerman. Crops and Soils, Volume 17, No. 5, pp. 8-9, April-May 1965.

(4271) PLASTIC-LINED MOLE DRAIN STUDIES.

(b) Laboratory project in cooperation with the Ohio Agricultural Experiment Station.

(c) Mr. James L. Fouss, Research Agricultural Engineer, Agricultural Engineering Dept., Ohio State University, Columbus, Ohio.

(d) Experimental and field investigations, both basic and applied.

(e) The purpose of these investigations is to improve plastic mole drainage techniques and test the effectiveness of other subsurface and surface drainage systems. Tile, mole and other subsurface drainage systems are developed and their effectiveness determined.

(g) The work is continuing on improving plastic mole drainage materials and equipment. Recent field test results showed that thin-walled plastic mole lining installed 30 inches deep, deformed much more when the soil (silty clay loam) was saturated for prolonged periodic farming operations when the soil was drier. Research has also begun on the use of corrugated plastic tubing for lining mole-drain channels; this material looks promising.

(h) "A Look at the Use of Plastics in Subsurface Drainage," J. L. Fouss. Soil and Water Conservation, Vol. 20, No. 4, pp. 183-184, July-August 1965.

(4273) SURFACE AND SUBSURFACE DRAINAGE.

(b) Laboratory project in cooperation with the Minnesota Agricultural Experiment Station.

(c) Mr. Lee Hermsmeier, Agricultural Engineer, North Central Soil Conservation Field Station, Morris, Minnesota 56267.

(d) Experimental and field investigations, both basic and applied.

(e) The purpose of these investigations is to develop engineering techniques that will provide maximum effective control and management of water. Techniques are developed for managing surface water flow through land forming and surface drainage systems. Tile, mole and other subsurface drainage systems are developed and their effectiveness determined.

(f) Discontinued.

(4274) NATIONAL SUMMARIZATION AND ANALYSIS OF RUNOFF AND SOIL-LOSS DATA.

See Purdue University, Agricultural Engrg. Dept., Project No. 3808.

(b) Laboratory project, cooperative with the Purdue Agricultural Experiment Station.

(c) Mr. W. H. Wischmeier, Research Statistician, ARS, Agricultural Engineering Department, Purdue Univ., Lafayette, Indiana 47907.

(d) Data analyses, applied research.

(e) Objectives of the national data summarization and analysis project are (1) to consolidate all available past, current, and future runoff, soil loss and related data in standardized form to make them available for application of current methods of hydrologic and statistical analyses; (2) to analyze the data on an over-all basis, with special emphasis on identification and evaluation of significant factor interactions; and (3) to develop bases for prediction of runoff and soil losses from different landscapes under various land use and management conditions. In analyses of the assembled data, special emphasis is directed toward identication and evaluation of factors and interaction effects responsible for the frequent wide differences in results of localized studies at various locations. Over-all results are reduced to charts and tables readily usable by application technicians.

(g) Refinements in the area of field soil-loss prediction techniques to help guide farm planning for soil and water conservation were summarized in Agriculture Handbook No. 282. The goal of current analyses of the assembled data is an empirical equation for prediction of surface runoff from agricultural areas. Mathematical relationships of several physical and management factors to runoff have been derived. The analyses have shown that, over a broad range of medium-textured soils, runoff was inversely related to crop productivity, surface roughness, residual soil organic-matter content, and quantity of plant residues incorporated annually; directly related to slope steepness and kinetic energy of the rainstorms; and only very slightly related to length of slope and particle-size distribution. Work under objective (1) is kept continuously current.

(h) "Predicting Rainfall-Erosion Losses from Cropland East of the Rocky Mountains - Guide for selection of practices for soil and water conservation," W. H. Wischmeier and D. D. Smith. Agr. Handbook No. 282. 47 pages. U. S. Government Printing Office, 1965.
"Effect of Organic-Matter Content of the Soil on Infiltration," W. H. Wischmeier and J. V. Mannering. Jour. Soil & Water Cons. 20(4): 150-152, 1965.
"Relation of Field-Plot Runoff to Management and Physical Factors," W. H. Wischmeier. Soil Sci. Soc. Amer. Proc. 30(1), 1966.

(4275) BASIC MECHANICS OF RAINFALL, RUNOFF, SOIL MOVEMENT, AND LOSS.

See Purdue University, Agricultural Expt. Station, Project No. (4182).

(b) Laboratory project, cooperative with the Minnesota, South Dakota and Purdue Agricultural Experiment Stations.

(c) Dr. L. D. Meyer, Agricultural Engineer, ARS, Agricultural Engineering Building, Purdue Univ., Lafayette, Indiana 47907.

(d) Experimental; laboratory investigations, basic research.

(e) The mechanics of the soil erosion process have been investigated at several locations. At Morris, Minnesota, the geometry of raindrop splash patterns is being described mathematically, using high-speed photography. At Brookings, South Dakota, the effect of wind on the trajectory of falling drops was studied. At Lafayette, Indiana, fundamental mathematical relationships of erosion to various soil, crop, and topographic factors are being determined.

(g) The geometry of raindrop splash was appreciably influenced by drop size, surface softness, surface inclination, surface roughness, and water depth. The trajectory of falling water drops in wind can be related to drop diameter, wind velocity, and fall distance. Runoff erosion increased with increased particle roughness, slope steepness, and slope length but decreased with increased particle size. Rainfall plus runoff, as compared to runoff alone, increased the erosion of particles smaller than medium-sized sand.

(h) "Waterdrop Formation from Capillary Tubes," C. K. Mutchler. ARS 41-104, July 1965.
"Using the Drift of Waterdrops during Fall for Rainfall Simulator Design," C. A. Mutchler. Jour. Geophys. Research 70(16): 389913902. 1965.
"Effects of Wind on Falling Drops," C. R. Umback. M. S. thesis. South Dakota State University, 1965.
"Effect of Particle Roughness on Soil Erosion by Surface Runoff," G. D. Bubenzer, L. D. Meyer and E. J. Monke. ASAE Paper No. 65-227. Presented at 1965 ASAE Annual Meeting.
"Simulation of Rainfall and Soils for Laboratory Research," G. D. Bubenzer and L. D. Meyer. Trans. ASAE 8(1): 73 & 75. 1965.
"Resume: Mathematical Relationships Governing Soil Erosion by Water," L. D. Meyer. Jour. Soil Water Cons. 20(4), July-Aug. 1965.

(4276) IMPROVED PRACTICES FOR CONTROL OF RUNOFF AND EROSION.

(b) Laboratory project in cooperation with the Purdue Agricultural Experiment Station.

(c) Mr. J. V. Mannering, Soil Scientist, ARS, Department of Agronomy, Purdue University, Lafayette, Indiana 47907.

(d) Experimental; field investigations, applied research.

(e) The purpose of these studies is to determine the effects of soil properties, slope characteristics, type and extent of canopy cover, quantity and management of crop residues, seedbed and tillage practices, and various factor interactions on infiltration and erosion. Replicated tests are conducted on selected plots on Purdue-owned and privately-owned farms in Indiana and adjoining states under simulated rainfall applied with the ARS-Purdue "Rainulator".

(g) Residue mulches that dissipated some of the rainfall energy and reduced the flow velocity of runoff were highly effective. Even small amounts of surface residue significantly reduced erosion. Recent tests have shown that improved productivity and annual incorporation of large quantities of residue material at plowing time have increased infiltration and substantially reduced erosion from continuous corn, but they have not replaced the very substantial reductions in soil and water loss that are effected by meadow sod turned under before corn. Wheeltrack planting on rough-plowed land and cultivating only when needed to destroy surface crusts significantly reduced both runoff and erosion throughout the entire growing season, increased available soil moisture in periods of deficient rainfall, and did not significantly affect corn-yield average.

(h) "Effect of Minimum Tillage for Corn on Infiltration and Erosion," J. V. Mannering, L. D. Meyer and C. B. Johnson. Soil Sci. Soc. Amer. Proc. 30(1), 1966.
"Simulation of Rainfall for Soil Erosion Research," L. Donald Meyer. Trans. ASAE 8(1): 63-65, 1965.

(4277) SOIL ERODIBILITY DETERMINATIONS.

(b) Laboratory project, cooperative with the Purdue, Iowa, and Minnesota Agricultural Experiment Stations.
(c) Mr. W. H. Wischmeier, Research Statistician, ARS, Agricultural Engineering Dept., Purdue University, Lafayette, Indiana 47907.
(d) Experimental; laboratory and field investigations, basic and applied.
(e) The purpose is to investigate differences in the erodibility of soils; identify and evaluate the soil properties and profile characteristics that influence erodibility; and, if possible, derive an equation that expresses the functional relationship of soil erodibility to these variables. The equation would serve as a means of computing locational values of the soil-erodibility factor in the universal erosion equation. Both "in situ" measurements on field plots and laboratory measurements on small, disturbed soil samples are made under simulated rainfall and related to laboratory analyses of the soils.
(g) The laboratory studies have shown very important interactions between those soil properties that affect infiltration and permeability and those that affect detachment and transportability of soil particles. In field-plot studies over a broad range of medium-textured soils, differences in particle-size distribution had only minor effect on infiltration of 2.5-inch rains but significantly influenced detachment and transportability. Infiltration rates on medium-textured fallow soils having residual organic-matter contents varying from 0.5 to 4.0 percent were directly proportional to organic-matter content. Infiltration was significantly improved by repeated annual incorporation of large amounts of crop residue. The field-plot data suggest that soil erodibility is largely a function of eight soil properties and their interactions.
(h) "Effect of Organic-Matter Content of the Soil on Infiltration," W. H. Wischmeier and J. V. Mannering. Jour. Soil Water Cons. 20(4): 150-152, 1965.
"Influence of Rainfall Energy on Soil Loss and Infiltration Rates - Effect over range of texture," W. C. Moldenhauer and D. C. Long. Soil Sci. Proc. Amer. 28(6): 813-817, 1964.
"A Procedure for Studying Soil Characteristics Using Disturbed Samples and Simulated Rainfall," W. C. Moldenhauer. Trans. ASAE 8(1): 74-75, 1965.
"Relationship Between the Energy Necessary to Initiate Runoff and the Energy of Rupture for Aggregates of Eight Iowa Soils," W. C. Moldenhauer, A. S. Rogowski and D. Kirkham. Agronomy Abstracts, p. 113, Amer. Soc. Agron. 1965.

(4278) RAINFALL ENERGY AND SOIL EROSION RELATIONSHIPS.

(b) Laboratory project, cooperative with the Illinois Agricultural Experiment Station.
(c) Mr. J. S. Rogers, Agricultural Engineer, ARS, Turner Hall, Univ. of Illinois, Urbana, Illinois 61803.
(d) Experimental; field investigation, basic research.
(e) Raindrops were photographed to determine sizes and impact energies. Runoff was measured and soil loss determined from fallow and continuous corn plots. Various characteristics of rainstorms are being related to the resulting erosion.
(f) Suspended.

(4279) RUNOFF AND EROSION STUDIES IN IOWA.

(b) Laboratory project, cooperative with the Iowa Agricultural Experiment Station.
(c) Dr. W. C. Moldenhauer, Soil Scientist, ARS, 225 Agronomy Bldg., Iowa State University, Ames, Iowa 50010.
(d) Experimental; field investigations, applied research.
(e) Purpose is to evaluate soil and crop management practices in relation to water management and erosion control on the major Iowa soils. Runoff, soil loss and related data, under natural rainfall, are taken on fractional-acre plots on Grundy, Ida and Carrington silt loam soils.
(g) Consistent high crop productivity and good management of abundant residues have very effectively reduced soil erosion from both small grain and corn during intense rains that caused quite severe erosion on the check plots. However the effectiveness of large amounts of corn or small-grain residue incorporated by plowing has not equaled that of a good quality grass-and-legume sod before corn. In a 7-year period, soil loss from corn after oats with sweetclover intercrop averaged 2.4 times that from corn after two full years' meadow.

(4280) RUNOFF AND EROSION STUDIES ON THE SLOPING LANDS OF WISCONSIN.

(b) Laboratory project, cooperative with the Wisconsin Agricultural Experiment Station.
(c) Mr. R. E. Taylor, Soil Scientist, ARS, P. O. Box 6, Lancaster, Wis. 53813.
(d) Experimental; field investigations, applied research.
(e) Studies using field-plot techniques and small natural watersheds were begun in 1931 at LaCrosse, Wisconsin to study erosion-control and water-management problems of the Upper Mississippi Valley Region. Major problems and control methods studied included: effects of length and steepness of slope, degree of erosion, crop rotations, residue management; contouring; terrace grade, spacing, maintenance and outlets; contour strip cropping; methods of seedbed preparation and tillage; and pasture renovation. The field work at LaCrosse was discontinued at the close of the 1963 crop season. Continuation of hydraulic research on a new State-owned farm in southwestern Wisconsin, near Lancaster, is planned.
(g) Technical reports have been listed in previous years. A 30-year summary report is in preparation.

(4281) RUNOFF AND EROSION STUDIES IN THE MIDWEST CLAYPANS.

(b) Laboratory project, cooperative with the Missouri Agricultural Experiment Station.
(c) Mr. Fred D. Whitaker, P. O. Box 208, Columbia, Missouri 65201.
(d) Field investigation, basic and applied research.
(e) The purpose is to evaluate the effect of soil treatments, tillage practies, cropping, and supplemental irrigation on runoff, erosion, and crop yields from Midwest claypan soils. Measurements of runoff, soil loss, rainfall, and concomitant variables on a series of fractional-acre plots and small watersheds under natural rainfall are continuing.
(g) The data are continuing to show that fertilization adequate to produce high crop yields, together with regular incorporation of large amounts of residue materials, has greatly reduced the magnitude of soil and water losses on this gently sloping, claypan soil. "Full fertility" treatment increased the 11-year average annual infiltration on corn land by 0.8 inch above "started fertilizer only" and 2.4 inches above the unfertilized check plots. At the high level of fertility, on 3% slope, contouring reduced average annual soil loss by 30% and reduced runoff by 15%. Adequately-fertilized corn averaged 0.22 inch of water use per bushel of corn, while corn with only starter fertilizer averaged 0.52 inch per bushel.

(4282) RUNOFF AND EROSION INVESTIGATIONS IN MINNESOTA

UNDER SIMULATED RAIN.

(b) Laboratory project, cooperative with the Minnesota Agricultural Experiment Station.
(c) Mr. R. A Young, Agricultural Engineer, ARS, North Central Soil Conservation Research Center, Morris, Minnesota 56267.
(d) Experimental; field investigations, applied research.
(e) Simulated rainstorms of design erosivity, applied in each of three cropstage periods, are used to evaluate the relations of runoff and soil erosion to slope steepness, slope shape, row direction, intensity of cropping, residue management, tillage methods, and other variables in relation to crops that are common in this climatic area. Runoff hydrographs are obtained and changes in soil concentration of the runoff are determined by periodic sampling throughout each test. Tests are conducted on various soils of west-central Minnesota and eastern South Dakota.
(g) Practices such as minimum tillage and incorporation of crop residue in the plow layer have been relatively less effective as erosion-reducing measures on the Barnes soil than on the silt loams in the higher rainfall areas of the Corn Belt. Erosion in the Barnes soils area was, however, substantially influenced by grass sod before corn, by growing-canopy or plant residues on the surface, and by contouring. Percent of effective land cover significantly influenced the relationships of both slope and row direction to soil loss. The effect of increasing slope steepness was greatest during the seedbed period and least under dense oats or meadow cover. Concave slopes lost less soil than either uniform or convex slopes of corresponding average fall and length. The soil-loss reduction by across-slope tillage was relatively greatest on the medium slopes of 7 to 8 percent. Cropping-factor evaluations have included flax, oats, grain sorghum and soybeans in various crop sequences.
(h) "Influence of Row Direction and Type of Vegetal Cover on the Slope-Soil Loss Relationship," R. A. Young, C. K. Mutchler and W. H. Wischmeier. Ag. Engin. 7(3): 316-317, 320, 1964.
"A Review of Rainfall Simulators," C. K. Mutchler and L. F. Hermsmeier. Trans. ASAE 8(1): 67-68, 1965.

(4307) RESERVOIR FORMULAS AND THE VOLUME-WEIGHT OF RESERVOIR SEDIMENT.

(b) Laboratory project, cooperative with the Soil Conservation Service and State Agrucultural Experiment Stations.
(c) Mr. H. G. Heinemann, Hydraulic Engineer, P. O. Box 208, Columbia, Missouri 65201.
(d) Field investigation, basic and applied research.
(e) This project provides criteria for more accurate determination of sediment yield of watersheds from reservoir survey data. The investigation includes refinement of survey procedures and methods for determining reservoir capacities and sediment volume from reservoir sedimentation survey data.
(f) Reservoir formula portion of this study is now completed. Investigations of volume-weight of reservoir sediment have been transferred to Reservoir Sedimentation Studies (4825).
(g) This study showed that the stage-area curve method is the most direct, simple, accurate, and uniformly adaptable way to determine the capacity of a reservoir. Volumes of sediment deposits can best be obtained from capacity differences.
(h) "Improved Volumetric Survey and Computation Procedures for Small Reservoirs," H. G. Heinemann and V. I. Dvorak. Proceedings of the Inter-Agency Sedimentation Conference 1963, USDA Miscellaneous Publication 970, pp. 845-856, June 1965.

(4817) EROSION AND MOISTURE CONSERVATION STUDIES ON BARNES SILTY CLAY LOAM.

(b) Laboratory project, cooperative with the Minnesota Agricultural Experiment Station.
(c) Mr. R. E. Burwell, Soil Scientist, ARS, North Central Soil Conservation Research Center, Morris, Minnesota 56267.
(d) Experimental; field investigations, applied research.
(e) Field plots under natural rain are used to characterize runoff and erosion on the Barnes soil of the North Central Region and to evaluate moisture conservation aspects of soil and crop management practices. Automatically controlled devices to heat the collecting and measuring equipment enable measurement of runoff from snow-melt and thaw. Soil moisture is measured by neutron probe techniques. Wind direction and velocity are automatically recorded.
(g) Four years of measurements have shown that these soils are highly erodible in periods of concentrated rainfall and that erosion damage is often a serious problem. Moisture conservation for crop use is also of primary concern in this climatic area. About 50% of the runoff from corn and about 90% of the runoff from oat plots occurred during the first 2 months after planting. The greatest water loss from hay plots resulted from melting snow and ice. Only a very small portion of the moisture from snow contributed to replenishment of soil moisture. Snowmelt runoff from hay plots has equaled from 80 to 90 percent of the water equivalent of the measured snowfall.

(4825) RESERVOIR SEDIMENTATION STUDIES.

(b) Laboratory project, cooperative with the Soil Conservation Service and State Agricultural Experiment Stations.
(c) Mr. H. G. Heinemann, Hydraulic Engineer, P. O. Box 208, Columbia, Missouri 65201.
(d) Field investigations, basic and applied research.
(e) Numerous small reservoirs form the basis for this study. The objectives of this project are: (1) Determine the amounts, rates, and character of sediment yields from agricultural watersheds; and (2) relate sediment accumulation in the reservoirs with sediment yield, precipitation, runoff, watershed characteristics, and cultural practices; (3) explain variations in the volume-weight of reservoir sediment; (4) make recommendations on determination of the total weight of reservoir sediment; (5) develop procedures for predicting the volume-weight of sediment in a proposed conservation structure; (6) to determine the distribution of sediment accumulation in vertical and horizontal planes in the reservoir and relate this to reservoir shape, amount and rate of runoff, storage depletion, soils, topography and normal water level of the reservoir; and (7) to evaluate all equipment and procedures used in reservoir sedimentation surveys.

(5033) DRAINAGE INVESTIGATIONS FOR AGRICULTURAL LANDS.

See Ohio Agriultural Experiment Station, Dept. of Agricultural Engineering, page 59.

(5204) HYDROLOGIC STUDIES ON WATERSHEDS IN MISSOURI VALLEY DEEP LOESS.

(b) Laboratory project, cooperative with the Iowa Agricultural Experiment Station.
(c) Mr. K. E. Saxton, Hydraulic Engineer, P. O. Box 208, Columbia, Missouri 65201.
(d) Field investigations, basic and applied research.
(e) Two sets of paired agricultural watersheds are instrumented to observe the hydrologic budget of watersheds having deep loessal

soils. Level terracing will be introduced as a variable on one of the watersheds of one of the pairs. A comparison of level terracing and grass cover will be made on the other pair. Another mixed-use watershed is being observed. Variables observed are precipitation, soil moisture to 20-foot depths, surface flow, ground water recharge and outflow, air temperature and pan evaporation.

(5205) ANALOG STUDIES OF SUBSURFACE DRAINAGE.

(b) Laboratory project in cooperation with the Ohio Agricultural Experiment Station, Dept. of Agronomy.
(c) Dr. George S. Taylor, Dept. of Agronomy, Ohio State Univ., 1885 Neil Ave., Columbus 10, Ohio.
(d) Theoretical and experimental; basic and applied.
(e) An electrical resistance network analog is used to study the placement of subsurface drain tubes to provide optimum water table control for plant growth.
(f) Discontinued.
(g) Removal of excess rainfall and artesian water from a surface peat horizon, underlain with a thick slowly permeable silt layer, can be better achieved with tile drains on 40-foot spacings in the peat layer than with artesian relief wells into the aquifer.

(5561) EROSION AND MOISTURE CONSERVATION STUDIES IN EASTERN SOUTH DAKOTA.

(b) Laboratory project, cooperative with the South Dakota Agricultural Experiment Station.
(c) Mr. T. C. Olson, Soil Scientist, Agronomy Dept., South Dakota State Univ., Brookings, South Dakota 57007.
(d) Experimental; field investigations, applied research.
(e) Field plots under natural rain are used to characterize runoff and erosion on the Poinsett soils of eastern South Dakota and to evaluate moisture conservation aspects of soil and crop management practices. The surface water storage capacity of various types of tillage is being studied, and watersheds are being developed for evaluating improved terrace designs for moisture conservation and erosion control.
(g) Three years' measurements have shown these soils to be susceptible to very serious erosion by rainfall when not protected by erosion-control measures. Runoff from conventially tilled corn on 73-foot slope length ranged from 1.3 to 3.6 inches and soil loss ranged from 4.9 tons per acre in 1963 to 18.9 tons in 1962. Mulch tillage reduced soil loss, and in a year of low moisture supply it increased yields. Six major storms accounted for 77% of the 3-year soil loss.
(h) "Soil and Water Losses," T. C. Olson and C. W. Doty. South Dakota Farm & Home Research 16(3): 15-18, 1965.

(5562) RESERVOIR TRAP EFFICIENCY.

(b) Laboratory project, cooperative with the Soil Conservation Service and Iowa and Missouri Agricultural Experiment Stations.
(c) Mr. D. L. Rausch, Agricultural Engineer, P. O. Box 208, Columbia, Missouri 65201.
(d) Field investigations, basic and applied research.
(e) The purpose of this research is to evaluate those parameters that affect the sediment trapping ability of water-retarding structures. This will enable prediction of the trap efficiency of structures. Measurements are made of the sediment content of the inflow and outflow and the volume retained in the reservoir. Characteristics of the sediment, watershed, reservoir, and other parameters are also used in the analyses.

(5563) GULLY EROSION STUDIES IN DEEP LOESS.

(b) Laboratory project, cooperative with the Iowa Agricultural Experiment Station.
(c) Mr. Robert F. Piest, Hydraulic Engineer, P.O. Box 208, Columbia, Missouri 65201.
(d) Field investigations; basic and applied research.
(e) Measurements are being made on several actively-eroding gullies in controlled watersheds in the Missouri Valley deep loess. The objectives are to learn the causes of gully and channel erosion, the rate of this erosion, and the effect of level terraces on gully growth. Measurements include amount eroded, changes in dimensions, surface flow, soil moisture, and ground water elevations.

(5564) EVALUATING INTERFLOW WITHIN CLAYPAN SOILS.

(b) Laboratory project, cooperative with the Missouri Agricultural Experiment Station.
(c) Dr. V. C. Jamison, Soil Scientist, P. O. Box 208, Columbia, Missouri 65201.
(d) Field investigation, basic and applied research.
(e) Field investigations are being conducted to identify and evaluate quantitatively the contribution to surface flow by the return to the surface of moisture infiltrated up the slope. Various lengths of plots and degrees of soil saturation are used.
(h) "Interflow in Claypan Soils," N. E. Minshall and V. C. Jamison, Water Resources Research, Vol. 1, No. 3, pp. 381-390, 1965.

(5565) RUNOFF FROM CLAYPAN SOIL AREA OF MISSOURI AND ILLINOIS.

(b) Laboratory project, cooperative with the Missouri Agricultural Experiment Station.
(c) Mr. Frank D. Jones, Agricultural Engineer, P. O. Box 208, Columbia, Missouri 65201.
(d) Field investigation, basic and applied research.
(e) Precipitation, runoff, pond evaporation and seepage, pan evaporation, and land use are being measured on a 160-A. watershed near McCredie, Missouri. These and other rainfall-runoff data throughout the soil area are being analyzed to evaluate water yield and surface runoff.

(5973) SEDIMENT YIELDS FROM SMALL WATERSHEDS IN THE CORN BELT.

(b) Laboratory project, cooperative with the Agricultural Experiment stations of Missouri and other Corn Belt states.
(c) Mr. Robert F. Piest, Hydraulic Engineer, P. O. Box 208, Columbia, Missouri 65201.
(d) Field investigations, basic and applied research.
(e) The purposes of this project are to: (1) Determine average annual sediment yields from existing suspended-sediment records and information from small watersheds throughout the Corn Belt; (2) to analyze the pattern of sediment yield variation caused by different meteorologic and watershed conditions within the various subregions of the Corn Belt; (3) to develop procedures, based upon these analyzed data, for predicting sediment yields from unsampled watersheds; and (4) to recommend, on the basis of this intensive record review, the best possible avenues for future research.

(5974) THE DESIGN OF TERRACES AND THEIR USE IN CROP PRODUCTION.

(b) Laboratory project, cooperative with the Missouri Agricultural Experiment Station.
(c) Mr. Fred Whitaker, P. O. Box 208, Columbia, Missouri 65201.
(d) Field investigation, basic and applied research.
(e) The purpose of this project is to determine the rate and amount of runoff from individual terraces of standard design for cultivated land receiving full soil treatment and

to determine the channel capacity required to carry this runoff. Runoff measurements are being made on four terraces near McCredie, Missouri.

(5975) MOISTURE RETENTION CHARACTERISTICS OF SELECTED SOILS IN THE CORN BELT.

(b) Laboratory project, cooperative with the Agricultural Experiment Stations of Missouri and other Corn Belt States.
(c) Dr. V. C. Jamison, Soil Scientist, P. O. Box 208, Columbia, Missouri 65201.
(d) Field investigation, basic and applied research.
(e) The purposes of this project are (1) to determine the moisture retention characteristics of the various soil horizons in the soils studied, (2) to estimate the available water storage for the soils studied, and (3) to determine seasonal changes in moisture-volume conditions for different soils growing different crops.

(5976) THE DISTRIBUTION OF SOIL MOISTURE IN LEVEL TERRACED FIELDS IN MISSOURI VALLEY DEEP LOESSAL SOILS.

(b) Laboratory project, cooperative with the Agricultural Experiment Stations of Missouri and Iowa.
(c) Dr. V. C. Jamison, Soil Scientist, P. O. Box 208, Columbia, Missouri 65201.
(d) Field investigation, basic and applied research.
(e) The purpose of this project is to determine the soil moisture distribution in the soil profile under the terraces and the interterrace intervals in deep loessal soils. Numerous measurements of soil moisture to a depth of twenty feet are being made on watersheds near Treynor, Iowa.

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NORTHEAST BRANCH, Plant Industry Station, Beltsville, Maryland 20705. Dr. Jesse Lunin, Branch Chief.

(3867) LEAF AREAS, LEAF WEIGHTS AND TOTAL DRY MATTER PRODUCTION OF TOBACCO AS AFFECTED BY ENVIRONMENTAL CONDITIONS.

(b) Cooperative project with the Virginia Agricultural Experiment Station.
(c) Mr. J. N. Jones, Agricultural Engineer, Agricultural Engineering Dept., Virginia Polytechnic Inst., Blacksburg, Va. 24061.
(d) Field investigations.
(e) Irrigation studies are designed to determine the effect of irrigation practices on the yield and quality of tobacco. Plant response, as measured by Leaf Area Index, is related to consumptive use of water and evapotranspiration.
(g) Maintenance of a high soil moisture regime gave lower leaf areas than for a soil moisture regime which was allowed to fluctuate from 100 to 25 percent available soil water. Dry matter yield and value per hundredweight were both favored by the treatment allowing the soil moisture to fluctuate. The relationship between LAI and marketable yield indicated that only 50 percent of the variation as measured by cured leaf weights could be associated with variations of LAI.

(4283) A STUDY OF FLOOD FLOWS AND THEIR EFFECTS ON STREAM CHANNELS.

(b) Cooperative project with Soil Conservation Service and Cornell University.
(c) Mr. R. P. Apmann, Hydraulic Engineer, Civil Engineering Dept., Parker Engrg. Bldg., State Univ. of New York at Buffalo, Buffalo, New York 14214.
(d) Experimental field investigations.
(e) To determine the important streamflow qualities which materially affect the intensity of attack upon the stream channel periphery material and the variation throughout the flow boundary of forces destructive to the channel periphery material. Investigations are conducted on selected natural reaches of Buffalo Creek and tributaries in the vicinity of East Aurora, New York and on the Pequest River in Warren County, New Jersey.
(g) Thorough study and analysis are continuing on stream geometry and of hydraulic characteristics of channel improvements and stabilization works constructed by Soil Conservation Service on Buffalo Creek. The analysis of the March 30, 1960 and other floods is being carried out by assembling an atlas of high-water data and by preparing a topographic map showing the contours of the stream channel and of the flood plains. A method is being developed for estimating discharge by using the superelevation of the water surface in an open channel bend. This method is based on the principle that the transverse difference in water surface at an open channel bend is related to the geometry of the bend and to the velocity head of the flow.
(h) "Sedimentation and Stream Improvement," R. P. Apmann. New York Fish and Game Jour. (in press).

(4284) DEVELOPMENT AND EVALUATION OF METHODS FOR CHANNEL STABILIZATION.

(b) Cooperative project with Soil Conservation Service and Cornell University.
(c) Mr. R. P. Apmann, Hydraulic Engineer, Civil Engrg. Dept., Parker Engrg. Bldg., State Univ. of New York at Buffalo, Buffalo, New York 14214.
(d) Experimental field investigations.
(e) To develop economical methods for streambank stabilization through observation and measurement of the effectiveness of various vegetal and structural measures in relation to streamflow over a range of streamflow conditions and channel geometry. Principal investigations are conducted on Buffalo Creek and tributaries in the vicinity of East Aurora, New York.
(g) Observations of flood flows and subsequent damage to the experimental concrete block revetment over the past eight years on Buffalo Creek have demonstrated its satisfactory performance under severe conditions. The revetment has been subjected to estimated shear stresses of 3.2 psf at its surface and to the impact of massive ice floes. Only three of more than 600 blocks originally laid have been lost from flow conditions. In contrast, the quarried stone riprap in adjacent areas has been unable to withstand these forces. Whereas the stone revetment contains a median stone size of 17 inches and maximum stone weight of 3/4 ton, the cellular concrete blocks are only 4 inches thick and weigh approximately 83 pounds each. Although the maintenance costs for the concrete block revetment have been small, the losses of several blocks have pointed out the necessity for protecting all outside edges of the revetment, and for using only the most durable materials in constructing the blocks. Frequent destruction of adjacent parts of the quarried stone revetment demonstrate the necessity of designing these revetments for the velocity heads and bend geometry that prevail in addition to consideration of the higher boundary velocities that result from floodwaters accelerating over a relatively smooth surface. When the concrete blocks are mass produced and where quarried stone is available locally, the cost of the two types of revetments would be nearly the same. The 4-inch concrete block revetment has been found to be more effective in resisting erosive forces during extreme flood conditions than the 17-inch quarried

stone riprap.

(h) "Cellular Concrete Block Revetment," D. A. Parsons and R. P. Apmann. Jour. of Waterways and Harbors Div., ASCE. May 1965.
"Stream Stabilization Research on Buffalo Creek, New York," R. P. Apmann, submitted to Agron. Jour. for publication.

(4285) CHANNEL HYDRAULICS AND FLOOD ROUTING IN STEEP MOUNTAIN STREAMS.

(b) Cooperative project with the Vermont Agricultural Experiment Station and College of Technology of the University of Vermont, Vermont Water Conservation Board, and Soil Conservation Service.
(c) Mr. M. L. Johnson, Hydraulic Engineer, Route 2, Danville, Vermont 05828.
(d) Experimental field investigations.
(e) Studies on a 1.5-mile reach of the Sleepers River channel involving determination of: travel speed of controlled waves of different volumes; profiles of natural and controlled waves of different volumes; practical field methods of measuring the friction slope of mountain channels; comparisons between results obtained with flood routing formulas and observed flood wave data; and the relationship between channel efficiency, flow duration curves, and watershed morphology.
(g) Short reaches within the 1.5-mile reach were found to have a Manning's "n" value of between 0.035 and 0.040 for the bank-full conditions and a maximum of about 0.20 for very low flows. Channel roughness and geometry are intricately related to each other and to the lithology and climate of the watershed. This mountain stream is characterized by a relatively narrow and deep cross-section. It is postulated that this geometry causes a rapid increase in velocity with increasing discharge, providing the erosional energy required for the eventual attainment of a most probable state. There is an upper limit to roughness in a stream channel, and this is approached in the length of stream studied. Addition of more roughness elements would only create a new bed with similar characteristics. The removal of a number of the element would very probably increase the resistance to flow because it would reduce the phenomena of shielding, in which the elements reduce the frictional effectiveness of one another due to close grouping.
(h) "Channel Roughness in Steep Mountain Streams," M. L. Johnson. Submitted for publication to Jour. Geophys. Res.
"A Re-examination of A Flood Routing Method Comparison," D. L. Brakensiek and G. H. Comer. Jour. of Hyd. Vol. 3, pp. 225-230, Nov. 1965.

(4286) INFLUENCE OF SNOW AND FROZEN SOIL ON RUNOFF.

(b) Cooperative project with the Vermont Agricultural Experiment Station, Vermont Water Conservation Board, and Soil Conservation Service and College of Technology of the University of Vermont.
(c) Mr. M. L. Johnson, Hydraulic Engineer, Route 2, Danville, Vermont 05828.
(d) Experimental field investigations.
(e) This study on the 43-square mile Sleepers River Watershed is concerned with the factors influencing the accumulation and melting of snow; the relationship of frozen soil to runoff; and the development of methods for predicting runoff associated with snow melt. Data are collected and analyzed from snow courses, precipitation gages, temperature records, heat budgets, soil moisture and frost measurements, and snow melt in conjunction with streamflow records at nine stations in the subdivided watershed.
(g) A 12-foot diameter snow pressure pillow, made of nylon reinforced butyl, was installed in 1964 to measure accurately changes in snow accumulation and snowmelt. The pillow was filled with about 200 gallons of a 2:1 mixture by volume of methyl alcohol and water. The use of a 6-inch iron pipe stilling well and water level recorder minimized the mechanical and electrical difficulties which other scientists have had. Agreement between water equivalent as measured by the snow pillow and cumulative precipitation as measured by a recorder is excellent during periods of accumulation in the 1964-65 season. Agreement between the snow course data and the snow pillow is good. Comparison of snow pillow and precipitation gage for storm periods indicates that the snow pillow responds instantaneously with no measurable time lag. Preliminary results indicate that the water equivalent for a snow pillow can be measured to ± 0.02 inches.
(h) "Evaluation of a Pressure Pillow Snow-Measuring Device," E. T. Engman. To be published in the Proceedings of the Feb. 1966 annual meeting of the Eastern Snow Conference.
"Snowmelt Runoff from Agricultural Watersheds," M. L. Johnson. Submitted for publication in Amer. Soc. Agr. Engin.

(4287) PRECIPITATION PATTERNS AND CHARACTERISTICS.

(b) Cooperative project with the Vermont Agricultural Experiment Station and College of Technology of the University of Vermont, Vermont Water Conservation Board, and Soil Conservation Service.
(c) Mr. E. T. Engman, Hydraulic Engineer, Route 2, Danville, Vermont 05828.
(d) Experimental field investigations.
(e) The purpose of this study is to develop a method for calculating average precipitation on the 43-square mile Sleepers River watershed and its subdivisions in relation to elevation, storm source and direction; to study the behavior of summer convective storms in the northeast; and to provide information on rainfall depth-area-duration in relation to point rainfall in this part of the northeast.
(g) An analysis was made to determine what effects precipitation-intensity patterns, storm duration, and areal distribution of precipitation have on hydrograph timing or basin lag. No correlation was found between storm-intensity patterns (advanced, uniform, and delayed) and basin lag. It was not determinable whether or not this result was due to the interaction of storm-intensity pattern term with those for areal coverage and storm duration. The storm duration was taken as the total time from beginning to end of rainfall. Storm duration was found to be a factor when the basin lag determination was based on the center of mass of rainfall, but not when based on maximum rainfall intensity. Since the latter was not significant by itself in determining basin lag for this watershed, it would appear that storm duration is a significant factor in relation to basin lag. Areal distribution of precipitation was found to affect basin lag significantly when a storm concentrated in the upper portion of watershed produced a basin-lag time of 30 percent above average, and one concentrated in lower portion of watershed, a basin-lag time of 15 percent below average.

(4288) INFLUENCE OF SOIL AND LAND USE ON STREAMFLOW FROM AGRICULTURAL WATERSHEDS.

(b) Cooperative project with the Vermont Agricultural Experiment Station and College of Technology of the University of Vermont, Vermont Water Conservation Board, and Soil Conservation Service.
(c) Mr. G. H. Comer, Hydraulic Engineer, Route 2, Danville, Vermont 05028.
(d) Experimental field investigations.
(e) Investigations of the influence of land use,

climatic factors, and physical characteristics such as soils, geology, and topography upon runoff rates and water yields from the 43-square mile Sleepers River watershed and its important subdivisions to derive relationships for predicting the hydrologic performance of ungaged watersheds in the other parts of the physiographic area.

(g) The largest water yield and highest peak flow appears to be more related to amount and distribution of poorly drained soils than to the size of watershed, which varies from 116 acres to 43-square miles.

(4289) SUBSURFACE CONTRIBUTIONS TO STREAMFLOW IN SLEEPERS RIVER WATERSHED.

(b) Cooperative project with the Vermont Agricultural Experiment Station and College of Technology of the University of Vermont, Vermont Water Conservation Board, and Soil Conservation Service.

(c) Mr. G. H. Comer, Hydraulic Engineer, Route 2, Danville, Vermont 05828.

(d) Experimental field investigations.

(e) To investigate procedures for separating streamflow into components of surface runoff, return flow, and base flow for storm and annual flows; to investigate the rates, amounts, and seasonal time distribution of subsurface contributions to streamflow; and to investigate the relationship of the physical characteristics of watersheds to baseflow recession equations and to groundwater hydrograph shapes.

(g) The constant "K" in the basic groundwater recession equation has been found to vary with seasons and with soil types and land use.

(4290) GROUNDWATER ACCRETION AND MOVEMENT IN RELATION TO WATERSHED CHARACTERISTICS.

(b) Cooperative project with the Vermont Agricultural Experiment Station and College of Technology of the University of Vermont, Vermont Water Conservation Board, and Soil Conservation Service.

(c) Mr. E. T. Engman, Hydraulic Engineer, Route 2, Danville, Vermont 05828.

(d) Experimental field investigations.

(e) To develop information on ground water accretion and movement as affected by land use, soils, geology, and topography; and to develop methods for predicting ground water accretion and movement in relation to the physical, hydraulic, and meteorological characteristics of the 43-square mile Sleepers River Watershed.

(4291) INFLUENCE OF LAND USE ON THE HYDROLOGY OF AGRICULTURAL WATERSHEDS IN VIRGINIA.

(b) Cooperative project with the Virginia Agricultural Expt. Sta., Virginia Polytechnic Inst., and the Soil Conservation Service.

(c) Mr. J. B. Burford, Hydraulic Engineer, Agricultural Engrg. Dept., Virginia Polytechnic Inst., Blacksburg, Va. 24061.

(d) Experimental field investigations.

(e) To provide additional knowledge concerning the disposition of precipitation in agricultural watersheds, and to develop procedures based upon watershed characteristics, climatic factors, and various land use practices for the prediction of flood peaks and seasonal and annual water yields in three physiographic areas. Hydrologic, geologic, soils, plant cover and cultural data are being obtained on 4 unit source watersheds varying in size from 3.5 to 19.3 acres in the Appalachian Valleys and Ridges and on 10 complex watersheds from 182 to 3,054 acres in the Appalachian Valleys and Ridges, Blue Ridge Mountains, and the Piedmont Plateau.

(g) Preliminary analyses of Brush Creek and Crab Creek watersheds, two of the ten complex watersheds being studied in Virginia, indicate extreme differences in their hydrologic behavior, even though they are similar in size, shape, topography, and are within 11 miles of each other. The annual precipitation of Brush Creek averages consistently about 10 percent higher than that for Crab Creek. The annual runoff for Brush Creek is 19.83 inches and that for Crab Creek, 7.11 inches. The differences are largely ascribed to differences in geology, parent soils, and geomorphic characteristics. Brush Creek watershed has crystalline rock, gneiss and schists, and Crab Creek watershed, dolomitic limestone and shale. The drainage density for Brush Creek is 129.7 ft./ac. and for Crab Creek, 34.2 ft./ac. Brush Creek watershed has 224 streams and Crab Creek, 25. The total stream length of Brush Creek is 21.96 miles, and of Crab Creek, 4.85 miles.

(4292) HYDROLOGIC EFFECTS OF CHISELING SHALLOW SHALE SOIL IN WEST VIRGINIA APPALACHIAN VALLEYS AND RIDGES.

(b) Cooperative with West Virginia Agricultural Experiment Station and the Soil Conservation Service.

(c) Mr. V. O. Shanholtz, Hydraulic Engineer, U. S. Hydrograph Laboratory, ARS. Plant Industry Station, Beltsville, Md. 20705.

(d) Experimental field investigations.

(e) The purpose of this study is to determine the effect of chiseling shallow shale subsoil upon rainfall-runoff relationships of small watersheds. Four 10-acre watersheds were calibrated over a period of six years, from the Spring of 1958 to the Fall of 1964. Treatment was applied to two of the four watersheds in September 1964.

(f) Discontinued.

(4294) ERODIBILITY OF SOILS IN THE NORTHEAST.

(b) Laboratory project, cooperative witth Maine Agricultural Experiment Station.

(c) Mr. Eliot Epstein, Soil Scientist, Univ. of Maine, Orono, Maine 04473.

(d) Laboratory and field investigations both basic and applied for development and design.

(e) The purpose of these investigations is to obtain fundamental information on the erodibilty of Northeast soils and to determine the interrelations of climate, cover (including rock fragments), runoff, and soil loss.

(g) Results continue to show increased erosion due to rock removal and beneficial effects of a rotation over continuous potatoes. Progress is being made on a laboratory technique for evaluating soil erodibility using a rainfall simulator.

(4295) TILLAGE AND OTHER MANAGEMENT PRACTICES FOR WATER AND EROSION CONTROL AND THE FIELD DETERMINATION OF ERODIBILITY OF CERTAIN SOILS.

(b) Laboratory project, cooperative with the New York Agricultural Experiment Station, and the Soil Conservation Service.

(c) Mr. George R. Free, Soil Scientist, Bailey Hall, Cornell Univ., Ithaca, N. Y. 14850.

(d) Field investigations.

(e) The purpose of one part of these investigations has been to determine under natural rainfall the effectiveness of certain tillage practices on the control of surface runoff and erosion. A similar objective is part of a continuing series of investigations using a rainfall simulator. These latter investigations just starting also include field determination of the relative erodibility of a limited number of contrasting soils and the measurement of residual effects on runoff and erosion of a wide range of past intensive cropping treatments.

(f) A study of diversion terraces cited in 1965 has been discontinued. (See also (e) above.)

(g) Marked reduction of runoff and erosion under

natural rainfall were found associated with minimum tillage compared to conventional. A formal report is being prepared. Results of the diversion terrace study cited in 1965 showed that dual-purpose diversions for erosion control and interception drainage were an effective drainage-improving practice on fragipan soils. Channel grades were an important determinant of effectiveness.

(4819) DEVELOPMENT AND EVALUATION OF DRAINAGE PRACTICES IN THE NORTHEAST.

(b) Laboratory project cooperative with the Vermont Agricultural Experiment Station and the Soil Conservation Service.
(c) Mr. Joseph Bornstein, Agricultural Engineer, Univ. of Vermont, Burlington, Vt. 05401.
(d) Field investigation both basic and applied research.
(e) The purpose of this study is to develop and evaluate drainage practices for sloping lands of the Northeast. This involves development of techniques for determining directional components of subsurfae water flow before and after installation of drainage treatments. Surface drainage practices are instrumented to measure runoff from rainfall and snowmelt. Measure the seasonal changes in soil moisture in relation to drainage treatment; evaluation of crop root development above and in fragipan layer, characterization of moisture-tension relationships of disturbed and undisturbed fragipan samples, including through the freeze-thaw cycle.
(f) Instrumentation of this project is completed and two years data are available on diversion ditch runoff and tile outflow. Extensive piezometric data, crop yield and soil moisture changes are also available.
(h) "Depth to Fragipan in Cabot Silt Loam - Variability in a Characteristic Area," J. Borstein, R. J. Bartlett, M. H. Howard, Jr. Soil Sci. Soc. of Am. Proc. 29(2): 201-205, 1965.
"Tile Drainage of a Sloping Fragipan Soil," T. J. Thiel and J. Bornstein. Trans. Amer. Soc. Agr. Engrs. (in press)

(4820) HYDROGRAPH LABORATORY.

(b) Laboratory project. Cooperative efforts on occasion.
(c) Mr. H. N. Holtan, Director, Hydrograph Lab., ARS, Beltsville, Md. 20705.
(d) Basic and applied research.
(e) The purposes of this project are to evolve and test new concepts, theories and principles for understanding the hydrologic processes on agricultural watersheds; to test and adapt information from various sources for application to water control and related problems encountered in watershed engineering; to conduct special analyses involving ARS data from more than one Station or more than one Branch that can be more adequately carried out at a central location which has available a full-time staff of scientists with specialized training in hydraulics, hydrology, meteorology, and mathematics; and to provide case assistance to field personnel detailed to the Laboratory for specific analyses as requested by the field.
(g) In a continuation of a study reported last year, watershed storage-flow relationships are being developed for synthesis of upland runoff hydrographs. As an alternative development, a mathematical expression describing simple runoff hydrographs is being utilized. Currently, the Hydrograph Laboratory has completed a field sampling program of selceted soils occurring on Agricultural Research Service experimental watersheds. Laboratory studies are now determining moisture-holding capacities and hydraulic conductivities. These data are intended for use in computing rainfall excesses and watershed retentions. Low level aerial photography on seven experimental watersheds is being processed for stream and valley cross sections and for watershed topography. Numerical studies are continuing in the hydraulics of flood flow utilizing both kinematic and kinetic formulations. Computer program (IBM 1620) are presently available for prismatic or nonprismatic channel geometry. Depth-area duration studies of rainfall expectancies are underway using data from dense network watersheds as supplied by various participating agencies. Distribution patterns for major storms are also under study.
(h) "Effective Rainfall and Irrigation Water Requirements," D. M. Hershfield, Jour. Irrig. & Drainage Div., Proc. 3920, Amer. Soc. Civil Engin., Vol. 90, No. IR2, pp. 33-47, June 1964.
"The Frequency of Small Daily Rainfall Amounts in Eastern United States," D. M. Hershfield. Bul. I.A.S.H., IX Annee No. 1, pp. 5-11, 1964.
"Estimating the Maximum 24-hour Snowfall," D. M. Hershfield, Bul. I.A.S.H., IX Annee No. 4, pp. 32-39, 1964.
"Methods for Estimating the Probable Maximum Rainfall," D. M. Hershfield. Jour. Amer. Waterworks Assoc., Vol. 57, No. 8, pp. 965-972, Aug. 1965.
"Hydrodynamics of Overland Flow and Nonprismatic Channels," D. L. Brakensiek. Trans., Amer. Soc. Agr. Engin. (in press)
"Numerical Techniques for Small Watershed Flood Routing," D. L. Brakensiek, A. L. Heath and G. H. Comer. USDA-ARS 41-113. (in press)
"Automated System for Analysis of Runoff Hydrographs," D. L. Brakensiek. USDA-ARS 41-120. (in press)
"A Model for Computing Watershed Retention from Soil Parameters," H. N. Holtan. Jour. Soil & Water Conserv., Vol. 20, No. 3, pp. 91-94, May-June 1965.
"Hydrologic Characteristics of Soil Types," H. N. Holtan, C. B. England and D. E. Whelan. Jour. Irrig. and Drainage Div., Amer. Soc. Civil Engrs. (in press)
"Simplified Techniques for Fitting Frequency Distributions to Hydrologic Data," D. L. Brakensiek and J. L. McGuinness. USDA Handbook 259, 42 pp., 1964.
"National Summaries and Analyses of Experimental Watershed Data," H. N. Holtan and D. E. Whelan. Bul. I.A.S.H., Symposium, Budapest. Pub. No. 66, pp. 351-360, Sept-Oct. 1965.
"Hydraulics in Synthesis of Upland Runoff Hydrographs," D. E. Overton. Trans. Amer. Soc. Agr. Engin. (in press)

(4821) EFFECTIVENESS OF STREAM BANK STABILIZATION AND PROTECTION MEASURES IN REDUCING SUSPENDED SEDIMENT LOAD.

(b) Cooperative project with Soil Conservation Service and Cornell University.
(c) Mr. R. P. Apmann, Hydraulic Engineer, Civil Engrg. Dept., Parker Engrg. Bldg., State Univ. of New York at Buffalo, Buffalo, New York 14214.
(d) Experimental field investigations.
(e) To develop procedures for estimating effectiveness of streambank stabilization and other measures in reducing the sediment discharge of a stream. It is postulated that the total sediment load of a stream is directly related to the mean concentration of the suspended sediment for a flood series, and that changes in time of the mean concentration resulting from installation of streambank stabilization measures are indicative of changes in total sediment load. The streambank stabilization measures are being installed by Soil Conservation Service as part of the authorized flood prevention program in the Buffalo River watershed. Measurements of suspended sediment load

concentration and of stream discharges are made for all floods above a certain magnitude.

(f) Completed.

(4822) A STUDY OF THE MOVEMENT OF COARSE-TEXTURED BED MATERIAL OF TWO NEW YORK MOUNTAIN STREAMS.

(b) Cooperative project with Soil Conservation Service and Cornell University.

(c) Mr. R. P. Apmann, Hydraulic Engineer, Civil Engrg. Dept., State Univ. of New York at Buffalo, Buffalo, New York 14214.

(d) Experimental field investigations.

(e) To relate the quantities of transported bed materials to flood discharge rates and durations, to determine applicability of bed load equations in coarse material transport problems and, if appropriate, devise new or revised relationships. In 1963 a stream reach was instrumented and debris basin made larger on the Little Hoosic River near Berlin, New York. In 1964 a stream reach and debris basin were instrumented on Dean Creek, Tioga County, New York.

(g) The first significant movement of bed material on the Little Hoosic River occurred on March 5, 1964 when a peak flow of 250 c.f.s. was measured. The amount of bedload material trapped in debris basin was about 260 cubic yards. When the hydraulic characteristics were used in the Meyer-Peter's formula, it was found that the weighted mean particle size was so large that no bedload transport should have taken place under the observed conditions. However, when the mean size of the bank material was substituted for that of the bedload material, then the formula produced almost exactly the amount of material deposited in the debris basin.

(4823) COMPILATION AND PUBLICATION OF SELECTED HYDROLOGIC DATA.

(b) Cooperative project with various State Experiment Stations and Land Grant Colleges and with the Soil Conservation Service.

(c) Mr. H. W. Hobbs, Hydraulic Engineer, Plant Industry Station, Beltsville, Md. 20705.

(d) Office assembling and processing of current hydrologic data.

(e) To provide information on monthly precipitation and runoff, annual maximum discharges and volumes of runoff, and selected runoff events with associated data on rainfall, land use and practices, soils, geology, and antecedent conditions for all current ARS research watersheds in the United States. Hydrologic Data publications will be published at regular intervals.

(h) "1960-61 Hydrologic Data for Experimental Agricultural Watersheds in the United States," H. W. Hobbs and F. Crammatte. USDA Misc. Pub. No. 994, May 1965.

(5206) DRAINAGE PRACTICES FOR LEVEL AND SLOPING LANDS.

(b) Cooperative project with the Virginia Truck Experiment Station and the Virginia Agricultural Experiment Station.

(c) Mr. Truman Goins, Agricultural Engineer, P. O. Box 2160, Norfolk, Virginia 23501.

(d) Laboratory and field investigations including both theoretical and applied phases.

(e) Drainage studies for level land include a study of drainage requirements of various vegetable crops with emphasis on the various factors related to high soil water contents and their effect on plant growth. Landforming will be studied as a means of minimizing the need for surface drains in flat Coastal Plains areas, and for more efficient soil and water management practices on sloping lands of the Piedmont.

(g) The effects of water table levels on the growth of tomatoes, snapbeans and sweet corn is being reported and prepared for publication and will be available in the near future. Water use efficiency and nutrient uptake by plants as affected by water table is included.

(5979) FACTORS AFFECTING MOISTURE CONSERVATION AND CROP GROWTH ON EXPOSED SUBSOIL.

(b) Laboratory project, cooperative with the Virginia Agricultural Experiment Station.

(c) Mr. A. R. Batchelder, Soil Scientist, Agricultural Engineering Dept., Virginia Polytechnic Institute, Blacksburg, Va. 24061.

(d) Field investigations.

(e) The study includes mulch management with and without irrigation to evaluate factors affecting soil moisture storage in exposed subsoils, infiltration, surface crusting and runoff.

(f) Initiated in 1965.

U. S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Soil and Water Conservation Div.

NORTHERN PLAINS BRANCH, P. O. Box E, Fort Collins, Colorado 80522, Dr. C. E. Evans, Branch Chief.

(2902) DEVELOPMENT AND IMPROVEMENT OF WATER MEASURING DEVICES.

Cooperative with Colorado Agricultural Experiment Station. See Colorado State University, Civil Engineering Section, Fort Collins, Colo., page 15.

(3217) HYDROLOGIC STUDIES OF GROUND WATER IN THE RED RIVER VALLEY OF NORTH DAKOTA.

(b) Laboratory project.

(c) Mr. L. C. Benz, Agricultural Engineer, P. O. Box 1644, Grand Forks, North Dakota 58201.

(d) Field investigation. Applied research.

(e) A field investigation covering more than 200 square miles to determine possible causes for a saline condition on a large area of land. Measurements consist of water tables, artesian conditions, soil and water physical and chemical data.

(g) Salt-affected soils are caused by high water tables, poor drainage conditions and saline artesian waters. High water tables are caused by precipitation. The salt source is the Dakota sandstone artesian aquifer.

(4296) HYDRAULICS OF SUB-CRITICAL FLOWS IN SMALL, ROUGH CHANNELS.

See Colorado State University, Civil Engrg. Section, Project No. 3400.

(b) Laboratory project, cooperative with the Colorado Agricultural Experiment Station.

(c) Mr. E. Gordon Kruse, Agricultural Engineer, Engineering Research Center, CSU Foothills Campus, Ft. Collins, Colorado 80521.

(d) Experimental investigations; basic and applied, portions used for masters and doctoral theses.

(e) This study is an experimental investigation utilizing a tilting flume in which a small channel 60-feet long is formed by natural soil which is fixed in position against movement by chemical spray. A variety of roughness forms can be created on the bed. The relation of roughness dimensions and channel shape to flow resistance is determined for a range of channel slopes and flow depths.

(f) Discontinued.

(g) Relationships between resistance coefficients and measured roughness dimensions were developed for both laminar and turbulent flows. The transition between these flows was found to occur at a Reynolds number (RV/v) of 500 for these channels. For low Reynolds number flows (Re less than 500) over rough boundaries, normal flow depth was proportional to discharge, viscosity and roughness height and inversely proportional to roughness spacing and channel slope. For turbulent flows, resistance was a logarithmic function of

roughness height and flow depth. The standard deviation of bed elevation measurements was used in both cases to represent the effective height of the nonuniform roughness elements. Effects of roughness spacing and channel shape on flow resistance could not be detected for turbulent flows.

(4297) COOPERATIVE WATER YIELD PROCEDURES STUDY.

(b) Laboratory project, cooperative with Soil Conservation Service, USDA, and the Bureau of Reclamation, USDI.
(c) Mr. A. L. Sharp, (Collaborator), 1697 S. W. 19th, West Linn, Oregon 97068.
(d) Office analyses, applied research.
(e) To develop and test methods for use by field engineers to evaluate the downstream effects of upstream conservation use and treatment of land on water yields of creeks and rivers. The project is one purely of analytic hydrology. The project uses available hydrologic and other data wherever it is available. It secures no new hydrologic data such as streamflow data, climatic data, or land-treatment data. The project is nearing completion.
(g) Studies have demonstrated that it cannot be proved statistically significant that there are downstream effects on stream flow of upstream conservation treatment and use of land, although it is axiomatic that in subhumid to arid areas such effects must exist. A rational method of evaluating such effects has been developed and tested. A summary of the studies performed and presentation of the rational method will be published through Department of Agriculture media during 1964.

(4298) COMPARISONS OF RATES AND AMOUNTS OF RUNOFF FROM SMALL SINGLE-COVER WATERSHEDS.

(b) Laboratory project, cooperative with the Nebraska Agricultural Experiment Station.
(c) Mr. Frank J. Dragoun, Hydraulic Engineer, ARS-SWC, P. O. Box 1000, Hastings, Nebraska 68901.
(d) Field investigations -- applied research.
(e) To evaluate the effect of (1) different land use treatment and (2) different crops on the runoff from single crop watersheds in the Central Great Plains, as one of the significant factors influencing runoff from complex watersheds. Replicate 4-acre single crop watersheds in meadow, pasture, cultivated and eroded cultivated land seeded to grass are instrumented with recording rain gages, flumes and waterstage recorders. Six cultivated watersheds are in a wheat-sorghum-fallow rotation. Mulch (subsurface) tillage, on the contour, is practiced. Effects of different crops and land uses on storm runoff rates and amounts are determined by analyzing hydrographs and histograms. Seasonal, annual, and long time effects are determined by analyzing precipitation and runoff data.
(g) Twenty-four years of record show that runoff from a single crop 4-acre watershed averaged 3.3 inches. During the same period a 4-acre native-pasture yielded 2.0 inches and a native-meadow yielded only 0.25 inches. Rainfall during the period averaged 22.4 inches. These results indicate the relative differences that can be expected in runoff under different land-use practices.

(4299) RUNOFF AND HYDROGRAPH CHARACTERISTICS OF LARGE MIXED-USE WATERSHEDS.

(b) Laboratory project, cooperative with the Nebraska Agricultural Experiment Station.
(c) Mr. Frank J. Dragoun, Hydraulic Engineer, ARS-SWC, P. O. Box 1000, Hasting, Nebraska 68901.
(d) Field investigations -- applied research.
(e) To determine characteristics of runoff from large mixed-use watersheds as related to, or affected by, precipitation, channel storage, transmission losses to valley alluvium, time of concentration, stream gradient, and watershed size. Three watersheds, in mixed use, 481, 2086 and 3490 acres in size, are instrumented with rain gages, weirs, and stage recorders for observing precipitation and runoff. Transmission losses to valley alluviums are estimated by use of gaged outflow and estimates of inflow from unit source areas of tributary land. These latter estimates are based on gaged rainfall on and runoff from small 4-acre single-use source area watersheds. Hydrographs and histograms are analyzed to obtain watershed retention (infiltration) rates and hydrograph characteristics.
(g) Twenty-four years of record indicate that average yearly runoff from a conventionally farmed area of 481 acres was 3.3 inches. On a single crop 4-acre area the average was 3.6 inches. Rainfall for the period averaged 22.4 inches. A comprehensive analysis of the 24 years of continuous records is underway.
(h) "Transmission Losses of Loesial Watersheds," J. A. Allis, F. J. Dragoun, and A. L. Sharp. Agricultural Engr. 7(3): 209-212, 217. November 1964.

(4300) COMPARISON OF RUNOFF AND SEDIMENT YIELDS FROM CONSERVATION AND CONVENTIONALLY FARMED WATERSHEDS.

(b) Laboratory project, cooperative with the Nebraska Agricultural Experiment Station.
(c) Mr. Frank J. Dragoun, Hydraulic Engineer, ARS-SWC, P. O. Box 1000, Hastings, Nebraska 68901.
(d) Field investigations -- applied research.
(e) To determine the effects of conservation farming, land use, climate, and physiography on rates and amounts of runoff and sediment yields. Two 400-odd-acre watersheds, one conventionally farmed and the other conservation farmed, are equipped with recording rain gages, weirs and stage recorders, and sediment samplers, to measure precipitation, runoff, and sediment yields. The two watersheds were operated the same during a calibration period from 1939 to 1947. One was then treated by terracing, contour tillage and seeding eroded cultivated land to grass.
(g) Current data substantiate previous analyses indicating conservation measures are effective in controlling soil erosion from average rainfall events. Six years of continuous measurement show that annual sediment yield from the area under conservation was 5.4 tons/acre compared with 8.7 tons/acre from the conventionally farmed area or a difference of 38 percent. In 1957, a year of above normal rainfall with intense storms, no significant reduction in sediment yield was realized under conservation practices whereas in 1963, a year of above normal rainfall but no intense storms, the sediment yield from the area under conservation was only 14 percent of that from the conventionally farmed area. The significance of kinetic energy of rainfall in sediment yield determinations is indicated.

(4301) RELATIONSHIP BETWEEN INTENSITY OF GRAZING AND RUNOFF AMOUNTS ON FINE-TEXTURED SOILS.

(b) Laboratory project, cooperative with South Dakota Agricultural Experiment Station.
(c) Mr. Clayton L. Hanson, Agricultural Engineer, Newell Irrigation and Dryland Field Station, Newell, South Dakota 57760.
(d) Field investigations -- applied research.
(e) To determine the effects of light, moderate and heavy grazing and other factors such as precipitation, antecedent soil moisture, soil frost and snow accumulation, on rates and amounts of runoff from fine-textured range soils in southwestern South Dakota.

Replicated plots of about 2 acres in each of the lightly, moderately and heavily grazed pastures are instrumented to observe runoff amounts (stage recorders and H-flumes) rates and amounts of precipitation (recording rain gages), soil moisture, soil frost and vegetative conditions. The studies are being made on the South Dakota Range Experiment Station near Cotton wood, South Dakota.

(g) Rainfall-runoff events during the first year of study indicate that grazing intensity materially influences range cover and that runoff is normally higher from heavily grazed areas although storm sequences and antecedent moisture conditions can significantly influence the normal trend.

(4302) MEDICINE CREEK WATERSHED INVESTIGATIONS.

(b) Laboratory project, cooperative with the Soil Conservation Service, U. S. Geological Survey, Bureau of Reclamation, and Nebraska Agricultural Experiment Station.

(c) Mr. V. I. Dvorak, Hydraulic Engineer, ARS-SWC, P. O. Box 1000, Hastings, Nebraska 68901.

(d) Field investigations; compilation and analysis of data.

(e) Data from this southwestern Nebraska project are being analyzed for the following purposes: (1) To estimate the long-time runoff and sediment yields from 8 years of observed hydrologic watershed data; (2) to determine if acquired runoff, sediment and channel data will adhere to the existing channel regime equations for six runoff stations; and (3) to compile and prepare a publication indicating what data have been collected as part of the cooperative investigations, and where these data may be found.

(g) The long-time sediment yields for the six watersheds have been computed by three different approaches. In each of these methods, the observed runoff and sediment data for 8 years were used for the projection.

(4303) SEDIMENT YIELD AS RELATED TO GULLY AND CHANNEL EROSION.

(b) Laboratory project, cooperative with the Soil Conservation Service, and Nebraska and Kansas Agricultural Experiment Stations.

(c) Mr. V. I. Dvorak, Hydraulic Engineer, ARS-SWC, P. O. Box 1000, Hastings, Nebraska 68901.

(d) Field investigations; compilation and analysis of data.

(e) The objectives of this project are (1) To determine and relate rates of gully and channel erosion to causal factors; (2) to provide basic data on rates of land loss and land depreciation due to gully erosion; and (3) to develop criteria, based upon hydrologic and physical factors, for estimating quantities of sediment derived from gully erosion.

(g) Results of studies covering an 11-year period indicate that channel slopes and shapes are related to erosion and runoff conditions. It was found that for a unit cross section area, depths of flow, in a gullied channel, increase in a downstream direction but the rate of increase declines with distance downstream from the head-cut. Head cutting erosion in one case was equivalent to 8 percent of the total sediment yield and the material removed from the channel was equivalent to 30 percent of the total sediment yield of the tributary drainage in the 11-year period.

(4304) SABETHA LAKE WATERSHED SEDIMENTATION STUDIES.

(b) Laboratory project, cooperative with the Soil Conservation Service and Kansas Agricultural Experiment Station.

(c) Mr. V. I. Dvorak, Hydraulic Engineer, ARS-SWC, P. O. Box 1000, Hastings, Nebraska 68901.

(d) Field investigations and office analysis.

(e) The objectives of this study are: (1) To determine the amount, rate, and character of the sediment yields from this 10-square mile watershed in northeast Kansas; (2) to relate sediment accumulation in the reservoir with sediment yield, precipitation, runoff and other watershed characteristics.

(4306) SEDIMENT DISTRIBUTION IN FLOODWATER RETARDING-TYPE RESERVOIRS.

(b) Laboratory project, cooperative with the Soil Conservation Service and State Experiment Stations.

(c) Mr. Verne I. Dvorak, Hydraulic Engineer, ARS-SWC, P. O. Box 1000, Hastings, Nebraska 68901.

(d) Theoretical and field investigations, and office analyses.

(e) This study was undertaken to improve the design criteria for floodwater retarding-type reservoirs by: (1) determining those factors that influence sediment distribution and evaluating their importance, and (2) deriving and testing methods for predicting the horizontal and/or vertical sediment distribution in floodwater retarding-type reservoirs. This is important in determining the minimum elevation of the principal spillway and the required original capacities of various storage pools.

(4309) ISOLATION AND RELATIVE EVALUATION OF RUNOFF PRODUCING POTENTIALS OF RANGE SITES OF WESTERN SOUTH DAKOTA.

(b) Laboratory project, cooperative with the South Dakota Agricultural Experiment Station.

(c) Mr. A. R. Kuhlman, Botanist, Newell Irrigation and Dryland Field Station, Newell, South Dakota 57760.

(d) Field and laboratory investigations -- applied research.

(e) To evaluate relative runoff producing potentials of principal range sites of Western South Dakota including sandy, silty, shallow, thin breaks, panspots, overflow, clayey, and dense clay range sites as characteristic of D-4, D-10, and D-11 soil conservation problem areas in the Dakotas, Montana and Wyoming. To evaluate relatively the same range sites by rainfall simulators. To isolate vegetative factors such as standing vegetation, mulch, root systems and soil factors that cause differences in runoff from different range sites.

(4310) WATER YIELD AND SEDIMENT ACCUMULATION FROM RANGELAND WATERSHEDS.

(b) Laboratory project, cooperative with the South Dakota Agricultural Experiment Station.

(c) Mr. Clayton L. Hanson, Agricultural Engineer, Newell Irrigation and Dryland Field Station, Newell, South Dakota 57760.

(d) Field investigations, applied research.

(e) To determine the frequency of water yields of various amounts from rangeland watersheds ranging in size from a few acres to 13,000 acres, and gross sediment yields (volumetric) from the same watersheds, as representative of the D-4, D-10, and D-11 soil conservation problem areas in eastern Montana, Wyoming and the Western Dakotas. Purposes of these studies are to provide data on water yields and information on which to estimate the probable useful life of ponds and reservoirs in the problem areas. The work is being done by gaging precipitation, measuring water yields in stockwater reservoirs, making reservoir sedimentation surveys, and securing data on watershed physical, topographic, ecologic and grazing use factors.

(g) Data continue to show that sediment yields from fine-textured soils are double those from the medium textured soils (7.5 tons/acre and 3.7 tons/acre respectively). Similarily, surface runoff from the fine-

textured soils has continued to average 4 times that from medium-textured soils. In 1962, 6.1 inches of runoff or 27 percent of the 22.6 inches of precipation occurred in a 90 acre fine-textured soil area which is the highest percentage measured since the studies were initiated in 1957. The highest runoff during 1962 from the medium-textured soils areas was 6 percent of the annual rainfall.

(4824) EVAPORATION AND SEEPAGE FROM RANGELAND STOCKPONDS.

(b) Laboratory project, cooperative with the South Dakota Agricultural Experiment Station.
(c) Mr. Clayton L. Hanson, Newell Irrigation and Dryland Field Station, Newell, South Dakota 57760.
(d) Field investigations -- applied research.
(e) To differentiate total stockpond water dissipation into evaporation and seepage and develop a basis for predicting expected stockpond water losses. The purpose of this study is to aid in the development of practical methods to reduce losses of water from stockponds to provide dependable water supplied for livestock.
(g) Data show that the ratio of the total pond evaporation (floating pan) to that from the Class A land pan is 0.64. Seepage and deep percolation in ponds in the medium-textured soils region amount to 55% of the total pond dissipation. In one 12 ac. ft. capacity stockpond the volume of daily seepage loss over a 37-day period averaged 910 cu. ft. per day or an equivalent volume to water more than 600 cows each day. Stockponds on medium-textured soils are continuing to show water losses exceeding inflow up to 80 percent of the time resulting in dry ponds nearly 50 percent of the time.

(4826) HYDRAULIC CHARACTERISTICS OF PARTIALLY SATURATED POROUS MEDIA.

(b) Laboratory project, in cooperation with Colo. Agricultural Experiment Station.
(c) Mr. R. H. Brooks, Agricultural Engineer, Engineering Research Center, CSU Foothills Campus, Ft. Collins, Colorado 80521.
(d) Basic research.
(e) Certain hydraulic characteristics of porous media must be known for laboratory modeling of complicated field problems involving water movement in soils. Problems involving flow of fluids in partially saturated soils often cannot be solved except by inferences derived from the performance of models. The purpose of the study is to be able to predict from equations how any porous medium will behave with respect to the functional relationship between permeability, degree of saturation (or fluid pressure) when certain media properties are known. A thorough understanding of the way permeability is effected by measurable properties of porous media might eliminate the necessity of selecting a porous medium by trial for use in model studies.
(g) A theory showing how the variables capillary pressure, water and air permeability are related to degree of saturation has been developed. Methods and equipment have been developed for measuring these variables using steady state experiments. Verification of the theory with experimental results has been good. It appears that hydraulic properties of partially saturated media can be described by three parameters: the bubbling pressure, P_b; a measure of the uniformity of the pores in the medium, η; and the saturated permeability K.
(h) "Similitude for Non-Drainage of Partially Saturated Soils," G. L. Corey, A. T. Corey and R. H. Brooks. Colo. State Univ., Hydrology Paper No. 9:1-37. August 1965.

(4827) HYDRAULICS OF FLOW IN BORDER CHECK IRRIGATION SYSTEMS.

(b) Laboratory project, in cooperation with Nebraska Agricultural Experiment Station.
(c) Mr. O. W. Howe, Agricultural Engineer, USDA-ARS-SWC, P. O. Box 786, Grand Junction, Colorado 81502.
(d) Field investigation; applied research, design.
(e) This is a study of the operational characteristics of low-gradient border checks on a medium textured soil. It involves measurement of the efficiency of irrigation, uniformity of distribution, effect of uneven grade, kind of crop, stage of crop development, etc., upon irrigation efficiency. Soil moisture samples are taken before and after irrigation at intervals in the length of the run. Continuous measurements are taken of depth of water at these stations throughout the set. The purpose is to obtain relationships regarding the effect of crop retardance, slope, surface configuration, intake rate, on rate of advance of irrigation water. Such relationships will be useful in designing and operating low-gradient border check irrigation systems.
(g) Slopes of 0 to 0.05 percent gave highest irrigation efficiencies, around 90 percent, when crop retardance to the flow of water was small. Slopes of 0.10 to 0.15 percent were needed to offset the high retardance caused by fully developed sugar beet foliage.

(4828) DESIGN DATA FOR LEVEL OR NEARLY LEVEL BENCH IRRIGATION SYSTEMS ON CLAY SOILS IN WESTERN SOUTH DAKOTA.

(b) Laboratory project, in cooperation with South Dakota Agricultural Experiment Station.
(c) Mr. C. J. Erickson, Soil Scientist, Newell Irrigation and Dry Land Field Station, Newell, South Dakota 57760.
(d) Field investigations. Results will be used for design purposes.
(e) This is a study of the operational characteristics of low-gradient border checks on a fine textured soil. It involves measurement of the efficiency of irrigation, uniformity of distribution, and effect of uneven grade, kind of crop, stage of crop development, etc, upon irrigation efficiency. Soil moisture samples are taken before and after irrigation at intervals in the length of the run. Continuous measurements are taken of depth of water at these stations throughout the set. The purpose is to obtain relationships regarding the effect of crop retardance, slope, surface configuration, intake rate, on rate of advance of irrigation water. Such relationships will be useful in designing and operating low-gradient border check irrigation systems.
(f) Discontinued.
(g) No significant findings have been obtained as yet since this project was just initiated in 1962.

(4831) LAND FORMING ON SALT-AFFECTED LACUSTRINE SOILS IN THE RED RIVER VALLEY HAVING AN INTERSECTING MINOR RIDGE-DEPRESSION TYPE OF MICRORELIEF.

(b) Laboratory project.
(c) Mr. L. C. Benz, Agricultural Engineer, P. O. Box 1644, Grand Forks, North Dakota 58201.
(d) Field experiment; applied research.
(e) Consists of four 5-acre plots under cultivation in a saline ridge-depression microrelief area. Two plots are leveled -- one having surface drainage, the other having only internal (tile) drainage (precipitation is impounded). One unleveled plot has internal drainage, the second one has none. Purpose of work is to determine effects of land forming and tile drainage on salt-affected land.

(4832) A STUDY OF THE FALLING WATER TABLE, SOIL MOISTURE, AND SOIL SALT TRANSLOCATION DURING WINTER MONTHS.

(b) Laboratory project.
(c) Mr. L. C. Benz, Agricultural Engineer, P. O. Box 1644, Grand Forks, North Dakota 58201.
(d) Field experiment; basic research.
(e) Experiment consists of two treatments (straw mulch and fallow) each replicated 3 times. Field plots are 60' x 60'. Measurements obtained are; soil moisture (neutron method), water tables, soil temperatures, freezing depth, water and soil physical and chemical data. Purpose of the experiment is to determine translocation of water table waters which recede during the winter months.

(4833) RELATIONSHIP OF MEASURED EVAPOTRANSPIRATION TO SOLAR RADIATION IN WESTERN U.S.A.

(b) Laboratory project, (joint project with Mr. M. E. Jensen, Northwest Branch.)
(c) Dr. H. R. Haise, Soil Scientist, Agricultural Research Service, P. O. Box E, Fort Collins, Colorado 80522.
(d) Analytical and theoretical; basic and applied.
(e) Measurements of evapotranspiration rates for one- to three-week periods made by USDA personnel during the past 35 years have been re-evaluated and selected data for field and orchard crops are being related to solar radiation and air temperature using an energy balance approach. Solar radiation data for 20 locations in the Western U.S.A. have been summarized and procedures developed for estimating radiation for specific periods. The resulting relationships can be used for estimating evapotranspiration for various crops.
(f) Completed.

(5207) VOLUMETRIC EROSION AND DEPOSITION ON A COMPLEX WATERSHED.

(b) Laboratory project, cooperative with the Soil Conservation Service and Nebraska Agricultural Experiment Station.
(c) Mr. Frank J. Dragoun, Hydraulic Engineer, ARS-SWC, P. O. Box 1000, Hastings, Nebraska 68901.
(d) Field investigations and office analysis; master's thesis study.
(e) To develop a method of determining volumes of erosion and deposition within a watershed using topographic maps developed from aerial photographs, and to delineate the areas, determine the volumes and indicate the depths of erosion and deposition with time. It is expected that from this research a new method will evolve for use in conservation work.

(5208) DEVELOPMENT OR CHANGES OF VEGETATION ON PERMANENT GRASS WATERSHEDS AS AFFECTED BY USE AND AS RELATED TO WATER YIELDS.

(b) Laboratory project, cooperative with the Nebraska Agricultural Experiment Station.
(c) Mr. Warren L. Rice, Engineering Technician, ARS-SWC, P. O. Box 1000, Hastings, Nebraska 68901.
(d) Field investigations--applied research; compilation and analysis of data.
(e) Objectives of the research are: (1) To follow deterioration of vegetation when converting from meadow to pasture; (2) to follow development of vegetation on cropland seeded to native grasses; and (3) to follow changes in vegetative cover of a permanent pasture watershed. In all cases the effect on water yields will be determined. It is the purpose of this research to provide needed information on the effect of changes in pasture and meadow land use on runoff and water yields.
(h) "Effects on Runoff Volume for Perennial Prairie Grass Seeded on Cultivated Land," W. L. Rice, F. J. Dragoun. J. of Soil and Water Conserv., Vol. 20, No. 2. March-April 1965.

(5566) LABORATORY STUDY OF DELTA DEVELOPMENT INDUCED BY FLOOD-WATER RETARDING AND SEDIMENT DETENTION STRUCTURES.

(b) Laboratory investigations cooperative with the Colorado Agricultural Experiment Station.
(c) Mr. R. H. Brooks, Engineering Research Center, CSU Foothills Campus, Ft. Collins, Colorado 80521.
(d) Experimental investigations; basic and applied.
(e) Purpose of project is: (1) To investigate the dynamic processes involved in delta (topset bed) development above floodwater or debris storage structures, and (2) to develop equations and graphical representations describing the delta development processes in terms of the variables involved.
(g) Project initiated September, 1964. As yet, no data have been obtained.

(5567) AUTOMATION OF SURFACE IRRIGATION SYSTEMS.

(b) Laboratory and field investigations.
(c) Dr. H. R. Haise, Soil Scientist, Agricultural Research Service, P. O. Box E, Fort Collins, Colorado 80522.
(d) Laboratory and field project. Applied research. Development, design and operation of automated system.
(e) To develop labor-saving devices for surface application of irrigation water to farm fields for more efficient use of existing water supplies. Study involves development and testing of remote operation of a pneumatic valve (patents pending) capable of controlling water in open ditch and closed pipe systems.
(f) In early stages of development.
(g) Water has been successfully applied to irrigation fields by radio control of pneumatic valves at distances up to one mile or more. Further studies are to be initiated at five locations where automatic systems will be operated and tested on a total farm basis.
(h) "Pneumatic Valves for Automation of Irrigation Systems," H. R. Haise, E. G. Kruse and N. A. Dimick, ARS 41-104. July 1965.

(5568) THE EFFECT OF SLOPE WITHIN A WATERSHED ON WATER INTAKE AND RUNOFF FROM RAINFALL.

(b) Laboratory project cooperative with Nebraska Agricultural Experiment Station.
(c) Mr. Norris P. Swanson, Agricultural Engineer, ARS-SWC, Lincoln, Nebraska.
(d) Field investigations; basic and applied.
(e) Purpose of the project is: (1) To measure and compare intake, runoff, and erosion from plots on slopes of approximately 3, 6, and 10 percent, located within small 4-acre watersheds using simulated rainfall; and (2) to construct runoff hydrographs using simulated rainfall data for comparison with hydrographs obtained from natural rainfall.
(f) Discontinued.

(5977) HYDRAULICS OF FLOW IN SUB-SURFACE DRAINS.

(b) Laboratory project.
(c) Dr. E. Gordon Kruse, Agricultural Engineer, SWC-ARS-USDA, Engineering Research Center, Colorado State University, Fort Collins, Colorado 80521.
(d) Experimental, laboratory investigation.
(e) Head losses are being determined for uniform flow in different underground drainage materials. Lines of clay and concrete tile are laid with varying joint spacings and alinements. Resistance is also being measured in new plastic and composition drain materials.

(5978) IRRIGATION BORDER DESIGN ON A SHALLOW, SANDY SOIL.

(b) Laboratory project.
(c) Dr. E. Gordon Kruse, Agricultural Engineer, SWC-ARS-USDA, Engineering Research Center,

Colorado State Univ., Fort Collins, Colorado 80521.
(d) Experimental, field investigation.
(e) Varying rates and times of water application are being made to irrigated borders of different lengths. Water applied, soil moisture and runoff are measured to determine proper design for maximum irrigation efficiency.

U. S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Soil and Water Conservation Research Division.

NORTHWEST BRANCH, P. O. Box 1096, Boise, Idaho 83701.
Mr. Dean C. Muckel, Branch Chief.

(3550) THE EFFECT OF SPRINKLER PATTERN VARIATION ON IRRIGATION EFFICIENCY.

(b) Laboratory project.
(c) Mr. Claude H. Pair, Research Engineer (Irr.), Agricultural Research Service, Snake River Conservation Research Center, Route 1, Box 186, Kimberly, Idaho 83341.
(d) Experimental; applied research and design.
(e) To determine the effect of sprinkler pattern on field irrigation efficiency and develop a method for calculation of field water application efficiency for a sprinkler system from sprinkler pattern, wind velocity, humidity, temperature, irrigation period, and related factors. Another phase of this project is to test typical sprinkler heads for reproducibility of water distribution pattern.
(f) Completed.

(3552) HYDRAULICS OF SURFACE IRRIGATION.

(b) Laboratory project.
(c) Mr. James A. Bondurant, Agricultural Engineer, Agricultural Research Service, Route 1, Box 186, Kimberly, Idaho 83341.
(d) Experimental; field investigation, basic research.
(e) To investigate the factors that influence the advance and recession of water in an irrigation border strip.

(3553) DEVELOPMENT OF AUTOMATIC SURFACE IRRIGATION EQUIPMENT.

(b) Laboratory-field project.
(c) Mr. Allan S. Humpherys, Agricultural Engineer, Agricultural Research Service, Snake River Conservation Research Center, Route 1, Box 186, Kimberly, Idaho 83341.
(d) Experimental; design and development.
(e) To develop automatic and semi-automatic control structures for surface irrigation.
(g) Gates which will check the flow of water in a head ditch for a pre-determined period of time are being developed. These allow a field to be irrigated a portion at a time. Automatic and manual reset gates are being developed for both lined and unlined ditches. These are controlled by mechanical timers, electrically and with floats.

(4311) FLOOD HYDROGRAPHS BY ELECTRONIC ANALOG.

(b) Laboratory project, cooperative with the University of Idaho.
(c) Mr. J. Marvin Rosa, Hydraulic Engineer, P. O. Box 414, Moscow, Idaho 83844.
(d) Analytical, basic and applied.
(e) Further development and adaption of electronic analog methods in the solution of flood routing problems and the prediction of flood hydrographs from agricultural and Foothill range watersheds of the northwest.

(4312) WATER YIELD AS INFLUENCED BY WATERSHED CHARACTERISTICS.

(b) Laboratory project, cooperative with the University of Idaho.
(c) Mr. J. Marvin Rosa, Hydraulic Engineer, P. O. Box 414, Moscow, Idaho 83844.
(d) Analytical.
(e) Regional analysis of water yield as affected by climatic, topographic, geologic, soil, land use and other characteristics of rangeland watersheds in the Northwest.

(4313) SNOWMELT HYDROGRAPHS AS INFLUENCED BY CLIMATIC FACTORS AND WATERSHED CHARACTERISTICS.

(b) Laboratory project, cooperative with the University of Idaho.
(c) Mr. J. Marvin Rosa, Hydraulic Engineer, P. O. Box 414, Moscow, Idaho 83844.
(d) Analytical, basic and applied.
(e) To develop improved methods for estimating daily hydrographs of streamflow from mountainous watersheds where the supply is from snowmelt and occasional rain.

(4314) PRECIPITATION CHARACTERISTICS OF A NORTHERN SEMI-DESERT WATERSHED.

(b) Laboratory project.
(c) Mr. Freeman M. Smith, Research Botanist, P. O. Box 2724, Boise, Idaho 83701.
(d) Experimental, basic and applied.
(e) The 93 square mile Reynolds Creek Experimental Watershed, Owyhee County Idaho, has recording raingages to a density in excess of one per square mile. From this network, methods for evaluating rainfall amounts and intensities for different areas are being developed. Seasonal distribution with respect to amounts, character, and areal extent of precipitation are being measured.
(g) Topography greatly influences precipitation in Reynolds Valley. The regression equations for the relation of precipitation to elevation, computed for the east and west half of the watershed are parallel, but there is a five inch difference in the constant term in the equations. This is attributable to the position of the valley in relation to incoming storms. Precipitation is extremely variable in the semi-arid Northwest. To estimate mean precipitation in a stream basin in the mountainous Northwest similar to Reynolds Creek in relation of precipitation to elevation, topography, elevation, storm patterns and rainfall with 95 percent confidence of being or - 1 inch would require approximately 55 rain gages.

(4315) THE DESIGN OF SELF-PROPELLED SPRINKLER SYSTEMS.

(b) Laboratory project.
(c) Mr. Claude H. Pair, Research Engineer (Irr.), Agricultural Research Service, Snake River Conservation Research Center, Route 1, Box 186, Kimberly, Idaho 83341.
(d) Experimental, applied research, design.
(e) Determine water application patterns of self-propelled sprinkler systems. Determine the effect of wind on application patterns of self-propelled sprinkler laterals, and develop method of designing self-propelled sprinkler laterals from theoretical formulas.
(f) Completed.

(4836) WATER BUDGET OF A UNIT SOURCE AREA.

(b) Laboratory project.
(c) Mr. Freeman M. Smith, Research Botanist, P. O. Box 2724, Boise, Idaho 83701.
(d) Experimental; basic and applied research.
(e) Determine as fully as possible the fate of water falling on a small representative watershed throughout the year and estimate evaporation and transpiration from readily obtained instrumental and climatological data. Such a general understanding of the disposition of precipitation on an area is basic to an understanding of the effects of soils, geology, vegetation and climate.

(f) Combined with project: WATER BUDGET OF WATERSHED (5980).

(4837) FACTORS AFFECTING SNOW ACCUMULATION AND MELT ON UNIT SOURCE AREAS.

(b) Laboratory project.
(c) Mr. Freeman M. Smith, Botanist, P. O. Box 2724, Boise, Idaho 83701.
(d) Experimental; basic and applied research.
(e) Determine physical and meteorological factors contributing to non-uniformity of snow accumulation and melt in a shrub covered unit source area in the sagebrush zone of Owyhee County, Idaho.
Any improvement in the quantity or timing of flow from snow fed streams by manipulation of vegetation or other practices requires a thorough understanding of the behavior of snow under these conditions. Such information must be derived from research.

(4838) A STUDY OF SURFACE WATER DIVERSIONS AND RETURN FLOW IN REYNOLDS VALLEY.

(b) Laboratory project.
(c) Mr. Clifton W. Johnson, Hydraulic Engineer, P. O. Box 2724, Boise, Idaho 83701.
(d) Experimental; basic and applied research.
(e) This investigation is designed to find the consumptive use of water by an upstream irrigated area as it affects downstream water supplies. All of the inflow to Reynolds Valley is measured as is the outflow and general ground water levels.
(g) About 50 percent of the water diverted for irrigation is used on the land with the remainder returning to the stream by overland and ground water flow.

(4839) GEOLOGIC CONTROL OF SUBSURFACE STORAGE AND FLOW CHARACTERISTICS OF BASALT TERRANE.

(b) Laboratory project.
(c) Mr. Gordon R. Stephenson, Geologist, P. O. Box 2724, Boise, Idaho 83701.
(d) Experimental and field investigation; basic and applied research.
(e) An intensive hydrogeologic study of the Reynolds Creek Experimental Watershed is being made, using various geologic, geophysical, and hydraulic methods to evaluate the hydrologic characteristics of the basalt terrane in this portion of Owyhee County, Idaho. One objective is being approached by studying the water balance on a closed basaltic basin.
(g) Boundaries of aquifers located, recharge rates computed, and permeability and transmissibility values determined for these basalts. The latter values for these upland basalts are low when compared to the aquifers in the basalts of the Snake River Plains.
(h) "Network Design for Ground Water Studies in a Small Watershed," G. R. Stephenson. Proceedings of W.M.O. and I.A.S.H. Symposium on Design of Hydrometeorological Networks, Quebec City, Quebec, Canada, 1965.

(4840) THE DEVELOPMENT OF A PORTABLE IRRIGATION SPRINKLER EVALUATION DEVICE.

(b) Laboratory project. See project 4368, page 140.
(c) Mr. Claude H. Pair, Research Engineer (Irr.), Agricultural Research Service, Snake River Conservation Research Center, Route 1, Box 186, Kimberly, Idaho 83341.
(d) Experimental; applied research.
(e) To design a portable device that can be used in the design and evaluation of sprinkler irrigation systems. To determine procedures for the use of this device.
(f) Completed.

(5209) DEVELOPMENT OF IRRIGATION WATER MEASURING DEVICES AND METHODS.

(b) Laboratory and field project.
(c) Mr. A. R. Robinson, Director, Snake River Conservation Research Center, Route 1, Box 186, Kimberly, (Twin Falls) Idaho 83341.
(d) Experimental design and development.
(e) To develop devices and methods for accurate measurement of flow of water.
(g) Improved devices will be developed to measure flow in pipes, channels and underground. Specifically, devices to be or being studied include: (1) Combination headgate and measurement structures, (2) improved measuring flumes, (3) runoff measuring structures for watersheds, (4) devices utilizing drag or deflection principles, and (5) dye diffusion techniques.
(h) "Simplified Flow Corrections for Parshall Flumes Under Submerged Conditions," A. R. Robinson. Engineers' Notebook, Civil Engineering, ASCE, September 1965.

(5569) IRRIGATION WATER MANAGEMENT ON SUGAR BEETS.

(b) Laboratory project.
(c) Mr. Marvin E. Jensen, Investigations Leader (Water Management), Agricultural Research Service, Snake River Conservation Research Center, Route 1, Box 186, Kimberly, Idaho 83341.
(d) Experimental, applied research.
(e) Two moisture levels each with 3 nitrogen rates are irrigated for 3 time durations to simulate the upper, middle and lower parts of a field. The influence of these practices on yield, sugar percentage, nitrogen recovery, and deep percolation water losses will be evaluated.

(5570) FACTORS AFFECTING FARM AND PROJECT IRRIGATION EFFICIENCIES.

(b) Laboratory project.
(c) Mr. Marvin E. Jensen, Investigations Leader (Water Management), Agricultural Research Service, Snake River Conservation Research Center, Route 1, Box 186, Kimberly, Idaho 83341.
(d) Field investigation; applied research.
(e) Detailed measurement of the disposition of irrigation waters on selected farms will be made by the USBR and ARS to evaluate the factors affecting farm and project irrigation efficiencies.

(5571) DESIGN OF RECIRCULATING IRRIGATION SYSTEMS.

(b) Laboratory project.
(c) Mr. James A. Bondurant, Research Agricultural Engineer, Agricultural Research Service, Snake River Conservation Research Center, Route 1, Box 186, Kimberly, Idaho 83341.
(d) Field investigation; applied research and design.
(e) This project will develop criteria for design of pumping systems to return irrigation runoff water to the distribution system. Possible amounts and rates of runoff waters will be determined, both theoretically and on a field basis. Size of system, (pump, sump, pipeline, etc.) as well as system operation are being investigated.
(h) "Recirculating Farm Irrigation Systems," J. A. Bondurant and L. S. Willardson (In press, ASCE Proceedings).

(5980) WATER BUDGET OF WATERSHEDS.

(b) Laboratory project.
(c) Mr. W. Russell Hamon, Research Hydraulic Engineer, Agricultural Research Service, P. O. Box 2724, Boise, Idaho 83701.
(d) Experimental; basic and applied research.
(e) Each hydrologic component is to be evaluated and the parameters of predictive equations related to easily determined physical characteristics and climate. Such equations will be used in combination with hydrologic storages to develop a hydrologic model for predicting the water budget on ungaged watersheds. These procedures will be developed principally for semi-arid range lands.

(h) "Reynolds Creek in Southwest Idaho: An Outdoor Hydrologic Laboratory," J. S. Robins, L. L. Kelly, and W. R. Hamon. Water Resources Research, Vol. 1, No. 3, pp. 407-413. Third Quarter 1965.
"Use of Experimental Watershed Data in Predicting the Water Balance," W. Russell Hamon and J. Marvin Rosa, Symposium of Budapest, International Association of Scientific Hydrology, Pub. No. 66, pp. 252-261, 1965.

(5981) TRANSIENT VERTICAL DRAINAGE IN IRRIGATED SOIL.

(b) Laboratory project.
(c) Dr. Marvin E. Jensen, Investigation Leader (Water Management), Agricultural Research Service, Snake River Conservation Research Center, Route 1, Box 186, Kimberly, Idaho 83341.
(d) Theoretical and experimental; and basic and applied.
(e) Numerical solutions for nonsteady state vertical drainage were obtained using a computer and independently determined hydraulic properties of the porous materials. These were compared with experimental data and used to evaluate approximate solutions. Deep percolation losses encountered when maintaining soil moisture within specific limits under various rates of evapotranspiration and root zone depths will be evaluated in a similar manner for developing practical methods of predicting the magnitude of these losses.
(g) Under drainage, without evapotranspiration, two flow regimes occurred in coarse-textured materials. During the first stage, the outflow rate from a column was related to the position and fluid pressure at the saturated front. Only a portion of the drainable fluid drains during this period. An approximate solution presented by Youngs in 1960 predicts the drainage rate adequately during this period, but only during this period, During the second stage, the change in outflow rate was not dependent on the movement of the saturated front but was now dependent on the unsaturated hydraulic conductivity and differential fluid capacity of the porous materials.
(h) "Nonsteady-State Drainage of Fluid from Porous Media and Drainable Porosity," Marvin E. Jensen, Ph.D. Dissertation, Colorado State University, Civil Engineering Department, August 1965.

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SOUTHERN BRANCH, P. O. Box 1039, Athens, Georgia 30601. Dr. A. R. Bertrand, Branch Chief.

(3870) AGGRADATION AND DEGRADATION AS RELATED TO CHANNEL STRUCTURES.

(b) Laboratory project, cooperative with the Univ. of Miss. and Miss. State University.
(c) Mr. Joe C. Willis, Hydraulic Engineer, Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi 38655, and Mr. Paul Yates, Hydraulic Engineer, P. O. Box 33, Watkinsville, Georgia 30677.
(d) Field and laboratory investigations; basic and applied research.
(e) It is necessary for proper planning and design of agricultural watershed conservation work to have knowledge of the extent of aggradation or degradation that is likely to occur with placement of structures in alluvial channels. Studies of deposition and scour as related to actual structures at various locations in Mississippi, Georgia, Wisconsin and other selected locations to provide the needed field data are underway to develop procedures and criteria useful in predicting channel adjustments with structural installations and accompanying changes in sediment transport and flow pattern.
(g) Channel surveys show a slow rate of degradation of the streambed of Barber Creek, Georgia, where the control of flood flows by flood water detention structure is greatest. Here the watershed is about 95 percent controlled. The degree of channel scour and channel erosion rates are being determined in connection with several structural installations in Mississippi. Case histories of over 70 gully control structures in Wisconsin have been established. Laboratory studies of degradation have been started. The rates of degradation of laboratory sand-bed channels following suspension of sand feed to the channel were measured. Three different sands were used.

(3871) LABORATORY STUDIES OF SEDIMENT TRANSPORT.

(b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.
(c) Mr. Joe C. Willis, Hydraulic Engineer and Dr. Neil L. Coleman, Geologist, USDA Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi 38655.
(d) Experimental; basic and applied research.
(e) Laboratory flume experiments are conducted to determine bed material transport, bed material qualities, and stream hydraulics.
(g) In laboratory tests with a 400-micron median-diameter sand and depths of flow ranging between 0.4 ft. and 1.1 ft. the variable $\frac{V - 1.1}{1.4\,(y + 1.0)}$ is related to the type of bed form, the mean dune height, and the Darcy-Weisbach friction factor rather well. Total load and bed load was determined by mean velocity when moving duens were present on the bed. When mean velocity was larger than the value producing minimum bed friction factor, total load was a function only of mean bed shear stress. A comparison of transport rates with those calculated by certain formulas, showed Schoklitsch's to be preferable because of applicability and ease of computation. Further tests with a 100-micron median-diameter sand are planned to test these relationships.
(h) "Laboratories Studies of Total Load and Apparent Bed Load," R. A. Stein, Journal of Geophysical Research, Vol. 70, No. 8, pp. 1831-1842, April 15, 1965.

(4305) TRAP EFFICIENCY OF RETARDING-TYPE RESERVOIRS.

(b) Laboratory project, cooperative with the Soil Conservation Service and the U. S. Geological Survey.
(c) Mr. D. A. Parsons, Director, Sedimentation Lab., P. O. Box 30, Oxford, Miss. 38655.
(d) Theoretical and field investigations, and office analyses.
(e) The trap efficiency of a reservoir is a measure of the effectiveness of the structure in retaining incoming sediment. Structures need to be designed and built with different degrees of trap efficiency, and information is needed so that the influencing parameters can be adjusted to provide the desired trap efficiency. In this study we are endeavoring to (1) collect and study data from retarding-type reservoirs in order to determine those factors that influence trap efficiency, and (2) derive and test methods for predicting the trap efficiency of retarding-type reservoirs.

(4316) HYDRAULICS OF CHANNELS RELATIVE TO CHANNEL STABILITY.

(b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.
(c) Mr. D. A. Parsons, Hydraulic Engineer, Sedimentation Laboratory, P. O. Box 30,

Oxford, Mississippi 38655.

(d) Experimental, field investigations, applied and basic research.

(e) The determination of flood flow qualities in selected reaches of Pigeon Roost Creek Mississippi, and other streams in studies of the resistance to erosion of streambank and bed materials, and streambank vegetation. Measurements of the boundary shear stresses in curved channels as affected by bend radius, bed angle, and Froude number.

(h) "Vegetative Control of Streambank Erosion," Donald A. Parsons, Proceedings, Federal Inter-Agency Sedimentation Conference, USDA Misc. Pub. 970, pp. 130-136, 1963.
"The Determination of Sediment Yields from Flood Water Sampling," D. A. Parsons, R. P. Apmann, and G. H. Decker, IASH Pub. No. 65, pp. 7-15, 1964.

(4317) PRINCIPLES OF STABLE CHANNELS IN COHESIVE MATERIALS.

(b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.

(c) Dr. Earl H. Grissinger, Soil Scientist, Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi 38655.

(d) Experimental, applied and basic research.

(e) To study the properties of cohesive materials that determine their stability to flowing water. Rates of erosion are measured by subjecting remolded materials to a constant erosive flow of water. Objectives are: (1) to determine the reasons for the resisting ability of soil and streambank materials to erosion by flowing water; (2) to determine the kinds of tests needed to measure the resistance; and (3) obtain the quantitative values of the resistance for natural and synthetic materials.

(g) The stability of cohesive material was found to be dependent upon the type, amount, and orientation of the clay minerals; the bulk density, antecedent moisture, and wetage time of the sample; and the temperature of the eroding water. In general, stability increases with increasing clay mineral content and with increasing density. Stability was greater for the 2:1 type clay mixture than for the 1:1 type.

(4318) METHODS OF CHANNEL STABILIZATION.

(b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.

(c) Mr. D. A. Parsons, Hydraulic Engineer, Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi 38655.

(d) Experimental, field investigations, applied and basic research.

(e) Includes: (1) Determination of the speeds of motion and the requisite conditions for beginning of motion of solid particles in fluid flow for various flow, particle quality, and boundary conditions in a laboratory study; (2) field investigations on Pigeon Roost Creek, Mississippi, and other streams of the resisting abilities of bank and bed materials and bank vegetation as determined by measured flood experiences (this study is associated with the one on channel hydraulics); and (3) laboratory and field study of the behavior of non-cohesive stands and silts in a stream channel bank for the conditions of lateral seepage flow to the stream.

(h) "Cellular Concrete Block Revetment," Donald A. Parsons and Robert P. Apmann. Journal of the Waterways and Harbors Division, Proceedings ASCE, Vol. 91, No. WW2, pp. 27-37, May 1965.
"Cellular Concrete Block Revetment," D. A. Parsons and R. P. Apmann, Civil Engineering, ASCE, pp. 66. Feb. 1965.

(4319) SEDIMENT YIELDS AND CORRELATION WITH WATERSHED CHARACTERISTICS.

(b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.

(c) Messrs. Farris E. Dendy and Andrew J. Bowie, Agricultural Engineers, Sedimentation Lab., P. O. Box 30, Oxford, Miss. 38655.

(d) Field investigation, applied research.

(e) Analyses of hydrologic, hydraulic, land use, soils, and physiographic characteristics of agricultural watersheds (varying in size from a fraction of an acre to 100 sq. mi.) are made to establish relationships with sediment transport rates, amounts, and delivery ratios. Establishment of methodology for determining long-time average annual sediment yields from fragmental field data, correlation of characteristics of the basic runoff-sediment relation (sediment rating curve) with affecting hydraulic and hydrologic parameters, and evaluation of the role of large storms as sediment contributors, are all basic objectives that will lead to better sediment yield prediction procedures.

(g) Data from Pigeon Roost Creek Basin, Miss., indicates that sediment yields are highly correlated with direct runoff. Variations in unit direct runoff (and therefore unit sediment) yields between watersheds of the basin are marked. They have to some extent been correlated with basin physiography and land use. There are significant channel transmission losses in streams of the basin.

(h) "The Role of the Large Storm as a Sediment Contributor," Robert F. Piest, Proceedings, Federal Inter-Agency Sedimentation Conference, USDA Misc. Pub. 970, pp. 98-108, 1963.
"Long-Term Sediment Yields for Small Watersheds," R. F. Piest, IASH Pub. No. 65, pp. 121-140, 1964.
"Sediment Yields from Small Watersheds Under Various Land Uses and Forest Covers," S. J. Ursic and F. E. Dendy, Proceedings, No. 970, pp. 47-62, 1963.
"Advances in Sedimentation Relevant to Watershed Problems," C. R. Miller, Transactions ASAE, Vol. 8, No. 1, pp. 146-152, 1965.

(4320) SEDIMENT ORIGIN AND ROUTING.

(b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.

(c) Dr. L. L. McDowell, Soil Scientist, Sedimentation Lab., P. O. Box 30, Oxford, Mississippi 38655.

(d) Experimental, basic research.

(e) Runoff and sediment production are measured from a small gully typical of the Yazoo-Tallahatchie Watershed. Sediment produced from this gully will be related to gully area, thereby providing information on the rate of gully erosion. When applicable, comparisons will be made between the estimated sediment discharge utilizing radioactive tracer sand, and the measured sediment discharge.

(g) Runoff and sediment measuring equipment have been installed. A detailed topographic survey has been made of the gully area. Surveys will be made periodically to observe changes in gully shape.

(h) "Sediment Movement as Defined by Radioactive Tracers: A Preliminary Report," L. L. McDowell, Proceedings Federal Inter-Agency Sedimentation Conference, USDA Mis. Pub. 970, pp. 550-568, 1963.

(4321) RESERVOIR SEDIMENTATION.

(b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.

(c) Mr. F. E. Dendy, Research Agricultural Engr., and Mr. Paul H. Hawks, Geologist, USDA Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi 38655.

(d) Experimental and field investigation for basic research and developmental work.

(e) To relate sediment accumulation in

reservoirs to sediment yields, runoff, and physical parameters of the watersheds. The nature of the sediment, its origin, mineralogy, chemistry, and biology are studied in relation to distribution and deposition within the reservoir. Nuclear methods are used where applicable.

(g) A number of reservoirs have been periodically surveyed for sediment accumulation. Nuclear means of determining in situ densities have been employed.

(h) "Summary of Reservoir Sediment Deposition Surveys Made in the United States through 1960," compiled by J. A. Spraberry, USDA Misc. Pub. 964, 1964.

(4322) DEVELOPMENT OF METHODS FOR UTILIZING RADIOACTIVE ISOTOPES AND RADIOACTIVE MATERIALS FOR SEDIMENTATION AND HYDROLOGY RESEARCH.

(b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.

(c) Dr. J. Roger McHenry, Soil Scientist and Dr. L. L. McDowell, Soil Scientist, Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi 38655.

(d) Experimental basic research.

(e) To devise, develop, and utilize procedures for "tagging" sediment particles with radioisotopes and identifying same in the laboratory and in the field. Results are to be used in predicting sediment production, transport and deposition.

(g) A satisfactory method has been developed for "tagging" quartz particles with scandium-46, silver-110, cerium-144, and antimony-124.

(h) "Measurement of Sediment Density with Gamma Probes," J. Roger McHenry and Paul H. Hawks, Proceedings Federal Inter-Agency Sedimentation Conference, USDA Misc. Pub. 970, pp. 899-908, 1963.
"Measurement of Sediment Density by Attenuation of Transmitted Gamma Rays," J. R. McHenry and F. E. Dendy. Proceedings, Soil Science Society of America, Vol. 28, No. 6, pp. 817-822, 1964.

(4323) SEDIMENT PRODUCTION AND CONTROL PRACTICES ON HIGHWAY CUTS AND FILLS.

(b) Laboratory project, in cooperation with Georgia State Highway Dept., Soil Conservation Service USDA, the University of Georgia College of Agriculture Experiment Stations, and Bartow County, Georgia.

(c) Mr. Ellis G. Diseker, Agricultural Engineer, P. O. Box 335, Cartersville, Georgia 30120.

(d) Experimental, field; applied.

(e) Measurements are made of runoff and soil losses from one pair of bare roadbank plots and two pairs of plots vegetated in early 1963 (approximately 1:1, 2:1, and 3:1) on Cecil clay subsoil using six H-flumes and Coshocton vane samplers. On the two pairs of vegetated plots, annual soil loss was approximately 13 times less than before the plots were vegetated. Metal hub stakes are used to measure deposition or scour in the flow channels. Over 35 plant species have been tested for erosion control on 1,292 roadbank plots.

(g) Losses on bare banks have varied from 25 to 453 tons per acre per year for the last 6 years, varying according to rainfall, frost action, bank aspect, and slope. Bank aspect and frost action are major factors in the erosion process. Northwest-facing banks, on an average, have lost 2.2 times as much soil as southeast-facing banks. Fescue, common Bermuda, lovegrass, broomsedge, Pensacola and Wilmington Bahiagrasses, crownvetch, sericea lespedeza, honeysuckle, and kudzu have proven to be satisfactory for erosion control. Mulches were necessary for satisfactory cover establishment on slopes 2:1 and steeper, especially for slowly developing plants such as crownvetch and Bahiagrasses. Proper fertilizer applications are necessary for maintenance of most species, especially the grasses. Outlined procedures for determining fertility requirements for maintaining vegetation on roadside areas in the Piedmont Uplands of Georgia were begun in the fall of 1962. In the spring of 1963, studies were begun on Cecil soil to determine rates and amounts of sediment delivery for selected storms at monthly intervals, and annual production and delivery from bare road banks in relation to (1) rainfall intensity, (2) antecedent moisture and temperature conditions, and (3) face-slope length with different aspects. Also in the spring of 1963, a study was initiated to determine sediment production and delivery ratios from fully developed mature stands of five representative plant species. Studies of sediment delivery ratios in the Southern Piedmont revealed that rates on Cecil soils were highly correlated with EI (rainfall energy-intensity) values. Other climatic factors, still to be evaluated, also affected these ratios. Comparison of sediment production from vegetated roadside areas with that from unvegetated areas revealed the loss from vegetated plots to be only 8 percent of that from unvegetated plots. Scouring of the unprotected road ditches was responsible for most of the sediment losses from vegetated plots. Investigations showed the point-count index evaluation to be closely correlated with vegetative yields obtained from harvested samples. The equation, $Y = 632X-58$, when Y is the total number of hits made on plant cover and X is the dry weight yield in tons per acre, gave the correlation coefficient, r, of 0.995. Visual rating appears to be biased (observers tended to underate poor stands of cover), however, such ratings may be useful in estimating the degree of vegetative erosion protection. Future tests on sediment production will be made with 2.5 tons/acre of vegetative cover obtained with mixtures of Pensacola Bahiagrass and Bermudagrass, sericea lespedeza and lovegrass, Kentucky fescuegrass and Italian ryegrass, and crownvetch and Abruzzi rye. EI was the best single prediction factor for annual sediment yield; however, alone, it does not always correlate well with annual sediment yield. Sediment yield was satisfactorily measured on a monthly basis; sediment production was measured annually because of channel deposition. Sediment yield and production often were abnormally high on paired plots because of ditch gradient. Monthly production and yield apparently were greatly influenced by temperatures and soil moisture.

(4324) UTILIZATION OF TRITIUM IN WATERSHED RESEARCH.

(b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.

(c) Dr. J. Roger McHenry, Soil Scientist, Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi 38655.

(d) Experimental basic research and development.

(e) To devise, develop, test and apply tracer techniques using tritium and other radioisotopes in support of studies of soil moisture and groundwater movement.

(f) Discontinued.

(g) Methods of high efficiency have been developed using a liquid scintillation counter. Laboratory studies have shown the precision and accuracy of the methods are adequate. Some field tests have been conducted. Results have not been conclusive. Tests designed to date water in limestone aquifers have not been completed.

(4325) RUNOFF FROM AGRICULTURAL WATERSHEDS.

(b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.

(c) Mr. A. J. Bowie, Hydraulic Engineer, USDA

sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi 38655.

(d) Field investigations; basic and applied research.

(e) To develop procedures for predicting flood runoff, water yield and hydrograph characteristics for ungaged upstream watesheds. Runoff and precipitation are observed for the 117 square-mile Pigeon Roost Creek Watershed in Northern Mississippi including 11 sub-watersheds, and for four unit-source watersheds under 4 acres in size. These data, accumulated over the past four years, are being processed by computer and analyzed to develop synthetic unit hydrographs by incorporating antecedent soil moisture and watershed factors. The predicted hydrographs will be used to establish flow-duration curves.

(4326) SUBSURFACE HYDROLOGY.

(b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.

(c) Mr. F. E. Dendy, Agricultural Engineer, Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi 38655.

(d) Experimental and field investigations; basic and applied research.

(e) To study the hydraulic characteristics of geologic strata and develop methods of predicting ground water accretion and movement; subsurface and ground water contribution to streamflow from a knowledge of geology, soils, topography, climate, land use and treatment of agricultural watersheds; and to evaluate hydrogeologic factors governing transmission gains and losses in stream channels. A portable drilling rig is utilized to obtain geologic samples, establish ground water observation wells, and conduct permeability field tests.

(g) Maps showing structural and stratigraphic characteristics and groundwater contours of the Pigeon Roost Creek watershed have been prepared. Estimates have been made of ground-water storage and outflow from the watershed.

(4327) MOISTURE REGIMES OF AGRICULTURAL WATERSHEDS.

(b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.

(c) Mr. John Kozachyn, Soil Scientist, Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi 38655.

(d) Field investigation; applied research.

(e) To provide soil moisture data for the development of prediction techniques for runoff and sediment production and to relate the moisture regimes of agricultural watersheds to soil, climate and vegetative parameters. Field observations of soil moisture to depths of 10 and 20 feet are obtained by the neutron probe method for different cover, slope, and soil complexes.

(g) The superiority of the neutron probe procedure over other available methods was established from laboratory and field tests. A method of installing access tubes has been perfected.

(4328) RELATION OF CLIMATE AND SOIL MOISTURE LEVELS TO PLANT GROWTH AND WATER USE.

(b) Laboratory project, cooperating with the Central and Southern Florida Flood Control District and the Florida Agricultural Experiment Station.

(c) Mr. E. H. Stewart, Soil Scientist, P. O. Box 9087, Ft. Lauderdale, Florida 33310.

(d) Laboratory and field investigations, both basic and applied for evaluating measured environmental conditions.

(e) Laboratory and field procedures are employed to determine moisture intake, retention and transmission characteristics of mineral and organic soils. Controlled water table studies in non-weighing lysimeters are conducted to determine evapotranspiration, crop growth, and soil physical properties as influenced by various water table depths. Field and plot studies in organic soils are conducted to determine soil subsidence.

(g) Laboratory studies with porous tile used for subirrigation have shown that treating the irrigation water with sodium hypochlorite prevented the tile from becoming clogged by filamentous-type water bacteria. Tile that usually clog seriously in less than two weeks have maintained adequate flow for more than six months when using the treated water. Results of 6 years of evapotranspiration studies with sod crops grown on Arzell fine sand with a 24-inch water table show a mean annual water consumption of 43 inches.

(h) "Subirrigation of Turf," E. H. Stewart, E. O. Burt, and R. R. Smalley. Proceedings, Florida Turf-Grass Assn., 1965.

(4329) HYDROLOGIC RESEARCH ON SMALL AGRICULTURAL WATERSHEDS IN CENTRAL AND SOUTHERN FLORIDA.

(b) Laboratory project, cooperating with the Central and Southern Florida Flood Control District and The Florida Agricultural Experiment Station.

(c) Mr. E. H. Stewart, Soil Scientist, Attention: W. H. Speir, Engineering Technician, P. O. Box 9087, Fort Lauderdale, Fla. 33310.

(d) Experimental, field investigations; basic and applied research.

(e) To collect, analyze, and correlate basic hydrologic data on agricultural watersheds ranging in size from 4,000 to 63,000 acres in the Coastal Plain of Florida. To determine the influence of climate, topography, soils, geology, and land use on the rate and volume of runoff and to evaluate the water balance. To devise methods of interpreting watershed characteristics as similitudes related to physiography of other areas.

(g) For an unimproved 98.7-sq mile watershed the maximum daily discharge (Oct. 1956) was 2.28 inches-over-area with an instantaneous peak rate of 71 c.f.s./sq. mile; and for the 15.7-sq. mile upper sub-basin the respective rates were 3.14 inches and 161 c.f.s./sq. mile. For an improved 78 square mile watershed the maximum daily discharge (Sept. 1960) was 2.37 inches-over-area with an instantaneous peak rate of 68 c.f.s./sq. mile. For an improved 6.2 square mile watershed the maximum daily discharge (Sept. 1960) was 2.33 inches-over-area with an instantaneous peak rate of 123 c.f.s./sq. mile. The ratio of runoff to rainfall averaged 0.43 for the artesian-irrigated 78 sq. mile watershed until 1959. Increased use of artesian irrigation water increased this ratio to 0.55 after 1959. For the 98.7 sq. mile unimproved watershed this ratio has averaged 0.32 and for the 15.7-sq. mile sub-basin, 0.27 since 1955. For the 6.2 square mile watershed the ratio has averaged 32% since 1956. This includes seepage runoff from pumped irrigation during dry periods. For the 98.7 sq. mile watershed base flow was averaged 66%, interflow 25%, and overland flow 9% of total streamflow. For the 78-sq. mile watershed these flow components have averaged 81%, 8%, and 11%, respectively. For the 15.7 sq. mile watershed they averaged 28%, 30%, and 42%. Storm rainfall in central and southern Fla. was characterized by analyzing records of 30 high-intensity rainfalls that occurred on 2 agricultural watersheds in that area. Periods of rainfall records on the watersheds were approximately 9 years and 13 1/2 years. Watershed areas were 98.6 sq. mi. and 78 sq. mi. Storm time-distribution patterns were established for storms of long duration (greater than 12 hours) and short duration (less than 12 hours). Depth-area relations were determined for both the long-duration storms and the short-duration storms for both watersheds.

(h) "Storm Rainfall in Central and Southern Florida," W. C. Mills, Soil and Crop Science Society of Florida Proceedings Vol. 24, 1965.

(4330) RUNOFF AND EROSION CHARACTERIZATION OF BROWN LOAM SOILS.

(b) Laboratory project.
(c) Mr. Cade E. Carter, Agricultural Engineer, North Mississippi Branch Experiment Station, P. O. Box 158, Holly Springs, Miss. 38635.
(d) Experimental, field; basic and applied.
(e) Rates and amounts of runoff and soil losses from small plots are measured. The plots range in size from 1/45 acre to 4 acres. The slopes of the smaller areas are 2-1/2 percent, 5 percent, and 10 percent. Land use varies from fallow and cultivated to pasture, with good and poor management conditions for the cultivated and pastured areas.
(g) Both water and soil losses are excessive on bare land, and are reduced as the degree of ground cover is increased.

(4331) HYDRAULICS OF FARM WATER CONTROL IN THE SOUTHERN PIEDMONT.

(b) Laboratory project in cooperation with the University of Georgia, College of Agriculture Experiment Stations.
(c) Mr. A. P. Barnett, Research Agricultural Engineer, Southern Piedmont Conservation Research Center, Box 33, Watkinsville, Ga. 30677.
(d) Experimental laboratory; basic and applied.
(e) Basic research on the mechanics of erosion and hydraulics of flow in individual crop rows and in terraced channels will be developed for both terrace systems and individual row systems for the different soils of the Piedmont.
(g) Initial studies are underway.

(4332) SURFACE DRAINAGE -- ROW LENGTHS AND GRADES FOR REMOVAL AND APPLICATION OF SURFACE WATER ON FORMED AGRICULTURAL LAND OF THE MISSISSIPPI DELTA.

(b) Laboratory project in cooperation with the Louisiana Agricultural Experiment Station.
(c) Mr. Irwin L. Saveson, Agricultural Engineer, P. O. Drawer U, University Station, Baton Rouge, Louisiana 70803.
(d) Experimental; basic and applied research.
(e) Approximately 80 acres of land have been formed with four different slopes, in two replications, of 0.1', 1.15', 0.2', and 0.25'. For each slope class, row lengths of 500', 700', 900', and 1,100' will be used to determine the maximum row length for formed land as related to slope.
Runoff, time-of-concentration, infiltration, soil temperature, and soil moisture data will be gathered and correlated with rainfall, wind humidity, and sunshine radiation.
Future studies are contemplated to evaluate flow characteristics of surface water in furrows on agricultural land. This information will be used to develop a furrow cross-section with the best hydraulic characteristics.
(g) An evaporation recorder has been developed. Data have been collected and are being analyzed for years 1963, 1964 and 1965.

(4333) RUNOFF AND EROSION STUDIES FOR THE SOUTHERN PIEDMONT.

(b) Laboratory project in cooperation with the University of Georgia, College of Agriculture Experiment Stations.
(c) Mr. A. P. Barnett, Research Agricultural Engineer, Southern Piedmont Conservation Research Center, Box 33, Watkinsville, Ga. 30677.
(d) Experimental field investigations, development and applied.
(e) The purpose of these studies is to determine the interrelations of climate, soil, topography, cover, management, row direction, runoff, soil movement and loss from Southern Piedmont soils. The work is conducted on fractional acre field plots under both natural and simulated rainfall.
The natural rainfall plot study includes six cover, two row direction and three slope steepness treatments on a total of 42 plots. Total amounts of runoff and soil loss are measured for individual rainstorms. Meteorological data are also secured.
The rainfall simulator designed to apply rain at 5, 2-1/2 and 1-1/4 inches per hour simultaneously to three adjacent plots is used to secure runoff, soil loss, and pesticide loss data from specific soil, slope, crop, and management complexes through the application of designed storms. These data are used to evaluate their runoff and erosion control effectiveness.

(4334) RUNOFF AND EROSION STUDIES FOR SOUTHERN COASTAL PLAINS SOILS.

(b) Laboratory project in cooperation with the Georgia Agricultural Experiment Stations.
(c) Mr. Adrian W. Thomas, Agricultural Engineer, ARS-SWC, Coastal Plains Experiment Station, Tifton, Georgia 31794.
(d) Field investigations; applied, for design.
(e) The purpose of these studies is to determine interrelations of climate, soil,land cover, runoff and soil loss for Southern Coastal Plain soils. The work is conducted on 18 field plots, 1/20 acre in size, under natural rainfall. There are four cover treatments. Total amount of runoff and soil loss are measured for individual storms. Meteorological data are also secured.
(g) Grass-based rotations and continuous corn have been evaluated, showing protective effects of perennial grass sods and of annual crop residues.

(4841) SURFACE WATER STORAGE AND SUPPLY ON FARMS IN THE COASTAL PLAINS.

(b) Laboratory project in cooperation with the Georgia Agricultural Experiment Stations and Soil Conservation Service, USDA, in Georgia.
(c) Mr. Adrian W. Thomas, Agricultural Engineer, ARS-SWC, Georgia Coastal Plains Experiment Station, Tifton, Georgia 31794.
(d) Field investigation; applied for design and development.
(e) Purpose of the studies is to determine pond storage efficiency under various soil and topographic conditions as affected by watershed yield, pond surface evaporation, seepage into and out of the impoundment, farm use of storage, and related factors. Initial study to be on one rather typical farm pond in the coastal plain, with anticipation of extending the work to other ponds.
(g) Study currently in progress.

(4842) SHALLOW WELLS AND IRRIGATION PITS FOR IRRIGATION AND OTHER FARM WATER SUPPLY IN THE COASTAL PLAINS.

(b) Laboratory project in cooperation with the Georgia Agricultural Experiment Stations and Soil Conservation Service, USDA, in Georgia.
(c) Mr. Adrian W. Thomas, Agricultural Engineer, ARS-SWC, Georgia Coastal Plains Experiment Station, Tifton, Georgia 31794.
(d) Field investigation; applied, for design and development.
(e) The purpose of the studies is to develop criteria by which engineers and soil scientists can classify sites for irrigation pits, shallow wells, or other access to shallow ground water aquifers in the coastal plains on the basis of topography and soils. Initial study is concerned with excavated

irrigation pits, their adequacy of supply, the relation of recharge to rainfall and soils, and other related influences. Investigations now involve 3 pits, each under somewhat different soil and topographic situations.

(g) Study currently in progress.

(4843) AN EFFICIENT DRAINAGE SYSTEM FOR SUGARCANE LAND.

(b) Laboratory project in cooperation with the Louisiana Agricultural Experiment Station.

(c) Mr. Irwin L. Saveson, Agricultural Engineer, P. O. Drawer U, University Station, Baton Rouge, Louisiana 70803.

(d) Experimental applied research.

(e) The present conventional system of sugarcane land requires considerable land occupied by ditches and is costly to maintain. Experimental work is underway to develop a more efficient drainage system which will consume less land and be more economical to maintain. This is an adaptation of the cotton drainage system to sugarcane.

(g) This system reduces the amount of land in ditches from 4 to 7 percent with a $5.22 per acre per annum savings in cost of maintenance.

(5210) RADIOCARBON DATING OF SEDIMENTS.

(b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.

(c) Dr. L. L. McDowell, Soil Scientist (Chemistry), Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi 38655.

(d) Laboratory and field investigations; basic research.

(e) To establish and maintain a radio-carbon dating laboratory meeting the requirements of sedimentation research. The program is used to supplement geomorphological investigations by providing information on (1) the age of sediments, e. g., buried soils and geologic horizons, and (2) the past rates of sediment aggradation and degradation.

(g) The carbon in samples to be dated is processed to benzene ($C_6{}^{14}H_6$) and the number of beta disintegrations arising from the natural C^{14} is determined by liquid scintillation spectrometry. The necessary equipment for synthesis of benzene has been built and tested for operation. The liquid scintillation spectrometer has been modified and stabilized for radio-carbon. The overall program has been standardized and calibrated using contemporary carbon standards (NBS) and inter-laboratory "check" samples from other dating laboratories. A few unknown samples have been dated; additional samples are now being processed.

(h) "USDA Sedimentation Laboratory Radiocarbon Dates I" L. L. McDowell and M. E. Ryan, Radiocarbon, Vol. 7, pp. 174-178, 1965.

(5572) CHANNEL BEHAVIOR FOLLOWING CHANNEL DREDGING.

(b) Laboratory project of USDA Sedimentation Laboratory, Oxford, Mississippi in cooperation with the Southern Piedmont Conservation Research Center, Box 33, Watkinsville, Georgia, and the Univ. of Georgia, College of Agriculture Experiment Stations.

(c) Mr. Paul Yates, Research Hydraulic Engineer, Southern Piedmont Conservation Research Center, Box 33, Watkinsville, Georgia 30677.

(d) Experimental field investigations; basic research.

(e) Basic research to determine the effects of stream channel dredging and realinement on channel geometry, flow velocities, sediment transport, scour and deposition, and retardance factors.

(5573) INFLUENCE OF FLOOD-RETARDING AND SEDIMENT DETENTION STRUCTURES ON CHANNEL REGIMES.

(b) Laboratory project of USDA Sedimentation Laboratory, Oxford, Mississippi in cooperation with the Southern Piedmont Conservation Research Center, Box 33, Watkinsville, Georgia, and the Univ. of Georgia, College of Agriculture Experiment Stations.

(c) Mr. Paul Yates, Research Hydraulic Engineer, Southern Piedmont Conservation Research Center, Box 33, Watkinsville, Georgia 30677.

(d) Experimental field investigations; basic and applied.

(e) Basic research to study stream channel adjustments that are induced by changes in water-and sediment-discharge characteristics, resulting from imposed channel alternations, dams, and other modifying installations. Also to develop procedures for predetermining channel changes likely to occur with structural installations and channel modifications.

(5574) A MODEL STUDY OF THE FORCES EXERTED ON A PARTICLE ON A STREAM BED.

(b) Laboratory project cooperative with the Univ. of Miss. and Miss. State Univ.

(c) Dr. Neil L. Coleman, Geologist, U. S. Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi 38655.

(d) Experimental project; basic research.

(e) An enlarged Reynolds Model of a section of stream bed has been constructed in a water tunnel. Transducers for measuring the force exerted on an exposed individual particle on the model bed are being developed. Attempts will be made to determine whether the force applied to the particle by the flow has lift and yaw components as well as a drag component. If the study is successful, the data obtained will be represented as plots of lift, drag, and yaw coefficients against Reynolds number. This information could then be used, with certain limitations, to predict the forces to be expected under various flow conditions on particulate beds of material ranging in size from that of sand grains to that of rip-rap stones.

(g) The development of transducers is progressing.

(5575) A STUDY OF BED FORMS IN SAND BED CHANNELS.

(b) Laboratory and field project, cooperative with the Univ. of Mississippi and Mississippi State University.

(c) Mr. Richard A. Stein, Hydraulic Engineer, Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi 38655.

(d) Basic and applied research.

(e) Relate the median and the standard deviation of dune height, dune propogation speed, water depths over dune crest, and water surface slopes to mean velocity and depth of flow. Define the bed material and hydraulic conditions that are related to types and size of bed configurations.

(f) Inactive.

(g) The parameter $\frac{V - 1.1}{1.75y + 1.25}$ appears to describes the median values of the dune properties studied. The standard deviations of these dune properties appeared to be independent of mean velocity and depth except for the depth of water over the dune crest, which increased with depth.

(5576) A STUDY OF BOUNDARY IRREGULARITY IN A CHANNEL WITH A SAND BED.

(b) Laboratory project, cooperative with the University of Mississippi and Mississippi State University.

(c) Dr. Neil L. Coleman, Geologist, U. S. Sedimentation Laboratory, P. O. Box 30, Oxford, Mississippi 38655.

(d) Experimental investigation, basic research.

(e) Flows with various bed regimes (dunes,

antidunes, or other) were established in a laboratory flume. An echo-sounding instrument called The Dual Channel Stream Monitor was used to take detailed bed and water surface profiles over a 50-foot reach in the flume. The profiles are now being analyzed by means of a computer program that yields the mean depth of each experimental flow, the standard deviation about the mean depth, and a depth autocorrelation function for each flow. The autocorrelation function can be integrated to yield a length which may be considered a wave length of the boundary irregularities. The depth standard deviation is an expression of the amplitude of the irregularities. The purpose of the study is to determine if these length scales will adequately portray the geometry in studies of bed forms, the migrations and the influences on open channel flow resistance.

U. S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Soil and Water Conservation Research Division.

SOUTHERN PLAINS BRANCH, ARS-USDA, Bushland, Texas, Dr. J. R. Johnston, Branch Chief.

(3879) CHARACTERIZATION OF THE "HOT SPOT" PROBLEM IN THE LOWER RIO GRANDE VALLEY OF TEXAS.

(b) Laboratory project.
(c) Mr. Ronald R. Allen, Agricultural Engineer, P. O. Box 267, Weslaco, Texas 78596.
(d) Experimental and field investigation - applied research.
(e) The purpose of the study is to determine the extent of salinity problems; characterize and correlate the water table, soil, topographic and related measurable factors associated with salinity problems in the area.
(f) Completed.
(g) Extensive water table observations show a fluctuating seasonally high saline water table beneath the area. The water table and ground surfaces slope approximately one foot per mile to the northeast in the general direction of the Gulf Coast.
(h) "Ground Water Table and Salinity Conditions in the Nonirrigated Area of the Lower Rio Grande Valley of Texas," R. R. Allen, L. R. Ussery, and B. M. Taylor. USDA ARS 41-115. (in press).

(3880) THE MICRODYNAMICS OF UNSATURATED MOISTURE FLOW.

(b) Laboratory project.
(c) Dr. Craig L. Wiegand, Soil Scientist, P. O. Box 267, Weslaco, Texas 78596.
(d) Experimental, basic research.
(e) The objectives are to obtain evidence on the generality of the parabolic moisture distribution with respect to the interface of extraction and to interpret unsaturated moisture flow in terms of molecular level mechanisms of flow. The experimental technique is that of inducing moisture flow by various techniques at a series of temperatures and measuring the flow rate. The Arrhenius equation is applied to the data and an activation energy calculated. The activation energy is then interpreted in terms of energy barriers to molecular level flow mechanisms. The soil columns are sampled at the end of the runs to determine the moisture distribution with respect to the interface of extraction.
(g) The results to date indicate that the resulting moisture distribution is a function of peculiarities of the microdynamic flow processes involved and independent of the method of extraction.
(h) "Water Transmission by Various Ceramic, Cellulose, Glass, and Steel Membranes," C. L. Wiegand and W. A. Swanson. Proc. Soil Sci. Soc. Amer. (in press).

(4335) THE HYDRAULICS OF STRUCTURES USED IN SOIL AND WATER CONSERVATION WORKS.

See U. S. Department of Agriculture, Agricultural Research Service, Soil and Water Conservation Research Division; Corn Belt Branch, Project 1723, and Illinois State Water Survey Division Project No. 1865.

(b) Laboratory project, cooperative with the Oklahoma Agricultural Experiment Station.
(c) Mr. W. O. Ree, Hydraulic Engineer, P. O. Box 789, Stillwater, Oklahoma 74074.
(d) Experimental and field investigation, applied research for design.
(e) Experiments employ small scale models as well as full size structures tested under simulated natural conditions to develop designs for structures needed for soil and water conservation. Closed conduit spillway entrances including drop inlets, hood inlets, and orifice plates are tested. Debris guards are tested using full size structures to provide verification of the small models.
(g) Air flow required in vents to prevent priming of drop inlet closed conduit spillways equipped with orifice plates was determined by full-scale experiments. A 30-inch square drop inlet was fitted with different orifice plates with orifices 10, 16, 18, and 20 inches in diameter. Air was provided to the underside of the plate through a 4-inch pipe with valve control. Air requirements for various flow rates were determined.

(4336) DESIGN AND CALIBRATION OF DEVICES FOR THE MEASUREMENT OF RUNOFF.

(b) Laboratory project, cooperative with the Oklahoma Agricultural Experiment Station.
(c) Mr. W. O. Ree, Hydraulic Engineer, P. O. Box 789, Stillwater, Oklahoma 74074.
(d) Experimental, applied research.
(e) The measuring devices tested are used in the hydrology research program of the Agricultural Research Service. Sites for runoff measuring stations are surveyed and then modeled in the laboratory. Proposed structures are placed in the model and tested to develop a satisfactory design. The final design is calibrated by model tests. All current work is on specific sites and no general experiments are done.
(g) Model calibrations were completed during past year for two supercritical flow flumes for measuring discharge rates up to 8,000 cubic feet per second. A V-notch and highway culvert combination runoff measuring station was rated by model test. A 9-inch H-flume was calibrated to measure runoff from a water harvesting catchment.

(4337) HYDRAULICS OF FLOW IN VEGETATION LINED CHANNELS.

(b) Laboratory project, cooperative with the Oklahoma Agricultural Experiment Station.
(c) Mr. W. O. Ree, Hydraulic Engineer, P. O. Box 789, Stillwater, Oklahoma 74074.
(d) Experimental, applied research.
(e) Channels or portions of channels are built full size on the outdoor hydraulic laboratory grounds. These are planted to the vegetation being investigated and then tested by flowing water at selected times. Friction factors and permissible velocities (or tractive force values) are determined. In recent years the establishment phase of vegetal channels has received the greater emphasis. This has included the evaluation of temporary, fabricated liners of jute, glass fiber, and asphalt.
(g) Analysis of data.
(h) "Tests of a Glass Fiber Channel Liner," D. K. McCool and W. O. Ree. USDA ARS 41-111. October 1965.

(4338) HYDRAULICS OF UNSTEADY FLOW IN OPEN CHANNELS.

(b) Laboratory project, cooperative with the Oklahoma Agricultural Experiment Station.
(c) Mr. W. O. Ree, Hydraulic Engineer, P. O. Box 789, Stillwater, Oklahoma 74074.
(d) Experimental, applied research.
(e) Studies are made of unsteady flow phenomena occurring in the runoff process. Included are investigations of overland flow, spatially varied unsteady flow in channels, and flood wave movement in channels. The initial phase of the study is an analytical one utilizing existing knowledge and theory. This phase will be followed by a large scale outdoor laboratory study to test hypotheses and evaluate coefficients.
(g) Water surface profile and velocity distribution measurements have been taken in a 400-foot long by 30-foot wide, V-shaped, grass-lined channel conveying a spatially varied flow. Momentum and velocity-head coefficients have been determined for different grass lengths for both nonuniform and spatially varied steady flow. A series of spatially varied unsteady flow tests has been conducted in the channel.

(4339) RUNOFF CHARACTERISTICS OF AGRICULTURAL AREAS IN THE RED PRAIRIE OF OKLAHOMA.

(b) Laboratory project, cooperative with the Oklahoma Agricultural Experiment Station.
(c) Mr. W. O. Ree, Hydraulic Engineer, P. O. Box 789, Stillwater, Oklahoma 74074.
(d) Field investigation, applied research for design.
(e) Three watersheds, 17 acres, 92 acres, and 206 acres in size and covered with native grass, are instrumented to measure rainfall and runoff. Annual water yield as well as peak flood flows are determined. Selected runoff events provide data for distribution graphs or unit hydrograph development.
(g) Data are on hand from continuous measurements since 1951.
(h) "Determining the Effect of Farm Ponds on Runoff from Small Watersheds," F. R. Crow and W. O. Ree. Okla. Agr. Expt. Sta. Bul. B-629, 14 pp. October 1964.

(4340) SEDIMENT PRODUCTION, MOVEMENT AND DEPOSITION IN THE WASHITA RIVER BASIN, OKLAHOMA.

(b) Laboratory project, cooperative with the Oklahoma Agricultural Experiment Station.
(c) Mr. M. A. Hartman, Hydraulic Engineer, P. O. Box 400, Chickasha, Oklahoma 73018.
(d) Field investigation, applied research.
(e) Suspended sediment sampling and total sediment transport determinations are made at selected tributary and main stream locations in the Washita River Basin. These samples are analyzed for size distribution.
(g) Analyzing available data.

(4341) STREAM CHANNEL STABILIZATION AND SEDIMENT CONTROL WORKS IN CHANNELS OF THE WASHITA RIVER BASIN.

(b) Laboratory project, cooperative with the Oklahoma Agricultural Experiment Station.
(c) Mr. M. A. Hartman, Hydraulic Engineer, P. O. Box 400, Chickasha, Oklahoma 73018.
(d) Field investigation, applied research.
(e) Selected reaches of channels representing different geologies, soils, and flow regimes are being established for detailed studies of stream channel morphology. Information is being obtained on cross-sections, slopes, thalweg lengths, alignments, vegetation, and bed and bank materials. Any control works are completely identified as to location, orientation, shape, size, and materials. Flow history will be recorded, including both water and sediment. Changes in channel conditions, or lack of change, will be related to flow history and other controlling factors for the development of criteria for stable channel design.
(g) Analyzing available data.

(4342) PRECIPITATION CHARACTERISTICS INFLUENCING RUNOFF FROM AGRICULTURAL WATERSHEDS IN THE WASHITA RIVER BASIN, OKLAHOMA.

(b) Laboratory project, cooperative with the Oklahoma Agricultural Experiment Station.
(c) Mr. M. A. Hartman, Hydraulic Engineer, P. O. Box 400, Chickasha, Oklahoma 73018.
(d) Field investigation, applied research.
(e) A network of 170 recording precipitation gages has been established on a 3-mile grid in an 1100-square mile area in the central portion of the Washita River Basin. The precipitation characteristics will be analyzed to determine and evaluate precipitation parameters useful in estimating runoff.
(h) Analyzing available data.

(4343) RUNOFF PRODUCTION BY UNIT SOURCE AREAS IN THE WASHITA RIVER BASIN, OKLAHOMA.

(b) Laboratory project, cooperative with the Oklahoma Agricultural Experiment Station.
(c) Mr. M. A. Hartman, Hydraulic Engineer, P. O. Box 400, Chickasha, Oklahoma 73018.
(d) Field investigation, applied research.
(e) Small watersheds generally not exceeding 100 acres in size, each representing a single soil-cover combination are being instrumented to measure rainfall, runoff, and soil moisture. Information on the runoff producing characteristics of the unit source areas will be useful in the development of equations for predicting runoff from ungaged complex watersheds.
(g) Analyzing available data.

(4344) RELATION OF INTEGRATED CLIMATIC AND WATERSHED FACTORS TO STORM RUNOFF AND WATER YIELD OF THE WASHITA RIVER AND TRIBUTARIES, OKLA.

(b) Laboratory project, cooperative with the Oklahoma Agricultural Experiment Station.
(c) Mr. M. A. Hartman, Hydraulic Engineer, P. O. Box 400, Chickasha, Oklahoma 73018.
(d) Field investigation, applied research.
(e) A reach of the Washita River extending from Anadarko, Oklahoma, to Alex, Oklahoma, has been selected for study. This reach has a length of 78 river miles and a drainage area along this length of 1128 square miles. Gaging stations are being established near the mouth of 10 tributaries and at 6 sites along the main stem of the Washita River in this reach. Watershed characteristics are being measured and defined. The watershed land use and structures development will be inventoried periodically. Flood peaks, total flow and its rate-time distribution will be determined and related to climatic and land factors.
(g) Analyzing available data.

(4345) EXPLORATORY STUDY OF THE REGIMES OF WASHITA RIVER MAIN STEM FLOWS.

(b) Laboratory project, cooperative with the Oklahoma Agricultural Experiment Station.
(c) Mr. M. A. Hartman, Hydraulic Engineer, P. O. Box 400, Chickasha, Oklahoma 73018.
(d) Analysis of record, applied research.
(e) The flow history of the Washita River, Oklahoma, for the 10-year period 1941 to 1950 is being analyzed to: (1) Determine parameters characterizing the regime flows prior to development of upstream flood abatement measures; and (2) establish a base for reference in defining any future changes in flow regimes associated with conservation and treatment programs in tributary watersheds.
(g) Analyzing available data.

(4346) AQUIFER-STREAMFLOW RELATIONS, GROUND WATER

BUDGET, WASHITA RIVER BASIN, OKLAHOMA.

(b) Laboratory project, cooperative with the Oklahoma Agricultural Experiment Station.
(c) Mr. M. A. Hartman, Hydraulic Engineer, P. O. Box 400, Chickasha, Oklahoma 73018.
(d) Field investigation, applied research.
(e) The alluvia and underground flow system of the Washita River Basin are being defined by use of drilling equipment and existing well logs. Permeability coefficients will be determined and ground water observation wells established. This is one part of a comprehensive research study of the total water budget in a portion of the Washita River Basin.
(g) Analyzing available data.

(4348) PRECIPITATION CHARACTERISTICS INFLUENCING RUNOFF FROM SELECTED AREAS IN TEXAS.

(b) Laboratory project.
(c) Mr. Walter G. Knisel, Research Hydraulic Engineer, P. O. Box 1147, Riesel, Texas 76682.
(d) Field investigation, applied research.
(e) Rain gage networks are established on the Blacklands Experimental Watershed near Riesel, Texas, and on the Edwards Plateau near Sonora, Texas. Information is being obtained on amounts, duration, seasonal distribution, and other characteristics of rainfall to the extent that the characteristics influence runoff from agricultural watersheds.
(g) Data from 25 recording rain gages on 4,683-acre experimental area near Riesel, Texas, and 14 recording rain gages on 48-square-mile area near Sonora, Texas. A study of depth frequency for periods from 1 to 15 days has been completed and a report prepared.
(h) Reported in USDA MISC. PUB. 945.

(4349) RELATION OF CLIMATIC AND WATERSHED FACTORS TO STORM RUNOFF AND TO WATER YIELD FROM AGRICULTURAL WATERSHEDS IN THE BLACKLANDS OF TEXAS.

(b) Laboratory project.
(c) Mr. Ralph W. Baird, Research Hydraulic Engineer, P. O. Box 1147, Riesel, Texas 76682.
(d) Field investigation, applied research.
(e) Twenty watersheds at the Blacklands Experimental Watershed near Riesel, Texas, varying in size from approximately 3 acres to 5860 acres, have been equipped with precalibrated flumes or with current meter rated weirs to measure runoff rates. Precipitation is measured by recording rain gages. The land factors are determined by periodic inventory of crops, covers, and crop systems on the land. Relationships between climatic and land factors and the runoff produced are analyzed to develop prediction methods for estimating storm peaks and water yields.
(g) The effects of conservation practices on storm runoff from major storms of infrequent occurrence is not great but is appreciable for many of the smaller storms.

(4350) RUNOFF PRODUCTION BY UNIT SOURCE AREAS IN THE BLACKLANDS OF TEXAS.

(b) Laboratory project.
(c) Mr. Ralph W. Baird, Research Hydraulic Engineer, P. O. Box 1147, Riesel, Texas 76682.
(d) Field investigation, applied research.
(e) Ten watersheds of from one-fourth to twenty acres in size and with single land use on each are instrumented with precalibrated flumes to measure runoff. Soil moisture, tillage operations, and crop yields are also obtained. The relationships between the runoff and the associated precipitation as influenced by the land characteristics are investigated. These relationships will facilitate the prediction of runoff from ungaged watersheds composed of combination of these single soil-cover, sub-watersheds or unit source areas.

(4351) SEDIMENT YIELD IN RELATION TO CLIMATIC AND WATERSHED CHARACTERISTICS OF AGRICULTURAL AREAS IN THE TEXAS BLACKLANDS AND THE EDWARDS PLATEAU.

(b) Laboratory project.
(c) Mr. Ralph W. Baird, Research Hydraulic Engineer, P. O. Box 1147, Riesel, Texas 76682.
(d) Field investigation, applied research.
(e) At the Blacklands Experimental Watershed near Riesel, Texas, sediment yield measurements have been or are being made on twenty-four plots or watersheds varying in size from one-quarter to 5860 acres. These sediment yields are correlated with precipitation, runoff, topography, soils, land use, and conservation practices. The data are analyzed to develop techniques and procedures for estimating sediment yield and sources from ungaged watersheds. On Lowry Draw in the Edwards Plateau area near Sonora, Texas, sediment range lines have been established, in cooperation with Soil Conservation Service, at two detention reservoir sites with drainage areas of 4.38 and 16.85 square miles. In addition, arrangements have been made for sampling the flow from the reservoir spillways.
(g) In the Texas Blacklands sediment yields from watersheds of 100 to 200 acres having a large percent of cultivated crops have been reduced about 85 percent by changing to a complete conservation program.
(h) "Sediment Yields from Blacklands Watersheds," Ralph W. Baird. Trans. Amer. Soc. Agr. Engrs., Vol. 7, No. 4, pp 454-456. 1964.

(4352) RELATION OF CLIMATIC AND WATERSHED CHARACTERISTICS TO STORM RUNOFF AND WATER YIELD IN THE EDWARDS PLATEAU AREA OF WEST CENTRAL TEXAS.

(b) Laboratory project.
(c) Mr. Walter G. Knisel, Research Hydraulic Engineer, P. O. Box 1147, Riesel, Texas 76682.
(d) Field investigation, applied research.
(e) Five detention reservoirs in Lowrey Draw are equipped with water level recorders. Runoff rates and volumes are measured by volume changes in the reservoirs. The watersheds above the reservoirs range in size from 686 to 10,787 acres. A current meter rated gaging station is at the outlet of the Lowrey Draw watershed which has a drainage area of 48 square miles. A rain gage network is used to determine the precipitation over the area. In addition to the development of the rainfall-runoff relationship for this area, a study will be made of the disposition of the water temporarily stored in the reservoirs.
(g) A major storm of 7 to 12 inches occurred on the 48-square-mile watershed Sept. 19-24. A special storm report is being prepared.

(4353) EVALUATION OF OPERATION AND DESIGN CRITERIA OF OLD TILE DRAIN SYSTEMS.

(b) Laboratory project.
(c) Mr. Victor I. Myers, Research Agricultural Engr., P. O. Box 267, Weslaco, Texas 78596.
(d) Field investigation - applied research.
(e) A study to evaluate the effectiveness of some old existing tile systems in draining and leaching soils; to evaluate the functioning of tile drains with and without filter materials; and, to evaluate the adequacy of tile drain design criteria.
(f) Completed; manuscript for publication in review stage.
(g) Tile lines laid in certain soils, without filter or envelope materials provided,

accumulate soil over a long period of time until they become plugged or only partially effective. Studies are shedding light on the occurrence of the salinity - clay mineral complex and interactions that influence movement of soil particles into drain lines.

(4354) INFILTRATION RATES AND PROFILE CHARACTERISTICS IN RELATION TO THE OCCURRENCE OF SALINITY.

(b) Laboratory project.
(c) Dr. Craig Wiegand, Research Soil Scientist, P. O. Box 267, Weslaco, Texas 78596.
(d) Field investigation; applied research.
(e) The purpose of the work is to relate infiltration rates to the occurrence of salt-affected profiles. Infiltration rates are to be determined on about a dozen salt affected and adjacent non-affected profile pairs which have been chemically and physically characterized. The infiltration rates will be related statistically to the severity of salinization and to the chemical and physical properties of the profiles.
(f) Completed.
(g) The final intake rate (5 hours) in the nonsaline sites averaged about 3 times those of the adjacent saline sites. Analysis of variance revealed that saline profiles were higher in percent clay, are slightly elevated relative to the nonsaline sites and have greater surface slope than do the nonsaline sites. Multiple regression analyses predicted 95% of the variation in final intake rate. Differences in clay content surface elevation and soil slope are concluded to result in differences in leaching effectiveness of rainfall due to their influences on infiltration and runoff.
(h) "Interspersed Salt-Affected and Unaffected Dryland Soils of the Lower Rio Grande Valley: II. Infiltration Rates and Profile Characteristics in Relation to the Occurrence of Salinity," C. L. Wiegand, L. Lyles and D. L. Carter. Proc. Soil Sci. Soc. Amer. (in press).

(4356) EFFECTS OF BENCHING AND TERRACING ON MOISTURE CONSERVATION ON SLOPING HARDLANDS OF THE SOUTHERN GREAT PLAINS.

(b) Laboratory project.
(c) Mr. Victor L. Hauser, Agricultural Engineer, USDA Southwestern Great Plains Research Center, Bushland, Texas 79012.
(d) Field investigation, applied and design research.
(e) 1. To test the feasibility of altering the configuration of the land to intercept, spread, and infiltrate surface runoff in contour basins. 2. To determine the extent to which such intercepted runoff will add to available soil moisture supplies and how such additional soil moisture may best be utilized for crop production. 3. To determine the relative value of the three types of terrace systems, conservation benching, graded, and level closed end for moisture conservation and crop production. 4. To measure runoff from well managed contour farmed hardland soils.
(g) It has been found that graded and level terraces are equally effective in conserving runoff water under semi-arid conditions where 10 or 11 months of fallow precade planting either wheat or grain sorghum. It has been found that the conservation bench terrace system is superior to either graded or level terraces in the conservation of runoff water.

(4357) EFFECT OF CROPPING SYSTEMS AND CLIMATE ON RUNOFF, EROSION, AND CROP YIELDS UNDER BLACKLAND CONDITIONS.

(b) Laboratory project.
(c) Mr. D. W. Fryrear, Agricultural Engineer, P. O. Box 748, Temple, Texas 76502.
(d) Experimental - applied research.
(e) Runoff and soil loss are measured from 12 field scale (1 1/2 acre) plots representing a typical cultivated slope of Blackland Prairie soils. The plots are in three cropping systems with row cropping every year, in alternate years, and every third year. By taking soil moisture and crop residue measurements, in the future the interactions of varying climatic influences with crops and management are determined as a basis for determining runoff and erosion on farms and watersheds.
(f) Terminated.
(g) Statistical analysis of runoff results for 4-year period 1959-62 indicated no significant difference between plot replications or cropping systems but a significant difference in runoff for different years. Similar analysis of soil loss data for this period showed no significant difference between cropping systems, and a significant difference between plot replications and years. Complete statistical analysis of runoff, soil loss, and yield data will be made after the 1964 harvest.

(4844) TESTING OF MATERIALS FOR IMPROVED SUBSURFACE DRAINAGE.

(b) Laboratory project.
(c) Mr. Victor I. Myers, Research Agricultural Engr., P. O. Box 267, Weslaco, Texas 78596.
(d) Experimental; applied research.
(e) Laboratory tank studies will be made to evaluate drainage materials with particular emphasis on filters and new drain tube materials. One or more field installations will be made in which drainage materials will be compared and evaluated. Electric analogue studies will be made for predicting flow rates into tile lines.
(g) Laboratory studies with semi-rigid plastic lines have shown that the material can withstand loadings imposed by deep installation, to 9 feet, if installed in a narrow 10-inch width trench and if installed in an excavated cradle to provide some lateral strength.

(4845) SOIL-WATER-PLANT RELATIONS OF IRRIGATED COTTON AS INFLUENCED BY DEPTH TO WATER TABLE.

(b) Laboratory project.
(c) Mr. L. N. Namken, Research Soil Scientist, P. O. Box 267, Weslaco, Texas 78596.
(d) Field investigation; applied research.
(e) A set of thirty-six lysimeters, one meter square and ten feet deep, are being utilized to study the influence of soil moisture level, water table depth and water table salt level treatments on evapotranspiration, vegetative growth and yield of cotton. The objectives of the project are: (1) To determine the contribution of a water table to the water requirement of cotton; (2) to study soil moisture use and extraction by cotton as influenced by various water table depths; and (3) to study the effect of water table salt concentration on salt movement and moisture uptake by the cotton plant.
(g) The 1964 data, following leaching, contrast sharply with the 1963 results obtained under relatively high salinity conditions. There was no significant difference in total moisture use by cotton due to moisture level or water table treatments in 1964; however, total moisture use was nearly twice as great in 1964 under low salinity conditions as in 1963 under high salinity conditions. Mean total moisture use for moisture levels I and II were 32.8 and 31.2 inches, respectively, in 1964 compared with 18.6 and 16.6 inches, respectively, in 1963. Lint cotton yields were also much greater in 1964 than in 1963. Mean line cotton yields for the 3-, 6-, and 9-foot water table treatments were 1820,

1617, and 1592 pounds/acre, respectively, in 1964, compared with 704, 989, and 950 pounds/acre, respectively, in 1963. There was no significant difference in lint cotton yields due to moisture level or water table treatments in 1964. Lint cotton yields and total dry weight production for 1963 and 1964 were closely related to total moisture use.
The percentage of the total moisture use by cotton attributable to use from the water table was significantly influenced by moisture level and water table treatments in 1964. Mean percentages for the 3 water table depths (3-, 6- and 9-foot) were 56.7, 36.4 and 23.6 percent, respectively, for the high moisture level treatment and 67.8, 63.9 and 51.1 percent, respectively, for the low moisture level treatment.
Mean daily rates of moisture use from the water table by cotton was closely related to the percent of available moisture in the profile above the water table and to the salinity level of the 3-4 foot zone above the water table. Under all water table conditions with similar profile moisture conditions, the mean daily rates of moisture use from the water table were considerably higher in 1964 (low salinity) than in 1963 (high salinity).
A multiple regression of the 9-foot water table treatment for 1963 and 1964, indicates that mean daily rates of moisture use from the water table by cotton is closely associated with the percent available moisture in the 0-6 foot zone and the osmotic stress of the 5-7 foot zone.

(4846) EFFECT OF VARIOUS METHODS OF STUBBLE MULCH TILLAGE ON RUNOFF FROM UNIT SOURCE WATERSHEDS.

(b) Laboratory project.
(c) Mr. M. B. Cox, Agricultural Engineer, P. O. Box 128, Cherokee, Oklahoma 73728.
(d) Field investigation; applied research.
(e) Comparison of three types of tillage tools for residue management on runoff from unit source watersheds ranging in size from 1.7 to 2.2 acres on land slopes from 2.2 to 3.5 percent, cropped annually to wheat. Six watersheds with three treatments and two replications.
(g) Treatment 1, large sweeps (8 ft.) conserved the most residue and produced the least amount of runoff; Treatment 3, chisel tool, was the next treatment for conserving residue, but more runoff resulted; Treatment 2, light disking and chisel tool, conserved the least residue and produced the most runoff.

(4848) GRADED FURROWS FOR RUNOFF AND EROSION CONTROL.

(b) Laboratory project.
(c) Mr. Ralph W. Baird, Hydraulic Engineer, P. O. Box 1147, Riesel, Texas 76682.
(d) Field investigation; applied research.
(e) Purpose of work is to determine relationships between furrow length and slope, runoff and soil loss, and to see if graded furrows will permit increased terrace spacing. Terrace spacing is doubled and a channel rather than a conventional ridged terrace is used to convey runoff water. Increased terrace spacing is accomplished by planting on 40-inch lister furrows on a 1 percent grade. The amount of runoff and soil loss from the furrows is measured along with rainfall intensities, soil moisture, and surface residues.
(g) Special techniques and methods of measuring runoff and soil loss have been designed and developed including sampling apparatus for separating runoff increments into various amounts to permit timing of major portion of erosion. Data shows total runoff and runoff rate from 600- and 900-foot rows to be practically the same and significantly less than from 300-foot rows thus indicating more moisture storage in longer rows. Soil losses, which represent an unstable condition because of recency of plot installation, averaged 2.1, 1.9, and 3.0 tons per acre for the 300-, 600-, and 900-foot rows respectively.

(4849) EVALUATION OF DRAINAGE METHODS FOR THE NONIRRIGATED AREA OF THE LOWER RIO GRANDE VALLEY OF TEXAS.

(b) Laboratory project.
(c) Mr. Ronald R. Allen, Agricultural Engineer, or Mr. Victor I. Myers, Research Agricultural Engineer, P. O. Box 267, Weslaco, Texas 78596.
(d) Experimental and field investigation; applied research.
(e) The purpose of the study is to compare the effectiveness and cost of installation operation and maintenance of three drainage methods; open drain ditches, subsurface drain tile, and drainage wells in reduction of soil salinity and control of a ground water table.
(g) An underlying permeable sand aquifer limits installation depth and effectiveness of open drain ditches and subsurface drain tile. Pump drainage by wells has incurred considerable expense for the small area affected.

(5211) LIMITED IRRIGATION OF GRAIN SORGHUM IN THE SOUTHERN PLAINS.

(b) Laboratory project.
(c) Mr. J. T. Musick, Agricultural Engineer, Southwestern Great Plains Research Center, Bushland, Texas 79012.
(d) Field investigation; applied research.
(e) To determine number and timing of irrigations for most efficient use of limited irrigation and expected precipitation; plant spacing for most efficient use of limited water; and some soil moisture-plant growth-yield relationships under limited soil moisture conditions.
(g) One or two well-timed seasonal irrigations resulted in good yields and efficient use of limited irrigation water which permitted a reduction in irrigation water requirements. In addition to considering soil moisture, proper timing of limited irrigation should consider expected seasonal rainfall and stage of plant development. Narrow row and plant spacings are necessary for most efficient use of water at higher yield levels.

(5212) SOIL LOSS FROM THE ENDS OF LEVEL TERRACES AND THE EROSION OCCURRING BETWEEN TERRACES.

(b) Laboratory project.
(c) Mr. M. B. Cox, Agricultural Engineer, P. O. Box 128, Cherokee, Oklahoma 73728.
(d) Field investigation; applied research.
(e) Purpose of work is to determine soil losses from terraces and from different sections downslope within terrace intervals. Runoff and soil loss are measured from a system consisting of 8 terraces and 20 small plots. Half of the area is clean tilled and half stubble mulched. Terraces are arranged in pairs, one concrete and one soil channel. Concrete lined channels are used to provide a permanent base for measuring soil movement into terrace channels. Plots, located at the ends of the pairs of terraces, permit determination of silt contribution from three sections of normal terrace intervals.
(g) Terrace installations are completed and 1963-64 runoff and soil loss data have been obtained. Data showed some variation between different pairs of terraces but marked similarity of both runoff and soil loss was obtained within pairs, i.e., between concrete and regular soil channel terraces. The small plot portion of the study is installed but no data have been obtained.

(5213) WATER INTAKE AND DISTRIBUTION OF SOIL MOISTURE UNDER GRADED FURROWS ON PULLMAN SILTY CLAY LOAM.

(b) Laboratory project.
(c) Mr. W. H. Sletten, Agricultural Engineer, Southwestern Great Plains Research Center, Bushland, Texas 79012.
(d) Field investigation; applied research.
(e) Determine water intake characteristics, storage, distribution, and irrigation efficiency of long furrows on Pullman silty clay loam soil.
(g) This soil has a high initial intake rate which rapidly drops to a very low basic rate. One to two inches of initial intake occurs during and soon after water passes a point in the furrow. The intake rate then declines rapidly to about 0.6 inch per hour for the first hour after runoff begins from a short furrow segment to a basic rate of 0.1 inch per hour or less about 4 hours later. Cutting off the water soon after it reaches the end of long furrows results in high application efficiencies, relatively good distribution and decreases tailwater runoff losses.

(5214) DEVELOPMENT AND TEST OF A SIMPLE SYSTEM TO CLARIFY PLAYA WATER WITH FLOCCULENTS AND THE USE OF AN IRRIGATION DITCH AS A SETTLING BASIN.

(b) Laboratory project.
(c) Mr. Victor L. Hauser, Agricultural Engineer, Southwestern Great Plains Field Station, Bushland, Texas 79012.
(d) Field investigation; applied and design research.
(e) To develop a simple system for removing sediments from muddy playa lake water. This research project will be an effort to assemble relatively simple equipment to clarify muddy lake water prior to injection into a shaft as a means of storing runoff water and thus prevent its loss to the atmosphere by evaporation.
(f) The experiment is continuing.
(g) The system design specified in the research outline is not capable of removing enough sediment to be used in widespread recharge projects. The modified system including a sand filter did remove enough sediment to be used in recharge work but the capacity of the system is low.

(5216) GEOPHYSICAL EXPLORATION OF A PLAYA AND ITS WATERSHED.

(b) Laboratory project.
(c) Mr. Victor L. Hauser, Research Agricultural Engineer, USDA Southwestern Great Plains Research Center, Bushland, Texas 79012.
(d) Determine the stratigraphy of a playa and its watershed using surface electrical resistivity and electric and gamma-ray well logging equipment.
(e) The playa will be surveyed with the electrical resistivity equipment on a 500 foot grid. Data will be collected and analyzed according to standard practice. Each bore hole drilled on the playa watershed will be logged electrically and these data correlated with the drillers log and the stratigraphy and properties of each lithologic member.
(f) Initiated in 1963, field and laboratory work is continuing.

(5217) RUNOFF PRODUCTION BY UNIT SOURCE AREAS IN THE EDWARDS PLATEAU OF TEXAS.

(b) Laboratory project.
(c) Mr. Walter G. Knisel, Jr., Research Hydraulic Engineer, P. O. Box 1147, Riesel, Texas 76682.
(d) Field investigation, applied research.
(e) Seven watershed installations are now complete and in operation. One watershed was completed in 1963, three in 1964, and three in 1965. These watersheds are all in range areas of different soil and geologic formations, and runoff will be measured by precalibrated flumes. The relationship between the runoff and the associated precipitation as influenced by range use, geology, and soils are investigated.

(5218) THE DURABILITY AND EFFECTIVENESS OF DRAINAGE MATERIALS UNDER FIELD CONDITIONS.

(b) Laboratory project.
(c) Mr. Victor I. Myers, Research Agricultural Engr., P. O. Box 267, Weslaco, Texas 78596.
(d) Field investigation; applied research.
(e) A field installation of several types of subsurface drainage tile, pipes, and tubes was made to evaluate the durability and effectiveness of the materials. The investigation also includes a study of the effectiveness of providing fiberglass or gravel envelope materials to increase the flow of water and decrease the movement of sediment into drain lines under stratified soil conditions.
(g) Three additional drain lines were installed in December 1964 to complete the field installation of 6 experimental 1/4-mile lines in a 40-acre citrus grove. The 6 lines include 6-inch concrete with and without a fiberglass envelope, 4-inch bituminous fiber pipe with fiberglass envelope, 4-inch polyethylene pipe with fiberglass and with graded gravel envelopes, and a 2-inch steel, plastic, and fiberglass drain tube.

(5577) SPECTRAL RECONNAISSANCE IN AGRICULTURE.

(b) Laboratory and field project, cooperative with NASA, Purdue University and University of Michigan.
(c) Mr. Victor I. Myers, Research Agricultural Engr., P. O. Box 267, Weslaco, Texas 78596.
(d) Part of the project is theoretical basic research and the remainder is applied research.
(e) The purpose of the project is (1) to adapt remote sensing procedures for multispectral characterization of crops and soils under natural conditions, (2) to study the effects of environmental conditions on reflectance and emission characteristics of plants and soils, and (3) to identify factors and mechanisms affecting reflectance and emission from plants and soils.
(h) "Light Reflectance and Chlorophyll and Carotent Contents of Grapefruit Leaves as Affected by Na_2SO_4, NaCl, and $CaCl_2$," David L. Carter and Victor I. Myers, Amer. Soc. Hort. Sci. Proc. 82:217-221, 1963.
"Photogrammetry for Detailed Detection of Drainage and Salinity Problems," Victor I. Myers, L. Roy Ussery and W. J. Rippert, Amer. Soc. Agr. Engin. Trans. 6(4):332-334, 1963.

(5578) AERATION MEASUREMENTS FOR DETERMINING DRAINAGE NEEDS.

(b) Laboratory project.
(c) Dr. Ross W. Leamer, Research Soil Scientist, P. O. Box 267, Weslaco, Texas 78596.
(d) Determine the suitability of (1) bare platinum electrodes, (2) membrane covered gold electrodes, and (3) gas chromatograph for indicating soil drainage conditions.
(e) Aeration measuring devices are installed in a soil column in which water table level can be varied. The response of aeration measurements resulting from changes in water table level determine sensitivity to drainage conditions.

(5579) EFFECT OF WIND ON A FALLING WATERDROP.

(b) Laboratory project.
(c) Dr. E. L. Skidmore, Agronomy Dept., Waters Hall, Kansas State University, Manhattan, Kansas 66504.
(d) Laboratory investigation; basic research.
(e) Purpose of research is to determine influence of wind on the velocity of a falling raindrop; to determine effect of wind on path of drop; to determine effect on horizontal acceleration

of drop; and to determine effect of wind on kinetic energy and momentum of raindrops. The experiment is being conducted in a wind tunnel-rain tower facility where conditions of wind and other variables can be rather precisely controlled.

(g) Air flow through the rain tower has been studied and modified with screening devices to develop a turbulent boundary layer and to provide a wind with profile characteristics similar to natural winds. Drop formation and lighting problems have been resolved and experimental data will be taken in 1966.

(5580) LIMITED IRRIGATION OF WHEAT AND SORGHUM IN A FALLOW-WHEAT-SORGHUM SEQUENCE.

(b) Laboratory project.
(c) Mr. J. T. Musick, Agricultural Engineer, Southwestern Great Plains Research Center, Bushland, Texas 79012.
(d) Field investigation; applied research.
(e) Determine response to limited irrigation of winter wheat and grain sorghum at two critical stages of plant growth on yields, water use efficiencies, and plant characteristics; and to evaluate the ability of an extended preseasonal crop period (11 to 12 months preceding both sorghum and wheat) to supply soil moisture storage at planting and thus decrease irrigation water requirements.
(g) Irrigation water requirements of winter wheat and grain sorghum can be reduced by growing the crops in the "dryland" fallow-wheat-sorghum sequences which permits eliminating the preplant or emergence irrigation in most years.

(5581) TIMING OF PRESEASONAL IRRIGATION IN RELATION TO EFFICIENCY OF SOIL MOISTURE STORAGE.

(b) Laboratory project.
(c) Mr. W. H. Sletten, Agricultural Engineer, Southwestern Great Plains Research Center, Bushland, Texas 79012.
(d) Field investigation; applied research.
(e) Determine relationship between the storage efficiency of preseasonal irrigation water and timing of irrigation and the effect of antecedent soil moisture on storage efficiency of preseasonal precipitation and/or irrigation.
(g) Results based on 1 year's data indicate that a late fall water application after harvest and initial tillage resulted in more available soil moisture at plant emergence (June 29) than a preseasonal application during winter, or early, mid or late spring. Preseasonal applied water that remained in the soil root zone for plant use ranged from 28 to 50 percent, depending on time of application.

(5582) WATER REQUIREMENTS OF MARRS ORANGES, RED BLUSH GRAPEFRUIT, AND VALENCIA ORANGES IN THE RIO GRANDE VALLEY.

(b) Laboratory project.
(c) Mr. Marvin D. Heilman, Research Soil Scientist, P. O. Box 267, Weslaco, Texas 78596.
(d) Field investigation - applied research.
(e) This field investigation is designed to provide quantitative information on moisture use of Marrs and valencia oranges and red blush grapefruit in the Rio Grande Valley. From this data water management recommendations will be made for citrus production grown under conditions of a limited water supply. In addition, the investigations will determine the effects of the various citrus varieties.

(5583) VARIATION OF SATURATED HYDRAULIC CONDUCTIVITY OF HOUSTON BLACK CLAY WITH SOIL DEPTH AND WITH DIAMETER OF SOIL CORES.

(b) ARS-SWC, Blackland Conservation Experiment Station, Temple, Texas. Laboratory project.
(c) Dr. Earl Burnett, Research Soil Scientist, P. O. Box 748, Temple, Texas 76502.
(d) Experimental and basic research.
(e) Saturated hydraulic-conductivity will be determined for each 6-inch interval of undisturbed 9-foot soil column of 16- and 29-inch diameter and for 3-inch long soil cores of 3- to 3 7/8-inch diameter. The purposes will be (1) to determine the saturated flow rate of water through undisturbed cores of Houston Black clay profiles and through various layers of the profile, (2) to develop methods and procedures for utilizing large diameter cores for measuring the hydraulic conductivity of soils, (3) to study the relation between core size and saturated hydraulic conductivity, and (4) to determine the relation between direction of water flow and hydraulic conductivity.
(f) Completed.
(g) Data analysis and interpretations are under way.

(5982) EVALUATION OF CONTINUOUS WHEAT AND SORGHUM IN AN ALTERNATE DOUBLE-BED SYSTEM FOR EFFICIENT USE OF LIMITED IRRIGATION AND PRECIPITATION IN THE SOUTHERN PLAINS.

(b) Laboratory project.
(c) Mr. J. T. Musick, Agricultural Engineer, Southwestern Great Plains Research Center, Bushland, Texas 79012.
(d) Field investigation; applied research.
(e) Determine yield potentials and water use efficiencies of wheat and sorghum in an alternate double-bed system under varied soil moisture management and to determine the ability of wheat and sorghum to utilize soil moisture from adjacent double-bed areas during the non-growing period of the adjacent crop.

(5983) MEASUREMENT OF RUNOFF AND SOIL LOSS DIFFERENCES BETWEEN ESTABLISHED PLOTS.

(b) Laboratory project.
(c) Mr. Ralph W. Baird, Hydraulic Engineer, P.O. Box 1147, Riesel, Texas 76682.
(d) Field investigation; applied research.
(e) Runoff and soil loss are measured from 12 field scale (1 1/2 acre) plots representing a typical cultivated slope of Blackland Prairie soils. All plots have the same cropping treatment. Data will be collected for 3 years to determine variability in runoff and soil loss between plots with a uniform cropping system.
(f) Started in 1965.

(5984) EFFECT OF SURFACE MODIFICATIONS ON SOIL SALINITY IN A NONIRRIGATED AREA.

(b) Laboratory project.
(c) Mr. Ronald R. Allen, Agricultural Engineer, P. O. Box 267, Weslaco, Texas 78596.
(d) Field investigation; applied research.
(e) To determine the effect of lowering the surface of salt spots by soil removal (to retain precipitation and collect runoff) on the total salt balance in selected nonirrigated, leveled fields of the Lower Rio Grande Valley of Texas.

(5985) EFFECT OF SOIL SALINITY AND RATE OF LOWERING OF WATER TABLE ON GROWTH OF VEGETABLES.

(b) Laboratory project.
(c) Dr. Ross W. Leamer, Research Soil Scientist, P. O. Box 267, Weslaco, Texas 78596.
(d) Experimental and applied research.
(e) Vegetables will be grown in a greenhouse where water table levels can be controlled. About three weeks after planting all treatments will be flooded and water maintained one inch deep on the surface for 24 hours. The water table will be lowered by pumping water from the drain lines each day to give the variable rate of lowering of the water table. The flooding cycle will be repeated each 30 days. A low soil moisture tension

will be maintained between floodings. Variables of soil salinity will be established prior to planting each crop.
(f) Active, initiated 1965.

U. S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL RESEARCH SERVICE, Soil and Water Conservation Research Division.

SOUTHWEST BRANCH, P. O. Box 2326, Riverside, Calif. 92506. Mr. W. W. Donnan, Branch Chief.

(151) LINING OF IRRIGATION CANALS AND RESERVOIRS.

(b) Laboratory project, in cooperation with the Utah State University and Bureau of Reclamation.
(c) Dr. C. W. Lauritzen, Soil Scientist, Utah State University, Mechanic Arts, 130, Logan Utah 84321.
(d) Experimental; basic and applied research.
(e) Linings for irrigation canals and reservoirs are being tested to develop more effective and lower cost methods of reducing seepage losses in irrigation systems. The investigation included: (1) Evaluation of physical properties of lining materials; (2) model testing of linings in an outdoor laboratory; and (3) field testing at selected sites to determine relative durability under varying subgrade and climatic conditions.
(g) Of the membranes tested for use as lining materials, cured butyl continues to be the most resistant to degradation when exposed in the weather. Buried vinyl and polyethylene liners in test reservoirs continue to provide excellent seepage control after more than ten years of service. This is true of 4-mil as well as 8-mil liners. Butyl, polyisobutylene, and ethylene propylene rubber sheet bonded to concrete specimens retained an excellent bond after more than 1,000 freeze-thaw cycles. Further tests are in progress to evaluate these materials for use in repairing concrete linings or as an overlay on old concrete canal lining. Butyl latex, when added to concrete mixes, acts as an air-entraining agent and imparts about the same frost protection as commercial air-entraining agents tested.

(2177) WATER REQUIREMENTS IN IRRIGATED AREAS OF SOUTHWEST.

(b) Laboratory project in cooperation with State and Federal agencies.
(c) Mr. William W. Donnan, Branch Chief, P. O. Box 2326, Riverside, California 92506.
(d) Field experiments and office analysis. Applied research.
(e) To determine the consumptive use of water by crops, phreatophytes, and other vegetation, and net irrigation supply requirements. To develop empirical formula from climatological and other data for determining rates of consumptive use.
(f) Discontinued.
(h) "Consumptive Use and Water Requirements in New Mexico," Harry F. Blaney and Eldon G. Hanson, Technical Report 32, New Mexico State Engineer, Santa Fe, New Mexico, 1965.

(2180) EVAPORATION LOSSES FROM RESERVOIRS AND LAKES.

(b) Laboratory project in cooperation with State of California, counties and other agencies.
(c) Mr. William W. Donnan, Branch Chief, P. O. Box 2326, Riverside, California 92506.
(d) Experimental; compilation and analysis of data. Applied research.
(e) To determine evaporation losses from reservoirs and lakes and develop empirical formulas from climatological data for computing monthly evaporation. Cooperative field measurements are being made of pan evaporation at stations in California ranging from near sea level in Santa Barbara County to 9,194 feet elevation at Kaiser Pass in the Sierra-Nevada Mountains.
(f) Discontinued.

(2181) ARTIFICIAL RECHARGE OF GROUND WATER FOR IRRIGATION IN CALIFORNIA.

(b) Laboratory project in cooperation with the California Department of Water Resources.
(c) Mr. Leonard Schiff, Hydraulic Engineer, 4816 East Shields Ave., Fresno, Calif. 93726.
(d) Experimental; laboratory and field investigations, applied research.
(e) To efficiently store imported water underground in quantity and of a qualty needed in various locations. The objectives are: (1) To determine the physical and chemical characteristics of surface soil and substrata on selected recharge sites and to relate these characteristics to infiltration and percolation rates, and to lateral aquifer flow; (2) to determine the feasibility of recharge irrigation (deep percolation by heavy irrigation of crops) as a means of storing water underground; (3) to determine the effect on recharge of the quality of water reaching the groundwater table under selected site conditions, and on the quality of the groundwater; and (4) to prepare a recharge guide which permits the evaluation of a site for recharge, suggests methods and systems of recharge to be used and indicates the quality of groundwater that may be expected as a result of recharge.
(h) "Unsaturated Flow Phenomena in Panoche Sandy Clam Loam as Indicated by Leaching of Chloride and Nitrate Ions," K. L. Dyer, Soil Sci. Soc. Amer. Proc. 29:121-126, 1965. "Interpretation of Chloride and Nitrate Ion Distribution Patterns in Adjacent Irrigated and Nonirrigated Panoche Soils," K. L. Dyer, Soil Sci. Soc. Amer. Proc. 29:170-176, 1965. "Field Measurement of Soil Water Movement During Artificial Ground-Water Recharge," W. C. Bianchi and E. E. Haskell, Jr. Trans. Amer. Soc. Agric. Eng. 7:341-343, 1964. "Development and Dissipation of Ground Water Mounds Beneath Square Recharge Basins," E. E. Haskell, Jr., and W. C. Bianchi, J. Amer. Water Works Assoc. 57:349-353, 1965. "Pressure Distributions in Layered Sand Columns during Transient and Steady-State Flows," J. J. Behnke and W. C. Bianchi. Water Resources Research, Vol. 1 (4):557-562, 1965.

(3556) FARM CONVEYANCE AND WATER APPLICATIONS.

(b) Laboratory project, in cooperation with the Utah State University.
(c) Dr. C. W. Lauritzen, Soil Scientist, Utah State University, Mechanic Arts, 130, Logan Utah 84321.
(d) Experimental; basic and applied research.
(e) New methods and equipment for conveying and applying irrigation water are being developed. The hydraulic properties of layflat tubing are being studied and new materials are being evaluated to determine their use in conveyance structures.
(g) Two devices for regulating and measuring water deliveries from irrigation canals and ditches have been developed. These devices are essentially leakproof and simple to regulate.
(h) "Collapsible Tubing for Headgate Metering and Turnout Structures," C. W. Lauritzen, Agricultural Engineering, Vol. 46(9), 506-507, 1965, illus.

(3558) LABORATORY MODEL AND FIELD STUDIES OF REDUCING SEEPAGE IN SANDS WITH BENTONITE.

(b) Laboratory and field project, in cooperation with the Nevada Agricultural Experiment Station.
(c) Mr. Myron B. Rollins, Research Soil Scientist, Agricultural Research Service, P. O. Box 8014.

University Station, Reno, Nevada 89507.
(d) Experimental; applied research.
(e) To determine factors influencing blanket treatments and sediment penetration and retention involved with sealing irrigation canals or reservoirs with bentonite, and to develop procedures to obtain effective seals. Laboratory experimentation is being done with sands placed in lucite cylinders 3 inches in diameter and 2 feet long. Ponds 20 x 40 feet are used in field tests. Bentonite is applied by blanket treatment and by dispersing it in the water. Numerous aspects concerning the chemical, physical, and mineralogical properties of the bentonites, waters, and sands will be evaluated.
(g) Investigations, to date, suggest that effective seals can be obtained within certain unknown limitations for the dispersion or sediment treatment. Blanket treatments are very effective if kept moist.

(3560) EVAPOTRANSPIRATION OF HUMBOLDT MEADOW VEGETATION AS MEASURED WITH LYSIMETERS.

(b) Laboratory and field project, in cooperation with University of Nevada Agr. Expt. Sta. and Nevada State Department of Conservation and Natural Resources.
(c) Mr. Anthony S. Dylla, Agricultural Engineer, P. O. Box 8014, University Station, Reno, Nevada 89507.
(d) Experimental, field investigation.
(e) To measure the evapo-transpiration of meadow vegetation in the Humboldt Basin area which subsists primarily under shallow water table conditions. The data will be used to determine areal use of ground waters by native vegetation and phreatophytes and to develop methods of more efficient utilization of those water supplies.
(g) Evapo-transpirational rates are being obtained by water use measurements of meadow grasses growing in plastic lysimeters. Vegetative growth, soil moisture, water table, and weather data are being collected to which evapo-transpiration rates from tanks can be related.

(3872) DYNAMIC SIMILARITY IN PIPE ELBOW FLOW METERS.

(b) Laboratory project.
(c) Mr. Lloyd E. Myers, Director, U. S. Water Conservation Laboratory, 4331 East Broadway, Phoenix, Arizona 85040.
(d) Experimental; applied research.
(e) ASA, class 125, cast iron, 90-degree, flanged elbows of 3-, 6-, 10-, and 12-inch diameters from five manufacturing sources were calibrated to determine the expected accuracy of flow measurements made with uncalibrated elbow meters. Effects of various fittings and installations on the calibration were determined for 3-inch diameter elbows.
(g) Uncalibrated elbow meters can be expected to be accurate within 5 percent if properly installed.

(3873) GROUND COVERS AND OTHER STRUCTURES FOR COLLECTING AND STORING PRECIPITATION.

(b) Laboratory project, in cooperation with the Utah State University.
(c) Dr. C. W. Lauritzen, Soil Scientist, Utah State University, Mechanics Art, 130, Logan, Utah 84321.
(d) Experimental and applied research.
(e) There are areas in many regions where water for livestock and even culinary uses is scarce or nonexistent, yet considerable water in the form of precipitation falls each year. As an example, the precipitation on one acre of land in an 8-inch rainfall area amounts to 217,248 gallons. This is enough to supply water to more than 200 head of cattle for 100 days. This study includes the development and testing of materials for ground covers and storage facilities to be used for the collection and storage of water in low rainfall areas together with the design and operation of these facilities.
(g) Ground covers and closed storage structures have been developed for intercepting and storing precipitation. To satisfy the need for a name this combination of structures has been termed a "Rain Trap." Butyl sheeting continues to be the most satisfactory material for both the interceptor and the storage reservoir. Other materials are being investigated, and there are indications that some of these will be less expensive and reasonably serviceable as ground covers. Modifications have been made in the design and fabrication of ground covers and storage bags made of butyl to improve their performance.

(4358) FLOOD WAVE MOVEMENT AND ROUTING IN ALLUVIAL CHANNELS.

(b) Laboratory project, cooperative with the Arizona and New Mexico Agricultural Experiment Stations, and the U. S. Soil Conservation Service.
(c) Mr. R. V. Keppel, Agricultural Engineer, P. O. Box 3926, Tucson, Arizona 85717.
(d) Experimental, field investigation.
(e) Water level recorders are located at 2,000-foot intervals in a 3-mile reach of natural channel. The reach has a gaging flume at the inlet and at the outlet, and major tributary inflow is gaged. Flood waves generated by cloudburst type thunderstorms are being studied.
(g) The velocity of a wave front on a dry channel bed was found to be relatively independent of the discharge, and is probably more dependent on the moisture content of the channel alluvium. Velocity of the flow peak increased with the 0.36 power of the discharge. Peak velocities were considerably higher than the wave front velocities. For the first time since the study was initiated, an abrupt translatory wave varying in height from 1.0 to 1.9 feet occurred. Observed velocity of 11.1 feet per second compared with a theoretical pure gravity velocity of 10.2 feet per second.

(4359) PRECIPITATION CHARACTERISTICS INFLUENCING RUNOFF FROM SEMIARID WATERSHEDS.

(b) Laboratory project, cooperative with the Arizona and New Mexico Agricultural Experiment Stations, and the U. S. Soil Conservation Service.
(c) Mr. H. B. Osborn, Hydraulic Engineer, P. O. Box 3926, Tucson, Arizona 85717.
(d) Experimental, field and laboratory; basic research.
(e) Raingage networks with densities of one recording gage per square mile are being operated on the 58-square-mile Walnut Gulch watershed in southeastern Arizona and the 67-square-mile Alamogordo Creek watershed in northeastern New Mexico. The walnut Gulch study is augmented by horizontal-search 3-cm. radar. Objectives of the study are to determine precipitation parameters of importance in predicting runoff and sediment yield, and to give particular attention to the small area, highly intense, convective summer thunderstorms typical of the region.
(g) Data from Walnut Gulch watershed for a 7-year period of record indicate that summer convective thunderstorms are elliptical in shape with the major axis approximately 1.5 times the minor axis. Within the boundary of the Walnut Gulch watershed, 80% of the storms cover less than 4 1/2 square miles in area, and 96% cover less than 10 square miles. Maximum runoff events are typically the result of multi-celled storms separated in space and time. On the Alamogordo Creek watershed, convective thunderstorms are of greater intensity and larger areal extent than at Walnut Gulch. The difference is due

to the greater amount of precipitable water in the air mass in eastern New Mexico as compared with southeastern Arizona, and to the fact that frontal action is more common thus giving an added lift to convective storm cells.

(h) "Dense Rain Gage Networks as a Supplement to Regional Networks in Semiarid Regions," H. B. Osborn and R. V. Keppel. Design of Hydrometeorological Networks Symp. Proc. I.U.G.G. 1965.

(4360) RUNOFF FROM COMPLEX WATERSHEDS AS INFLUENCED BY CLIMATIC AND WATERSHED CHARACTERISTICS.

(b) Laboratory project, cooperative with the Arizona and New Mexico Agricultural Experiment Stations, and the U. S. Soil Conservation Service.

(c) Mr. R. V. Keppel, Agricultural Engineer, P. O. Box 3926, Tucson, Arizona 85717.

(d) Experimental; applied research.

(e) On semiarid rangeland watersheds up to 43,000 acres in size, runoff measurements are being maintained, and an attempt is being made to relate water yield to climatic and watershed characteristics, and to evaluate the effects of a range conservation program on rates and amounts of flood runoff and on net water yields. A new design of critical depth flume with capacities up to 22,500 cfs is being used to gage the flashy, sediment-laden flows.

(g) On Walnut Gulch Watershed in southeastern Arizona, 8 watersheds ranging in size from 560 to 36,900 acres are under study. Annual water yield decreases exponentially with the 0.3 power of the watershed area. Peak discharges of 2.44 inches per hour (5030 cfs) has been recorded on the grass covered 3.2 square mile watershed 11. All of the water yields to date have occurred from June to September as a result of small diameter, highly intense convective thunderstorms. At the Alamogordo Creek Watershed in eastern New Mexico (43,000 acres), flow events originating on the central and upper portions of the valley floor cause flat-top hydrographs with sustained peaks of 2 or 3 hours duration. On the other hand, runoff events originating on the southeast and southwest branches have sharp hydrograph peaks typical of the semiarid Southwest. These differences can be explained on the basis of channel morphology and valley storage.

(4361) THE ROLE OF VALLEY AND CHANNEL MATERIALS AND VEGETATION IN THE HYDROLOGY OF SEMI-ARID WATERSHEDS.

(b) Laboratory project, cooperative with the Arizona and New Mexico Agricultural Experiment Stations, and the U. S. Soil Conservation Service.

(c) Mr. K. G. Renard, Hydraulic Engineer, P. O. Box 3926, Tucson, Arizona 85717.

(d) Experimental, field investigation.

(e) Measurements from tandem gaging stations are utilized to evaluate the losses that occur as runoff traverses ephemeral stream channels. Records from shallow wells show depletion patterns of the transmission loss water.

(g) Transmission losses of up to 50 acre-feet-per-mile of channel have been measured on one reach of channel in a single flash flow. Because of these high losses, the annual volume of surface runoff is sometimes greater from a subwatershed than from the entire area. Not only net runoff but also peak rates and the hydrograph shape are affected by the losses. Records from wells in both local and regional water tables indicate that the disposition of the loss water depends largely on the geology in and adjacent to the channels. Where impervious material underlies the channel, much of the water is dissipated by evapotranspiration. In other portions of the channel some recharge of regional water table occurs.

(h) "Performance of Local Aquifers as Influenced by Stream Transmission Losses and Riparian Vegetation," K. G. Renard, et. al. Trans. of Amer. Soc. of Agric. Engrs. Vol. 7, No. 4 pp 471-474, 1964.

(4362) THE HYDROLOGY OF SEMI-ARID WATERSHEDS AS INFLUENCED BY CHARACTERISTICS OF SOIL AND NATIVE VEGETATION.

(b) Laboratory project; cooperative with Ariz. and New Mexico Agricultural Experiment Stations, and the U. S. Soil Conservation Service.

(c) Dr. J. L. Gardner, Botanist, P. O. Box 3926, Tucson, Arizona 85717.

(d) Experimental, field and laboratory. Basic research.

(e) Interrelations of soils and native vegetation as they influence water and sediment yield are being evaluated on rangeland watersheds of 100 to 43,000 acres in Arizona and New Mexico. Supplementary to studies on entire watersheds, infiltrometer studies on 6 x 12' plots are in progress. A primary objective of the infiltrometer studies is determination of parameters of rangeland vegetation most effective in evaluating its influences on runoff and sediment production on watersheds.

(g) Cover of shrubs was shown to be negatively correlated with clay and silt in the soil crust, surface horizon and subsoil; positively correlated with gravel in the three strata. Grass cover was positively correlated with clay and silt. On small watersheds above stock ponds, average annual sediment production --but not runoff--is logarithmically correlated with basal area of grass cover. It may be that this influence of grass cover in reducing sediment yield has been responsible for these correlations.

(4363) HYDROLOGIC DATA REDUCTION WITH ANALOG-TO-DIGITAL CONVERTER.

(b) Laboratory projects, cooperative with the Arizona and New Mexico Agricultural Experiment Stations.

(c) Mr. D. L. Chery, Jr., Hydraulic Engineer, P. O. Box 3926, Tucson, Arizona 85717.

(d) Experimental; laboratory.

(e) Hydrologic records in analog form are being reduced to digital form by means of an automatic analog to digital converter. Information is transferred primarily from rainfall charts to punched cards for future computer programs.

(4364) RUNOFF AND SEDIMENT MOVEMENT ON UNIT SOURCE WATERSHEDS AS INFLUENCED BY MICRO-CLIMATE, WATER BALANCE, SOIL AND VEGETATION.

(b) Laboratory project, cooperative with the Arizona and New Mexico Agricultural Experiment Stations, and the U. S. Soil Conservation Service.

(c) Mr. H. B. Osborn, Hydraulic Engineer, P. O. Box 3926, Tucson, Arizona 85717.

(d) Experimental, field and laboratory. Basic research.

(e) Runoff and sediment yields are being measured from several small, single soil-cover subwatersheds located within larger experimental watersheds having mixed soil-cover situations. Objectives are to evaluate the effects of various, soil-vegetation complexes, microclimate and water balance phases on local runoff and sediment production, and to identify and characterize unit source-areas controlling the net storm runoff and sediment yields of larger, more complex watersheds.

(g) Average annual sediment yield from small predominantly grass-covered watersheds is about 1%, by weight, of their water yield. Sediment yield measured from predominantly brush-covered watersheds ranges from around 2%, by weight, of water yield upward.

(4365) SEDIMENT MOVEMENT ON COMPLEX WATERSHEDS AS INFLUENCED BY CLIMATE AND WATERSHED CHARACTERISTICS.

(b) Laboratory project, cooperative with the Arizona and New Mexico Agricultural Experiment Stations, and the U. S. Soil Conservation Service.
(c) Mr. Kenneth G. Renard, Hydraulic Engineer, P. O. Box 3926, Tucson, Arizona 85717.
(d) Experimental, field and laboratory.
(e) The objectives of this study are: (1) to determine the relationship of sediment production on unit source areas to sediment yields of complex watersheds, (2) to develop methods for sediment yield prediction, and (3) to develop methods for reducing sediment yields from semiarid rangeland watersheds in the Southwest. Integrated depth samples of suspended sediment are being collected, and single-stage samples by automatic samplers. Total load and particle sizes are being determined for correlation with storm and runoff measurements on several experimental watershed with varying soil, vegetation characteristics, and drainage features. Studies will be carried out over a number of years during which effects of changing range cover and corresponding changes in flow regimes of the watersheds may be evaluated.
(g) Suspended sediment samples collected to date do not indicate a simple water-sediment relationship for a flashy ephemeral stream such as Walnut Gulch. Because of the rapidly changing stages, samples are generally collected at one position in the cross-section. Suspended sediment samples collected in the mainstream of Walnut Gulch have been found to vary between 2 and 8 percent by weight. Unfortunately, these results have been confined so far to relatively small discharges. The following are indications from the samples analyzed to date: (1) The sediment peak precedes the hydrograph peak. (2) The sand load is relatively low in the samples collected before the hydrograph peak, and beyond the peak the sand load is higher and it seems to be more closely related to the actual discharge than are the small soil fractions. (3) Silt load is heavy at the sediment peak and drops off thereafter, i.e., clay to silt ratio rises after the sediment peak. (4) Correlation of consecutive depth-integrated samples is very good when the stage is not fluctuating rapidly. (5) The majority of the single stage samples on the main channel appear to agree well with the depth-integrated samples taken during the same period. (6) There is a considerable increase in the percentage of clay for samples taken in the mainstream as compared to samples taken upstream in the good grasslands. Greater gullying on other areas and bank erosion along the main channels are probably responsible for this increase.

(4368) DEVELOPMENT OF A PORTABLE IRRIGATION SPRINKLER EVALUATION DEVICE.

(b) U. S. Dept. of Agriculture, Agricultural Research Service, Soil and Water Conservation Research Division.
(c) Mr. Rhys Tovey, Agricultural Engineer, ARS, Box 8014, Univ. Station, Reno, Nevada 89507.
(d) Experimental; applied research.
(e) (1) To develop a portable device that can be used in the design and evaluation of sprinkler irrigation systems and (2) to determine procedures for the use of the portable irrigation sprinkler evaluation device in measuring soil intake rates, sprinkler application rates and other factors pertinent to the efficient design of sprinkler irrigation systems.
(f) Discontinued.
(g) A portable irrigation sprinkler evaluation device has been designed and constructed. Tests show that the device works satisfactorily. Procedures for measuring soil intake rates for sprinkler irrigation system design have been developed.

(4850) WATERSHED RELATIONS TO RECHARGE OF DIRECTLY ASSOCIATED GROUND WATER BASINS.

(b) Laboratory project, cooperative with Calif. Dept. of Water Resources, California Agric. Experiment Station, and the U. S. Soil Conservation Service.
(c) Mr. G. Paul Lawless, Soil Scientist, P. O. Box E, Lompoc, California 93438.
(d) Basic and applied research.
(e) Soil moisture measurements (made with neutron scattering moisture meters to depths of ten to twenty-eight feet) together with measurements of precipitation and other climatological factors are being made on a watershed near Lompoc, California, to determine how much, if any, of the rainfall in certain areas penetrates beyond the root zone, to recharge groundwater. The thirteen sites now being studied represent various cover, soil, and topographic conditions. A study is made of movement of water in various soils to help determine net contribution to ground water recharge by deeply penetrating rainwater. A technique for predicting ground water recharge by deep penetration of rainwater is being developed which will provide probability estimates of seasonal recharge based site conditions and climatological records.
(g) Downward translocation of moisture has been observed to continue during the dry season following winter precipitation. The magnitude of this migration is predictable and amount of downward movement of moisture through the root zone can be estimated fairly accurately without the benefit of periodic moisture determinations; provided monthly precipitation data are available and the range of available moisture in the root zone is known.

(4851) WATERSHED EVAPOTRANSPIRATION LOSSES IN CENTRAL AND SOUTHERN CALIFORNIA.

(b) Laboratory project, cooperative with Calif. Dept. of Water Resources, California Agric. Experiment Station, and the U. S. Soil Conservation Service.
(c) Mr. G. Paul Lawless, Soil Scientist, P. O. Box E, Lompoc, California 93438.
(d) Experimental and field investigation, basic and applied research.
(e) Measurements of soil moisture content are being made at 13 neutron scatter metering sites on a watershed near Lompoc, Calif. Soil suction is measured at one site by tensiometers. Precipitation is measured within a complex of four of the soil moisture sites. Outside of the watershed, in a plot (approx. one acre) of perennial ryegrass, soil moisture data are obtained by an electronically weighing lysimeter, neutron scatter meter, tensiometers and moisture blocks. Soil temperature, soil heat flux, drainage from the lysimeter, wind velocity and direction, solar, total hemispherical, and net radiation, albedo, air temperature and humidity are measured in or near the lysimeter. Most of this data is automatically recorded. Data is also obtained from an adjoining USWB class A type climate station, which contains extra instruments consisting of a hygrothermograph, spherical atmometers, and recording rain gage. Purpose of this work is to determine the relationships between evapotranspiration and various climatic, soil, and plant influences as these relationships affect watershed performance with respect to net water yield.
(g) Much of the available water in the root zones of the native vegetation was quickly used after each dry season started. The lack of available water reduced evapotranspiration rates. It was found that these rates of evapotranspiration correlated to con-

siderable degree with the soil moisture content of the root zones.

(4853) SALINITY BALANCE INVESTIGATION OF CITRUS IRRIGATION ON RESIDUAL SOILS, USING COLORADO RIVER WATER.

(b) Laboratory project, in cooperation with the U. S. Soil Conservation Service, and Riverside County (California) Flood Control Dist.
(c) Mr. Sterling Davis, Agricultural Engineer, 102 Irrigation Bldg., University of Calif., Riverside, California 92502.
(d) Experimental.
(e) The salinity of the soil and drainage water from this watershed is compared with total Colorado River water irrigation application plus rainfall to determine the salinity trends within a 1,000 acre watershed planted primarily to citrus orchards. Granodiorite rock underlying these soils minimizes loss of effluent to deep percolation. Bi-annual soil samplings are taken of selected sites within the watershed. Intensive investigations including flow recorders, flumes, and recording rain gages, were activated in May 1961. The program was expanded in 1962 to include sufficiently large flumes to measure winter storm runoff. The project was established as a five-year program.
(g) Salt accumulates in the soil during the summer growing season and leaches out during the winter rainfall season. Chemical analyses of the soil saturation extract and of the drainage water show an equilibrium is being established which is favorable to the continued growth of citrus trees.

(4854) EFFECT ON TILE DRAINS OF MANGANESE AND IRON SOLUBILITY IN SOILS.

(b) Laboratory project, in cooperation with the U. S. Soil Conservation Service.
(c) Mr. L. B. Grass, Soil Scientist, Southwestern Irrigation Field Station, P. O. Box 1339, Brawley, California 92227.
(d) Experimental.
(e) A study to determine the ability of various soils to yield ferrous or manganous ions in drainage effluent under varying conditions of reduction and pH and to develop an index for classifying soils as to their reduction potential. Tile line deposits of manganese and ferric oxide now represent a serious threat to irrigated agriculture, particularly in the Coachella and Imperial Valleys of California. SCS and ARS technicians have collected and forwarded soil samples from 11 locations throughout the United States where this problem has been observed in agricultural drain lines.

(5219) WATER DISCHARGE MEASUREMENTS WITH CHEMICAL TRACERS.

(b) Laboratory project.
(c) Mr. Lloyd E. Myers, Director, U. S. Water Conservation Laboratory, 4331 East Broadway, Phoenix, Arizona 85040.
(d) Experimental; applied research.
(e) Techniques and equipment for the integrated sample method of water discharge in open channels and in pipelines using fluorescent chemical tracers are being developed.
(g) A sensitive laboratory fluorometer has been adapted for field use. Preliminary field measurements indicate that uniform mixing of tracer with water flowing in an open channel is difficult to obtain.

(5220) UNSATURATED FLOW CHARACTERISTICS OF AGRICULTURAL SOILS.

(b) Laboratory project.
(c) Dr. S. L. Rawlins, U. S. Salinity Laboratory, P. O. Box 672, Riverside, California 92502.
(d) Experimental; basic research.
(e) The objectives are (1) To develop improved techniques (in terms of effort, reliability, and time) for measuring the water transmitting properties of agricultural soils at various matric suction values; and (2) to determine the unsaturated flow properties of a variety of agricultural soils. Diffusion theory and linear flow systems are being utilized.
(g) The measurement of the unsaturated flow properties of soil is by no means experimntally routine. However, the recent development of apparatus for accurately measuring and recording low rates of liquid flow simplifies the collection of the required outflow data.
(h) "Apparatus for Measuring Low Rates of Water Flow," E. J. Doering and D. L. Decker. Soil Sci. Soc. Am. Proc. 28:716-718, 1964. "Soil-Water Diffusivity by the One-Step Method," E. J. Doering. Soil Sci. 99:322-326, 1965.

(5221) THE ROLE OF SOIL MOISTURE IN SEMIARID RANGELAND HYDROLOGY AND SEDIMENT PRODUCTION.

(b) Laboratory project, cooperative with the Arizona and New Mexico Agricultural Experiment Stations, and the U. S. Soil Conservation Service.
(c) Dr. H. A. Schreiber, Soil Scientist, P. O. Box 3926, Tucson, Arizona 85717.
(d) Experimental; field and laboratory.
(e) The objectives of this study are: (a) To determine the relation of soil moisture to vegetation and soil characteristics; (b) to determine and evaluate effects of soil moisture and related vegetation conditions on detention, retention, and deep penetration of rainfall; (c) to compare with the naturally occurring moisture regime the effects produced by two imposed moisture regimes on soil and vegetation characteristics relating to the hydrology and sediment production of semiarid rangelands; (d) to study the effects and interactions with soil moisture of maintaining a higher than natural level of fertility on soil and vegetation characteristics affecting the runoff net water yield, and sediment yields and forage production of semiarid rangeland watersheds.
(g) Runoff produced from high intensity, short duration, convective thunderstorms increases with increasing precipitation quantity and intensity. Antecedent soil moisture has a significant, but very minor effect on runoff produced from these storms in the area under study.

(5222) PRECIPITATION CHARACTERISTICS AFFECTING HYDROLOGY AND SEDIMENT PRODUCTION OF SMALL AGRICULTURAL WATERSHEDS IN CENTRAL AND SOUTHERN CALIFORNIA.

(b) Laboratory project, cooperative with Tehachapi Soil Conservation District, and California Agricultural Experiment Station.
(c) Mr. G. Paul Lawless, Soil Scientiest, P. O. Box E, Lompoc, California 93438.
(d) Experimental and field investigations; basic and applied research.
(e) Objectives of this study are to develop storm time-depth-area relationships of rainfall in Central and Southern California to geographic location in the detail needed for design of flood runoff control works on agricultural watersheds of 400 square miles or less; and of characterize other precipitation parameters relating to the net water yields, flood runoff and sediment production of such watersheds.
(g) Additional instrumentation has been installed and data collection is underway.

(5223) DETERMINING THE EFFECTS ON PHYSICAL WATERSHED MODELING RELATIONSHIPS CAUSED BY MANIPULATING THE PHYSICAL PROPERTIES OF THE FLUID USED IN THE MODEL'S RAINSTORM SIMULATOR.

(b) Laboratory project, cooperative with the Utah Water Research Laboratory, Utah State

University.
(c) Mr. D. L. Chery, Jr., Hydraulic Engineer, P. O. Box 3926, Tucson, Arizona 85717.
(d) Experimental laboratory. Applied research (also for a doctoral thesis).
(e) To determine the effect on model-prototype relationships of changes in the physical properties of water-chemical mixtures used in a model watershed's rainstorm simulator. Data from the model are compared with records of the prototype watershed (97-acre semiarid watershed near Albuquerque, New Mexico) to ascertain which water-chemical mixtures give the best model verification. The watershed model consists of a 1:175 fiberglass topographical model and an automatically operated rainstorm simulator. In the storm simulator the liquid is applied in several independent subunits by positive displacement pumps driven by variable speed D.C. electric motors. The fluid is distributed evenly over a subarea by equal length polyethylene tubing (0.011 inch ID).
(h) "Construction, Instrumentation, and Preliminary Verification of a Physical Hydrologic Model," D. L. Chery, Jr. Utah Water Research Laboratory, 152 pages, July 1965. (Obtain from Utah Water Research Laboratory, Utah State University, Logan, Utah 84321.)

(5224) GROUND WATER AS A FACTOR IN THE WATER BUDGET OF SEMIARID WATERSHEDS.

(b) Laboratory project, cooperative with the Arizona and New Mexico Agricultural Experiment Stations, and the U. S. Soil Conservation Service.
(c) Mr. D. E. Wallace, Geologist, P. O. Box 213, Tombstone, Arizona 85638.
(d) Experimental, field; applied research.
(e) Objective of the study is to provide information on ground water accretion and movement and aquifer-streamflow relationship as affected by surface and subsurface geologic conditions.
(g) Research will include: (1) Preparing maps and stratigraphic sections of the watershed and associated areas; (2) keeping an accurate annual log on groundwater fluctuations in the watershed and adjoining areas; (3) collecting cores and samples of the various materials for laboratory analysis; (4) utilizing drilling techniques and sensory methods to determine porosity, permeability, and transmissability of aquifers and valley material. Pumping tests and tracers will also be utilized in determining flow movement in subsurface strata. Neutron-scattering, borehole logging equipment will be used in an attempt to determine water movement from ephemeral streambeds to regional water table. These seepage losses form a subsurface mound beneath the channels. The magnitude of this contribution to regional groundwater has not yet been determined.

(5225) HYDROLOGIC EFFECTS OF RANGE CONSERVATION TREATMENTS.

(b) Laboratory project, cooperative with Agricultural Experiment Stations of Arizona and New Mexico, U. S. Soil Conservation Service, local ranch owners.
(c) Mr. D. R. Kincaid, Research Botanist, P. O. Box 3926, Tucson, Arizona 85717.
(d) Experimental, field; applied research.
(e) Treatments comprise combinations of brush removal, soil pitting and reseeding to perennial range grasses. They are applied to replicated 6x12-foot plots, and to drainage areas up to 10 acres. Objective is to investigate effects of a practical range conservation program on yields of water and sediment.
(g) Twenty-four 6x12-foot surface runoff plots were treated by combinations of brush removal, soil pitting and reseeding to perennial range grass. Summer rainfall reduced the roughness produced by pitting to less than half the pre-rainy-season condition. Seeding the plots to grass reduced runoff more than did pitting. Clearing brush extended the period moisture was available for plant growth following the rainy season by about 35 days. A 560-acre watershed was contour furrowed with a soil ripper in Spring 1965.

(5226) DYNAMICS OF WATER AVAILABILITY TO PLANTS.

(b) Laboratory project.
(c) Dr. W. R. Gardner, U. S. Salinity Laboratory, P. O. Box 672, Riverside, California 92502.
(d) Experimental and theoretical; basic research.
(e) Principles involving uptake of water from soil by plants and subsequent loss to atmosphere are under study. A mathematical model for the soil-plant atmosphere system has been derived. Experiments are conducted in the greenhouse and growth chamber to test the validity of the model.
(g) The unsaturated conductivity of the soil as well as the soil suction has been shown to be important in governing water uptake by plants. The mathematical model has been extended to provide a quantitative relation between transpiration and soil moisture.
(h) "Relation of Root Distribution to Water Uptake and Availability," W. R. Gardner. Agron. Jour. 56:41-45, 1964.
"Relationship Between Transpiration and the Internal Water Relations of Plants," C. F. Ehlig and W. R. Gardner. Agron. Jour. 56: 127-130, 1964.
"Dynamic Aspects of Soil-Water Availability to Plants," W. R. Gardner. Ann. Rev. Plant Physiol. 16:323-342, 1965.
"Physical Aspects of the Internal Water Relations of Plant Leaves," W. R. Gardner and C. F. Ehlig. Plant Physiol. 40:705-710, 1965.
"Rainfall, Runoff, and Return," W. R. Gardner, Meteorological Monographs 6:138-148, 1965.

(5584) SEDIMENT SOURCES AND DELIVERY PROCESSES ON AGRICULTURAL WATERSHEDS.

(b) Laboratory project in cooperation with Soil Conservation Service.
(c) Mr. Joseph B. Murphey, Geologist, P. O. Box E, Lompoc, California 93438.
(d) Basic and applied research.
(e) To determine sediment producing characteristics of watershed lands as related to their geology, climate, soils, land use, and treatment; their stream sediment movement and depositional characteristics as related to hydraulic and hydrologic influences; and to develop therefrom methods for prediction of sediment deposition on agricultural flood plain areas and sediment carried out of agricultural watersheds.
(g) None. Preliminary investigations are being developed.

(5585) WATER REQUIREMENTS OF LAWN GRASSES.

(b) Field project in cooperation with the U. S. Navy and the Nevada Agricultural Experiment Station.
(c) Mr. Rhys Tovey, Research Agricultural Engineer, Agricultural Research Service, P. O. Box 8014 University Station, Reno, Nevada 89507.
(d) Experimental; applied research.
(e) 1. Determine minimum water requirements, including depth and frequency of application, to maintain a lawn in a top well dressed condition.
2. Determine minimum water requirements, including frequency and depth of application, to maintain a lawn where it is desirable to reduce maintenance operations to a minimum. Good turf must be maintained that will go dormant during hot seasons and revive when watered by precipitation or irrigation.
Study being carried on with nonweighing lysimeters.

(5588) WATER BUDGET OF EPHEMERAL STREAM CHANNELS IN RELATION TO WATER DYNAMICS, GEOLOGY, AND VEGETATION.

(b) Field and laboratory project in cooperation with Arizona Agricultural Experiment Station.
(c) Mr. D. R. Kincaid, Botanist, P. O. Box 3926, Tucson, Arizona 85717.
(d) Laboratory and field research, basic and applied,
(e) The investigations are aimed at (1) assessment of ground water in local, water tables and development of management practices for sustained supply and improved quality of usable water; and (2) basic research on the relation of temperature variation and fluctuation of the water table to soil moisture movement and evaporation. During the summer rainy season, large proportions of the ephemeral flows are absorbed by the stream channel, resulting in a rise of the surface of the local water table. Many channels with deep alluvial deposits overlying these perched water tables support dense stands of phreatophytes. Evapotranspiration from such areas on the Walnut Gulch Experimental Watershed is being studied by means of both the water budget and the heat balance approach. Amounts of water storage and rates of recharge are determined in the field. Outflow from the area is recorded to the nearest cubic foot, and diurnal fluctuation of the outflow and of the surface of the water table is continuously noted. Using Darcy's Law and a combination of methods for determining soil permeability and hydraulic conductivities, rates of subsurface inflow are computed. By use of a portable seismic unit and 28 observation wells, extent of the aquifer has been determined and an area-depth curve has been prepared.

(5589) RELATION OF SEDIMENTS AND STRATIGRAPHY TO THE HYDROLOGY OF SEMIARID WATERSHEDS.

(b) Laboratory project, cooperative with the Arizona and New Mexico Agricultural Experiment Stations and the U. S. Soil Conservation Service.
(c) Dr. Philip Seff, Research Geologist, P. O. Box 3926, Tucson, Arizona 85717.
(d) Experimental, field and laboratory; basic research.
(e) Sediment collection stations are located at half-mile intervals where good surface exposures exist near the various experimental watersheds. Detailed sample collections of each stratigraphic unit are made and subsequently analyzed in the laboratory. This procedure coupled with a fluvial geomorphic analysis of the existing stream channels provides the necessary data for geologic interpretations, and recognition of changing climatic conditions.
(g) Subsurface water flow is restricted on both the Alamogordo and Walnut Gulch watersheds by high to medium indurated beds of Mesozoic age and older. There are three major stratigraphic gravel units within the Walnut Gulch watershed, each displaying varied degrees of cementation. The older covers the upper part of the study area and is very tightly cemented, hence relatively impermeable. The youngest is largely unconsolidated and covers the lowest part of the watershed. It is very permeable and is a source of much water loss through seepage. Additional studies reveal the bulk of the present sediments in Walnut Gulch are supplied through erosion of the older gravels. Very little of the modern sediments are supplied by the adjacent mountainous areas.
(h) "Rates of Rounding of Quartz Granules and Nature of Sedimentary Maturity, San Pedro Valley, Cochise County, Arizona," Philip Seff and Walter Smith, ARS 41-108, July 1965.

(5986) EVALUATION OF SUBSURFACE IRRIGATION SYSTEMS.

(b) Laboratory project, in cooperation with the Soil Conservation Service and the California Agricultural Experiment Station.
(c) Mr. Sterling Davis, Agricultural Engineer, 102 Irrigation Building, University of California, Riverside, California 92502.
(d) Experimental.
(e) Objectives are to evaluate a variety of devices, such as porous tubes and conduits, as to their ability to supply irrigation water beneath the soil surface thereby reducing water loss attendant to conventional surface water application in citrus groves.

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, Central States Forest Experiment Station.

Inquiries concerning the following projects should be addressed to R. D. Lane, Director, 111 Old Federal Bldg., Columbus, Ohio 43215.

(3563) SUBSURFACE WATER MANAGEMENT ON NORTHERN HARDWOOD FOREST AREAS.

(b) Laboratory project.
(c) R. Z. Whipkey, Project Leader, Forest Service, U.S.D.A., Hydrology Laboratory, 2240 North High Street, Columbus, Ohio 43201.
(d) Experimental and field investigations; basic and applied research.
(e) Movement of subsoil water will be studied in various geologic and soil types to: (1) Develop techniques for quantitatively measuring subsurface water movement from small plots; (2) to learn the effect of artificial rainfall on quantity and timing of subsurface water movement; and (3) to develop a flow equation, including coefficients for the significant variables affecting that flow. This information will aid watershed technicians in making land management decisions on areas that have lots of subsurface stormflow.
(g) A plot 125 feet long by approximately 18 feet wide was bordered by a trench 18 inches wide by 30 inches deep. This plot is described in the Central States Publication CS-29 and the cover, soil, and topography in the 1965 Issue of Hydraulic Research in the United States.
The plot was wetted by a sprinkler system consisting of five separate manifolds, each controlling five sprinkler heads. Thus, rainfall could be applied over the entire plot or at any 25-foot segment of the plot, i.e., from 0-25, 25-50, 50-75, etc. or combinations of the above 25-foot sections. Rainfall intensities applied ranged from 0.5 to 1.0 inch per hour in steady applications. Storm lengths varied from 90 to 150 minutes. Seepage was measured in a trough system described in the 1965 Issue and in Publication CS-29. The following results were noted: (1) No surface runoff occurred during 30 storms. Observation showed occurrence of flow over the litter in a few instances, but distances involved were usually less than 4 feet after which the flow disappeared into the permeable A horizon. This surface runoff sometimes occurs where leaf litter is thick and saturated from previous wetting runs. The surface runoff occurring under these conditions is due to the "shingle-effect" of the imbricated leaves. (2) Patterns of flow were as measured in previous years, i.e., greatest volumes of seepage occurred from the uppermost soil horizon. Where upper-slope portions of the plot were wetted 50 feet above the face, no flow seeped from the face. However, where the 25 to 50 foot section was wetted, flow did occur through the unwetted 0-25 foot section and seep from the downslope face into the collection system. (3) Seepage occurred in the trench surrounding the trough in every run. This seepage came from root channels, along root courses,

through about 4 lateral feet of unwetted soil, it was felt that the biological and structural channels within this forest soil are important sources of turbulent subsurface flow occurring through shallow depths of forest soil in the Allegheny-Cumberland plateau. (4) To learn something of the effect of opening the fine-textured, relatively tight subsoils, a pit was dug across the plot from 40 to 50 feet above the downslope face. This pit extended laterally from the boundary trenches and was approximately 11 feet deep. The material removed was then replaced in a haphazard manner, with care taken to minimize mechanical layering and compaction. Our objective was to see if disturbance of natural bedding planes and the impeding layers affected subsurface stormflow. This will be tested in detail after the disturbed area has settled over the winter season. (5) Observed subsurface stormflow coming from forested drainages during winter storms and from plots during simulated storms has been of the turbulent type. While it seems logical that Darcy's Law does not hold for this type of flow, we are testing several methods of measuring hydraulic conductivity of permeable forest soils. These are: (a) an oversized, 6-inch core sampler that will give four times the cross-sectional area but only twice the perimeter of the standard 3-inch core, (b) the 8-inch Bouwer double-ring apparatus for measuring hydraulic conductivity above a saturated zone, and (c) a meter-square block equipped in place with outlet and inlet reservoirs. In the latter small head differences will be employed to measure movement rates. We hope to compare these techniques and perhaps learn if there is a practical, sound method for determining hydraulic conductivity of highly permeable forest soils.

(h) "Measuring Subsurface Stormflow from Simulated Rainstorms - A Plot Technique," by R. Z. Whipkey. Central States Forest Experiment Station Note, CS-29, Feb., 1965, 6 pp.
"Subsurface Stormflow from Forested Slopes," by R. Z. Whipkey. Bulletin, IASH, Fall 1965, pp. 44-85.
"Theory and Mechanics of Subsurface Stormflow," by R. Z. Whipkey. Proceedings, Int'l Symposium on Forest Hydrology, held at Penn. State Univ., Sept. 1965, (in press).

(4373) USE OF NUCLEAR RADIATION EQUIPMENT FOR MEASURING FOREST SOIL MOISTURE AND DENSITY.

(b) Laboratory project.
(d) Experimental and field investigations; basic and applied research.
(e) Some newly developed equipment, operating on the principle of nuclear radiation, facilitates the measurement of soil moisture and the soil's closely allied property--bulk density. We now have a five-piece set of this nuclear radiation equipment. We are investigating principles that will guide us in the use of this equipment.
(f) Completed.
(h) "Access Tubes and Timers for Use with Nuclear Soil Moisture Meters," by R. B. Marston. Central States Forest Experiment Station Research Note CS-30, 4 pp., March 1965.
"Checking the Calibration of Nuclear Soil Moisture and Density Measuring Equipment," by R. B. Marston. Central States Forest Experiment Research Note CS-31, 4 pp., March 1965.
"Volumes of Field Soil and of Water Measured by Subsurface Nuclear Probes," by R. B. Marston. Central States Forest Experiment Station Research Note CS-32, 6 pp., March 1965.

(4752) THE CHARACTERISTICS OF A CONIFEROUS PLANTATION THAT ARE MOST CLOSELY RELATED TO TREE GROWTH AND TO WATER AVAILABLE FOR STREAMFLOW.

(b) Laboratory project.
(d) Experimental and field investigations; basic and applied research.
(e) This is an intensive soil-moisture study initiated to discover some basic tree stand characteristics that are closely related to tree growth and to water available for stream flow and to develop guides for field use in managing forest plantations to obtain optimum production of wood and water.
(g) Preliminary results are not yet analyzed; in the process of compiling and analyzing during winter 1965-66.

(4753) FOREST RESTORATION AND WATERSHED MANAGEMENT ON SURFACE MINED AREAS IN THE APPALACHIAN COAL FIELDS.

(b) Laboratory project.
(d) Experimental and field investigations; basic and applied research.
(e) Surface runoff on spoil banks, freshly formed during strip mining in the Appalachian coal fields, has a high soil erosion and sediment transport potential. This seriously affects water quality and has other deleterious effects on watersheds in which coal is harvested. It is highly desirable to establish a vegetative cover as quickly as possible after mining disturbance in order to minimize erosion and maintain water quality. The purpose of this project is to (1) develop practical methods of reducing damage to watershed values during surface mining operations and (2) find feasible ways to restore mined areas to productive forest uses.
Studies by individual scientists are divided among five disciplines including (1) Spoil Placement, (2) Soil Chemistry, (3) Haul Roads, (4) Revegetation, and (5) Hydrology. General hydrology studies recently started include (1) A study of stormflow and sediment yield from stripmined terraces; (2) a study of stormflow and sediment yield from outslopes of stripmined soil banks; and (3) a study of the hydrology of ponds originating on stripmined lands.
In these studies a number of small San Dimas flumes have been installed to measure storm runoff from a number of terrace and outslope drainages. In the pond hydrology study a number of stilling wells and recorders have been installed on ponds. Raingage networks have been installed to cover each sample drainage area.
(g) Design criteria have been established for piling spoil overburden on hillsides. Assuming complete drainage control and a fill material free of trees and brush, spoils material can safely be piled on slopes up to 33°. The amount of material piled should vary with the slope. At 33° a bench width of 45 feet is considered safe. At 14° a bench width of 250 feet should be free from slides.
The soil solution composition in acid producing coal mine spoil bank materials is related to the soil pH. Concentrations of Fe, Al, Mn, Zn, Cu, and Ni were found to be high in low pH materials especially below pH 3. Maximum concentrations were: Fe, 20,000 ppm; Al, 8,000 ppm; Mn, 1,800 ppm; Zn, 145 ppm; Cu, 31 ppm; and Ni, 26 ppm.
(h) "Designing Coal Haul Roads for Good Drainage," by Weildon K. Weigle. Central States Forest Experiment Station. 23 pp. illus. 1965.
"The Selection of Experimental Watersheds and Methods in Disturbed Forest Areas," by W. David Striffler. Proceedings of Symposium of Budapest, Representative and Experimental Areas. IASH, Publication No. 66, Vol. II, pp. 464-473. 1965.

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, Intermountain Forest and Range Experiment Station, Ogden, Utah.

(5296) SOILS STABILIZATION IN RELATION TO LOGGING ON STEEP TIMBERED SLOPES IN THE NORTHERN ROCKY MOUNTAINS.

(b) Laboratory project.

(d) Experimental and field investigations; basic and applied research.
(e) To identify and quantify the interrelations of soil, water, and vegetation to soil stability; to determine mechanical and vegetation requirements for stabilizing soil; and to determine effects of timber harvesting and roadbuilding on soil movement and water yield.
(g) From the inception of a study of cutting ponderosa pine on 16 small watersheds in the Boise Basin Experimental Forest, sedimentation was checked reasonably well because of careful advance planning, close supervision of logging, and application of intensive measures for controlling erosion promptly after harvest. Sediment that reached the stream channels originated primarily on haul roads. Proximity of a road to a stream affected the frequency with which sediment flows reached that stream. Sediment reached channel bottoms through undisturbed buffer strips averaging 8 feet wide, but did not reach them if the strips were more than 30 feet wide. After 3 years, movement of sediment "en route" had almost halted.
Six different surface treatments were applied to the fill section of a newly constructed road in the Zena Creek area of the Payette National Forest, Idaho. Treatments were: (1) One layer of "erosionet" plus grass seed and fertilizer, (2) three layers of "Erosionet" plus grass seed and fertilizer, (3) asphalt-straw mixture plus grass seed and fertilizer, (4) chipped logging slash plus grass seed and fertilizer, (5) surface holes plus grass seed and fertilizer, (6) control, no treatment. Best soil stabilizing results were obtained in the use of one layer of "erosionet" and the application of an asphalt and straw mixture.
Steep rugged terrain is characteristic of millions of acres of forested land in central Idaho. Natural rates of soil movement are high, and may be increased by improper land use. The purpose of one of our studies is to determine natural rates of soil movement and to ascertain change in rates caused by different methods of logging: jammer versus high-lead. Soil movement is measured both on small watersheds and on 1/100-acre plots. Roads were built in the jammer area in 1961, and then both jammer and high-lead areas were logged in 1962. Immediately following road construction, heavy soil losses were observed in the jammer area. After the logging operation, soil losses did not increase in either the high-lead or jammer areas. In 1964 (3 years following road construction and 2 years after the logging operation) soil losses in the two areas appear to be of the same magnitude.
Further analysis of sediment yield from the 1/100-acre plots corroborates the results of another study. These plots are on both southwest and northwest exposures; plots on hot, southwest exposures yield significantly larger amounts of sediment than those on northwest exposures as a result of high-intensity rainfall.
(h) "Probable Return Periods of Rainstorms in Central Idaho," W. Joe Kidd, Jr. 1964. U. S. Dept. Agr., Forest Serv. Res. Note INT-28, 8 pp., illus.
"Good Logging Practices Reduce Sedimentation in Central Idaho," H. F. Haupt and W. Joe Kidd, Jr. 1965. Jour. Forestry 63: 664-670.

(5297) WATERSHED PROTECTION REQUIREMENTS AND REHABILITATION MEASURES FOR THE REDUCTION OF FLOOD RUNOFF, EROSION, AND SEDIMENT FROM DETERIORATED FOREST AND RANGELANDS.

(b) Laboratory project.
(d) Experimental and field investigations; basic and applied research.
(e) To relate soil and vegetation characteristics to infiltration, overland and subsurface flow, and soil erosion; to develop flood and erosion hazard criteria and protection requirements for deteriorated rangeland; and to determine effects of watershed rehabilitation on erosion hazard and flood potential.
(g) The effects of seeding and grazing on infiltration capacity and soil stability were studied on a subalpine range in central Utah. Seven years after the range land was disked and seeded to grass, the main effects were: decreased organic matter and capillary porosity in the surface soil, greater soil bulk density, and decreased plant and litter cover. Seeding did not significantly affect infiltration or soil stability. Grazing during the previous 4 years decreased plant and litter cover and noncapillary soil porosity, but increased capillary porosity in the surface soil and decreased infiltration and soil stability.
Another study has been completed in central Utah on 164 infiltrometer plots distributed over a wide range of soil, topographic, and plant-cover conditions. Data obtained were subjected to a stepwise multiple-regression analyses to determine which combinations of site factors exert the greatest influence on infiltration and soil erosion processes. Equations were developed that provide good estimates of infiltration and soil erosion values from several readily measured site factors.
The single site factor most closely correlated with total infiltration was bulk density of the surface inch of the soil mantle. This factor accounted for 35 percent of the variance in total 30-minute infiltration. When combined with other site factors in multiple-regression analyses, bulk density remained the most important factor affecting total infiltration, but average bulk density in the surface 4 inches of soil proved to be more influencing than that in the surface inch. Seven other variables in combination with bulk density added significantly to the explained variance in total infiltration. These are: clay content of the surface inch of soil, air-dry weight of vegetation, air-dry weight of litter, capillary porosity of the 1- to 2-inch depth, soil organic matter content at the 4- to 6-inch depth, plot slope gradient, and aspect. This combination of factors accounted for 65.3 percent of the variance in total infiltration and had a standard error of regression of 0.379 inch of infiltrated water. This was the smallest standard error obtained in the analyses.
The amount of soil eroded from the plots during the 30-minute application of simulated rain was related exponentially rather than linearly to the site factors. Consequently, it was necessary to transform the dependent variable to obtain a good fit of the data by regression analysis. After several transformations were tried, the following regression model was accepted and used:

$$\log (E + 1/2) = b_0 + b_1 X_1 + b_2 X_2 + \ldots$$

in which E is soil eroded in tons per acre, b's are regression coefficients, and the X's are site factors.
The proportion of the ground surface exposed as bare soil on the infiltrometer plots was the single site factor most closely correlated with the amount of soil eroded. The percent of exposed bare soil accounted for 52 percent of the variance in the dependent variable ($\log E + 1/2$). Plot slope gradient accounted for an additional 10 percent of the variance, and bulk density of the surface 2 inches of the soil mantle accounted for another 4 percent. Together, these three factors explained 66 percent of the variance in soil erosion. Only 1 percent additional variance was accounted for by the next three ranking factors: soil organic matter content, soil aggregates and particles larger than 0.05 mm. in diameter, and the percent of organic cover provided by plants and litter.
A study of infiltration characteristics of

ponded water in contour trenches and their change with time, was begun in 1964 in northern Utah.
First-year measurements show that the average infiltration rates in these trench sections during the time required for them to completely drain (several hours) were 15.8 inches per hour on coarse-textured soil material, 15.4 inches per hour on medium-textured material, and 9.2 inches per hour on fine-textured material. Laboratory measurements of the saturated permeability of the surface 2 inches of soil material from the trench sections were 13.9, 11.3, and 9.1 inches per hour, respectively, for the coarse-, medium-, and fine-textured soils. Differences in permeability between cut slopes and fill slopes in the trenches were not significant.
Differences in the infiltration characteristics of trenches in coarse and fine soils are reflected more sharply by comparisons of infiltration rates with time. Initial infiltration rates, during the first 3 to 5 minutes after the plastic liners were removed, ranged from 130.0 inches per hour on a site where 61 percent of the soil material exceeded 19 mm. in diameter to 25.2 inches per hour on a site where 60 percent of the soil material was smaller than 2 mm. After the trenches were more than three-fourths drained (several hours) the infiltration rates on these same sites had decreased, respectively, to 12.1 and 0.6 inches per hour.
Although data from the 1965 tests have not been analyzed, the long periods of time (from 12 to more than 30 hours) required for equivalent amounts of ponded water to infiltrate indicate that infiltration capacities of these trenches 1 year after construction have decreased to perhaps 1/6 to 1/3 of their 1964 capacities. These reductions in infiltration appear to be due to sealing of the soil surface by silt and clay-size soil fractions. A major source of these fine fractions is believed to be wind-blown soil carried from the trench fill slopes during periods of strong upslope winds.

(h) "Land Use and Ecological Factors in Relation to Sediment Yields," Otis L. Copeland, 1965. Federal Inter-Agency Sedimentation Conf. Proc. 1963. U. S. Dept. Agr., Misc. Pub 970, pp. 72-84.
"Effects of Seeding and Grazing on Infiltration Capacity and Soil Stability of a Subalpine Range in Central Utah," Richard O. Meeuwig, 1965. Jour. Range Mangt. 18: 173-180.

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, Lake States Forest Experiment Station.

Inquiries concerning the following projects should be addressed to the Director, Lake States Forest Experiment Station, St. Paul Campus, University of Minnesota, St. Paul, Minn., 55101, unless indicated otherwise for a specific project.

(3887) WATERSHED MANAGEMENT RESEARCH IN NORTHERN MINNESOTA.

(b) Laboratory project.
(d) Experimental and field investigations; basic and applied research.
(e) Tests the influence of forested bogs on streamflow and ground water behavior. Present studies are concentrating on: (1) Hydrology of 6 small bogs instrumented by a total of 5 flumes and 1 weir and by 6 recording and 56 nonrecording wells. (2) Laboratory and field studies to evaluate the hydrological and physical properties of peat soils. Laboratory tests have been made of rate of water movement through 86 peat cores, and 72 in situ hydraulic conductivity tests have been run using the piezometer and tube methods. (3) Evapotranspiration studies have been conducted on thirteen 10-foot-diameter bottomless steel lysimeters and four with surface areas of 1 square meter, which have been driven to impermeable peat material in forested and nonforested bogs.
(g) Results to date of a study of water table relationships in a perched and nonperched bog indicate that the water table in the former is perched well above the regional flow system and is controlled by precipitation and evapotranspiration. The water table in the nonperched bog is continuous with the regional ground water flow system and is partially controlled by it. Different peat materials with different physical properties were found in each bog because of the influence or lack of influence of mineral-enriched bog water. Waters in the perched bog were more acidic.
Evapotranspiration in bottomless 10-foot-diameter lysimeters compared with other methods of measuring evaporation or evapotranspiration showed the following correlations: With open pans, r= 0.907; with Thornthwaite ET values, r = 0.883; and with Hamon ET values, r = 0.920.
(h) "Laboratory Techniques for Measuring Water Storage Properties of Organic Soils," D. H. Boelter. Soil Sci. Soc. Amer. Proc. 28: 823-824, 1964.
"Drainage Along Swamp Forest Roads--Lessons From Northern Europe," Joseph H. Stoeckeler. Jour. Forestry 63: 772-776, 1965.

(3889) WATERSHED MANAGEMENT RESEARCH IN THE DRIFTLESS AREA OF SOUTHWESTERN WISCONSIN.

(b) Laboratory project, with some aspects in cooperation with Wisconsin Conservation Dept.
(d) Field investigations; basic and applied research.
(e) Major emphasis is given to the influence of the forests on runoff and erosion. Studies are also underway on gullies in forested land, particularly the evaluation of small structures and the reduction of gullying by water spreading into the forest. A total of 37 water-measuring devices, including 3 weirs and 34 flumes, are in operation on 12 separate watersheds and in 3 springflow areas. In addition, 32 wells are under observation, with 2 equipped with recording instruments; 30 are of the non-recording type.
(g) Preliminary results indicate that runoff water from small fields of ridgetop agricultural lands can be directed and spread safely into forest land by means of (1) log barriers placed across the direction of flow in the forest or (2) small detention ponds in tandem. Of 20 runoff events, no water passed through the outlet flumes in the plot with the 3 detention ponds. Four storms out of 20 resulted in outflow from the contour log treatment. On a third plot, where runoff was diverted into untreated woods, 16 of the 20 storms produced outflow.
(h) "Forestry Research to Benefit Trout?", R. S. Sartz. Wis. Conserv. Bul. 30 (2): 20-21, 1965.

(3890) WATERSHED MANAGEMENT RESEARCH IN LOWER MICHIGAN.

(b) Laboratory project.
(d) Field investigation; basic and applied research.
(e) The major projects involved here deal with (1) ground water recharge and evapotranspiration of various cover types in deep sandy soils, (2) streambank stabilization on trout streams, and (3) sedimentation in trout streams. Measurements of ground water recharge are based on the behavior of 112 wells and 12 stacks of Bouyoucos soil moisture units. Of the 112 wells, 8 are of the recording type. Suspended sediment samples are being obtained on three streams at six separate sampling stations. A cooperative study on sedimentation has been initiated with the Biology Dept. of Central Michigan Univ. to measure effects of sedimentation in terms of trout habitat, and especially in terms of aquatic insect popu-

lations.

(g) Measurements of eroding streambanks which received chemical mulch treatments 2 years previously have shown no significant improvement in vegetation density due to mulching when compared to seed and fertilizer treatments. These tests apply only to sandy streambanks where survival of the herbaceous cover is affected more by the availability of soil moisture than by surface erosion of seeds.
Studies of evapotranspiration losses from shallow water table lands showed that diurnal well fluctuations produced by such losses effectively ceased when the water table was more than 4.5 feet below mean ground level in lowland hardwoods and below 5.5 feet beneath a jack pine plantation. Since the water table levels have dropped below these levels each year over a 4-year period, it is obvious that these forests on poorly drained sand soils do not act as phreatophytes through the entire growing season. A low capillary fringe in the sand subsoils is evident from these results.

(h) "Suspended Sediment Concentration in a Michigan Trout Stream as Related to Watershed Characteristics," W. David Striffler. Federal Inter-Agency Sedimentation Conf. Proc. 1963 (U. S. Dept. Agr. Misc. Publ. 970): 144-150, 1965.

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, Northeastern Forest Experiment Station.

Inquiries concerning the following projects should be addressed to Dr. Ralph W. Marquis, Director, Northeastern Forest Experiment Station, 102 Motors Avenue, Upper Darby, Pennsylvania 19082.

(1188) WATERSHED MANAGEMENT RESEARCH, FERNOW EXPERIMENTAL FOREST, WEST VIRGINIA.

(b) Laboratory project.
(d) Field investigation; basic and applied research.

(e) Studies were started in 1951 on the Fernow Experimental Forest, Tucker County, W. Va., to determine the effect of different levels of cutting practices, different logging methods, and different forest uses upon water quantity and quality. Nine watersheds have been equipped with streamgaging stations and rain-gages.

(g) Sreamflow data from control and clearcut watersheds at the Fernow Experimental Forest were reanalyzed to determine if measurements taken once a day, twice a week, once a week, twice a month, or once a month could be used instead of continuous records. The results suggest that, under some situations, much might be learned from relatively few measurements.
Errors in streamflow measurement from stage-discharge relations, manual checks of stage, and methods used in compilation of data were evaluated, and estimated to total not more than 3 to 5 percent of annual streamflow values.
Dew deposition was measured at the Fernow Experimental Forest in a recording rain gage modified to accommodate a section of live turf. The total for August, the month of maximum deposition, was 0.055 inch. The accumulation was not large enough to warrant consideration as a factor in watershed management research.
Before clearcutting a portion of an experimental watershed on the Fernow Experimental Forest during the winter of 1963, all trees above 1-inch dbh were basal sprayed with 2,4,5-T in No. 2 diesel oil. After cutting sawlogs and pulpwood all stumps were sprayed with the same mixture. In the following May and June the foliage of residual vegetation was sprayed with 2,4,5-T with knapsack misblower. During these treatments numerous water samples were obtained from the stream immediately below the treatment area and sniff-tested. There was no evidence of contamination by the herbicide. The watershed treatment increased water yield from the treated area by almost 200,000 gallons per acre during May-October 1964.

(h) "Frequency of Streamflow Measurements Required to Determine Forest Treatment Effects," by Kenneth G. Reinhart. U. S. Forest Serv. Res. Note NE-23. 7 pp., illus. Northeast. Forest Expt. Sta., Upper Darby, Pa.
"The Importance of Dew in Watershed-Management Research," by James W. Hornbeck. Forest Serv. Res. Note NE-24, 5 pp. Northeast Forest Expt. Sta., Upper Darby, Pa.
"Accuracy in Streamflow Measurements on the Fernow Experimental Forest," by James W. Hornbeck. U. S. Forest Serv. Res. Note NE-29, 8 pp., illus. Northeast Forest Expt. Sta., Upper Darby, Pa.
"Logging and Erosion on Rough Terrain in the East," Proc. Fed.-Inter Agency Sedimentation Conf., U. S. Dept. Agr. Misc. Pub. 970: 43-47, 1965.
"Herbicidal Treatment of Watersheds to Increase Water Yield," by K. G. Reinhart. Proc. Northeastern Weed Control Conference 19: 546-551, 1965.

(2419) WATERSHED MANAGEMENT RESEARCH, HUBBARD BROOK EXPERIMENTAL FOREST, NEW HAMPSHIRE.

(b) Laboratory project.
(d) Field investigation; basic and applied research.

(e) The objective is to determine the effect of forest type, condition, and treatment on quantity and quality of streamflow. Studies are conducted in plots and experimental watersheds on the 7500-acre experimental forest in the White Mountains at West Thornton, New Hampshire. Seven weirs have been built and climatic stations established.

(4756) WATERSHED MANAGEMENT RESEARCH, SYRACUSE UNIVERSITY, NEW YORK.

(b) Laboratory project, in cooperation with the State University College of Forestry at Syracuse University, Syracuse, New York.
(d) Field investigation; basic and applied research.

(e) This cooperative project was started in 1961 to determine quantitative relationships of forest types and stand conditions to the amount, timing, and quality of streamflow in the Adirondacks, the glaciated Appalachian Plateau, and the Catskills.

(g) On the basis of equations for turbulent heat and vapor transfer, and reasoned application of knowledge about intercepted snow, great differences are predicated in the energy and vapor balance between an intercepted "snowfield" and one on level open ground. The differences, resulting from the complex surface geometry of a closed conifer forest, are sufficient to account for considerably greater losses from intercepted snow.

(h) "The Surface Geometry of A Closed Conifer Forest in Relation to Losses of Intercepted Snow," by Donald R. Satterlund and Arthur R. Eschner. U. S. Forest Serv. Res. Paper NE-34, 16 pp., Northeast. Forest Expt. Sta., Upper Darby, Pa.

(5323) WATERSHED MANAGEMENT RESEARCH, UPPER DARBY, PA.

(b) Laboratory project in cooperation with: (1) the School of Forestry, Pennsylvania State University and the Pennsylvania Dept. of Forests and Waters; (2) Baltimore (Md.) Bureau of Water Supply; and (3) Division of Water Supply of the City of Newark, N. J.
(d) Field investigation; basic and applied research.

(e) At Pennsylvania State University a cooperative study was started in 1957 to determine the effect of forest cover and treatment on quantity and quality of streamflow in the oak-hickory type in Pennsylvania, and to study

associated and basic soil-water relationships. Six experimental watersheds have been selected, weirs have been constructed, and climatic stations established.
At Baltimore, Md. a cooperative study started in 1958 to determine effect of growth of loblolly and white pine in plantations on streamflow, and to compare streamflow from watersheds in conifer plantations with streamflow from a hardwood-forest watershed. Streamflow of three experimental watersheds is being measured and a climatic station has been established.
At Newark, N. J. a cooperative study to determine the influence of selected treatments of forested municipal watersheds on water supply. Weirs on 3 experimental watersheds were built in the fall of 1958 and stream gaging and climatic measurements were started in the spring of 1959.

(g) In a cooperative study with the School of Forestry of the Pennsylvania State University an analysis was made to determine the amount of annual and seasonal water yield, flow duration, and peak flow frequency for seven major physiographic units in the northeast. All watersheds (137) in the Northeast that were less than 100 square miles in area, that had continuous records from 1940 to 1957, and that were not appreciably affected by regulation and diversion were included in the analysis. In addition, streamflows of four small forested experimental watersheds were compared with average streamflow values of the physiographic units in which they were located. The longest simultaneous record available was for a 3-year period from 1959 to 1962. Results indicate significant differences in water yield between physiographic units as well as between watersheds within units. Water yields from the small experimental watersheds, although based on a shorter and different period of time, were found to correspond closely with average water yields of their respective physiographic units.

(h) "Streamflow Characteristics of Physiographic Units in the Northeast," by William E. Sopper and Howard W. Lull. Water Resources Res. 1: 115-124.

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, Northern Forest Experiment Station.

Inquiries concerning the following project should be addressed to Mr. Richard M. Hurd, Director, Northern Forest Experiment Station, 210 Admiral Way, Juneau, Alaska 99801.

(2654) EFFECT OF LOGGING ON PHYSICAL CHARACTERISTICS OF SALMON STREAMS IN SOUTHEAST ALASKA.

(b) Laboratory.
(d) Field investigation, applied.
(e) This work is concerned with the relationships between salmon spawning streams and timber harvesting in Southeast Alaska. Work is concentrated on 3 streams lying 40 miles west of Ketchikan. Two of the watersheds have been logged. The third watershed will remain unlogged.
Study is concentrated on factors that can exert a major influence on pink and chum salmon development and survival in streams in a logged watershed. During 1964 stream discharge and stream temperature measurements were obtained.

(g) The possibility of improving estimates of effective salmon spawning areas was explored using large-scale (1:1, 620) aerial photographs and stream profiles. Stream obstructions, such as debris jams, may alter the 1 to 3 feet per second stream velocity range usable for spawning to higher or lower rates. In 15,000 lineal feet of stream studied, 13 percent of the bed area was occupied by pool and pool-influenced areas associated with fallen tree and log debris in the stream. The combination of aerial photo interpretation, stream profile measurement, and estimates of roughness parameters appears to be a way to estimate potential spawner use in stream reaches. The concept has not yet been tested under field conditions.
Two log debris jams artifically constructed in a salmon stream caused streambed scouring under the debris concentrations, downstream deposition, unstable streambeds immediately upstream, and removed streambed areas from spawning salmon use. The highest flood in 13 years of record removed the artificial jams. Streambed gravel movement associated with the flood and log jams significantly decreased the amount of fine material in the gravels in some areas and caused small net reductions in others. In one area intragravel water dissolved oxygen content was significantly higher after the flood than before debris jam construction. In the other area the oxygen content was initially high and increased only slightly after the flood.

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, Pacific Northwest Forest and Range Expt. Station.

Inquiries concerning the following projects should be addressed to Mr. Philip A. Briegleb, Director, Pacific Northwest Forest and Range Expt. Sta., P. O. Box 3141, Portland, Oregon, 97208.

(4757) WATER YIELD AND EROSION, WENATCHEE, WASH.

(b) Laboratory project.
(d) Field investigations; basic and applied research.
(e) Field studies in ponderosa pine and mixed-conifer forests and foorest-ranges on the east slopes of the Cascade Range in Oregon and Washington: Erosion in forests and ranges: (1) Sediment production from Swauk sandstone-ponderosa pine; (2) sediment production from grazed pine-fir-larch ranges, Blue Mountains; (3) stimulation of seeded and natural grass cover by fertilization - Swauk sandstone soils; (4) relation of parent material and vegetative cover to organic matter, aggregation, pH, and bulk density of forest-range soils - eastern Washington; (5) effect of climate on development of soils from identical parent rock. Evapotranspiration: Includes studies with the overall objective of measuring factors which affect distribution and use of water in forests and related ranges: (1) Measurement of solar energy in a pine forest; (2) seasonal changes in soil moisture under a lodgepole pine forest; (3) measurements of moisture use by plants; (4) effect of removing brush and tree growth in three experimental watersheds on water yield (Entiat watershed study, in calibration stage -- no treatment yet applied); (5) water-holding capacity and drying rates for humus types characteristic of ponderosa pine-Douglas-fir forests - east side of the Cascade Range.

(g) Early results of a study of soil moisture depletion dramatically illustrate the manner in which soil depth governs the potential water yield increases due to timber harvest. Measurements made during the past year confirmed those made the previous year. The shallow soil (2-3 ft.) lost 2.5 inches while the deeper soil lost 6.4 inches during the drying season. A vegetation inventory was completed and half of all the plots were cleared of all tree growth during late October. These data indicate that removal of lodgepole pine from the deeper soils will result in storage of more soil water than would be gained in shallow soils. Thus, it can be presumed that on deeper soils, more water can be made available for streamflow by timber management practices.

(h) "The Energy Budget and its use in Estimating Evapotranspiration," by William B. Fowler. Soc. Amer. Foresters Proc.: 101-

104. September 1964.
"Tracing Soil Particle Movement with Fe^{59} ", by David D. Wooldridge. Soil Sci. Soc. Amer. Proc. Vol. 29: 469-472, July and Aug. 1965.

(4758) WATERSHED LOGGING METHODS AND STREAMFLOW.

(b) Laboratory project with some phases in cooperation with City of Portland, Bureau of Water Works and Oregon State University.

(d) Field investigations; basic and applied research.

(e) Research is conducted at three field locations in the Cascade Range of western Oregon: Bull Run watershed (domestic supply area for Portland), H. J. Andrews Experimental Forest, and South Umpqua Experimental Forest. Studies are confined to two forest types representing major segments of the remaining old-growth forests of the Pacific Northwest: (1) Douglas-fir, western hemlock, western redcedar, and (2) Douglas-fir, sugar pine. Investigations represent an initial effort to study precipitation runoff, erosion, and soil moisture in undisturbed stands, and to follow changes caused by several methods of logging. Included are studies in four categories: (1) Soil movement on logged land and an evaluation of effectiveness of grass seeding on roadbanks; (2) changes in water quality resulting from roadbuilding, two methods of cable logging, two degrees of forest removal -- 25 percent and 100 percent -- and slash burning; (3) changes in streamflow caused by clear cutting and partial cutting in groups of varying size on matched watersheds in old-growth Douglas-fir and sugar pine-fir. Pretreatment measurements are still being made to provide statistical basis for treatment evaluation; (4) soil moisture movement and disposition and the role of vegetation in evapotranspiration, including measure of seasonal changes in soil moisture under a Douglas-fir stand, vertical movement of water in Douglas-fir soils, rainfall interception by crowns of old-growth Douglas-fir soils, rainfall interception by crowns of old-growth Douglas-fir, and changes in plant succession following logging and slash burning.

(g) Second year measurements after logging showed a storage capacity at the end of the summer of 3.5 inches of water in the top 4 feet of soil. Had the timber not been logged, storage capacity would have been an estimated 6.7 inches. With some recovery of vegetation following logging and burning, water removed from the top 4 feet of soil was about half what it would have been under undisturbed conditions. First measurements of suspended sediment from tractors crossing small streams during road construction show that during low summer flow there is a ten-fold reduction in sediment concentration after the stream flows through 1,000 feet of natural channel. Suspended sediment was reduced from 1,000 to 100 parts per million. Particle size analysis showed the following concentrations.

Distance downstream from road crossing feet	Suspended sediment concentrations parts per million			
	Sand	Silt	Clay	Total
150	80	618	358	1.055
300	3	238	440	681
600	1.5	39	410	450
1200	0.8	3	104	108

Water samples collected in spring, summer, and winter of 1964 were analyzed. Form and concentration of nitrogen was erratic. Nitrate form in spring changed to ammonia form in summer and winter. Alkalinity, greater from burned watersheds in spring, returned to lower levels in summer and winter. Hardness (combined alkaline earths), greater in spring from logged and burned watersheds, returned to same levels in both burned and unburned watersheds summer and winter. Phosphate levels were greater from logged and burned watersheds except during summer low flows. Sodium was consistently slightly greater from logged and burned watersheds. K, Fe, and Mn showed no difference. Total dissolved solids were 88 percent HCO_3 plus hardness plus Si. The other 12 percent included h, Cl, PO_4, Mn, K, Na. pH remained near neutral except during one sampling.
First-year results from snow measurements in 2-chain-wide, east-west, clearcut strips show greater accumulation but more rapid melt of snow in the strips. At the time of maximum accumulation in March, water content of snow on the clearcut strip was 35 percent greater than that under undisturbed forests. By June 15, only 3 of 36 plots in the open were snow-covered in contrast to 26 of 36 plots snow-covered under the undisturbed forest.

(h) "Streamflow from Small Watersheds on the Western Slope of the Cascade Range of Oregon," by Jack Rothacher. Water Resources Res. 1(1): 125-134, illus. First Quarter 1965.
"Some Physical and Chemical Properties of Pumice Soils in Oregon," by C. T. Youngberg and C. T. Dyrness. Soil Sci. 97(6): 391-399. June 1964.
"Snow Accumulation and Melt in Strip Cuttings on the West Slopes of the Oregon Cascades," by Jack Rothacher. U. S. Forest Service Research Note PNW-23, 7 pp., May 1965.
"Sedimentation after Logging Road Construction in a Small Western Oregon Watershed," by Richard L. Fredriksen. In Proceedings of the Federal Inter-Agency Sedimentation Conference, 1963. U. S. Dept. Agr. Misc. Pub. 970, pp. 56-59, illus., June 1965.
"Christmas Storm Damage on the H. J. Andrews." U. S. Forest Service Res. Note PNW-29, 11 pages, August 1965.

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, Pacific Southwest Forest and Range Experiment Station.

(4996) WATERSHED MANAGEMENT RESEARCH IN CALIFORNIA'S SNOW ZONE (SNOW MANAGEMENT RESEARCH).

(b) Laboratory and the following cooperators: State of California, Dept. of Water Resources, Atomic Energy Commission, and Pacific Gas & Electric Company.

(c) Dr. James L. Smith, Project Leader, Snow Management Research, Pacific Southwest Forest & Range Experiment Station, 1960 Addison Street, Berkeley 1, California.

(d) Experimental; field investigations; basic and applied research.

(e) The objective of this project is to determine methodology for increasing water yield and changing of timing of water delivery by vegetation manipulation, by evaporation suppressants, etc. Its area of interest is confined to the snowpack zone of the Sierra Nevada of California. Present studies emphasize development of methods for management of high elevation snowpacks for yield and control of water; the effects of timber cutting upon soil moisture losses and snow accumulation and melt; and the evapotranspiration from various sites -- species combinations.
Project scientists are located in Berkeley with field personnel and studies located at the Central Sierra Snow Laboratory, Soda Springs, California, and studies only located at Teakettle Experimental Forest in the headwaters of the north fork of the Kings River above Fresno, California. Both sites lie at 7000-8000 feet elevation. At the Teakettle Experimental Forest four small watersheds (0.27-0.86 square miles in area) are under study prior to installation of log roads and a timber harvest to determine their

effects upon water yield. At the Central Sierra Snow Laboratory five small watersheds are gaged for the study of logging effects upon water yield. In the headwaters of the Feather River a practical sized logging is being tested for snow accumulation and melt effects. Gamma and neutron probes are being tested for measuring hydrologic characteristics of snowpacks. Evaporation suppressants are being tested for reduction of such losses from snowpacks.

(g) Rapid measurement of hydrologic characteristics of snowpack which may permit more accurate appraisal and prediction of delivery of snowmelt water has been possible using gamma and neutron probes. Commercially available probes with gamma source (Troxler Laboratories SC-10 and SC-20 probes) were tested for the ability to measure snow density of the individual layers in the snowpack.
Usable regressions of snow density (D) measured gravimetrically and gamma counts (Cg) in CPM in the snowpack were obtained. Only one calibration curve is needed regardless of how close to the snow-air interface one takes measurements.
A snow gage has been tested with which one may accurately measure snow density in 1/2-inch vertical increments to 1.2 percent accuracy of actual density. With this system a 10-foot snowpack may be profiled in 10 minutes by moving the detector and source through the snowpack at a constant rate. Output was recorded on an analog chart.
The system operates on the theory of gamma transmission. Gammas from the source pulse through the snowpack to the crystal detector, thence through a pulse-height analyzer set to pass photo-peak energy only and from there to the ratemeter-scaler. Output can be fed to a chart.
Problems of temperature effects upon the crystal are controllable. "Sun-cupping" problems are negligible with use of proper access tubing.
Effect of crystalline structure of snow, ice, and water upon gamma attenuation are shown to be negligible if present at all. Count was shown to be wholly dependent upon density of material between the source and detector.
Soil samples were obtained for analysis in a study designed to identify the hydrologic constants of the major soils in the Sierra Nevada of California. Snow accumulation was increased by 45 percent in clear-cut strips 132 feet wide. These strips were cut in virgin red fir at an elevation of 7,000 feet. However, approximately a quantity of snow almost equal to the increase was "stolen" from the bordering forest "downwind" from the cut strips. Snowmelt in east-west cut strips was shown to be drastically affected by the heating up of the tree trunks of mature timber to the north of the cut strips. These in turn radiated heat to the snowpack and melted the pack rapidly from the north edge progressively to the south edge.
Winter surface evaporation from snowpack at high elevation sites was reduced by the addition of the suppressant hexadecanol. It was shown that hexadecanol did not materially increase snowmelt.

(h) "Radio-Snow Gages: A Review of the Literature," by James L. Smith and Donald W. Willen. Isotopes and Radiation Technology (Div. of Tech. Info./Div. of Isotopes Devel., U. S. Atomic Energy Commission) 2 (1):41-49. 1964.

(4997) WATER SOURCE HYDROLOGY.

(b) Laboratory project. Cooperators are: State of California, Department of Water Resources; University of California; State of Hawaii, Division of Forestry.

(c) Mr. Henry W. Anderson, Project Leader, Pacific Southwest Forest and Range Experiment Station, P. O. Box 245, Berkeley 1, California.

(d) Experimental and theoretical; basic and applied research.

(e) The objective is through analytical modeling to advance the state of knowledge of watershed hydrology and sedimentation, and particularly, knowledge of the relationship of watershed management and other hydrologic processes at the water sources to water yield, floods, sedimentation, and water quality delivered from wildland watersheds.

(g) The relation of snow accumulation and melt to terrain and forest conditions measured at 163 snow courses in central California were determined, using principal component analysis. Snow data included wet years and dry, 1958, 1959 and 1960.
Terrain was expressed in two parts: first, meso terrain, representing the surroundings within a few hundreds or thousands of feet around the snow course, and second, the local terrain at the course. Meso terrain variables were shade from surrounding mountains, forest or lack of it at distances up to one mile to the windward, and position on the mountain slope, ridge vs. valley, etc. Interactions of these with the local terrain were also investigated. Local terrain variables included topographic and forest variables; topographic variables were elevation, slope and aspect; measured variables were expressed in energy terms and included interactions with meso terrain and the forest. The effects of topography at the snow course were represented by variables affecting the amount of snowfall, and the heat--both the solar energy and the exposure to winds affecting advective heating at the course. Forest variables: the forest variables were density of forest canopy, vegetative species, tree heights, sizes of openings and position of the snow course within the forest or opening.
Under conditions when average snow (at all sites) was greater than 20 inches, the largest contrasts between amounts of snow on north and south slopes occurred in the forest; openings were next; and forests near openings showed very little contrast between slopes. Under all three forest conditions, maximum differences occurred at about 35 inches of snow storage. The principal components analysis also indicated the possible magnitude of meso-effects of forests for distances one-half mile to the windward (SWW) of snow courses. For a snow course with a dense forest (66 percent canopy) to windward, and a comparable course with the forest canopy thinned to 33 percent, the analysis indicated 4 to 8 inches more snow at the course with the less dense forest to the windward.
In studies of the application of multivariate techniques in appraising the adequacy of current sediment networks, some interesting relations of sediment discharge to past land use and condition have been indicated. For a selected group of 23 watersheds in northern California the relation of suspended sediment discharge (SED) to watershed fires in the last ten years (FIRE10), to unimproved roads (UROADS), to "poor" logging (LOG1), to steep grassland (IGS) and to mean annual streamflow (MAQ) were determined. Principal component regression gave the following equation: $\log(SED) = + 0.456 + 0.434 \log(RRA) + 0.240 \log(FIRE10) + 0.159 \log(UROADS) + 0.105 \log(LOG1) + 0.278 \log(IGS) + 1.957 \log(MAQ)$
By solving the equation one can obtain estimates of the effects of a change in a particular land use or change in streamflow. For example, one can arrive at the conclusion that man's activities (as characterized by FIRE10, UROADS, and LOG1) have increased average sediment loads for some northern California streams by seventeen times.

(h) "Integrating Snow Management with Basin Management," by Henry W. Anderson. To be published in Western Resources Symposium, John Wiley & Sons, N. Y., 1965.
"Some Interpretations of Sediment Sources and Causes, Pacific Coast Basins in Oregon and

California," by Henry W. Anderson and James R. Wallis, Proc. Federal Interagency Sedimentation Conf., 1963. U. S. Dept. Agric. Misc. Publ. 970, pp 22-30, 1965.
"Snow Accumulation and Melt in Relation to Terrain in Wet and Dry Years," by Henry W. Anderson and Allan J. West, Proc. 33rd West. Snow Conf. (In press.)
"A Factor Analysis of Soil Erosion and Stream Sedimentation in Northern California," by James R. Wallis, Univ. of Calif., Berkeley, Ph.D. Dissertation, 141 pp., University Microfilms, Ann Arbor, Mich., No. 65-8113,1965.
"Multivariate methods of hydrology. A Comparison Using Data of Known Functional Relationship," by James R. Wallis, Water Resources Research 4(1): 48-59, 1965.
"An Application of Multivariate Analysis to Sediment Network Design," by James R. Wallis and H. W. Anderson, Bul. Internat. Assoc. Sci. Hydrol. X Annee No. 3, 1-22, 1965.
"Surface Soil Textural and Potential Erodibility Characteristics of Some Southern Sierra Nevada Forest Sites," by Donald W. Willen, Soil Sci. Soc. Amer. Proc. 29(2): 213-218,1965.

(4998) WATER YIELD IMPROVEMENT, AND FLOOD AND SEDIMENT REDUCTION IN THE LOWER CONIFER ZONE OF CALIFORNIA.

(b) Laboratory project. Cooperators are: California Department of Water Resources, California Division of Forestry, East Bay Municipal Utilities District, California Department of Fish and Game.

(c) Mr. Robert P. Crouse, Project Leader, Lower Conifer Zone, Pacific Southwest Forest & Range Experiment Station, 1960 Addison Street, Berkeley, California.

(d) Experimental; field investigations; basic and applied research.

(e) This project conducts basic studies of forest hydrology which will suggest methods of land management for improving water yield, preventing floods and controlling sediment in the commercial timber zones of California below the snowpack.
A study of soil moisture depletion in the Sierra zone of the Lower Conifer Zone concerns the magnitude of soil moisture storage and depletion under different stand and timber cutting intensities.
Because soil creep and landslides are prevalent in the zone, a study of gravitational mass movement will form an effort to develop the means of estimating the consequences of mass movement in terms of sedimentation. The ultimate objective is to develop the means of predicting the role of land management practices, such as logging and road building in initiating or accelerating mass movement.

(g) Soil moisture data has been collected at 2-intervals for an additional summer's depletion period from 84 neutron moisture meter access tubes installed to a depth of 20 feet in a wide range of forest vegetation densities. Distance and bearing to all vegetation within 84 feet (1/2 acre) of each access tube has been collected. Soil texture has been determined for each plot to a depth of 50 feet.
An additional 20 access tubes have been installed to a depth of 17 feet around a single isolated sugar pine. Recording water table stage recorders have been installed at 3 locations.
The initial base survey of natural soil creep rates has been completed at the Moraga and Northern Coast Range sites. A preliminary standard penetration test survey has also been completed in holes adjacent to all inclinometer holes. A refraction seismograph survey of soil thickness is at present being carried out at all sites.
The watershed calibration period at Caspar Creek is continuing with measurements of streamflow, sediment discharge, and precipitation.

(4999) FLOOD AND SEDIMENT REDUCTION FROM STEEP UNSTABLE BRUSHLANDS OF THE SOUTHWEST.

(b) Laboratory project. Cooperators: California Division of Forestry, Los Angeles County Flood Control District, Los Angeles County Fire Department, University of California, Berkeley, Los Angeles, and Riverside, Angeles National Forest.

(c) Mr. Raymond M. Rice, Project Leader, Pacific Southwest Forest and Range Experiment Station, 110 North Wabash Avenue, Glendora, Calif.

(d) Experimental; field investigations; basic and applied research.

(e) Purposes are (1) to determine how watersheds function: what happens to the precipitation, and how water and soil movement are influenced by conditions of vegetation, soil, geology, and topography; and (2) to develop methods of watershed management, including treatment of areas denuded by fire, to insure maximum yield of usable water and satisfactory flood runoff and soil erosion control.
Principal work center is the 17,000-acre San Dimas Experimental Forest situated in the San Gabriel Mountains. A fire started by lightning in July 1960 consumed the vegetation, mostly brush, on 90 percent of the area and destroyed or damaged many of the research installations. Immediately after the fire a major emergency research program was started to test the effectiveness of various measures used to reduce flood runoff and erosion on the denuded watersheds. These rehabilitation measures include seeding grasses and mustard singly and in combination with physical treatments such as wattling, channel barriers and contour terraces. The tests are being made on 38 watersheds of 2 to 90 acres each, equipped to measure rainfall intensity, peak discharge and suspended sediment. Twenty-five have basins to measure bedload. Studies of the erosion processes and tests of applied management methods to decrease the erosion potential are being continued.

(g) Plots installed in the fall of 1965 to evaluate two methods of applying a wetting agent for post-fire erosion control yielded negative results. There were no significant differences between the surface runoff and erosion from treated and controlled plots. The lack of effectiveness is attributed to wind blowing the treated surface soil from the plots. Most of the erosion measured occurred during dry inter-storm periods. Only trivial amounts of water borne erosion were measured. As a result of this finding four sideslope erosion plots have been equipped with anemometers to evaluate the role of wind in soil movement on steep sideslopes. Wind travel is being measured at the surface, at the vegetation crown level, and at a free air station.
Laboratory findings have been reported under (5000).

(h) "Soil Wettability: A Neglected Factor In Watershed Management," by Jay S. Krammes and Leonard F. DeBano, Water Resources Res., 1(2): 283-286, 1965.
"Effect of 2, 4-D and 2, 4, 5-T on Water Quality After A Spraying Treatment," by Jay S. Krammes and David B. Willets, Pacific S.W. Forest & Range Expt. Sta., U. S. Forest Serv. Res. Note PSW-52, 4 pp., 1964.
"The Influence of Vegetation on the Thermal Regime at the San Dimas Lysimeters," by Hasen K. Qashu and Paul J. Zinke, Soil Sci. Soc. Amer. Proc., 28(5):703-706, illus., 1964.
"Emergency Measures to Control Erosion After A Fire on the San Dimas Experimental Forest," by R. M. Rice, R. P. Crouse, and E. S. Corbett, Proc., Federal Inter-Agency Conference on Sedimentation, Jackson, Miss., 1965.
"The Effect of Former Plant Cover on Herbaceous Vegetation After Fire," by Raymond M. Rice and Lisle R. Green, Jour. of Forestry, 62(11):820-821, 1964.

(5000) WATER YIELD IMPROVEMENT FROM THE BRUSHLANDS OF THE SOUTHWEST.

(b) Laboratory project. Cooperators: California

Division of Forestry, Los Angeles County Flood Control District, and University of California at Berkeley, Riverside, and Los Angeles.

(c) Mr. Leonard F. DeBano, Project Leader, Pacific Southwest Forest and Range Experiment Station, 110 North Wabash Avenue, Glendora, Calif.

(d) Experimental; field investigations; basic and applied research.

(e) The work center is the 17,000-acre San Dimas Experimental Forest in the San Gabriel Mountains of Southern California.
Field investigations include studies concerned with the hydrologic factors of chaparral watersheds, riparian zone hydrology, and evaluation of water yield improvements.
Laboratory studies on the movement (saturated and unsaturated), loss and storage of water in brushland soils supplement field studies on chaparral and riparian zone hydrology.
Purpose of the work is (1) to establish fundamental plant, soil, water relationships as they influence water losses and water yields; and (2) to develop and test cultural practices aimed at improving water yield.

(g) Abstracts of unpublished material. "Water Repellent Soils and Their Relationship to Wildfire Temperatures," by L. F. DeBano and J. S. Krammes (to be submitted to the International Association of Scientific Hydrology).
A naturally occurring water resistent soil was exposed to different burning times and temperatures after which the soil samples were tested for non-wettability. The less intense treatments produced an extremely non-wettable condition. Temperatures of 800 and 900 degrees applied for 20 minutes completely destroyed the non-wettable property. Heat treatments within the realm of soil temperatures existing during wildfires were capable of producing the extreme non-wettable condition. The increase surface runoff and erosion from burned southern California watersheds could be the result of this relationship.
"Effects of Hydrophobic Substances on Moisture Movement During Infiltration," by Leonard F. DeBano (presented to Division S-1, Soil Science Society of America, National Meetings of the American Society of Agronomy, Nov. 3, 1965).
The effect of a hydrophobic substance on moisture movement was studied during infiltration into soil columns. Physically similar wettable and non-wettable soils were used for the experiments. Data on infiltration rates and soil moisture distributions obtained during horizontal infiltration were used to calculate soil moisture diffusivities for the two soils. Horizontal infiltration rates were used to calculate soil moisture diffusivities for the two soils. Horizontal infiltration rates were reduced 25 fold by the presence of a hydrophobic substance. Also, soil moisture distributions developed in a non-wettable soil during infiltration were different than in the wettable soil. In a non-wettable soil there was a decrease in moisture content between the water source and the wetting front while the wettable soil the decrease over this interval was smaller. The ratios of soil moisture diffusivities of wettable to those of non-wettable soil increased as relative moisture content decreased. This indicates that the hydrophobic substance has a greater effect on unsaturated soil moisture movement at lower moisture contents. Results of this study taken as a whole suggests a non-wettable soil property may be a significant factor in moisture movement in southern California brushland soils.
"Longevity of a Wetting Agent Treatment for Water Resistent Soils," by J. S. Krammes and L. F. DeBano (presented to Division S-1, Soil Science Society of America, National Meetings of the American Society of Agronomy, Columbus, Ohio, November 3, 1965).
Field sampling in burned chaparral watersheds shows a "non-wettable" soil property to be widespread in southern California. Restricted moisture movement and penetration in this soil condition results in high surface runoff and erosion rates during storm periods. A wetting agent treatment has been used to modify the wetting charactistics of these soils on burned watersheds. The longevity of such remedial treatment was evaluated in the laboratory leaching study. Both surface tension measurements of the leachate solution and capillary rise data shows that wetting agent treatment to have a residual effect. It persisted in the soil until an amount of water equivalent to more than 16 inches of natural precipitation was applied.
Other experiments.
Preliminary laboratory infiltration experiments were conducted on soil columns containing a layer of non-wettable soil located below the soil surface. The non-wettable layer was 2 inches thick with the upper interface being 2 1/2 inches below the top of the column. Similar textured wettable material was packed above and below the non-wettable layer.
The results of infiltration experiments indicated that a non-wettable layer located in this position reduced total infiltration into columns. Infiltration rates decreased when the wetting front entered and passed through the non-wettable layer. Infiltration rates into the wettable soil overlying the non-wettable layer was similar to those in columns packed with wettable soil. As the wetting front entered the non-wettable layer, infiltration rates dropped below those for columns packed only with non-wettable soil. When the wetting front left the non-wettable layer and passed into the wettable soil, infiltration rates increased slightly and maintained a rate similar to those of the non-wettable soil. The non-wettable layer appeared to influence not only infiltration when the wetting front was located in the non-wettable layer, but also has a residual effect at lower depths in wettable soil.

(h) "Soil Wettability: A Neglected Factor in Watershed Management," by Jay S. Krammes and L. F. DeBano, Water Resources Research, 1:283-286, 1965.

(5001) WATER YIELDS IN HAWAII.

(b) Laboratory project. Cooperators: State of Hawaii, Department of Land and Natural Resources, Div. of Forestry.

(c) Mr. Robert E. Nelson, Chief, Hawaii Research Center, Pacific Southwest Forest and Range Experiment Station, 400 South Beretania St., Honolulu, Hawaii.

(d) Experimental; field investigations; basic and applied research.

(e) The objective is to develop a hydrological and meteorological base in Hawaii's wildland watersheds that will suggest methods of land management for maintaining or improving water yield and water quality and minimizing soil erosion and sedimentation; to obtain adequate understanding of the processes of receiving and discharging water and being able to predict the effects of a wide span of forest land management practices upon water yield and water control; such studies are to suggest ways to manage watersheds that will (1) assure the continued protection of watersheds; (2) improve the distribution of the water yield by modifying the balance between the groundwater recharge and surface waterflow; (3) increase water yields by decreasing evapotranspiration losses; and (4) minimize flood runoff and sedimentation.
Major work center is in Honolulu. The principal studies under way are the determination of soil erodibility indices for forest soils in Hawaii, the measurement of evapotranspiration from several selected wildland vegetation types, and a study of rainfall-runoff relations on two small forest watersheds.

(g) Studies of soil erodibility indices, their predictability from recognizable site characteristics such as parent material, vegetation and precipitation, and their relation to measured splash under artificial rain conditions are nearing completion. Publication of these results is expected this year (1966).
Measurements of soil moisture depletion under

a grass cover and under an aluminum-roofed plot were made. This study complements earlier measurements of soil moisture depletion under several tree and brush plots in adjacent areas.
A study of rainfall interception and fog-drip was begun in several forest plantations on Maui and Oahu. These studies will be expanded to include the effects of size, shape and other characteristics of natural and artificial leaves on water storage and drip under laboratory conditions.

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, Rocky Mountain Forest and Range Experiment Station.

Inquiries concerning the following projects should be addressed to Mr. Raymond Price, Director, Rocky Mountain Forest and Range Experiment Station, Room 221 Forestry Building, Fort Collins, Colorado 80521.

(377) WATERSHED MANAGEMENT RESEARCH, FRASER HYDROLOGIC LABORATORY.

(b) Laboratory project.
(d) Field investigations; applied research.
(e) To determine influence of lodgepole pine and spruce-fir forests and of the management of these forests for wood products on factors associated with the yield of water, largely from stored snow. The purpose is to solve problems in the management of forested watersheds of the high altitude zone of the Rocky Mountains for maximum yields of usable water.
(g) The energy budget for a snowpack is evaluated to determine energy available for evaporation. The effect of turbulence is considered. Results were checked by determining sensible heat flux with known gradients of specific humidity and temperature. Agreement was close. In February and March 1963 evaporation from 0600 to 1800 on clear days was ranged from 0.02 inch to 0.07 inch. Nighttime condensation was 0.008 to 0.012 inch.
From oblique aerial photographs, significant relationships between areal snow cover and seasonal water yield have been derived for watersheds at Fraser Experimental Forest. The characteristic rate of snow-cover depletion on a given basin can be indirectly determined from topographic characteristics such as aspect and elevation. Near-identical relationships were obtained when two adjacent watersheds having similar aspects were compared with respect to: (1) The distribution of area with elevation and (2) areal extent of snow cover. Watersheds are highly correlated with respect to residual runoff volumes. This indicates that small index watersheds may provide a reliable basis for making accurate short-term residual volume forecasts for large drainage basins.
An automatic system has been devised to record heat pulse velocities at preselected intervals. Heat pulse velocities in tree stems are an index to velocity and direction of sap movement. Most rapid rates have been observed in both spruce and lodgepole pine during snowmelt when soils are throughly wet. Rates later in the summer are reduced. Apparently, even with old, well-established trees soil moisture controls moisture loss from the trees more than do other environmental factors.
Seismic determination on Fool Creek watershed at Fraser revealed that depth of soil and weathered rock is about 14 feet on slopes. Concentration of runoff in the period during and shortly after snowmelt indicates high permeability of these regolith materials.
(h) "Evaporation from a Winter Snow Cover in the Rocky Mountain Forest Zone," James D. Bergen and R. H. Swanson. West. Snow Conf. Proc. 32: 52-58, 1964.
"Process and Significance of Interception in Colorado," Marvin D. Hoover and Charles F. Leaf. To be published in Internatl. Symposium Forest Hydrology Proc., Penna. State Univ. 1965.
"Seasonal Course of Transpiration of Lodgepole Pine and Engelmann Spruce," R. H. Swanson. To be published in Internatl. Symposium Forest Hydrology Proc., Penna. State Univ. 1965.

(657) WATERSHED MANAGEMENT RESEARCH, TEMPE,ARIZONA.

(b) Laboratory project.
(d) Experimental; basic and applied research.
(e) To study the disposition of rainfall as influenced by waterhed vegetation; to determine the influence of various types of forest and grassland vegetation as well as vegetation modified by cultural treatment such as grazing and timber harvest, on streamflow, water use, water loss, and erosion and sediment yield; and to determine for phreatophytic vegetation (water-loving plants) the amount of water used, methods for reducing water use by phreatophytes or for replacing them with more useful plants.
At Sierra Ancha Experimental Watersheds in central Arizona, rainfall, runoff, and erosion are measured on three watersheds in the pine-fir vegetation type at high elevation, on two watersheds in the ponderosa-chaparral type, and from four watersheds in the grassland-chaparral type at intermediate elevations, and on nine small watersheds in the semidesert-chaparral type at low elevations. Water use by different types of plants in various soils is studied on eleven large lysimeters. Three watersheds have been established on the ponderosa pine type, three in the mixed-conifer type and two watersheds in the high (9,300-foot elevation) grassland type. Current plans are to treat one ponderosa pine watershed in 1965, testing current Forest Service methods of harvesting mature timber, but adjusting cutting methods to lead to eventual even-aged management.
Soils from grass, aspen, and mixed-conifer plots are being laboratory tested for hydrologic characteristics. Soil moisture is followed with a neutron probe. Gaging stations for four watersheds in the pure chaparral type are also available to evaluate watershed-game interrelations. One cluster of two watersheds and and another cluster of three watersheds are available for testing the effect of manipulating chaparral cover. Supplemental studies are determining the proper use of chemicals, fire, and mechanical treatment for manipulating shrub in the type. Ecology of Tamarix pentandra and other phreatophytes is under investigation. Germination, seedling survival, sprouting ability, and rate of spread studies were continued.
(g) Salt glands in T. Pentandra are distinct structures composed of eight cells. The glands excrete salt solutions through a single pore during relatively high humidity conditions.
More herbaceous plants emerged after complete litter removal than after burning, scarifying, or no treatment. Burning appeared to favor morning-glory and yerba-santa. Required germination conditions for shrubs probably were not met in these laboratory tests.
Five years after converting one-third of the 248-acre North Fork Workman Creek watershed from moist-site forest vegetation (White and Douglas fir) to perennial grass, the increase in water yield is statistically highly significant. The slope of the posttreatment regression is also significantly different from the pretreatment regression. The significant difference in slope of the pretreatment and the posttreatment regression lines, indicates the two converge near zero flow but diverge for high flows. This suggests a logical deduction that the largest increases should occur during years of high streamflow when soil moisture deficits are satisfied over larger parts of the watershed. The

increased water yield on North Fork has varied from 44 percent in 1960 to 65 percent in 1963, and has averaged 55 percent for the 5 posttreatment years.
After 12 years, 1954-1965, the data from South Fork indicates that streamflow has not been increased significantly. The changes in water yields following treatment have shown increases 9 out of 10 years, but the average increase was only 4 percent. If future increases are maintained in the same magnitude, approximately 40 years would be required to obtain statistical significance. The 12 years' data indicate that small water yield increases may be expected from an individual trees selection timber harvest which leaves a heavy stand of timber in the watershed.
In contrast to the two previous years, no frozen soils have been observed in the White Mountain area (elevation 9,300 feet) during the 1964-65 winter to February 1, 1965. This appears to be related to early snow that has remained to protect both forest and grassland soils. This lack of soil frost will be related to runoff during the spring runoff period.
High water savings from "control" of sprouting shrubs on the burned Three-Bar experimental watersheds continue into the fourth posttreatment year. Sediment movement has declined on all watersheds after the very high yield of the first postfire year. The three watersheds left in shrubs are still releasing significant amounts of sediment, but watershed C converted to grass, has yielded no sediment in the past 2 years even though this period included the largest high-intensity summer storm since the watersheds were established in 1956.
In Whitespar A and B, the previously noted strong correlation with respect to timing of peaks and lengths of spring recessions continues. No particular change has occurred in the sporadic flows from the three Mingus watersheds.
A water vapor adsorption apparatus is being developed for measuring the transpiratory water losses from plants. Water vapor in air is absorbed by a desiccant, and the amount adsorbed is determined gravimetrically. Initially the method is being developed for potted plants.
The control of transpiratory water losses from plants by means of chemical treatments is being explored. The objective of a recent study was to determine the influence of foliage sprays of 4 amino, 3,5,6-trichloropicolinic acid (picloram) on the transpiratory water losses from potted shrub live oak plants. Picloram is a phytotoxic chemical which shows promise for the control of brush. Soil-applied treatments of picloram are lethal to potted shrub live oak plants, whereas low-volume foliage sprays are not. In the present study low-volume foliage sprays of picloram were applied to potted shrub live oak plants and the transpiratory water losses of the treated plants were compared with those of untreated control plants. A low-volume foliage spray of picloram at a sublethal rate (1/2 lb./A) reduced transpiration of shrub live oak temporarily only. Repeated applications were necessary to maintain or reduce the transpiration rate below the level achieved by the initial treatment.
A field reconnaissance survey has been developed by a relatively fast and accurate sampling technique for measuring the riparian vegetation. The survey was designed to test the value of aerial photography in mapping inaccessible riparian vegetation. The majority of the riparian hardwood species can be identified from the large-scale aerial photographs.

(h) "Salt Gland Anatomy in Tamarix Pentandra (Tamaricaceae)," C. J. Campbell and J. E. Strong, Southwest. Naturalist 9(4): 232-238, illus.
"The Mechanism of Fenuron Injury to Plants," Edwin A. Davis, Res. Note RM-50, 2 pp.
"Picloram: A Promising Brush Control Chemical," Edwin A. Davis, Res. Note RM-35, 2 pp.
"Effect of Litter Treatment on Germination of Species Found Under Manzanita (Arctostaphylos)," George E. Glendening and C. P. Pase, Jour. Range Mangt. 17: 265-266, illus.
"Reduction of Litter and Shrub Crowns by Planned Fall Burning of Oak-mountainmahogany Chaparral," C. P. Pase and George E. Glendening, Res. Note RM-49, 2 pp. illus.
"Burned Chaparral to Grass: Early Effects on Water and Sediment Yields at Three-Bar," C. P. Pase and P. A. Ingebo. To be published in Ariz. Watershed Symposium Proc. 1965.
"Results From Mixed Conifer Watersheds and Possible Future Treatments," Lowell R. Rich. To be published in Ariz. Watershed Symposium Proc. 1965.

(1969) WATERSHED MANAGEMENT RESEARCH, ALBUQUERQUE, NEW MEXICO.

(b) Laboratory project. Some work in cooperation with Bureau of Land Management and Geological Survey.

(d) Applied research.

(e) Evaluation of range-watershed conditions on small watersheds in the San Luis drainage of the Rio Puerco. Three contiguous watersheds, ranging from 338 to 555 acres located about 8 miles north of the San Luis community and west of the Rio Puerco main channel provide the study area. Water and sediment inflow are measured in small reservoirs formed by earthen dams. Precipitation rates and amounts of vegetation changes are periodically measured over the watersheds. Ten years of data have been collected under cattle grazing during a 5 1/2-6 month overwinter period (November 1 to April 30).
Evaluation of soil ripping on surface runoff, erosion, and vegetation. Surface runoff plots (64), 10' x 31', are installed on a north and south aspect and upper and lower slopes representing different soil conditions in the Rio Jemez drainage. Precipitation, runoff, and sediment are measured.
To obtain inventory information on the hydrologic variables of the pinyon-juniper type, six small watersheds with ephemeral streams are being gaged by means of a prefabricated, fiberglassed version of the Beaver Creek flume.

(g) Ripping killed 28 percent of the perennial grass ground cover on the Rio Puerco watersheds, caused a 50 percent loss of litter, and a 24 percent increase in bare soil. Beneficial effects of ripping were: an increase in forage production from 265 pounds per acre to 476 pounds per acre; the first year after treatment no runoff was produced, and the second year runoff was about half as might be expected. Plot studies indicate ripping effectiveness in stopping runoff will decline in about 3 years.
Protection from grazing has given some interesting results. Two grazing seasons are hardly enough to forecast what will ultimately occur but trends are evident. Ground cover has declined by 32 percent, but litter increased 333 percent. Bare soil stayed about the same. Forage production has declined about 11 percent. Forage production measurements separate current growth from last year's litter, thus total plant material is greater than reflected in the production measurements.
Fiberglassed plywood sheets are undergoing strength and durability tests for use in gully control check dams near Albuquerque, New Mexico. A low cost, rapidly installed, durable gully check dam is needed for use in rehabilitating watersheds in the Southwest. Tests were begun this year on the use of prefabricated dams made of 4 foot by 8 foot fiberglassed plywood sheets and plywood sheets treated with pentachlorophenol. Plywood is used as the apron and dam wall.
Field construction is simple. After sites are selected, keyways are dug, the support frames

installed and the plywood is placed and screwed to the frame.
As with any gully check dam, success is dependent primarily on proper location, installation, and design for accommodating peak flows. Since these initial dams are restricted to size, their widespread use is at present limited. Currently work is being done to design dams that can lap plywood pieces to extend effective dam widths.
Those installed in the summer of 1965 were given a severe test when between 1.25 and 1.5 inches of precipitation fell in an hour on the watersheds. The dams caught and held sediment without downstream or side scour.

(h) "Ground Cover Changes in Relation to Runoff and Erosion in West-central New Mexico," Earl F. Aldon, Res. Note RM-34. 4 pp.
"Changes in Perennial Grass Cover Following Conversion from Yearlong to Summer-deferred Grazing in West-central New Mexico," W. C. Hickey, Jr., and George Garcia, Res. Note RM-33, 3 pp.
"A Prefabricate Flume for Gaging Ephemeral Streams," Earl F. Aldon and Fletcher J. Brown Res. Note RM-55, 8 pp.

(2658) WATERSHED MANAGEMENT RESEARCH, RAPID CITY, SOUTH DAKOTA.

(b) Laboratory project.
(d) Experimental; basic and applied research.
(e) (1) To evaluate water yield and sediment production in relation to standard forest management practices in ponderosa pine. (2) To determine surface runoff and rates of recovery from soil compaction on Kentucky bluegrass range in the Black Hills. (3) To determine soil moisture relations of ponderosa pine thinned to different reserve densities and by stand types.
(g) Amount of precipitation reaching the ground under ponderosa pine is dependent primarily on the amount of precipitation in the open. Coefficients for linear correlation of weekly throughfall with weekly gross precipitation were 0.998 and 0.989 for thinned and unthinned pine respectively, leaving only 0.4 and 2.2 percent of variation in throughfall unaccounted for. Relationship of unaccounted for variation in throughfall with canopy factors was tested for the unthinned pine. Results indicated a probable curvilinear relationship, throughfall increasing with increase in canopy density from 40 percent to about 57 percent and then a drop in percent throughfall with increase in canopy density to 70 percent, the limit of the data. Possible explanation for such a relationship lies in effects of canopy density on wind velocity and turbulence factors.
An impact penetrometer with cone point for measuring depth of soil freezing was developed. Use of a cone point (45°) with the base of the cone slightly larger than drive rod diameter virtually eliminated frictional resistance compared to a straight rod, making breakthrough from frozen into unfrozen soil much more distinct.
A diversion slot for sampling streamflow and suspended sediment off the end of a supercritical velocity flume was designed and tested. Laboratory tests indicated a tapered slot is necessary for constant proportional sampling. Theoretical consideration of the relationship of mean cross section flow velocity to mean velocity in center vertical of flume flow supports the hypothesis. From laboratory measurements approximate conformation of taper was calculated. There remains the practical problem of preventing debris from lodging on the slot in field operation.

(3569) WATERSHED MANAGEMENT RESEARCH, LARAMIE, WYOMING.

(b) Laboratory project.
(d) Field investigation; applied research.
(e) (1) To determine the effects of big sagebrush on total runoff from snowmelt, snow accumulation and storage pattern. Three high elevation sagebrush watersheds, 60 to 106 acres, in western Wyoming provide the study area. V-notch weirs gage the runoff, and suspended sediment samples are taken periodically. Snowpack is sampled along permanent transects and at random points. Precipitation is sampled by a network of recording and non-recording gages. (2) To determine the soil moisture withdrawal pattern under natural stands of big sagebrush, and the effect of sagebrush eradication on moisture withdrawal. Four 0.1 acre plots on an east and a west exposure have been established within high elevation sagebrush type in western Wyoming. Sagebrush on two of the plots on each exposure has been eradicated by spraying. Soil moisture samples are taken periodically to trace moisture withdrawal under each condition. (3) To evaluate the comparative efficiencies in terms of water stored in accumulated snow, of tandem 4-foot slatted snow fences erected at different spacing intervals on open windswept slopes in southeast Wyoming. (4) To evaluate the effects of inducing snow accumulation on a watershed through use of artificial barriers. Three experimental grassland-type drainages, 88 to 144 acres, have been selected for the study area in southeastern Wyoming where snow transport by wind commonly occurs. V-notch weirs are installed to measure water yield. Snowpack is sampled in areas of natural accumulation along permanent transects. Summer precipitation is sampled by a network of recording and non-recording gages. (5) To determine the basic hydrology of mountain bogs in Wyoming. The prevalence of small bogs along many perennial streams in the mountains of Wyoming has stimulated the posing of various questions concerning the hydrologic significance of these areas in relation to management techniques for water yield improvement. To provide information basic to advanced studies oriented toward this problem, hydrologic characteristics of a 3-acre bog were studied intensively during the summer of 1963 and will be continued for another field season. Observations of vegetation and physical conditions on the bog indicate possible relationships between various species and environmental conditions such as peat depth and surface-water depth.
(g) The chemical control of big sagebrush has become an important method of range improvement. To provide information basic to understanding results of a sagebrush watershed study presently underway, a plot study of the effect of sagebrush eradication by spraying on soil moisture withdrawal has been in progress since 1960. Results during 1964, the third year following spraying of the treated plots, indicate that soil moisture content as measured by neutron probe equipment at depths of 0-8 feet on 0.1 acre treated and untreated plots were significantly different (at the 0.90 confidence level) on one date near the commencement of snowmelt. Moisture levels were not significantly different between treatments on seven other sampling dates. There were significant differences between treatments when changes in soil moisture content between consecutive sampling dates were analyzed, particularly in late spring and late summer. Soil moisture accretion and depletion rates generally were greater on the untreated plots than on sprayed plots.
(h) "Inducing Snow Accumulation on High Windswept Plains in Southeastern Wyoming," H. W. Berndt, Jour. Soil & Water Conserv. 19(5): 196-198, illus.
"Snow Accumulation and Disappearance in

Lodgepole Pine Clearcut Blocks in Wyoming," H. W. Berndt, Jour. Forestry 63(2): 88-91, illus.

(3895) WATERSHED MANAGEMENT RESEARCH, ALPINE HYDROLOGIC LABORATORY.

(b) Laboratory project.
(d) Field investigations; basic research.
(e) To determine methods for increasing the amount of snow storage in alpine snowfields, and to develop control of evaporation and melting to insure maximum effective contribution to summer streamflow. To reduce snow avalanche danger by improved forecasting of hazard, and methods of stabilizing snowpacks on mountain slopes.
(g) A joint study with the SCS was initiated in October 1964 at Berthoud Pass, Colorado, to test a pressure pillow designed to record the weight of the snowpack. The circular pillow is made of rubber 12 feet in diameter and is filled with 300 gallons of methyl alcohol. The pressure of the snowpack on the pillow is continuously recorded on an F-35 water level recorder. Weekly increments on the pillow compared closely to snow board readings. However, short-term increments do not compare with snow board readings because of the diurnal effects of temperature on the alcohol in the standpipe.
(h) "Relative Importance of Weather Factors Creating Slab Avalanches in Colorado," Arthur Judson. West. Snow Conf. Proc. 32: 60-67, illus.
"Watershed Management in the Rocky Mountain Alpine and Subalpine Zones," M. Martinelli, Jr., Res. Note RM-36, 7 pp. illus.
"Influence of Gap Width Below a Vertical Snow Fence and the Size and Location of Lee Drift," M. Martinelli, Jr., Bul. I.S.A.H. 4(4): 48-57, illus.
"An Estimate of Summer Runoff From Alpine Snowfields," M. Martinelli, Jr., Jour. Soil & Water Conserv. 20(1): 24-26, illus.

(3896) WATERSHED MANAGEMENT RESEARCH, FORT COLLINS, COLORADO.

(b) Laboratory project.
(d) Field investigations; applied research.
(e) Field plot to observe the adaptability and growth characteristics of twenty-three tree shrub and twenty-six grass and forb species for further testing on critical erosion sites.
Research to find the influences of mechanical watershed rehabilitation measures on the microclimate and other site factors in the southern Rocky Mountains. To determine the effect of range conditions and related factors on sediment production and runoff on three mountain grassland watersheds in western Colorado. Range condition is being measured by means of 20 or more 3-step transects on each watershed. Ninety degree V-notch weirs are used to gage the watersheds which vary in size from 86 to 272 acres. Water samples are taken several times daily during snowmelt and periods of storm runoff for determination of suspended sediment; bedload is measured in the weir ponds.
(g) Costs of loose rock, wire bound, single fence and double fence rock check dams were determined for heights of dams of 2 and 6 feet and for gully bottom slopes of 5 to 15 percent. (a) The double fence type while more complicated had lowest installation. (b) Costs per cubic yard of structure decreased with increasing height of dam for all types. (c) Costs of gully control increased with increasing gradient. (d) Cost of gully control with double fence dams was less when 6-foot-high dams were used except on gradients of 5 percent. One prefabricated concrete check dam successfully passed a severe test when heavy runoff from snowmelt filled the catch basin to spillway crest with 4,000 cubic feet of sediment.
On three Black Mesa watersheds spring snowmelt averaged 1.95 inches on a lightly grazed watershed, 3.73 inches on a heavily grazed watershed, and 7.09 inches on a moderately grazed watershed. Correlating precipitation received (peak snowpack plus incoming precipitation during the snowmelt period) with spring runoff yield highly significant correlation coefficients. From 84 to 96 percent of the variation in runoff is explained by the precipitation variable and the standard errors are about 1 inch. Using spring and fall soil moisture measurements to compute water available for runoff does not yield improved correlation coefficients. In addition in multiple linear regressions relating peak snowpack, soil moisture recharge index and runoff the soil moisture variable does not contribute significantly to the regression.
Suspended sediment yields for the light and heavily grazed watersheds are quite similar (average 62 and 63 pounds per acre). Suspended sediment yields vary widely from year to year, but these are not in step with the small changes in ground cover index or bare soil hits obtained from transect data.
(h) "A Pavement Breaker Attachment to Drive Steel Fenceposts," Burchard H. Heede, Jour. Soil & Water Conserv. 19(5): 181-182, illus.
"Multipurpoase Prefabricated Concrete Check Dam," Burchard H. Heede, Res. Note RM-12, 16 pp., illus.

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, Southeastern Forest Experiment Station.

Inquiries concerning the following projects should be addressed to Dr. T. F. McLintock, Director, Southeastern Forest Experiment Station, P. O. Box 2570, Asheville, North Carolina 28802.

(380) WATER RESOURCE AND WATERSHED MANAGEMENT RESEARCH.

(b) Laboratory project. For general public use and information.
(d) Experimental; basic and applied research.
(e) Basic research into forest hydrologic processes governing the disposition of precipitation on forest lands of the southeastern United States. Demonstrations of several cover types and land management practices and their effect upon the amount, quality, and timing of water yield. Development of watershed management methods pertinent to the region including pilot testing, cooperative trials, and demonstrations of these methods. The work is centered at the 5,600-acre Coweeta Hydrologic Laboratory in the mountains of western North Carolina near Franklin. Located in the zone of maximum precipitation in the eastern United States, the research area receives an average of 80 inches of precipitation each year, mostly coming as rain in about 100 separate climatic events. The basic hydrologic gaging network at Coweeta includes 3 multiple, 12 unit, and 16 standby watersheds ranging from 4 acres to 8 square miles with continuous streamflow records up to 31 years in length; 12 recording and 11 standard rain gages; 1 evaporation pan; 1 metering anemometer; 2 recording pyrheliometers; and 1 hygrothermograph. A small laboratory provides facilities for routine soil moisture work and for turbidity measurement of streamflow. Soil moisture is measured in the field by 3 neutron scattering devices. Now largely inactive, a unit located near Union, South Carolina has been the site of considerable work on erosion control, comparative water use by different forest cover types, and soil moisture recharge in the piedmont.

Research studies include: (1) forest treatment effects on water yield; (2) the hydrology of mountain unit watersheds under several cover types; (3) movement and storage of soil water on steep slopes; (4) predicting soil moisture in steep terrain for hydrologic purposes; (5) morphology of the soil mantle related to water storage and release to streamflow; (6) incident solar radiation on forested and cleared slopes; (7) effect of forest cover and mountain physiography on the radiant energy balance; (8) rainfall interception by white pine; (9) mechanizing hydrologic data collection and processing; (10) stream diversion to deep soiled slopes to stabilize and increase late summer flows; and (11) pilot testing multiple use of forest for water, timber, recreation, and wildlife on a 365-acre watershed.

(f) Active; as individual studies are completed they are reported via technical reports and publications.

(g) A 22-acre catchment converted from hardwood to grass in 1959-1960 has continued to yield more water each year as the original grass cover declined in vigor. Water yield increases for the past 5 years have been 0, 0.9, 1.3, 4.6, and 6.9 inches as dry matter production of grass declined from about 3.5 to 1.5 tons per acre per year. Grass vigor was restored to the 1960 level by heavy fertilization in April 1965; the effect on water yield is not yet known. A computer method of separating a continuous streamflow hydrograph into quick and delayed flow components has been developed to facilitate study of streamflow behavior from small catchments. This technique employs a straight line of separation projected forward at beginning of hydrograph rise until it intersects the recession side of the storm hydrograph. All flow above the separation line is quick flow, all below it is delayed flow. Using this technique, 15 forested watersheds in eastern United States were separated into quick and delayed flow by computer and ranked according to mean precipitation, quick flow, and response factors quick flow/precipitation and quick flow/total water yield. The overriding prevalence of subsurface flow was indicated and other important relationships determined by this technique. Use of computer separated components of the hydrograph is continuing to develop new and better streamflow prediction methods and for analysis of forest treatment effects based on the climatic event. A clearcutting experiment on a 40-acre watershed was repeated after 23 years of regrowth since the first cut in 1940. The water yeild increase during the first year after the second cut was almost identical with results after the first cut, 14.7 and 14.6 inches respectively. A review of worldwide forest cutting experiments reveals that 100 percent reduction of forest vegetation may give water yield increases as large as 18 inches during the first year following treatment, but that most treatments give considerably less, depending primarily on climate and distribution of precipitation throughout the year.

(h) "Test of a Transpiration Inhibitor on a Forested Watershed," by P. E. Waggoner and J. D. Hewlett, Water Resources Research 1(3): 391-396, 1965.
"Canopy and Litter Interception of Rainfall by Hardwoods of Eastern United States," by J. D. Helvey and J. H. Patric, Water Resources Research 1(2): 193-206, 1965.
"Soil Water Absorption by Mountain and Piedmont Forests," by J. H. Patric, J. E. Douglass and J. D. Hewlett, Soil Science Society of America Proceedings 29: 303-308, 1965.
"Volumetric Calibration of Neutron Moisture Probes," by J. E. Douglass, presented at the Annual Meeting of Soil Science Society of America, Columbus, Ohio, Nov. 1-6, 1965.
"A Specific Application of the Energy Balance Approach to the Interpretation of Watershed Response," by L. W. Swift, Jr., presented at the Research Conference on Energy Balance, Washington, D. C., November 15-19, 1965.
"Some Effects on Soil Moisture of Midseason Forest Defoliation," by J. H. Patric and J. E. Douglass, presented at the Annual American Geophysical Union Meeting, Wash., D. C., April 19-22, 1965.
"Gaging Networks to Adequately Sample Rainfall Interception by Forests," by J. D. Helvey and J. H. Patric, presented at the International Symposium on Design of Hydrometerorological Networks, Quebec, Canada, June 15-22, 1965.
"$P = (T + I + E) + R + \Delta S$." by R. H. Stroud, Sport Fishing Institute Bulletin, No. 160: 4-7, March 1965.
"Effects of Species and Arrangement of Forests on Evapotranspiration," by J. E. Douglass, presented at the International Symposium on Forest Hydrology, Penn. State University, August 30-September 10, 1965.
"Forest Treatment Effects on Water Yield," by A. R. Hibbert, presented at the International Symposium on Forest Hydrology, Penn. State University, August 30-Sept. 10, 1965.
"Streamflow Data Processing Opportunities and Applications," by A. R. Hibbert and G. B. Cunningham, presented at the International Symposium on Forest Hydrology, Penn. State University, August 30-September 10, 1965.
"Factors Affecting the Response of Small Watersheds to Precipitation in Humid Areas," by J. D. Hewlett and A. R. Hibbert, presented at the International Symposium on Forest Hydrology, Penn. State University, Aug. 30-September 10, 1965.
"Research in Forest Hydrology at the Coweeta Hydrologic Laboratory," by J. E. Douglass, presented at the Clemson University Council on Hydrology, Clemson, South Carolina, March 17, 1965.

(5813) HYDROLOGY AND MANAGEMENT OF WETLAND SOILS.

(b) Laboratory project. For general public use and information.

(d) Experimental; applied and basic research.

(e) Project objective is to develop effective and reliable water control and soil management techniques through increased knowledge of the hydrology, soil properties and soil-water-plant relations of wetland forests. Research is conducted in wetland forests of various types throughout the southeastern control plain from Virginia through Florida. Accordingly, much of the program consists of water control and soil studies in cooperation with wood-using industries, and other wetland forest managers who have made or plan capital investments to manage the water on their land. In addition, research is also conducted on the Santee Experimental Forest, located 32 miles north of Charleston, which has a small soils laboratory and three stream gaging stations on watersheds of 400, 1,200, and 11,000 acres. Active studies include: (1) response of wet, slash pine flats to drainage; (2) relationships between soil and water conditions and their effect on tree growth on drained wetlands; (3) study of the water balance of selected wetland units; (4) precipitation-runoff relations on small forested watersheds in the coastal plain; (5) effects of understory control on soil moisture; and (6) moisture characteristics of representative wetland forest soils.

(f) Active; as individual studies are completed they are reported via technical reports and publications.

(g) Study of water tupelo, a valuable timber species, in a swamp along the Santee River in South Carolina, showed maximum diameter and height growth occurred where soil and site were poorly drained and subject to

long periods of wetness. It also appeared that seepage into the swamp from adjacent upland areas provides important supplemental moisture for this water-loving species. With increasing intensive management of water levels in lowland swamps, close attention must be paid to their control if water tupelo is to be perpetuated on these sites. On the other hand, large-scale drainage programs underway in other wetland forests are being evaluated to aid forest managers in determining the desirability of drainage to favor other species. Changes in soil productivity were assessed by measuring growth rates of pines before and after drainage on wet, sandy pinelands in northwest Florida. Comparison of observed increments with expected showed soil drainage has resulted in increased site productivity. Surveys have shown that, under certain conditions, increased site productivity for some southern pines by controlled drainage could almost double pulpwood yields from certain wet pinelands in the southeastern coastal plain.

(h) "A Method for Sealing Soil Moisture Access Tubes," by Cortland E. Young, Jr. and James E. Henderson, Soil Science, Vol. 99 (3) : 213-214. 1965.
"Woodland Drainage in the Southeast," by Ralph A. Klawitter, Jour. Soil and Water Cons. Vol. 20(4) : 181-182. 1965.
"Forest Drainage Research in the Coastal Plain," by Ralph A. Klawitter and Cortland E. Young, Jr., Jour. Irr. and Drain. Div., Amer. Soc. Civil Engineers, Vol. 91 (IR3), Proc. Paper 4456, Sept. 1965, pp 1-7.

U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE, Southern Forest Experiment Station.

Inquiries concerning the following projects should be addressed to Mr. W. M. Zillgitt, Director, Southern Forest Experiment Station, T-10210 Federal Bldg., 701 Loyola Avenue, New Orleans, Louisiana 70113.

(2914) WATERSHED MANAGEMENT RESEARCH, OXFORD, MISSISSIPPI.

(b) Laboratory project, in cooperation with Soil Conservation Service, Agricultural Research Service, and University of Mississippi.
(d) Field investigation of runoff and erosion from small experimental watersheds on forest and potential forest lands; basic and applied research.
(e) Twelve small natural headwater catchments, two to four acres each, were installed in batteries of three to determine runoff and erosion from old fields, depleted upland hardwoods, pine plantations, and mature upland pine-hardwoods. Four of the six old field and depleted hardwood watersheds were planted to pine in 1964, after site preparation which included burning. Treatments on the pine and pine hardwoods are deferred until after a suitable calibration period. Five additional watersheds in pine plantations are being calibrated prior to testing effects of timber harvesting on runoff, erosion, and sediment flows. Related studies include restoration of depleted watersheds and plant-soil-water relationships.
(f) Data collection on all watersheds is continuing.
(g) Runoff and erosion appear to have increased moderately after prescribed burning.
(h) "Diameter Growth and Phenology of Trees on Sites with High Water Tables," D. C. McClurkin. U. S. Forest Serv. Res. Note SO-22, 1965.
"Site Index Predictions for Pines in Mississippi," D.C. McClurkin and R.R. Covell. U. S. Forest Service Res. Paper SO-15, 9 pp., illus. 1965.
"Estimating Foliage on Loblolly Pine," T. L. Rogerson. U.S. Forest Serv. Res. Note SO-16, 3 pp., illus. 1964.
"Sediment Yields from Small Watersheds Under Various Land Uses and Forest Covers," S.J. Ursic and F.E. Dendy. Proceedings of the Federal Inter-Agency Sedimentation Conference, 1963, pp., 47-52, illus. and USDA Miscellaneous Publication No. 970, June 1965.

(3225) WATERSHED MANAGEMENT RESEARCH, HARRISON, ARKANSAS.

(b) Laboratory project.
(d) Field investigations on effects of forest type and condition on timing of flows in streams of the Ozark-Ouachita uplands; basic and applied research.
(e) Runoff and sediment from three small mountain watersheds are measured currently. H-flumes and stage recorders were installed on eight additional watersheds ranging from 2 to 40 acres. Cover conditions will be changed after an adequate calibration period. Related studies of soil moisture and erosion are continuing.
(f) Records of runoff and sediment collected currently.

CORPS OF ENGINEERS, U. S. ARMY, Coastal Engineering Research Center.

Inquiries concerning the following projects should be addressed to the Director, Coastal Engineering Research Center, 5201 Little Falls Road, N. W., Washington, D. C. 20016.

(181) EQUILIBRIUM PROFILE OF BEACHES AND STUDY OF MODEL SCALE EFFECTS.

(b) Laboratory project.
(d) Experimental; basic research.
(e) Equilibrium beach profiles will be determined experimentally for waves up to 6 feet in height in a prototype tank; the waves will be modeled at a 1 to 10 scale in small laboratory tanks (to determine scale effects) for various median diameter and specific gravity sediments.
(g) Analysis is underway.

(660) OBSERVED WAVE CHARACTERISTICS.

(b) Laboratory and field project.
(d) Field investigation; basic research.
(e) To secure a more thorough knowledge of the characteristics of ocean waves. Wave gages have been installed in a number of locations in coastal waters. These wave gages provide a pen and ink strip chart recording and also magnetic tape recordings. The records from the paper chart records are analyzed for significant wave height and wave period. The records from the magnetic tape recorders are analyzed to provide a spectral analysis of wave frequency (or period) versus: (1) Linear average wave height; (2) squared average wave height; and (3) peak wave height.
(g) Additional wave recording stations were installed at the U. S. Coast Guard Light Tower, Frying Pan Shoals, N. C., and Pleasure Pier, Galveston, Texas. The previously planned installation of 3 wave sensors at the Buzzards Bay Light Tower (Coast Guard) has been re-scheduled for installation on a new Coast Guard Light Tower at the entrance to Chesapeake Bay. These gages will used to obtain pressure records at different water depths. This data will be compared to surface waves as recorded by a surface wave gage. Additional wave recording stations are planned to be installed at: (a) Lake Worth, Florida (b) Galveston, Texas (18 miles offshore on oil production platform) (c) U. S. Coast Guard Light Tower at entrance to Chesapeake Bay. Two wave gages are to be installed in Chesapeake Bay (Chesapeake Beach, Md. and Tilghman Island) for observation of wave characteristics relative to erosion processes

in this area.

(975) METHODS OF BY-PASSING SAND PAST INLETS.

(b) Laboratory project.
(d) Field investigation; applied research.
(e) To study methods and requirements for pumping sand past inlets and to determine the applicability of the methods in stabilization of beaches adjacent to inlets. Data are being procured on the effect to the shoreline of sand by-passing operations at Port Hueneme, California and Lake Worth Inlet, Fla. and on the effect to the shoreline of a new harbor constructed at Ventura, California. This latter harbor involves an offshore detached breakwater along with entrance jetties to the new harbor. Data at the three locations include periodic hydrographic surveys south and north of the inlet, wave data, sand samples, detailed records of pumping operations, and detailed records of entrance channel maintenance. A general study is being made of the possibility of adapting commercial instruments utilizing a radioactive source to the discharge line to measure quantity of material pumped in by-passing operations.

(976) ESTABLISHMENT OF CRITERIA FOR CONSTRUCTION OF ARTIFICIAL BEACHES.

(b) Laboratory project.
(d) Theoretical; applied research.
(e) To develop criteria for construction of beaches by artificial means. The present continuing phase of this general study involves the measurement of a natural beach slope and attempts to determine its response to the forces normally incident upon the shore such as wave height and period, angle of wave approach, tide, and direction and magnitude of littoral current. By statistical methods the relative importance of the forces or combinations of forces may be evaluated.
(g) Computing machine techniques have been applied to the statistical evaluation of the importance of the forces and of the parameters.

(977) DEVELOPMENT OF WAVE HEIGHT AND WAVE DIRECTION GAGES.

(b) Laboratory project.
(d) Experimental; development.
(g) An ultrasonic flowmeter was checked in the laboratory large wave tank as a wave direction gage. Data shows good promise of adapting the flowmeter to function as a wave direction gage. Tests of the flowmeter were conducted at Atlantic City, N. J. in March of 1965. Results of these tests were somewhat encouraging. Results of the tests to date were presented in a paper at the ISA Oceanographic Instrumentation Conference, Miami, Florida, held 21 April 1965. Further tests in both laboratory and field are planned.
(h) "An Ocean Wave Direction Gage," Leo C. Williams, Marine Sciences Instrumentation, Volume 3, 16 pp., January 1966.

(2190) STUDY OF EFFECT OF A GROIN ON THE RATE OF LITTORAL MOVEMENT.

(b) Laboratory project.
(d) Experimental; basic research.
(e) To study the effect of groins on the rate of littoral drift passing a groin system. Initial tests consist of waves generated at a 30-degree angle to the sand beach with measurement of material movement being made at the downdrift end. The tests planned for the immediate future, as have the current season tests, will continue to emphasize the task of collecting and establishing reliable calibration data on the relationship between the littoral transport rate and the wave characteristics. These generalized (not to specific model scale) studies are being made in the Shore Processes Test Basin of the Coastal Engineering Research Center.
(g) Littoral transport tests in the Shore Processes Test Basin continue. Training and splitter walls have been removed and a rubble absorber beach has been installed. The new setup is arranged to permit generation of a wave crest approximately 80 feet long which approaches the toe of the test slope at a 30 degree angle, shoals and refracts and finally impinges along a test shoreline 92 feet long. The downdrift part of the test beach is a concrete slab (1 on 10 slope) about 30 feet long including a recessed trap for catching sand drift caused by the wave ation. The updrift section of the test area is also a concrete slab. The test beach is 0.20 mm sand, is about 42 feet long, and lies between the two concrete slabs.
An initial test of this new sand beach setup was made with waves at T = 3.75 sec. for a duration of 40 hours. At the end of 27 hours a large cut had eroded just updrift of the sand trap. Wave diffraction analysis of the test setup showed that waves diffracting from both the updrift and downdrift ends of the wave generator pusher blades concentrated wave energy in the area of the eroded cut. At the end of 27 hours of test, the downdrift generator was turned off so that during the remaining 13 hours of the test a wave crest 60 feet in length was generated in contrast to an 80-foot crest length up to this time. As the tests continued beyond 27 hours the eroded cut filled in so that at the end of 35 hours the shoreline was essentially straight from trap to feeder. The shoreline remained essentially straight throughout the remainder of the test, ending at 40 hours total test time. Turning off the downdrift wave generator after 27 hours testing had the effect of shifting the K' line (attributable to the downdrift wave diffraction) a distance of approximately 23 feet updrift along the shoreline. The main result of this updrift shift of wave diffraction was a redistribution of the wave energy reaching the shore. This redistribution resulted in less energy reaching the previously eroded area immediately updrift of the trap and more energy reaching the shore in the area of the feeder, with the general result of a more uniformly distributed energy along the shore from trap to feeder. This result from the test is based on a preliminary analysis of the data. A more comprehensive analysis is in progress but it is not expected to change the general results and conclusion given here.

(2192) REGIONAL STUDIES OF THE ATLANTIC COAST OF NEW JERSEY; AND THE DELAWARE-MARYLAND-VIRGINIA SHORE LINE FROM CAPE HENLOPEN TO CAPE CHARLES.

(b) Laboratory project.
(d) Field investigations; basic research.
(e) To compile all existing data pertinent to shore processes on a regional scale. Reports to consist of three chapters: geomorphology and shoreline histories, littoral forces, and littoral materials. Subject matter to include physiography, geological development of the shore region, sources of littoral material, waves, tides or water level fluctuations, current physical characteristics of the littoral materials, interrelation of sedimentary properties, relation of properties of littoral materials to position in the littoral zone, and changes in shoreline configuration.
(g) The Delaware-Maryland-Virginia shoreline from Cape Henlopen to Cape Charles is currently under study. Data compilation for this reach is essentially completed and the report is under preparation.

(2193) SHORE PROTECTION PLANNING AND DESIGN.

(b) Laboratory project.

(d) Design.
(e) To supplement and revise the Coastal Engineering Research Center's (formerly Beach Erosion Board) Technical Report No. 4, "Shore Protection Planning and Design" as new data and techniques are developed for use in the solution of coastal engineering problems.
(g) The supply of the 1961 edition of the report has been depleted. It is anticipated that the new edition will be available in the Spring of 1966.

(2195) RE-EXAMINATION OF ARTIFICALLY NOURISHED AND CONSTRUCTED BEACHES.

(b) Laboratory project.
(d) Field investigation; applied research.
(e) To study the behavior of beach fills placed to restore or nourish a beach sector and the effect of the fill on adjacent shores. A selected number of beach fills are being re-examined.
(g) Follow-up reports prepared but not yet published on beach fill projects at Sherwood Island State Park, Conn., and Presque Isle Penninsula, Pa. Other reports are in preparation for beach fill projects at Hammonassett Beach State Park, Conn., and Key West, Fla., and sand bypassing and beach nourishment operations at Channel Islands Harbor - Port Hueneme, Calif. Arrangements were made to collect follow-up data at an inlet bypassing and feeder beach nourishment project on Long Island, N. Y., groin construction on Long Island, N. Y., and protective beach and dune fill projects in North Carolina.
(h) "Behavior of Beach Fill and Borrow Area of Seaside Park, Bridgeport, Conn.," W. H. Vesper, Tech. Memo. No. 11 of CERC, 14 pp., Feb. 1965. Limited number of copies available for free distribution upon request to Director, CERC, 5201 Little Falls Rd., N. W. Washington, D. C. 20016.

(2660) STUDY OF QUANTITY OF SEDIMENT IN SUSPENSION IN THE SURF ZONE (INCLUDING TEMPERATURE EFFECTS).

(b) Laboratory project.
(d) Experimental; basic research.
(e) To determine the relationship between wave, water, and sand characteristics, and the amount of material maintained in suspension and, hence, available for longshore transport by currents.
(g) Analysis of suspended sand samples collected at Nags Head, N. C. continues. An additional 415 suspended samples were collected in May 1965 at Ventnor, N. J. Analysis of these samples and related data and observations of the shore processes are in progress. Moment parameters from the samples at each location are being digitized for analysis through a computer program which is now operational. In addition to the suspended sand samples, data at Ventnor, N. J. included wave height, wave breaker angles, bottom soundings along the pier, and a few observations of littoral current velocity. When the analysis of these samples are completed the results will be published in the CERC Technical Memoranda series.
(h) "A Tractor-Mounted Suspended Sand Sampler," John C. Fairchild, Shore and Beach, Vol. 33, No. 2, pp. 31-34, October 1965.

(2661) WAVE RUN-UP ON SHORE STRUCTURES.

(b) Laboratory project.
(d) Experimental; design.
(e) Wave run-up is determined experimentally for various waves for different types of shore structures. Effect of both structure roughness and permeability is being investigated.
(g) Analysis of some field measurements of run-up on a beach obtained in an attempt to delineate the run-up distribution function is underway.

(3228) MODEL TESTS OF WAVE SETUP ON BEACHES.

(b) Laboratory project.
(d) Experimental; basic research.
(e) Measurement of the mean water level of shoaling waves on beaches using damped piezometers buried in the beach. Study is being made in order to (1) Check existing theory for setup offshore of breaking; (2) estimate rate of energy supply required to maintain setup in surf zone; and (3) provide engineering criteria for design of coastal structures.
(g) Setup measurements on concrete beaches with slopes of 0.05, 0.10, and 0.20 indicate that the mean water level is depressed below the still water level in the shoaling zone offshore of the breaking point. The mean water level rises above the still water level at, or slightly shoreward of the breaking point.

(3897) RADIOACTIVE TRACERS FOR BEACH STUDIES.

(b) Laboratory project.
(d) Experimental; research.
(e) (1) Studies of possible field sites for the application of radioactive and/or fluorescent tracers are being continued. (2) Further tests using fluorescent tracers were made repeating 2 runs to estimate sand movement on a flat bed under wave action. These tests at large scale repeat small scale tests made by the Hydraulics Research Station in England. (3) An analytic study of waiting times for probablistic motion of tracer particles was made, and a model developed.
(g) A selected bibliography on tracers was published in the Bulletin of the Coastal Engineering Research Center, Vol. I, 1964.
(h) "A Theoretical Distribution of Waiting Times for Tracer Particles on a Sand Bed," C. J. Galvin, Jr., Bulletin, Coastal Engineering Research Center, Vol. I, 1964.

(4760) EXPERIMENTAL STUDY OF DUNE BUILDING WITH SAND FENCES.

(b) Laboratory project.
(d) Experimental; design.
(e) The experimental study consists of the construction of various types and arrangements of sand fences to determine the fence type and arrangement most effective in building a dune by trapping and holding wind-blown sand. Slat-type snow fencing and locally constructed brush fencing have been used in straight, straight-with-side spurs, and zigzag configurations. The study is being conducted on the Outer Banks of North Carolina between Cape Hatteras and Cape Lookout.
(g) Multiple sand fences have been used to construct a dune 8 feet high and 80 feet in base width in 3 years. Vegetation (American Beach Grass) has been planted in an attempt to grow a grass stabilized dune.

(4762) CORRELATION OF STORM WAVE ATTACK AND BEACH EROSION.

(b) Laboratory project.
(d) Field and office investigation to develop quantitative correlation between storm violence and shore erosion.
(e) Repetitive profiles are taken at selected beach areas. The storm wave action between surveys is analyzed and correlations between the wave action and observed profile changes are established. Repetitive profile lines were established in September 1962 at nine locations between Delaware Bay and Cape Cod. These profiles were re-surveyed at weekly and bi-weekly intervals. The resurvey interval now is 4 to 6 weeks. Storm wave action is measured by the Coastal Engineering Research Center ocean wave gages and storm surges by U.S.C. & G.S. tide gages.
(h) An article entitled "The Study of Pilot Beaches in the New England Area for the Improvement of Coastal Storm Warnings," John M.

Darling is being prepared for publication in a forthcoming CERC Bulletin.

(4763) OFFSHORE SAND SOURCES.

(b) Laboratory project.
(d) Field investigation; applied research.
(e) Exploration along the Atlantic Coast of Fla. by geophysical (sonic) methods and by shallow borings is scheduled for completion by Dec. 31, 1965. Further testing of the pump-ashore system is planned for 1966.

(5079) WAVE HEIGHT PREDICTION FOR WAVE MAKERS IN SHALLOW WATER.

(b) Laboratory project.
(d) Theoretical and experimental; basic research.
(e) By equating the volume of water displaced in half a period by a displacement-type wave maker to the volume of wa.er raised above mean water level in a sine-shaped wave, a simple relation results for shallow water waves which gives wave height as a function of wave length, wave maker stroke, and wave maker geometry. For shallow water, this relation agrees with hydrodynamic theory for piston-type and flap-type wave makers, and with published and unpublished data for waves generated by displacement-type wave makers in absolute water depths ranging from 0.5 feet to 13 feet.
(f) Suspended.
(g) Data from a flap-type wave generator support the approximate and the complete theories for wave height prediction.

(5325) FIELD MEASUREMENT OF LONGSHORE CURRENT VELOCITY.

(b) Laboratory project.
(d) Field investigation.
(e) Longshore current velocity was measured by timing the travel of water filled balloons in the surf on the beach near Nags Head, N. C.; breaker angles were measured with a Brunton compass, by triangulation and by measuring the speeds of the crest and plunge point of the breaking wave; beach slope was obtained from profiles through the surf zone; and wave heights and periods were measured from wave gage records.
(f) Suspended.
(g) For the five sets of data obtained, longshore current velocity is roughly predicted by two of the several equations available to predict longshore current velocity.
(h) "Longshore Currents at Nags Head, North Carolina" (abstract), C. J. Galvin and R. P. Savage, Trans. A.G.U., March 1965.

(5326) RESONANT EDGE WAVES ON LABORATORY BEACHES.

(b) Laboratory project.
(d) Experimental.
(e) An unusual standing wave in the runup on laboratory beaches is under study. The combinations of slope, period, breaker type, standing wave length, and resonant amplification are being measured in order to describe the phenomena and to understand its affect on laboratory and natural beaches.
(g) The run-up from lightly plunging or surging waves occasionally resonates between the sidewalls of a wave tank 1.5 ft. wide. The resonant period is twice the period of the waves reaching the beach. Whenever the resonance is present on the plane beach, it always has a resonant period, beach slope, and tank width (1.5') which fits the equation for resonant edge waves. When this resonance occurs on a sand beach 40 feet wide, it occasionally produces cusps whose spacing is one-half the edge wave length. The width of the sand beach is not necessarily an integral multiple of the cusp spacing.
(h) "Resonant Edge Waves on Laboratory Beaches" (abstract), C. J. Galvin, Trans. A.G.U., March 1965.

(5327) THE EFFECT OF SECONDARY WAVES ON WAVE RUN-UP.

(b) Laboratory project.
(d) Experimental; basic research.
(e) This project was begun to learn the cause of certain pecularities in the variability of wave run-up with wave period and height on steep slopes. Run-up tests were made in a 2' x 1-1/2' x 72' wave tank on smooth slopes installed at various locations along the tank. Slopes varied from 1:15 to 1:6. Each slope was tested in three water depths (0.65, 0.90, and 1.25 feet) in an attempt to determine the effect of water depth on the wave run-up.
(g) It was learned from an analysis of the tests that a strong correlation exists relating the phase angle between the primary and secondary waves and the height of wave run-up. The run-up for a given wave condition is a maximum if the primary and secondary waves are 180° out of phase (i.e.if the secondary wave is in the trough of the primary wave) and a minimum when the two waves are in phase. This variable phase relationship of primary and secondary waves causes the run-up to vary up to a factor of 3 for steep slopes. For flatter slopes (about 1:6) this effect had essentially disappeared. Parameters useful in correlating run-up to wave characteristics are currently under study.

(5328) CHARACTERISTICS OF A PLUNGING BREAKER.

(b) Laboratory project.
(d) Experimental and theoretical, basic research.
(e) The wave height, mean water depth, and distance traveled in the breaking process are being measured for waves which break by plunging on a plane concrete beach in a wave tank 96 feet long and 1.5 feet wide. Parallel wire resistance wave gages measure the wave heights, damped piezometers buried flush with the beach surface measure the mean water level and photographs record the distance traveled in breaking. This study is undertaken to increase knowledge of the breaking process, to relate the energy flux of the incoming waves to the resulting wave setup, and to provide engineering criteria for the design of coastal structures.
(g) The horizontal distance between the observed breaking point and the point where the wave crest touches down in the trough before it breaks was measured from movies of plunging waves. On laboratory beaches this distance decreases as the beach slope increases, the ratio of this distance to breaker height averaging 3.5 for 100 waves on a 0.05 slope, 3.2 for 102 waves on a 0.10 slope, and 1.9 for 43 waves on a 0.20 slope.

(5834) LONGSHORE CURRENT VELOCITY REVIEW.

(b) Laboratory project.
(d) Review of experimental, theoretical and field investigations.
(e) A search of the literature was made to collect all available data on longshore currents and all published relations for predicting longshore current velocity, for comparison purposes.
(g) Eight equations and 502 sets of data were obtained from the literature. All data were used in all applicable equations and the predicted and measured velocities compared. No single equation predicted well for more than a limited part of the data.

(5835) ORIGIN AND TRANSMISSION OF SECONDARY WAVES.

(b) Laboratory project.
(d) Experimental; basic research.
(e) This project has as its purpose the study of the origin and transmission of secondary waves. Tests have been conducted to determine the effect of scale with a length ratio of 1:10 and 1:20. Tests have been made of the effect of the type of generator on the

formation of these waves and of the ability of energy absorbers to damp-out the secondary waves. Current study is directed toward the breakdown of the unstable wave train into a sum of stable components and wave records have been collected in the CERC 635' tank for this purpose. In these tests wave records were taken once each foot for 400' along the tank and a generator driven timing mechanism was used so that the water surface is known as a function of both time and distance along the tank. A water depth of 2' was used so that a relatively large length to depth ratio could be obtained.

(g) The results of the scale tests indicated that a Froudian Scale ratio is appropriate.

(5836) FEASIBILITY STUDY OF A MODEL WAVE-POWERED SAND DREDGE.

(b) Laboratory project.
(d) Experimental investigation.
(e) The model of a wave-powered sand dredge consisted of a float-supported vertical array of check valves. The purpose of these tests was to determine if this device could use the wave energy present to bring sand through the nearshore and surf zones in sufficient quantities to be useful in beach replenishment operations. The tests were conducted on a 1:15 scale in a 65 foot long tank using waves having prototype periods of 5, 9, and 13 seconds. The dredge was floated in the flume (with the valve array parallel to the impinging wave crests) over an equilibrium profile having an average 1 on 10 slope, with the bottom material composed of crushed anthracite having an average specific gravity of 1.52 and a median diameter of .2 mm. The dredge was placed at various locations along the length of the profile and its valve array was set so that either 1, 2, 3, or 4 valves operated, with the deepest valve being close to the bottom surface. Tests were made in which the dredge remained in a single location for the duration of a run, lasting about 13 minutes, as well as where the dredge was moved, by means of a winch and cable system, some distance along the length of the flume at a rate of .2 feet per 5 minutes of wave action. A total of 27 runs was completed.
(f) Completed.
(g) The results of the test series indicate that the device is not suitable for use as a dredge in its present form and actually increased the erosion rate by flushing far greater volumes of coal downslope on the seaward side of the dredge than were flushed through the valve array on the upslope side of the dredge.

(5837) NEW BERN STONE STABILITY TESTS.

(b) Laboratory project.
(d) Experimental; applied research.
(e) A rubble breakwater with an armor layer of clayey limestone on a 1 on 1 1/2 slope is being tested for stability with non-breaking waves. Stone weights for the armor layer vary from 230 to 430 pounds and tests are being made with wave periods of 3.75, 5.60, and 7.87 seconds. Wave heights used vary from 2 to 4.5 feet. The tests are being conducted in a wave tank 635 feet long, 20 feet deep, and 15 feet wide.

(5838) RAYLEIGH DISC WAVE DIRECTION GAGE.

(b) Laboratory project.
(d) Experimental; development.
(e) This project is being undertaken in an attempt to evaluate the feasibility of utilizing a Rayleigh Disc as a wave direction gage. A dampening chamber with two fixed and two moving vanes, mounted on the shaft with the disc, is employed to reduce the instantaneous response of the disc to changes in the flow field and thereby to cause the disc to respond only to changes in the mean of the directional velocity field. The gage has been tested in unidirectional and bidirectional wave fields.
(g) Indications are that the Rayleigh Disc wave direction gage will indicate the direction of simple wave trains and the mean of the directions of mixed wave trains - the accuracy of the indication being a function of the torques involved. The Rayleigh Disc gage is subjected to four distinct torques; a primary moment induced by the velocity field, a periodic torque induced by secondary flows, a damping torque, which is a function of the wave configuration, and a friction torque, caused by the shaft bearings. When the potential friction torque exceeds the primary moment, the gage does not respond to the waves and indicate wave direction; hence there are sufficiently small waves whose direction is not to be indicated by the gage. As the wave energy increases and the periodic torque increases, the damping mechanism has been found to be relatively effective in reducing the motion resulting from the periodic torque, but for sufficiently large waves, the motion of the disc becomes quite erratic and the direction of the wave train is only poorly indicated.
(h) Memorandum for Record, Subject: The Rayleigh Disc as a Wave Direction Gage.

U. S. ARMY ENGINEER DIVISION, NORTH PACIFIC, Division Hydraulic Laboratory.

Inquiries concerning the following projects should be addressed to the Director, Division Hydraulic Laboratory, U. S. Army Engineer Division, North Pacific, Corps of Engineers, Bonneville, Oregon 97008.

(1462) GENERAL MODEL STUDY OF THE DALLES DAM, COLUMBIA RIVER, OREGON AND WASHINGTON.

(b) Department of the Army, Corps of Engineers, Portland District, Portland Oregon.
(d) Experimental; for design.
(e) A 1:80-scale, undistorted, fixed bed model reproduces 2.7 miles of the Columbia River at the dam site. The original layout consisted of a circular-arc, 30-bay spillway, a 22-unit powerhouse, an 86- by 675-foot navigation lock, a rock-fill non-overflow section, and facilities for passing fish over the dam. Maximum head is 90 feet. Revised layout has a straight 23-bay spillway. Purposes are to study the structures alignment and flow conditions affecting navigation, power generation, cofferdam placement, rockfill dam construction, and fish passage.
(f) Completed.
(g) Four major layout plans were tested and the most economical plan that effected satisfactory hydraulic conditions was selected. Tests indicated ability to reduce length of spillway and to reduce forebay excavation by 30 feet. Data relative to water-surface elevations and velocities in the tailrace, and the effects of excess fill placed in the forebay have been obtained. Flow conditions during various stages of construction and with the project completed have been observed with special attention given to navigation and fish migration problems.
(h) "The Dalles Dam, Columbia River, Oregon and Washington," U. S. Army Engineer Division Hydraulic Laboratory, Bonneville, Oregon. Tech. Report No. 52-1, June 1965. (Available on loan). Final report covering tests in general (1462), and powerhouse intake models (1729), respectively).

(1464) MODEL STUDY OF ROCK FILL, THE DALLES DAM, COLUMBIA RIVER, OREGON AND WASHINGTON.

(b) U. S. Army Engineer District, Portland, Corps of Engineers, Portland, Ore.
(d) Experimental; for design.
(e) The 1:40-scale model of the 500-foot-wide closure section of the rockfill nonoverflow section of the Dalles Dam included portions of the river channel upstream and downstream

therefrom and the eight partially completed units at the upstream end of the powerhouse through which the river flow was diverted as the closure fill was constructed. A study of the rock sizes and placement procedure required to construct the fill at a river flow of 200,000 cfs and for stability of 300,000 cfs was made.

(f) Completed.

(g) The fill has been constructed by placing quarry-run rock (1000 lb and less) in 10-foot lifts or by end-dumping from the Oregon shore at river discharges of 200,000 cfs and less. Owing to the faster placing program possible with the end-dump procedure, studies were concentrated on this method of closure. The 1000 lb and smaller material was placed without loss in bottom velocities of 17 fps and surface velocities of 24 fps. The higher velocities caused some movement of material but owing to the 250-foot width of fill the material did not move beyond the confines of the fill. Flow data were obtained during the prototype closure for correlation with model data. A model check of three stages of the prototype closure showed good agreement of flow conditions.

(h) "Closure Fill and Skeleton Powerhouse Units, The Dalles Dam, Columbia River, Oregon and Washington," U. S. Army Engineer Division Hydraulic Laboratory, Bonneville, Oregon. Tech. Report No. 57-1, May 1965. (Available on loan). Final report covering tests in rock fill and powerhouse skeleton unit models (1464 and 1975, respectively).

(1466) MODEL STUDY OF THE DALLES DAM NAVIGATION LOCK, COLUMBIA RIVER, OREGON AND WASHINGTON.

(b) U. S. Army Engineer District, Portland, Corps of Engineers, Portland. Oregon.

(d) Experimental; for design.

(e) A 1:25-scale model reproduced the 86- by 675-ft lock chamber, its culvert systems, and portions of the upstream and downstream approach channels. Studies were made of various types of filling and emptying systems to determine the most advantageous design from the standpoints of rate of operations during a maximum lift of 90 ft, degree of turbulence, and economy. The proposed plans included lateral culverts within the lock chamber combined with several locations of intake ports, longitudinal culverts, and outlet ports.

(f) Completed.

(g) Designs were selected for all features of the lock. A valve-opening schedule of 4 min resulted in a filling time of 12.5 min and a maximum hawser force of 8 tons, without supplemental use of the upstream lock tainter gate. The lock emptied in 16 min. Studies have shown that staggered valve operation will reduce maximum hawser forces. Operational tests of the final design were made with several heads and barge positions using a 4-min valve-opening schedule. One combination of head and barge position corresponded to conditions existing during prototype tests performed in December 1957.

(h) "Navigation Lock, The Dalles Dam, Oregon and Washington," U. S. Army Engineer Division Hydraulic Laboratory, Bonneville, Oregon. Tech. Report No. 56-1. June 1965 (Available on loan). Final report covering the test results.

(1728) MODEL STUDY OF THE DALLES DAM FISH LADDERS, COLUMBIA RIVER, OREGON AND WASHINGTON.

(b) U. S. Army Engineer District, Portland, Corps of Engineers, Portland, Oregon.

(d) Experimental; for design.

(e) Experiences with fish facilities at existing large dams, together with results of tests on seven hydraulic models and other test apparatus, were used to solve the complex problems associated with passing migrant fish upstream at this huge project.

(f) Completed.

(g) The possible effects of the following on flow conditions affecting upstream passage of salmonids were investigated: length of spillway training walls adjacent to fishway entrances, adequacy of proposed quantities of attraction flows from all fishway entrances, fish ladder operating characteristics for alternative weir crest designs, distribution of auxiliary attraction water from diffusion chambers in powerhouse fish collection system, scheduled sequences of project construction, and different methods of project operation. Pressure tests with live fingerling salmon showed that few young fish would be killed by rapid decompression as they pass under the spillway gates.

(h) "Fish Facilities, The Dalles Dam, Columbia River, Oregon and Washington," U. S. Army Engineer Division Hydraulic Laboratory Bonneville, Oregon Tech Report No. 61-1. June 1965. (Available on loan). Final report covering tests of fish facilities in the general (1462), spillway (1465), powerhouse skeleton unit (1975), rockfill closure (1464), fish ladder (1778), powerhouse fishway diffuser (1974) and fish ladder surge (2196) models.

(2665) MODEL STUDY OF ICE HARBOR POWERHOUSE INTAKE GATES, SNAKE RIVER, WASHINGTON.

(b) U. S. Army Engineer Distric, Portland, Corps of Engineers, Portland, Oregon.

(d) Experimental; for design.

(e) A 1:25-scale model included a typical main powerhouse unit with intake, scroll case, emergency closure gates, and gate slots. The middle closure gate was reproduced in plastic and was operated at simulated prototype speeds by means of a synchronous electric motor. Correlation of model-prototype downpull forces on Chief Joseph powerhouse intake gates was made as a basis for evaluating tests of intake gates for Ice Harbor powerhouse. Hydraulic downpull forces on a moving gate were measured electronically Forces on a stationary gate were computed from pressures at piezometers on the lip, bottom beam, and top seal.

(f) Completed.

(g) Model-protype correlation of downpull forces on Chief Joseph powerhouse intake was satisfactory. Maximum hydraulic downpull on the lip and bottom beam was about 94 per cent of the total downpull on each gate design that was tested for Ice Harbor. Maximum downpull on the gate was reduced by extending the gate lip from 12 to 20 in. and by increasing the bottom taper (no lip) from 30 to 45 degrees.

(h) "Hydraulic Downpull Forces on Powerhouse Intake Gates, Ice Harbor Dam, Snake River, Washington," U. S. Army Engineer Division Hydraulic Laboratory, Bonneville, Oregon. Tech. Report No. 87-1. November 1965. (Available on loan). Final report covering the tests results.

(4504) GENERAL MODEL STUDY OF LITTLE GOOSE LOCK AND DAM, SNAKE RIVER, WASHINGTON.

(b) U. S. Army Engineer District, Walla, Corps of Engineers, Walla Walla, Washington.

(d) Experimental; for design.

(e) A fixed-bed model constructed to an undistorted scale ratio of 1:100 reproduces the Snake River bed and pertinent overbank topography between river miles 68.3 and 71.6. The dam axis is at mile 70.3. The original layout consists of a straight, 8-bay, gravity-type spillway controlled by 50- by 59-ft tainter gates, a powerhouse for six Kaplan turbines (initial installation three units), an 86- by 675-ft navigation lock having a maximum lift of 101 ft, concrete nonoverflow sections, rockfill abutments,

and facilities for passing migratory fish over the dam. The initial power installation will produce 405,000 kilowatts. Purposes of the model are to check the structures layout and flow conditions affecting cofferdam placement, power generation, navigation, and fish passage.

(g) Following verification and tests of various cofferdam plans, alternative structural arrangements and excavation amounts adjacent to the structures were studied. Operational tests of the final design structures and excavation plans are in progress.

(5068) MODEL STUDY OF SPILLWAY FOR LITTLE GOOSE DAM, SNAKE RIVER, WASHINGTON.

(b) U.S. Army Engineer District, Walla Walla, Corps of Engineers, Walla Walla, Washington.
(d) Experimental; for design.
(e) The 1:42.47-scale model includes a 3-bay section of the 8-bay spillway and stilling basin. Tests are being made to evaluate hydraulic performance of the proposed spillway and to develop revisions in design that would increase performance or reduce construction and maintenance costs.
(f) Completed.
(g) Pressures, head-discharge relationships, and pier contraction coefficients were determined for free flow over the crest and for unequal openings of adjacent crest gates. Although an acceptable design for a horizontal stilling basin was derived in the model, protection against unusual amounts of artesian water underneath the concrete apron will greatly increase construction costs if a conventional stilling basin is adopted. Attempts to eliminate the stilling basin paving through use of a conventional roller-type bucket were not satisfactory. Satisfactory hydraulic conditions and minimum downstream erosion were obtained with a denated roller-type bucket.

(5069) MODEL STUDY OF LITTLE GOOSE NAVIGATION LOCK, SNAKE RIVER, WASHINGTON.

(b) U.S. Army Engineer District, Walla Walla, Corps of Engineers, Walla Walla, Washington.
(d) Experimental; for design.
(e) A 1:25-scale model reproducing the intake manifolds, 86-ft-wide by 675-ft-long lock chamber, split lateral filling and emptying system, outlet culverts, and portions of adjacent approach and outlet areas is being used to check the suitability of the original design and to develop improvements if needed. An alternative method for distributing flow to the lateral culverts through a central junction chamber is being studied in a separate 1:25-scale model.
(f) Completed.
(g) Satisfactory designs for all elements of the structure were developed. The lock chamber can be filled in 11.5 minutes and emptied in 12.8 minutes under an initial head of 101 feet through a split lateral hydraulic system. Maximum hawser forces on an 8-barge tow completely filling the lock will average about 5 tons. After numerous revisions, good flow distribution was obtained in the junction chamber model. This hydraulic system was not tested in the comprehensive model.

(5070) MODEL STUDY OF SPILLWAY FOR DWORSHAK DAM, NORTH FORK CLEARWATER RIVER, IDAHO.

(b) U.S. Army Engineer District, Walla Walla, Corps of Engineers, Walla Walla, Washington.
(d) Experimental; for design.
(e) An undistorted, 1:50-scale, fixed-bed model reproduces the river bed and pertinent overbank topography for about 3600 feet upstream and downstream from the project axis during tests of the cofferdams, diversion tunnel, tunnel outlet channel, and temporary fishway entrance. The 673-ft-high dam, spillway, stilling basin, regulating outlets, and exit channel are being reproduced for tests of these elements.
(g) Verification of the model and diversion studies were completed. Tests indicated that relocation of the tunnel entrance and realignment of tunnel and downstream approach were required.

(5071) GENERAL MODEL STUDY OF LOWER GRANITE LOCK AND DAM, SNAKE RIVER, WASHINGTON.

(b) U.S. Army Engineer District, Walla Walla, Corps of Engineers, Walla Walla, Wash.
(d) Experimental; for design.
(e) An undistorted, 1:100-scale, fixed-bed model will reproduce the Snake River bed and pertinent overbank topography for 1.4 miles upstream and 1.7 miles downstream from the project axis (107.5 river miles upstream from the junction of the Snake and Columbia Rivers). Studies will be made to determine flow conditions during successive construction stages and after proposed structures have been installed.
(g) Verification tests and studies of successive cofferdam and first-step diversion plans were completed.

(5315) MODEL STUDY OF REGULATING OUTLETS FOR DWORSHAK DAM, NORTH FORK CLEARWATER RIVER, IDAHO.

(b) U. S. Army Engineer District, Walla Walla, Corps of Engineers, Walla Walla, Wash.
(d) Experimental; for design.
(e) With the spillway gates closed, or with pool level below the spillway crest, reservoir outflows will be controlled by three 9- by 12.5-ft tainter gates located near the upstream end of separate conduits at elevation 1350. Head on the conduits will vary from 95 feet at minimum pool elevation 1445 to slightly more than 250 feet at maximum pool elevation 1601. The outlet conduits will discharge onto the spillway chute at about elevation 1150. Total outlet capacity will vary from 28,300 cfs at minimum pool to approximately 40,000 cfs at maximum pool. Pressures, flow conditions, and discharge relationships will be checked in a 1:20-scale sectional model that reproduces a portion of the forebay, an outside conduit (with streamlined entrance and center line angled 5 - 38' to head wall), and a section of spillway downstream from the conduit outlet.
(g) Bellmouthed conduit entrances having simple and elliptical curves (plans A and B) were investigated with two 15-in. and one 60-in.-diam air vents in the valve housing and with one or two 20-in. vents in the bulkhead slot. Pressures within the cavitation range existed in both bellmouths when the tainter valve was fully opened (12.5 ft). Pressures were satisfactory for valve openings less than 12.0 ft. Pressure conditions were not improved when the horizontal skew (5^{o}-38'-01" in plan) was eliminated but the vertical skew (10^{o} in elevation) was retained (plan C). Revision of the model for tests of plan D bellmouth, which will eliminate skew in both plan and elevation, is in progress.

(5317) MODEL STUDY OF COLUMBIA RIVER, OAK POINT TO VANCOUVER, WASHINGTON.

(b) U. S. Army Engineer District, Portland, Corps of Engineers, Portland, Oregon.
(c) District Engineer, U. S. Army Engineer District, Portland, 628 Pittock Block, Portland, Oregon 97205.
(d) Experimental; for design.
(e) A 40-ft-deep by 600-ft-wide navigation channel between Columbia River miles 52 and 109 and from the Willamette River mouth to Portland, Oregon was authorized recently. Five separate movable-bed models, with 1:300 horizontal and 1:100 vertical scales, will

be required to cover improvements in the Columbia River. The models will be used initially to check plans for constructing and maintaining the 40-ft channel. During these studies the location and need for pile dikes, channel alignment and location of spoil areas will be investigated. Later the models will be useful on a continuing basis to check operation and maintenance activities and new construction.

(g) Verification tests on the first model, of Columbia River miles 64 to 78, were continued. Construction of the second model (miles 52 to 65)was completed and verification tests were begun.

(5318) MODEL STUDY OF POWERHOUSE SKELETON UNIT FOR JOHN DAY DAM, COLUMBIA RIVER, OREGON AND WASHINGTON.

(b) U. S. Army Engineer District, Walla Walla, Corps of Engineers, Walla Walla, Washington.
(d) Experimental; for design.
(e) Owing to an accelerated schedule for completing construction of the John Day powerhouse, it is proposed to place as much of the draft tube concrete as diversion requirements will allow. The proposed skeleton bay interior would be much different from the present contract plans and from that at The Dalles Dam, which is the only unit that has been model tested. Tests of the contract plan and proposed skeleton unit were made in a 1:25-scale model.
(f) Completed.
(g) Discharge capacity of the contract plan draft tube was inadequate to meet design requirements. Improved designs were developed for units 11 to 19 (with drainage tunnel over draft tube) and for special unit 20 (without drainage tunnel).
(h) Final report is in preparation.

(5814) MODEL STUDY OF SPILLWAY FOR LIBBY DAM, KOOTENAI RIVER, MONTANA.

(b) U. S. Army Engineer District, Seattle, Corps of Engineers, Seattle, Washington.
(d) Experimental; for design.
(e) The project, located at mile 219 on Kootenai River, 17 miles upstream from Libby, Montana, will include a spillway with two 48-ft wide bays (design discharge 145,000 cfs under maximum head of 54 ft), three regulating outlets with total capacity of 41,000 cfs at maximum pool elev 2459 and 35,000 cfs at minimum pool elev 2287, and a powerhouse for eight Francis units (ultimate installation, 840,000 kw). Three powerhouse units having a total rated capacity of 315,000 kw will be installed initially. The powerhouse and spillway, with approach and exit channels, are installed in a 1:50-scale model to determine hydraulic characteristics of spillway crest, pier, abutments, chute, regulating outlets, and stilling basin and to check flow conditions with and without powerhouse discharge.
(g) Design and construction of the model were completed during 1965. Test results indicated that revisions of original designs for the stilling basin and spillway abutments were needed. Development of improved designs for these elements is in progress.

(5815) TESTS OF CONDUIT VALVE SEALS, DWORSHAK DAM, NORTH FORK CLEARWATER RIVER, IDAHO.

(b) U. S. Army Engineer District, Walla Walla, Corps of Engineers, Walla Walla, Wash.
(d) Experimental; for design.
(e) Three tainter valves with eccentric trunnions are proposed for use in the outlet works. Rubber seals mounted in the valve shaft upstream from each valve must be compressed by horizontal valve motion to prevent blow-by from hydrostatic heads up to 250 ft.
(g) Sealing tests on a 3-ft-long section of prototype rubber seal were made in a pressure chamber under heads up to 300 ft. Owing to residual "set" of the rubber under pressure, satisfactory sealing was obtained under slightly different amounts of nominal compression in successive pressure tests. The need for actual compression amounts greater than 3/8 in. was not indicated. Mechanical tests showed that a force of 5300 lb per lineal ft of seal was required to compress the seal 9/16 in. when the rate of valve motion was 1-1/2 in. per min. Maximum forces needed to compress two modifications of the original seal 5/8 in. were 7700 and 6270 lb per lineal ft, respectively, under the same test conditions. With the modified seal designs, adequate sealing should occur with no more than 1/4 in. of seal compression.

U. S. ARMY ENGINEER DISTRICT, CORPS OF ENGINEERS, St. Paul.

(194) A STUDY OF METHODS USED IN MEASUREMENT AND ANALYSIS OF SEDIMENT LOADS IN STREAMS.

U. S. Army Engineer District, St. Paul and U. S. Geological Survey, in cooperation with St. Anthony Falls Hydraulic Laboratory. See St. Anthony Falls Hydraulic Laboratory, page 73.

U. S. DEPARTMENT OF COMMERCE, BUREAU OF PUBLIC ROADS.

(856) HYDROLOGY OF STORM DRAINAGE SYSTEMS IN URBAN AREAS.

Cooperative with the Johns Hopkins Univ. See page 42.

(3805) INVESTIGATION OF SUPERCRITICAL FLOW CHANNEL JUNCTIONS.

Cooperative with Oregon State Univ., Dept. of Civil Engrg. See page 61.

(2435) HYDRAULICS OF PIPE CULVERTS.

Cooperative with the National Bureau of Standards. See page 166.

(4101) UNSTEADY FREE SURFACE FLOW IN A LARGE STORM DRAIN.

Cooperative with Colorado State Univ., Civil Engrg. Section. See page 16.

(3597) CORRUGATED PIPE ROUGHNESS STUDY.

Cooperative with U. S. Army Engineer Waterways Experiment Station. See page 195.

(4617) MECHANICS OF LOCAL SCOUR.

Cooperative with Colorado State Univ., Civil Engrg. Section. See page 18.

(5457) A NEW TYPE ENERGY DISSAPATOR FOR CULVERT OUTLETS.

Cooperative with Univ. of Texas, Dept. of Civil Engrg. See page 84.

(5533) USE OF LARGE ROUGHNESS ELEMENTS FOR HYDRAULIC ENERGY DISSIPATION.

Cooperative with Virginia Polytechnic Inst., Dept. of Civil Engrg. See page 94.

U. S. DEPARTMENT OF COMMERCE, NATIONAL BUREAU OF STANDARDS, Fluid Meters Section.

(6012) CALIBRATION AND PERFORMANCE OF TURBINE FLOWMETERS, SIZE 2-INCH AND SMALLER.

(b) Bureau of Weapons, Dept. of the Navy.
(c) Mr. M. R. Shafer, Research Engineer, NBS, Washington, D. C. 20234.
(d) Experimental; applied research.
(e) To develop calibration procedures for and investigate the performance of typical turbine-type flowmeters, flowrate range 0.5 to 250 gallons per minute, while metering liquid hydrocarbons. Purpose: to improve the accuracy of typical fuel and hydraulic oil metering applications in the aircraft industry.
(g) Recent investigations have been concerned with applications in which the turbine meters are operating at pressure levels up to 1500 psig. The meters may be calibrated conveniently while operating at high pressure levels by throttling meter discharge and measuring with conventional gravimetric or volumetric calibration systems. Influence of pressure on the density (0.5 to 1.0% per 1000 psi) and kinematic viscosity (10 to 20% per 1000 psi) of liquid hydrocarbons must be considered. Pressure and/or flow pulsations, originating from piston and gear-type pumps in high pressure applications, may cause turbine flowmeters to indicate a flow higher than actual by an amount zero to 2%.
(h) "Performance Characteristics of Turbine Flowmeters," M. R. Shafer, Trans. ASME, Vol. 84, Series D, No. 4, pp 471-485, Dec. 1962.

U. S. DEPARTMENT OF COMMERCE, NATIONAL BUREAU OF STANDARDS, Hydraulics Section.

(2435) HYDRAULICS OF PIPE CULVERTS.

(b) Bureau of Public Roads.
(c) Mr. John L. French, Hydraulic Engineer, National Bureau of Standards, Washington, D. C. 20234.
(d) Experimental; applied research.
(e) To determine hydraulic characteristics of various types of culvert entrances and to develop inlets of improved design.
(g) Experiments completed.

(2436) FLOW OVER HYDROPHOBIC MATERIALS.

(b) Office of Naval Research, Dept. of the Navy.
(d) Experimental; applied research.
(e) To evaluate the increased dissipation at the air - water interface due to a hydrophobic condition of the surface of partially immersed plates oscillating vertically.
(h) "Friction at Menisci on Hydrophobic Surfaces," by G. H. Keulegan and M. R. Brockman (being revised).

(4400) MOTION AROUND A BODY IN A STRATIFIED FLUID.

(b) Office of Naval Research, Dept. of the Navy.
(c) Mr. Karl Lofquist, Physicist, National Bureau of Standards, Washington, D. C. 20234.
(d) Theoretical and experimental; basic and applied research.
(e) A study is made of the internal waves produced by the horizontal motion of spheres through a stably stratified liquid.
(g) Experiments completed.

(4891) WAVE PROPAGATION IN A TURBULENT LIQUID.

(b) Office of Naval Research, Dept. of the Navy.
(c) Dr. G. Kulin, Hydraulic Engineer, National Bureau of Standards, Washington, D. C. 20234.
(d) Experimental; basic research.
(e) A study is being made of additional gravity wave damping due to turbulence.
(h) Report in preparation.

(4892) TURBULENT SHEAR FLOW THROUGH COMPLIANT WALLED TUBES.

(b) Office of Naval Research, Dept. of the Navy.
(c) Dr. G. Kulin, Hydraulic Engineer.
(d) Experimental; basic research.
(e) Investigation of effect of compliancy of boundaries on a turbulent flow with a view toward possible damping of turbulence and potential reduction in wall shear stress.
(g) Experimental work completed.

(5252) WIND ACTION ON PRE-EXISTING WAVES.

(b) Office of Naval Research, Dept. of the Navy.
(c) Dr. G. Kulin, Hydraulic Engineer.
(d) Experimental; basic research.
(e) Investigation of effect of a following wind on a mechanically produced swell, with emphasis on changes in wave damping and on hydraulic roughness of the resulting surface.
(f) Completed.
(g) Wind shear forces were deduced for a variety of wind speeds and wave configurations.
(h) "Wind Effect on Pre-Existing Waves, G. Kulin, Proc. ASCE Coastal Engineering Conference, 1965. (In press)

(5613) RESPONSE OF A DENSITY-STRATIFIED LIQUID TO A SOURCE OR SINK IMPULSE.

(b) Office of Naval Research, Dept. of the Navy.
(c) Mr. Karl Lofquist, Physicist, National Bureau of Standards, Washington, D. C. 20234.
(d) Theoretical and experimental; basic research.
(e) A study of the internal waves produced by the sudden inflation or contraction of a small spherical membrane situated within stratified liquid.
(g) Some theoretical work has been completed.

(5614) INTERACTION BETWEEN LONG WAVES AND SUPERPOSED SHORT WAVES.

(b) Office of Naval Research, Dept. of the Navy.
(c) Dr. G. Kulin, Hydraulic Engineer, National Bureau of Standards, Washington, D. C. 20234.
(d) Experimental; basic research.
(e) Investigation of the change of form of the shorter waves, and of the effect, if any, on damping of the longer waves.
(g) Experiments in progress.

(5615) INTERCOMPARISON OF TOWING TANK AND WATER TUNNEL CALIBRATIONS OF CURRENT METERS.

(b) Laboratory project.
(c) Mr. John L. French, Hydraulic Engineer, National Bureau of Standards, Washington, D. C. 20234.
(d) Experimental; basic and applied research.
(e) Investigation of wall interference and turbulence effects on current meter calibrations in water tunnels.
(g) Apparatus under construction.

(6013) DAMPING OF SHALLOW-WAVES: SUMMARY OF AVAILABLE INFORMATION.

(b) Office of Naval Research, Dept. of the Navy.
(c) Dr. G. Kulin, Hydraulic Engineer, National Bureau of Standards, Washington, D. C. 20234.
(d) Analytical; basic research.
(e) A state-of-the-art review of viscous damping of waves, with analysis of available theoretical and experimental results.
(g) Literature review in progress.

U. S. DEPARTMENT OF COMMERCE, WEATHER BUREAU, Environmental Science Services Administration.

(5664) STREAMFLOW FORECASTING RESEARCH.

(b) Laboratory project.
(c) Mr. William E. Hiatt, Associate Director of Weather Bureau (Hydrology), Wash. D. C. 20235.
(d) Theoretical and field; applied research.
(e) In Wash., D. C., and at River Forecast Centers throughout the U. S., phenomena are being investigated for improved objective forecasts of streamflow. These phenomena include (1) storage and movement of rain and snowmelt through the soil, including the influence of evapotranspiration, and (2) routing of flow

in natural channels.

(g) Major results are adaptation of field procedures to digital computer operation at several River Forecast Centers, using a more sophisticated model than was possible earlier.

(h) "Rainfall-Runoff Models," Max A. Kohler, Publication No. 63 of the I.A.S.H. Symposium on Surface Waters, 1964, pp. 479-491.
"Role of Digital Computers in Hydrologic Forecasting and Analyses," J. P. McCallister, Publication No. 63 of the I.A.S.H. Symposium on Surface Waters, 1964, pp. 68-76.

U. S. DEPARTMENT OF THE INTERIOR, GEOLOGICAL SURVEY.

(2948) ANALOG MODEL ANALYZER FOR STEADY-STATE GROUND-WATER FLOW PROBLEMS.

(b) Laboratory project.
(c) Mr. R. W. Stallman, U.S. Geol. Surv., Denver, Colo.
(d) Theoretical study and instrument development.
(e) Use of a variable-resistance gird analyzer in analyzing steady-state ground-water flow problems in which the transmissibility varies in space.
(f) Completed.
(h) "From Geologic Data to Aquifer Analog Models," R. W. Stallman, Geotimes, v. 5, no. 7, p. 8-11, 37, 1961.
"Calculation of Resistance and Error in an Electric Analog of Steady Flow through Non-Homogeneous Aquifers," R. W. Stallman, U. S. Geological Survey Water-Supply Paper 1544-G, 20 p., 1963.
"Evaluation of Numerical-Analysis Methods for Determining Variations in Transmissibility," Edward A. Sammel, International Association of Scientific Hydrology, no. 64, p. 239-251, 1963.
"Electric Analog of Three-Dimensional Flow to Wells and Its Application to Unconfined Aquifers," Robert W. Stallman, U. S. Geological Survey Water-Supply Paper 1536-H, p. 205-242, 1963.

(2950) SEDIMENT TRANSPORT AND CHANNEL ROUGHNESS IN NATURAL AND ARTIFICIAL CHANNELS.

(b) Laboratory project.
(c) Mr. Thomas Maddock, Jr., U. S. Geological Survey, Tucson, Arizona
(d) Basic research.
(e) Field and laboratory studies, original and other investigations will be analyzed in terms of sediment movement, channel roughness, shear distribution in channel prism and other effects on shape of natural channels.
(g) Relations between velocity and sediment load have been developed. Relations involving slope are shown to be indeterminate within certain limits.
(h) "The Behavior of Straight Alluvial Channels," U. S. Geol. Survey Prof. Paper now in stage of final review.

(3260) SOIL-MOISTURE EQUIPMENT.

(b) Laboratory project.
(c) Mr. A. I. Johnson, Chief, Hydrologic Laboratory, U.S. Geological Survey, Denver, Colo.
(d) Laboratory and field investigation; applied research.
(e) Laboratory model and field comparative study of techniques and of various commercially available instruments for measuring soil moisture. New equipment may also be designed as result of study.
(f) Completed.
(g) Field and laboratory calibrations of neutron meter, tensiometers, moisture blocks and sampling equipment. Evaluation of neutron meter. Design of small-diameter fast-response tensiometer. Library research.

(3263) SPECIFIC YIELD AND RELATED PROPERTIES.

(b) Cooperative with the State of California.
(c) Mr. A. I. Johnson, Chief, Hydrologic Laboratory, U.S. Geological Survey, Denver, Colo. or Mr. Walter Hoffman, District Chief, WRD, U.S. Geological Survey, Menlo Park, Calif.
(d) Laboratory and field investigation; basic and applied research.
(e) Theoretical, laboratory and field study of specific yield, and related properties, such as moisture equivalent, field capacity, moisture tension, unsaturated permeability and time-drainage relationships, as related to ground-water storage. Evaluation of existing, and possible development of new methods for determing these properties.
(g) Library research, laboratory study in progress or completed of factors affecting column drainage, centrifuge moisutre equivalent, moisture tension and unsaturated permeability.
(h) "Compilation of Specific Yields for Various Materials," A. I. Johnson; U.S. Geological Survey open-file report. (1965).
"Specific Yield--Laboratory Experiments Showing the Effect of Time on Column Drainage," R. C. Prill, A. I. Johnson and D. A. Morris: U. S. Geological Survey Water-Supply Paper 1662-B (1965).
"Specific Yield--Column Drainage and Centrifuge Moisture Content," A. I. Johnson, R. C. Prill and D. A. Morris: U. S. Geological Survey open-file report; also U. S. Geological Survey Water-Supply Paper 1662-A (1963).
"Centrifuge Technique for Determining Time-Drainage Relations for a Natural Sand," R. C. Prill and A. I. Johnson: U.S. Geological Survey Prof. Paper 450-E (1963).
"Research on Specific Yield," (abstract) by A. I. Johnson and D. A. Morris, California Association Engineering Geologists Meeting, October 1961: U. S. Geological Survey open-file report (1961).

(3264) SUBSURFACE EXPLORATION EQUIPMENT AND TECHNIQUES.

(b) Laboratory project.
(c) Mr. A. I. Johnson, Chief, Hydrologic Laboratory, U. S. Geological Survey, Denver, Colo.
(d) Laboratory and field investigation; applied research.
(e) Evaluate and adapt subsurface sampling and coring equipment and techniques to ground-water investigations.
(g) Core samplers designed, and some commercial models procured and compared under field conditions. Library research in progress.

(3265) INVESTIGATION OF VADOSE FLOW THROUGH POROUS MEDIA.

(b) Laboratory project.
(c) Mr. A. I. Johnson, Chief, Hydrologic Laboratory, U. S. Geological Survey, Denver, Colo.
(d) Experimental; basic and applied research.
(e) Laboratory model study of infiltration of fluids from surface pits into a thick unsaturated zone above the water table.
(f) Completed.
(g) Model tank designed and constructed; several test runs with beads of different particle size completed; library research; test runs photographed by slide and lapse-time movies.

(4187) MECHANICS OF FLUID FLOW IN POROUS MEDIA.

(b) Laboratory project.
(c) Dr. Akio Ogata, U. S. Geological Survey, P. O. Box 657, Honolulu, Hawaii.
(d) Experimental tnd theoretical study; basic research.
(e) Theoretical and laboratory study of microscopic and macroscopic aspects of flow through porous media.

(5075) DOPPLER VELOCITY METER.

(b) Laboratory project.
(c) Mr. G. F. Smoot, U. S. Geological Survey, WRD, Washington, D. C. 20242.
(d) Experimental; instrument development.
(e) The objective is to measure the instantaneous local velocity by means of the Doppler frequency shift of an ultrasonic signal reflected by minute particles of suspended sediment.
(g) Models undergoing laboratory and field tests.

(5077) CONTROLS AND INSTRUMENTATION FOR GAGING ALLUVIAL CHANNEL STREAMS.

(b) Laboratory project.
(c) Mr. F. A. Kilpatrick, Project Chief, U. S. Geological Survey, c/o Engineering Research Center, Foothills Campus, Colorado State University, Fort Collins, Colorado 80521.
(d) Experimental field and laboratory investigation; applied research.
(e) Project comprises two distinct approaches to solution of stream gaging problems on alluvial channel streams. (1) Field construction and evaluation of experimental controls specifically for gaging alluvial channel streams. The following different types of controls have been installed and are being evaluated: (a) Supercritical flow flume - Owl Creek, Wyoming; (b) Wire covered rock control - Badwater Creek, Wyoming; (c) Dual weir sheet piling controls - Republican River and Pumpkin Creek, Nebraska; and (d) Subcritical weir - Rio Grande Conveyance Channel, New Mexico. (2) Evaluation of the Dye dilution method of measuring discharge in alluvial channels.
(g) Despite earlier difficulties, all three types of controls appear promising for gaging alluvial channels. Discharges from 3 to 3000 cfs have been measured satisfactorily by the dye dilution method.
(h) "Stream Gaging Control Structure for the Rio Grande Conveyance Channel Near Bernardo," D. D. Harris and E. V. Richardson, New Mexico: U. S. Geol. Survey Water Supply paper 1369E, 154 p. 1965.
"Use of Flumes in Measuring Discharge at Gaging Stations," F. A. Kilpatrick, U. S. Geol. Survey Surface Water Techniques Manual on Hydraulic Measurement and Computation. 1965.

(5078) ALLUVIAL CHANNEL HYDRAULICS.

(b) Laboratory project.
(c) Messrs. H. P. Guy, E. V. Richardson, and D. B. Simons, U. S. Geological Survey, c/o Engineering Research Center, Foothills Campus, Colorado State University, Fort Collins, Colorado 80521.
(d) Experimental; basic research.
(e) A laboratory study of resistance to flow, sediment transport and related problems in alluvial channels.
(f) Completed.
(g) Five different bed materials ranging in size from 0.19 millimeters to 0.93 millimeters have been studied. The forms of bed roughness which occur and their relation to sediment transport and resistance to flow have been studied and described. The effect of large concentrations of suspended fine sediment (clay), the viscosity of the water and the specific weight and gradation of the bed material on the mechanics of flow and on sediment transport in alluvial channels have also been investigated.
(h) "Total Bed-Material Transport," A. A. Bishop, D. B. Simons and E. V. Richardson; Am. Soc. Civil Engineers Jour. v. 91, no. HY 2, 1965.
"A Study of Variables Affecting Flow Characteristics in Alluvial Channels," D. B. Simons and E. V. Richardson; Proc. Federal Inter-Agency Sedimentation Conf. 1963, Misc. Pub. No. 970 Agr. Research Service, USDA, 1965.
"Sedimentation Structures Generated by Flow in Alluvial Channels," D. B. Simons, E. V. Richardson and C. F. Nordin, Jr; Soc. Econ. Paleont. and Minerolog. Spec. Pub. No. 12.
"Discussion of Hyperconcentrations of Suspended Sediment," E. V. Richardson and T. F. Hanly, Am. Soc. Civil Engineers Jour., v. 91, no. HY5, 1965.

(5599) RESEARCH ON PERMEABILITY.

(b) Cooperative with the State of California.
(c) Mr. A. I. Johnson, Chief, Hydrologic Laboratory, U. S. Geological Survey, Denver, Colo. or Mr. Walter Hoffman, District Chief, WRD, U. S. Geological Survey, Menlo Park, Calif.
(d) Laboratory and field investigation; basic and applied research.
(e) Theoretical, library, laboratory, and field study of permeability, mainly as related to water movement through rock and soil materials, both as saturated and unsaturated flow. Evaluation of existing laboratory and field methods and development of new or improved methods.
(g) Library research leading to an annotated bibliography on permeability (manuscript in preparation). Laboratory study of factors affecting saturated permeability measurements in progress. Laboratory study of relation between particle-size parameters and permeability. Laboratory evaluation of unsaturated permeability methods.

(5600) MOVING BOAT TECHNIQUE FOR MEASUREMENT OF OPEN-CHANNEL DISCHARGE.

(b) Laboratory project.
(c) Mr. G. F. Smoot, U. S. Geological Survey, WRD, Washington, D. C. 20242.
(d) Experimental; instrument and technique development.
(e) The purpose of this research is to provide the instrumentation and to develop the technique needs to rapidly, accurately and inexpensively measure flow, especially unsteady flow, in rivers and tidal estuaries.
(g) A Doppler navigator, Doppler velocity meter, and a sonic sounder are being coupled together to provide channel discharge. The navigator provides the transverse distance traveled across the channel, the sonic sounder provides the cross-section depth, and the velocity meter provides the flow vector from which the discharge may be electronically integrated.

(5603) ORIGIN OF BASE FLOW.

(b) Laboratory project.
(c) Dr. G. R. Kunkle, U. S. Geological Survey, WRD, 508 Hydraulics Laboratory, Iowa City, Iowa 52241.
(d) Field investigation; basic and applied research.
(e) The purpose is to study the mechanics of ground-water discharge to streams by relating the hydrologic and geologic characteristics of the contributing reservoirs to the resultant ground-water runoff. This knowledge is used to construct a detailed hydrograph separation of ground from surface runoff.
(f) Suspended.
(g) Ground-water runoff is supported by an interconnected two-reservoir system composed of bottom-land alluvial sand and upland loess. The percentage contribution from each reservoir is time dependent. The alluvial sand is the major contributor.
(h) "Computation of Ground-Water Discharge to Streams During Floods, or to Individual Reaches During Base Flow, by Use of Specific Conductance," G. R. Kunkle: U. S. Geological Survey Professional Paper 525-D (in press).
"A Hydrogeologic Study of the Reservoirs Contributing Ground-Water Runoff, Four Mile Creek, Iowa," G. R. Kunkle: (in preparation).

(5604) MECHANICS OF FLUID RESISTANCE.

(b) Laboratory project.
(c) Dr. H. J. Tracy, U. S. Geological Survey, WRD, Room 164 Peachtree Seventh Building, Atlanta, Georgia 30323.

(d) Theoretical and laboratory investigation; basic research.
(e) The objective of this study is to attempt to describe the effects of the boundary on fluid resistance in terms of dimensionless ratios characterizing the physical size and shape of the roughness.
(g) The experimental aspect of the work is being conducted in an artifically roughened, closed circular, air tunnel using hot-wire anemometer equipment to determine velocity profiles, turbulence, and energy spectra. The work consists of tests in which roughness element size, density of spacing, and shape are systematically varied. The resulting turbulence spectra are being analyzed in order to correlate the physical dimensions of the roughness with the energy and momentum transfer mechanisms in turbulent flow.

(5606) MULTIPLE CHANNEL DIGITAL RECORDING SYSTEM.

(b) Laboratory project.
(c) Mr. G. F. Smoot, U. S. Geological Survey, WRD, Washington, D. C. 20242.
(d) Instrument development.
(e) The objective of this project is to develop a reliable, battery powered, sensing instrument for field operation which is capable of positioning a punched paper-tape digital recorder. The instrument would be used to provide a variety of hydrologic parameters in rapid sequence for recording on tape.
(g) A transistorized system incorporating an A-C Wheatstone bridge balanced by a D-C servo system of minimum power requirements has been developed and is undergoing field testing.
(h) "New Instrumentation for Watershed Investigations," G. F. Smoot, Proceedings of the Symposium on Experimental and Representative Areas, IASH, 1965.

(5607) EVALUATION OF DEPENDENT AND INDEPENDENT VARIABLES IN OPEN CHANNEL FLOW.

(b) Laboratory project.
(c) Messrs. H. P. Guy and R. E. Rathbun, U. S. Geological Survey, c/o Engineering Research Center, Colo. State Univ. Fort Collins, Colo. 80521.
(d) Experimental; basic research.
(e) The objective is to identify and evaluate the dependency characteristics of flow and sediment measures of alluvial channel flow. The experiments are designed to (1) determine mean flow parameters and channel adjustments when bed material is an independent variable; (2) determine the importance of depth as a scale parameter and as a driving force; (3) determine the time for change when an independent variable is changed; (4) determine the variance of slope, depth, velocity, sediment transport, and bed conditions in time and space.

(5608) DISTRIBUTION AND CONCENTRATION OF RADIOACTIVE WASTE IN STREAMS BY FLUVIAL SEDIMENT.

(b) Laboratory project.
(c) Mr. W. W. Sayre and Dr. F. M. Chang, U. S. Geological Survey, c/o Engineering Research Center, Foothills Campus, Colo. State Univ., Fort Collins, Colo. 80521.
(d) Experimental and theoretical; basic and applied research.
(e) A significant fraction of the low level liquid radioactive wastes which are discharged into surface streams is often sorbed by bed material and fine material sediment particles. Consequently the manner in which these sediments are transported is a significant factor in determining the distribution of radioactive wastes in the stream environment. The project is devoted to investigating the dispersion and transport of both fine and bed material sediment particles. Experiments are conducted in natural streams and in laboratory flumes. Radioactive tracer techniques, fluorometry and nephelometry are among the experimental techniques being employed. Analytically and experimentally the phenomenon of sediment transport is being treated from a Lagrangian point of view.
(f) Completed.
(g) The degree of mixing and the behavior of the longitudinal dispersion coefficient during the initial phases of the dispersion process in turbulent open channel flow has been related analytically to the dimensions of the channel, the resistance coefficient, and the von Karman turbulence coefficient.
(h) "Transport and Dispersion of Labeled Bed Material, North Loup River, Nebraska," W. W. Sayre and D. W. Hubbell, U. S. Geol. Survey Prof. Paper 433-C, 48 p., 1965.
"Closure to Sand Transport Studies With Radioactive Tracers," D. W. Hubbell and W. W. Sayre, Proc. Am. Soc. Civil Engineers, v. 91, HY 5, p. 139-149, September 1965.
"Application of Radioactive Tracers in the Study of Sediment Movement," D. W. Hubbell and W. W. Sayre, Proc. Fed. Inter-Agency Sedimentation Conf. 1963, Misc. Publ. no. 970 Agric. Res. Serv., p. 569-578, June 1965.
"Discussion of Canal Discharge Measurements with Radioisotopes," W. W. Sayre, Proc. Am. Soc. Civil Engineers, v. 91, No. HY6, Nov. 1965.

(5609) STEP LENGTHS AND REST PERIODS OF SEDIMENT PARTICLES IN ALLUVIAL CHANNELS.

(b) Laboratory project.
(c) Mr. W. W. Sayre and Dr. F. M. Chang, U. S. Geol. Survey, c/o Engineering Research Center, Foothills Campus, Colo. State Univ., Fort Collins, Colo. 80521.
(d) Experimental and theoretical; basic research.
(e) The object is to study the individual and collective motions of bed-material sediment with a view to obtaining better understanding of the fundamental transport processes. Radioactive tracer and other techniques will be used to determine (1) distribution functions for the step lengths and rest periods of sediment particles and (2) how the parameters describing the distribution functions are related to sediment and flow characteristics.
(g) Preliminary experiments with lightweight plastic particles indicate that the step lengths of particles are gamma distributed and that mean step lengths are on the order of one-half to two-thirds of a ripple or dune length. Experiments with the same particles indicated that the rest period durations are exponentially distributed. It remains to be determined from single particle experiments with radioactive tracer particles whether or not the same conclusions apply to natural sand particles.

(5610) MECHANICS OF FLOW STRUCTURE AND FLUID RESISTANCE--MOVABLE BOUNDARY.

(b) Laboratory project.
(c) Dr. E. V. Richardson, U. S. Geol. Survey, c/o Engineering Research Center, Foothills Campus, Colo. State Univ., Fort Collins, Colo. 80521.
(d) Experimental, theoretical and field investigation; basic research.
(e) The objective is to measure the internal flow field of turbulent shear flow in an open channel in order to obtain a fundamental understanding of the mechanics of fluid resistance. Further knowledge of the mechanics of flow structure will give a better understanding of the phenomena of energy dissipation, velocity distribution, shear distribution and the transport and dispersion of solutes and sediment.
(g) The velocity distribution for flow over a plain sand bed with appreciable bed material transport has an inner and outer zone. The distribution is logarithmic in both zones. In the inner zone the parameters for the distribution vary with the size, density, and

concentration of the bed material, whereas in the outer zone they are constant. The coefficients of a general resistance to flow equation for equilibrium flow in a sand channel vary widely because (1) the flow may be steady or unsteady, uniform or nonuniform depending on the bed configuration; (2) there are four types of energy dissipation; (3) there is a range of shear stress where the bed configuration may range from dunes to plain bed or antidunes.

(h) "Resistance to Flow in Sand Channels," E. V. Richardson, Ph.D. dissertation, Colo. State Univ., Fort Collins, Colo. 1965.

(5611) FALL VELOCITY OF GRAVEL-SIZED PARTICLES.

(b) Laboratory project.
(c) Mr. H. P. Guy, U. S. Geol. Survey, c/o Engrg. Research Center, Foothills Campus, Colo. State Univ., Fort Collins, Colo. 80521.
(d) Experimental and theoretical; basic and applied research.
(e) The objective is to evaluate the effects of size, shape, density, and fluid characteristic on the fall velocity of gravel-sized sediment particles and to make exploratory studies on the physical significance of the Reynolds number and the effect of turbulence on fall velocity.
(g) Studies of the behavior of spheres, disks, oblate spheroids, cylinders, and prolate spheroids falling in quiescent liquids show that (1) the fall pattern of disks changes from stable to oscillating to glide-tumble to tumble as the Reynolds number increases, (2) the stability number and the frequency number can be correlated with stability, and (3) particles with small values of the Corey shape factor are less stable than those with large values.
(h) "Behavior of Geometric Particles Falling in Quiescent Viscous Fluids," G. E. Stringham, Ph.D. Dissertation, Colo. State Univ., Ft. Collins, Colorado, 1965.

(5612) STATISTICAL ANALYSIS OF RIPPLES, DUNES AND ANTIDUNES.

(b) Laboratory and field.
(c) Messrs. C. F. Nordin and J. H. Algert.
(d) Experimental; basic and applied research.
(e) The objective is to statistically analyze the frequency distribution of length, amplitude, and shape of bed forms and their sequential dependence on parameters of flow and sediment transport. Data are obtained from sonic records of the movement of these forms under conditions of equilibrium flow in laboratory flumes.
(f) Suspended.
(g) Techniques of correlation and spectral density analysis were applied to describe dune profiles for data from a 0.4-ft flume, an 8-ft flume and a conveyance channel near Bernardo, New Mexico. The first three values of the covariance functions were found to be sufficient for computing approximate models. Two parameters describe the bed elevation as a function of distance by a second order autoregression scheme. The first value of covariance also relates well with unit discharge.
(h) "A Statistical Study of Bed Forms in Alluvial Channels," J. H. Algert, M. S. Thesis, Colo. State Univ.. Fort Collins, Colo., 1965.

(5839) MECHANICS OF GROUND-WATER FLOW.

(b) Laboratory project.
(c) Mr. H. H. Cooper, Jr., U. S. Geological Survey, Washington, D. C.
(d) Theoretical investigations with field applications; basic and applied research.
(e) Analysis of ground-water flow problems for which practical need has developed out of field investigations or other sources.
(g) (1) A solution for the response of well-aquifer systems to seismic waves as a function of well geometry, aquifer constants, and frequency of seismic wave was derived and checked by an electric analog model. (2) A technique for determining the rate of ground-water flow through semiconfining beds from the earth's thermal profile was devised. (3) Solutions for the nonsteady radial flow toward a well pumping from (a) an infinite two-layered aquifer, and (b) an infinite anisotropic aquifer were derived.
(h) "Rates of Vertical Groundwater Movement Estimated from the Earth's Thermal Profile," J. D. Bredehoeft and I. S. Papadopulos, Water Resources Research, vol. 1, no. 2, p. 325-328, 1965.
"Seismic Fluctuations in an Open Artesian Water Well," J. D. Bredehoeft, H. H. Cooper, Jr., I. S. Papadopulos and R. R. Bennett. USGS Prof. Paper 525-C, p. C51-C57, 1965.
"The Response of Well-Aquifer Systems to Seismic Waves," H. H. Cooper Jr., J. D. Bredehoeft, I. S. Papadopulos and R. R. Bennett. Jour. Geophys. Res., vol. 70, no. 16, p. 3915-3926, 1965.

(5840) AREAL GROUND-WATER CONTROL.

(b) Laboratory project.
(c) Mr. R. W. Stallman, U. S. Geological Survey, Denver Federal Center, Denver, Colorado.
(d) Field investigation; applied research.
(e) Objective is to test, in the field, methods of measuring the hydraulic conductivity of the unsaturated zone, and to find the relation between evapotranspiration and depth to the water table.
Measurements of liquid head and liquid content, as functions of time and depth, will be used for computing hydraulic conductivity and evapotranspiration. Data from several sites will be plotted for relating evapotranspiration and depth to the water table. Tensiometers, moisture measurement access tubes, and piezometers were installed at four field locations; and a column of thermistors for measuring the temperature profile was installed at one site. Weekly measurements of head were made at all operable sites. Moisture measurements were made sporadically until February 1965, monthly thereafter. Preliminary data analysis was made in May 1965.

(5841) DENVER MULTIPHASE FLOW.

(b) Laboratory project.
(c) Mr. R. W. Stallman, U. S. Geological Survey, Denver Federal Center, Denver, Colorado.
(d) Theoretical and field investigation.
(e) Devise and test methods of measuring flow in and hydraulic properties of, the unsaturated zone in the field. Measure velocities of fluids underground by analysis of temperature profiles. Develop and test methods of predicting the nature of flow in the unsaturated zone. Improve, and develop new techniques for field measurement of evapotranspiration.
(g) Measurement of the time lag and attenuation of fluctuations in gas pressure due to barometric changes as functions of depth below the land surface were made in the unsaturated zone near Cuba, New Mexico, for determining permeability of the unsaturated zone. Although the field tests were successful, improvement in the instrumentation adopted is indicated.
Type curves for analyzing drawdowns observed in well fields having variable discharges at scattered locations were developed for the New Mexico ground-water district through the Geological Survey Computations Unit. The computer program evolved is available for calculating the hydraulic properties of aquifers in areas where intensive use of ground-water is monitored at observation wells.
Underground temperature profiles were observed in the field near Globe, Arizona and Roswell, New Mexico to test the possibility of using the temperature profile for indicating vertical velocities of ground water

through beds having low permeability. Indications are that vertical velocities as small as 0.1 ft. per year can be identified by analysis of the steady-state temperature profile observed in beds about 100 feet or more in thickness.
The relation between losses from ground water and evapotranspiration is being studied with the aid of the field offices of the Water Resources Division, U. S. Geological Survey, in Colorado. Measurements of ground-water levels, soil moisture tension and content, and temperature are being made at four 25 acre sites in the Arkansas River Valley. Lateral contribution to ground-water loss, due to spatial changes in flow through the aquifer, is monitored by finite-difference analysis of the shape of the water table. Project interest lies in testing of field techniques of measuring the hydraulic properties of the unsaturated zone, and defining the relation between evapotranspiration and depth to the water table. Field installations were completed in May 1965, and rebuilt by October 1965 after destruction by floods.

(h) Discussion of "Analysis of Data from Non-equilibrium Pumping Tests Allowing for Delayed Yield from Storage, by N. S. Boulton," Robert W. Stallman, Inst. Civil Engineers Proc. (British) v. 28, p. 603-604, 1964.
"Multiphase Fluids in Porous Media--a Review of Theories Pertinent to Hydrologic Studies," Robert W. Stallman, U. S. Geological Survey Professional Paper 411-E, 51 p., 1964.
"Effects of Water Table Conditions on Water Level Changes Near Pumping Wells," R. W. Stallman, Water Resources Research, v. 1, no. 2, p. 295-312, 1965.
"Steady One-dimensional Fluid Flow in a Semi-infinite Porous Medium with Sinusoidal Surface Temperature," R. W. Stallman, Journal of Geophysical Research, v. 70, no. 12, p. 2821-2827, 1965.

(5842) THE MOVEMENT OF RADIONUCLIDES IN THE COLUMBIA RIVER ESTUARY.

(b) U. S. Atomic Energy Commission.
(c) Mr. D. W. Hubbell, Project Chief, U. S. Geological Survey, P.O. Box 3202, Portland, Oregon 97208.
(d) Experimental and theoretical; applied research.
(e) Certain radionuclides enter the Columbia River from the Hanford installation of the U. S. Atomic Energy Commission. Part of the radionuclides remain in solution, part are sorbed by fluvial sediments, and part are sorbed by biota. In order to insure that no dangerous condition prevails or develops in the Columbia River estuary, it is important to know the distribution of radionuclides in time and space, and the processes by which the distribution is altered. The purpose of this investigation is to study the movement of radionuclides in the Columbia River estuary as it is affected by flow, sediment transport, and chemical processes; to assess the distribution of radioactivity in the estuary; to develop measurement methods and techniques for large estuaries; and to contribute knowledge of estuarine processes.
(g) Measurement equipment and techniques have been developed for collecting necessary data in the estuary. The equipment includes systems for measuring water discharge rapidly, for collecting large-volume water and suspended-sediment samples, for filtering large-volume samples rapidly, for collecting 6-foot long bed-material cores, and for monitoring radioactivity in situ. The areal distribution of radiaactivity in the estuary varies markedly and, in general, high activities are associated with fine sediments.
(h) "A Sampler for Coring in Rivers and Estuaries," E. A. Prych and D. W. Hubbell; submitted for publication as a short note in the Geological Society of America Bulletin.
"Measurement Equipment and Techniques Used in Studying Radionuclide Movement in the Columbia River Estuary," E. A. Prych, D. W. Hubbell and J. L. Glenn; submitted to the American Society of Civil Engineers for publication in a Special Proceedings Volume for the Coastal Engineering Conference, Santa Barbara, California, October 11-13, 1965.

(5843) THE OCCURRENCE, TRANSPORT, AND DISPOSITION OF RADIONUCLIDES AS SOLUTES AND ASSOCIATED WITH FLUVIAL SEDIMENTS IN THE LOWER COLUMBIA RIVER.

(b) U. S. Atomic Energy Commission.
(c) Mr. W. L. Haushild, Project Chief, U. S. Geological Survey, P. O. Box 3202, Portland, Oregon 97208.
(d) Field investigation; applied research.
(e) Small amounts of minerals in the water used for cooling the reactors at the Hanford installation near Richland, Wash. are activated and subsequently discharged into the Columbia River in the controlled release of the cooling water. The purpose of the project is to determine the disposition of these radionuclides in and along the channel and the mechanics of transport of the radionuclides by the water and sediment in the river. The investigation is intended to supply information from the 330-mile reach of the Columbia River between Hanford and the head of the estuary.
(g) The transport and retention of radionuclides correlates with (1) the flow characteristics of the river system, and (2) the influence of the chemical and physical composition of the environmental system. The radionuclides affixed to the sediments varies for specific radionuclides and correlates with the physical and mineral characteristics of the sediments. There is a differential transport of these affixed radionuclides because of the differences in the fall velocity of the sediments, and this difference in transport affects the retention of radionuclides in the study reach. The digital computer solutions of a mathematical model for transient river flow have been successfully applied to the production of continuous discharge data for tidal-affected flows of the Columbia River at Vancouver, Wash.
(h) "An Electric-Powered Vehicle for Large River Measurements," H. H. Stevens, Jr., and G. R. Dempster, Jr., Civil Engineering, v. 34, no. 6, p. 74, June 1964.
A discussion of "Annual Variation of Stream Water Temperatures," J. C. Ward; by W. L. Haushild and G. R. Dempster, Jr., Am. Soc. Civil Engineers Proc., v. 90, no. SA4, p. 90-92, August 1964.
"Concurrent Collection of Hydraulic and Sediment Data in Rivers," G. R. Dempster, Jr, and H. H. Stevens, Jr., Jour. Am. Water Works Assoc., v. 57, no. 9, p. 1135-1138, September 1965.

U. S. DEPARTMENT OF THE INTERIOR, BUREAU OF MINES, Morgantown Research Center.

(4436) FLOW PROPERTIES OF COAL-WATER SLURRIES.

(b) U. S. Bureau of Mines, Morgantown Coal Research Center.
(c) Mr. J. P. McGee, Research Director, Morgantown Research Center, Morgantown, West Virginia.
(d) Experimental; applied research.
(e) The object of the project is to establish friction factor-Reynolds number relationships for coal-water slurries of various concentrations with coals of different ranks and size analyses. Work is being done with 1/2 inch, 3/4 inch, and 1 inch pipes. Data are processed on an IBM-1620 computer.
(f) Inactive for the present.

U. S. DEPARTMENT OF THE INTERIOR, BUREAU OF RECLAMATION.

Inquiries concerning the following projects, except where otherwise indicated, should be addressed to Office of Chief Engineer, Bureau of Reclamation, Denver Federal Center, Denver, Colo. 80225.

(2959) STILLING BASINS FOR SLIDE GATE CONTROLLED OUTLET WORKS.

(b) Laboratory project.
(d) Experimental; for design.
(e) A model was constructed to generalize stilling basin dimensions, using either one or two slide gates.
(g) Data were taken for two types of stilling basins for high-head slide gates. Preliminary design curves were developed for the usual hydraulic jump basin and for a simple plunge-type basin.

(3274) CONSTANT HEAD ORIFICE TURNOUT.

(b) Laboratory project.
(d) Experimental; applied research for design.
(e) A 24-inch slide gate turnout was calibrated by means of a 1:2 scale model. Design changes resulting from use of the turnout have necessitated an analysis and calibration of the variables affecting the discharge capacity.
(f) Suspended.
(g) Results show that submergence of the orifice or of the upstream gate of the two-gate turnout has a major effect on the discharge coefficient. A calibration curve for a 9 cfs standard turnout and several comparative calibrations of modified turnouts have been obtained.

(3278) CAVITATION OF CONCRETE SURFACE IRREGULARITIES.

(b) Laboratory project.
(d) Experimental; applied research and design.
(e) Into-the-flow offsets with abrupt edges, chamfered edges, and rounded edges were tested to determine the velocity-head relationships for incipient cavitation.
(g) Data analysis not completed.
(h) Progress report to be prepared.

(3611) ADJUSTABLE WEIR.

(b) Laboratory project.
(d) Combined laboratory and field research.
(e) Weirs having adjustable crest height are used for checking water surface levels for upstream water delivery and for water measurement beyond the weir. An investigation of the head discharge capacity of a single 2-foot crest-length weir was completed.
(f) Single weir investigation completed.
(g) Capacities of weir for crest heights greater than 0.1 foot above fixed blade compare very favorably with standard 2-foot cipolletti weir.
(h) "Vertical Adjustable Weir," J. C. Schuster, Report No. Hyd-553, 1965.

(3612) DISCHARGE COEFFICIENTS FOR RADIAL GATES.

(b) Laboratory project.
(d) Experimental, laboratory and field investigations; applied research.
(e) Radial gates are used extensively in irrigation systems for discharge and water surface level control. Intelligent operation of the systems requires that the rate of flow passing the gated structure be known. Literature research resulted in an analytical approach and adjusted equation for the gate capacity with unsubmerged flow.
(g) Extensive model and prototype radial gate data were obtained from the TVA Hydraulic Laboratory. The data are being analyzed to verify the proposed discharge formula and to extend the scope of presently available information.

(3985) DISCHARGE CAPACITY OF LARGE CONCRETE-LINED CANALS.

(b) Laboratory project.
(d) Experimental, laboratory and field investigations; applied research and design.
(e) This study is for the purpose of exploring the effects on the hydraulic gradient of the relationship of boundary surface resistance to the cumulative resistance of crossings, inlets, turnouts, checks, and other local items in concrete-lined canals of different sizes, shapes, and grades. This study is part of a program to explain why design procedures used successfully for small and medium sizes of canals may not be adequate for large concrete-lined canals on flat slopes.
(f) Completed.
(g) Between 1957 and 1962, tests were made on 170 miles of nine large (700 to 13,200 cfs) canals having ages ranging from 7 to 25 years. Resistance coefficients varied with the amount growth, canal alinement, and canal size and ranged from 0.013 to 0.016 for the smaller canals, and from 0.015 to 0.019 for the larger canals.
(h) "Analyses and Descriptions of Capacity Tests in Large Concrete-lined Canals," Paul J. Tilp and Mansil W. Scrivner, Technical Memorandum 661, April 1964.

(3994) HYDRAULIC JUMP CHUTE BLOCK AND BAFFLE BLOCK PRESSURES.

(b) Laboratory project.
(d) Experimental; applied research.
(e) A spillway stilling basin model has been constructed to study chute block and baffle block pressures and to relate these pressures to the Froude number of the entrance flow and to tailwater depth.

(4791) HIGH-VELOCITY JET ON PROTECTIVE COATINGS.

(b) Laboratory project.
(d) Experimental; for operation and maintenance.
(e) A 100-fps, 1-inch-diameter jet was impinged at 45 degrees on protective coverings proposed for application on concrete surfaces to be subjected to high-velocity flow.
(f) Completed.
(g) All protective coatings tested, in which the surface was unbroken, withstood the jet for 4 hours. All coatings tested in which a broken or cut surface extended to the concrete were ripped from the concrete test blocks in less than 5 minutes.
(h) Report in preparation.

(4792) CANADIAN RIVER AQUEDUCT CHECK TOWERS.

(b) Laboratory project.
(d) Experimental; for design.
(e) Laboratory tests are being made to determine the hydraulic losses and air-entrainment potential of check towers to be installed in the 125-mile-long Canadian River Aqueduct. The aqueduct consists of 54-, 60-, and 66-inch-diameter concrete conduit. The check towers are so designed that the top of each is slightly below the hydraulic grade line when the aqueduct is flowing full. Each check tower consists of a 90 degree vertical bend to direct the conduit upward, a 180-degree return bend at the top of the tower, and a 90-degree bend at the bottom of the downstream leg to return the conduit to the original alinement. There is a 22-inch air vent at the top of each tower.
(f) Completed.
(g) Head loss was determined for each size check tower. During filling or evacuating the tower, air was entrained in the downstream leg and carried into the horizontal conduit. A 36-inch-diameter vent was installed 120 feet downstream from each tower to release the entrained air.
(h) Report in preparation.

(4794) VERTICAL STILLING WELL.

(b) Laboratory project.
(d) Applied research.
(e) The purpose is to obtain the optimum size, depth, and internal configuration of vertical stilling wells for high-head discharges. The test installation has a 4-foot by 4-foot-square well 6 feet deep, followed by a canal with a 4-foot bottom width and 1-1/2:1 side slopes. An adjustable downspout is symmetrically located in the well and discharges against the flat floor. Piezometers are located in the floor and lower sidewalls of the well. Adjustable corner fillets provide a means for determining optimum fillet angle, size, and height.
(f) Continuing.
(g) The addition of corner fillets to the well results in much smoother water surfaces. The fillets direct the flow from the corners back to the center of the well inducing roller action. Optimum fillet configuration has been determined for one ratio of downspout area to well area. Additional studies will determine optimum fillet configurations for larger downspouts.

(4802) STUDIES ON ORIFICES FOR AUTOMATIC RADIAL GATE CONTROLS.

(b) Laboratory project.
(d) Experimental; for design.
(e) The studies are for the purpose of determining flow characteristics and discharge coefficients for various size orifices in floatwell intakes of automatic radial gate controls. A 1:1 scale model of a floatwell intake structure was constructed to determine discharge coefficients of the irregular orifice configuration in the regulating structure.
(g) Although the test arrangements differed substantially from arrangements for which data are presently available, measured coefficients compared closely with existing data.

(4807) MORROW POINT DAM SPILLWAY AND OUTLET WORKS.

(b) Laboratory project.
(d) Experimental; for design.
(e) A 1:24 scale model was constructed to aid in the development of the unusual design of the spillway and outlet works for the thin-arch concrete dam. The original design, consisting of a free overfall spillway and an outlet works located near the bottom of the dam, was abandoned because of undesirable flow conditions in the artificially formed stilling pool at the base of the dam. The present design includes four fixed-wheel gate controlled conduits near the top of the dam which discharge 34,400 cfs, allowing it to fall approximately 400 feet to the stilling pool. The small slide-gate-controlled outlet works in the lower portion of the dam and the underground powerplant tailrace channels are also included.
(f) Completed.
(g) Model studies have proven the acceptability of the present design. Design of the control weir which forms the stilling pool was modified and the two inside spillway conduits were tipped downward to provide more even distribution of impact of the free-falling jets. Revisions were made to the topography of the downstream river channels to improve flow conditions in those areas.
(h) Report in preparation.

(4947) OROVILLE DAM INCLINED POWERPLANT INTAKE TOWERS.

(b) California Department of Water Resources.
(c) California Dept. of Water Resources, State of California, Sacramento 2, California.
(d) Experimental; for design.
(e) Hydraulic phenomena of the unique inclined intake towers were studied in a 1:24 scale model. Temperature control shutters were arranged on the towers so water could be drawn from selected levels in the reservoir to maintain desired river temperatures for irrigation and for fish propagation. Differential pressures across these very large gates, and any tendencies for hydraulic instability during operation were studied.
(f) Completed.
(g) (1) The uppermost temperature control shutters must be a minimum of 40 feet below the reservoir water surface to prevent air entrainment by vortices. (2) The head loss is 2.9 feet for maximum discharge (8,600 cfs) with water flowing through the trashracks, past the temperature control shutters and emergency closure gate, and into the 22-foot-diameter penstock. (3) A head differential of 3 feet will exist across the 40- by 42-foot temperature control shutters during normal power plant operation.
(h) "Hydraulic Model Studies of the Oroville Dam Powerplant Intake Structure, California," K. G. Bucher, Report No. Hyd-509, June 1965.

(4948) OROVILLE DAM FLOOD CONTROL OUTLET AND SPILLWAY.

(b) California Department of Water Resources.
(c) California Department of Water Resources, State of California, Sacramento 2, Calif.
(d) Experimental; for design.
(e) Models built to 1:48 and 1:78 scale are being used to study the hydraulic features of a revised design of the flood control outlet. The general flow conditions, discharge coefficients, water surface profiles, flow velocities and energy dissipation as the flow reaches the Feather River are being tested on the 1:78 scale model of the entire outlet structure. The 1:48 scale sectional model of four of the eight outlet bays is being used to obtain discharge capacities for controlled and uncontrolled releases. Pressures along the pier walls and bellmouth roof of the bays were recorded from this model. A 1,740-foot-long uncontrolled overfall spillway which will operate only during extreme flood conditions was not modeled.
(f) Completed.
(g) Flow through the outlet approach area, bays and channel was good except for slight vortex action at the outlet entrances. Modifications at the left abutment virtually eliminated the vortices. Pressures on the pier sides and bellmouth roof were all at or slightly below atmospheric. The discharge capacity was slightly higher than design capacity. Spillway chute and bucket were developed for discharge of 250,000 cfs.
(h) "Hydraulic Model Studies of the Flood Control Outlet and Spillway for Oroville Dam--Calif. Dept. of Water Resources, State of Calif.," T. J. R hone and W. F. Arris, Report No. Hyd-510, September 30, 1965.

(4950) NAVAJO MAIN CANAL HEADWORKS.

(b) Laboratory project.
(d) Experimental; for design.
(e) A 1:16 scale model containing two 9- by 12-foot top seal radial gates, a divided underground stilling basin, and a horseshoe-shaped downstream tunnel was constructed to aid in evaluating and improving the stilling basin performance, and to test the unusual application of radial gates. Discharges ranged up to 1,800 cfs, and heads ranged from 15 to 126.5 feet.
(f) Completed.
(g) Abasin was developed that provided good energy dissipation and smooth water surface conditions in the downstream tunnel. Backflow, which struck the downstream faces of the radial gates for a wide range of heads and discharges, was prevented by placing

curtain walls above the 15° chutes just above the path of the high velocity jets. An underpass wave suppressor in the downstream portion of the basin prevented large waves from entering the tunnel.

(h) "Hydraulic Model Studies of Main Canal Outlet Works, Navajo Indian Irrigation Project, New Mexico," T. J. Isbester, Report No. Hyd-536, January 1965.

(4952) SURGE STUDIES IN LONG, LOW-HEAD PIPELINE SYSTEMS.

(b) Laboratory project.
(d) Experimental; applied research and design.
(e) Laboratory studies will be made to verify an electronic computer program for analyzing low frequency surge characteristics of long pipeline systems. The test facility consists of 1,400 feet of 4-inch pipe, a constant head water supply, a constant head terminal reservoir, and a slow closing and opening valve for producing controlled changes in rate of flow. The pipeline is interrupted at 160-foot intervals with open check stands that divide the line into individual reaches with pressure heads not greater than 2.8 feet. Total drop of the line is 24 feet.
(f) Continuing.
(g) A series of test runs with varying control valve closure times have been made. The results, listing head versus discharge for various stations and time intervals have been furnished for debugging and modifying an ADP program which will be used to predict prototype results.

(4954) SAN LUIS FOREBAY PUMPING PLANT INTAKE TRANSITIONS.

(b) Laboratory project.
(d) Experimental; for design.
(e) A 1:15 scale model was used to compare head loss, velocity distribution, and flow patterns in various configurations of canal transitions to pumping plant intakes.
(f) Completed.
(g) On the basis of velocity distribution and surface flow patterns in the transition and pump intake bays a symmetrical transition was found to be more desirable than an angled transition. Head losses were too small to justify comparison on this basis. The angled transition was chosen for the final design after consideration of economic factors. Numerical methods and a digital computer were used to analyze the large volume of velocity data.
(h) "Hydraulic Model Studies of the Inlet Transition at Radar Pumping Plant, Columbia Basin Project, Washington," D. L. King, Report No. Hyd-547, April 1965.

(4955) SAN LUIS FOREBAY CANAL SURGE STUDIES.

(b) Laboratory project.
(d) Experimental; for design.
(e) A 1:48 scale model was tested to determine the magnitude and velocity of surge in a pumping plant supply canal after power failure and rejection of flow. Effects of bifurcations, curves, and canal structures and methods of relieving surges were investigated.
(f) Completed.
(g) Comprehensive data were obtained on the size, form, and velocity of surge waves following rejection of the canal flow and drainage from the pump discharge lines. A longitudinal side weir was developed to attenuate the surge to an allowable height.
(h) "Hydraulic Model Studies of Surges Developed by Rejection of Flow at the San Luis Forebay Pumping Plant, Central Valley Project, California," D. L. King, Report No. Hyd-546, December 1965.

(4956) YELLOWTAIL AFTERBAY DAM SLUICEWAY AND OVERFALL WEIR.

(b) Laboratory project.
(d) Experimental; for design.
(e) One to twenty-four scale models were used to determine the hydraulic operating characteristics of the afterbay dam sluiceway and overfall weir, and to develop satisfactory stilling basins for both structures. The basins were judged on appearance of flow conditions and downstream bed erosion.
(f) Completed.
(g) The model study resulted in hydraulic jump type stilling basins containing chute blocks, baffle piers, and an end sill (Type III) being recommended for the sluiceway and overfall weir. Both recommended structures provided smooth approach-, chute-, stilling basin-, and downstream channel-flow, and produced no erosion or movement of downstream riverbed or riprap. Discharge capacity and coefficient curves were prepared for both structures.
(h) "Hydraulic Model Studies of the Sluiceway and the Overflow Weir, Yellowtail Afterbay Dam, MRBP, Montana," W. F. Arris, Report No. Hyd-523, April 1965.

(4957) BAFFLED PIPE OUTLET ENERGY DISSIPATORS.

(b) Laboratory project.
(d) Applied research.
(e) Hydraulic model studies are being made to extend present information concerning this type of impact energy dissipator. Prototype data from existing operating structures will be compared with model data. Investigation of erosion around the structures and in the downstream bed will be studied.
(f) Suspended.

(4958) AIR DEMAND TESTS ON 84-INCH JET FLOW GATE--TRINITY DAM, CALIFORNIA.

(b) Laboratory project.
(d) Field investigations.
(e) Field measurements were obtained to compare model and prototype air demand for the complete range of gate openings at maximum operating head (369 feet) on the gate. A laboratory model study was made to obtain centerline velocity coefficients for the prototype air duct to provide for quantitative analysis of field measurements.
(f) Completed.
(g) Maximum velocity in the air supply conduit was within design limits.
(h) Report in preparation.

(4959) FLAT BOTTOMED TRAPEZOIDAL VENTURI FLUMES.

(b) Laboratory project.
(d) Experimental; for design.
(e) A pilot study of a single flume is being conducted to determine the best approach to a comprehensive program to generalize the design and calibration of this type of water measuring device.
(g) The model study has demonstrated that the particular pilot flume tested is an adequate measuring device.
(h) Report in preparation.

(4960) PROTOTYPE PIEZOMETRIC AND AIR DEMAND MEASUREMENTS OF 4- BY 4-FOOT TANDEM GATE--NAVAJO DAM, NEW MEXICO.

(b) Laboratory project.
(d) Field investigation.
(e) To compare the model and prototype, piezometric measurements were obtained for the complete range of gate openings with a head of 164.5 feet. Prototype air demand measurements were made simultaneously with piezometric valves to evaluate adequacy of the air supply system. Further tests are planned at heads of about 230 feet and 300 feet to more fully evaluate the hydraulic characteristics of this gate and to check the model scaling.

(4962) LABORATORY INVESTIGATION OF THE REMOVAL OF SALT WATER FROM A TWO-PART AQUIFER USING TILE DRAINS INSTALLED IN THE UPPER MEMBER, AND PUMP WELLS INSTALLED IN THE LOWER AQUIFER.

(b) Laboratory project.
(d) Applied research.
(e) Tests were performed on a 16-foot-long 1:40 scale model containing two-part and single-part aquifers to determine the hydraulic action of simulated tile ground-water drains placed 0.2 foot below the model surface. The lower aquifer was composed of coarse sand 50 times more permeable than the fine sand in the upper aquifer. For initial conditions the model was charged with salt water, concentration 6,000 ppm NaCl, dyed blue for visual identification. Tests are continuing using vertical pump wells in the lower aquifer as drains.
(g) For the given prototype conditions, tile ground-water drains will not intercept and discharge fresh water if the lower aquifer contains salt water. The fresh water tends to drive the salt water ahead of it to the drain.
(h) Progress Report No. 2 in preparation.

(5331) INVESTIGATION OF THE EFFECT OF TURNOUT GEOMETRY ON THE ACCURACY OF A PROPELLER-TYPE OPEN FLOW METER.

(b) Laboratory project.
(d) Experimental; for design.
(e) The purpose of the investigation was to determine whether a change in the design of outlet structures for open flow meters from a relatively unconfined outlet to a confined outlet changed the registration accuracy of the meter.
(f) Completed.
(g) Results indicate that a confinement just large enough to pass the design discharge of the turnout did not significantly change the meter registration accuracy.
(h) "Investigation of the Effect of Turnout Geometry on the Registration Accuracy of a Propeller-Type Open-flow Meter," C. E. Brockway, Report No. Hyd-545, May 1965.

(5335) HIGH PRESSURE SLIDE GATE STUDIES FOR RUEDI AND MORROW POINT DAM OUTLET WORKS.

(b) Laboratory project.
(d) Experimental; for design.
(e) A 1:9 scale model is being used to determine operating characteristics and pressure conditions on slide gates to be used for regulation at heads up to 355 feet. The flow passages of the gates slope downward 30° in the direction of flow, and the gate leaves and bonnets are vertical. Effects of flaring the sidewalls immediately downstream from the leaf are being studied.
(g) Preliminary studies show that a gate slot design used very successfully on gates with horizontal flow passages and vertical leaves is not satisfactory for gates with 30° sloping passages and vertical leaves. Also, flaring the downstream walls in the normal fashion just downstream from the leaf leads to extremely subatmospheric pressure conditions and cavitation. By offsetting the walls abruptly 3 or 4 inches outward a very short distance downstream from the leaves, an excellent design with either parallel or diverging downstream walls is apparently obtained.

(5336) BUTTERFLY VALVE STUDIES WITH CAVITATION OCCURRING.

(b) Laboratory project.
(d) Experimental; for design.
(e) A commercial 8-inch, 125 psi butterfly valve is being tested under portotype head to determine the effects on cavitation characteristics, air demand, and discharge coefficients that result from discharging the valve directly into sudden enlargements, or through short conduits into the enlargements. Tests are made with and without the admission of air, and quantities of air needed to just quiet the cavitation are being obtained. Effects of air admission on the discharge coefficient are also being obtained.
(g) Preliminary results show that satisfactory pressure reducing stations for high differential heads and low back pressures can be obtained with butterfly valves if the valves discharge directly into a 2.0 dia enlargement. Air in sufficient quantities to relieve cavitation when the discharge enters the enlargement directly, or through short sections of pipe, has little effect upon the discharge coefficient.

(5337) PRESSURE RELIEF PANELS FOR OROVILLE DAM POWER PLANT INTAKE TOWERS.

(b) California Dept. of Water Resources.
(c) California Dept. of Water Resources, Sacramento 2, Calif.
(d) Experimental; for design.
(e) The 40- by 42-foot temperature control shutters for the inclined intake towers are designed to withstand a maximum head differential of 5 feet of water. Under maximum discharge through the power plant the head differential across the shutters will be 3 feet. Surges caused by power plant demand fluctuations, or removal or replacement of temperature control shutters, could cause pressures across the shutters in excess of the design maximum allowable.
(f) Completed.
(g) Relief panels have been designed which will open under a head differential of 3 1/2 feet. The recommended panel was calibrated to determine the number of panels required to furnish the discharge demand of the power plant for a maximum head differential of 5 feet of water.
(h) "Hydraulic Model Studies of the Pressure-relief Panels in the Powerplant Intake Structure--Oroville Dam, California Dept. of Water Resources, State of California," D. Colgate, Report No. Hyd-549, October 1965.

(5338) LABORATORY TESTS OF GATE SEALS UNDER PROTOTYPE HEADS.

(b) Laboratory project.
(d) Experimental; for design
(e) A facility for testing gate seals under heads of up to 200 feet was used on two similar double stem rubber gate seals. One seal bulb was capped with teflon and the other was uncapped. The program consisted of extrusion tests under sustained load, and tests with relative motion to determine the seal action as it approached, touched, and moved on the seat. A new facility is being built to test seals at heads of approximately 600 feet.
(g) The teflon cap added to the rigidity of the seal and prevented much of the distortion noted with the uncapped seal. Also, when the seal was moved relative to the seat, the teflon cap prevented the seal from being pinched between the clamp bar and seal seat.

(5339) MODEL-PROTOTYPE CORRELATION OF AIR DEMAND.

(b) Field tests and laboratory project.
(d) Theoretical and experimental; applied research.
(e) Basic parameters are being developed to correlate model results with prototype measurements for the flow of air in a closed conduit partially filled with moving water. Prototype measurements are essentially complete. Laboratory tests are beginning in a variable slope, enclosed, rectangular channel. The mean air velocity and turbulence intensity of the air stream will be measured for various water velocitites, various water depths and various pressure gradients.

(5341) GRANBY DAM SPILLWAY.

(b) Laboratory project.
(d) Experimental; for design.
(e) A 1:36 scale model was used to study the modification to the spillway chute and the proposed flip bucket and plunge basin for flows up to 12,000 cfs at velocities in the flip bucket ranging up to approximately 100 feet per second.
(f) Completed.
(g) A deflector and transition in the curved super elevated, horizontal portion of the chute was developed to provide good flow distribution in the flip bucket. The flip bucket and plunge basin were developed to provide effective energy dissipation for flows up to 3,000 cfs and to prevent erosion in the area adjacent to the flip bucket for flows up to 12,000 cfs.
(h) "Hydraulic Model Studies of Granby Dam Spillway Modification, Colorado-Big Thompson Project," G. L. Beichley, Report No. Hyd-539, May 1965.

(5342) SWIFT DAM SPILLWAY.

(b) Laboratory project.
(d) Experimental; for design.
(e) A 1:42 scale model was studied to determine necessary modifications to rehabilitate a 46-year-old chute spillway.
(f) Completed.
(h) "Hydraulic Model Studies of Swift Dam Spillways--Pondera County Canal and Reservoir Company, Montana," G. L. Beichley, Report No. Hyd-548, December 1965.

(5343) STRATIFIED FLOW.

(b) Laboratory project.
(d) Library study.
(e) Library research is being made to determine the extent of work that is being done and has been done in this field. An abstract will be prepared and a proposal made for laboratory research. Particular interest is being given to regulation of reservoir releases and the design of outlet works to maintain desirable oxygen balance in streams.

(5345) YELLOWTAIL AFTERBAY DAM SPAWNING CHANNEL.

(b) Laboratory project.
(d) Experimental; for design.
(e) A 1:8 scale model was constructed to study the stilling basin and diffuser chamber in the intake to the resting pool of the spawning channel.
(f) Completed.
(g) A slotted baffle for the stilling basin was developed to dissipate the energy of the incoming flow and to provide good flow distribution from the diffuser chamber into the resting pool.
(h) "Hydraulic Model Studies of Yellowtail Afterbay Dam Spawning Channel Stilling Basin and Diffuser Chamber," G. L. Beichley, Report No. Hyd-525, March 1965.

(5346) GLEN ELDER DAM SPILLWAY.

(b) Laboratory project.
(d) Experimental; for design.
(e) A 1:72 scale model is being used to study the hydraulic features of the spillway. The model contains 12 radial gate controlled spillway bays, the approach channel, surrounding topography, the hydraulic jump stilling basin and concrete lined apron, and a portion of the downstream channel.
(f) Completed.
(g) The flow in the approach area, through the bays, and in the downstream channel is smooth. The operation of the stilling basin is efficient. There is no excessive erosion of the downstream channel. No major changes to the initial design were recommended as a result of the model study.
(h) Report in preparation.

(5347) LITTLE PANOCHE CREEK DETENTION DAM OUTLET WORKS INTAKE STRUCTURE.

(b) Laboratory project.
(d) Experimental; for design.
(e) A 1:15 scale model was built to study the flow conditions in a square, submerged vertical inlet and bend when stop logs are used to control the flow into the inlet.
(f) Completed.
(h) Report in preparation.

(5844) PORTAGE MOUNTAIN DAM LOW LEVEL OUTLET WORKS.

(b) British Columbia Hydro and Power Authority, W. F. Miles, General Manager.
(c) International Power and Engineering Consultants, Ltd., 570 Dunsmuir Street, Vancouver 2, Canada.
(d) Experimental; for design.
(e) The outlet works will utilize two of the three 48-foot-diameter horseshoe-shaped diversion tunnels and will consist of two conduits through each of the two diversion tunnel plugs. An 84-inch Howell-Bunger valve at the downstream end of each conduit is used to control the flow. Each conduit is designed to discharge 2,500 cfs at an approximate head of 450 feet but may discharge twice this amount in emergencies. A 1:14 scale model of the valves and the horseshoe-shaped tunnel has been constructed to develop the design of the air supply system to the valves, the optimum location of the valves, and the energy dissipating devices required in the diversion tunnel.

(5845) PATILLAS DAM SPILLWAY.

(b) Puerto Rico Water Resources Authority.
(c) Rafael V. Urrutia, Executive Director, Puerto Rico Water Resources Authority, San Juan, Puerto Rico.
(d) Experimental; design.
(e) The existing spillway has operated over the years and a considerable amount of erosion has occurred in the natural channel at the downstream end of the spillway. Numerous modifications to the original spillway have been ineffective in reducing the erosion. A 1:36 scale model is being constructed to develop the required modifications to eliminate this adverse operating condition.

(5846) CRYSTAL DAM SPILLWAY.

(b) Laboratory project.
(c) Experimental; design.
(e) A 1:40 scale model of the spillway will be tested to investigate overall flow conditions. In addition, a structure at the end of the spillway tunnel will be developed which will function as a stilling basin for flows up to 11,000 cfs and as a flip bucket for higher discharges. Determination of discharge coefficients for a tainter gate on the spillway crest and the development of an atmospheric pressure spillway crest will be accomplished through the use of a 1:24 sectional model.

(5847) CRYSTAL DAM OUTLET WORKS.

(b) Laboratory project.
(d) Experimental; design.
(e) A 1:12 scale model will be tested to evaluate the operation of the outlet works stilling basin. Two 3-foot 3-inch-square high-pressure slide gates discharge a maximum of about 2,000 cfs into the stilling basin under a head of approximately 200 feet. The energy dissipating efficiency of the basin and the downstream flow conditions will be investigated. Special attention will be given to the measurement and evaluation of hydrodynamic forces acting on various parts of the structure, particularly the cantilevered vertical concrete wall which separates the flow from the two gates.

(5848) EL VADO DAM OUTLET WORKS.

(b) Laboratory project.
(d) Experimental; design.
(e) A 1:30 scale model was used to develop a flip bucket which would minimize river channel erosion by dispersing sizable releases, and would allow small releases to be bypassed through an offset opening in the right wall. The model contained a section of the dual gate controlled outlet works tunnel, the flip bucket, a section of the existing spillway, and a section of river channel.
(g) The recommended flip bucket contained two vertical confining walls and two sloping plane surfaces to intercept and direct the flow to the lip of the bucket. The best flow dispersion occurs for normal releases of from 2,000 to 4,000 cfs. Small releases are passed through an offset opening in the right wall.
(h) Report in preparation.

U. S. DEPARTMENT OF THE NAVY, DAVID TAYLOR MODEL BASIN.

Inquiries concerning the following projects should be addressed to the Comanding Officer and Director, David Taylor Model Basin, Washington, D. C. 20007.

(1778) HYDRODYNAMIC NOISE.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Hydrodynamic research.
(e) Investigations of the characteristics of underwater noise associated with various hydrodynamic phenomena such as cavitation, bubble oscillations, surface disturbances, turbulence, and unsteady flow. Attention is now being given to measurement of spectra and space-time correlations of pressure fluctuations on walls adjacent to turbulent flows, such as curved plate boundary layer flows, turbulent boundary layers on buoyancy propelled bodies, and fully turbulent pipe flows.
(g) The effect of flush microphone size on measurements of boundary layer pressure fluctuations has been determined. The pressure distribution on the noses of various bodies of revolution have been examined. The pressure fields below multipole sources near a free surface have been studied.
(h) "The Pressure Fields Below Low-Frequency Monopoles and Vertical Dipoles Near a Free Surface," Gerald J. Franz. Proceedings of the 5th International Congress of Acoustics Liege Belgium, Volume Ib, 1965.

(1783) MATHEMATICAL SHIP LINES.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Theoretical research.
(e) Development of a suitable method for the mathematical determination of ship lines which can be applied to a wide variety of ship forms especially to those of modern design.
(f) Inactive.
(g) A method has been developed for the mathematical fairing of graphical lines. This is a first step toward the development of a flexible system of mathematical ship lines. Future work is directed toward the development of a system of mathematical lines which will permit the derivation of a hull form for a given set of parameters.

(1786) STUDIES OF THE SLAMMING OF SHIPS.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Experimental and theoretical basic research.
(e) Phase 1: Statistical study to clarify the basic nature of slamming phenomenon experienced by a ship in rough seas and to develop a method for predicting the frequency of occurrence of slamming as well as its severity.
Phase 2: Computations and measurements of the pressure distribution and impact forces on the bottoms of slamming ship for the purpose of developing criteria to effect their reduction.
(f) Phase 1: Partially completed. Phase 2: Partially completed.
(g) Phase 1: Basic nature of ship slamming phenomenon has been clarified by conducting tests on a MARINER model. Effects of sea severity, ship speed, course angle, and loading conditions on slamming were obtained. A theory for predicting the frequency of occurrence and severity of slamming has been developed.
Phase 2: A theory which is applicable to almost any practical ship forebody section has been developed for determining impact force and pressures on ship's bottom during slamming. A two-dimensional drop test to evaluate the effect of sectional form on impact pressure was conducted for three different ship forms ranging from extreme U to extreme V form. A comparison between theoretical and experimental results was made on impact pressure.
(h) "Random Impact Loads due to Ship Slamming in Rough Seas," Michel K. Ochi. First Conference on Ship Vibration, January 1965. "Two-Dimensional Experiments on the Effect of Hull Forms on Hydrodynamic Impact," M. K. Ochi and F. M. Schwartz. David Taylor Model Basin Report, in review.

(2229) NEAR SURFACE EFFECTS.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Hydrodynamic research.
(e) A mathematical study of the forces and moments acting on bodies due to the proximity of a free surface. The studies include both the case in which the surface is initially undisturbed and the case in which there are disturbances originating at a distance. Experiments are being conducted to verify the theoretical developments.
(g) Methods were developed for computing the forces and moments acting on bodies of revolution, both due to waves generated by the body itself and to regular trains of waves. Experiments with a spheroid moving under waves largely confirmed the theory except in following seas. The damping forces on a submerged translating ellipsoid which is oscillating in any of its six degrees of freedom have been developed theoretically. The effect of tank walls has been evaluated theoretically as well.
Theoretical methods have been developed for the determination of wave resistance of floating bodies in steady motion from wave measurements along a parallel cut.
The first and second order diffraction and radiation forces acting on a submerged two-dimensional circular cylinder have been developed and computations have been made. Analytic expressions have been obtained for arbitrary bodies relating the radiation and diffraction forces to each other.
For a submerged, translating, two-dimensional cylinder, it has been shown that second-order forces due to nonlinearity of the free surface boundary conditions are comparable to second order forces resulting from exact satisfaction of the body boundary conditions.
Formulas have been derived for the sinkage and trim of ships moving in shallow water. These agree well with experiments except for speeds near to the shallow water critical speed.
Formulas have been derived for the force and moment on a slender body of revolution moving parallel to a plane infinite rigid wall.

(2230) THEORY OF SEAWORTHINESS.

(b) Bureau of Ships; David Taylor Model Basin.

(d) Hydrodynamic research.
(e) A theoretical study, with experimental confirmation, of the factors affecting the seaworthiness of ships, for the purpose of developing procedures for predicting their motions.
(g) Theoretical results for ship motions based on the "thin-ship" idealization have generally proved to be either inaccurate or incomplete. Recent results from application of slender body theory have shown good agreement with experiments at zero speed of advance. The corresponding theory has been developed for non-zero speeds, but calculations have not yet been made, and so it is not known whether the success at zero speed can be extended to the more general situation. Improved methods of testing ship models have been developed, and the entire frequency response of a ship at a single speed can be determined from one test run. The form of the equations of motion have been obtained by a very general theoretical approach. These equations are characterized by the appearance of convolution integrals involving the entire past history of the motion; they are free of the usual frequency-dependent coefficients. Tests have been conducted to characterize the dynamics of a ship, relating the kernels of these convolution integrals to the common added mass and damping coefficients. A survey of ship-motion theory has been prepared.
Formulas have been derived for the drift force and moment on slender ships in regular waves, at zero forward speed.

(2237) LIFTING SURFACE THEORY OF PROPELLERS.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Theoretical; applied research.
(e) Studies of the corrections on lifting line theory which arise from the finite extent of the blades.
(h) "Hydrodynamic Aspects of Propeller Design Based on Lifting Surface Theory, Part II: Arbitrary Chordwise Load Distribution," H. M. Cheng, DTMB Report 1803 (June 1965).
"A Comparison of the Lifting Surface Corrections Calculated by Different Methods for Three Propeller Designs," E. E. Harley, DTMB Report 2049 (Sept. 1965).

(2971) FULL SCALE TRIALS AND MODEL PREDICTION CORRELATION.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Experimental testing and re-evaluation of existing test data.
(e) The accuracy of full scale power predictions from model test results depends upon the proper selection of the correlation allowance (ΔC_F) to be used in model tests. The results of about 54 correlations of surface ships have been completed and published. The present target is the analysis of correlations submarines, considering all trials conducted, and selecting those most acceptable to this program.
(g) Same analysis has been done in connection with submarines. Further analysis of the data derived from the surface ship trials is continuing.

(3284) UNSTEADY HYDROFOILS.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Experimental and theoretical applied research.
(e) The Bureau of Ships uses results of this work to design high speed, sea-going hydrofoil craft. Two experiments are being run to determine: (1) The unsteady forces on two-dimensional hydrofoils due to hydrofoil motions, surface waves, and cavitation. (2) The forces on surface-piercing struts as functions of profile, angle of yaw and ventilation.
Computations are done, based on existing theories, to determine cavitation inception speeds of hydrofoils as functions of surface roughness.
(f) Tests were completed with a subcavitating, NACA 16-209 profile hydrofoil model in smooth water. For the surface-piercing strut study, profiles were determined and equipment is being designed and assembled. For the surface roughness study, computations are being made on the IBM 7090 computer.
(g) Reports will be written on the smooth water tests. Tests will be continued under waves. The surface-piercing struts will be tested. A report will be written on the surface roughness study.
(h) "Calculated Hydrodynamic Loads on an Oscillating Hydrofoil," T. J. Langan and D. W. Coder, TMB Report 1695, January 1965.
"Hydrofoils Beneath a Free Surface at Various Cavitation Numbers," J. H. Pattison, TMB Report 1776, March 1965.
"Unsteady Hydrodynamic Loads and Flutter of Two-Dimensional Hydrofoils," D. S. Cieslowski and J. H. Pattison, presented at the Spring Meeting of the Society of Naval Architects and Marine Engineers, May 1965.
"Computation of Oscillatory Loads on a Supercavitating Hydrofoil," Jon Patton and Avis Borden, Ph.D., TMB Report 1840, August 1965.
"Experimental Measurements of the Steady Lift, Drag, and Moment on Surface-Piercing Struts," G. M. Wilburn and H. S. Haller, Jr., TMB Report 1778, October 1965.
"Survey of Steady Lift and Moment on Two-Dimensional Flat-Plate Hydrofoils Beneath a Free Surface at Various Cavitation Numbers," J. H. Pallism, TMB Report 1776, (in review).

(3285) HYDROELASTICITY PROBLEMS.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Experimental and Theoretical Applied Research.
(e) Investigations to determine the flutter parameters of two-dimensional, two-degree of freedom hydrofoils. The effects of speed, frequencies, mass distribution, free surfaces, ventilation and waves are being studied. This work is related to Unsteady Hydrofoils (Reference No. 3284).
(g) Flutter tests have been conducted in the 36" Variable Pressure Water Tunnel and in the High Speed Towing Basin at various submergence depths. All tests have been performed with a NACA 16-209 hydrofoil.
There was good flutter speed correlation between the tests carried out in the Water Tunnel and in the Towing Basin at a submergence of one chord. An increase in the flutter speeds was noticed at submergences less than one chord length beneath the free surface.
(h) "Flutter of a Two-Dimensional, Two-Degree of Freedom Hydrofoil," Daniel S. Cieslowski, DTMB Hydromechanics Test Report 051-H-01, February 1965.
"Unsteady Hydrodynamic Loads and Flutter of Two-Dimensional Hydrofoils," Daniel S. Cieslowski and John H. Pattison, presented at the Spring Meeting of the Society of Naval Architects and Marine Engineers, Seattle, Washington, Paper 2b, May 13-14, 1965.

(3286) SUPERCAVITATING PROPELLER DEVELOPMENT.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Theoretical and experimental; applied research.
(e) Studies and design of propellers designed to operate at high speeds including improved section shapes for good operating characteristics and better strength capability.
(g) Recent calculations using nonlinear methods have shown some improvement in predicting test results. A unified supercavitating propeller design theory is being developed. The off-design problem is being considered

for computer programming.

(3292) EXPLORATORY STUDIES AND PLANS AT DTMB FOR MODEL TESTS IN 3-DIMENSIONS.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Experimental; basic research.
(e) A new seakeeping test facility is now in operation. Techniques for generating irregular short-crested seas and measuring the response of ship models at oblique headings is under development.
(g) Segmented wave generators provide the ability to produce oblique waves. Programming to individual wavemakers results in generation of confused seas of almost any nature. The rectangular basin offers opportunity to test in any relative heading to the waves and even in cross seas. Problems in analysis involve determination of the seaway (in the tank) as a function of frequency and direction. Ship motions in confused seas will be random in nature and will be analyzed by spectrum methods.

(3617) VENTILATED PROPELLER DEVELOPMENT.

(b) David Taylor Model Basin.
(d) Theoretical and experimental; applied research.
(e) Studies and design of ventilated propellers for operation at intermediate speeds.
(g) New instrumentation is being assembled for tests scheduled for this winter during which cavity pressures on an operating ventilated propeller will be measured. Some work showing the feasibility of low-speed ventilation on foils has been completed. This work will be reported this fiscal year (1966).

(3619) VERTICAL AXIS PROPELLER.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Experimental and theoretical; applied research.
(e) Theoretical and experimental studies of performance characteristics of various types of vertical axis propellers.

(4426) DEVELOPMENT OF A LOW WAVE DRAG HULL FORM.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Basic research.
(e) To establish a series of basic hull forms which can be used as a guide to evaluate the merit of future high speed ship designs.
(g) Results of resistance tests of 27 models of conventional hull form up to speed-length ratio of 5-0 has been reported.

(4427) A METHOD OF CALCULATING SPINDLE TORQUE OF CONTROLLABLE PITCH PROPELLERS.

(b) David Taylor Model Basin.
(d) Theoretical; applied research.
(e) A method of calculating the spindle torque of a controllable pitch propeller over the complete range of operating conditions and a theoretical investigation of the effect of various design parameters upon spindle torque In order to calculate spindle torque at off design conditions, the off design performance of the controllable pitch propeller must first be determined.
(f) Inactive.
(g) A method of calculating the spindle torque at design conditions has been completed. The geometric problem of determing the effective distortion of blade sections at off design pitch settings has been solved. The solution has been programmed for the 7090 Computer.

(4428) COMPUTER SOLUTIONS OF FREE SURFACE FORCES.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Hydrodynamic research.
(e) The linearized potential problem of a body oscillating on the free surface will be solved directly on a digital computer by distributing pulsating sources over the surface of the body and calculating the required source density. The individual source potentials are chosen to satisfy the free surface boundary condition.
(g) The integral equations for the case of two dimensional bodies have been approximated by algebraic equations. Solutions have been obtained for heave, sway, and roll motions of several bodies. Forces and moments have been calculated.
An extension to 3-dimensional solutions has been made for zero and infinite frequencies, and computations of added masses performed for actual ship hulls.

(4429) LATERAL FORCES.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Hydrodynamic research.
(e) The lateral force on a translating body which vertically cuts the free surface is being formulated theoretically. Two special cases are included: (a) If the draft is large compared to the length, the body is a strut with angle of attack. (b) If the draft is very small, the body corresponds to a yawed thin ship.
(f) Suspended.
(g) An integral equation has been derived for the density of a surface distribution of dipoles, such that the boundary conditons are satisfied.

(4809) TURBULENT BOUNDARY LAYERS IN PRESSURE GRADIENTS ON ROUGH SURFACES.

(b) Laboratory project, David Taylor Model Basin.
(d) Theoretical and experimental; basic and applied research.
(e) Research in the behavior of rough surface turbulent boundary layer in pressure gradients leading to separation. Roughnesses are screens of various gages fastened to wall of wind tunnel. Pressure gradients are obtained by deforming the opposite wall. Velocity surveys and turbulence measurement will be made.
(g) Data have been obtained, with one wall roughness in three pressure conditions. Measurements are in progress to obtain smooth wall data under similar pressure conditions. Boundary layer velocity profiles are measured with a pitot tube and hot wire. Longitudinal turbulent intensities are measured with a hot wire. Measurements are made at numerous longitudinal positions along the wall. Two reports on this work will be published in the near future.
(h) "The Influence of Pressure Gradient on a Turbulent Boundary Layer Over a Rough Surface," Victor E. Scottron and John L. Power, DTMB Report 2115 (to be published early 1966.) "The Low Turbulence Wind Tunnel," Victor E. Scottron and D. A. Shaffer, DTMB Report 2116 (to be published 1966).

(4810) SHIP WAKE SIMULATION STUDIES.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Experimental and theoretical; applied research.
(e) To produce ship wake distributions in a ariable pressure water tunnel in order to determine the performance of propellers in non-uniform wake flows.
(f) Completed.
(g) A theoretical method has been obtained for determining the wire grid geometry necessary to produce arbitrary, steady, three-dimensional flows. Simple experimental confirmation of the method has been obtained.
(h) "Steady Flow Past Nonuniform Wire Grids," J. H. McCarthy, Journal of Fluid Mechanics, Vol. 19, Part 4, 1964.

(4811) STEADY-STATE FORCES ON SUPERCAVITATING AND VENTILATED HYDROFOILS.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Theoretical and experimental; applied research.

(e) To study the steady-state lift and drag characteristics of supercavitating hydrofoil configurations for application to hydrofoil craft and supercavitating propeller design.

(g) Experimental determination of the lift and drag of various three-dimensional supercavitating hydrofoils is in progress. These include foils with 2-term, 5-term and flat-faced sections. The effects of aspect-ratio and taper are being investigated. Ventilation by blowing air through holes in the suction surface of the foil is used to extend the range of cavitation number. Future research includes the determination of two-dimensional lift and drag, studies of flap configurations and measurement of the interaction of tandem and cascade foils.

(h) "Performance Characteristics of the BuShips Parent Hydrofoil," G. F. Dobay, TMB Report 2084, August 1965.

(4812) PROPELLER AND BODY INTERACTION.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Theoretical and experimental; applied research.
(e) Study and development of design criteria for determining propulsion characteristics of submerged bodies and hydrofoil-supported craft.

(g) Axial clearance between a submerged body of revolution and a stern propeller has been optimized on the basis of propulsive coefficient. A method has been developed for computing thrust deduction for submerged hydrofoil-propeller arrangements.

(4813) INVESTIGATION OF DUCTED PROPELLERS.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Theoretical and experimental; applied research.
(e) To develop a design method for ducted propellers and to conduct a parametric study of ducted propeller performance.

(g) A theory of the ducted propeller with finite number of blades has been developed. From this theory a design method will be developed and then a parametric study of ducted propeller performance will be conducted.

(h) "Prediction of the Aerodynamic Characteristics of Annular Airfoils," W. B. Morgan and E. B. Caster, TMB Report 1830, January 1965.

(4816) FUNDAMENTAL PROPERTIES OF SHIP ROLLING.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Experimental and theoretical.
(e) Though extensive studies of rolling have been made in recent years, a great deal remains to be learned concerning the fundamental properties of rolling for both surface ships and submarines. Areas which require additional research are (1) applicability of superposition principle for rolling motion especially in short crested waves, (2) unstable rolling motion in oblique regular and in irregular waves, (3) nonlinear roll behavior in rough seas, etc. In order to clarify the fundamental nature of rolling, forced oscillation tests as well as model tests in regular and irregular waves will be conducted. Parameters significant for roll will be investigated.

(g) The effect of bilge keels on roll magnitude and damping characteristics has been clarified through forced and free rolltests at various speeds of advance.

(5121) SERIES 60 - PROPELLER INDUCED VIBRATION.

(b) David Taylor Model Basin.
(d) Experimental; basic research.
(e) Measurement of propeller induced vibratory forces to study the effect of fore and aft clearance in the propeller aperture of the clearwater type. The effect of number of blades and the tip clearance will also be determined. In addition, the pressure transmitted and shaft transmitted forces will be measured independently to determine the significance of each.

(g) Technique and instrumentation capable of measuring the hydraulically transmitted propeller forces on ship models has been developed in the past few years. Using these measurements obtained on various types of ship models the optimum parameters for horizontal and vertical propeller clearances (position) will be established to minimize the effect of propeller forces on the ship structure. Improved stern and appendages designs to reduce these forces will be developed.

(5122) FLOW VISUALIZATION STUDIES.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Experimental; applied research.
(e) To visually determine in water the effect of boundary-layer growth and trailing edge geometry on separation, and the mechanism of vortex shedding, from stationary and oscillating hydrofoil shapes.

(g) The hydrogen bubble visualization technique has been adopted to the 12-INCH water tunnel and preliminary flow studies have been made on a number of two-dimensional bodies. The experiments are being extended to study vortex shedding from stationary foils having different trailing edge geometrics.

(h) A report has been written and is under review titled "The Hydrogen-Bubble, Flow Visualization Technique" G. E. Mattingly TMB Report, Sept. 1965.

(5123) THE EFFECT OF GAS NUCLEI ON CAVITATION.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Experimental; applied research.
(e) To determine the effect of gas nuclei on the inception of cavitation.

(g) Acoustic techniques to measure the distribution and size of nuclei are being studied, and one will be applied to the water tunnels at DTMB. Cavitation inception studies will be made for a simple body and propellers and the results correlated with gas nuclei content of the water.

(5124) PROPELLER OSCILLATING PRESSURE FIELD.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Experimental; applied research.
(e) To experimentally determine the oscillating pressure field about marine propellers and correlate these measurements with theoretical predictions.

(g) Pressures have been measured on a flat plate parallel to the axis of two propellers, one a propeller of conventional design and the other of double blade thickness, in both uniform and non-uniform flow.

(5125) HYDRODYNAMICALLY EXCITED PROPELLER SINGING.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Experimental; applied research.
(e) To determine the characteristics of flow induced propeller singing and investigate methods to suppress singing.

(g) Tests on a model propeller have demonstrated the feasibility of studying singing at model scale by suitable trailing edge modification. The investigation will be extended to determine the applicability of two-dimentional flow-excited vibration data to propeller blades and to study the influence of variations in trailing edge geometry and other design parameters, including the use of high damping alloys, on propeller singing.

(h) "A Preliminary Study of Vortex-Induced Propeller - Blade Vibrations and Surging," R. A. Cumming, TMB Report 1838, Sept. 1965.

(5126) CAVITATION INCEPTION ON A ROUGH SURFACE.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Experimental and theoretical; applied research.
(e) An investigation to determine the effect of surface roughness on cavitation inception.

The incipient cavitation number of various types of surface roughnesses mounted in boundary layers will be determined as a function of boundary layer parameters. Theoretical studies will attempt to establish scaling laws for cavitation.

(g) The incipient cavitation number has been obtained for idealized three-dimensional roughnesses in the form of cylinders, cones and semi spheres. These roughnesses were mounted in a flat plate boundary layer. The cavitation number was determined as a function of the ratio of roughness height to boundary layer thickness. This work will soon be published as TMB Report 2104. Similar tests will be conducted on roughness that more closely simulate roughnesses found on ship hulls.

(5127) INTERACTION FORCES BETWEEN LIFTING SURFACES.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Theoretical; applied research.
(e) A two-dimensional theory for determining the forces and moments acting on two lifting surfaces as one passes through the wake of the other will be developed. This theory will be applied to the prediction of propeller-appendage interaction forces on a ship.
(g) A theoretical analysis has lead to a system of coupled multiple integral equations. Methods for solving this system are presently being investigated.

(5128) BOUNDARY-LAYER STUDIES.

(b) David Taylor Model Basin; basic and applied research.
(d) Theoretical and experimental; basic and applied research.
(e) Studies of boundary-layer phenomena important to naval hydrodynamics; methods for reducing frictional resistance, prediction of transition from laminar to turbulent flow for bodies of revolution.

(5324) CAVITY FLOW STUDIES.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Experimental and theoretical, basic research.
(e) A study of the vortex shedding phenomenon recently observed in fully cavitating flow. The study comprises (1) The experimental investigation of the dependence on cavitation number and ventilation index of a modified Strouhaul number for simple two-dimensional bodies; (2) the development of a new mathematical model for cavity flows; and (3) the investigation of the relationship between vortex shedding and hydrofoil oscillation. The purpose is to gain more understanding of cavity flows.

(5849) SHIP HULL FORM RESEARCH.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Theoretical as well as experimental research.
(e) The wavemaking resistance theory is used in the design of practical ships forms with low resistance characteristics. Model experiments are conducted to supplement the theoretical analysis.
(g) A new ship design procedure has been used to develop a number of hull forms. Test results of these forms have shown significant reductions in total resistances in the vicinity of designed speeds.
(h) "Theoretical and Experimental Study of Wavemaking Resistance of Ships," Pao Chi Pien and Wilburn L. Moore, International Seminar on Theoretical Wave Resistance, Volume I, pp. 133-188, August 1965, University of Michigan Ann Arbor, Michigan.
"The Application of Wavemaking Resistance Theory to the Design of Ship Hulls with Low Total Resistance," Pao C. Pien, Fifth Symposium on Naval Hydrodynamics, Sept. 1964, Bergen, Norway.
"Some Experimental Results of Hull Form Research," Pao C. Pien. DTMB Report 2144, Dec. 1965.

(5850) SHIP DESIGN WAVE RESEARCH.

(b) Bureau of Ships, David Taylor Model Basin.
(d) Experimental; applied research.
(e) To provide a meaningful simulation of oceanographic environmental conditions in the Model Basin's Seakeeping Facility. To provide for measurements of directional seaways by use of buoys or other devices.
(g) Long crested random seaways can be generated in the Model Basin Seakeeping Basin. Point spectrum of wave height can be measured using telemetering wave buoys.
(h) "Simulation of a Long Crested Gaussian Seaway," M. C. Davis, David Taylor Model Basin Report 1755 (Mar 1963).

(5851) TRANSIENT RESPONSE IN WAVES.

(b) Bureau of Ships, David Taylor Model Basin.
(d) Experimental; applied research.
(e) To develop various experimental techniques for rapidly determining transfer functions of ship motions.
(g) Techniques have been developed to determine motion responses to transient waves and transient forces.
(h) "Testing Ship Models in Transient Waves," Lt. Cdr. Davis USN and E. E. Zarnick, David Taylor Model Basin Report 2128, (in publication).

(5852) RELATION OF HULL FORM TO SEAWORTHINESS.

(b) Bureau of Ships, David Taylor Model Basin.
(d) Experimental; applied research.
(e) A systematic series investigation will be carried out in order to determine the effect of basic hull form parameters on seakeeping qualities and speed loss at sea. Design criteria for ships with minimum motions, dry decks and high speed will be established.

(5853) UNSTEADY PROPELLER FORCES.

(b) Bureau of Ships; David Taylor Model Basin.
(d) Experimental; applied research.
(e) To experimentally determine the oscillating forces and moments on a propeller operating in a nonuniform velocity field and correlate these measurements with theoretical predictions.
(g) A six component propeller dynamometer for unsteady forces has been developed along with instrumentation for on-the-spot determination of amplitude and phase of the harmonic components of the oscillating forces and moments. Propeller tests are in progress.

(5854) WATER TUNNEL CAVITATION STUDIES.

(b) Bureau of Ships, David Taylor Model Basin.
(d) Experimental; applied research.
(e) Experiments are being performed to evaluate the differences between open and closed-jet tunnels, to evaluate the effect of a resorber on cavitation inception on bodies and conventional propellers, and to evaluate propeller size and loading effects on supercavitating propellers. These tests are being performed in the TMB 24-inch open-jet water tunnel, and in the TMB 36-inch water tunnel with both open-jet and closed-jet sections.
(g) No results are available at this time since the first phase of testing has not been completed.

(5855) CAVITATION INCEPTION ON HYDROFOILS.

(b) BuShips, David Taylor Model Basin.
(d) Theoretical and experimental; applied research.
(e) Project objective is to predict inception on practical hydrofoils from macroscopic principles.
(g) Methods of pressure predictions on two-

dimensional hydrofoils have been examined and refined to insure the predicted minimum is obtained. Inception tests are being performed on two-dimensional foils by varying significant parameters.

(h) "Steady Two-Dimensional Pressure Distributions on Arbitrary Profiles," T. Brockett, DTMB Report 1821, (Oct. 1965).

(5856) SELF-EXCITED PLANING VIBRATION.

(b) BuShips, David Taylor Model Basin.
(d) Experimental and theoretical basic research.
(e) A study of the self-excited vibration of lifting shapes planing on a water surface. The purpose of the work is to define the conditions of incipient vibration and explain the mechanism involved.
(f) Completed.
(g) The effects of beam, sweepback, trim, load, speed, natural frequency and vibrational direction on the incipience of vibration of planing surfaces with large wetted aspect ratio were investigated. Experimental results are presented in non-dimensional form and correlated with results from a semi-empirical analysis. These results lead to the conclusion that the vibration under study was a dynamic instability involving an induced rise of the water surface ahead of the planing surface. Based on the results of this study, means of alleviation of the vibration are suggested.
(h) "Investigation of Self-excited Planing Vibration at Large Wetted Aspect Ratio," E. J. Mottard, DTMB Report 2017.

(5857) ELECTRIC ANALOG TECHNIQUE FOR HYDROFOIL INDUCED DRAG.

(b) BuShips, David Taylor Model Basin.
(d) Basic research.
(e) Modification and refinement of an electric analog technique for determining load distribution of non-planar lifting lines having minimum induced drag.
(g) Analog results have been obtained for some simple configurations. Comparison with analytical computations indicate that good accuracy is possible.

(5858) HIGH SPEED TESTS OF BUSHIPS "PARENT HYDROFOIL."

(b) BuShips, David Taylor Model Basin.
(d) Experimental applied research.
(e) Tests in the NASA High Speed Hydrodynamics Facility to determine the lift and drag of the BuShips "Parent Hydrofoil" at high speed.
(g) Tests in the 45-70 knot range are complete. Agreement with lower speed results is acceptable where the cavity is similar; however, there is considerable variation of cavity ventilation with speed.

For sponsored projects see the following:

PHILADELPHIA NAVAL SHIPYARD, Naval Boiler and Turbine Laboratory.

(3623) HIGH PRESSURE-TEMPERATURE WATER FLOW METER CALIBRATION.

(b) Bureau of Ships; Philadelphia Naval Shipyard (Naval Boiler and Turbine Laboratory).
(c) Mr. J. W. Murdock, Head, Applied Physics Division, Naval Boiler and Turbine Laboratory, Phila. Naval Shipyard, Phila. 12, Penna.
(d) Experimental; applied research.
(e) A facility is available for calibrating with water at pressures and temperatures up to 2500 psi and 600 F respectively. Capacity is 100 gpm at maximum pressure and temperature and greater at lower pressures and temperatures. After flowing through the metering section the water is cooled and weighed. The facility is also used to investigate and verify orifice meter coefficients at pressures and temperatures above those at which the coefficients in use were

established. A number of flow meters which measure the flow in nuclear reactor loops have been calibrated.

(f) Inactive.

(g) A limited amount of test data indicate good agreement between orifice flow rates obtained by calibration at high pressures and temperatures and those obtained by extrapolating from cold water calibrations. Other meter tests show the need to include suitable corrections for change in shape, size, density, etc.

(4001) HIGH PRESSURE STEAM AND WATER FLOW TESTS.

(b) American Society of Mechanical Engineers.

(c) Mr. J. W. Murdock, Head, Applied Physics Division, Naval Boiler and Turbine Laboratory, Phila. Naval Shipyard, Phila. 12, Penna.

(d) Experimental; applied research.

(e) Although the ASME Research Committee on Fluid Meters has sponsored many fundamental research programs dealing with the development of basic constants used with primary elements, hardly any of this work has been done on steam flow at high pressures and temperatures. Neither has research been done on high temperature water flow. Analysis of many tests indicate that the basic calibrations obtained with low temperature water (air and gas) could be extrapolated with high accuracy to the measurement of high pressure and temperature steam and water flow provided suitable corrections were made for the change in the shape and size of the primary element, the pipe and the fluid. This procedure has been experimentally verified for steam up to 2000 psi and 1050 F and for water to 2500 psi and 600 F.

(f) Completed.

(g) Nozzles and orifices were calibrated with water at 240 F, 2200 psia, and with steam at 1050 F, 2000 psia. Pipe Reynolds numbers averaged 600,000 for the water and 4,000,000 for the steam. Coefficients were generally in agreement with ASME predicted coefficients. Two and a quarter percent (2 1/4%) chrome-molybdenum steel proved unsatisfactory for the steam nozzles showing rusting and pitting after less than 10 hours. Type 430 stainless steel was substituted and was satisfactory.

(h) "ASME Research on High Pressure-High Temperature Steam and Water Flow Measurement," Rept. of Subcommittee 7 of the ASME Fluid Meters Research Committee by J. W. Murdock, presented at the 1964 Winter Annual Meeting of the ASME (Paper No. 64-WA/FM-4).

(5286) MEASUREMENT OF ACOUSTIC VELOCITY OF STEAM.

(b) Joint research project, Naval Boiler and Turbine Laboratory and Office of Naval Research.

(c) Mr. J. W. Murdock, Head, Applied Physics Division, Naval Boiler and Turbine Laboratory, Phila. Naval Shipyard, Phila., Pa. 19112.

(d) Experimental; basic research.

(e) Objective is to obtain precise knowledge of acoustic velocity values for steam in liquid-vapor and vapor phase. Data will be obtained with steam pressures and temperatures up to 5000 psi and 800F respectively.

U. S. NAVAL ORDNANCE LABORATORY.

(4867) THE HYDROBALLISTICS OF WATER ENTRY.

(b) Bureau of Naval Weapons, Department of the Navy.

(c) Commander, U. S. Naval Ordnance Laboratory White Oak, Silver Spring, Maryland.

(d) Experimental, theoretical, basic and applied research.

(e) The purpose is to study high velocity water entry as related directly or indirectly to the behavior of missiles. The study includes the stability and forces during the entry, cavity development and pressure, and the missile trajectory. A wide range of developmental and research configurations and of esperimental conditions are investigated. The missiles are launced from gas or powder guns.
A large tank facility, under construction, is scheduled for completion in early 1966. This facility, which was designed for use with large, high-speed missiles, will be supplemented by the smaller, lower-speed tank now in operation. Both tanks are suited to experimental projects such as water-entry, water exit, and trajectory studies, and both permit atmospheric pressure reduction for water-entry scaling.

(g) Data have been obtained on the water-entry whip of missiles with cone noses. These include preliminary experimental results and calculations using an unsophisticated mathematical model.

(h) "The Proposed Large Variable-Pressure Tank at the Naval Ordnance Laboratory," by A. May and A. E. Seigel. Proceedings of Symposium on Cavitation Research Facilities and Techniques, ASME 1964.
"Degeneration of Image Contrast and Resolution in Underwater Photography," by A. May and P. H. Cords, Jr.. Physical Aspects of Light in the Sea; A Symposium, University of Hawaii Press 1964.
"A Study of the Water-Entry Cavity," by A. May Developments in Mechanics, Pergamon Press, 1965.
"A Study of the Water Entry Cavity," by A. May and W. R. Hoover, NOLTR 63-264, 1965.
"Approximate Impact Drag Coefficients for the Vertical Water-Entry of Families of Cone, Ellipsoidal and Tangent Ogive Nosed Missiles," by W. R. Hoover and P. J. Readon, NOLTR 64-110, Oct. 1964.
"NOL Hydroballistics Facility," by V. C. D. Dawson, Journal of Aircraft, Vol. 2, No. 4, p. 350, 1965.

U. S. NAVAL ORDNANCE TEST STATION.

(4002) MISSILE BEHAVIOR DURING WATER EXIT.

(b) Bureau of Naval Weapons, Navy Department.

(c) Commander, U. S. Naval Ordnance Test Station, Attn: Dr. John G. Waugh, Code P8074, 3202 E. Foothill Blvd., Pasadena, California.

(d) Experimental; basic research.

(e) The objectives of this project are as follows: (1) To study missile water-exit behavior and associated phenomena under different conditions to determine if problems exist in missile water-exit technology and to establish scaling techniques for modeling missile water-exit behavior. (2) To evaluate qualitatively the inherent value of slender-body theory in predicting the underwater and water-exit behavior of an underwater launched missile in the presence of various sea states.

(g) The following studies were made in collaboration with the California Institute of Technology, Pasdena, California: (1) A series of tests was made to determine the added mass of a 1-inch-diameter steel sphere impulsively accelerated vertically upward from rest along the axis of Lucite cylinders filled with water and the results correlated with ideal fluid theory. No free surface effects were involved. The sphere was accelerated electromagnetically and the acceleration regime was sufficiently brief so that essentially potential frictionless flow obtained. Eight cylinders were used whose inside diameters ranged from 1.11 to 4.45 inches. The agreement between experiment and theory was very good. (2) Further tests were made to determine the effect of water surface proximity on the added mass of a 1-inch-diameter steel sphere accelerated vertically upward

from rest in open water and the results correlated with ideal fluid theory. Again, essentially frictionless potential flow obtained during the acceleration regime. The agreement between experiment and theory was very good and the results indicate that surface proximity has practically no effect on the added mass until the sphere center is about two diameters from the surface. For lesser depths, the added mass decreases with depth. (3) Several techniques for metric photography were developed and used in the studies described above. In the first, missile position-time data are obtained from measurement of photographs of the virtual image produced in a precision-ground sphere by a timed stroboscopic point-source lamp. In the second, a rotating circular film disk is covered with sector-shaped exposures using a timed stroboscopic lamp. In the third, the previously described techniques are combined to obtain data simultaneously.

(h) "The Variable-Atmosphere Wave Tank," J. G. Waugh and A. T. Ellis. Published in Cavitation Research Facilities and Techniques, 1964, The American Society of Mechanical Engineers, United Engineering Center, 345 East 47th St., New York, pp. 114-117.
"Techniques for Metric Photography," J. G. Waugh, A. T. Ellis and S. B. Mellsen. Submitted for publication in the Journal of the Society of Motion Picture and Television Engineers.

(4434) SHROUDED PROPELLER DESIGN.

(b) Bureau of Naval Weapons, Navy Department.
(c) Commander, U. S. Naval Ordnance Test Sta., Attn: Mr. J. F. Reynolds, Code P8074, 3202 East Foothill Blvd., Pasadena, Calif.
(d) Theoretical; applied research.
(e) This study involves the analysis of flow fields induced by shrouded propeller models. This will lead to a pumpjet configuration which includes boundary layer, central body and wide blade effects. The analysis will also allow for a pumpjet design at any level of complexity based on calculations of the induced inlet velocities. This gives an improved estimate of the inlet velocity profile.
(g) (1) Computer programs are available which compute the average radial velocities induced by a finite bladed propeller operating in a uniform or non-uniform flow field. (2) A computer program is available which determines the axial velocities at the propeller plane induced by an average shroud load distribution. These velocities can be computed at locations both on and off the cylindrical vortex surface representing the shroud. The above computer programs will give a preliminary design procedure for an open water or wake adapted shrouded propeller model, neglecting central body effects.
(h) "Summary of Shrouded Propeller Theory," to be published.

(4868) NON-NEWTONIAN FLUIDS.

(b) Bureau of Naval Weapons, Department of the Navy.
(c) Commander, U.S. Naval Ordnance Test Station, Attn: J. W. Hoyt, Code P807, 3202 E. Foothill Boulevard, Pasadena 8, California.
(d) Experimental; basic research.
(e) The turbulent flow characteristics of dilute solutions of various high polymers are being studied to understand why they often display anomalous flow behavior.
(g) Pipe flow tests and chemistry studies are being made of high polymers which seem to reduce the intensity of turbulence.
(h) "The Effects of Additives on Fluid Friction," by J. W. Hoyt and A. G. Fabula, NAVWEPS Rpt. 8636, Dec. 1964.
"An Ultra-Low Shear-Rate Viscosimeter," J. M. Caraher, in Symposium on Rheology, ASME, 1965.
"A Turbulent-Flow Rheometer," J. W. Hoyt in Symposium on Rehology, ASME, 1965.
"Algal Cultures: Ability to Reduce Turbulent Friction in Flow," J. W. Hoyt and Giorgio Soli, Science, Vol. 149, p. 1509-11, 24 September 1965.

(4872) A METHOD FOR COMPUTING TURBULENT BOUNDARY LAYERS BASED ON THE LAW OF THE WALL AND THE LAW OF THE WAKE.

(b) Bureau of Naval Weapons, Navy Department.
(c) Commander, U. S. Naval Ordnance Test Station Attn: Mr. David M. Nelson, Code P8074, 3202 E. Foothill Boulevard, Pasadena 8, California.
(d) Theoretical; applied research.
(e) A method for computing turbulent boundary layers based on the law of the wall and Coles' law of wake is under development. This method is applicable to two dimensional bodies and to bodies of revolution in axial-symmetric flow where the boundary layer thickness is not necessarily small compared to the body radius. A simultaneous solution of the momentum integral equation and the energy integral equation is carried out assuming the mean velocity profiles are given by a universal, two-parameter representation as suggested by Coles. The computational procedure will be programmed for an IBM 7090 computer.
(g) All theoretical work, computer programming, and comparisons with experimental data have been completed. A final report is in preparation.

(4873) RING WING LOADINGS.

(b) Bureau of Naval Weapons, Navy Department.
(c) Commander, U. S. Naval Ordnance Test Station, Attn: J. F. Reynolds, Code P8074, 3202 East Foothill Blvd., Pasadena 8, Calif.
(d) Theoretical; applied research.
(e) Analysis of loadings and induced flow from isolated ring wings with applications to shrouded propeller design.

(4920) UNDERWATER GAS-JET PROPULSION STUDY.

(b) Bureau of Naval Weapons, Dept. of the Navy.
(c) Commander, U. S. Naval Ordnance Test Station, 3202 E. Foothill Blvd. Pasadena 8, Calif. Attn: H. V. L. Patrick or T. G. Lang, Code P5006.
(d) Experimental; applied research.
(e) The thrust and efficiency of a submerged supersonic gas-jet propulsion system will be studied on a model propelled by a solid propellant grain generating hot gas at 4,000 psi exhausted through four nozzles along its afterbody. The efficiency of the momentum exchange with the surrounding water will be studied in an effort to increase the normally low propulsion efficiency of high speed jets.
(g) Propulsion tests at speeds to 40 knots in a ring channel have been successfully completed.

(5381) BASE-VENTED TORPEDO STUDY.

(b) Bureau of Naval Weapons, Dept. of the Navy.
(c) Commander, U. S. Naval Ordnance Test Station, Attn: H. V. L. Patrick or T. G. Lang, Code P5006, 3202 E. Foothill Boulevard, Pasadena 8, California.
(d) Experimental; applied research.
(e) The drag of several truncated torpedo models with air exhausted through their bases is measured as a function of gas flow rate, water tunnel speed, and angle of attack. Cavity pressure is also measured.
(f) Completed.
(g) The drag of all models remained the same as that of a streamlined model for truncations up to 90% of the maximum diameter, one of the models was fully base vented.
(h) "Water Tunnel Tests of Base-Vented Torpedo Models," T. G. Lang and H. V. L. Patrick, Nov. 30, 1964, ASME publication 64-WA/UNT-5. Also, NAVWEPS Report 8559, Nov. 1964.

(5382) DROP TESTS OF OBJECTS IN A HIGH-POLYMER SOLUTION.

(b) Bureau of Naval Weapons, Dept. of the Navy.
(c) Commander, U. S. Naval Ordnance Test Station, Attn: H. V. L. Patrick or T. G. Lang, Code P5006, M. A. Ruszczycky, Code P8076, 3202 E. Foothill Boulevard, Pasadena 8, California.
(d) Experimental; applied research.
(e) In the first experiments, twenty-five small objects were dropped in a tank of water with zero, 200, and 1000 wppm of Polyox additive. The majority of the objects were spheres and cones. A second series of tests has been completed to determine whether high-polymer solutions, in relatively high concentrations, (up to 1.5%), affect the velocity of steel spheres falling at laminar-separation flow conditions.
(g) In the first series of tests the drag of spheres up to 2 1/2 inches in diameter was reduced up to 70%; and drag of cones was only slightly reduced. Wake photographs showed that the Polyox additive moved the separation point rearward. In the second series, different diameter spheres dropped in high-polymer solutions showed definite velocity increases over that obtained in water. Within the sphere sizes tested, the apparent drag reduction noted was 33.5%. The increased viscosity effect accounts for only about 18% reduction in drag. The highest Reynolds number reached in the tests was 5.19×10^4, based on water; and from this it was concluded that all the steel spheres in the tests experienced laminar-separation flow only.
(h) "Sphere Drop Tests in High-polymer Solutions," M. A. Ruszczycky, Nature, Vol. 206, No. 4984, pp. 614-15, May 8, 1965.

(5383) COLLAPSE OF GAS FILLED BUBBLES AGAINST A RIGID BOUNDARY.

(b) Bureau of Naval Weapons, Dept. of the Navy.
(c) Commander, U. S. Naval Ordnance Test Station, Attn: A. O. Musolf, Code P8076, 3202 E. Foothill Boulevard, Pasadena 8, Calif.
(d) Experimental research.
(e) The investigation of a high velocity water jet formed during the collapse of small cavitation bubbles is extended to larger, 6-inch maximum diameter, explosively formed bubbles. High speed motion pictures and resilient boundaries clearly show that the jet is capable of imparting a large force to the boundary.
(f) Work is completed.

(5384) LIFTING-SURFACE DESIGN METHOD FOR COUNTER-ROTATING PROPELLERS.

(b) Bureau of Naval Weapons, Dept. of the Navy.
(c) Commander, U. S. Naval Ordnance Test Station, Attn: Mr. David M. Nelson, Code P8074, 3202 E. Foothill Blvd., Pasadena 8, Calif.
(d) Theoretical; applied research.
(e) The lifting-surface propeller design method for single-rotating propellers developed at the U. S. Naval Ordnance Test Station(NAVWEPS Reports 8442 and 8772) is being extended to counter-rotating propellers. A lifting line solution for counter-rotating propellers serves as the starting point for the lifting surface solution. The camber lines and pitch angles are computed as for the single-rotating propeller except the variation across the chord of the axial component of the interference velocities (velocities induced at one propeller by the other) is accounted for.
(g) All theoretical work and computer programming is complete. A description of the method will be published later with the work on the inclusion of the hub boundary condition described in another section.

(5385) DETERMINATION OF THE HYDRODYNAMIC COEFFICIENTS OF BODIES OF REVOLUTION USING THE DOUGLAS POTENTIAL FLOW PROGRAMS.

(b) Bureau of Naval Weapons, Dept. of the Navy.
(c) Commander, U. S. Naval Ordnance Test Station, Attn: Mr. David M. Nelson, Code P8074, 3202 E. Foothill Blvd., Pasadena 8, Calif.
(d) Theoretical; applied research.
(e) The Douglas Aircraft Company computer programs for the solution of the potential flow about bodies of revolution, where the bodies are represented by a surface source density, are being used to theoretically determine hydrodynamic coefficients for bodies of revolution. A comparison between the theoretical values and the experimental values for blunt base bodies will be made first. Depending on the success of the method for these blunt base bodies, the method will then be applied to streamlined bodies having thick boundary layers on the aft end. This will be done by a combination of boundary layer calculations and potential flow calculations to obtain, if possible, a reasonable theoretical model of the flow about such bodies.
(g) All theoretical work related to blunt based bodies has been completed and a comparison with experimental data has been made.
(h) "Hydrodynamic Coefficient Calculation using Douglas Potential Flow Computer Program," D. M. Nelson. NAVWEPS Report 8799, NOTS TP 3905, U. S. Naval Ordnance Test Station, China Lake, California.

(5859) INCLUSION OF THE HUB BOUNDARY CONDITION IN LIFTING SURFACE PROPELLER DESIGN.

(b) Bureau of Naval Weapons, Dept. of the Navy.
(c) Commander, U. S. Naval Ordnance Test Station, Attn: Mr. David M. Nelson, Code P8074, 3202 E. Foothill Blvd., Pasadena, Calif. 91107.
(d) Theoretical; applied research.
(e) A method of including the hub boundary condition in lifting surface propeller design is under development. The hub is represented by a surface source distribution by utilizing a recently developed Douglas potential flow computer program for three-dimensional bodies in an arbitrary onset flow. The onset flow to the hub is computed from the singularity distributions representing the blade surfaces. This onset flow and the hub geometry is then input to the Douglas program which yields the hub induced flow at the propeller blades. The camber lines and angles of attack of the blade sections are then computed including the hub induced flow.

(5860) EFFECT OF POLYMER ADDITIVES ON SEPARATED FLOW.

(b) Bureau of Naval Weapons, Dept. of the Navy.
(c) Commander, U. S. Naval Ordnance Test Station, Attn: H.V. L. Patrick, Code P5006, 3202 E. Foothill Blvd., Pasadena, California 91107.
(d) Experimental; applied research.
(e) The diffuser efficiency is evaluated on conical diffusers exhibiting transitory and fully established separated flow using high molecular weight polymer solutions. The purpose is to evaluate what effect polymer additives will have on separated flow as a function of Reynolds number and solution concentration.
(g) The diffuser efficiency of a conical diffuser with a transitory separated flow regime is improved by approximately 11%. These results were obtained when using J2-FP guar gum solutions at concentrations of 1/64 to 1/8% and Reynolds numbers greater than fifty thousand but less than eighty thousand.

U. S. DEPT. OF THE NAVY, OFFICE OF NAVAL RESEARCH.

For sponsored projects see the following:

TENNESSEE VALLEY AUTHORITY, Engineering Laboratory.

Inquiries concerning the following projects should be addressed to Mr. Rex A. Elder, Director, TVA Engineering Laboratory, P. O. Box 37, Norris, Tenn. 37828.

(3629) LOW POWER VHF RADIO GAGES FOR REPORTING RAINFALL AND STREAM LEVEL DATA.

(d) Development.
(e) Transistorized radio components powered from nicl cadimum batteries, which will be charged by thermoelectric generators and/or solar cells, will be used. Data in gray code will be transmitted by audio tone pulses. Unattended operation of long duration is a primary objective in the design of these stations.
(g) Construction of station components is under way.

(4441) MEASUREMENT OF KAPLAN TURBINE DISCHARGES USING OTT COMPONENT CURRENT METERS.

(d) Equipment development and field measurement operation.
(e) Turbine discharge rating equipment, using the Ott component type current meters, has been developed to measure the discharge of turbine units. Twenty-seven current meters mounted on three frames are used to simultaneously measure velocities in the three intakes of each unit by either the step or integration method. Measurements made at several fixed loads are employed to calibrate the Winter-Kennedy scroll case pressure taps. The Winter-Kennedy taps are used with suitable measuring equipment to determine the discharge for any turbine loading.
(g) Measurements have been taken at four main river hydro dams, Wilson, Kentucky, Guntersville and Wheeler. Forty-one turbine units at these facilities have been measured.

(4881) BASIC STREAM AND RESERVOIR HEAT BUDGET STUDIES.

(d) Experimental; for basic and applied research.
(e) This is a study to develop the basic tem-

perature prediction equations for a stream or reservoir into which a volume of water at a different temperature is injected. All known variables such as stream flow characteristics, meteorological conditions and thermal characteristics will be included. Theoretical studies, field tests, and possible laboratory studies will be combined to produce verified equations. Additional field data were collected during the year and the measured water temperatures are being compared to the predictions produced by the basic heat budget equation.

(g) Several particular solutions, involving the equilibrium temperature concept, have been obtained from the basic differential equation relating hydraulic, meteorologic, and thermal parameters, and an intensive study of individual heat budget terms has been made to determine the most reliable means of evaluating each term. Five sets of field data have been collected for evaluating the accuracy of the prediction equations.

(5004) NICKAJACK PROJECT.

(d) Experimental; for design.
(e) Studies using the 1:150 horizontal by 1:90 vertical scale distorted model of the Nickajack Project were completed and a 1:100 scale undistorted model constructed to study the apron development problems. The 1:100 scale model represents an area of approximately 2 miles in length by 1 mile in width of the river site. In addition to the apron studies, the 1:100 scale undistorted model was used to develop information on the training wall dimensions, bank protection designs and the design of various other features in the river areas immediately upstream and downstream from the dam structures.

(h) Thirteen internal reports have been issued to date.

(5386) NICKAJACK PROJECT--LOCK MODEL.

(d) Experimental; for design.
(e) A 1:25 scale model of the 800' x 110' main Nickajack lock was used to adapt the multiport filling and emptying system to this size chamber. The proposed intake and outlet structures for both the main and 600' x 110' auxiliary lock are being tested by incorporating them with the main chamber model and a simplified model of the auxiliary chamber.

(h) Three internal reports were issued describing the results of lock chamber studies, lock intake systems studies and the development of the 600-foot-lock outlet system.

(5387) NICKAJACK PROJECT--VALVE-CULVERT MODEL.

(d) Experimental; for design.
(e) A 1:10 model of an existing lock filling valve, with related culvert appurtenances, is being used to determine the nature and origin of the hydrodynamic forces which act on reversed tainter lock filling valves. The model was specifically designed to reproduce the transient conditions existing while the valve is opening. Two valve designs are being compared with respect to their reaction to hydrodynamic forces.

(h) Three internal reports were issued.

(5388) NICKAJACK PROJECT--SPILLWAY MODEL.

(d) Experimental; for design.
(e) Studies were conducted on a 1:35 scale model of three of the ten spillway bays of the Nickajack project. Tests were for the purposes of determining the spillway capacity under the maximum design head, developing the optimum upstream pier shape, and finding a relatively simple yet effective apron design. Such factors as water surface profiles through a bay and pressures on the piers under adverse gate openings were also investigated.

(g) An upstream pier shape with a relatively sharp nose was found to decrease vortex action upstream from the gate for gated discharges. A simple horizontal spillway apron with a dentated end sill minimized scour and produced acceptable wave action.

(5392) MODEL FLUME TO BE USED TO STUDY THERMAL DENSITY RECIRCULATION PROBLEMS.

(d) Experimental; operations and basic research.
(e) A model flume was constructed of transparent material and equipped with circulating pumps to simulate a typical steam power plant's condensate intake and outlet system. The flume is approximately 100 feet in length and 9 inches deep by 12 inches wide.
The basic intent is to develop and prove the analytical equations for flows in the vicinity of a steam plant or in similar areas.

(g) Data on lengths and depths of warm wedges near the intake and outlet, for various river and intake flows and for various initial density differences have been obtained, but have not been analyzed.

(5709) WALL-PRESSURE FLUCTUATIONS IN A CAVITATING TURBULENT SHEAR FLOW.

See Project 5709, University of Kansas, page 43.

(5943) NICKAJACK PROJECT--TURBINE INTAKE GATE STUDIES.

(d) Applied research; operations.
(e) Tests on multi-leaf gates have indicated an interdependence of the design of the lifting beam and gate when the gates are to be positioned in flowing water. A 1:36 scale model of a complete three-bay turbine intake and a 1:12 scale model of one bay were used in tests conducted to develop an operable lifting beam and gate design for the Nickajack Project. Double leaf gates 18' x 18' are to be used.

(g) A lifting beam and gate design was developed which solved the basic problems of successfully lowering and releasing the gate and beam in flowing water.

(h) An internal report of these results was issued.

(5944) WATER QUALITY STUDY; MEASUREMENTS OF THE STRUCTURE OF STRATIFIED RESERVOIRS.

(d) Field investigation, basic research.
(e) Effective and optimum water resource development requires knowledge of the yearly cyclic changes of the various properties of the water in deep, stratified reservoirs. This study will measure current velocities, dissolved oxygen content, temperature, conductivity, and density as a function of depth at various stations in Fontana Reservoir during the stratification season. All measurements are performed from a barge securely moored to each bank of the lake. Currents are measured with a deep water isotopic current analyzer which utilizes a radioactive tracer material and which is capable of measuring velocities from 0.005 to 1 fps. Oxygen content is measured from water samples with a simplified Winkler method. Temperatures are measured continuously in situ with a resistance-type thermometer. Conductivity and water densities are measured in water samples with a capacitance instrument and precision hydrometer, respectively. Depth is measured continuously with a pressure transducer.

(g) Thermal stratification causes selective withdrawal from the reservoir. The thickness and speed of the flowing layer are being established. The equipment will be used in other reservoirs which have different outlet structures.

(5945) TIMS FORD PROJECT.

(d) Experimental; applied research.

(e) A 1:100 scale model will be used to determine the characteristics of the proposed flip bucket spillway. Particular attention will be given to erosion patterns and means of limiting scour.

TENNESSEE VALLEY AUTHORITY, Hydraulic Data Branch.

Inquiries concerning projects should be addressed to Mr. James W. Beverage, Chief, Hydraulic Data Branch, Tennessee Valley Authority, Knoxville, Tenn. 37902.

(765) EVAPORATION IN THE TENNESSEE BASIN.

(d) Field investigation; applied research.
(e) To provide data for estimating reservoir losses and derive a general rule, applicable to the Basin, permitting computation of evaporation from pans at six locations in Basin, together with standard meteorological readings.
(h) Results published in monthly and annual bulletins, "Precipitation in Tennessee River Basin" (Project 768).

(768) PRECIPITATION IN TENNESSEE RIVER BASIN.

(d) Field investigation; basic research.
(e) A comprehensive study of rainfall and other weather phenomena for purposes of water dispatching and improvements in water control; storm studies as related to maximum precipitation, rainfall-runoff, spillway design and operation, etc.
(h) Monthly and annual bulletins, "Precipitation in Tennessee River Basin."

(769) RESERVOIR AND STREAM TEMPERATURES.

(d) Field investigation; basic research.
(e) Study of water utilization and water movement as concerns industrial and steam plant locations and stream pollution. Variations in temperature from surface to bottom in selected reservoirs are determined by soundings, and by continuous recording gages in selected natural streams. Periodic observations are made at gaging stations.

(771) GALLERY DRAINAGE IN LARGE DAMS.

(d) Field investigations; design.
(e) Weirs are placed in main galleries and drainage measured as check on tightness and stability.

(779) MAXIMUM POSSIBLE PRECIPITATION IN TENNESSEE VALLEY.

(b) Cooperative with U. S. Weather Bureau.
(d) Theoretical; applied research.
(e) Hydrometeorological analysis of large storms with upward adjustments of controlling factors to maximum limits as applied to the Tennessee Valley and subdivisions.
(g) Results to be published as one of current series of hydrometeorological reports by the U.S.W.B. and cooperating agencies.

(780) PERIODIC EVALUATION OF GROUND-WATER STORAGE.

(d) Theoretical; operation.
(e) By analysis of current records of stream discharge, the volumes of runoff in ground-water and channel storage are determined for use in operation of multi-purpose reservoirs.
(g) Results reported weekly within the organization.
(h) "Uncontrolled Storage Evaluation in the Tennessee Valley," Paul C. Sodemann. Paper for AGU meeting, April 1963.

(785) SEDIMENTATION OF EXISTING RESERVOIRS.

(d) Field investigation; basic research.
(e) Selected ranges in reservoirs are probed and sounded, volumetric samples are collected and analyzed, quantity and distribution of sediment are computed to determine deposition by stream, probable life of reservoir, effect of sediment storage on navigation channels and sedimentation of down-stream reservoirs, and probable sedimentation in future reservoirs.

(3306) COOPERATIVE RESEARCH PROJECT IN WESTERN NORTH CAROLINA.

(b) Project conducted in cooperation with North Carolina State College of Agriculture and Engineering.
(d) To determine water-land relationships for some of the principal soils used for agricultural purposes in western North Carolina under important vegetative covers. Observations include rainfall, runoff, soil-moisture, potential evapotranspiration, and actual evapotranspiration.
(e) A statistically designed rotation of four covers on four small watersheds and a separate evaluation of deep-rooted crop on a fifth watershed.
(f) Instrumentation has been added to observe evaporation for correlation with evapotranspiration and soil moisture data.
(g) Results to date are summarized in annual reports on the project.

(3307) PARKER BRANCH PILOT WATERSHED RESEARCH PROJECT.

(b) Project conducted in cooperation with North Carolina State College of Agriculture and Engineering.
(d) To determine the effects upon the hydrology of the watershed of an intensive farm development program designed to give the optimum economic well-being of the people using the land. Rainfall, runoff, suspended and deposited sediment are observed, periodic soils-land-use and inventories are made and records of income summaries and public and private investments are maintained.
(e) Project activities are divided into calibration, action, and evaluation phases.
(f) Agricultural economics portion of project terminated June 30, 1962; hydrologic portion terminated September 30, 1962.
(g) Results are summarized in annual reports on the project.

(3308) WHITE HOLLOW WATERSHED.

(d) To study the effect of changes in the vegetal cover on a watershed taken out of cultivation on the hydrologic factors of runoff and soil erosion.
(e) Continuous record from 1935 of rainfall, runoff, and suspended sediment, and periodic determination of vegetal cover indexes.
(f) Logging road system has been located, construction started. Selective cutting to begin in winter of 1965-1966.
(g) During the 24-year period 1935-1958, the forest cover improvement in the watershed resulted in greater watershed protection with no measurable change in water yield, no change in volume of either surface runoff or ground-water runoff, marked reduction in summer peak rates of discharge with lesser reduction in winter rates, a prolongation of the period of draining of surface runoff from the channel system, and a 96 percent reduction in the sediment load.
(h) "Effects of Forest Cover Upon the Hydrologic Characteristics of a Small Watershed in the Limestone Region of East Tennessee," by Paul C. Sodemann and Jones E. Tysinger. Paper prepared for presentation at Symposium sponsored by UNESCO, October 1965.

(3309) PINE TREE BRANCH WATERSHED.

(d) To determine the effects upon the hydrology of the watershed by reforestation and erosion control measures.
(e) Continuous record from 1941 of rainfall, runoff, ground water, and sediment loads.

(f) Selective cutting delayed, now scheduled for 1965-66.
(g) During the 20-year period 1941-1960, the cover improvement and erosion control in the watershed resulted in a decrease in surface runoff volumes and an increase in groundwater discharges, marked reductions in summer and winter peak flood discharges, a reduction in overland surface velocities, a prolongation of the period of draining of surface runoff from the channel system, an appreciable decrease in water yield, and a 96 percent reduction in sediment load.

(4011) NORTH FORK CITICO CREEK RESEARCH WATERSHED.

(b) Project conducted in cooperation with U.S. Forest Service.
(d) Field investigation; basic research.
(e) To determine the effects of normal, high-standard National Forest Multiple-use management upon the hydrology of the area. Observations include rainfall, runoff, air and water temperature, and humidity. Timber inventories, soil surveys, wildlife inventories, and evaluations of soil disturbances will be made. Project activities are divided into calibration, development, and evaluation phases.
(f) Calibration period completed. "Action" phase started with access road construction into watershed to site of first timber sale.
(g) Results are published in annual reports distributed to cooperating agencies.
(h) "North Fork Citico Creek Watershed Study," Report for 1964 Water Year, Tennessee Valley Authority, U. S. Forest Service, Tennessee Game and Fish Commission, August 1965.

(4884) UPPER BEAR CREEK EXPERIMENTAL PROJECT.

(b) TVA Tributary Area Development project cooperative with U. S. Forest Service and Auburn University.
(d) Quantitative determination of the effect of soil type, slope, and vegetative cover upon runoff, peak discharge, and erosion on small watersheds progressing to large watersheds. Development of procedures to make data usable in projecting effects from small watersheds to larger drainage areas and to transfer results of the study to ungaged areas.
(e) Four general types of land cover and use will be considered in the study of the watersheds that progress downstream from areas of several hundred acres through intermediate-sized watersheds to a drainage area of 143 square miles.
(f) Hydrologic condition surveys made in March and August 1965.
(g) Results are published in quarterly and special reports on the project.
(h) "Upper Bear Creek Experimental Project - Research in Area-Stream Factor Correlation," Water Resources Research Paper No. 1, TVA, February 1965.
"The Upper Bear Creek Experimental Project - 1962-1964," TVA, U. S. Forest Service, May 1965.

U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS.

Inquiries concerning the following projects should be addressed to the Director, U. S. Army Engineer Waterways Experiment Station, Corps of Engineers, P. O. Box 631, Vicksburg, Miss. 39181.

(236) MISSISSIPPI BASIN MODEL.

(b) Office of the Chief of Engineers, Department of the Army, Washington, D. C.
(d) Experimental; for design.
(e) The project provides for construction and operation of a model of the Mississippi River watershed including the Missouri, Ohio, White, Arkansas, and Red Rivers and their principal tributaries. All existing and proposed flood-control reservoirs as well as levees, dikes, floodwalls, and other pertinent works are reproduced.
The model area comprises 200 acres, and measures 4500 ft east and west, and 3900 ft north and south. Completed construction consists of the Upper Mississippi River from Hannibal, Mo., to Baton Rouge, La; the Missouri River from Sioux City, Iowa to the mouth; the Arkansas River from Blackburn Dam site, Okla., to the mouth; the Ohio River from Louisville, Ky., to the mouth; the Cumberland River from Old Hickory Dam, Tenn., to the mouth; the Tennessee River from Pickwick Dam to the mouth; and the Atchafalaya River to the Gulf of Mexico. The topography of the streams and floodplains is being reproduced to a horizontal scale of 1:2000 and vertical scale of 1:100. Water-surface elevations are measured by electrically operated stage devices with the recorders located in central control buildings. Streamflow is introduced and controlled by automatic instruments called inflow controllers.
The purpose is to study the coordination of releases from reservoirs, investigate the effect of reservoir operation on flood stages, check the routing of project and other floods, establish and check levee grades, predict stages, and determine the effect of floodways on stage reduction.
(g) The extent of model operation each year is determined by the testing programs directed by the Mississippi Basin Model Board and Chief of Engineers and requested by Divisions and Districts that have operable sections on the model. The model was operated as an integrated unit to Memphis, Tenn., for comprehensive (basinwide) tests. Tests were completed of the four historical floods--1937, 1943, 1945 and 1950--using those reservoirs (EN) scheduled for completion in the near future (approximately 1970), and with ultimate reservoirs (END) operated to full capacity to store inflows that affect crest stages of the Lower Mississippi River, and of the three hypothetical floods--M 52-A, M 56 and M 58-AOR--using flows unmodified by reservoirs, and modified by EN and END reservoirs for local and Lower Mississippi River benefits for the basinwide testing program. Tests were completed also for the U. S. Army Engineer Division, Ohio River, to obtain effect of proposed interstate highway fill on Wabash River in vicinity of Grayville, Ill. Tests were conducted for Sverdrup and Parcel and Associates, Inc., St. Louis, Mo., on the portion of the MBM model that is in the Lower Mississippi Valley Division. These tests were concerned with the size and effect of various waterway openings for the proposed Mississippi River Bridge to be constructed near Caruthersville, Mo., on Interstate Route 155.

(425) COMPREHENSIVE MODEL STUDY, DELAWARE RIVER, PENNSYLVANIA.

(b) District Engineer, U. S. Army Engineer District, Philadelphia, Corps of Engineers, Philadelphia, Pa.
(d) Experimental; for design.
(e) The project provides for a navigation channel about 96 miles long from Trenton, N. J., to Delaware Bay. As modified in 1954, the project provides a 40-ft depth generally 800 ft wide along the west side of the channel from the bay to the upper end of Philadelphia, a 40-ft-deep by 400-ft-wide channel between Philadelphia and the upper end of Newbold Island, thence a 35-ft-deep by 300-ft-wide channel to Trenton. Included in the project are provisions for constructing dikes and training walls for regulation of tidal flows, and dredging to provide turning basins and adequate anchorage at several points.
The purpose is to develop and test plans for reduction of shoaling in several ranges of the navigation channel; and to determine the probable effect on the hydraulic and salinity

regimen in the estuary that would result from modifications of channel depth and alignment and flow regulation.
The model is of the fixed-bed, silt-injection type with linear-scale ratios of 1:1000 horizontally and 1:100 vertically, and reproduces the entire tidal portion of Delaware River and Bay from the Capes to Trenton, including tidal portions of major tributaries. Tides and tidal currents are reproduced by automatic tide control mechanisms, and freshwater discharges of the Delaware River and significant tributaries are introduced by means of Van Leer weirs. Observed prototype salinities are reproduced in the Delaware Bay portion of the model, and provisions have been made for the injection of silt into the model, and for measuring silt deposits on the bed of the model. Studies of the dispersion of various contaminants are made by releasing permanent dyes and tracing their movement and concentrations with time after release and distance from the release points.

(g) A preliminary report, Delaware River Model Study; Results of Hydraulic and Shoaling Studies in the Marcus Hook - Schuylkill River Reach, was furnished the Philadelphia District in October for review and comment. The tests were conducted in the existing model to determine the effects on tides, currents, and shoaling of filling several large back-channel areas with dredge spoil. Several proposed sediment traps, conveniently adjacent to spoil disposal areas, were tested to determine whether or not depositing of sediments would occur in the traps and if such depositing would cause significant reductions in channel shoaling. Special tests to determine the effects of the current (1965) drought on salinities in the Delaware estuary were undertaken and completed.
Tests on the existing Delaware River model to determine the effects of diking off several back-channel areas to provide disposal areas for dredge spoil and the dredging of adjacent sediment traps indicated that closure of both the Tinicum Island and the Chester Island back channels would have no detrimental effects on the main navigation channel. A small-boat channel should be provided through Tinicum Island. Overdredging in Mantua Creek anchorage and in Tinicum range to create sediment traps would cause no significant increase in deposition and is not considered justified. Sediment traps in Marcus Hook anchorage and adjacent to Chester Island would be beneficial to channel shoaling.

(993) CAVITATION RESEARCH.

(b) Office of the Chief of Engineers, Department of the Army, Washington, D.C.
(d) Experimental; applied research.
(e) This is a general study, be means of model tests, of the cavitation characteristics of various elements of hydraulic structures, and of the resistance of construction materials to cavitation damage. Further, the investigation includes a review of literature to evaluate the many variables that affect cavitation results.
The purpose is (a) To study cavitation characteristics of such elements as baffle piers, steps in stilling basins, spillway and conduit gate slots, and offset joints. This program will include tests to determine the conditions for dynamic similarity of the cavitation phenomenon. (b) To determine the resistance to cavitation damage of construction materials with particular emphasis on materials suitable for patching concrete.
The cavitation characteristics of the various elements are investigated in a variable pressure water tunnel with a 12-by 12-in. test section. Velocities in the test section can be varied from 8 to 35 fps. Resistance-to-damage tests are conducted in apparatus in which cavitation is induced in velocities of 90 fps by an alignment change.

(994) EFFECTS OF MODEL DISTORTION ON HYDRAULIC ELEMENTS.

(b) Office of the Chief of Engineers, Department of the Army, Washington, D.C.
(d) Experimental; applied research.
(e) This is a general study of similitude relations in distorted models.
The purpose is to determine the hydraulic effects of various types and degrees of model scale distortion on velocity distribution and other hydraulic conditions, with the ultimate aim of establishing limits of permissible distortion for the various types of models. Tests have been conducted in a 5-ft-wide masonry flume having a 90-degree bend of 10-ft radius, with a straight approach channel 20 ft long and exit channel 60 ft long, in which can be reproduced a hypothetical stream to a horizontal scale of 1:200 and variable vertical scales to produce distortions up to 1:10. The flume was provided with three venturi meters of different sizes for the control of discharge and a tailgate for the control of tailwater elevation.
(f) Suspended.

(998) WAVE FORCE ON BREAKWATERS.

(b) Office of the Chief of Engineers, Dept. of the Army, Washington, D. C.
(d) Experimental; applied research.
(e) This a general investigation to (a) study existing literature and adapt or acquire testing equipment; (b) verify experimentally the clapotis pressure theory; (c) determine maximum shock-type pressures caused by breaking waves, and delineate the critical conditions necessary to create the extremely high shock pressures; and (d) determine the magnitude of pressures due to partially breaking waves.
The purpose is to conduct theoretical and experimental investigations of wave pressures and impact forces on vertical-wall and composite breakwaters from which the magnitude, duration, and location of forces on these structures, caused by breaking waves, can be determined with sufficient accuracy to ensure the design of safe and economical structures.
A 3- by 3- by 6-ft steel tank was used for the experiments on shock pressures caused by the impact of an accelerated plate with a water body. Plastic, aluminum, and steel plates of different masses were dropped into water in the tank and the shock pressures developed were measured and recorded electrically. A 2- by 5.5- by 140-ft concrete wave flume will also be used for conducting experiments on shock pressures and total impact forces caused by waves breaking against vertical-wall breakwaters.
(g) A series of experiments on shock pressures caused by the impact of an accelerated plate with a water body was conducted in the 3- by 3- by 6-ft steel tank. The data obtained from these experiments were analyzed and compared with experimental and prototype data available on shock pressures caused by waves breaking against a vertical wall. Preparation of a report on this phase of the study was initiated.

(999) STABILITY OF RUBBLE-MOUND BREAKWATERS.

(b) Office of the Chief of Engineers, Department of the Army, Washington, D.C.
(d) Experimental; applied research.
(e) A general study of rubble-mound breakwaters to determine weight, specific weight, and shape of armor units required for stability under wave attack.
To develop design procedures and formulas, supported by experimental data, from which the design of safe and economical rubble-mound breakwaters can be determined. In addition to quarrystone, the investigation includes tests of tetrapods, tetrahedrons,

tribars, quadripods, modified cubes, and other specially molded armor units.
Tests will be conducted in a 50- by 5.5- by 250 ft, L-shaped wave flume designed to allow the testing of breakwater sections using various angles of wave incidence.

(g) Preparation of the 50- by 5.5- by 250-ft wave flume for the testing of breakwater sections using various angles of wave incidence was initiated. Preparation of a final report describing the results of tests conducted on breakwater trunks constructed of quarrystones, tetrapods, tetrahedrons, quadripods, modified cubes, hexapods, and tribars using nonbreaking waves in deep water was initiated.

(1002) EFFECTS OF SCALE AND OPERATING TECHNIQUES ON HARBOR WAVE ACTION AND BREAKWATER MODELS.

(b) Office of the Chief of Engineers, Department of the Army, Washington, D.C.
(d) Experimental; applied research.
(e) A general study is being conducted to determine effects of various model scales and distortion on wave characteristics in harbor and breakwater stability models. The effects on test results of various model-testing techniques are also being investigated.
The purpose is to obtain information which will allow more accurate determination of optimum scales for wave models, and the effects of different scales and operating techniques on the accuracy of model results.
A 2- by 4.5- by 8.0-ft, rocking, rectangular steel basin will be used for studying the wave-damping effect of expanded metal screens.
(g) Preparation of the rectangular steel basin for studying the wave-damping effect of expanded metal screens was initiated.

(1004) INSTRUMENTATION.

(b) Office of the Chief of Engineers, Department of the Army, Washington, D.C.
(d) Experimental; development.
(e) Development of instruments for use in hydraulic models and in field measurements.
To develop various types of measurement and control equipment for use in hydraulic models and in the field.
(g) The development of improvements for a current-direction indicator was completed. Development of a revolution-sensing and remote-indicating device for velocity meters, development of a spherical-head turbulence meter, and development of a water-level indicator for tests of prototype locks were continued.

(1467) DEVELOPMENT OF HYDRAULIC DESIGN CRITERIA.

(b) Office of the Chief of Engineers, Dept. of the Army, Washington, D. C.
(d) Analytical (model and prototype); for design.
(e) Hydraulic design criteria relating to the design of spillways, outlet works, gates, valves, navigation structures, flood-control channels, and natural waterways are developed from laboratory research, model studies, and prototype observations. Results are prepared in the form of design charts and distributed to design offices.
To analyze hydraulic data, theories, and procedures, to develop design criteria therefrom, and to disseminate this information in the form of Hydraulic Design Criteria to insure adequate capacity, economy of design and construction, and safe and satisfactory operation of the large hydraulic structures being designed, built, and operated by the Corps of Engineers.
(g) Preparation of the reproduction copy of the thirteenth issue of Hydraulic Design Criteria was in progress. This issue provides design criteria on energy losses for high overflow spillways and discharge coefficients for low ogee crests with 45-degree upstream sloping faces, for flows over low monoliths in concrete gravity dams, and for vertical-lift spillway gates. Charts are also included on crest shapes for overhanging spillways, low ogee crest toe curve pressures, hydraulic jumps on sloping aprons, and stilling basin end-sill heights. Fourteenth issue studies undertaken included minimum pressure in pipe bends, loss coefficients for outlet works control structures with one or more gate passages closed, and discharge coefficients for spillway vertical-lift and tainter gates operating under submerged conditions. The final contract report from the University of Missouri was received and published as WES Contract Report 2-116, Analytical Study of Flow Characteristics for Flow Over a Curved Spillway Bucket, by J. J. Cassidy, May 1965. An electronic computer analysis of flow patterns in spillway flip buckets based on a contract study on this report was undertaken. Extensive studies pertinent to the hydraulic design of riprap were in progress. A draft of a miscellaneous paper on hydraulic design of riprap was prepared.
The study of experimental data on minimum pressures in pipe bends showed that two-dimensional flow analysis was applicable to pipe bends as well as to circular bends in rectangular conduits. The study of loss coefficients for multiple gate-passage outlet works control structures with one or more passages inoperative indicated that loss coefficients for abrupt expansion are not applicable to the control structure problem. The studies on hydraulic design of riprap indicate the need for field and laboratory investigations to provide firm criteria for design purposes.

(1986) INVESTIGATION OF SALINITY INTRUSION AND RELATED PHENOMENA.

(b) Committee on Tidal Hydraulics, Corps of Engineers (correspondence should be addressed to Mr. J.B. Tiffany, Chairman, Committee on Tidal Hydraulics, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Miss.).
(d) Experimental; applied research.
(e) The project consists of the following three broad phases: (a) analysis of prototype data to define the range of conditions for which investigations appear desirable; (b) flume tests to study the effects of the various factors involved; and (c) analytical studies aimed at establishment of fundamental laws describing the phenomena involved, and preparation of the data for use in application to specific prototype problems. Dr. Donald Harleman, consultant, has been engaged to assist in phase (c) above.
To determine the effects of the physical and hydraulic features of estuaries such as tidal prism, tidal range, freshwater discharge, channel depth, channel width, etc., on the extent of salinity intrusion, the nature of salinity intrusion, the magnitudes and durations of current velocities, and other factors considered essential to proper solution of estuarine problems encountered by the Corps of Engineers.
The flume studies under phase (b) above are being carried out in a transparent flume 327 ft long, 1.5 ft deep, and 0.75 ft wide. One end of the flume is connected to a tidal basin 25 ft square and 5 ft deep, which is equipped with a tide generator capable of producing tides of any desired range, period, or other characteristic. The opposite end of the flume is connected to a circular headbay equipped with weirs for measuring and introducing freshwater inflows. Salt water to fill the tidal basin and flume is supplied from an adjacent underground sump equipped with the necessary appurtenances to mix salt and fresh water and control the salinity of the mixture. The tidal basin is equipped with skimming weirs to maintain a constant basin salinity during tests. Current velocities are measured in the flume by timing the travel of indicators over measured ranges, and salinity measurements are made either by

withdrawing samples for chemical titration or by means of a recording salinity meter which operates on the electrical conductivity principle.

(g) No flume tests were required during the year; however, prototype and model physical, hydraulic, and salinity data from Savannah Harbor were furnished to Dr. Harleman for his use in checking the validity of equations developed from flume test data.
Analysis of flume data, and checking of results obtained against prototype and model data from Savannah Harbor are in progress by Dr. Harleman and his staff. Additional flume tests will be conducted as necessary to supplement available data.

(1987) RIPRAP PROTECTION AT HYDRAULIC STRUCTURES.

(b) Office of the Chief of Engineers, Department of the Army, Washington, D.C.
(d) Experimental; applied research.
(e) The erosion characteristics of various sizes of riprap and gravel material are being studied with a view to securing adequate protection at minimum cost. Measurements of velocity and turbulence at which movement of material begins are being made.
The purpose is to develop design criteria for riprap at hydraulic structures.

(1988) WATER TEMPERATURE EFFECTS ON BED FORMS AND ROUGHNESS.

(b) Office of the Chief of Engineers, Department of the Army, Washington, D.C.
(d) Experimental; applied research.
(e) It has long been known that water temperature variations caused marked variations in the nature and rate of bed movement, which are of major significance in movable-bed model studies. The onset of cold weather produces excessive riffling of bed surfaces, resulting in sharp increases in roughness values and changes in volumes of material transported. The investigation of this phenomenon is being conducted in existing laboratory flumes, in which water temperatures can be varied to simulate normally experienced summer and winter temperatures.
The purpose is to determine the effects of water temperature on streambed forms and bed roughness of various types of bed material.
(g) Review of the work accomplished to date and literature available on the subject was completed, and a future comprehensive testing program was developed.

(2428) MODEL STUDY OF SAVANNAH HARBOR, GEORGIA.

(b) District Engineer, U. S. Army Engineer District, Savannah, Corps of Engineers, Savannah, Georgia.
(d) Experimental; for design.
(e) The purpose is to determine if the present rate of shoaling can be reduced by proposed plans of channel realignment, freshwater diversion, and other remedial measures; to develop relief for the critical spoil disposal problem; and to test ultimate harbor developments. Studies were also made to determine effects of proposed improvement plans on dispersion and dilution of contaminants discharged into the harbor.
The investigation was conducted in a model which reproduced the following: (a) that portion of the Atlantic Ocean, adjacent to the harbor entrance, from Calibogue Sound on the north to Wassaw Sound on the south; (b) the Savannah River and its floodplain to the head of tide at Ebenezer Landing; and (c) that portion of the Intra-coastal Waterway which crosses the area included in the model. The model was of fixed-bed construction with scale ratios, model to prototype, of 1:800 horizontally and 1:80 vertically. Automatic tide generators were used to reproduce tides and tidal currents throughout the harbor, and salt water was used in the model ocean to reproduce the effects of density difference on current velocities and distributions. Shoaling studies were made by injecting finely ground gilsonite into the model to reproduce the patterns of shoaling as observed in the prototype, following which the effects of proposed improvement plans on shoaling patterns could be observed and evaluated.
(f) Completed.
(g) Measurements were made of sediment load, suspended and colloidal, moving in Savannah River above the tidal prism. In Savannah Harbor, periodic surveys and sampling of the dredge discharge material were performed to determine the consolidation rates and the locations of the shoaling. A separate report of prototype investigations is not required.
The results of model tests indicated that the effectiveness of the previously recommended plan for reducing shoaling in the Savannah Harbor would not be materially changed by construction of the authorized deeper and wider channel. Model tests indicated that pollution of Wilmington River by the City of Savannah municipal and industrial wastes could be reduced by closure of the South Channel and/or St. Augustine Creek. Model tests indicated that bank erosion in the North Channel would probably be reduced by construction of the authorized deeper and wider channel.
(h) Section 4, "Results of Tests of Increased Channel Dimensions," Section 5, "Wilmington River Pollution Studies," and Section 6, "Results of Tests of Bank Erosion in North Channel," of TR 2-580, Volume III, were published in March, April and October 1965, respectively.

(2673) MODEL STUDIES OF BARKLEY LOCK AND DAM, CUMBERLAND RIVER, TENNESSEE.

(b) District Engineer, U.S. Army Engineer District, Nashville, Corps of Engineers, Nashville, Tennessee.
(d) Experimental; for design.
(e) A 1:120-scale comprehensive model of the fixed-bed type reproduced the Cumberland River from mile 29.4 to mile 32.2 and the lock, dam, and powerhouse. A 1:36-scale section model reproduced the riverward, downstream lock wall including the culvert manifold which discharges into the spillway stilling basin, five spillway bays, the landwall culvert discharge manifold which discharges through the floor of the spillway apron, 324 ft of approach and 596 ft of exit channel. The emergency lock gate was studied in a 1:25-scale model which reproduced the gate, gate sill, and portions of the upstream lock approach and the lock chamber downstream from the gate.
To determine the best arrangement of lock and appurtenant walls and to study approach contitions under various flows; to develop a satisfactory stilling basin and determine the feasibility of emptying the lock into the spillway stilling basin; and to determine (a) hydraulic forces on and stability of the emergency lock gate under various flows including free flow over the lock miter sill, (b) hydrostatic forces on the gate in various positions, (c) gate wheel reactions and sill roller reactions at given positions, and (d) head loss through the bridge decking.
(f) Completed.
(g) Adequacy of the spillway stilling basin was verified, and the orientation of the lock and alignment of the right bank downstream from the powerhouse were accomplished. The original design of the emergency lock gate was unsatisfactory as uplift forces exceeded the dry weight of gate. This was corrected by the use of a 45-degree lip on the apex of the gate. For this design the gate was stable throughout its operational range and hydraulic forces were in the range of 107 kips downpull and 207 kips uplift. No rotation of

the gate in a downstream direction was noted.

(h) TR 2-689, "Tests of Structure Orientation, Spillway, and Lock Emergency Gate, Barkley Lock and Dam, Cumberland River, Kentucky; Hydraulic Model Investigation," August 1965.

(2678) MODEL STUDY OF NAVIGATION CONDITIONS, McALPINE LOCKS AND DAM, OHIO RIVER.

(b) District Engineer, U. S. Army Engineer District, Louisville, Corps of Engineers, Louisville, Kentucky.

(d) Experimental; for design.

(e) A 1:120-scale, fixed-bed model was used for the investigation. The model reproduced the reach of the Ohio River from about mile 602 to about mile 608 below Pittsburgh, Pa., including adjacent overbank areas to an elevation of approximately 445 ft msl, the locks and dam structures, and all bridges and other structures that might affect flow conditions.
To determine the effects of location, size, and alignment of the dam on stages and currents within the upper pool; study the effects of location, size, and alignment of a new approach channel on navigation and surge conditions; determine the best location for a new navigable span on the Pennsylvania Railroad bridge; determine a method of operating the dam for optimum navigation conditions; study navigation conditions in the lower approach as affected by flow through dam, powerhouse, and lock emptying system; and provide a means for navigation interests to satisfy themselves as to the acceptability of the proposed plan by observing the model in operation.

(g) Satisfactory plans were developed covering composition and location of the dam, upper and lower approach channels, and lock filling and emptying. Tests of various gated sections of the dam provided data for use by the District office in developing discharge rating and stage-duration curves. Data were also obtained on the effects of various dam designs on head at the hydroplant, and on velocities along the Indiana shore.

(h) Preparation of final report is in progress.

(2681) SCALE-EFFECT TESTS OF RUBBLE-MOUND BREAKWATERS.

(b) Office of the Chief of Engineers, Department of the Army, Washington, D.C.

(d) Experimental; applied research.

(e) To investigate the effects of model scale on the results of experimentally determined criteria for design of rubble-mound breakwaters.
Stability tests were made of a breakwater slope of 1 on 1-1/2 using wave periods of 2.61, 3.75, 7.87, and 11.33 sec. Tests in the CERC wave flume (15 by 20 by 635 ft) were conducted using a linear scale of 7.5 to 1 based on the tests conducted in the WES 5- by 4- by 119-ft wave flume. Additional stability tests will be conducted in the WES 5- by 4- by 119-ft wave flume using linear scales of 0.5 to 1, and 1 to 1, and following the same testing procedure used in the tests conducted in the CERC wave flume. Therefore, data on the stability or rubble-mound breakwaters will be available for three different linear scales, 0.5 to 1, 1 to 1, and 7.5 to 1. Test data from the CERC wave flume will be correlated with data from the WES flume.

(g) Revisions were made to a 5- by 4- by 119-ft concrete wave flume to be used for the test on the stability of rubble-mound breakwaters conducted using linear scales of 0.5 to 1 and 1 to 1.

(2931) MODEL STUDY OF SOUTHWEST PASS, MISSISSIPPI RIVER.

(b) District Engineer, U. S. Army Engineer District, New Orleans, Corps of Engineers, New Orleans, Louisana.

(d) Experimental; for design.

(e) To determine the effectiveness of proposed improvement works (jetty extensions, channel realignments, and contraction works) in the elimination or reduction of maintenance dredging in the jetty and bar channels.
The investigation was conducted in a model constructed to linear scale ratios, model to prototype, of 1:500 horizontally and 1:100 vertically, and reproduced the lower 12 miles of Southwest Pass and the Gulf area adjacent to the Pass. The entire bed of the model was molded in concrete to the latest hydrographic survey available at the time of construction. Provisions were made for reproducing prototype tides, tidal currents, littoral currents, and wave action in the simulated Gulf of Mexico and saltwater and freshwater density flows in Southwest Pass and the bar channel. Shoaling studies were made by introducing various mixtures of plastic materials, simulating prototype shoaling materials, into the model and reproducing the shoaling patterns and distribution that occur in the prototype.

(f) Completed.

(g) Tests of proposed plans for reducing shoaling in the jetty and bar channels indicated that plans involving a curved realignment to the jetty channel, and plans involving relocating the bar upstream from ends of the jetties would greatly reduce shoaling for the authorized project depth of -40 ft, as compared to a 40-ft-deep channel on the alignment of the existing channel. The tests indicated that reducing the jetty channel width from 800 to 600 ft would also be beneficial in reducing shoaling.

(h) "Plans for Reducing Shoaling, Southwest Pass, Mississippi River; Hydraulic Model Investigation," TR 2-690, August 1965.

(2932) MODEL STUDY OF SHOALING, HUDSON RIVER, N. Y.

(b) District Engineer, U. S. Army Engineer District, New York, Corps of Engineers, New York, N. Y.

(d) Experimental; for design.

(e) To determine the source of material shoaling the Hudson River in the vicinity of Edgewater and Weehawken piers and the most effective means of reducing or eliminating this shoaling; to determine the causes of shoaling in the pier slips in New York Harbor and develop plans for alleviating this shoaling.
Two models were used in this study. Shoaling in the river channel was studied on a fixed-bed model, built to scales of 1:100 vertically and 1:1000 horizontally. The model reproduced Upper and Lower New York Bays, Raritan Bay, Hudson River to Hyde Park, East River to Throg's Neck, and tributaries flowing into the model bodies of water. Provisions were included for reproducing tides, freshwater discharge, salinity intrusion, and shoaling. The study of pier-slip shoaling was conducted in a section model reproducing that portion of the Hudson River between pier 21 (Duane St.) and West 158th St., Manhattan, constructed to scales of 1:100 vertically and 1:300 horizontally, in which the tides, tidal currents, and shoaling of navigation slips was reproduced.

(f) Completed.

(g) Tests in the comprehensive model indicated that the best plan involving increasing the river cross section at the George Washington Bridge would decrease shoaling of the navigation channels by about 25 percent and would decrease shoaling of the slips by about 15 percent. Field and office studies indicated that a control structure in the Harlem River is technically infeasible, although model tests showed that such a structure would significantly reduce shoaling both in the navigation channels and in the slips. Tests showed that deepening the channel through Haverstraw Bay would not reduce shoaling of channels or slips. A sediment trap in the

upstream end of the 30-ft project channel would reduce shoaling in the remainder of this channel, although similar reduction can be attained by overdredging the area involved at frequent intervals. Test in the pier-slip m model indicated that approximately 25 percent of any dredge spoil free-dumped in the navigation channel would return to and deposit in the slips. These tests also showed that free-dumping, if permitted, should not be done within 500 ft of the pierhead line.

(h) "Hudson River Channel, New York and New Jersey, Plans to Reduce Shoaling in Hudson River Channels and Adjacent Pier Slips; Hydraulic Model Investigation," TR 2-694, September 1965.

(3243) MODEL STUDY OF NAVIGATION CONDITIONS OF LOCKS AND DAM NO. 4 (RECONSTRUCTED), MONONGAHELA RIVER.

(b) District Engineer, U.S. Army Engineer District, Pittsburgh, Corps of Engineers, Pittsburgh, Pennsylvania.

(d) Experimental; for design.

(e) Reconstruction of dam 4 will involve replacement of the existing fixed dam with a non-navigable-type gated dam in order to raise the pool 6 ft, as required for the Maxwell project upstream. The reconstructed dam will have five 84-ft crest gates. A raised fixed weir will extend the dam to the existing locks, which are 56 ft wide, and 720 and 360 ft long. Provision is being made in the dam structure for ultimate replacement of the existing locks by two locks each 720 ft long, with one lock to be 84 ft wide and the other 110 ft wide.
The purpose is to determine the effects of modifications of the existing locks and dam on navigation conditions, and to develop modifications required to overcome any undesirable conditions.
A 1:120-scale, fixed-bed, comprehensive model reproduced about 2.5 miles of the Monongahela River and the locks and dam structures.

(g) The last series of tests showed that additions of concrete cells at the end of the upper guard wall would tend to improve navigation conditions with the existing locks and reconstructed dam.

(h) Preparation of final report is in progress.

(3584) MODEL STUDY OF STILLING BASIN AND CONDUIT OUTLET PORTAL, RED ROCK DAM, DES MOINES RIVER, IOWA.

(b) District Engineer, U. S. Army Engineer Disrict, Rock Island, Corps of Engineers, Rock Island, Illinois.

(d) Experimental; for design.

(e) Red Rock Dam, a flood-control structure to be located at mile 143 on the Des Moines River, 10 miles east of Knoxville, Iowa, will be an earth fill 6260 ft long, rising about 112 ft above the river floor. The ogee-type spillway will be 241 ft wide, surmounted by five 41- by 45-ft tainter gates, and will contain fourteen 5- by 9-ft controlled conduits. A hydraulic jump-type stilling basin with two rows of baffle piers and an end sill will return flow to the Des Moines River.
The investigation was conducted on a 1:50-scale model reproducing 900 ft of the approach channel above the spillway, an 825-ft-wide section along the dam, the spillway, conduits, stilling basin, and 575 ft of the outlet channel. The model reproduced on the entire spillway and stilling basin, sufficient approach area to assure natural flow conditions over the spillway and at the abutments, and sufficient exit area to permit formation of the natural flow pattern in the exit channel.
A 1:16-scale model of the intersection of the spillway face and conduit outlet portal was used for the armor-plate requirements tests.
To verify stilling basin and training wall design; to calibrate the spillway; to study flow conditions in the upper approach, particularly at the abutments; to determine armor-plate requirements at the outlet portal; to determine the reduction in conduit flow during combined operation; and to study the effects of deflectors above the conduit outlet portals.

(f) Completed.

(g) Tests on the 1:16-scale model indicated that during combined operation, siumlating spillway and conduit flow at maximum reservoir elevation, pressures within the conduit and in the outlet portal were positive. "Eyebrows" or deflectors above the portal increased conduit flow and dropped the grade line within the conduit. The Folsom Dam high-level conduit, reproduced in the model, verified prototype cavitation-damage areas and furnished a basis for interpretation of Red Rock conduit test results. The general model provided information on spillway capacity as affected by abutment changes; velocities in the approach, particularly against the dam; optimum basin elevation consistent with safety and economy; basin elements of minimum size; and bottom velocities in the exit channel.

(h) "Spillway and Sluices, Red Rock Dam, Des Moines River, Iowa; Hydraulic Model Investigation," TR 2-673, March 1965.

(3586) MODEL STUDY OF DRAGHEAD FOR HOPPER DREDGE.

(b) District Engineer, U.S. Army Engineer District, Philadelphia, Corps of Engineers, Philadelphia,Pennsylvania.

(d) Experimental;for design.

(e) This study is a component of a comprehensive "Program for the Improvement of Hopper Dredges and Hopper Dredging." It involves comparison of the effectiveness of hopper dredge dragheads of different designs in various types of materials.
The investigation was conducted in a 60- by 10-ft flume containing various types of bed material. The draghead and suction line, constructed to a scale of 1:6, were connected to a suction pump mounted on a double carriage that provided travel, both longitudinally and transversely, along the top of the flume. The carriage traveled on rails extending the length of the flume.
To develop improved dragheads designed to attain a greater rate of intake of solids when dredging mud and silt mixtures (soft materials) and dredging densely packed, fine sand (hard material).

(g) The results demonstrated how the performance of dragheads can be affected by variations in design and operating procedures. The factors affecting the performance of draghead were indicated to be shape and dimensions of the draghead, position of draghead with respect to the bottom, vacuum, and draghead speed.

(h) Preparation of final report in progress.

(3590) MODEL STUDY OF EFFECTS OF HURRICANE BARRIER ON NAVIGATION CONDITIONS IN EAST PASSAGE, NARRAGANSETT BAY, RHODE ISLAND.

(b) Division Engineer, U.S. Army Engineer Division, New England, Corps of Engineers, Waltham, Massachusetts.

(d) Experimental; for design.

(e) A barrier across East Passage, Narragansett Bay, has been proposed to limit the quantity of water entering the bay from hurricane surges.
To examine ship navigation conditions with respect to barrier location and its navigation opening under current, wave, and wind conditions created by astronomical tides and hurricane surges. Also, to investigate the discharge characteristics of the navigation opening.
A 1:150-scale model of East Passage was used in the study of navigation conditions. Currents, waves, and wind effects were simulated. A self-propelled, radio-controlled, model aircraft carrier, constructed dynamically similar to its prototype, was used in the

tests. In the study of the discharge characteristics of the navigation opening, two section models, reproducing the barrier to scales of 1:50 and 1:150, were used to determine the effects of approach depth, roughness of the barrier, model scale, and weir design on the discharge characteristics. In addition, the 1:150-scale, three-dimensional model was used to determine the discharge characteristics of two weir plans.

(g) Tests showed that a velocity of 3.5 knots through the roughened barrier is produced by a head differential of 0.5 ft across the barrier. This is equivalent to the maximum differential caused by a 2.8-ft tide range.

(h) Preparation of final report is in progress.

(3597) CORRUGATED PIPE ROUGHNESS STUDY.

(b) Office of the Chief of Engineers, Department of the Army, and Bureau of Public Roads, Department of Commerce, Washington, D.C.

(d) Experimental; applied research.

(e) This was a general investigation to determine a resistance coefficient and the law of velocity distribution for flow in structural-plate corrugated pipe. A fiber-glass test section reproducing a 5-foot-diameter standard corrugated pipe at a scale of 1:4 was tested in order to obtain additional data on the resistance coefficient and velocity distribution and to correlate model work with full-scale tests. Fiber-glass test sections reproducing a 5-foot-, 10-foot-, and 20-foot-diameter structural-plate pipe at scales of 1:2.2, 1:8, and 1:16, respectively, were tested to determine the effect of relative roughness upon the resistance coefficient and velocity distribution. The hydraulic gradient and the energy loss through 20- to 80-diameter lengths of test section were established by piezometers located at 5-foot intervals. These piezometers were 1/8 inch in diameter, on center of the crests of the corrugations, and four in number around the periphery of the pipe. Velocity traverses were made by means of calibrated pitot tubes at several locations along the test section for determination of the velocity distribution.

(f) Completed.

(g) Hydraulic gradients, velocity distributions, and static pressure measurements across a diameter for a range of Reynolds number were used to develop a mean flow equation with which the resistance ccefficients due to the corrugations for all sizes of structural plate pipe can be computed. A method for determining the increment of resistance attributable to the assembly bolts of structural plate pipe is presented (Appendix A). In addition, empirical equations were developed that enable determination of the maximum values of the Darcy-Weisbach f and the Manning's n for any diameter of corrugated pipe of the common structural plate and standard varieties as well as the relatively new type with annular 1- by 3-inch corrugations.

(h) "Resistance Coefficients for Structural Plate Corrugated Pipe; Hydraulic Model Investigation." U. S. Army Engineer Waterways Experiment Station Technical Report No. 2-715, February 1966. (Available on loan.)

(3902) RADIOACTIVE TRACER TESTS OF SEDIMENT, GALVESTON BAY (HARBOR), TEXAS.

(b) District Engineer, U.S. Army Engineer District, Galveston, Corps of Engineers, Galveston, Texas.

(d) Experimental; field investigation.

(e) To study the movement of sediment in the vicinity of the Galveston Bay jetties by use of radioactive gold-impregnated glass. A radioactive sediment tracer labeled with gold 198 was used to follow sediment movement in the vicinity of the north and south jetties in Galveston Bay. The pattern of sediment movement is needed to verify the Galveston model and to aid in design of corrective measures to prevent silting of the Galveston ship channel.
The glass tracer was ground to the particle size of the natural sediment and deposited on the gulfside of the jetties. It was expected that the tidal action, littoral current, and wind waves would move the material around the jetties into the ship channel or through the jetties. The path of the activated gold-impregnated glass particles was traced by instruments from a small boat.

(f) Completed.

(g) The results of the north jetty tests indicated that, while small amounts of tracer moved through the small boat pass in the jetty and perhaps through the jetty proper, much larger amounts of tracer moved around the seaward end of the jetty and into the navigation channel. In the one south jetty test, the movement of the tracer was generally seaward for the duration of the test, and there was no indication of tracer movement around the end of the jetty into the entrance.
Personnel monitoring was performed during all high-activity handling operations including transportation and release. In addition, adjacent beaches were monitored for possible contamination. Maximum dosage to personnel was less than 15 percent of maximum permissible weekly dosage; no beach contamination was observed during the tests.
Equipment and procedures used during the tests were satisfactory and will be used again in the event of future tests. It should be noted for future programs of this type that periods of time up to 6 months or more may be required to obtain approval by all agencies involved and to secure the necesary license for such tests.

(h) "Radioactive Sediment Tracer Tests near the North and South Jetties, Galveston Harbor Entrance, MP 2-472, November 1965.

(3903) MODEL STUDY OF TSUNAMIS AND NAVIGATION IMPROVEMENTS AT HILO HARBOR, HAWAII.

(b) District Engineer, U.S. Army Engineer District, Honolulu, Corps of Engineers, Honolulu, Hawaii.

(d) Experimental; for design.

(e) Field study: To measure wave and surge action at piers 1 and 2 in the harbor to provide data for use in determining the cause of the surge problem. Model study: To determine the optimum breakwater plan to decrease wave and surge action in the harbor so that troublesome and damaging ship motion at piers 1, 2, and 3 will be alleviated, and to investigate effects of different plans of construction on reduction of damage to the city of Hilo from tsuamis.
The model, about 62 ft wide and 92 ft long, is constructed to a vertical scale of 1:200 and a horizontal scale of 1:600 and is contoured from 220 ft above mean lower low water. This model area of 2286 sq ft is comprised of 12- by 12-ft sections with jacked supports to compensate for differential settlement of the foundation, and also includes a 1809-sq-ft concrete slab in the wave generator pit. The wave generator is comprised of eight pneumatic chambers, each being 6 by 8 by 10 ft. A programmer operates the generator to simulate tsunami waves.

(f) Tests are complete.

(g) The Honolulu District completed its test program except for the analysis and final report of test data. Five basic plans, with several variations to each plan, were tested during the year with a total of approximately 1500 test runs being completed.
The Hilo Harbor model consultants held a conference in Hawaii in March. The test program was realigned to the recommendations of the consultants. The Hilo Tsunami Technical Advisory Council (consultants to local interests) met in Hawaii in December to discuss results of the model tests. They concluded that the test results were valid.

Analysis of test data is incomplete. The model is being transferred to the University of Hawaii in accordance with the Memorandum of Understanding. However, it will be available for use by the Corps of Engineers, if needed, until construction is under way.

(h) Preparation of final report is in progress.

(3906) POWER-PLANT TRANSIENTS TESTS, GARRISON AND OAHE DAMS, MISSOURI RIVER, N. DAK. AND S. DAK.

(b) Division Engineer, U.S. Army Engineer Division, Missouri River, and District Engineer, U.S. Army Engineer District, Omaha, Corps of Engineers, Omaha, Nebraska.

(d) Field investigations; applied research and design.

(e) Hydraulic prototype measurements of power-plant transients for different plant loadings, and instantaneous pressure values at a number of locations in the power tunnel, the surge tank system, turbine scroll case, and draft tube were obtained simultaneously with instantaneous values of tunnel flow velocity, reservoir and tailwater elevations, turbine speed and gate opening, power output, and other elements (including governor system). Pressure and water-level measurements were made with electrical pressure transducers, velocities were measured with pressure transducers mounted in probes projecting into the flow and connected to pitot-static tubes on cross struts in the penstock, and mechanical and electrical values were obtained with appropriate transducers. Measurements were recorded on about 90 channels of oscillograph and magnetic tape recorders, and digitized for use in the digital computer analyses by Massachusetts Institute of Technology.
To evaluate results of a comprehensive digital computer study made by the Missouri River Division, Omaha District, and Massachusetts Institute of Technology and to determine extent operation corresponds to design, in order to develop a solution of the entire problem of power-plant transients, with primary emphasis on governing stability.

(g) Data are being digitized by the Omaha District for computer analyses. The final report on the test operations is being prepared.

(h) Preparation of final report is in progress.

(3907) SHOALING PROCESSES.

(b) Office of the Chief of Engineers, Department of the Army, Washington, D.C.

(d) Experimental; for design.

(e) The annual cost to the Federal Government of maintaining navigable channels in tidal waterways is estimated to be of the order or $60,000,000. The Committee on Tidal Hydraulics has concluded that a thorough study of shoaling processes in tidal waterways would lead to improvements in channel design, dredging, and spoiling practices, and other maintenance techniques which would reduce this large expenditure. The Committee concludes that the following program of research is essential in arriving at the objective of reducing maintenance cost: (a) flume studies to determine the basic laws involved in the movement and deposition of muddy sediments; (b) flume studies to determine effects of repetitive scour and deposition on sedimentation; (c) the development of techniques for using radioactive tracers for observing the movement and deposition of sediments in nature; (d) the development of a simple and accurate instrument for in-place measurement of turbidity; (e) a study of the physical chemical, and hydraulic factors involved in the stabilization of deposits in navigable channels; (f) determination of the effects of flocculation on shoaling; (g) prototype studies aimed at correlation of sedimentation phenomena in tidal waterways with physical, chemical, hydraulic, salinity, and other significant factors; and (h) classification of the sediments which constitute all major repetitive shoals in tidal waterways.

(g) Item (a) above has been completed under terms of a contract between the University of California and the San Francisco District, and all pertinent reports have been published; item (b) is presently inactive; item (c) is presently inactive; item (d) is presently inactive; item (e) was completed by the University of California, under terms of a contract with WES, and a report entitled A Study of Rheological Properties of Estuarial Sediments was published as Technical Bulletin No. 7 of the Committee on Tidal Hydraulics; item (f) is under study by the Committee on Tidal Hydraulics and WES, and a program of field research on this item has been formulated; and items (g) and (h) are in progress at WES.

(3908) MODEL STUDY OF NAVIGATION ENTRANCE TO ARKANSAS RIVER.

(b) District Engineer, U. S. Army Engineer District, Little Rock, Corps of Engineers, Little Rock, Arkansas.

(d) Experimental; for design.

(e) Tests were conducted on a fixed-bed model reproducing to scales of 1:600 horizontally and 1:100 vertically about 33 miles of the Mississippi River near the mouths of the White and Arkansas Rivers, 57 miles of the lower Arkansas River, 12 miles of the lower White River, and the major portion of the White-Arkansas River backwater area.
The model was used to demonstrate alternate routes for the entrance to the Arkansas-White Cutoff, and problems related to the location and alignment of the navigation entrance to the Arkansas River from the Mississippi River.

(g) Data on stages for various combinations of flow from the three streams, velocity measurements at critical points, and current directions were obtained under various test conditions for use of design engineers in determining the most feasible plan from both a navigation and economical standpoint.

(h) Preparation of final report is in progress.

(3909) HANNIBAL (FORMERLY OPOSSUM CREEK) LOCKS AND DAM, OHIO RIVER.

(b) District Engineer, U. S. Army Engineer District, Pittsburgh, Corps of Engineers, Pittsburgh, Penna.

(d) Experimental; for design.

(e) Tests were conducted in a 1:120, fixed-bed, comprehensive model reproducing about 4 miles of the Ohio River and the lock and dam structures.
The purpose is to study navigation conditions in the approaches to the locks, determine suitability of the selected site, and develop modifications required to overcome any undesirable conditions found.

(f) Suspended.

(3911) MODEL STUDY OF MATAGORDA SHIP CHANNEL, TEXAS.

(b) District Engineer, U.S. Army Engineer District, Galveston, Corps of Engineers, Galveston, Texas.

(d) Experimental; for design.

(e) The fixed-bed model, constructed to scale ratios of 1:1,000 horizontally and 1:100 vertically, reproduced about 800 square miles of prototype area, including all of Matagorda Bay, part of the connecting bay system, and a portion of the Gulf of Mexico adjacent to Pass Cavallo. Tides and tidal currents were reproduced by one primary and one secondary tide generator, and fresh-water discharges of tributaries, together with the rainfall over the area, are introduced by means of weirs and flowmeters. Salt water was used in the model gulf to reproduce the prototype salinity regimen, and provisions were made for the injection of silt in the model for measurements of deposits on

the bed of the model. Studies were made to determine: (1) The best location for the entrance channel; (2) the best route for the channel from the entrance to Point Comfort; (3) such protective works as may be required in the interests of navigation and maintenance of the channel; and (4) the effects of the deep-draft navigation channel on the salinity regimen of the bay system.

(g) Test results indicate that proposed channel Route C is superior to any of the other channel routes tested. Model tests also indicate an arrangement of spoil disposal areas for use with this channel route which will have the least adverse effects on tidal currents, circulation, and salinity.

(h) Preparation of final report is in progress.

(3912) MODEL STUDY OF GALVESTON BAY (HARBOR), TEXAS.

(b) District Engineer, U.S. Army Engineer District, Galveston, Corps of Engineers, Galveston, Texas.

(d) Experimental; for design.

(e) A movable-bed model, with scale ratios of 1:500 horizontally and 1:100 vertically, reproduces about 174.5 square miles of prototype area, including a small portion of Galveston Bay and a portion of the Gulf of Mexico extending 8 miles north of the north jetty, 6-1/2 miles south of the south jetty, and offshore to about the 50-foot contour of depth. Tides, tidal currents, littoral currents, and wave action in the Gulf of Mexico are reproduced. Studies have been made to determine: (1) Plans for relocation and stabilization of the jetty channel on an alinement and depth suitable for navigation of supertankers; (2) means of protecting the north jetty from undermining action of tidal currents; (3) shoaling characteristics of the relocated and deepened jetty (inner bar) channel and plans for minimizing shoaling; and (4) shoaling characteristics of the deepened outer bar channel.

(g) The following studies were conducted during the year: Eight-year movable-bed tests of (a) three proposed deepwater anchorage areas furnished by the Galveston District; (b) the effectiveness of a spur dike normal to the north jetty in impounding drift presently moving around the outer end of the jetty; (c) the effects of closure of Galveston Harbor channel on conditions in the entrance; (d) the plan 2 realigned channel with the channel width reduced from 800 to 600 ft; (e) three proposed jetty modifications in conjunction with a deepened channel realignment (inner bar -46 ft mlt; outer bar -48 ft mlt). (a) The results of the proposed deepwater anchorage area tests indicate that anchorage area "B", located on the north side of the inner bar channel, would require an annual maintenance dredging of about 250,000 cu yd, whereas the addition of anchorage area "C" would increase the annual maintenance dredging to 1,463,000 cu yd. Anchorage area "C" is located on the south side of the channel. (b) The results of the spur dike tests indicate that a spur dike normal to the north jetty, 3000 ft long with a crest elevation of -12 ft mlt, would reduce total shoaling about 23 percent. (c) The results of the tests of the closure of Galveston Harbor channel indicate that total shoaling would be increased about 60 percent. (d) The results of tests of reducing the width of the plan 2 channel from 800 ft to 600 ft indicate a reduction in total shoaling of about 15 percent. (e) The results of the jetty modification tests indicate no improvement in channel shoaling with the jetty modifications installed in the model.

(3914) MODEL STUDY FOR MODERNIZATION OF EXISTING LOCK, McALPINE LOCKS, OHIO RIVER.

(b) District Engineer, U.S. Army Engineer District, Louisville, Corps of Engineers, Louisville, Kentucky.

(d) Experimental; for design.

(e) A 1:25 model which reproduced the filling and emptying system was used to develop feasible modifications which will improve prototype performance.

(g) Tests established the need for connecting the filling and emptying culverts and determined the best port arrangement and valve schedule for filling the locks. Tests indicated that the best port arrangements still will not permit filling in less than 16 min if requirement for a maximum hawser stress of 5 tons is satisfied. A filling time of 16 min with approximately equal hawser stresses can be obtained, either by use of the type 2 intake and a 12-min valve schedule or the type 1 intake and a 4-min valve schedule. If maximum hawser stresses greater than 5 tons are allowed, advantages can be gained by use of the type 2 intake.

(h) Preparation of final report is in progress.

(3915) MODEL STUDY OF DROP STRUCTURE, GERING VALLEY PROJECT, GERING VALLEY, NEBRASKA.

(b) District Engineer, U.S. Army Engineer District, Omaha, Corps of Engineers, Omaha, Nebraska.

(d) Experimental; for design.

(e) The Gering Valley project in western Nebr. will consist of low rectangular drop structures designed for alluvial channels, a series of which will be located in the main Gering drain as well as in the tributaries. Structure widths will vary from 6 to 33 ft and lengths from 16 to 47 ft, with drop heights of 5 and 10 ft.
A 1:12-scale model and a 1:33-scale model were used in the investigation. Each model reproduced a typical drop structure, adjacent overbank areas, and about 300 ft of the approach and exit areas. The smaller scale model permitted more rapid modifications of the structure.
Purpose of the investigation to examine the hydraulic performance of the drop structures with particular interest in basin performance, discharge capacity, and the extent and size of riprap required upstream and downstream of structure.

(g) Families of curves were developed that permitted drop structure design based on drop height and discharge conditions. Design criteria based on investigation of structures having a 5-ft drop height were applicable to structures with drop heights up to 10 ft. A satisfactory plan for placement of riprap material in the vicinity of the structure was developed.

(h) Preparation of final report is in progress.

(3917) GENERAL SPILLWAY MODEL TESTS.

(b) Office of the Chief of Engineers, Department of the Army, Washington, D.C.

(d) Experimental; for design.

(e) A general study, by means of model tests, of various elements of spillways to develop improved designs and to better define values of coefficients used in design formulas.
A flume 70 ft long by 6 ft wide and 6 ft high comprises the test facility. Section models designed for study of particular elements of spillways are installed in the test flume.
To study hydraulic characteristics of spillway crest shapes with heads greater than the design head, including the effects of approach depth, crest piers and gates, elevation of downstream floor of spillway, and of downstream slope of spillway, and to establish general rules for design of roller-type energy dissipators.

(4382) HYDRAULIC PROTOTYPE TESTS.

(b) Office of the Chief of Engineers, Department of the Army, Washington, D. C.

(d) Field investigations for applied research and design.

(e) The purpose of the investigation is to coordinate the hydraulic prototype testing program of the Corps in order to ensure complete coverage of needed testing, prevent unnecessary duplication of testing facilities and tests, recommend instrument installations at projects where physical and hydraulic conditions will be suitable for obtaining data, and investigate hydraulic performance.

(g) Assistance in planning prototype instrumentation and tests was furnished to 16 Districts for 22 projects. Other hydraulic prototype tests related to and conducted partly under this study are described in detail under: (a) Power-Plant Transients Tests, Garrison and Oahe Dams, Missouri River, N. Dak. and S. Dak.; (b) Barren River Dam, Barren River, Ky., Stilling Basin Prototype Pressure Tests; (c) Prototype Hawser-Force Measurements, Jackson Lock, Tombigbee River, Ala.; (d) Prototype Spillway Tests, Analysis and Report, Fort Randall Dam, Missouri River, S. Dak.; (e) Prototype Culvert Pressure Tests, Greenup Locks and Dam, Ohio River, Ky. and Ohio; (f) Protyotype Tests, Gated Intake and Tunnel, Nolin Dam, Nolin River, Ky.; (g) Acoustic Flowmeter Installation and Prototype Tests, Summersville Dam, Gauley River, W. Va.; and (h) Old River Control Structure, La., Prototype Tests.

(h) Prototype Hawser - Force Measurements, Jackson Lock, Tombigbee River, Ala., TR 2-685, August 1965.

(4383) MODEL STUDY OF TURTLE CREEK CHANNEL IMPROVEMENT.

(b) District Engineer, U.S. Army Engineer District, Pittsburgh, Corps of Engineers, Pittsburgh, Pennsylvania.

(d) Experimental; for design.

(e) To evaluate proposed channel improvements and determine the necessity for raising bridges and modifying piers and abutments in the lower 7700 ft of the project.
The model reproduced the lower 7700 ft of the Turtle Creek channel to a scale of 1:50. Provisions were made to test the lower 1500 ft of the creek in existing and improved conditions.

(g) Tests indicated that the proposed channel was adequate to carry the design discharge, although low-level railroad bridges in the reach would project into the flow. Additional reduction in stages and improvement in flow conditions could be obtained by realignment of the lower 800 ft of channel to eliminate projecting piers and abutments, and by removing projections and obstructions remaining in the channel upstream.

(h) Preparation of final report is in progress.

(4385) GENERAL MODEL STUDY BELLEVILLE LOCKS AND DAM, OHIO RIVER, OHIO AND W. VA.

(b) District Engineer, U.S. Army Engineer District, Huntington, Corps of Engineers, Huntington, West Virginia.

(d) Experimental; for design.

(e) The project involves construction of a non-navigable-type dam with parallel locks about 204 miles below Pittsburgh, Pa.; the main lock will be 1200 by 110 ft and the auxiliary lock 600 by 110 ft. The dam will consist of eight gate bays, each 110 ft wide, and a 265-ft-long fixed-crest weir. The locks and dam will have a lift of 22 ft and will replace four of the existing low-lift locks and dams. A 1:120-scale, fixed-bed model, reproducing about 3 miles of the river, adjacent overbank area, and the locks and dam structures, was used for the investigation. The model included sufficient piezometer-type gages to permit an accurate study of the effects of the installation on stages at the dam, at the ends of the lock walls, and upstream and downstream from the ends of the walls.
To study navigation conditions in the lock approaches and the effects of the structures on flood stages under various flow conditions; to develop modifications required to overcome any undesirable conditions; and to demonstrate to navigation interests the acceptability of the proposed design from a navigation standpoint.

(h) Preparation of final report is in progress.

(4386) GENERAL MODEL STUDIES OF HOLT LOCK AND DAM, WARRIOR RIVER, ALA.

(b) District Engineer, U.S. Army Engineer District, Mobile, Corps of Engineers, Mobile, Alabama.

(d) Experimental; for design.

(e) To study flow conditions in the lock approaches and in the approach and exit channels for all arrangements of the structures; to determine the adequacy of the weir and stilling basin design; to determine the most advantageous type of filling and emptying system from the standpoints of rate of operation, degree of turbulence, and economy; and to study proposed valve designs.
Four models were used in this study: a 1:80-scale model reproducing the structures, 4800 ft of the approach channel, and 4800 ft of the exit channel; a 1:36-scale section model reproducing one full bay and two adjacent half bays of the spillway and stilling basin; a 1:25-scale model reproducing 800 ft of the lock approach channel, intake manifolds, the 670-ft lock chamber culverts, bottom laterals, outlet stilling basin, and 730 ft of the downstream exit channel; and a 1:15-scale model of a culvert valve.

(g) The 1:80 general model indicated that the overall arrangement and location of the structures are generally satisfactory. Installation of a 300-ft-long dike in the downstream river channel afforded improved flow conditions in the lower approach to the lock. Tests on the 1:36 section model indicated that the 80-ft-long, apron-type basin can be replaced with a small, 20-ft-radius bucket. In the 1:25 lock model the original design laterals were revised for better flow distribution between the 12 ports. The bottom, middle-third lateral system was found to be feasible. Increasing the spacing between the laterals in this system improved its performance. The final design middle-third system consisted of 12 laterals spaced on 17-ft centers with the first lateral 237 ft below the upstream miter gate pintle. A satisfactory split-lateral filling system was also developed, consisting of 12 laterals divided into two groups of six each at 17-ft centers. The land-wall group began 177 ft from the upstream miter gate pintle and the river-wall group began 401 ft from the upper miter gate pintle. With either filling or emptying system installed the lock could be filled in 9.3 min with a 4-min valve or emptied in 11 min with a 2-min valve. Hawser stresses of 5 tons or less obtained. A vertically framed culvert valve was developed in the 1:15 valve model.

(h) "Lock Filling and Emptying System, Holt Lock and Dam, Warrior River, Ala., Hydraulic Model Investigation," TR 2-698, November 1965.

(4388) SECTION MODEL STUDY OF SPILLWAY, TYPICAL LOW HEAD NAVIGATION DAM, ARKANSAS RIVER, ARKANSAS.

(b) District Engineer, U.S. Army Engineer District, Little Rock, Corps of Engineers, Little Rock, Arkansas.

(d) Experimental; for design.

(e) Stability of the stone blanket was investigated on a 1:25-scale model reproducing a 5-ft depth of approach channel, one 60-ft gate bay and two adjacent half bays, the spillway, stilling basin, and outlet channel. Observations of gate sill performance and stilling basin action were made on a 1:50-scale section model installed in a 1-ft-wide, glass-sided flume.
Supplementary tests were conducted to investigate (a) flow conditions and maximum bottom velocities downstream of a trapezoidal gate

sill without stilling basin; (b) relative merits of a parabolic gate sill with a roller bucket energy dissipator and same sill with a horizontal apron stilling basin terminated by a sloping end sill for dissipating energy at low-head navigation dams, specifically, proposed Locks and Dams 5 and 7; and (c) stability of a horizonatal protective stone blanket downstream of the most practical energy dissipator.

(f) Completed.

(g) The trapezoidal gate sill permitted separation of the nappe from the gate sill and formation of an undesirable flow condition termed an undulating jet which created high bottom velocities and objectionable surface waves in the exit channel. Therefore, use of such a sill and the possibility of eliminating stilling basins at certain low-head dams on the Ark. River were dropped from further consideration. Tests revealed the relatively short apron and end sill to be the most practical design for use with the parabolic gate sill and the conditions expected at the proposed Locks and Dams 5 and 7. The model also indicated that horizontal protective stone blankets consisting of stone up to 36 and 48 in. in diameter were stable downstream of the horizontal apron and end sill for all possible flow conditions other than spray action. The additional tests indicated that the elimination of stilling basins was not practical for the conditions investigated. However, a 40-ft-long, horizontal apron terminated by a 4-ft-high sloping end sill provided satisfactory performance and was found to be more effective in dissipating energy than were various roller buckets.

(h) "Gate Sills and Stilling Basins for Locks and Dams Nos. 5 and 7," Appendix A to the final report on the principal study, TR 2-655, Spillway for Typical Low-Head Navigation Dam, Arkansas River, Arkansas: Hydraulic Model Investigation, October 1965.

(4390) GENERAL MODEL STUDY OF CANNELTON LOCKS AND DAM, OHIO RIVER, IND. AND KY.

(b) District Engineer, U.S. Army Engineer District, Louisville, Corps of Engineers, Louisville, Kentucky.

(d) Experimental; for design.

(e) The project involves the construction of a nonnavigable dam approximately 721 miles below Pittsburgh, Pa., with parallel locks, the main lock to have clear dimensions of 1200 by 110 ft and the auxiliary lock to be 600 by 110 ft.
Two models were used in this study. A 1:120-scale model reproduces about 9 miles of the river and sufficient overbank areas to permit the reproduction and study of flows up to the maximum of record (1937 flood). The model includes the locks and dam structures with provisions for the installation of powerhouse facilities. Also, 20 piezometer-type gages are provided to permit study of swellheads as affected by the locks and dam and the powerhouse facilities. A 1:25-scale model reproduced 500 ft of the lock approach channel, intake manifolds, the 1200-ft lock chamber, culvert, sidewall port manifolds, outlets, and 200 ft of the downstream exit channel.
To investigate navigation conditions in the lock approaches and effects of the structures on flood stages; to obtain data for development of rating curves; to determine the effect of powerhouse installation on flow and navigation conditions; and to determine the suitability of a sidewall port filling system under heads and submergences which will obtain at the Cannelton Lock and other locks on the Ohio River.

(g) Tests on the 1:120-scale model indicated that the powerhouse should be placed on an angle of 70°45' with the axis of the dam, and that satisfactory navigation conditions could be obtained during floods by degrading a portion of the left overbank upstream of the powerhouse entrance channel. Lock model tests indicated that satisfactory performance should be obtained with a sidewall port arrangement for a 110-by 1200-ft lock based on the following recommendations: (a) Port-area to culvert-area ratios should be about 0.95. (b) Ports should be spaced 28 ft on centers. (c) The port group should extend over about 50 percent of the lock chamber, and be centered in the chamber. (d) Triangular deflectors or recesses are desirable at the upstream one-third of the ports.

(4391) MODEL STUDY OF NAVIGATION CONDITIONS OF LOCK AND DAM NO. 3, ARKANSAS RIVER, ARKANSAS.

(b) District Engineer, U.S. Army Engineer District, Little Rock, Corps of Engineers, Little Rock, Arkansas.

(d) Experimental; for design.

(e) A movable-bed model reproducing about 13 miles of the Arkansas River and adjacent overbank area, constructed to a scale of 1:120 horizontally and 1:80 vertically, was used.
The purpose is to determine the suitability of the proposed site for the lock and dam structure, the effects of proposed regulating works in the vicinity including a cutoff, and modifications which might be required to provide adequate channel depths in the lock approaches and safe navigation conditions with minimum maintenance.

(g) Tests to determine the effects of various combinations of training dikes and gate operation were accomplished.
Results indicated that shoaling in the lower lock approach can be reduced by selected operation of the lock gates and the installation of training dikes in the channel upstream of the dam.

(h) Preparation of final report is in progress.

(4396) MODEL STUDY OF COLUMBIA RIVER ESTUARY, ENTRANCE TO OAK POINT, OREGON AND WASHINGTON.

(b) District Engineer, U.S. Army Engineer District, Portland, Corps of Engineers, Portland, Oregon.

(d) Experimental; for design.

(e) The model reproduces the lower 52 miles of the Columbia River and pertinent offshore areas to linear scales of 1:500 horizontally and 1:100 vertically. Tides and tidal currents, density currents, waves, and other phenomena significant to the movement and deposition of sediments are reproduced and studied. Some portions of the model are of the fixed-bed type, while some portions are to be converted to the movable-bed type at a later date. The purposes of the study are to determine the need for and to develop optimum plans for rehabilitation of existing jetties and proposed additional improvements; to investigate future shoaling developments in the entrance channel and in the reach between the entrance and Oak Point, and means of alleviating such shoaling; and to investigate existing and proposed spoil-disposal areas to establish locations that will not permit movement of material back to the channel.

(g) Fixed-bed shoaling tests indicated that construction of the proposed 40- by 600-ft channel will increase channel shoaling by the following amounts: Miller Sands Bar, 41.0 percent; Tongue Point Bar, 124.4 percent; Wauna-Lower Westport Bar, 75.8 percent; and Pillar Rock Bar, 60.2 percent. An improvement plan at Miller Sands Bar, consisting of a combination of 4 pile dikes and an 8700-ft-long dredge spoil fill, was developed which reduced the 40- by 600-ft channel shoaling rate by 47.8 percent. Dredge spoil areas at Tongue Point Bar were developed which will not affect the shoaling rate at this bar. An improvement plan at Wauna-Lower Westport Bar, consisting of a combination of 4 pile dikes and 3 dredge spoil fills, was developed which reduced the 40- by 600-ft channel shoaling rate by 29.6 percent.

(4593) GENERAL MODEL STUDIES OF MILLERS FERRY LOCK AND DAM, ALABAMA RIVER, ALABAMA.

(b) District Engineer, U. S. Army Engineer Dist., Mobile, Corps of Engineers, Mobile, Ala.
(d) Experimental; for design.
(e) The project is located 142.2 miles above the mouth of the Alabama River and is part of the development program of the Alabama River waterway. It will include a nonnavigable dam with a gated and an overflow section, a lock on the left bank having clear dimensions of 600 by 84 ft, and a powerhouse.
To investigate navigation conditions through an existing bridge and in the lock approaches, the effects of the structures on flood stages, and the effects of powerhouse operations on navigation conditions. A separate model study investigated the suitability of a longitudinal floor culvert system for filling and emptying the lock under heads and submergences which will obtain at the Millers Ferry Lock site.
A 1:100-scale general model reproducting about 3.1 miles of river was used to study navigation conditions, and a 1:25-scale model reproducing 700 ft of the lock approach channel, the 600-ft by 84-ft lock chamber, the entire culvert system, and 800 ft of the downstream exit channel was used to study filling and emptying of the lock.
(g) Results in the general model indicated the need for modification of the excavation along the left bank to facilitate the movement of downbound tows leaving the lock. In the lock studies, two satisfactory floor culvert arrangements were developed. One arrangement was adapted to the particular foundation conditions existing at the Millers Ferry Lock site which confined the culvert system to the middle third of the lock chamber. The second arrangement was developed for locations with less restrictive foundation conditions.
(h) Preparation of final reports on general and lock model studies is in progress.

(4594) MODEL STUDY OF SPILLWAY, SHELBYVILLE DAM, KASKASKIA RIVER, ILLINOIS.

(b) District Engineer, U. S. Army Engineer Dist., St. Louis, Corps of Engineers, St. Louis, Missouri.
(d) Experimental; for design.
(e) The investigation was conducted on a 1:40-scale model that reproduced the spillway and allied structures, a portion of the earth embankment on each side of the spillway, 1550 ft of the approach channel, and 1150 ft of the exit channel.
The purpose of the investigation is to study the overall hydraulic performance of the spillway and outlets of the sluices, verify chute and stilling basin designs, and develop an exit channel protection plan.
(g) Adequate spillway capacity and flow conditions at the abutments were obtained by placing rock dikes at the abutment to guide flow into the weir. The diversion blockout was found to be adequate and satisfactory for the release of the expected diversion flows. Exit channel protection, with and without berms behind the stilling basin training walls, consisting of riprap and concrete paving was developed.
(h) Preparation of final report is in progress.

(4595) GENERAL MODEL STUDY OF COLUMBIA LOCK AND DAM, OUACHITA RIVER, LA.

(b) District Engineer, U. S. Army Engineer Dist., Vicksburg, Corps of Engineers, Vicksburg, Mississippi.
(d) Experimental; for design.
(e) The project involves construction of a cutoff channel about 5,600 feet long with a bottom width of 522 feet, a gated structure (consisting of four tainter gates each 50 feet wide and 26 feet high) located about midway of the cutoff, a 200-foot-wide navigable pass on the right of the dam, and a 600- by 84-foot lock on the left. A 1:100 model, reproducing about 2.6 miles of the river, was used to investigate navigation conditions in the approaches to the lock and navigable pass, and the effects of the structures on flood stages.
(f) Final report in preparation.

(4598) MODEL STUDY OF DROP STRUCTURE, CAYUGA INLET, ITHACA, NEW YORK.

(b) District Engineer, U. S. Army Engineer Dist., Buffalo, Corps of Engineers, Buffalo, N. Y.
(d) Experimental; for design.
(e) The investigation was conducted on a 1:20-scale model which reproduced 300 ft of the approach channel, the drop structure, and about 400 ft of the exit channel.
The purpose of the study was to confirm the suitability of the drop structure, and if indicated, to develop advantageous modifications thereto. Of particular concern is the magnitude of channel velocities below the structure.
(f) Completed.
(g) Tests demonstrated that the original design structure was unsatisfactory as little or no energy dissipation occurred at low and intermediate flows. The length of the stucture was reduced and baffle piers were eliminated from the basin. A 3-ft-high sill was added to the weir crest to reduce velocities in the channel upstream from the structure. Use of a 12-ft-radius abutment wall improved conditions at the entrance to the structure and reduced construction costs.
(h) "Drop Structure, Cayuga Inlet Cayuga Lake, New York Hydraulic Model Investigation," TR 2-709, Dec., 1965.

(4599) MODEL STUDY OF CONTROL STRUCTURES, LITTLE SIOUX RIVER PROJECT, LITTLE SIOUX, IOWA.

(b) District Engineer, U. S. Army Engineer Dist., Omaha, Corps of Engineers, Omaha, Nebraska.
(d) Experimental; for design.
(e) The 1:30-scale model reproduced about 700 ft of the channel and berms upstream of the structure, the drop structure, and about 1300 ft of the channel and berms below the structure. Portions of the levees containing the structure were reproduced adjacent to the berms. The approach channel and berms were initially molded in sand; subsequent tests were conducted with this area molded in cement mortar to sheet-metal templates. Prototype roughness was simulated by installing expanded metal mesh (7/8-in.) on the upstream berms. The concrete area of the drop structure was fabricated of plastic-coated plywood.
Studies were made of the placement of riprap materials in the vicinity of the structure, and the discharge capacity of the structure.
(g) As the design of the drop structure for Little Sioux was based on the successful design of the Gering Valley structure, and as initial observations revealed satisfactory performance of the structure from a hydraulic standpoint no changes were made to the drop structure during the course of the model study. Model tests were mainly concerned with the determination of an adequate riprap plan to protect the structure and obtain the most economical use of the rock. Calibration data for submerged and unsubmerged flows were obtained. It was determined from the model study that while the overall performance of the structure was excellent, and the dimensions of the drop structure based on the Gering Valley tests were satisfactory, certain modifications to the structure would improve hydraulic performance and effect economies in construction.
Tests indicated that stone sizes in the original riprap plan were larger than necessary and smaller sizes could be used with a resulting saving in construction costs. Tests also indicated that approximately 150 ft of riprap protection on the channel banks upstream from the structure could be eliminated.

The capacity of the control sturcture was found to be adequate.

(h) Preparation of final report is in progress.

(4602) LOCK FILLING AND EMPTYING SYSTEMS.

(b) Office of the Chief of Engineers, Dept. of the Army, Washington, D. C.

(d) Experimental; applied research.

(e) The following models were used in this study during the past year: the 1:25-scale model of the 670- by 110-ft low-lift locks on the Arkansas River project, the 1:25-scale model of the 655- by 84-ft Jones Bluff Lock, Ala. River, and a 1:36-scale model of the culvert system for a longitudinal floor-culvert system in 1200-ft locks.
The purpose of the studies is to provide new or improved design information and procedures to assist in the design of navigation lock filling and emptying systems.

(g) Tests were conducted in the low-lift lock test facility to provide additional information on the desirable culvert and port sizes for use in sidewall port filling and emptying systems. The longitudinal floor-culvert filling and emptying system developed for the Jones Bluff Lock was tested at a head of 69 ft to provide data on the performance of this type system at high heads. Developmental tests of a floor-culvert system for use in high-lift locks were initiated in the 1:36-scale model. Tests to date have been directed toward improving the design of the transitions, bifurcations, and bends required in the culvert system. Several designs have been tested in an effort to minimize head losses while maintaining the desired distribution of flow in the culvert system.
Correlation of results from the low-lift lock tests with other data resulted in design recommendations for low-lift lock systems. Results of the tests on the Jones Bluff Lock model indicated that the longitudinal floor-culvert system has potential for adaptation to larger locks with intermediate and high lifts.

(h) Final report in preparation.

(4603) MODEL STUDY OF FILLING AND EMPTYING SYSTEM FOR LOW-LIFT LOCKS, ARKANSAS RIVER, ARKANSAS.

(b) District Engineer, U. S. Army Engineer Dist., Little Rock, Corps of Engineers, Little Rock, Arkansas, and other interested Corps of Engineers offices.

(d) Experimental; for design.

(e) The investigation was conducted on a 1:25-scale model which reproduced 700 ft of lock approach channel, intake manifolds, a 670-ft-long lock chamber, culvert, sidewall port manifolds, outlet manifold, and 700 ft of downstream channel. It is being used to determine an optimum port arrangement for the filling and emptying system for low-lift locks.

(g) Results of the generalized tests indicated that a satisfactory sidewall port arrangement for a 110- by 600-ft lock should result from the following recommendations: (a) Port-area to culvert-area ratio should be about 0.95. (b) Ports should be spaced 28 ft on centers. (c) The port group should extend over about 50-60 percent of the lock chamber and be centered about the midpoint of the lock chamber or a point slightly downstream. (d) Triangular deflectors or recesses are desirable at the upstream one-third of the ports. Filling and emptying characteristics were obtained for a range of lifts and submergences for the optimum arrangements of 14 type A ports (type 35) and 13 type D ports (type 56).

(h) Preparation of final report is in progress.

(4604) MODEL STUDY OF INTAKE AND FLOOD-CONTROL OUTLET, DEGRAY DAM, CADDO RIVER, ARKANSAS.

(b) District Engineer, U. S. Army Engineer Dist., Vicksburg, Corps of Engineers, Vicksburg, Mississippi.

(d) Experimental; for design.

(e) The investigation was conducted on a 1:23-scale model that reproduced the intake tower and a portion of the reservoir, the 29-ft-diam diversion tunnel, stilling basin, and 240 ft of the exit channel. At the conclusion of the diversion tests, the flood-control gate was installed at the end of the 29-ft-diam conduit for additional flow studies.
Purpose is to develop a conventional hydraulic jump-type stilling basin, and to study flow through the intake tower, elbow, tunnels, and the flood-control regulating gate at the end of the 29-ft diam. conduit.

(f) Completed.

(g) A cylinder-gate intake tower functioned with less head loss and less surging than did the slide-gate intake tower. Pressures in the tunnel and elbow were positive and no zones of separation were evident. Pressures in the flood-control transitions indicated a gradient that approximated that of the area curve. The stilling basin developed for the large diversion releases was found to be adequate for dissipation of the high-energy flood-control releases.

(h) "Outlet Works, DeGray Dam, Caddo River, Arkansas; Hydraulic Model Investigation," TR 2-684, July 1965.

(5228) CRITERIA FOR THE DESIGN OF SMALL-BOAT HARBORS.

(b) Office of the Chief of Engineers, Dept. of the Army, Washington, D. C.

(d) Experimental; applied research.

(e) To develop equations and experimental coefficients for use in predicting the motion of samll boats moored to floating docks under the action of progressive- and standing-wave systems; determine the optimum shape of harbors and types of perimeter walls with respect to the response characteristics of small-craft harbors and the surging of moored craft in the harbors; and provide design criteria for protective structures at the entrance to small-craft harbors.
Wave basins of various sizes will be used in the laboratory tests.

(h) "Wave Induced Oscillation of Small Moored Vessels," by Fredrich Raichlen, Report No. CR-2-131, October 1965.

(5229) GENERAL COASTAL INLET STUDIES.

(b) Office of the Chief of Engineers, Dept. of the Army, Washington, D. C.

(d) Experimental; applied research.

(e) This is a general study to develop means for computing discharge and velocity distribution through tidal inlets, leading to determination of tidal prisms and water-surface elevations in inner bay systems; and to determine the factors involved in both inner and outer bar formation, the shoaling of inlet channels, and the stability of inlet shape and location. The project will consist of the following three phases: (1) Tests in four generalized test facilities, three of which (Facilities A, B, and C) will be located at the Waterways Experiment Station and the fourth at the Coastal Engineering Research Center; (2) analysis of results of these tests by the Waterways Experiment Station, the Coastal Engineering Research Center, and the Committee on Tidal Hydraulics; and (3) field observations under sponsorship of the Committee on Tidal Hydraulics to confirm the principles developed. Construction of Facility A at WES, including the control system and pumping plant, has been completed, and design of the initial inlets to be tested in this facility has been completed. The basic structure of Facility C, located at WES, has been constructed and materials for the water supply and control systems have been obtained. Design of Facility B to be located at WES has been completed. Fabrication of the shelter to house Facilities B and C has been initiated.

(5230) MODEL STUDY OF NAVIGATION CONDITIONS, LOCK AND DAM NO. 4, ARKANSAS RIVER, ARKANSAS.

(b) District Engineer, U. S. Army Engineer District, Little Rock, Corps of Engineers, Little Rock, Arkansas.
(d) Experimental; for design.
(e) The investigation was conducted on a 1:120-scale, fixed-bed, comprehensive model, reproducing about 5 miles of the Arkansas River and adjacent overbank areas, the lock and dam structures, and all bridges and other structures that might affect flow conditions. The purpose is to determine the suitability of the proposed site for the lock and dam structure, and the effects of regulating works in the lower approach, and to develop modifications which might be required to overcome any undesirable navigation conditions.
(g) The location and arrangement of the lock, dam, and overflow sections were satisfactory. The upper guard wall should be on the riverside rather than landside. Modification of the Rob Roy Bridge and alignment of the right bank near the bridge would be desirable to improve navigation. The mooring area would have less effect on navigation through the lock if moved upstream. Shoaling in the lower approach will depend on amount of sediment moving through the dam.
(h) Preparation of final report is in progress.

(5231) MODEL STUDY OF NAVIGATION CONDITIONS, OZARK LOCK AND DAM, ARKANSAS RIVER.

(b) District Engineer, U. S. Army Engineer District, Little Rock, Corps of Engineers, Little Rock, Arkansas.
(d) Experimental; for design.
(e) A 1:120, fixed-bed model, reproducing about 3 miles of the Arkansas River, adjacent overbank areas to an elevation of approximately 385 ft msl, the lock and dam structures, and all bridges and other structures that might affect flow conditions, is being used to determine the suitability of the proposed site for the lock and dam structures, and to develop modifications which might be required to overcome any undesirable navigation conditions.
(g) Tests have resulted in modifications in the lock approaches and in the excavation in the approach to the powerhouse, and in the development of a suitable plan for spoil disposal.
(h) Preparation of final report is in progress.

(5233) MODEL STUDY OF SUBMERGED SILLS, ST. CLAIR RIVER.

(b) District Engineer, U. S. Army Engineer District, Detroit, Corps of Engineers, Detroit, Michigan.
(d) Experimental; for design.
(e) To study effects of one or more submerged sills at different locations on backwater effect, to study sedimentation characteristics and velocities and current directions, and to verify the adequacy of the submerged sills to withstand propeller wash with an initial velocity of 25 fps.
The comprehensive model reproduced the St. Clair River from Lake Huron to a point about 3.1 miles downstream to a scale of 1:60; this model was of the fixed-bed type with provisions for the study of sediment movement and for the study of shoaling in the critical area. A 1:20-scale section model installed in an existing, 2.5-ft-wide flume was used to investigate the stability of the submerged sills and the ability of 15-ton precast units and various sizes of stone to withstand propeller wash with an initial velocity of 25 fps.
(g) Tests on the comprehensive model to determine the effects of various submerged sill combinations were conducted. Construction of the section model and tests to determine the stability and discharge coefficients of various submerged sills were completed. Tests to determine the effects of a new type sill (selected as a result of the section model tests) and the effects of sediment deposition were accomplished.
The results indicated that: the new type sill would be slightly less effective than the vertical-faced sills; sediment deposition between sills would tend to reduce the effectiveness of the sills; and sills would have no appreciable effect on navigation conditions in the reach.

(5234) MODEL STUDY OF SEAWALL, TEXAS CITY, TEXAS.

(b) District Engineer, U. S. Army Engineer District, Galveston, Corps of Engineers, Galveston, Texas.
(d) Experimental; for design.
(e) A levee and seawall system has been proposed to protect Texas City and adjacent areas of the shore of Galveston Bay from flooding caused by hurricanes. To develop designs for (1) vertical-faced seawalls, (2) rubble-mound structures to protect the natural ground at the base of a vertical wall on its bayside, and (3) rubble-mound armor layers to protect the bayside slope and crown of an earth levee, 1:35 section models of the structures are being tested in a concrete flume 119 feet long, 5 feet wide, and 4 feet deep. Model waves are generated by a plunger-type wave machine, and measured and recorded electrically.
(g) To stabilize the type 1 design, when attacked by 6-second, 15-foot waves, 6-ton stones instead of 3.3-ton stones were required at the bayside toe. The landside slope was made stable by using 3.3-ton stones instead of riprap. The type 2 and type 3 designs were made stable under the attack of 6-second, 15-foot waves by using a mound of 1- to 1-1/2-ton stones to scotch the toe of the 6-ton cover layers. The results of the pressure distribution tests showed that the forces acting on the vertical-wall section were greater than those obtained from Sainflou's theory for nonbreaking waves, and less than those obtained from Minikin's formula for breaking waves.
(h) Final report in preparation.

(5235) MODEL STUDY OF BESSIE CUTOFF, MISSISSIPPI RIVER.

(b) District Engineer, U. S. Army Engineer District, Memphis, Corps of Engineers, Memphis, Tennessee.
(d) Experimental; for design.
(e) The proposed Bessie Cutoff would eliminate the river bend at New Madrid, Mo., and shorten the river about 21 miles. A model, reproducing 85 miles of the river to a horizontal scale of 1:500 and a vertical scale of 1:100, is being used to obtain indications of the probable effects of various degrees of cutoff development on velocities, current directions, water-surface profiles, navigation depths, channel meandering tendencies, and general navigability of the affected reach. The model is of the fixed-bed type with provision for converting to a movable bed the reaches expected to be affected appreciably by the cutoff.
(f) Completed.
(g) Test results indicated no serious navigation difficulties during the time of the intermediate or final development stages of the cutoff, except for locally high velocities. The low-water slopes upstream of the cutoff would be increased by about 50 percent, with stages lowered from 1.5 ft at Columbus, Ky. (about 37 miles upstream of the cutoff), to 6.5 ft at the head of the cutoff with a flow of about 200,000 cfs. Flood stages would be lowered by amounts ranging from about 9.5 to 11.0 ft at the head of the cutoff, depending on the magnitude of the flood and whether or not the Birds Point-New Madrid Floodway is in operation. The study also indicated the general effects of the cutoff on channel development and stabilization, the effects of

the floodfree roadway connecting the severed area with the mainland, and the movement of sediment at the head of the cutoff during the initial development.

(h) "Model Study of Bessie Cutoff, Mississippi River; Hydraulic Model Investigation," Report No. TR 2-692, September 1965.

(5238) MODEL STUDY OF SPILLWAY, STOCKTON DAM, SAC RIVER, MISSOURI.

(b) District Engineer, U. S. Army Engineer District, Kansas City, Corps of Engineers, Kansas City, Kansas.

(d) Experimental; for design.

(e) A 4-gated, ogee spillway and one 45,000-kilowatt powerhouse unit located in a concrete nonoverflow section adjacent to the spillway are proposed for Stockton Dam. A 1:60 model reproducing 1,700 feet of the approach area, the entire spillway and powerhouse, the stilling basin, and 1,100 feet of the exit channel was used to investigate the hydraulic adequacy of the spillway, stilling basin, and appurtenances, and determine any desirable modifications for various operating conditions.

(f) Tests completed.

(g) The overall performance of the original design structure was satisfactory. Flow conditions in the approach, at the abutments, over the spillway, and on the chute were adequate. The capacity of the spillway as determined on the model was greater than that computed. No alterations to the original design spillway section were made during the course of the model study. However, in several tests the discharge per foot of crest width was adjusted upward to simulate flow over a slightly reduced crest width. The performance of the original design stilling basin was satisfactory in the dissipation of all spillway discharges. However, three alternate designs were investigated in an attempt to effect economies in construction costs. A stilling basin (type 3) was developed which permitted a reduction in the size of basin elements and permitted the basin elevation to be raised 5 ft. The model tests also indicated that the height of the stilling basin divider wall could be reduced 5 ft without affecting the efficiency of the basin.

(h) "Spillway for Stockton Dam, Sac River, Mo.; Hydraulic Model Investigation," final report no. TR 2-683, July 1965.

(5241) MODEL STUDY OF WAVE ACTION AND SHIP MOORING, POINT LOMA, CALIFORNIA.

(b) Department of the Navy.

(d) Experimental; for design.

(e) The Navy Electronics Laboratory desires to use an aircraft carrier, moored behind a protective breakwater about 4,000 feet offshore, in the design and development of electronic equipment. A 1:100 model reproducing about 4.5 square miles of the locality, and a 1:100 model of an Essex class aircraft carrier were used to: (1) Determine wave-action conditions that will obtain within the mooring area; (2) study variations in design and location of the breakwater; (3) secure data on actual movement of the model ship due to wave action; (4) investigate the feasibility of a proposed floating causeway shoreward from the ship; and (5) study adequacy of design of a proposed small-craft landing area in the immediate vicinity. Waves were generated by a 60-foot-long wave machine, and are measured and recorded electrically. The model of the aircraft carrier was dynamically balanced to reproduce the physical characteristics of the prototype ship.

(f) Completed.

(g) (1) Breakwater length was reduced from 3,600 to 2,100 feet, a 40 percent reduction from original design. (2) It was determined that wave heights behind the breakwater, and the resulting ship motion, would not be excessive insofar as waves from average severe storms are concerned. (3) The optimum crown elevation for a rubble-mound causeway and small boat landing area was established. (4) It was determined that a nearby sewer outfall pier would be unsafe for fishermen during periods when wave heights approached 13 to 18 feet because of overtopping of the structure.

(h) "U. S. Navy Ship Mooring Facility, West Coast of Point Loma, San Diego, California; Hydraulic Model Investigation," U. S. Army Engineer Waterways Experiment Station Technical Report No. 2-708, December 1965. (Available on loan.)

(5242) PROTOTYPE CULVERT PRESSURE TESTS, GREENUP LOCKS AND DAM, OHIO RIVER, KENTUCKY AND OHIO.

(b) District Engineer, U. S. Army Engineer District, Huntington, Corps of Engineers, Huntington, West Virginia.

(d) Experimental; for design.

(e) The project, located on the Ohio River 341 miles downstream from Pittsburgh, Pa., consists of a 110- by 600-ft auxiliary lock, a 110- by 1200-ft main lock, and a nine-bay, 1287-ft-long spillway dam. The lift of the locks is 32 ft at present, but will be 30 ft when additional downstream development is completed. The filling and emptying system of the main lock consists of two culverts and a split-lateral system.
To measure prototype pressures in the filling and emptying system of the main lock and water-surface elevations in the lock chamber for comparison with model results and for further development of lock design criteria. Electrical transducers connected to piezometers by air-purged lines were used to measure pressures in the lock culverts and water-surface elevations in the lock. Circular potentiometers were used to indicate the positions of the filling and emptying valves. All data, accompanied by a common time indication, were recorded on light-beam oscillographs. Other data included photographic records of flow conditions and staff gage readings.

(g) The data analysis and model-prototype comparison in report form were furnished by the St. Paul District. These were combined with remainder of the report. Final editing is in progress.
Analysis of prototype pressures in the filling and emptying systems of the main lock for two-culvert (normal) operation, single-culvert operation, and steady-flow conditions indicates reasonable confirmation of the model results. Discrepancies between model and prototype similitude are thought to cause the dissimilarity in the data.

(5243) PROTOTYPE TESTS, GATED INTAKE AND TUNNEL, NOLIN DAM, NOLIN RIVER, KENTUCKY.

(b) District Engineer, U. S. Army Engineer District, Louisville, Corps of Engineers, Louisville, Kentucky.

(d) Experimental; for design.

(e) Nolin Dam is a rock-fill dam, 169 ft in ht, used for flood control. The outlet works, consisting of a three-gated intake structure and semielliptical-shaped tunnel, has a 16,000-cfs capacity. An uncontrolled saddle-type spillway is located on the right abutment.
To measure the tunnel hydraulic grade line and gate-hoist cylinder pressures. From these measurements, tunnel friction and intake losses can be evaluated and gate forces computed.
Test facilities included five pairs of sidewall piezometers connected to a manifold. Pressures at full tunnel flow were measured by means of the air-purge technique, using a mercury manometer and a pressure gage. Pressure taps were provided in one of the operating gate-hoist cylinders and measurements of

gate hydraulic cylinder pressures were made with pressure gages.

(g) Tests were conducted in December 1964. Preliminary analysis of the data has been completed and a report prepared. Additional tests are planned when water becomes available.

(5245) MODEL STUDY OF HOUSTON SHIP CHANNEL, TEXAS.

(b) District Engineer, U. S. Army Engineer District, Galveston, Corps of Engineers, Galveston, Texas.

(d) Experimental; for design.

(e) Houston Ship Channel is a 52-mile reach extending from the Gulf of Mexico across Galveston Bay to the Turning Basin at Houston. A model study is being conducted to determine if the present cost of maintenance dredging in the channel can be reduced by proposed plans of channel realinement, partial or complete diking of connecting bays, sediment traps, dikes in Galveston Bay, local contractions, enlargements, and other remedial measures. The model reproduces a portion of the Gulf of Mexico outside the entrance to Galveston Bay; all of Galveston and Trinity Bays; Dickinson Bay and Clear Creek to the head of project; the tidal portion of Trinity River; the Houston Ship Channel in its entirety; and Buffalo Bayou from the Turning Basin to the confluence of White Oak Bayou. The model is of fixed-bed construction with scale ratios, model to prototype, of 1:600 horizontally and 1:60 vertically. Tides and tidal currents are reproduced by a tide generator located in the Gulf of Mexico portion of the model, and the salinity of the model Gulf is reproduced to scale so that the effects of salinity differences on the vertical distribution of current velocities, as well as salinity concentrations throughout the model, accurately reproduce those of the prototype. The model will be used to establish the effects of all proposed improvement works on tidal current velocities, current patterns, and salinities in all critical areas. All hydraulic and salinity data obtained from the model will be quantitative and can be applied directly to the prototype. Shoaling studies will be made by injecting finely ground gilsonite into the model to reproduce the patterns of shoaling as observed in the prototype, following which the effects of proposed improvement plans on shoaling patterns may be observed and evaluated from a qualitative viewpoint.

(g) Operation of the model with salt water for verification of salinities, tidal elevations, and current velocities for conditions of low and medium freshwater discharges was in progress; model verification is about 90 percent complete.

(5246) MODEL STUDY OF NAVIGATION CONDITIONS, UNIONTOWN LOCK AND DAM, OHIO RIVER.

(b) District Engineer, U. S. Army Engineer Dist., Louisville, Corps of Engineers, Louisville, Kentucky.

(d) Experimental; for design.

(e) The project involves construction of a dam consisting of a gated section with sill elevation at 317, a fixed overflow section with crest at elevation of 344, and two parallel locks. The main lock chamber will have clear dimensions of 110 by 1200 ft. The auxiliary lock, 110 by 600 ft, will be located on the right bank.
To investigate navigation conditions with the proposed structures, to determine the effects of modifications in the composition and arrangment of the structures, and to develop any modifications considered desirable.
The investigation is being conducted on a 1:120 model reproducing about 8.6 miles of the Ohio River and adjacent overbank area near Uniontown, Ky., the lock and dam structures, and the lower reach of the Wabash River.

(5247) MODEL STUDY OF FILLING AND EMPTYING SYSTEM, JONESVILLE LOCK AND DAM, OUACHITA-BLACK RIVER, LOUISIANA.

(b) District Engineer, U. S. Army Engineer District, Vicksburg, Corps of Engineers, Vicksburg, Mississippi.

(d) Experimental; for design.

(e) A 1:25 model, reproducing 750 feet of the lock approach channel, intake manifold, the 84- by 600-foot lock chamber, culvert, sidewall port manifolds, outlets, and 650 feet of the exit channel, is being used to develop the optimum side port filling and emptying system for the lock.

(f) Completed.

(g) The original design intake and outlet manifold performed satisfactorily. Tests of 31 sidewall port arrangements resulted in the adoption of 17 ports per culvert spaced 20 ft on centers with 8- by 8- by 2-ft-deep recesses in the lock chamber floor in front of each port. With the adopted hydraulic system installed in the model, hawser stresses on 4- and 6-barge tows were well within the 5-ton limit during operation at normal and probable maximum heads and submergences. Flow conditions in the upstream lock approach indicated that rectangular guide wall piers contributed to vortex tendencies at the intake manifold; therefore, the use of circular guide wall piers is recommended. Flow conditions in the downstream approach were satisfactory during emptying operations.

(5249) PROTOTYPE HAWSER-FORCE MEASUREMENTS, JACKSON LOCK, TOMBIGBEE RIVER, ALABAMA.

(b) District Engineer, U. S. Army Engineer District, Mobile, Corps of Engineers, Mobile, Alabama, and Office, Chief of Engineers, Washington, D. C.

(d) Experimental; for design.

(e) The Jackson Lock chamber is 110 feet wide by 670 feet long and has a 34-foot maximum lift. Reverse tainter valves control flow in two 12.5-foot-square culverts, each of which has 6 intake ports in the upper approach walls, 14 side ports to the lock chamber, and an outlet discharging outside the lower lock approach.
To measure prototype hawser loads resulting from hydraulic forces acting on a tow of loaded barges. Data obtained with rigid- and flexible-type connections between the tow and floating mooring bitts were compared with model results and used in developing lock design criteria.
The rigid connections, containing calibrated dynamometers, were installed fore and aft on the portside of the tow and connected to floating mooring bitts in the lock land wall. One connection measured lengitudinal hawser forces, and the other measured transverse forces. Potentiometers were mounted on the culvert-valve operating arm to measure valve opening. Differential-type pressure transducers were used for measuring the slope of the water surface in the lock chamber, and absolute pressure transducers were used for drawdown measurements of the water surface in the approach channel. Potentiometers also were installed on the land-wall floating bitts to measure tow movement during the rigid connection tests. For the flexible-connection tests, the rigid connections were replaced by flexible hawsers of 1-inch-diameter wire rope at all four corners of the tow, and calibrated dynamometers were installed in the hawsers and connected to floating bitts in both lock walls. Other instrumentation was identical with that of the rigid connection tests.

(f) Completed.

(g) Good agreement was found between the prototype cable hawser measurements and the model results with maximum longitudinal forces of

about 4 tons and maximum transverse forces of about 1-1/2 tons. Unscheduled overfilling of the lock chamber, resulting from the momentum of the flow in the filling system, forced the upstream miter gates to open near the end of the 4-min-valve tests, causing longitudinal forces of 8 tons. Prototype hawser loads in the rigid-connection tests were much higher than with the cable connections because allowable clearances between the floating mooring bitt rollers and guides permitted the tow to move freely about 2 in., resulting in impact-type loads.

(h) "Prototype Hawser-Force Measurements, Jackson Lock, Tombigbee River, Alabama," Technical Report 2-685, August 1965.

(5250) PROTOTYPE SPILLWAY TESTS, ANALYSIS AND REPORT, FORT RANDALL DAM, MISSOURI RIVER, SOUTH DAKOTA.

(b) District Engineer, U. S. Army Engineer District, Omaha, Corps of Engineers, Omaha, Nebraska.

(d) Experimental; for design.

(e) Fort Randall Dam, in southeastern South Dakota, is one of a system of multiple-purpose reservoirs. The dam consists of a rolled-earth-fill embankment alomost 2 miles long with a maximum height of 160 ft. Four 22-ft-diam conduits discharging into a common stilling basin provide for flood-control releases. Eight 22-ft-diam penstocks supply water for power generation. A 1000-ft-wide, concrete-chute spillway with a design capacity of 620,000 cfs is located in the left abutment. Spillway discharge is controlled by 21 tainter gates, each 29 ft high and 40 ft wide.
To obtain vertical velocity distribution and water-surface depths on the spillway chute for use in checking design resistance coefficient assumptions and computing discharge over the spillway. These data will assist in eliminating a deficiency in the information on full-scale chute spillway flows used in design of such structures.
Two pitot piers were fabricated and installed on the spillway chute. The pitot piers instrumentation consisted of eight total-head tubes to measure vertical velocity distributions. Water-surface measurements along the spillway length were made with wire-weight gages. Visual observations and photographic records of flow conditions were also made.

(g) Water-surface depths measured on the chute spillway appeared to be close to the normal depths at the downstream end of the chute. Vertical velocity distributions on the spillway slab were in good agreement with a logarithmic equation for the supercritical flow conditions of the tests. Flow resistance was relatively high, possibly due to the concrete spillway slab joints or water-surface wave effects in the super-critical flow. Equivalent sand grain roughness values and the slope of the velocity distribution curve agree with results of previous investigations.

(h) Preparation of final report is in progress.

(5251) MODEL STUDY OF NAVIGATION CONDITIONS, ROBERT S. KERR LOCK AND DAM, ARKANSAS RIVER.

(b) District Engineer, U. S. Army Engineer District, Tulsa, Corps of Engineers, Tulsa, Oklahoma.

(d) Experimental; for design.

(e) The Robert S. Kerr Lock and Dam, to be located at about mile 395 on the Arkansas River, will involve construction of a nonnavigable-type dam, a 110- by 600-ft lock, and a powerhouse. The lock will provide a maximum lift of about 48 ft.
To study navigation conditions in the approaches to the lock, determine suitability of the selected site, and develop modifications required to overcome any undesirable conditions. The model reproduces about 3.2 miles of the Arkansas River and the lock and dam structures to a scale of 1:120. It is a fixed-bed model with provision for a movable-bed section below the dam for use in the development of channel configurations in the reach.

(g) Tests have indicated the need for modification of the alignment of the right bank downstream of the powerhouse and for an extension to the lower guard wall to improve navigation in the lower approach with existing and ultimate channel, and a fill along the left side of the approach channel to eliminate objectionable crosscurrents.

(5634) MODEL STUDY OF BREAKWATERS, DANA POINT HARBOR, CALIFORNIA.

(b) District Engineer, U. S. Army Engineer District, Los Angeles, Corps of Engineers, Los Angeles, California.

(d) Experimental; for design.

(e) Dana Point Harbor is a proposed small-craft harbor to be located on the southern Calif. coast in Orange County, about 40 miles southeast of Los Angeles. This harbor is to be constructed at a site which is exposed to ocean waves. The harbor will be protected by rubble-mound breakwaters which are permeable and allow some of the wave energy to pass through the structures into the calm area.
To determine the effectiveness of the proposed breakwater sections in reducing transmitted wave energy, and the stability of the breakwaters to provide a basis for the design of the proposed harbor; and to add to the available basic data on the transmission of wave energy into artificial harbors.
Tests were conducted in a concrete wave flume 119 ft long, 5 ft wide, and 4 ft deep on section models of the proposed structures constructed to linear scales of 1:50 and 1:100. Model waves were generated by a plunger-type wave machine and measured and recorded electrically.
Stability tests, wave-transmission tests, and wave runup and rundown tests were conducted on breakwater sections with crown elevations of +14 and +18 ft mllw. Tests were also conducted on wave absorbers on the face slope of the mole with a view to reducing the wave runup on the mole and wave heights in the fairway between the mole and the breakwater.

(g) Stability tests showed that the proposed breakwater section would be adequate to withstand the attack of the 12-sec, 16-ft design waves. The maximum transmitted wave height measured on the harborside was found to be about 45 percent of the incident wave height. The average value of the wave transmission coefficient (H_T/H_I) is about 15 percent of the incident wave height. The longer the wave period, the more wave energy is transmitted through a rubble-mound breakwater. Appreciable scale effect in wave transmission was found between the results of tests obtained from the 1:50-scale and the 1:100-scale model. It was found that a 25-ft-wide berm at elevation +4 ft mllw when used in combination with the model-developed breakwater at crown elevation of +18 ft mllw would provide a mole revetment and breakwater combination that would satisfy the selected wave-height criterion in the fairway between the mole and the breakwater.

(h) Preparation of final report is in progress.

(5635) INVESTIGATION OF WAVE REFLECTING AND TRANSMITTING CHARACTERISTICS OF RUBBLE-MOUND BREAKWATERS, RUBBLE-WAVE ABSORBERS, SAND BEACHES, WAVE TRAPS, AND RESONATORS.

(b) Office of the Chief of Engineers, Dept. of the Army, Washington, D. C.

(d) Experimental; applied research.

(e) A theoretical study of the phenomena of wave transmission through rubble breakwaters in the light of turbulent flow through porous media has been initiated. Experiments to study the effects of breakwater permeability and wave characteristics on wave transmission through rubble breakwaters are being conducted in a 1- by 1.5- by 85-ft wave flume. Break-

water sections having different crown width, side slopes, and rock characteristics (size, shape, and roughness) are being built and subjected to waves having different heights and periods. Both the incident and transmitted waves are measured and recorded electrically. Similar tests will also be conducted in a 2- by 5.5- by 149-ft wave flume. Laboratory investigations of the wave reflecting-absorbing characteristics of the different types of wave absorbers will be conducted. The scale effects relating to wave absorbers will be investigated.
To establish design criteria (a) for rubble breakwaters with respect to their wave reflecting-transmission characteristics, and (b) for the different types of wave absorbers (natural sand beaches, wave traps, resonators, and rubble mound).
A 1- by 1.5- by 85-ft steel wave flume is used in which waves are generated by a hinged-plate type wave generator and are measured and recorded electrically. A 2- by 5.5- by 149-ft concrete wave flume will also be used.

(g) A theoretical study of the phenomena of wave transmission through rubble breakwaters in the light of turbulent flow through porous media has been initiated. Revisions were made to the 1- by 1.5- by 85-ft steel wave flume in which tests on wave transmission through rubble breakwaters are being conducted.

(h) "Wave Absorbers in Harbors," Bernard Le Mehaute, Waterways Experiment Station Contract Report 2-122, 1965.

(5636) FLUSHING STUDIES OF VICTORIA CHANNEL, TEXAS.

(b) Model study, Waterways Experiment Station, for Galveston District.

(d) Experimental; for design.

(e) The Gulf Intracoastal Waterway, Channel to Victoria, Tex., is located along the gulf coast in south-central Texas. The navigation channel extends northwesterly from the Gulf Intracoastal Waterway in San Antonio Bay about 35 channel miles to a turning basin about 7 miles south of Victoria, Tex. The channel when completed will have a controlling depth of 10 ft below mean sea level over a bottom width of 100 ft and 1-on-3 slopes. The proposed turning basin and flushing system will be located at the end of the navigation channel. The flushing system is to consist of a freshwater intake ditch, flushing canal, gate structure, underground conduit, and stilling basin. It is anticipated that the navigation channel will require two flushings per year to eliminate objectionable surface debris, oil, and foul water. Although an average annual inflow of 14,400 acre-ft can be expected to enter the channel from local runoff, the unpredictable magnitude of storms and the distribution of the inflow throughout the length of the navigation channel may not insure two thorough flushings per year. Flushing will be accomplished with fresh water taken from the Guadalupe River which will be conveyed through the intake ditch, control gates, conduits, and stilling basin and introduced near the head of the navigation channel. Since most of the Guadalupe flow is used for irrigation and other purposes, it is likely that diversion will only be possible during flood peaks lasting two to three days and occurring once or twice per year.
To determine the flow requirements of the flushing system to replace the stagnant water in the navigation channel.
The tests were made in the Waterways Experiment Station salinity flume which is 327 ft long, 0.75 ft wide, and 1.5 ft deep. Duplicate tests were made for two depth scales (1:15 and 1:30) to determine if the data contained any significant scale effects. In both series of tests, the horizontal scale for length along the channel was 1:323, and that for width across the channel was 1:173. Use of different horizontal scales for length and width was necessary to make the existing flume dimensions conform to those of the landlocked portion of the channel. The salinity scale used for the tests was 1:1.

(g) Tests indicate that the rate of flushing of the channel is initially high and decreases with time. While flushing of the surface stratum over the entire length of the channel is fairly rapid, as was flushing of the entire depth over the major portion of the channel length, flushing of the bottom stratum for the downstream few miles of the landlocked reach is relatively slow. It is possible that complete flushing of the entire channel volume may not be necessary, and that complete flushing of the surface stratum would constitute a satisfactorily flushed condition. The design discharge of 1000 cfs requires about 22 hr to flush the surface stratum over the entire length of the channel, at which time only about 62 percent of the entire channel volume has been flushed. Thus, if flushing of the surface stratum only should prove to be acceptable, this can be effected in considerably less time and with less fresh water than would be required to flush the entire channel volume.

(h) Preparation of final report is in progress.

(5637) SECTION MODEL OF SPILLWAY, BELLEVILLE DAM, OHIO RIVER, W. VA.

(b) District Engineer, U. S. Army Engineer District, Huntington, Corps of Engineers, Huntington, West Virginia.

(d) Experimental; for design.

(e) Belleville Dam spillway will consist of a concrete sill surmounted by eight tainter gates, and a conventional horizontal stilling basin with baffle piers and end sill. A 1:36 model, reproducing approximately 700 feet of the approach area, one central gate bay and approximately one-half of the adjacent bays as well as the piers that separate them, a 216-foot-wide section of the stilling basin, and approximately 800 feet of the exit area, was used to determine the optimum shape for the downstream face of the gate sill, develop a satisfactory stilling basin, and verify the stability of the riprap blanket proposed downstream from the stilling basin.

(f) Completed.

(g) Tests revealed that flow conditions were satisfactory for all partial gate openings with the original design gate sill shape. The original design stilling basin resulted in high bottom velocities in the exit channel which were reduced by lowering the elevation of the basin apron. The stability of a stone protection blanket placed on a 1-on-6 slope downstream from the end sill was determined.

(h) "Spillway for Belleville Locks and Dam, Ohio River, Ohio and West Virginia; Hydraulic Model Investigation," Technical Report No. 2-687, August 1965.

(5638) MODEL STUDY OF NAVIGATION CONDITIONS, LOCK AND DAM NO. 9, ARKANSAS RIVER.

(b) District Engineer, U. S. Army Engineer District, Little Rock, Corps of Engineers, Little Rock, Arkansas.

(d) Experimental; for design.

(e) The project involves construction of a gated dam and lock. As proposed, the dam will contain 14 gate bays (60-ft span) with sill at el 253. The lock will have clear dimensions of 110 by 600 ft. The maximum lift will be 19 ft.
To investigate navigation conditions with the proposed structures, to determine the effects of modifications in the composition and arrangement of the structures, and to develop such modifications as might be considered desirable.
The investigation is being conducted on a 1:120-scale model reproducing about 6 miles of the Arkansas River and adjacent overbank area near Morrilton, Ark. The model is of the fixed-bed type with provisions for changes in the channel based on the effects of the

proposed regulating structures.

(g) Design and construction of the model were completed, and tests for the development of satisfactory navigation conditions were undertaken.
Results have indicated the need for improvement in navigation conditions in the upper and lower lock approach.

(5639) MODEL STUDY OF NAVIGATION CONDITIONS, LOCK AND DAM NO. 7, ARKANSAS RIVER.

(b) District Engineer, U. S. Army Engineer District, Little Rock, Corps of Engineers, Little Rock, Arkansas.
(d) Experimental; for design.
(e) A 1:120, fixed-bed, comprehensive model, reproducing about 7 miles of the Arkansas River, adjacent overbank areas, the lock (110 by 600 feet) and dam structures, and other structures that might affect flow conditions, will be used to study navigation conditions in the lock approaches, the design of the upstream guard wall, and location and design of any training works needed to improve navigation conditions and distribution of flow to the spillway.
(g) Design and construction of the model were completed, and tests for the development of channel configurations based on proposed regulating structures were accomplished. Tests for development of satisfactory navigation conditions were undertaken.
Results indicated the need for modification in regulating works upstream of the lock for the improvement of navigation conditions and distribution of flow through the gated spillway.

(5640) POLLUTION MODEL STUDY, CHARLESTON HARBOR, SOUTH CAROLINA.

(b) District Engineer, U. S. Army Engineer District, Charleston, Corps of Engineers, Charleston, South Carolina.
(d) Experimental; for design.
(e) The Charleston Harbor model reproduces about 17 miles of the South Carolina shoreline, 230 square miles of the Atlantic Ocean, and the entire tidal portions of the Cooper, Ashley, and Wando Rivers and their tributaries. The model is of the fixed-bed type and is constructed to scales of 1:100 vertically and 1:2000 horizontally. Provisions are included for reproducing tides and tidal currents, upland freshwater flows, ocean salinities, and salinity intrusion. Conservative-type fluorescent dyes will be introduced to simulate industrial and municipal waste, and the effects of variations in the upland flow on the dispersion and flushing characteristics of the dyes will be determined.
To provide data on dispersion and transport of wastes in the harbor under various conditions of freshwater inflow along with data on tides, currents, and salinities for all inflow conditions studied.
(g) The testing program to provide data on the dispersion and transport of wastes in the harbor was undertaken. Several special series of tests to determine the effects of various plans and suggested changes were undertaken and completed. The special studies involved: (a) extension of the navigation channel in the Cooper River to Pinopolis, (b) construction of a sediment trap in lower Wando River, (c) construction of a spoil disposal area in the shallows adjacent to Daniel Island, and (d) diversion of the powerhouse discharge from the Cooper River into the Wando River.

(5641) MODEL STUDY OF FREMONT DROP STRUCTURE, SANDUSKY RIVER, OHIO.

(b) District Engineer, U. S. Army Engineer District, Buffalo, Corps of Engineers, Buffalo, New York.
(d) Experimental; for design.
(e) The project provides for widening, deepening, and streamlining the main channel of the Sandusky River in the vicinity of Fremont, Ohio. A drop structure will be constructed near the upper end of the project area to dissipate energy created by the difference in elevation of the water surface above and through the improved reach. The structure will include a concrete weir 10 ft high, concrete paved sloping abutments and stilling basin, and riprap protection above and below the paved sections.
Model tests were conducted on a 1:36-scale model reproducing the drop structure and 800 ft of the channel upstream and 900 ft downstream. Tests were also conducted on a 1:40-scale rock-lined channel which reproduced about 2000 ft of the proposed channel.
To develop an economical design of the drop structure which will assure the dissipation of the kinetic energy developed when the water-surface profile drops from existing levels upstream of the improvements to levels within the improved channel. Tests were also conducted to investigate the adequacy of a rock-lined friction channel in lieu of the drop structure.
(g) The length of basin below the weir was increased from 22 to 41 ft and the basin depressed 2 ft in elevation (alternate weir arrangement). No riprap protection was required upstream of the structure and the downstream rock protection could replace all but 20 ft of the concrete below the structure (plan 5 riprap). The alternate weir arrangement with its multiarea openings (total area 675 sq ft) provided satisfactory fish passage facilities through the structure. The channel below the structure could be reduced in width from 450 to 350 ft without materially affecting flow conditions in the exit. A friction channel that will provide a drop in water surface of about 4 ft in a 2000-ft-long reach with minimum size stable slope stone was developed.
(h) Final report is in preparation.

(5642) MODEL STUDY, DESIGN OF SMALL BOAT HARBOR, DANA POINT HARBOR, CALIFORNIA.

(b) District Engineer, U. S. Army Engineer District, Los Angeles, Corps of Engineers, Los Angeles, California.
(d) Experimental; for design.
(e) The inner-harbor berthing area and navigation channels will comprise about 200 acres. The inner-harbor basin will be enclosed by a mole and will be accessible through 200-foot-wide navigation entrances, one at each end of the 3,500-foot-long inner basin. The inner harbor will be protected by two arms of rubble-mound breakwater having a total length of about 7,700 feet. Tests to study the effects of storm-wave action on the proposed harbor design and to determine what, if any, design modifications are necessary to ensure that wave heights during storms do not exceed (1) 1.5 feet in the inner-basin anchorage, (2) 4 feet in the approaches to the entrances of the inner-harbor berthing areas, (3) 5 feet in the fairway channel paralleling the proposed west breakwater, and (4) 2.5 feet in the ramp basin area in the eastern sector of the inner harbor, are being conducted on a 1:100, fixed-bed model. The model reproduces sufficient area of the shoreline and oceanward to ensure that propagation of waves toward the problem area is adequately simulated. Waves are generated by a 60-foot-long, plunger-type wave machine, and are measured and recorded electrically.
(g) Wave-height tests were performed with model conditions simulating (a) basic or existing prototype conditions, (b) the first phase of proposed prototype construction wherein only the proposed rubble-mound breakwater system will be installed, and (c) the overall proposed inner-harbor elements in combination

with the protective rubble-mound breakwater system. Modifications in the alignments and lengths of the rubble-mound breakwaters, and also different crown heights and rock distribution were tested to determine the adequacy of the proposed harbor design. Tests were performed simulating storm waves generated from all critical directions reckoned counterclockwise between west and south-southeast. All tests were performed using a still-water level of +6.0 ft above mllw. Companion two-dimensional flume tests performed to determine the characteristics of the optimum slope and rock composition of the mole-section slope, along the fairway, indicate that a berm section along the mole-section slope will ensure reduction of waves reflected from this structure sufficiently to meet the required wave-height criterion.

(5643) ACOUSTIC FLOWMETER INSTALLATION AND PROTOTYPE TESTS WORKS, SUMMERSVILLE DAM, GAULEY RIVER, WEST VIRGINIA.

(b) District Engineer, U. S. Army Engineer District, Galveston, Corps of Engineers, Huntington, West Virginia.
(d) Experimental; field investigation.
(e) The outlet works consist of an intake structure, 29-foot-diameter operating tunnel, three 11-foot-diameter outlet conduits, and one 3-foot-diameter low-flow outlet pipe. Tests will be made with an acoustic flowmeter to gage operational discharges, and to measure pressure gradients through the three-branch manifold connecting the 29-foot tunnel to the three 11-foot conduits; from these measurements, evaluations of tunnel resistance and intake and manifold losses will be made. The acoustic flowmeter includes a pair of transducers in the tunnel and each conduit and the accompanying circuitry to indicate the discharge from the effects of the flow rates on the acoustic signals. The pressure test facilities consist of six pairs of piezometers along the tunnel and three pairs along each conduit.
(g) The final report is being prepared on evaluation tests made at Oahe Dam in November 1964. The equipment will be installed in Summersville Dam early in 1966.
Equipment for measurements in the 3-ft pipe was added to the flowmeter.

(5644) MODEL STUDY OF NAVIGATION CONDITIONS, LITTLE ROCK REACH, ARKANSAS RIVER.

(b) District Engineer, U. S. Army Engineer District, Little Rock, Corps of Engineers, Little Rock, Arkansas.
(d) Experimental; for design.
(e) A fixed-bed model reproducing about 3 miles of the Arkansas River and adjacent overflow areas to a scale of 1:100, is being used to study navigation conditions through six bridges at Little Rock, Ark., to determine modifications required in the existing bridges, and to develop a plan of regulating structures required to provide satisfactory navigation conditions.
(g) The need for modifications in dimensions of some of the bridge spans with pier protection and training structures has been indicated.

(5645) MODEL STUDY OF OUTLET WORKS, COCHITI DAM, NEW MEXICO.

(b) District Engineer, U. S. Army Engineer District, Albuquerque, Corps of Engineers, Albuquerque, New Mexico.
(d) Experimental; for design.
(e) The dam will contain a concrete, gravity, uncontrolled spillway with a 460-foot-long ogee crest. A 160-foot-long section of the spillway crest will be lowered 10.5 feet to provide a service spillway. The outlet works will consist of a triple box conduit. The necessity for providing a reliable water supply for irrigation throughout the range of conduit releases, and the need for a two-level stilling basin 60 feet wide to provide for flows as large as 15,200 cfs made it desirable to test the energy dissipator, and the irrigation and silt sluices in a model. Tests were conducted in a 1:20 model that reproduced the downstream 150 feet of the triple box conduit, the chute, the primary and secondary stilling basins, the irrigation and the silt sluices, and 670 feet of exit channel.
(f) Completed.
(g) The performance of the energy dissipator was improved by raising the apron of the secondary basin 5 ft, and modifying the position of the baffle piers and end sill in the secondary basin. Capacity of the irrigation diversion sluices was found to be adequate. Realignment of one of the irrigation sluices to eliminate a relatively sharp horizontal bend was proposed in order to reduce wave action in the downstream end of the sluice. Hydraulic performance of the silt sluices was as anticipated, but at low discharges, fine sand was removed from the model only in the immediate vicinity of the sluice intakes.
(h) "Outlet Works, Cochiti Dam, Rio Grande, New Mexico; Hydraulics Model Investigation," TR 2-705, Nov. 1965.

(5646) SECTION MODEL OF SPILLWAY, HANNIBAL DAM, OHIO RIVER.

(b) District Engineer, U. S. Army Engineer District, Pittsburgh, Corps of Engineers, Pittsburgh, Pennsylvania.
(d) Experimental; for design.
(e) The spillway will consist of a concrete sill surmounted by 8 tainter gates and a conventional, horizontal stilling basin with baffle piers and end sill. A 1:36 section model, reproducing approximately 700 feet of the approach area, one central gate bay and the adjacent half-bays of the spillway, a 216-foot-wide section of the stilling basin, and approximately 800 feet of the exit area, will be used to investigate the adequacy of the proposed stilling basin for a full range of tailwater elevations at which the structure will be required to operate.
(g) Tests to determine the optimum elevation and length of the stilling basin and the size and arrangement of its elements were conducted. The spillway rating curves for full and partial gate openings were determined.
The original design stilling basin resulted in high bottom velocities in the exit channel with one gate open approximately halfway and minimum tailwater. These velocities were reduced by lowering the elevation of the basin apron.

(5647) GATE VIBRATION TESTS.

See Project No. 5321, Iowa Institute of Hydraulic Research, page 40.

(5648) MODEL STUDY, BRUNSWICK HARBOR, GEORGIA.

(b) District Engineer, U. S. Army Engineer District, Savannah, Corps of Engineers, Savannah, Georgia.
(d) Experimental; for design.
(e) The investigation is being conducted in a model reproducing the following areas: (a) from vicinity of Jekyll Island and St. Simons Island on the downstream end to the upper limits of Turtle River and Brunswick River on the upstream end; (b) East River in its entirety; (c) Jekyll Creek from Brunswick River to Highway 84 Bridge; and (d) all marsh areas surrounding the rivers, creeks, and tributaries of the system. The model is of the fixed-bed molded of concrete to linear scale ratios, model to prototype, of 1:100 vertically and 1:500 horizontally. Automatic tide generators reproduce tides and tidal currents throughout the harbor. Shoaling studies will be made by injecting finely ground gilsonite into the model to reproduce the patterns of shoaling observed in the prototype, and to determine the effects of

proposed improvement plans on shoaling patterns. Changes in shoaling patterns as effected by each proposed improvement plan will be determined and evaluated.

(g) Design and construction of the model were completed, and adjustment of the model to reproduce prototype tides and currents was undertaken.

(5649) SECTION MODEL OF SPILLWAY, CANNELTON DAM, OHIO RIVER, INDIANA.

(b) District Engineer, U. S. Army Engineer District, Louisville, Corps of Engineers, Louisville, Kentucky.

(d) Experimental; for design.

(e) The spillway will consist of a concrete sill surmounted by 12 tainter gates and a conventional horizontal stilling basin with baffle piers and end sill. A riprap blanket will be provided downstream from the stilling basin to prevent undermining of the structure. A 1:36 section model, reproducing approximately 70 feet of the approach area, one central gate bay and adjacent half bays of the spillway, a 216-foot-wide section of the stilling basin, and approximately 800 feet of the exit area, is being used to determine the flow characteristics of the spillway, the optimum elevation and configurations of the apron, baffle piers, and end sill, and to develop an adequate protective stone blanket downstream from the stilling basin.

(f) Completed.

(g) The conditions at which failure of various protective stone blankets downstream from the stilling basin occurred were determined. The final report, TR 2-710, Spillway for Cannelton Locks and Dam, Ohio River, Kentucky and Indiana; Hydraulic Model Investigation, was published in December.
Tests revealed that flow separated from the downstream face of the original gate sill which utilized submergible gates, and a parabolic shape was added to the weir crest in order to prevent separation and guide flow into the stilling basin. Rating curves were determined for the submergible-gate spillway with both weir crest shapes. Tests to determine effect of gate radius and trunnion location on stilling basin action with the submergible-gate spillway revealed that a 64-ft-radius gate with its trunnion at elevation 388.0 was more effective in preventing undesirable basin actions than was a 50-ft-radius gate with its trunnion at elevation 383.0. Although adequate performance was obtained with the submergible-gate spillway utilizing the parabolic weir crest, tests revealed that satisfactory flow conditions, adequate energy dissipation, and effective passage of debris could be obtained with a nonsubmergible-gate spillway which is considered to be the most practicable design. Several stilling basin designs were tested, but the original basin design was recommended for adoption because of structural advantages. Riprap requirements were investigated, and the conditions at which failure occurred were determined.

(h) "Spillway for Cannelton Locks and Dam, Ohio River, Kentucky and Indiana; Hydraulic Model Investigation," TR 2-710, December 1965.

(5650) MODEL STUDY OF FILLING AND EMPTYING VALVES, CORDELL HULL LOCK, CUMBERLAND RIVER, TENN.

(b) District Engineer, U. S. Army Engineer District, Nashville, Corps of Engineers, Nashville, Tennessee.

(d) Experimental; for design.

(e) The lock will be 84 by 400 feet. A 1:25 model, reproducing only the portion of the lock between filling and emptying valves, is being used to evaluate the overall performance of the multiport system, with particular emphasis on determining the optimum number and position of chamber ports, and to investigate methods of controlling pressures below the filling valves.

(g) Multiport arrangements using 14-in.-diam ports were tested. Tests confirmed that acceptable performance could be expected from the original design multiport arrangement for Cordell Hull Lock. Additional tests resulted in the development of satisfactory multiport arrangements using 8-, 10-, and 12-in.-diam ports. No satisfactory arrangement using 14-in.-diam ports was developed. For a lift of 62 ft, these arrangements resulted in a filling time of about 8.9 min with a maximum hawser stress of about 3.5 tons. Tests indicated that pressure conditions in the critical area just downstream from the filling valve were improved by flaring the culvert roof at the downstream end of the valve well. The effect of air venting on culvert pressures was also investigated.

(h) Report in preparation.

(5651) MODEL STUDY OF JAMES RIVER, VIRGINIA.

(b) District Engineer, U. S. Army Engineer District, Norfolk, Corps of Engineers, Norfolk, Virginia, and the State of Virginia.

(d) Experimental; for design.

(e) The James River, which discharges into Chesapeake Bay, presently has a controlling channel depth from Newport News to Richmond of 25 feet mean low water. An improvement plan has been proposed to increase the channel depth to 35 feet mean low water, and widen the channel at several locations. Because the James River estuary and tributaries provide ideal locations for oyster beds, an important industry in the area, a model study will be made to determine the effects of the channel improvements on hydraulic and salinity conditions in an adjacent to the oyster beds. The fixed-bed model will reproduce 300 square miles of the Atlantic Ocean, the James River estuary, and all its principal tributaries from Norfolk to Richmond, Va., to scales of 1:1,000 horizontally and 1:100 vertically. Tides and tidal currents will be reproduced by a tide generator located in the ocean portion of the model. The ocean salinity will be reproduced so that the effects of salinity differences on the vertical distribution of current velocities, as well as salinity concentrations throughout the model, will accurately simulate those of the prototype.

(g) Design and construction of the model were completed, and the hydraulic and salinity verifications were initiated. Verification of the model was about 50 percent complete as of December 31, 1965.

(5652) MODEL STUDY OF NAVIGATION CONDITIONS, WEBBERS FALLS LOCK AND DAM, ARKANSAS RIVER.

(b) District Engineer, U. S. Army Engineer District, Tulsa, Corps of Engineers, Tulsa, Oklahoma.

(d) Experimental; for design.

(e) The Webbers Falls Lock and Dam, to be located about mile 432.2 on the Arkansas River, will involve the construction of a nonnavigable-type dam, a 110- by 600-ft lock, and a powerhouse. The lock will provide a maximum lift of about 30 ft.
To study navigation conditions in the approaches to the lock, determine the adequacy of the design, and develop modifications required to overcome any undesirable conditions.
The model reproduces about 3.1 miles of the Arkansas River and the lock and dam structures to a scale of 1:120. It is of the fixed-bed type with provisions for changes which can be anticipated at this time.

(g) Construction of the model was completed, and tests to develop satisfactory navigation conditions were undertaken.
Results indicated the need for modification in the design of the upper lock approach

channel and that by use of a training dike upstream the elevation of the nonoverflow section could be reduced. Tests have also indicated that the length of the upper guard wall and dredging in the approach channel could be reduced.

(5653) LAKE ERIE-LAKE ONTARIO WATERWAY MODEL STUDIES.

(b) District Engineer, U. S. Army Engineer District, Buffalo, Corps of Engineers, Buffalo, New York.
(d) Experimental; for design.
(e) The project will provide a second navigation passage from Lake Erie to Lake Ontario to supplement the existing Welland Canal. The plan includes a control structure at the head of the Niagara River, a new lock to replace the Black Rock Lock at Buffalo, and improvements to the existing navigation channel around Grand Island to the entrance of the proposed overland canal downstream of Tonawanda Island. The canal (with locks) will connect the Niagara River and Lake Ontario.
An existing Niagara River model is being used to investigate control structure and lock arrangements and navigation channel features including compensating excavations or structures required to maintain existing stage-discharge relations. Navigation conditions at the entrance to the overland canal are being studied in a second model.
The initial phase of the study utilized an existing distorted-scale model which reproduces the Niagara River from approximately 11,500 ft above the Peace Bridge at Buffalo to Rainbow Bridge below the falls. The upper limit extends into Lake Erie. The model was constructed to scale ratios of 1:360 horizontally and 1:60 vertically. It is of the fixed-bed type with all channel and overbank areas molded in concrete. An undistorted-scale model of a reach of the river at the overland canal entrance was constructed for studying navigation conditions in this area. The model is of the fixed-bed type, constructed to a scale of 1:120.
(g) Four lock plans were investigated in the distorted model and a fifth possible lock plan location is being considered. Each plan was tested with an improved navigation channel. Construction was completed and testing was initiated on the undistorted model of the overland canal entrance and improved navigation channel. A radio-controlled model ship is being used to study navigation conditions in this model.
Of the four lock plans tested in the distorted model, lock plan 1 appeared to be the most feasible. Lock plan 1 is the only one of the plans tested which can be used without a control structure at the mouth of the river. This plan also requires less excavation. A fifth lock plan is being considered which positions the lock farther downstream than lock plan 1. Current patterns in the improved channel near the canal entrance, as shown in the undistorted model, indicate the need for widening of the improved channel between Tonawanda Island and the canal entrance. A widened channel would not only tend to reduce the severity of currents across the channel, but also could be designed to provide an anchorage area for use in times of severe weather.

(6011) MODEL STUDY OF HARBOR DESIGN, SANTA BARBARA, CALIFORNIA.

(b) District Engineer, U. S. Army Engineer District, Los Angeles, Corps of Engineers, Los Angeles, Calif.
(d) Experimental; for design.
(e) The enlarged harbor, to be enclosed by the protective breakwater system, will have an area of about 188 acres. Of this area, three moles and their perimeter wave-absorber slopes will occupy about 48 acres, leaving about 140 acres within the west, center, and east basins and the access channels leading thereto. New breakwater required under the project plan will aggregate about 5700 lin ft, 1600 ft of which would be a detached structure about 1600 ft long protecting the harbor entrance. To study the effects of storm wave action on the proposed harbor design and to determine in advance of prototype construction what, if any, design modifications are necessary to ensure that (a) wave heights in the berthing areas do not exceed specified criteria during storms, and (b) these criteria are met while using the minimum amount of protective breakwater positioned to provide minimum requirements for navigation to and from the harbor by pleasure craft and also commercial fishing boats.
The 1:100-scale model is of the fixed-bed type and is molded of concrete except for the breakwaters and absorbers flanking the inner-harbor moles which are constructed of rubble, sized to simulate that required for prototype construction. The model reproduces sufficient area along the shoreline east and west of the harbor site and oceanward to ensure that propagation of waves toward the problem area is adequately simulated. The model has an area of about 10,700 sq ft, equivalent to about 3.84 square miles in nature. Waves are generated by a 60-ft-long, plunger-type wave machine. Electrical printed-circuit-type wave-measuring rods are used in connection with automatic recording equipment to obtain necessary wave-height data.
(g) The model was designed and construction initiated.

(6014) MODEL STUDY OF BREAKWATER STABILITY, SANTA BARBARA HARBOR, CALIFORNIA.

(b) District Engineer, U. S. Army Engineer District, Los Angeles, Corps of Engineers, Los Angeles, Calif.
(d) Experimental; for design.
(e) Additional protection by construction of rubble-mound breakwaters is proposed. These structures are permeable and thus will allow some wave energy to pass through the structure into the protected area.
To determine the effectiveness of the proposed breakwater sections in reducing transmitted wave energy and to develop a breakwater section at a 1:100 scale that will transmit the same amount of energy as transmitted at a 1:33 scale.
Wave transmission tests were conducted in a concrete wave flume 119 ft long, 5 ft wide, and 4 ft deep on section models of the proposed structures constructed to linear scales of 1:33 and 1:100. Model waves were generated by a plunger-type wave machine and measured and recorded electrically.
(g) Wave transmission tests were conducted on a breakwater design proposed by the District Engineer. Tests were conducted using 8-, 12-, and 16-sec waves and wave heights of 6, 10, 14, and 18 ft. These tests were conducted using model scales of 1:33 and 1:100.
Wave transmission tests indicated that changing the scale of model test sections from 1:33 to 1:100 reduced the heights of transmitted waves about 25 percent. It was found that for waves less than about 14 ft in height, wave transmission characteristics for 1:33- and 1:100-scale breakwaters would be similar if the armor stone size for the 1:100-scale test section was increased about 100 percent. Also, the crown elevation of the core stone in the 1:100-scale model was lowered about 6 ft. For waves greater than 14 ft in height, wave transmission in the 1:100-scale model breakwater section was less than obtained in the 1:33-scale model.

(6015) MODEL STUDY OF HARBOR DESIGN, NOYO HARBOR, CALIFORNIA.

(b) District Engineer, U. S. Army Engineer District, San Francisco, Corps of Engineers, San Francisco, Calif.
(d) Experimental; for design.
(e) The plan of harbor improvement will entail

construction of two arms of rubble-mound-type breakwater. One arm would stem from shore on the south side of Noyo Cove and extend 1100 ft or more in a northwesterly direction while the companion arm would stem from the north side of the cove. A navigation entrance into the harbor not less than 400 ft in width, measured at -35 ft mllw, would be required. Inside the harbor local interests would construct a lumber-loading pier or wharf about 1050 ft long.

To study the effects of storm wave action and characteristics of the Noyo area on the proposed harbor design and determine in advance of any prototype construction what, if any, design modifications are necessary to ensure that (a) wave heights during storms do not exceed the selected criterion of 2 ft along the outer 600 ft of the proposed inner-harbor pier, and (b) the minimum system of breakwater necessary to satisfy finalized criteria for the harbor.

The 1:100-scale model is of the fixed-bed type and is molded of concrete except for the breakwaters which are constructed of rubble, sized to simulate that required for prototype construction. The model reproduces sufficient area along the shoreline north, south, and oceanward of the harbor site to ensure that propagation of waves toward the problem area is adequately simulated. Special emphasis was placed on reproducing all wave-reflecting and wave-absorbing characteristics of the prototype in all plan elements. A weir to permit simulation of Noyo River floodflow was also an element of the model. The model has an area of 5500 sq ft, equivalent to about 2 square miles in the prototype. Waves are generated in the model by a plunger-type wave machine, and electrical, printed-circuit-type wave rods in connection with automatic recording equipment are used to obtain necessary wave-height data.

(g) The model was designed and constructed, and wave-height tests were performed with model conditions simulating (a) basic or existing prototype conditions, and (b) the effects of storm wave action attacking the harbor with the "project-document" plan and several alternate variations thereof installed in the model. In these tests the characteristics of the waves were varied with respect to period, height, and direction of attack. Waves used in the tests of the proposed improvement plans were generated alternately from the west, west-northwest, and northwest deepwater directions using waves ranging in period from 10 to 17 sec and in height from 16 to 26 ft adjacent to the harbor approaches. The primary plans tested used the project-document plan consisting of a rubble breakwater 1100 ft in length stemming from the south side of Noyo Cove in combination with a 400-ft-long companion structure stemming from the north side of the cove to form the required navigation entrance. Modifications of the project-document plan were tested using alternate lengths for the south breakwater. The alternate lengths for the south breakwater used in combination with the cited north breakwater were 1300, 1500, 1700, 1900, and 2100 ft. Other variations involving realignment of the north breakwater in combination with 1500-, 1700-, and 1900-ft lengths of south breakwater were also tested. All tests were performed using a still-water level of +6.9 ft mllw.

Results obtained to date show that no plan tested met the selected 2-ft wave-height criterion specified for acceptability. However, the plan characterized by a 1900-ft-long south breakwater, and companion 400-ft-long north breakwater would allow waves to average from 2 to 3 ft no more than 30 hours per year as a result of severe storm wave action. The project document plan would permit the selected criterion to be exceeded about 215 hours per year and would allow waves as high as 8.5 to 9.0 ft in height to occur for about 4 hours per year. The SFD is conducting a reanalysis of project-construction costs on the basis of a revised criterion for plan acceptability. Further testing must await decisions specifying the modified criterion.

(6016) MODEL STUDY OF BREAKWATER STABILITY, NOYO HARBOR, CALIFORNIA.

(b) District Engineer, U. S. Army Engineer District, San Francisco, Corps of Engineers, San Francisco, Calif.

(d) Experimental; for design.

(e) The harbor will be protected by rubble-mound breakwaters which are permeable and allow small amounts of energy to pass through the structure into the protected area.

To develop stable rubble-mound breakwaters using quarrystone and molded concrete armor units. Also the effectiveness of crown elevation of a concrete cap will be investigated with respect to overtopping and transmission of wave energy through the breakwater.

Tests will be conducted in a concrete wave flume 119 ft long, 5 ft wide, and 4 ft deep on section models of the proposed structures to linear scales of 1:61.4 and 1:50. Model waves are generated by a plunger-type wave machine and measured and recorded electrically.

(g) Stability tests were conducted on a section of the south breakwater constructed of two layers of 36-ton tetrapods placed on seaside slopes of 1:3, 1:4, 1:5, and 1:6. Wave-transmission tests were conducted on breakwater sections with crown elevations of +25 and +30 ft mllw. All breakwater sections tested were capped with a concrete cap 2 ft thick and the stone beneath the cap was grouted from the base of the concrete cap down to the base elevation of the tetrapod armor layer.

Stability tests showed that a breakwater with a crown elevation of +20 ft mllw (elevation of concrete concrete cap +20 ft mllw and elevation of armor layer crown +30 ft mllw) constructed of two layers of random-placed, 36-ton tetrapods on a slope of 1:4 from crown to -5 ft mllw and 1:1-1/2 from -5 ft mllw to bottom would be stable for the selected prototype design wave 29 ft in height. Wave-transmission tests showed that for 14-sec waves greater than 29 ft in height, the heights of the transmitted waves were reduced about 67 percent by raising the crown elevation of the armor layer from +25 to +30 ft mllw.

(6017) MODEL STUDY OF EAU GALLE OUTLET STRUCTURE, SPRING VALLEY, WISCONSIN.

(b) District Engineer, U. S. Army Engineer District, St. Paul, Corps of Engineers, St. Paul, Minn.

(d) Experimental; for design.

(e) The project provides for a flood-control reservoir immediately upstream from Spring Valley, Wis.; enlargement of the river channel through the village; and levees, drop structures, and improved channels for the two creeks, Mines and Burghardt, which flow through the village.

A 1:20-scale plastic model reproduced the morning glory intake, the elbow below the intake, the horseshoe conduit, a stilling basin, and about 400 ft of the exit channel. The morning glory intake was housed in a headbay which reproduced appropriate entrance conditions.

(g) Tests demonstrated that the original design structure was unsatisfactory, as negative pressures in the range of one atmosphere (-34 ft of water) were recorded in the intake structure. Satisfactory pressure conditions were obtained by modifying to the morning glory intake and replacing the 90-degree elbow below the intake with a streamlined conduit intake shape.

(h) Preparation of final report is in progress.

(6018) MODEL STUDY OF MONTEREY HARBOR, CALIFORNIA.

(b) District Engineer, U. S. Army Engineer District, San Francisco, Corps of Engineers, San Francisco, Calif.
(d) Experimental; for design.
(e) The approved project entails extension of the existing rubble-mound-type breakwater about 1600 ft in an easterly direction to the west side of a proposed 400-ft-wide navigation entrance which would be formed by construction of a companion dogleg-aligned east breakwater about 2150 ft long that would extend in a southeasterly direction to shore. This expanded enclosure will provide increased protection for the fishing fleet operating from this basin and will permit development of greatly expanded recreational facilities associated with boating and other water sports.
To study the effects of storm wave action on the harbor associated both with the surge-type waves having periods ranging from about 25 to 300 sec and short-period waves considered to range from about 5 to 20 sec. Determination of the effect of this range of wave conditions on the approved harbor expansion is required in advance of actual construction to ensure that (a) selection of an optimum navigation entrance to the harbor is possible both with respect to width and position, (b) the minimum amount of breakwater is used in satisfying wave-protection requirements for proposed inner-harbor development, and (c) any resonance characteristics an otherwise satisfactory harbor boundary may have are fully investigated to permit optimum positioning of inner-harbor anchorage areas.
The 1:120-scale model is of the fixed-bed type and is molded of concrete except for the breakwaters which are constructed of rubble, sized to simulate that required for prototype construction. The model reproduces sufficient area along the shoreline northerly, easterly, and oceanward to ensure that propagation of waves shoreward is adequately simulated. The model has an area of 7800 sq ft, equivalent to about 4 square miles in nature. Waves are generated by two sections of vertical-bulkhead plunger-type wave machine which can be aligned so as to reproduce the average curvature of a wave front bent by refraction as it travels through shallow water. The generators, by use of couplings, operate from a single motor power source. Electrical printed-circuit-type wave measuring rods are used in connection with automatic recording equipment to obtain necessary wave-height data.
(g) Under a contract, Dr. Basil W. Wilson, Science Engineering Associates, San Marino, Calif., performed a study of the wave and surge problems charaterizing Monterey Bay. In his report, Contract Report 2-136, Feasibility Study for a Surge-Action Model of Monterey Harbor, Calif., October 1965, sufficient information was made available to permit WES to adequately design the required model. Design and construction of the model are in progress.

(6019) MODEL STUDY OF FORT SMITH REACH, ARKANSAS RIVER.

(b) District Engineer, U. S. Army Engineer District, Little Rock, Corps of Engineers, Little Rock, Ark.
(d) Experimental; for design.
(e) The project involves the improvement of the Arkansas River for navigation from the vicinity of Tulsa, Okla., to its junctions with the Mississippi River. The 9-ft channel will be provided by a system of locks and dams and channel regulating and stabilization works. The channel will have a minimum width of 250 ft in the Arkansas River reach and 150 ft in Verdigris River reach with lock chambers 110 by 600 ft.
To study navigation conditions at the mouth of Poteau River and the two bridges at Fort Smith, Ark., to determine modification required in the existing bridge; and to develop a plan of regulating structures required to provide satisfactory navigation conditions. The investigation is being conducted on a 1:120-scale, semifixed-bed model, reproducing about 3.3 miles of the Arkansas River and adjacent overflow areas, the mouth and about 1.4 miles of the Poteau River, one railroad and one highway bridge, and other structures that might affect flow conditions.
(g) Design and construction of the model were accomplished.

(6020) MODEL STUDY OF NAVIGATION CONDITIONS, LOCK AND DAM NO. 14, VERDIGRIS RIVER, OKLA.

(b) District Engineer, U. S. Army Engineer District, Tulsa, Corps of Engineers, Tulsa, Oklahoma.
(d) Experimental; for design.
(e) The project involves the improvement of the Arkansas River for navigation from the vicinity of Tulsa, Okla., to its junction with the Mississippi River. The 9-ft channel will be provided by a system of locks and dams and channel regulating and stabilization works. The channel will have a minimum width of 250 ft in the Arkansas River reach and 150 ft in the Verdigris River reach with lock chambers 110 by 600 ft.
To investigate navigation conditions with the proposed structures, to determine the location and width of a navigation channel, and to develop a plan of regulating structures required to provide satisfactory navigation conditions.
The investigation will be conducted on a 1:120-scale semifixed-bed model, reproducing about 4.25 miles of the Arkansas River, Bruce Island, Cherokee Chute, and adjacent overbank area near Old Fort Coffee on the right bank and Wilsons Rock on the left bank. The model will also include the lock and dam structure and existing channel regulating structures.
(g) Design and construction of the model were accomplished, and adjustment of the model was undertaken.

(6021) MODEL STUDY OF NAVIGATION CONDITIONS, LOCK AND DAM NO. 17, VERDIGRIS RIVER, OKLAHOMA.

(b) District Engineer, U. S. Army Engineer District, Tulsa, Corps of Engineers, Tulsa, Okla.
(d) Experimental; for design.
(e) The project involves the improvement of the Arkansas River for navigation from the vicinity of Tulsa, Okla., to its junction with the Mississippi River. The 9-ft channel will be provided by a system of locks and dams and channel regulating and stabilization works. The channel will have a minimum width of 250 ft in the Arkansas River reach and 150 ft in Verdigris River reach with lock chambers 110 by 600 ft.
To determine the adequacy of the proposed channel dredging and realignment, and to develop modifications which might be required to overcome undesirable navigation conditions. The investigation will be conducted on two 1:120-scale, fixed-bed comprehensive models. One model will reproduce about 1.7 miles of the Verdigris River and adjacent overbank area in the vicinity and upstream of Lock and Dam No. 17. The second model will reproduce about 2.1 miles of the Verdigris River and adjacent overbank area downstream of Lock and Dam No. 17.

(6022) MODEL STUDY OF NAVIGATION CONDITIONS, LOCK AND DAM NO. 8, ARKANSAS RIVER.

(b) District Engineer, U. S. Army Engineer District, Little Rock, Corps of Engineers, Little Rock, Arkansas.
(d) Experimental; for design.
(e) The project involves the improvement of the Arkansas River for navigation from the vicinity

of Tulsa, Okla., to its junction with the Mississippi River. The 9-ft channel will be provided by a system of locks and dams and channel regulating and stabilization works. The channel in the Arkansas River reach will have a minimum width of 250 ft and in the Verdigris River reach, 150 ft. Lock chambers will be 110 by 600 ft.
To investigate various plans of regulating structures and to develop modifications as required for the development of a channel of adequate dimensions and satisfactory navigation conditions in the approaches to the lock. The investigation is to be conducted on a movable-bed model reproducing about 10 miles of the Arkansas River and adjacent overbank areas to a scale of 1:120 horizontally and 1:80 vertically.

(6023) MODEL STUDY OF LOCK CULVERT DISCHARGE BASINS.

(b) District Engineer, U. S. Army Engineer District, Huntington, Corps of Engineers, Huntington, W. Va.
(d) Experimental; for design.
(e) A review of project plans for several of the Ohio River locks indicated that predominant lock culvert outlet positions used at these projects had the outlet either normal to the lock wall or turned slightly downstream at an angle of approximately 65 degrees to the lock wall. At several of the completed Ohio River locks with lock culvert outlet basins located outside the riverward lock wall, difficulty has been experienced in fully emptying the lock when river discharge conditions were near maximum locking stage. At these projects, the lock emptying operation resulted in a residual head differential across the lower miter gates. Detailed investigation of the various projects was not considered feasible. Consequently, a generalized investigation was recommended to provide information on possible corrective measures.
To provide information on possible outlet basin modifications which could be used to alleviate the operating difficulty at completed projects or obviate it at projects proposed or under construction.
A 1:25-scale model of the lock culvert outlet basin was constructed in an existing flume. The model reproduced a 125-ft-wide section of rectangular river channel. A 25-ft-wide by 75-ft-long tank located outside the channel simulated a portion of the lock chamber. The single culvert outlet basin located in the channel section was connected to the tank by a 16- by 18-ft culvert. The shape and size of the outlet basin were based on an outlet design used at the Cannelton Locks.
(g) Tests were made to determine the effect of the following features on head differential between the simulated lock chamber and the adjacent river: (a) position of the basin with respect to direction of flow, (b) height of basin wall above river floor, (c) vertical extensions on basin walls, and (d) velocity of flow past basin.
The predominant positions of outlets at these projects were normal to the lock wall or turned slightly downstream at 65 degrees to the wall. Results of tests with the outlet at these positions indicate that construction of the basic outlet walls above the river floor or addition of vertical wall extensions will result in a lowering of the lock chamber water-surface elevation with respect to the adjacent river water-surface elevation. Test data also show that no advantage results from turning the basin downstream (parallel to the lock wall).

(6024) MODEL STUDY OF NAVIGATION CONDITIONS, JONES BLUFF LOCK AND DAM, ALABAMA RIVER.

(b) District Engineer, U. S. Army Engineer District, Mobile, Corps of Engineers, Mobile, Alabama.
(d) Experimental; for design.
(e) The project involves the construction of a dam, a 68,000-kw power plant, and a 45-ft-lift, 84- by 600-ft lock 245.4 miles above the mouth of the Alabama River. The project will provide 9-ft navigable depths for 80 miles upstream.
To investigate navigation conditions with the proposed plan and to develop modifications which might be required to overcome any undesirable navigation conditions.
The investigation will be conducted on a 1:100-scale, fixed-bed comprehensive model reproducing the proposed structures and about 3.6 miles of the Alabama River and adjacent overbank area.
(g) Design of the model was undertaken.

(6025) MODEL STUDIES OF TEXAS COAST HURRICANE SURGE.

(b) District Engineer, U. S. Army Engineer District, Galveston, Corps of Engineers, Galveston, Texas.
(d) Experimental; for design.
(e) The Galveston Bay hurricane surge model reproduces the coast from Freeport on the south to High Island on Bolivar Peninsula on the east. The model includes an average width of the Gulf of Mexico of about 25 miles, measured normal to the Gulf; all of the barrier islands in the bay interior, including its many connecting arms, lakes, and lagoons; and the coastal area within this sector up to a maximum elevation of 20 ft msl. The model is of the fixed-bed type molded of concrete to linear scale ratios, model to prototype, of 1:100 vertically and 1:3000 horizontally. Automatic tide generators reproduce normal tides and tidal currents throughout the model. The hurricane surges will be reproduced by a horizontal-displacement type surge generator.
(g) Design and construction of the model were completed, and adjustment of the model to reproduce prototype tides and current velocities was undertaken. Analysis of prototype tidal and hurricane surge data was undertaken.

(6026) MODEL STUDY OF UMPQUA RIVER ESTUARY, OREGON.

(b) District Engineer, U. S. Army Engineer District, Portland, Corps of Engineers, Portland, Texas.
(d) Experimental; for design.
(e) The existing authorized project in the Umpqua River entrance provides for a channel 26 ft deep at mllw with no specified width for about 5000 ft across the entrance bar, and thence 22 ft deep and 200 ft wide to Gardiner and Reedsport. The north and south jetties at the river mouth are about 7800 and 3800 ft long, respectively. A training jetty inside the south jetty is 5500 ft long.
To obtain the optimum layout of a jetty system or other structure to reduce entrance maintenance dredging to a minimum, and (b) with the optimum for a guide to adapt the existing jetty system to approach the optimum to the limit allowed by economic considerations.
The model will reproduce the lower 14 miles of the Umpqua River and pertinent offshore areas to linear scales of 1:300 horizontally and 1:100 vertically. An additional 14 miles of the Umpqua River and 20 miles of the Smith River will be reproduced schematically in order to include the upstream tidal reaches. All portions of the model will initially be of the fixed-bed type, with provisions for converting the entrance area to a movable-bed type if movable-bed studies are required. Tides and tidal currents, freshwater inflow, density currents, waves, and other phenomena significant to the movement and deposition of sediments will be reproduced and studied.
(g) Design of the model was completed, and construction was initiated.

(6027) MODEL STUDY OF GASTINEAU CHANNEL, ALASKA.

(b) District Engineer, U. S. Army Engineer District, Alaska, Corps of Engineers.
(d) Experimental; for design.
(e) The existing authorized project in Gastineau Channel provides for a channel 75 ft wide with a depth of 0.0 mllw from Fritz Cove to naturally deep water near Juneau, Alaska. The navigation channel is flanked by continuous tidal flats having elevations as much as 15 ft above the channel bottom for a distance of about 3 miles.
To reduce shoaling in order to maintain a suitable navigation channel, various dike layouts which will isolate the channel cut from the surrounding area will be investigated.
The model reproduces the westernmost 8 miles of Gastineau Channel and Fritz Cove to linear scales of 1:500 horizontally and 1:100 vertically. Tides, tidal currents, and freshwater inflow significant to the movement and deposition of sediments are reproduced and studied. All portions of the model are of the fixed-bed type.
(g) Design and construction of the model were completed, and adjustment of the model was initiated.

(6028) MODEL STUDY OF FIRE ISLAND INLET, LONG ISLAND, NEW YORK.

(b) District Engineer, U. S. Army Engineer District, New York, Corps of Engineers, New York, N. Y.
(d) Experimental; for design.
(e) Fire Island Inlet, located on the south shore of Long Island, N. Y., connects the Atlantic Ocean with Great South Bay. The inlet is about 3 miles long and approximately 1/2 mile wide, extending generally east and west between Oak Beach on the north and the western end of Fire Island on the south. Great South Bay, the inland waterway to which Fire Island Inlet is the main entrance, is a tidal body 25 miles long and 2 to 5 miles wide with a general depth of about 6 to 25 ft at mlw. Attempts have been made to stabilize an entrance channel through Fire Island Inlet with little success.
To provide quantitative data on the direction and velocity of tidal currents under existing conditions and with various proposed training structures installed, and by qualitative movable-bed tests to determine probable areas of erosion and deposition.
A movable-bed model, with scale ratios of 1:500 horizontally and 1:100 vertically, reproduces all of Fire Island Inlet and a portion of the Atlantic Ocean. Tides, tidal currents, and wave action in the Atlantic Ocean are reproduced.

(6029) MODEL STUDIES OF EFFECTS OF PNEUMATIC BARRIERS ON SALINITY INTRUSION.

(b) District Engineer, U. S. Army Engineer District, Philadelphia, Corps of Engineers, Philadelphia, Pa.
(d) Experimental; for design.
(e) Prolonged drought conditions, plus diversion of water from the Delaware Basin to supply New York City, resulted in reduced upland flows into the Delaware estuary. Upland flow is the controlling factor in preventing the upstream advance of the salinity front in the estuary to the extent that the Philadelphia water supply is contaminated. Other means for retarding the advance of salt water up the Delaware are being sought.
To determine if the additional agitation provided by pneumatic barriers would displace the salinity front in a downstream direction for steady-state conditions, or retard the rate of advance of the salinity front periods of decreasing upland flow.
(g) Five tests were conducted in the Delaware model to determine the effects of pneumatic barriers on salinities. The barriers extended completely across the estuary at several locations, and barrier combinations were tested both for steady-state and transient conditions. One test was performed in the existing New York Harbor model, and this test involved four pneumatic barriers located in the lower Hudson River.
The results of tests in the Delaware model indicated that pneumatic barriers would have no significant effects on salinity intrusion for either steady-state or transient conditions. This is attributed to the fact that salt and fresh water in the Delaware are well mixed vertically by existing tidal forces, and additional mixing by supplemental means has little effect on the phenomena.
The results of the one test in the New York Harbor model indicate that the pneumatic barriers would be very effective in reducing the extent of salinity intrusion for steady-state conditions. Additional testing to determine such things as the number of barriers required and the best barrier locations is indicated.
(h) Preparation of final report (letter report) is in progress.

(6030) GENERAL MODEL STUDY OF WEST POINT DAM, CHATTAHOOCHEE RIVER, GEORGIA.

(b) District Engineer, U. S. Army Engineer District, Savannah, Corps of Engineers, Savannah, Ga.
(d) Experimental; for design.
(e) The project is a part of the general plan for the development of the Apalachicola, Chattahoochee, and Flint Rivers. The proposed structure is on the Chattahoochee River at mile 201.4 above the mouth and 3.2 miles north of West Point, Ga. It is 147 river miles below Buford Dam and 126 miles above Walter F. George Lock and Dam. The project calls for a gravity-type concrete spillway with crest gates across the main river channel, a penstock intake section and powerhouse, and a concrete nonoverflow section along nonoverflow section along the right riverbank. Earth enbankments extend to high ground on each side of the structure. The structure will provide hydroelectric power, flood control, and more dependable streamflow for navigation and recreational uses.
To verify the performance of the structure with emphasis on approach conditions to the spillway and the development of a satisfactory energy dissipator below the spillway.
The model tests are being conducted on a 1:60-scale general model reproducing about 1700 ft of the approach, the spillway, powerhouse, and 1500 ft of the exit area. Sufficient overbank areas on each side of the structure are provided to reproduce expected flow conditions. Initial study of the energy dissipator was conducted on a 1:60-scale section model of the spillway and stilling basin which was installed in a 1-ft-wide glass-sided flume. This permitted observation of subsurface flow conditions in the basin and facilitated modifications of the basin.
(g) Design and construction of the general model were completed and testing was initiated. The original design bucket-type energy dissipator was unsatisfactory. Tests indicate that an apron-type basin (75 ft long) with a single row of 6-ft-high baffle piers and a 4-ft-high sloped end sill will provide excellent energy dissipation.

(6031) MODEL STUDY OF DROP STRUCTURE, WALNUT CREEK, CALIFORNIA.

(b) District Engineer, U. S. Army Engineer District, Sacramento, Corps of Engineers, Sacramento, Calif.
(d) Experimental; for design.
(e) The Walnut Creek project, located 15 miles east of San Francisco Bay, will provide for enlargement and rectification of the existing channels of Walnut, Lower San Ramon, and Los Trampas Creeks. The project has a drainage area of 145 square miles and flows northerly to empty into Suisun Bay. Grade control

structures will be used to reduce velocities and dissipate excessive energy from floodflows.
To determine the optimum dimensions for the stilling basin at drop structure 2 that will result in maximum energy dissipation and minimum surface waves downstream in the rock-lined channel, and to determine the stability of the riprap in this channel.
A 1:20-scale model was used to reproduce sections of a trapezoidal earth channel, a 50-ft-wide concrete-lined channel, an inlet transition, and drop structure 2.

(g) Tests to determine the optimum dimensions of the stilling basin and the stability of riprap downstream from the basin were completed. The stilling basin of original design resulted in excessive velocities and wave action in the channels downstream from the drop structure. Several modifications to drop structure 2 were tested. A satisfactory design was developed by flaring the basin walls 1 on 10, adding a trajectory curve at the drop, replacing an 8-ft-high vertical end sill with 10-ft-high baffle blocks, adding quadrant-type wing walls below the basin, and sloping the channel invert up 1 on 6 from the basin floor to the trapezoidal channel invert. Tests of the riprap protection plan in the earth channel indicated the stone to be stable for the design discharge.

(h) Preparation of final report is in progress.

(6032) PROTOTYPE TESTS OF OLD RIVER CONTROL STRUCTURE, LA.

(b) District Engineer, U. S. Army Engineer District, New Orleans, Corps of Engineers, New Orleans, La.

(d) Experimental; for design.

(e) The project, located on the Mississippi River approximately 50 miles downstream from Vidalia, La., consists of an 11-bay, 484-ft-long gated spillway. Flood control is obtained by diverting through the structure approximately one-fourth of the flow in the Mississippi River.
To measure vibration of the structure during periods of high discharge and determine the magnitude of the resulting displacements. Utilizing these data, stresses caused by the dynamic response of the structure will then be computed.
Accelerometers to measure vibration in the principal directions were located on the piers, gate guides, and crane rail of bays 6 and 10 as well as the left downstream wing wall and the bridge walkway. Data were recorded on both magnetic tape and oscillograms.

(g) Two test series were conducted at Mississippi River project stages of 40 and 47 ft. The analysis of the oscillograms and a report describing a frequency spectrum analysis of the data from one of the tests have been furnished the New Orleans District. Plans are being made for another test in 1966 at a higher river stage.
Due to the very low level of structure acceleration, measurements at more severe flow conditions are needed before a definite conclusion can be made concerning the magnitude of the vibration.

(6033) GENERAL MODEL STUDY OF KAYSINGER BLUFF DAM, OSAGE RIVER, MO.

(b) District Engineer, U. S. Army Engineer District, Kansas City, Corps of Engineers, Kansas City, Kansas.

(d) Experimental; for design.

(e) The multipurpose dam is located on the Osage River near Warsaw, Mo., and has the primary functions of flood control and power generation. Plans call for an earth-fill dam about 5000 ft long with a height of 97 ft above the valley floor, a 4-bay gated overfall, a hydraulic jump-type stilling basin and an adjacent power facility in the right terrace.
To study the adequacy of the spillway and the performance of the hydraulic jump-type stilling basin with and without diversion through the powerhouse.
A 1:60-scale undistorted model that reproduces 1400 ft of the approach and 1900 ft of the exit areas, the spillway, powerhouse, nonoverflow sections, and portions of the earth embankment is being utilized to conduct the study.

(g) The weir was calibrated for uncontrolled flows, pressures on the weir crest along the center of a gate bay were measured, and basic stilling basin performance data were obtained.
A surging occurred at the weir for gated flows. Capacity of the weir was slightly below that anticipated. The stilling basin may be raised 5 ft.

(6034) MODEL STUDY OF OUTLET WORKS, BRANCHED OAK DAM, NEBR.

(b) District Engineer, U. S. Army Engineer District, Omaha, Corps of Engineers, Omaha, Nebr.

(d) Experimental; for design.

(e) Branched Oak Dam will create one of several flood-control reservoirs of the Salt Creek project near Lincoln, Nebr. The outlet works will consist of a rectangular intake structure with two inlets (3.5 by 12 ft) and a 6- by 12-ft riser shaft 30 ft high, followed by an elbow and transition, a 6-ft-diam circular conduit 370 ft long, a flared transition with a parabolic invert, an SAF stilling basin, and an exit channel.
To verify the performance of the structure, and particularly to ensure against undesirable characteristics such as surging during transition from weir control to pressure flow or excessive vibration under pressure flow.
A 1:10-scale plastic model reproduced the outlet works including the intake structure, the elbow, the transition, the circular tunnel, the outlet transition, the stilling basin, and about 150 ft of exit channel. Pressures in the model were determined by piezometers located in appropriate areas of the model. The intake structure was installed in a baffled headbay which reproduced the approximate geometry and conditions at entry.

(g) All model tests to verify the adequacy of the design of the outlet structure have been completed; however, tests are under way to determine the effects of other heights of the riser shaft in order to obtain more generalized results.
Discharge characteristics, entrance losses, flow conditions, and pressures throughout the original design outlet works for Branched Oak Dam were found to be satisfactory. The SAF stilling basin provided adequate energy dissipation, and a practical scheme of riprap protection for the exit channel was determined.
Additional tests will be conducted to investigate the performance of the outlet works with increased heights of the riser shaft.

(6035) STILLING BASIN PROTOTYPE PRESSURE TESTS, BARREN RIVER DAM, BARREN RIVER, KY.

(b) District Engineer, U. S. Army Engineer District, Louisville, Corps of Engineers, Louisville, La.

(d) Experimental; for design.

(e) Barren River Dam is a 146-ft-high earth dam used for flood control, recreation, and low flow augmentation. The outlet works are a three-gated intake structure and a 17-ft, elliptically shaped tunnel with a 10,000-cfs capacity. An uncontrolled, saddle-type spillway is located on the right abutment. The stilling basin is 40 ft wide with a single row of streamlined baffle blocks and an end sill.
To measure average and fluctuating pressures against the stilling basin sidewall and on a baffle block. The sidewall pressure magnitude and areal extent will give useful

data for the design of similar stilling basins. Baffle pressures will provide full-scale data on turbulence pressure fluctuations and possible cavitation.
Prototype test facilities include four slots for pressure transducer carriages and ten embedded pressure transducer boxes on and near a baffle block. A pressure transducer will be installed on each carriage and measurements made at various flow depths. Data will be recorded on oscillographs and magnetic tape for later electronic correlation.

(g) Preliminary sidewall pressure measurements were made in April at a discharge of 3600 cfs. Tests are planned in January 1966 at a flow of 6000 cfs to measure both sidewall and baffle block pressures.
Preliminary data indicated that extreme pressure fluctuations against the stilling basin sidewall were less than 0.3 times the entering velocity head. Predominant fluctuations were about 3 ft of water.

(6036) SECTION MODEL STUDY OF SPILLWAY OF BANKHEAD DAM, BLACK WARRIOR RIVER, ALA.

(b) District Engineer, U. S. Army Engineer District, Mobile, Corps of Engineers, Mobile, Ala.
(d) Experimental; for design.
(e) The existing spillway at John H. Bankhead Lock and Dam, Black Warrior River, Ala., which has served its useful life, is to be modified to provide an adequate structure and, under present criteria, extend its economic life 50 years.
To study existing and modified spillway conditions.
A 1:30-scale section model reproduces a 49-ft-wide gate bay and adjacent half bays (net spillway length 98 ft) with sufficient length of approach and exit channels.
(g) Model tests of existing and modified conditions indicated cavitation-range pressures on the weir. Aerating the low-pressure zones failed to raise pressures out of the cavitation range as the air did not spread sufficiently in a lateral direction.

(6037) MODEL STUDY OF NEW BUFFALO HARBOR, NEW BUFFALO, MICHIGAN.

(b) District Engineer, U. S. Army Engineer District, Chicago, Corps of Engineers, Chicago, Illinois.
(d) Experimental; for design.
(e) The proposed small-boat harbor at New Buffalo is located at the mouth of Galien River on the southeast shore of Lake Michigan. This project is cosponsored by the Corps of Engineers and local interests. The harbor will be protected by the north and south breakwaters which converge westward toward the entrance in the form of an arrowhead to furnish an enclosed area of about 8 acres. The proposed 200-ft navigation opening faces west and is located about 800 ft northwesterly from the mouth of the Galien River. The entrance channel is 80 to 180 ft wide by 10 ft deep and 800 ft long. New Buffalo Harbor is used as a base or port of call for light-draft recreational and commercial fishing vessels.
To determine (a) the relative effects of waves of various magnitudes that approach the harbor site from the predominant storm directions; (b) the optimum length and alignment of the proposed arrowhead breakwater system; (c) the optimum crown heights or north and south breakwaters to meet the selected wave-height criteria for the inner-harbor basin during severe storms on Lake Michigan; and (d) the optimum direction and width of navigation opening with respect to reducing wave action in the protected area.
The harbor model tests were conducted on a 1:75-scale, undistorted, fixed-bed model, constructed of concrete except for the breakwaters which simulated the stone characteristics of the proposed breakwaters. The model reproduced all the inner-harbor area, the breakwater system, and sufficient beachline and offshore hydrography to permit simulation of waves propagated toward the harbor from the directions between north-northeast and west. The model covered an area of 5600 sq ft, approximately 1.1 square miles in nature. Waves were generated by a 40-ft-long plunger-type wave machine. Wave heights at selected locations in the model were measured with electrical printed-circuit staff gages, and were recorded electrically with a multichannel oscillograph.
(g) The model was designed and constructed. Wave-height tests were performed with model conditions simulating (a) basic or existing prototype conditions; (b) various combinations or breakwater lengths, alignments, and harbor entrance widths with a +12 ft lwd crown elevation for determination of the optimum length and alignment of the proposed arrowhead-type breakwater system; and (c) selected improvement plans with various breakwater crown elevations for determination of the optimum crown elevations of breakwater systems. Tests were performed simulating storm waves generated from all critical directions reckoned counterclockwise from north-northeast through north to west. All tests were performed using a still-water level of +4.5 ft lwd.
Results obtained indicate that 9 of the 15 improvement plans tested met the wave-height criteria selected for the navigation entrance, navigation channel, and ramp and mooring area of the harbor. The recommended plan, selected from these nine on the basis of economy and direction of littoral transport, provides a total length of 1305 ft of north breakwater and 861 ft of south breakwater with a crown elevation of +9 ft lwd.
(h) Preparation of final report is in progress.

(6038) MODEL STUDY OF MAGIC ISLAND AND KEWALO BASIN, HONOLULU, HAWAII.

(b) District Engineer, U. S. Army Engineer District, Honolulu, Corps of Engineers, Honolulu, Hawaii.
(d) Experimental; for design.
(e) Magic Island is a land-reclamation project. Fronting Ala Moana Park in Honolulu, approximately 120 acres of shallow coral reef will be filled in to create new land for recreational and associated commercial use. Ala Wai Boat Harbor, a pleasure-boat harbor, lies to the east of the project; Kewalo Basin, the home of Hawaii's commercial fishing fleet, lies to the west.
(a) To study wave action in Kewalo Basin for existing conditions and following the proposed construction; (b) to develop remedial plans for alleviation of undesirable navigation conditions and wave action in Kewalo Basin; (c) to determine extent of pollution in inner lagoon and develop a satisfactory circulation system therein; and (d) to study wave action in Ala Wai Harbor before and after proposed revisions to that harbor. The three-dimensional, 1:100-scale model was molded in cement mortar, and reproduces the entire problem area and underwater contours to an offshore depth of 80 ft. Sufficient additional off-shore area was included to permit generation of test waves from all critical directions. Waves in the model are generated by an 85-ft-long wave machine; wave-height data are secured by the use of electrical measuring and recording apparatus. Model appurtenances also include a system for manual reproduction of tide levels in the area.
(g) Design and construction of the model were accomplished. All model operation was completed except the tests pertaining to the Ala Wai Boat Harbor. Analysis of data from the Kewalo Basin tests was in progress.
A circulation system was developed for the inner lagoon which resulted in negligible pollution and stagnation for prevailing wave conditions.

(6039) STABILITY TESTS OF NAVIGATION OPENING STRUCTURES, HILO HARBOR TSUNAMI BARRIER, HAWAII.

(b) District Engineer, U. S. Army Engineer District, Honolulu, Corps of Engineers, Honolulu, Hawaii.
(d) Experimental; for design.
(e) The project will provide a breakwater of barrier across the entrance to Hilo Harbor, Hawaii, to protect the harbor and the city of Hilo against the attack of damaging tsunami waves. A navigation pass will be provided through the barrier. Passage of tsunami waves will result in several minutes of high-velocity flow through the navigation opening. To provide information on the barrier head shape and stone size required to withstand steady flow at a head differential across the barrier of 28 ft. (The effects of wave action on the barrier were investigated in other model studies.)
Two model arrangements were used during the test program. Tests designed primarily to provide data on the stone size required for stability of the barrier heads were conducted in a 1:60-scale model which reproduced one-half of the navigation opening. Tests conducted to provide information on channel bottom or barrier toe protection were made with the full navigation opening reproduced at a scale of 1:72.
(g) Eighteen modifications of the basic navigation opening plan were tested to determine the stone sizes required and to evaluate two methods of providing protection for the toe of a barrier constructed on sand.
Test results showed that barrier head stone sizes required for stability under the maximum anticipated steady-flow conditions were considerably smaller than those required to withstand the attack of the design waves. Test data also indicated that, if possible, the barrier heads should be constructed on a rock foundation. This was considered the only reliable method of obtaining stable heads. However, if foundation conditions at the site make this method of construction impractical, a protective blanket covering the entire channel bottom through the opening would provide protection for the toe of the barrier heads. The second method of toe protection investigated was the "armoring" technique in which additional stone is placed around the toe of the barrier head to armor the toe as the sand is scoured away. Use of this method is not recommended unless the depth of sand is shallow and unless repair and maintenance operations are scheduled after each tsunami until the currents have removed all sand and the barrier heads rest on rock.
(h) Preparation of final report is in progress.

(6040) MODEL STUDY OF BREAKWATER STABILITY, HILO HARBOR, HAWAII.

(b) District Engineer, U. S. Army Engineer District, Honolulu, Corps of Engineers, Honolulu, Hawaii.
(d) Experimental; for design.
(e) Hilo Harbor is on the northeast coast of the Island of Hawaii, about 195 nautical miles southeast of Honolulu. The proposed plan to protect the harbor against seismic waves (tsunamis) and short-period wind waves (sea and swell) consists of extending the existing breakwater westward to a total length of about 10,570 ft. providing a navigation opening 600 ft wide and 35 ft deep, and constructing a breakwater about 4000 ft long on the west side of the harbor, extending eastward. The breakwaters are to be constructed of quarrystone and concrete armor units.
To develop a breakwater trunk section that will be stable against the attack of seismic waves (tsunamis) and short-period wind waves (sea and swell).
Stability tests of the breakwater trunk when subjected to seismic waves (tsunamis) were conducted at a 1:50 scale in a steel flume 230 ft long, 6 ft wide, and 4 ft deep. Model seismic waves (bores) were generated by a pneumatic-type bore generator, and measured and recorded electrically. Stability tests of the breakwater trunk when subjected to short-period waves were conducted at a 1:50 scale in a concrete wave flume 119 ft long, 5 ft wide, and 4 ft deep. Model waves were generated by a plunger-type wave machine, and measured and recorded electrically.
(g) The existing flume facilities were revised for the study. A pneumatic bore generator was designed, constructed, and programmed to generate the required tsunamis. Preliminary tests were conducted on a typical section of the breakwater trunk to study the causes and remedies of failure of breakwater trunks when subjected to tsunamis. Several overtopping and nonovertopping sections of the breakwater trunk were designed and tested for stability against tsunamis. Some of the breakwater trunk sections, which were found to be stable against the attack of tsunamis, were checked for stability against the attack of short-period waves.
It was found that: (a) Rehabilitation of the existing breakwater will require the addition of one layer of 20-ton stone (placed with tongs) to the existing breakwater section, grouting 4 ft of the top of the harborside slope of the cover layer of the existing barrier, and addition of a concrete impervious diaphragm on top of the grouted layer, (b) extension of the existing breakwater westward and construction of a breakwater on the west side of the harbor extending eastward will require the construction of a nonovertopping barrier with 3-ft freeboard, a seaside slope of 1 on 1-1/2, and a harborside slope of 1 on 2. The nonovertopping barrier consists of core material ranging in size from 50- to 1500-lb stone, one layer of about 10-ton stone (placed with tongs) on the harborside slope extending from elevation -10 ft to elevation +25 ft, and armor cover layers on the seaside slope adequate to withstand the attack of short-period waves.

(6041) MODEL STUDY OF HARBOR, CRESCENT CITY, CALIFORNIA.

(b) District Engineer, U. S. Army Engineer District, San Francisco, Corps of Engineers, San Francisco, Calif.
(d) Experimental; for design.
(e) The existing recommended project entails dredging to a 20-ft depth an area of about 18 acres adjacent to the Citizens Dock, thus reducing the adjacent 10-ft project depth area to 12 acres, and a 300-ft-long extension, aligned in the northwest direction, of the existing inner breakwater. Other alternate improvements which have been requested by local interests involve (a) possible construction of an arm of breakwater extending about 2400 ft southwesterly from Whaler Island to provide, with the existing outer breakwater, a navigation entrance about 400 ft wide, and (b) rock removal to 20-ft depths in the Dutton Wharf area of the northwest sector of the harbor.
To study the effects of storm wave action involving short-period waves, 5 to 20 sec, on the existing harbor and with various proposed plans of improvement installed in the model. These proposed plans of improvement involve determination of (a) optimum arrangements for an increased breakwater system, (b) effects on harbor wave action within an area inside the harbor which would be dredged to and maintained at increased project depths necessary to satisfy navigation requirements for deeper draft vessels, and the effects of wave action on the small craft in existing marina areas and also the feasibility of possible marina expansion should such action become desirable in the future.
The 1:125-scale model is of the fixed-bed type, and is molded of concrete except for the breakwaters which are constructed of

rubble, sized to simulate that required for prototype construction. The model reproduces sufficient area along the shoreline north, south, and oceanward of the harbor site to ensure that propagation of waves toward the problem area is adequately simulated. The model has an area of about 7800 sq ft, equivalent to about 4.4 square miles in nature. Waves are generated by a 60-ft-long, plunger-type wave machine. Electrical printed-circuit-type wave measuring rods in conection with automatic recording equipment are used to obtain necessary wave-height data.

(6042) LABORATORY RESEARCH ON DIKE DESIGN.

(b) District Engineer, U. S. Army Engineer District, Memphis, Vicksburg and New Orleans Districts.
(d) Experimental; for design.
(e) The project involves the construction of dikes for the regulation and improvement of alluvial streams, such as the Mississippi River, to provide for adequate channel depth and alignment for navigation.
To determine the relative effectiveness of various factors, such as alignment, elevation, length, permeability, etc., in stabilizing low-water channels and in providing the required increase in depth.
The investigation is being conducted in a flume 230 ft long by 20 ft wide, including two bends and a relatively long, straight reach between bends. The study is of the movable-bed type with a fine, uniform sand used for bed material.
(g) Tests of 15 dike systems were completed. Results have indicated some of the factors affecting the performance of rock dikes, performance characteristics of various types of dike systems, and factors which should be considered in the design of a dike system. The most promising dike designs are being built and tested in the field.

H. G. ACRES & COMPANY LIMITED, Hydraulic Laboratory.

Inquiries concerning the following projects should be addressed to Mr. O. M. Erickson, Head, Hydraulic Department, H. G. Acres & Company Limited, Consulting Engineers, Niagara Falls, Canada.

(S618) MODEL TESTS OF THE ROCKFILL CAUSEWAY CROSS SECTION FOR THE NORTHUMBERLAND STRAIT CROSSING.

(b) Northumberland Consultants Limited, Charlottetown, Prince Edward Island.
(d) Experimental; design.
(e) The rockfill causeway section of the Northumberland Strait Crossing will be approximately three miles in length. The rockfill core must be protected against the combined effects of a 20-foot design wave, currents resulting from partial closure of the Strait which at present experiences 8-foot tides, and the movement of extremely large ice floes. Wave studies are being carried out on a 1:20 scale model to determine the most economic combination of dyke freeboard, dyke slope, primary precast concrete armour units and secondary riprap requirements, which will meet the design conditions.

(S619) TIDAL MODEL TESTS FOR THE PROPOSED NORTHUMBERLAND STRAIT CROSSING.

(b) Northumberland Consultants Limited, Charlottetown, Prince Edward Island.
(d) Experimental; design.
(e) To study the effect of partial closure of the Northumberland Strait by the building of a causeway. Model studies are being made of the Strait to scale of 1:6400 horizontal and 1:64 vertical. Tidal movements within the Strait are caused by the tides imposed on the entrances; two tide generators are therefore used. The principal objectives of the study are to confirm conclusions derived from analytical calculations, to determine the velocity distribution through the causeway opening, the overall velocity pattern, and the maximum tidal difference across the causeway. On completion of the studies for design data, the model will be available for studies required by other interested agencies such as the Department of Fisheries.

(S620) MODEL STUDY OF BRIDGE PIERS SUBJECTED TO PRESSURES FROM LARGE ICE FLOES.

(b) Northumberland Consultants Limited, Charlottetown, Prince Edward Island.
(d) Experimental; design.
(e) Piers for the bridged section of the proposed crossing of Northumberland Strait will be subjected to ice pressure. Various shapes are being tested on a 1:60 scale model to find the magnitude and direction of the forces, and to observe the mechanics of the splitting and breaking of ice floes against these piers. A special substance has been devised having the appropriate mechanical properties to simulate the ice to the scale of the model. The piers are supported by a specially designed dynamometer and placed in the centre of a raceway. The artificial ice floes, floating in the water, are either carried by the current of water, or forcibly propelled and made to collide with the pier.

(S987) WAVE MEASUREMENTS IN NORTHUMBERLAND STRAIT.

(b) Northumberland Consultants Limited, Charlottetown, Prince Edward Island.
(d) Field; design.
(e) To enable calibration of wave formula for local conditions, a wave recorder consisting of an electronic circuitry cabinet and electrode probe mounted on a mast 50 feet in length and anchored to the ocean floor approximately one mile off Borden, P.E.I., was designed and used to obtain wave data. The sensing device on the mast was connected by a 7-conductor submarine cable to a power source and chart recorder located on the shore. The wave records obtained are being analyzed for significant wave, wave spectrum and wave period.
(g) Preliminary analysis of wave data indicates good agreement with Bretschneider's technique for wave forecasting, although some adjustment seems justified for use of the technique for an intermediate size body of water. Wave spectrum data was found to be in good agreement with the Longuet-Higgins data.

(S988) INVESTIGATION OF HYDRODYNAMIC FORCES ON BRIDGE PIERS AND TUNNEL ELEMENTS DURING PLACEMENT.

(b) Northumberland Consultants Limited, Charlottetown, Prince Edward Island.
(d) Experimental; design.
(e) To determine the hydrodynamic forces on the bridge piers and tunnel elements of the Northumberland Strait Crossing, 1 to 35 scale models of the piers and tunnel elements are being tested in a flume 11 feet wide, 4 feet deep and 80 feet long. The flume, which is equipped with pneumatic wave generator, is so designed that both current and wave forces can be simulated simultaneously on the models.

(S989) MODEL STUDY OF PORTAGE DIVERSION SPILLWAY AND STILLING BASIN.

(b) Water Control and Conservation Branch, Dept. of Agriculture and Conservation, Government of Manitoba, Winnipeg 1, Manitoba.
(d) Experimental; design.
(e) The Portage Diversion spillway which will be located on the Assiniboine River, near Portage la Prairie, has a capacity of 25,000 cfs. The flow will be controlled by means of two 14-foot high by 75-foot long bascule gates located on the crest of the spillway. A 1 to 36 scale model was used to investigate the performance of the stilling basin for discharge over the spillway crest and through an 8-foot by 10-foot low level outlet conduit. Tests were also carried out to determine hydraulic loads for design of the gate operator. Qualitative tests of gate vibration and aeration were also undertaken.
(f) Completed.
(g) A large baffle pier was found to be required at the outlet of the low level conduit to disperse the flow throughout the stilling basin to obtain satisfactory energy dissipation.
(h) A report has been prepared and submitted to the client.

(S990) MODEL STUDY OF MACTAQUAC STILLING BASIN.

(b) The New Brunswick Electric Power Commission, Fredericton, New Brunswick.
(d) Experimental; design.
(e) The main spillway of the Mactaquac Development has a capacity of 285,000 cfs and is located adjacent to the powerhouse. Five 45-foot wide by 53-foot high spillway crest gates regulate the flow into the stilling basin. The difference between the headwater and the tailwater is about 90 feet. A 1 to 72 scale movable bed model was used to study the performance of the stilling basin and to determine the optimum arrangement of baffle blocks, end sill and length of stilling basin. Scour patterns downstream from the stilling basin and adjacent to the powerhouse were also investigated.
(f) Completed.
(g) A satisfactory design was developed using a stilling basin length equal to approximately 0.3 times the length of the hydraulic jump.
(h) Report prepared and submitted to the client.

(S991) MODEL STUDY OF PROPOSED LOCK 6 WEST INTAKE

STRUCTURE.

(b) The St. Lawrence Seaway Authority, Montreal, Canada.
(d) Experimental; design.
(e) A new filling system for Lock 6 West of the Welland Canal requires construction of a new intake. The proposed intake structure consists of a funnel shaped entrance transition, symmetrically divided to convey water to two tunnels. The flow in each tunnel is regulated by a reverse taintor gate. A 1 to 40 scale model was used to investigate the possibility of separation, air entrainment and vortex formation at the intake.
(f) Completed.
(g) A tendency for vortex formation was found in the model. Several types of vortex suppressors were tested at 1, 2 and 2.5 times the Froude velocity and a canopy type suppressor recommended as a permanent feature of the intake.
(h) Report completed and submitted to the client.

(5992) MODEL STUDY OF LOCK 7 WEST OUTLET STRUCTURE.

(b) The St. Lawrence Seaway Authority, Montreal, Canada.
(d) Experimental; design.
(e) The new emptying system for Lock 7 West of the Welland Canal consists of two concrete tunnels, each 20 feet wide by 20 feet high, and an outlet structure. The outlet structure consists of two conduits curved, in plan, 66.23 degrees on a horizontal radius of 98.5 feet, with two vertical bends having radii varying from 60 to 80 feet. Each conduit of the outlet structure is 20 feet high by 20 feet wide at the entrance, and is expanded and divided by a separation wall along its centreline, into two branch conduits, each with dimensions 14 feet by 29 feet at outfall. A 1 to 40 scale model was used to investigate flow separation along the curve walls, flow distribution at outfall and energy losses.
(f) Completed.
(g) The model showed separation to take place along the inside wall of the horizontal curves of each branch and guide vanes were added to improve the velocity distribution and turbulence at outfall.
(h) Report prepared and submitted to the client.

UNIVERSITY OF ALBERTA (EDMONTON), Dept. of Civil Engineering.

(5665) ALBERTAN CO-OPERATIVE STUDIES OF RIVER REGIME.

(b) University, with NRC grant.
(c) Dr. T. Blench, Dept. of Civil Engrg., Univ. of Alberta, Edmonton, Canada.
(d) Laboratory study; Master's thesis.
(e) Literature study and attempt to co-ordinate the maximum scour for a given depth in sand and coal bed material.
(g) A useful formula was obtained containing a power of the buoyant specific gravity of the bed material. Maximum scour was found to be, paradoxically, less in the light-weight material.
(h) "Co-ordination of Model Bridge-Pier Scour", A. S. Qureshi, M.Sc. Thesis, University of Alberta, 1965.

(5666) ALBERTAN CO-OPERATIVE STUDIES OF RIVER REGIME.

(b) University and Alberta Research Council.
(c) Dr. T. Blench, Dept. of Civil Engrg., Univ. of Alberta, Edmonton, Canada.
(d) Field study under Co-operative Highway Research Program; Master's thesis and official report.
(e) Fluviological field study and analysis of sand-river regime.
(g) Bed behaviour over 3 miles were observed in detail at three low flood stages using a sonic sounder and careful ground control. Space alternations of scour and deposition were recorded as discharge varied; dune patterns were studied; scour pattern changes with time were noted at a bend. A preliminary quantitative analysis was attempted in terms of regime theory parameters, Manning's n, and a friction factor; the variations of these factors were considered in terms of the qualitative river behaviour.
(h) "Field Observations of Bed Changes in Red Deer River, near Duchess", N. Bobey, M.Sc. Thesis, Univ. of Alberta, 1965.

(5667) ALBERTAN CO-OPERATIVE STUDIES OF RIVER REGIME.

(b) University of Alberta, with NRC grant.
(c) Dr. T. Blench, Dept. of Civil Engrg. Univ. of Alberta, Edmonton, Canada.
(d) Laboratory Study, Master's thesis.
(e) Study of laminar flow of sand suspension in vertical tubes, and co-ordination of theory.
(f) Terminated.
(g) An attempt was made to co-ordinate the many formulas offered in Chemical Engineering literature for dilatant behaviour of suspensions. V/D was found to be a suitable factor for correlating with boundary shear stress. The Bagnold experiments and ideas on dilatancy suggested non-dimensional parameters and the use of a linear separation factor instead of concentration; the resulting formula was a simple power one with an index that changed at high concentration where particles probably interfered with each other violently.
(h) "Investigation of Rheological Characteristics of Sand-Water Suspensions", N. Subramanya, Univ. of Alberta, M.Sc. Thesis, 1965.

(5668) ALBERTAN CO-OPERATIVE STUDIES OF RIVER REGIME.

(b) University of Alberta, with NRC grant.
(c) Dr. T. Blench, Dept. of Civil Engrg., Univ. of Alberta, Edmonton, Canada.
(d) Laboratory study; Ph.D. thesis.
(e) Study of sand suspension in pipes near the drop-out condition.
(f) Continuing to other problems.
(g) Scattering of Gamma-Rays was used to measure sediment concentration on vertical and horizontal lines. The technique proved satisfactory. Concentration followed an approximately exponential decay law from bottom of pipe to top of observable material. Bagnold's ideas on dilatancy were used to give a rough explanation of results. The work follows from Ansley's, 1964, and aims, inter alia, at ultimate understanding of bed-load transfer.
(h) "Investigation of the Concentration Gradient in Fluidized Solids Transport", M. P. duPlessis, Ph.D. thesis, Univ. of Alberta, 1965.

(5675) SUBMERGED SLUICE GATE FLOW AS A WALL JET PROBLEM.

(b) University on NRC Grant.
(c) Dr. N. Rajaratnam, Dept. of Civil Engrg., University of Alberta, Edmonton.
(d) Basic problem with practical application; experimental and theoretical in nature.
(e) This work is being done to treat the submerged flow below a sluice gate as the case of a plane turbulent wall jet under essentially zero pressure gradient and to understand the mechanics of the jet diffusion and energy dissipation.
(f) Completed.
(g) The analysis has been successful. The velocity scale factors have been determined and it has been found possible to predict the jet diffusion and the energy dissipation.
(h) "Submerged Sluice Gate Flow as a Wall Jet Problem," by N. Rajaratnam, Proc. 2nd Australasian Conf. on Hydraulics & Fluid Mechanics, Auckland, New Zealand, Dec. 1965.

(5676) SUBMERGED HYDRAULIC JUMP AS A WALL JET.

(b) University on NRC Grant.
(c) Dr. N. Rajaratnam, Dept. of Civil Engrg.,

University of Alberta, Edmonton, Canada.
(d) Basic problem with practical application; - theoretical and experimental.
(e) The purpose of this work is to develop a sound method of understanding the diffusion and energy dissipation in the submerged jump.
(f) Completed.
(g) The submerged jump has been treated as a plane turbulent wall jet, with an adverse pressure gradient with backward flow on top. The forward flow has been successfully studied; the friction on the bed has been measured with a Preston tube and a method has been developed to predict the backward flow on top. The effect of the submergence factor has been brought out clearly.
(h) "Submerged Hydraulic Jump," by N. Rajaratnam. Proc. American Society of Civil Engineers, J. Hydraulics Divn., July 1965.

(5677) HYDRAULIC JUMP AS A WALL JET.

(b) University on NRC Grant.
(c) Dr. N. Rajaratnam, Dept. of Civil Engrg. University of Alberta, Edmonton, Canada.
(d) Basic problem with practical application; theoretical and experimental.
(e) The purpose of this work is to understand the diffusion and energy dissipation in the jump and also to find out the effect of the adverse pressure gradient on the growth of a wall jet.
(f) Completed.
(g) The velocity distribution in the boundary layer and the free mixing region have been studied and have been found to be similar. The corresponding scale factors have been determined. The boundary friction has been measured with a Preston tube. A more correct form of the momentum equation for the jump has been developed. The surface profile and energy fall in the jump have been predicted.
(h) "The Hydraulic Jump as a Wall Jet" by N. Rajaratnam, Proc. ASCE, J. Hydraulics Divn., September 1965.

(5678) PLANE TURBULENT WALL JETS ON ROUGH BOUNDARIES.

(b) University on NRC Grant.
(c) Dr. N. Rajaratnam, Dept. of Civil Engrg., University of Alberta, Edmonton, Canada.
(d) Basic problem with applications; theoretical & experimental.
(e) The purpose of this work is to study systematically, the effect of boundary roughness on the growth of the wall jet.
(g) The growth and diffusion of the plane turbulent wall jet on rough boundaries has been studied over a fairly wide range of relative roughness under essentially zero pressure gradient. Further work is in progress to study the effect of adverse pressure gradients.
(h) "Plane Turbulent Wall Jets on Rough Boundaries," by N. Rajaratnam. Submitted for Publication to the ASCE, J. of the Hydraulics Divn.

(5679) PRESTON TUBE - A THEORETICAL CALIBRATION CURVE.

(b) University with NRC Grant.
(c) Dr. N. Rajaratnam, Dept. of Civil Engrg., University of Alberta, Edmonton, Canada.
(d) Basic problem with applications.
(e) The purpose is to develop a refined theoretical calibration curve for the Preston tube on smooth boundaries for large Reynolds numbers.
(f) Completed.
(g) The theoretical curve developed agrees very well with the extensive and precise results of Rechenberg and Patel.
(h) "A Theoretical Calibration Curve for the Preston Tube on Smooth Boundaries for Large Reynolds Numbers," J. of the Royal Aero. Soc., London, February 1965.

(5680) THE STATIC HOLE ERROR PROBLEM.

(b) University on NRC Grant.
(c) Dr. N. Rajaratnam, Dept. of Civil Engrg., University of Alberta, Edmonton, Canada.
(d) Basic problem with applications.
(e) The purpose is to study the static hole error problem with a view of using it for the measurement of boundary shear stress.
(g) A method has been developed for predicting the true static pressure using two holes of different diameters. Also Shaw's curve has been found to be applicable for open channel flows.
(h) "A Note on the Static Hole Error Problem," by N. Rajaratnam, J. of the Royal Aero. Soc., London (in press). Discussion of "Errors in Piezometric Measurement," by N. Rajaratnam, Proc. ASCE, J. Hydraulics Divn., Sept. 1965.

(5681) PRESTON TUBE WITH A HEMISPHERICAL NOSE.

(b) University on NRC Grant.
(c) Dr. N. Rajaratnam, Dept. of Civil Engrg., University of Alberta, Edmonton, Canada.
(d) Basic problem with applications.
(e) The purpose is to develop a method of using the familiar Prandtl-type pitot-static tube for the measurement of the boundary shear stress.
(f) Completed.
(g) A calibration curve has been developed for the pitot-static tube to predict the boundary shear stress.
(h) "On the Preston Tube with a Hemi-spherical Nose," by N. Rajaratnam, Civil Engineering and Public Works Review, London (in press).

(5682) SUBMERGED JUMP IN TRIANGULAR CHANNEL.

(b) University on NRC Grant.
(c) Dr. N. Rajaratnam, Dept. of Civil Engrg., University of Alberta, Edmonton, Canada.
(d) Applied research.
(e) To understand the effect of submergence on the jump in a triangular channel.
(f) Completed.
(g) The momentum equation has been found to be satisfactory to predict the overall flow pattern and the energy loss.
(h) "Experiments on Submerged Jump in a Triangular Channel," by N. Rajaratnam, Civil Engineering and Public Works Review, London, July 1965.

(5683) HYDRAULIC JUMP IN HORIZONTAL CONDUITS.

(b) University on NRC Grant.
(c) Dr. N. Rajaratnam, Dept. of Civil Engrg., University of Alberta, Edmonton, Canada.
(d) Applied research.
(e) To develop simplified charts to predict the jump characteristics in conduits.
(f) Completed.
(g) Simple charts have been developed for predicting the jump formation in horizontal conduits of circular or exponential cross-section. The effect of air entrainment has also been considered.
(h) "Hydraulic Jump in Horizontal Conduits," by N. Rajaratnam, Water Power, London, Feb. 1965.

UNIVERSITY OF BRITISH COLUMBIA, Hydraulics Lab.

(4451) HEAD LOSS IN SPHERICAL AND CONVENTIONAL WYES.

(b) Laboratory project.
(c) Dr. E. Ruus, Dept. of Civil Engineering, University of British Columbia.
(d) Applied research. Much of the experimental work is being done by an M.A.Sc. student.
(e) Lucite models of spherical and conventional type of wyes were constructed and the head losses measured. For all wyes the inside diameter of the main pipe and the branch pipes are 5 1/4 and 3 3/4 inches respectively. Several modifications such as tierods, tapered outlets, rounded corners and different sphere diameters are being investigated.
(h) M.A.Sc. Thesis by Sirajuddin Ahmed, Oct. 1965.

(5993) FLOW THROUGH PIPE NETWORKS.

(b) Laboratory project.
(c) Prof. J. F. Muir, Dept. of Civil Engineering, Univ. of British Columbia, Vancouver, B. C.

(d) Theoretical; applied research.
(e) Preparation of Fortran IV computer programs for determination of flow and friction losses through water pipe networks served (a) by gravity from one or more storage reservoirs, (b) by a combination of pumps and reservoirs.

(5994) THE USE OF AIR BUBBLERS TO PREVENT SHOALING AT A WHARF IN A NAVIGABLE, ALLUVIAL, TIDAL RIVER.

(b) Laboratory project.
(c) Prof. E. S. Pretious, Dept. of Civil Engrg., Univ. of British Columbia, Vancouver, B. C.
(d) Laboratory experiments and field tests. Applied research to aid operation and development. Project used for master's thesis.
(e) A grain elevator wharf owned and operated by the Fraser River Harbour Commission on the left bank of the Fraser River at New Westminster, B. C., is subject to severe shoaling annually, immediately following a freshet. This shoal is removed by conventional dredging which is inconvenient for shipping using the wharf. If dredges are not immediately available the wharf has to close, resulting in serious financial loss. The shoal is composed of fine sand having a median diameter of about 0.1 m.m. which may be carried in suspension during the freshet. By creating a curtain of air bubbles it might be possible to deflect the sediment deposition away from the wharf; in the manner of an underwater deflecting groin, except that it would not constitute a hazard to shipping. Compressed air will be forced through perforations in plastic pipe anchored to the river bed in the vicinity of the wharf, which is 1,129 feet long parallel to the bank.
(g) It will be necessary to know the optimum arrangement of the air lines on the river bed and at what stage of the river flow to commence the air bubbler operation. Furthermore, the local tidal action may produce shoaling patterns which can best be countered by varying the operation to suit flood, slack, and ebb tides. To be a success, the air-bubbler system will have to compete with conventional dredging as regards cost, apart from the other advantages mentioned.
(h) The findings will be presented in a master's thesis.

(5995) A GENERAL-PURPOSE, LABORATORY WAVE GENERATOR.

(b) Laboratory project supported by National Research Council of Canada.
(c) Prof. E. S. Pretious, Dept. of Civil Engrg., Univ. of British Columbia, Vancouver, B. C.
(d) Design and construction of a wave generator and wave absorbers to provide laboratory facilities for wave research.
(e) The short length of the existing laboratory flumes precludes long spending beaches and also makes it necessary to generate the type of wave desired (shallow-water, deep-water or transitional type) right at the generator. By a suitable linkage the wave generator can act as a hinged paddle, a plunger, or as a combination of the two, depending on the water-particle motion desired. This wave research facility will be available for demonstration and graduate research.
(g) The electronic controls for accurately measuring wave lengths (periods), profiles and heights have been designed and completed. The existing generator is being built for a small flume which will act as a pilot model for a much larger flume. The experience gained with the small flume should benefit the larger installation.
(h) A laboratory report including mechanical drawings, circuit diagrams and photographs will be prepared.

(5996) OPTIMUM CLOSING OF HYDRAULIC TURBINE GATES.

(b) Laboratory project.
(c) Dr. E. Ruus, Dept. of Civil Engineering, Univ. of British Columbia, Vancouver, B. C.
(d) Theoretical, for Master's thesis.
(e) To find for a hydraulic turbine, served by a penstock from a distant reservoir, the optimum gate closure arrangement resulting in minimum speed rise. The change in power output at the gate, caused by an arbitrary gate closure operating, is derived in terms of (1) changes in energy input at the intake, (2) changes in kinetic and pressure energy of water and (3) strain energy of the penstock walls.

(5997) RIVER FLOOD FORECASTING.

(b) British Columbia Disaster Relief Fund.
(c) Dr. R. Singh, Dept. of Civil Engineering, Univ. of British Columbia, Vancouver, B. C.
(d) Applied research (mostly theoretical).
(e) To forecast the floods on the Fraser River from snow and temperature data by considering an analogous system.
(f) Under study.
(g) Satisfactory.
(h) "River Flood Flows and Probabilities," Journal of the Hydraulics Division, ASCE, Vol. 91, No. HY3, Proc. Paper 4312, May 1965, pp. 1-18.

ECOLE POLYTECHNIQUE, Department of Civil Engineering, Hydrodynamics Laboratory.

(4043) STUDY OF THE RELIABILITY AND OPERATION OF BACK-WATER VALVES ON PLUMBING SYSTEMS AGAINST FLOODING BY PUBLIC SEWERS.

(b) City of Montreal, City Planning Department, Inspection Division.
(c) Professor Raymond Boucher, Director, Hydrodynamics Laboratory, Ecole Polytechnique, 2500 Marie-Guyard Avenue, Montreal 26, Quebec, Canada.
(d) Experimental; applied research.
(e) A full scale three-story plumbing system has been erected in the Hydrodynamics Laboratory of Ecole Polytechnique. The diameter of the pluvial column, the soil stack and the drain is 4 inches. The drain has many sections of pyrex glass to permit observations at critical points. A system of valves and of cross-connections on the vents lends to various combinations of tests. The back-water valves have a transparent lucite cover to enable visual observations. As air entrainment has a great importance on the venting capacity, the rate of air entrained in the vertical columns is measured at the inlet by means of a hot-wire air-meter. Various flooding conditions of the public sewers are simulated by a tank in which the water level can be controlled by gate valves. This research is aimed at determining whether back-water valves can offer home dwellers a reliable protection against flooding due to any overload of combined sewers.
(f) Reactivated.
(g) The mechanism of air entrainment has been studied and tests have revealed the best position for some of the vents. Recent tests have been conducted with new positions of the vents and new arrangements in the piping.
(h) Interim report entitled "Etude experimentale des soupapes de surete contre les surcharges d'egout", BY Andre Leclerc, Roger Labonte and Raymond Boucher, December 1963, submitted to sponsor. Final report in preparation.

(5513) HYDRAULIC MODEL STUDY OF THE INTAKE FOR THE MANICOUAGAN 5 HYDRO-ELECTRIC PROJECT.

(b) Quebec Hydro-Electric Commission.
(c) Professor Raymond Boucher, Director, Hydrodynamics Laboratory, Ecole Polytechnique, 2500 Marie-Guyard Ave., Montreal

26, Quebec, Canada.
(d) Experimental; for design.
(e) A comprehensive model built to an undistorted scale of 1:60 reproduces the forebay topography, the intake canal and intake structures. This investigation is conducted to examine the overall performance of the structures and to verify the design. A second model of the intake structures of a different design has also been built to the same scale. The first model of the intake structures has been tested. Testing of the second model is being executed at the present time.
(h) Progress reports submitted to sponsor.

(5946) HYDRAULIC MODEL STUDY OF LOG-PASSING DEVICES AT DAMS.

(b) Quebec Hydro-Electric Commission.
(c) Prof. Andre Leclerc, Associate Director, Hydrodynamics Laboratory, Ecole Polytechnique, 2500 Marie-Guyard Ave., Montreal 26, Quebec, Canada.
(d) Theoretical and experimental for design.
(e) The study is conducted to determine the best geometry of intakes, transitions, flumes and chutes to prevent log jamming and ascertain efficient flow especially in vertical and horizontal bends of chutes. The main purpose of this study is to design an intake that will pass the largest flow of logs of 4, 8, 12 and 16 feet with the minimum of water per log. Consideration must be given to the fact that the water level upstream of the dam may vary with time up to 35 feet at some locations. The elevation of the intake structure must be varied accordingly to control the rate of flow.
(g) Two intakes have been designed which seem to conform to the requirements. Tests are now conducted on a 1:16 scale model to refine the shapes and determine the best slopes. Theoretical designs of transitions have been made which will be subjected to experimental verification in the near future.
(h) Progress reports submitted to sponsor.

(5947) HYDRAULIC MODEL STUDY OF HEAD LOSSES THROUGH VARIOUS RESTRICTED ORIFICES FOR THE SURGE TANKS OF MANICOUAGAN 5 HYDROELECTRIC PROJECT.

(b) Quebec Hydro-Electric Commission.
(c) Prof. Raymond Boucher, Director, Hydrodynamics Laboratory, Ecole Polytechnique, 2500 Marie-Guyard Ave., Montreal 26, Quebec, Can.
(d) Experimental; applied research (M. S. thesis).
(e) One model has been built to a scale of 1: 107.3. Head loss coefficients of various orifice shapes have been studied for the two flow directions under steady flow conditions. To obtain a given loss coefficient ratio for the two flow directions, a final form of the orifice to be installed in the surge tanks has been determined. Fundamental study is planned on four models built to different scales to verify possible scale effects.

(5948) THEORETICAL STUDY ON THE TIDAL MOTION IN THE ST. LAWRENCE ESTUARY.

(b) National Research Council; laboratory project.
(c) Dr. H. Werner Partenscky, Ecole Polytechnique, Hydrodynamics Lab., 2500 Marie-Guyard Ave., Montreal 26, Quebec, Canada.
(d) Theoretical and field investigation; applied research for M.S. thesis.
(e) Investigation of the tidal characteristics of the St. Lawrence Estuary by means of a mathematical model. Empirical determination of geometric and roughness effects on tidal amplitudes and velocities. Calculation of tidal discharges. Study of geostrophic effects. Comparison of computed tidal velocities with field measurements.
(f) Almost completed.
(g) Theoretical results showed good agreement with field measurements for average tidal amplitudes and velocities.
(h) "An Investigation of the Tidal Characteristics of the St. Lawrence Estuary by a Mathematical Model," Rene Vincent, M. S. thesis, Laval University, Nov. 1965. Final report in preparation.

(5949) SALINITY INTRUSION STUDY FOR THE ST. LAWRENCE ESTUARY.

(b) National Research Council; laboratory project.
(c) Dr. H. Werner Partenscky, Ecole Polytechnique, Hydrodynamics Lab., 2500 Marie-Guyard Ave., Montreal 26, Quebec, Canada.
(d) Theoretical and field investigation.
(e) One-dimensional study on the salinity intrusion in the St. Lawrence Estuary based on mean tidal velocities obtained from theoretical investigations and field measurements. Comparison of computed salinity values with prototype data.
(f) Preliminary studies completed. Investigations continuing.

(5950) STUDY ON THE OSCILLATIONS OF FLAP GATES.

(b) National Research Council; laboratory project.
(c) Dr. H. Werner Partenscky, Ecole Polytechnique, Hydrodynamics Lab., 2500 Marie-Guyard Ave., Montreal 26, Quebec, Canada.
(d) Experimental; fundamental study; M.S. thesis.
(e) The excitation of flap gates to oscillate are being investigated for different gate shapes and operating positions. Measures to prevent the oscillations are being studied. Criteria are to be established for the design and operation of flap gates.
(g) Investigation in planning stage.

THE HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO, Hydraulic Model Laboratory.

Inquiries concerning the following projects should be addressed to Mr. J. B. Bryce, Hydraulic Engineer, Hydraulic Generation Department, 620 University Avenue, Toronto 2, Ontario, Canada.

(4026) NIAGARA RIVER MODEL.

(b) Ontario Hydro.
(d) Experimental; for design and operation.
(e) An existing 1:250 x 1:50 scale model reproducing five miles of the Niagara River from Buckhorn Island to below the Cataracts is being used to determine the operational characteristics of the Niagara River Control Structure under developed conditions. This model was previously used to investigate the remedial works necessary for the Preservation and Enhancement of Niagara Falls and for the location of the intakes and necessary river improvements of both Ontario Hydro and the Power Authority of the State of New York. To fully realize the terms of the 1950 Niagara Treaty, additional remedial works have been designed. These include a five-gate extension to the existing 13-gate control structure as well as a system containing an upstream accelerating wall, a downstream training wall and overflow weir for the safe passage of ice past the various intakes along the Canadian shore of the river above the Falls. The sequence of construction of these works and the conditions during their construction were determined in the model. Rating of the structure under cofferdammed conditions was obtained. An echo-sounding survey with electronic fixing was made in the field in 1962 and portions of the model re-contoured. Certain river improvements were designed and executed to assist in the passage of ice floes.

(4455) ARROW LAKES DAM - COLUMBIA RIVER.

(b) British Columbia Hydro and Power Authority.

(d) Experimental; for design.
(e) An 1:80 scale model of the Arrow Lakes and dam and environs was built to determine the detailed location and adequacy of the water passages in a concrete structure and the energy-dissipating works necessary to ensure the protection of an associated earth dam. Numerous tests have been made with a movable bed of fine sand to determine erosion characteristics and navigation velocities upstream and downstream of a lock situated between the concrete structure and the earth dam.
A 1:50 scale model was tested in a flume to determine the hydraulic design of the tunnel ports in the concrete structure and to develop the associated energy-dissipating work. Rating of these ports was obtained as well as the hydraulic loadings on the port gates. A 1:60 scale model of one of the four sluiceways is being tested in the flume to determine the rating of the sluice and the hydraulic loadings on the sluice gate. Piezometers are being used to determine under varying conditions of flow, the rollway pressures as well as the pressures at selected locations in the energy-dissipating bucket and associated tooth-like projections of the dissipator.
(f) Design completed, but model still active.

(5516) SIR ADAM BECK-NIAGARA GENERATING STATIONS.

(b) Ontario Hydro.
(d) Experimental; for design.
(e) A 1:80 scale model was built of the two canals leading to the plants including the crossover, in order to determine the performance with the increased flow of Sir Adam Beck No. 1 canal due to its enlargement.
(f) Work completed and model inactive.

(5517) LAMBTON GENERATING STATION.

(b) Ontario Hydro.
(d) Experimental; for design.
(e) A 1 to 80 scale model reproduces about one mile of the St. Clair River topography. The model will determine the location and size of the intake channels for cooling water and any river excavation for the channel and shipping.
(f) Work completed and model inactive.

(5691) SIR ADAM BECK-NIAGARA GENERATING STATIONS.

(b) Ontario Hydro.
(d) Experimental; for design.
(e) A 1:50 model of the trapezoidal section of the hydraulic canal leading to Sir Adam Beck No. 1 Generating Station was constructed in order to redesign an enlarged trapezoid in the earth section to accommodate the larger flows of the enlarged rock canal section up and downstream.
(f) Work completed and model inactive.

(5692) SIR ADAM BECK-NIAGARA GENERATING STATIONS.

(b) Ontario Hydro.
(d) Experimental; for design.
(e) A 1:50 scale model was constructed of the downstream end of the enlarged hydraulic rock canal leading to Sir Adam Beck No. 1 Generating Station, to design an enlarged section in order to recover velocity head of water travelling 17 fps and reducing to 12 fps where it merges with water in the new canal leading to Sir Adam Beck No. 2 Generating Station. Included in the model was an inclined ramp and a large central pier, 12 feet by 80 feet, for dewatering purposes.
(f) Work completed and model inactive.

(5693) MOUNTAIN CHUTE GENERATING STATION.

(b) Ontario Hydro.
(d) Experimental; for design.
(e) A 1:80 scale topographic model of the power site was constructed to determine cofferdam layout, tunnel port details and operation with a hinged-flap closure gate, sluiceway location, and downstream training walls and rock excavation, tailrace configuration and excavation, and beneficial location of spoil excavation.

(5694) INTAKE STUDY.

(b) Ontario Hydro.
(d) Experimental; for design.
(e) A 1:24 plexiglass model was constructed to determine the minimum opening in the dam face consistent with performance for a single-gated bell mouth type of opening. An upper transition from square to round and a lower transition made with a reducing elbow were also studied. Pressure planes were also tested with piezometer rings for use with the Gibson Method of testing a short penstock. Variations in opening radii, height of sill above bed etc., will be investigated later.

(5695) BARRETT CHUTE GENERATING STATION.

(b) Ontario Hydro.
(d) Experimental; for design.
(e) A 1:60 model was constructed for an existing station with a long headrace canal excavated in rock to which will be added two large units for peaking purposes. The model is being used to determine the design of a modified inlet to the deepened canal and an enlarged forebay leading to the new units.

(5696) PICKERING GENERATING STATION.

(b) Ontario Hydro.
(d) Experimental; for design.
(e) A 1:36 model of the hydraulic passages from Lake Ontario to the C. W. & Service water pumps for four 500 Mw units of a nuclear plant are being studied. Of particular interest are the waterways from the screenhouse, under the spent fuel bay and the pump well design. The water requirement is over 1,000 cfs per unit. Surge heights at shutdown are also being examined.

LASALLE HYDRAULIC LABORATORY LTD.

(4517) MONTREAL - SOREL SHIP CHANNEL.

(b) Department of Transport.
(d) Theoretical and experimental: design.
(e) Two models representing a section of the St. Lawrence River from Laprairie Basin including Montreal Harbour to Sorel Islands were built at a scale 1/150 vertically and 1/600 horizontally.
The purpose of the model was to study the improvement of navigation in this section of the St. Lawrence River.

(5425) LITTLE CURRENT SHIP PASSAGE.

(b) Dept. of Public Works, Canada and consulting engineers.
(d) Scale model study of navigation problems in Little Current Narrows with the aid of radio-guided ship model.
(e) Study of corrective measures for currents induced by wind, tide and seiche action.
(f) Completed.
(h) Report submitted to sponsor.

(5427) ARROW LAKES LOCK.

(b) C B A Engineering Ltd.
(d) Experimental; design.
(e) The purpose of the study carried out on a 1/20 scale model is to ascertain the hydraulic performance of the design of the lock and make the modifications suggested by these preliminary tests.
(f) Completed.
(h) Report submitted to sponsor.

(5428) PEACE RIVER TAILRACE.

(b) I P E C (International Power and Engineering Consultants Ltd).
(d) Experimental and theoretical; design.
(e) Study of a 1/96 scale model of the head losses and surge waves in the tailrace manifold and tunnel. A study of the flood spillway is in progress.

(5429) SNOW MELTING DEVICE.

(b) City of Montreal.
(d) Theoretical and experimental; design.
(e) Study on a 1/12 scale model of a circular type of snow melter in which the burnt gas of the burners develops a swirling flow in the snow dumping basin. This swirling flow improves heat exchanges, carries the floating slush on a circular weir in the center of the basin and transports the sand and debris on the bottom of the basin in a sand trap. With this patented type of snow melter, practically no mechanical components other than the burners are required.
(f) Completed.
(h) Report submitted to sponsor.

(6043) ILE NOTRE DAME ARTIFICIAL FOUNTAINS.

(b) D. W. Graham & Associates.
(d) Theoretical; design.
(e) Assistance in designing attractive layout of artificial watercourses for 1967 World's Fair.
(f) Completed.
(h) Report submitted to sponsor.

(5717) CHANDLER HARBOR BREAKWATER.

(b) Dept. of Public Works (Harbours and Rivers Engineering Branch), and Picard, Rochette and Marquis, Consulting Engineers.
(d) Experimental; for design.
(e) Flume tests at scale 1 in 50 to check the stability of the breakwater profile recommended in the preliminary phase of the design work.
(f) Completed.
(h) Report sumbitted to sponsor.

(5718) BURLEIGH FALLS LOCK (TRENT CANAL).

(b) Dept. of Transport (Canada), Canals Division.
(d) Experimental; for design.
(e) Hydraulic model investigation of the lock, at scale 1/20. Fast rates of operations had to be achieved, without detriment to light pleasure craft; emphasis was put on elimination of residual turbulence and surging in the lock, as well as immediately downstream from it, in the navigation channel, into which the lock is dumped.
(f) Completed.
(h) Report submitted to sponsor.

(5719) LAKE ST. JOHN SHORELINE PROTECTION.

(b) Saguenay Power Company Ltd.
(d) Field investigation and theoretical; design.
(e) Study of protective measures against wave erosion of fine sand deposits forming much of shoreline. Difficulties encountered were the extreme fineness of this sand, a dearth of cheap local stone or gravel of intermediate grades for construction, and great length of shoreline being eroded.
(f) Completed.
(h) Report submitted to sponsor.

(5720) QUEBEC ATOMIC POWER REACTOR.

(b) Atomic Energy of Canada Ltd.
(d) Theoretical and experimental; design.
(e) Study on scale models of the hydraulic problems involved by the emergency dumping process of the heavy water moderator.
Dump port shape was first studied on a 1/4 scale two-dimensional model in order to maximize the discharge capacity of the dump port. Then a 1:9.46 model of the reactor vessel was used to study problems pertaining to the dumping process.

(5721) NORTHERN MONTREAL SEWER COLLECTOR.

(b) City of Montreal.
(d) Theoretical; design.
(e) Study of the modification to be made to the sewer outlet to improve sewage flow discharge in the Riviere des Prairies.
(f) Completed.
(h) Report submitted to sponsor.

(5722) BACK FILLING IN THE ST. LAWRENCE RIVER.

(b) Department of Public Works, City of Montreal.
(d) Theoretical and design.
(e) A theoretical study was made to determine the influence which the back filling of the Ilets Verts would have on the flow velocities of the St. Lawrence River, as well as the ice conditions prevailing in this region, with respect to water levels.
(f) Completed.
(h) Report submitted to sponsor.

(5723) RAJASTHAN ATOMIC POWER PROJECT.

(b) Montreal Engineering Company Ltd.
(d) Theoretical; design.
(e) Study of a cooling water intake withdrawing from the bottom cool water layer and minimizing the hazard of vortices.
(f) Completed.
(h) Report submitted to sponsor.

(5724) TIDE MACHINE.

(b) Laboratory project.
(d) Designed and developed as laboratory equipment.
(e) Comparison of water level in model and cam reproducing the law of variation. Correction by pulse generated device.
(f) Completed.
(h) In operation in a scale model.

(5725) TRANSPORTATION OF PULPWOOD CHIPS IN PIPELINES.

(b) Laboratory project.
(d) Experimental; design.
(e) The use of an ejector to introduce the pulpwood chips into the pipeline was studied. The different characteristics of this ejector were determined. The problem of separating the chips from the water, at the end of the pipeline.
(f) Completed.
(h) Internal report.

(5726) CLOSING OF A DIVERSION TUNNEL.

(b) Hydro-Quebec.
(d) Experimental.
(e) A 1/96 scale model was used to determine the conditions pertaining to the closure of a diversion tunnel on the Outardes River. The method used consists in the blasting off of a mass of rock, suspended above the entrance to the tunnel. Completion of the closure is achieved by the piling up of layers of materials of diminishing size.
(f) Completed.
(h) Report submitted to sponsor.

(5727) ICE THRUST ON THREE RIVERS BRIDGE CAISSONS.

(b) Dufresne Engineering, Montreal.
(d) Theoretical and design.
(e) Estimation of forces of impact due to the ice on the caissons of the bridge under construction, across the St. Lawrence river.
(f) Completed.
(h) Report submitted to sponsor.

(5728) CURRENT DEFLECTORS - THREE RIVERS BRIDGE CAISSONS.

(b) Dufresne Engineering, Montreal.
(d) Experimental and design.
(e) A 1/78 scale model was used to determine the current conditions along the caissons of the proposed Three Rivers bridge when a deflector with a total nose angle of 90° is placed in front. Elimination of the surging motion in the protected area was achieved.
(f) Completed.
(h) Report submitted to sponsor.

729) SURGE TANK ORIFICE.

(b) Shawmont Engineering, Montreal.
(d) Empirical and design.
(e) An orifice was designed and tested on a 1/48 scale model, to obtain the required head losses. The corresponding head loss coefficient for flow conditions in both directions was measured.
(f) Completed.
(h) Report submitted to sponsor.

730) MANIFOLD DESIGN.

(b) Hydro-Quebec and consulting engineers.
(d) Theoretical and experimental.
(e) Two types of manifolds for the Manicouagan V Power project were tested on a 1/48 scale model. The head-loss coefficient pertaining to those two types were determined.
(f) Completed.
(h) Report submitted to sponsors.

731) ICE THRUST ON PILES.

(b) Montreal World Exhibition.
(d) Theoretical and design.
(e) Estimation of the ice thrust on the piers of a bridge in the St. Lawrence River.
(f) Completed.
(h) Report submitted to sponsor.

732) OUTARDES 4 POWER PROJECT: TAILRACE CANAL.

(b) Hydro-Quebec and consulting engineers.
(d) Experimental and theoretical; design.
(e) Study on a 1/96 scale model of the head losses at the exit from the turbines into the canal and from the canal into the river. Determination of the geometry best suited for minimum losses in both transitions.
(f) Completed.
(h) Report submitted to sponsor.

733) OUTARDES 3 RIVER: TAILRACE TUNNEL.

(b) Hydro-Quebec and consulting engineers.
(d) Experimental; design.
(e) Study on a 1/60 scale model of the head losses and surge waves in the tailrace tunnel. Determination of the dimensions of the tunnel best suited to ensure free surface flow.

734) SCOUR PATTERN UNDER SINKING CAISSON.

(b) Dufresne Engineering Ltd.
(d) Experimental for design.
(e) Model study of scouring of fine material as floating caisson is slowly sunk on the bottom of the river.
(f) Completed.
(h) Report submitted to sponsor.

735) STUDY OF PARTIAL CLOSURE OF THE ST. LAWRENCE RIVER.

(b) Canadian Corporation for the 1967 World Exhibition, and Consulting engineers.
(d) Theoretical and experimental for design.
(e) Determination of water levels and current patterns as one arm of the St. Lawrence between the South Shore and an island is closed.
(f) Completed.
(h) Report submitted to sponsor.

736) DESIGN OF A DAM IN A TIDAL ESTUARY.

(b) Department of Public Works of Canada.
(d) Study of different construction stages as an estuary with 18 ft. tides is gradually closed by a dam. Verification of scour conditions, determination of percolation conditions during operations. Study of the hydrology of the estuary; design of floodways and energy dissipators, etc.
(f) Completed.
(h) Report submitted to sponsor.

UNIVERSITY OF MANITOBA, Hydraulics Laboratory.

Inquiries concerning the following projects should be addressed to Prof. E. Kuiper, Dept. of Civil Engrg., Univ. of Manitoba, Fort Garry, Manitoba, Canada.

(5255) MOVABLE BED MODEL SCALES.

(b) University of Manitoba.
(d) Basic research in the hydraulics laboratory towards a masters degree.
(e) Tests have been conducted in a movable bed channel, 4 feet wide, 1 foot deep, and 20 feet long. Erosion patterns have been established, resulting from a coffer dam that blocked off half of the channel cross-section. Subsequent tests were conducted with smaller models and different bed materials to reproduce the same scour pattern.
(f) Tests completed.
(g) It was found that at differet scales, representative scour patterns cannot be reproduced when using non-uniform sand.
(h) Report completed.

(5998) PORTAGE DIVERSION INLET STRUCTURE.

(c) Manitoba Water Control Branch.
(d) Hydraulic design of inlet structure.
(e) The intake of the diversion channel near Portage La Prairie, with a control dam with vertical lift gates, was reproduced at an undistorted scale of 1:48 resulting in a model of 30x60 ft. Tests were conducted for prototype discharges ranging from 5000 to 45000 cfs.
(f) Tests completed.
(g) Tests enabled to shorten the design of the approach channel and the length of the stilling basin.
(h) Report completed.

(5999) HELICOIDAL FLOW IN RIVER BENDS.

(c) University of Manitoba.
(d) Basic research in the hydraulics laboratory towards a masters degree.
(e) The study was conducted in a fixed bed channel, 40 feet long, 1.0 feet wide and 0.5 feet deep with four curves of different radii. The helicoidal flow phenomenon was studied for different depths of flow.
(f) Tests completed.
(g) The tests proved that helicoidal flow can take place in a curved laboratory flume. Direction of bottom currents and transverse water surface slope were in agreement with the theory.
(h) Report under preparation.

(6000) RIVER BANK STABILIZATION.

(c) University of Manitoba.
(d) Basic research in the hydraulics laboratory towards a masters degree.
(e) Tests have been conducted in a movable-bed channel, 40 feet long, 10 feet wide and 0.5 feet deep with four curves of different radii. Basic stabilization measures consisted of spur dikes, jetties and revetments.
(f) Tests completed.
(g) The effect of the stabilization measures on the natural erosion patterns was studied and recorded. The findings were in general agreement with established theories.
(h) Report under preparation.

MCGILL UNIVERSITY, Department of Civil Engineering

and Applied Mechanics.

(4546) CAVITATION AT HIGH-HEAD SLUICE GATES.

(b) National Research Council, Canada.
(c) Dr. A. J. Reynolds, Dept. of Civil Engrg. and Applied Mechanics, McGill Univ., Montreal 2, P. Q., Canada.
(d) Experimental; applied research, for Doctoral degree.
(e) Study of pressure fluctuations on wall behind an obstruction which produces cavitation.
(f) Work transferred to 11" by 11" water tunnel.
(g) The flow was established in a syphon tunnel of section 3" by 3". Mean pressure distributions were measured for a wide range of blockage ratios, with and without air addition. Overall pressure recovery was found to be accurately predicted by momentum balance assuming one-dimensional flow. Length of eddy behind gate (without air addition) agreed with previous measurements of Rouse and Forthmann. The length of the eddy was found to be as much as twice that of the eddy formed in the very similar flow at a sluice gate beyond which there is a nearly level free surface.
(h) "A Syphon Tunnel for Studies of Control Gates" by A. D. Kapur. M. Eng. Thesis, Dec., 1964. "Operator's Manual for the 26-cm. Water Tunnel", by N. Rangaswami, Fluid Mechanics Note 8, Dept. of Civil Engineering, McGill University, July 1965.

(4923) DIVISION OF OPEN-CHANNEL FLOW.

(b) National Research Council, Canada.
(c) Dr. A. J. Reynolds, Dept. of Civil Engineering and Applied Mechanics, McGill Univ., Montreal 2, P.Q., Canada.
(d) Experimental; basic research, for Master's degree.
(e) Detailed examination of flow at junction between straight channel and a branch at 90°.
(f) Completed.
(g) All three sections of the experimental channel are 8" wide, the walls and bottom being plexiglas and painted steel. The features noted in several earlier studies of such flows have been fitted into a consistent pattern. Simple mathematical models have been found to describe almost every feature of the flow well away from the junction.
(h) "Dividing Flow in an Open Channel", by S. W. Law. M. Eng. Thesis, August 1965.

(4924) WAVES IN AND NEAR PACK ICE.

(b) Defence Research Board, Canada.
(c) Dr. A. J. Reynolds, Dept. of Civil Engineering and Applied Mechanics, McGill Univ., Montreal 2, P.Q., Canada.
(d) Theoretical and experimental; basic and applied research, for Master's degree.
(e) Study of fundamental mechanical processes of interaction between surface waves and floating elastic bodies.
(g) The dependence of reflection and transmission coefficient on wave-length, wave steepness, and the nature of the edge of the floating sheet has been determined experimentally. Wave celerity and damping in the system composed of sheet and water have also been determined.
(h) "Wave Celerity in a Floating, Elastic Plate," "The Energy of Waves in a Floating, Elastic Plate," "Influence of a Layer of Water above a Floating Plate," by A. J. Reynolds, Fluid Mechanics Notes 1, 2 and 7 of the Dept. of Civil Engineering, McGill University, June 1963 and July 1965.

(5280) UNIFORM DISTORTION OF TURBULENCE.

(b) Defence Research Board, Canada.
(c) Dr. A. J. Reynolds, Dept. of Civil Engrg. and Applied Mechanics, McGill Univ., Montreal 2, P.Q., Canada.
(d) Experimental; basic research for Doctoral thesis.
(e) Study of uniformly distorted turbulence to investigate the approach to equilibrium structure and the nature of that structure.
(g) Several distorting ducts have been constructed, to allow both planar and three-dimensional irrotational straining of grid turbulence. The case of plane straining has been studied in detail, the turbulence being found to respond in two respects in a manner markedly different from that reported by Townsend. The degree of anisotropy attainable is much greater; the relaxation of anisotropy upon release of the strain is much more abrupt.

(5669) GENERATION OF SURGES AND SOLITARY WAVES.

(b) National Research Council, Canada.
(c) Dr. A. J. Reynolds, Dept. of Civil Engrg. and Applied Mechanics, McGill University, Montreal 2, P. Q., Canada.
(d) Experimental and theoretical; basic research for doctoral thesis.
(e) Study of the generation and development of waves by a single stroke of a piston at uniform velocity.
(g) Apparatus being set up.

NATIONAL RESEARCH COUNCIL, Hydraulics Section, Division of Mechanical Engineering.

(4466) AIR BUBBLERS FOR PREVENTING ICE COVER FORMATION.

(b) Laboratory project.
(c) Dr. S. Incè, Head, Hydraulics Section, Natl. Research Council, Montreal Road, Ottawa 7, Canada.
(d) Experimental; field investigations.
(e) Field measurements and laboratory tests were performed to determine the mechanism whereby an air bubbler prevents ice formation in an oceanic environment.
(f) Completed.
(g) Investigations revealed that the efficiency and success of the operation depend upon the thermal reservoir of the oceanic environment.
(h) "A Guide to the Design of Air Bubblers for Melting Ice," S. Ince. Proceedings of the IX Conference on Coastal Engineering, Lisbon, July 1964.

(4525) FORMATION OF ICE IN RIVERS.

(b) Laboratory project.
(c) Dr. S. Ince, Head, Hydraulics Section, Natl. Research Council, Montreal Road, Ottawa 7, Canada.
(d) Experimental; field investigations.
(e) Water temperatures are being recorded in the St. Lawrence River between Kingston, Ontario, and Three Rivers, Quebec, to obtain information on heat losses.
(g) Preliminary calculations show satisfactory agreement between measured and computed heat losses. For closer correlation more precise measurement of meteorological conditions- particularly radiation- will be necessary.
(h) "Observations on the Winter Temperature Structure of the St. Lawrence River," S. Incæ and G. W. T. Ashe. Proceedings of the Eastern Snow Conference, Utica, New York, February 1964.

(5090) CODROY HARBOUR, NEWFOUNDLAND.

(b) Department of Public Works, Canada.
(c) Mr. J. Ploeg, Hydraulics Section, Natl. Research Council, Montreal Road, Ottawa 7, Canada.
(d) Experimental, for design.
(e) A 1:180 by 1:120 fixed-bed wave and current model of the harbour has been constructed to investigate silting conditions in the harbour entrance and to devise remedial works.

(f) Completed.
(g) A 750-ft. long new breakwater and a change of direction of an existing breakwater was found to reduce siltation of the harbour.

(5094) PERFORATED VERTICAL-WALL BREAKWATER.

(b) Laboratory project.
(c) Mr. G. E. Jarlan, Hydraulics Section, Natl. Research Council, Montreal Road, Ottawa 7, Canada.
(d) Experimental and theoretical.
(e) Two-dimensional flume experiments are being made to determine the behaviour of an erodible bed in front of the breakwater.
(f) Completed.
(g) Results obtained hitherto indicate that, for a non-cohesive bed, no erosion develops at the toe of the breakwater regardless of the wave height or period.
(h) "A Perforated Vertical-Wall Breakwater," G. E. Jarlan. The Dock and Harbour Authority, Vol. XLI, No. 486, April 1961.

(5766) CHURCHILL HARBOUR, MANITOBA.

(b) National Harbours Board, Canada.
(c) Mr. T. M. Dick, Hydraulics Section, Natl. Research Council, Montreal Rd., Ottawa 7, Canada.
(d) Field investigation.
(e) Surveys are conducted to determine ice formation and movement in the estuary to determine means of extending the navigation season.

(5767) WAVE CLIMATE STUDY, LAKE SUPERIOR.

(b) Dept. of Transport, Canada.
(c) Mr. J. Ploeg, Hydraulics Section, Natl. Research Council, Montreal Rd., Ottawa 7, Canada.
(d) Field investigation.
(e) Accelerometer type wave recorders are installed at four locations in Lake Superior to measure waves and correlate with the wind field.

QUEEN'S UNIVERSITY AT KINGSTON, Hydraulic Laboratories.

(3364) LITTORAL DRIFT AND ITS EFFECT ON THE HARBOURS ON THE NORTH SHORE OF LAKE ONTARIO.

(b) The National Research Council of Canada.
(c) Dr. A. Brebner, Ellis Hall, Queen's Univ., Kingston, Ontario, Canada.
(d) Experimental and field; basic and applied.
(e) Two-dimensional investigation of mass transport and sediment movement with and without superimposed currents; three-dimensional model investigation of the waves generated by a moving vessel in shallow water.

(4057) THE TRANSPORT OF MATERIAL IN PIPE-LINES.

(b) The National Research Council of Canada.
(c) Dr. A. Brebner, Ellis Hall, Queen's Univ., Kingston, Ont., Canada.
(d) Laboratory investigation.
(e) Pipes of differing shapes being used to study the parameters affecting the critical velocity of deposition.
(h) "Derivation of Regime Equations From Relationships For Pressurized Flow By Use Of The Principle Of Minimum Energy-Degradation Rate," by K. C. Wilson, Queen's, C. E. Report No.51.

(5287) LABORATORY INVESTIGATION OF THE INTENSITIES OF SECONDARY CURRENTS IN AIR FLOWS.

(b) National Research Council of Canada.
(c) Prof. S. S. Lazier, Queen's Univ., Kingston, Ontario, Canada.
(d) Basic research for Master's Degree.
(f) Suspended.
(g) Report being prepared.
(h) Second Master's thesis accepted.

(5673) THE ATTENUATION OF WATER WAVES BY A FLOATING PULPWOOD BREAKWATER.

(b) The Pulp and Paper Research Institute of Canada.
(c) Prof. R. J. Kennedy, Queen's University, Kingston, Ont., Canada.
(d) Experimental project for Master's thesis.
(e) The attenuation of waves of various size and steepness by log masses of different characteristics was measured in the laboratory.
(f) Completed.
(g) Substantial dissipation of wave energy was achieved, a paper is being prepared.

(5674) STUDIES OF FLOW-THROUGH VORTICES.

(b) The National Research Council of Canada.
(c) Prof. R. J. Kennedy, Queen's University, Kingston, Ont., Canada.
(d) Experimental and theoretical project for Master's and Doctoral theses.
(e) Velocities, pressures and turbulence characteristics in a series of closed flow-through vortex chambers are being measured by photographic and electronic techniques.
(h) Master's thesis accepted.

UNIVERSITY OF TORONTO, Department of Mechanical Engineering.

(1298) DISCHARGE CHARACTERISTICS OF WEIR-TYPE SPILLWAYS.

(b) Laboratory project.
(c) Prof. L. E. Jones, University of Toronto, Toronto 5, Canada.
(d) Experimental; applied research for master's theses.
(e) A long-term research carried out with a view to systematizing discharge characteristics for spillways having various pier spacings and proportions.
(g) Significant correlations obtained via special plotting techniques.
(h) Report in preparation.

(2252) HYDRAULIC FLOW IN OPEN CHANNELS OF VARIABLE SLOPE.

(b) Laboratory project.
(c) Prof. L. E. Jones, Univ. of Toronto, Toronto 5, Ontario.
(d) Experimental; fundamental and applied research.
(e) A doubly-tilting, variable-section flume facility of 160 ft. length is under construction. Provision is being made for a wide range of experimental conditions.

(3003) ROUGHNESS PHENOMENA IN OPEN CHANNEL FLOW.

(b) Laboratory project.
(c) Prof. L. E. Jones, University of Toronto, Toronto 5, Canada.
(d) Experimental and analytical; basic research for doctoral thesis.
(e) Critical analysis of the hydraulic radius concept and the effect of cross-section geometry on the resistance to flow in conduits. Detailed evaluation of mean flow parameters such as friction coefficients, static pressures, velocities, and wall shear stresses. The channel under study was 70 feet long and had a variable rectangular cross-section of 3 x 1, 3, 9 inches, respectively, and used air as the fluid medium.
(f) First project completed; others in progress.

(4889) UNSTEADY LAMINAR FLOW IN SHORT, CLOSED CONDUITS.

(b) Laboratory project.
(c) Prof. H. J. Leutheusser, University of Toronto, Toronto 5, Canada.
(d) Experimental and analytical, basic research for master's thesis.

(e) Various cases of unsteady (oscillating) laminar flow as encountered in typical viscous damping devices are being investigated.
(f) Completed.
(h) Report in progress.

(4890) CHARACTERISTICS OF FLOW OF FLUID-SEDIMENT MIXTURES.

(b) Laboratory project.
(c) Prof. H. J. Leutheusser, University of Toronto, Toronto 5, Canada.
(d) Experimental, basic research.
(e) Evaluation has been achieved of mean flow parameters such as friction coefficients, static pressures, velocities and wall shear stresses in a two-dimensional closed conduit of 1:10 aspect ratio, for pure air flow. Work on fluid-sediment mixtures is in preparation.

(5256) OPTIMUM HEIGHTS OF CHIMNEYS.

(b) The Municipality of Metropolitan Toronto, Department of Works.
(c) Prof. G. R. Lord, University of Toronto, Toronto 5, Canada.
(d) Experimental, applied research for design information.
(e) Determination, in wind tunnel, of thickness distributions of zone of separated flow on roofs of various building shapes. Results will form basis for code on minimum heights of roof-mounted chimneys.

(5623) FLOW IN POROUS MEDIA.

(b) Laboratory project.
(c) Prof. L. E. Jones, Univ. of Toronto, Toronto 5, Canada.
(d) Experimental and analytical; applied research for master's thesis.
(e) As an approach to fundamental considerations of fluid flow in porous media, flow has been investigated in a two-dimensional wavy channel.
(g) Significant progress has been made on suitable computer procedures for various flow conditions.
(h) "Investigation of Flow in a Two-Dimensional Wavy Channel," K. B. Elgohary, M. A. Sc. thesis, Univ. of Toronto, 1966.

(5624) OPEN-CHANNEL PROFILE ANALYSIS.

(b) Laboratory project.
(c) Prof. L. E. Jones, Univ. of Toronto, Toronto 5, Canada.
(d) Analytical, basic research.
(e) Fundamental computational projects are being reviewed and investigated by computer analysis.
(g) Improved extrapolation procedures indicate that significant accuracy of integration can be achieved with confidence and economy.

(5626) FLOW IN A WEDGE WITH POROUS WALLS.

(b) Laboratory project.
(c) Prof. W. D. Baines, Univ. of Toronto, Toronto 5, Canada.
(d) Experimental and theoretical; basic research for doctoral thesis.
(e) The flow of a fluid with a narrow wedge (less than 10 degrees included angle) is being investigated for walls made of screen. Pressure gradients and velocity distributions are being studied.
(g) Peculiar characteristics have been found for flow approaching a screen at a small angle. Pressure drop is much greater than that predicted by simple theory.

(5627) BUILDING AERODYNAMICS.

(b) Division of Building Research, National Research Council of Canada.
(c) Prof. H. J. Leutheusser, Univ. of Toronto, Toronto 5, Ontario.
(d) Experimental; applied research for design information.
(e) Determination of pressure distributions for block-type and cylindrical buildings in a constant-velocity wind field. Critical analysis of model testing techniques as employed in building aerodynamics.
(g) Net uplift force on roofs with eaves increases with eave width and building height. Strong experimental evidence indicates that ratio of boundary-layer thickness to building height is a significant similitude parameter in experimental building aerodynamics.
(h) "Pressure Distribution on a Cube at Various Degrees of Boundary-Layer Immersion," H. J. Leutheusser, Univ. of Toronto, Mechanical Engrg. Tech. Publication Series, TP 6502, 1965.
"The Effects of Eaves on the Roof Pressure-Coefficients of Block-Type and Cylindrical Structures," H. J. Leutheusser, Univ. of Toronto, Mech. Engrg. Tech. Publ. Series, TP 6503, 1965.

(5628) WATER-FLOW-INDUCED AIR CURRENTS.

(b) Laboratory project.
(c) Prof. H. J. Leutheusser, Univ. of Toronto, Toronto 5, Ontario.
(d) Experimental, basic research for master's thesis.
(e) Using a covered 50-foot tilting flume, air motion as induced by uniform open channel flow is being studied.

(5629) DYNAMICS OF A TURBULENT LINE VORTEX PAIR.

(b) Laboratory project.
(c) Prof. J. F. Keffer, Univ. of Toronto, Toronto 5, Canada.
(d) Experimental and theoretical; basic research for doctoral thesis.
(e) Counter-rotating turbulent line vortices are convected by a free stream. The characteristics of the turbulence, entrainment, velocity profiles and vortex interaction are being determined by conventional hot-wire anemometer equipment and visual techniques.

(5630) MOTION OF BODIES IN STRATIFIED FLUIDS.

(b) Laboratory project.
(c) Prof. J. F. Keffer, Univ. of Toronto, Toronto 5, Canada.
(d) Experimental and theoretical; basic research for doctoral thesis.
(e) The initial wake formation, asymptotic turbulent wake are being examined for various shaped bodies. A heated wind tunnel is being used to obtain stratification.

(5631) INVESTIGATION OF PERIODICITY IN TURBULENT WAKES.

(b) Laboratory project.
(c) Prof. J. F. Keffer, Univ. of Toronto, Toronto 5, Canada.
(d) Experimental and theoretical; basic research.
(e) With hot-wire anemometer and flow visualization techniques, characteristics of a turbulent wake are examined. The wake has been strained laterally to amplify turbulent motions.
(g) Results indicate that the large eddy motions have a definite periodicity, not directly related to von Karman frequency. Indications are that large motions are initiated by interaction of von Karman street with lateral periodic motions. A more detailed investigation of conditions during the breakdown into turbulence is under way.
(h) "The Uniform Distortion of a Turbulent Wake" by J. F. Keffer, Journ. of Fluid Mechanics, 22 (1965), pp. 135-139.

(6001) TRANSITIONS FROM PRESSURE TO FREE-SURFACE FLOW.

(b) Laboratory project.
(c) Prof. H. J. Leutheusser, Univ. of Toronto,

Toronto 5, Canada.
(d) Experimental and theoretical; basic research for doctoral thesis.
(e) Fluid separation from ceiling of closed two-dimensional conduit is studied. Motion is laminar and steady. Analysis is completed, experimental proof in progress.

(6002) EFFECTS OF SKIN FRICTION ON PERFORMANCE OF HYDRAULIC JUMP.

(b) Laboratory project.
(c) Prof. H. J. Leutheusser, Univ. of Toronto, Toronto 5, Canada.
(d) Experimental; basic research for master's thesis.
(e) Effects of floor roughness on the efficiency of stationary hydraulic jumps in horizontal rectangular channels is being studied.

(6003) SMOKE DIFFUSION FROM INDUSTRIAL STACKS.

(b) Contract research.
(c) Prof. G. R. Lord, Univ. of Toronto, Toronto 5, Canada.
(d) Experimental; applied research for design purposes.
(e) Wind-tunnel study of stack discharge as affected by a highly complex array of surrounding buildings. Model measured 25 ft. x 25 ft. and included 20 different industrial-sized stacks.
(f) Completed.

(6004) JET SHEETS WITH LATERAL PRESSURE.

(b) Laboratory project.
(c) Prof. W. D. Baines, Univ. of Toronto, Toronto 5, Canada.
(d) Experimental; basic research for master's thesis.
(e) Measurements are made of the shape, velocity and pressure distribution of a two-dimensional jet sheet across which a pressure difference exists. Comparisons are made with elementary theory.
(g) For low pressures the jet shape obeys the one-dimensional momentum equation and the velocity distribution is not affected. The shape is strongly affected by downstream obstacles.

(6005) STRATIFIED FLOW THROUGH CURVED SCREENS.

(b) Laboratory project.
(c) Prof. W. D. Baines, Univ. of Toronto, Toronto 5, Canada.
(d) Experimental and theoretical; basic research for doctoral thesis.
(e) Uniform flow with a small lateral temperature gradient passes through a screen of arbitrary shape. Downstream velocity and temperature profiles are being studied.
(g) Theory has been developed which indicates shape required to produce linear velocity distribution. Preliminary tests confirm theory.

(6006) REYNOLDS STRESS IN TURBULENT STRATIFIED FLOW.

(b) Laboratory project.
(c) Prof. W. D. Baines, Univ. of Toronto, Toronto 5, Canada.
(d) Experimental; applied research for doctoral thesis.
(e) Measurements are being made of spread of temperature and velocity discontinuities in otherwise uniform flow of a temperature - stratified fluid, as well as of Reynolds stress and turbulent heat transfer.

(6007) FLOW-INDUCED VIBRATION OF CANTILEVER BEAMS.

(b) Laboratory project.
(c) Prof. W. D. Baines, Univ. of Toronto, Toronto 5, Canada.
(d) Experimental and theoretical; applied research for doctoral thesis.
(e) Cantilevered vertical cylinders are mounted on elastic bases in an air stream. Reaction to the von Karman vortex trail produces a vibration which interacts with the trail. Fluid force produced on such an elastic body is being studied.

(6008) PUMP AND PIPE SYSTEM TRANSIENTS.

(b) Laboratory project.
(c) Prof. L. E. Jones, Univ. of Toronto, Toronto 5, Canada.
(d) Analytical; applied research.
(e) Computer solutions of equations for various combinations of pump and pipe characteristics.
(g) Results to date indicate a significant effect caused by shape of characteristic curves.
(h) Report in preparation.

(6009) MATHEMATICAL STUDIES IN HYDROLOGY.

(b) Laboratory project.
(c) Prof. L. E. Jones, Univ. of Toronto, Toronto 5, Canada.
(d) Analytical; applied research.
(e) Various methods of analysis are under study: deterministic and probabilistic methods, stochastic processes, synthetic flow series, regulation procedures over short and long time-periods, etc.

(6010) LEAST-SQUARES FITTING OF RIVER RATING-CURVES.

(b) Laboratory project.
(c) Prof. L. E. Jones, Univ. of Toronto, Toronto 5, Canada.
(d) Analytical; applied research.
(e) Proper attention to statistical weighting requires involved computing techniques. Suitable simple alternatives have been developed which have a wide applicability.
(h) Report in progress.

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