NBSIR 79-1787

MIUS Feasibility - Five Exploratory Studies

by
David J. Mitchell

Center for Building Technology
National Engineering Laboratory
National Bureau of Standards

January 1980

hudmius
MODULAR INTEGRATED UTILITY SYSTEMS
improving community utility services by supplying electricity, heating, cooling, and water/ processing liquid and solid wastes/ conserving energy and natural resources/ minimizing environmental impact

For
Division of Energy, Building Technology and Standards
Office of Policy Development and Research
The Department of Housing and Urban Development
Washington, D.C. 20410

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FOREWORD

HUD - MIUS Program

The Department of Housing and Urban Development (HUD) conducted the Modular Integrated Utility System (MIUS) program devoted to development and demonstration of the technical, economic, and institutional advantages of integrating the systems for providing all or several of the utility services for a community. The utility services included electric power, heating and cooling, potable water, liquid waste treatment, and solid waste management. The objective of the MIUS concept was to provide the desired utility services consistent with reduced use of critical natural resources, protection of the environment, and minimized cost. The program goal was to foster, by effective development and demonstration, early implementation of the integrated utility system concept by the organization, private or public, selected by a given community to provide its utilities.

Under HUD direction, several agencies participated in the HUD-MIUS Program, including the Department of Energy, the Department of Defense, the Environmental Protection Agency, the National Aeronautics and Space Administration (NASA), and the National Bureau of Standards (NBS). The National Academy of Engineering provided an independent assessment of the program.

This publication is one in a series developed under the HUD-MIUS Program and is intended to further a particular aspect of the program goal.

CONTENTS

UNITS OF MEASURE AND S.I. CONVERSION FACTORS

In NBS Document LC 1056, revised August 1975, guidelines were established to reaffirm and stengthen the commitment of NBS to the greatest practicable use of the International System of Units (S.I.) in all of its publications and also in all of its dealings with the science and engineering communities and with the public. In this report the measurements are those of the U.S. Customary units.

The following conversion factors are appropriate for the units of measure that appear in this report:

Area

1 acre = 4046.873 square meter (m^2)
1 square foot (ft^2) = .09290304 square meter (m^2)

Energy

1 British thermal unit (Btu) = 1055.056 joule (J)
1 kilowatt-hour (kWh) = 3600000.0 joule (J)
1 ton-hour = 12660672.0 joule (J)

Flow Rate

1 U.S. gallon per minute (gpm) = 0.0000630902 meters^3/second
= 63.0902 centimeters^3/second (cm^3/s)
= 0.0630902 liters/second (L/s)

Length

1 inch (in.) = 0.0254 meter (m)
1 foot (ft.) = 0.3048 meter (m)
1 mile = 1609.347 meter (m)

Mass

1 pound-mass (1 lb) = .4535924 kilogram

Temperature

1 degree Fahrenheit (°F) = $(1.8)^{-1}$ kelvin (K) or (°K)
Temperature Fahrenheit (°F)= (459.67 + temp. °F)/1.8 (°K)

Time

1 hour (h) = 60 minutes (min) = 3600 seconds (s)

Volume

1 U.S. liquid gallon (gal) = 0.003785412 meter^3 (m^3)
= 3.785412 liters (L)

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Abstract

This report highlights the collaborative efforts of the National Bureau of Standards, the National Aeronautics and Space Administration, and their contractors in the comparative analysis of a Modular Integrated Utility System (MIUS) and conventional utilities for five separate housing projects. The collaborative efforts consist of three separate tasks:

1. Comparative Environmental Analysis
2. Comparative Energy Analysis
3. Utility System Design and Cost Analysis

1. EXECUTIVE SUMMARY

1.1 TASK DESCRIPTION

This report describes a collaborative effort to determine how much energy can be conserved for utilities by five housing projects serviced by a MIUS in lieu of conventional means. This collaborative effort also quantified relative MIUS cost in terms of initial costs, annual costs and environmental impact. The residential utilities studied were: electricity, heating, air conditioning, domestic hot water, potable water, wastewater treatment and solid waste disposal. The collaborative effort was based on housing projects selected at random. Both NASA and NBS completed separate energy and cost analyses. These analyses investigated the impact on each utility and on utility service to a housing project as a whole. This report also details the methods utilized to design and to evaluate MIUS and conventional utility systems for each housing project. It should be of interest to individuals interested in MIUS design and the projected relative impacts of MIUS on residential utility service.

The membership of the collaborative effort consisted of: Mr. Clinton W. Phillips (NBS) - Chairman; Mr. Carey F. Lively (NASA) - Alternate Chairman; Mr. Harold E. Benson - NASA; Mr. William L. Carroll - NBS; Mr. John R. Schaefgen - NBS; and Mr. Barry M. Wolfer - NASA. Hittman Associates Inc., Charles J. R. McClure Associates, Inc. and Wapora, Inc. provided contract support to NBS.

Section 1. is an overview of this report. It defines the tasks undertaken, the issues addressed, approach adopted, the preliminary results obtained, and how such results should be interpreted. Section 2. presents a comparative environmental analysis of each of five housing projects. Wapora, Inc. developed the environmental analyses for both MIUS and conventional utility service under contract to NBS. Section 3 presents a comparative energy analysis of MIUS and conventional utility service for each of the five housing projects.

The Urban System Planning Office (USPO) developed the comparative energy analyses for NASA; Hittman Associates and J.R. McClure Associates, for NBS. Section 4 presents the comparative economic analyses. The same teams developed the analyses in Section 4.

1.1.1 Task 1 - Comparative Environmental Analysis

MIUS and conventional utility system design information, including plant performance data (e.g., effluent quantity and quality), was received as input from Task 3 (1.1.3-Utility System Design and Cost Analysis). These performance data, combined with site characteristic data supplied by the developer and that determined by site visits, were used to determine the environmental impact of both MIUS and conventional utility systems on each housing project and on the region at large.

Under contract to NBS, Wapora has prepared an environmental evaluation system and checklist (Table 1.1.1.1) to be used for the five housing projects. Wapora evaluated proposals for four cases: Site Before Development; Development Only; Development With MIUS; and Development With Conventional Utilities. The basic system utilized is an adaptation and simplification of the Environmental Evaluation system as proposed by Battelle - Columbus in July 1973. Wapora has altered the methodology to reflect the terrestrial orientation of the housing projects and the modest amount of environmental data which was available at the time of the field survey. The field survey and environmental evaluation were performed by the same three individuals to minimize orientation and subjective errors.

1.1.2 Task 2 - Comparative Energy Analysis

The developer's site plans, conceptual building plans, and preliminary engineering reports were used to formulate input for the site load calculations. Supplemental information was obtained where necessary. A complete, detailed analysis of the housing project buildings was undertaken to generate the site loads, both occupancy and weather related, at both average and "design" conditions. These data were used as an input to initiate the utility system design activities under Task 3. The calculated site loads were compared to the developer's predicted site utility loads. Only the calculated site load data were used in Task 3.

MIUS and conventional utility system design data input from Task 3 were used along with the calculated loads data to calculate the comparative energy consumption. The energy consumption data included both the secondary (e.g., electricity, district heat at the point of conversion) and primary (e.g., oil, gas, nuclear, and coal) energy demand and consumption necessary to meet the calculated site loads.

Table 1.1.1.1

Environmental Evaluation System
MIUS
Parameter List

ECOLOGY
- Terrestrial Species and Populations
  - Vegetation
  - Large Animals
  - Small Animals
  - Pests
- Aquatic Species and Populations
  - Vegetation
  - Fish
  - Waterfowl
  - Pests
- Terrestrial Habitats and Communities
  - Rare and Endangered Species
  - Species Diversity
- Aquatic Habitats and Communities
  - Rare and Endangered Species
  - Species Diversity

PHYSICAL/CHEMICAL
- Biochemical Water Quality
  - Dissolved Oxygen
  - Nutrient Levels
  - Fecal Coliform
- Chemical Water Quality
  - Hazardous Materials
  - pH
- Physical Water Environment
  - Frequency of Extreme Flows
  - Temperature
  - Turbidity
- Land Use
  - Development Suitability
  - Induced Secondary Development
  - Soil Erosion
  - Solid Waste Disposal
- Noise Pollution

AESTHETICS
- Land
  - Surface Configuration
  - Land Appearance
  - Geological Surface Material
- Air
  - Odor
  - Visual
  - Sound
- Water
  - Flow
  - Clarity
  - Floating Material
- Biota
  - Terrestrial Animals
  - Aquatic Life
  - Vegetation
- Man-Made Structures
  - Architectural Design Structures
  - Compatibility with Other Structures and Natural Envir.
  - Planting and Site Design
- Composition
  - Composite Effect
  - Unique Composition

SOCIAL
- Environmental Interests
  - Recreational Activities
  - Educational/Scientific
- Community
  - Regional Economic Impact
  - Community Housing Participation
  - Impact on Community Services
  - Relocation

1.1.3 Task 3 - Utility System Design and Cost Analysis

Based on the calculated site load data received as input from Task 2, a conceptual design was generated for the conventional utilities system described by the developer. This design utilized existing power generation, solid waste, potable water and sewage treatment facilities as available to the site. If any of these services did not exist (e.g., sewer moratorium was in effect), the design utilized alternative typical systems.

Again based on the input data from Task 2, a generic MIUS design was tailored for the particular site. The generic MIUS design consisted of:

1. Engine-generators;
2. Exhaust and jacket heat recovery;
3. Auxiliary boiler;
4. Absorption and compression chillers;
5. Four-pipe hot and chilled water site distribution system
6. Solid waste incinerator with heat recovery (where beneficial);
7. Physical-chemical packaged liquid waste treatment systems with effluent recycle for cooling tower make-up, fire protection and lawn watering;
8. Potable water treatment (where beneficial);
9. Site electrical distribution system;
10. Plant control, monitoring and environmental control systems; and
11. Thermal storage (where beneficial).

The conventional and site-tailored MIUS conceptual design data were used as output to three parallel analysis activities: first, to the Task 2 comparative energy conservation analysis; second, to the utility system costing activity (another element of Task 3 analysis); third, to the Task 1 comparative environmental analysis. The utility system costing element of Task 3 consisted of: (1) initial capital cost estimating for all components of both the MIUS and conventional systems; (2) operating and maintenance (O & M) cost estimating for purchased services, fuel, labor, materials and applicable taxes; and (3) capital cost estimating for capital replacement items. The O & M estimating utilized energy data input from Task 2. Costs were developed using site or regional variations as available for fuel, labor, purchased utility services, and taxes. The O & M items and capital replacement items were cost-estimated for the first year of expected operation with appropriate cost escalation factors applied. The capital and O & M data were then used to calculate the cost on an annual basis, including debt service at 8% interest for 20 years.

1.1.4 HOUSING PROJECTS EVALUATED

In the course of the comparative analyses, many residential/commercial projects were identified which were in various stages of construction. This section will describe five such projects which were subjects of the study. Table 1.1.4.1 gives a brief comparative outline of the five housing projects.

Table 1.1.4.1

Housing Project Descriptors

	Housing Project				
	#1	#2	#3*	#4	#5
Dwelling Units:	767	344	1264	1628	500
MH (%)		58			
SFA (%)	69		29	34	100
SFD (%)		30	55	25	
MFLR (%)	31	12	16	41	
Building Number	76	151	773	515	94
Acerage	102	210	327	625	100
Density (DU/A):					
Gross	7.5	1.6	3.9	2.6	5.0
Net		4.2	6.3	6.1	
Present Land Use	Farm	Farm	Suburban	Suburban	Suburban

Legend:

MH - Mobile Home
SFA - Single-family attached
SFD - Single-family detached
MFLR - Multi-family low rise
MFHR - Multi-family high rise
Gross - Total site
Net - Immediate site occupied by DU's
* - Includes Village Center - 20,000 ft^2

1.1.5 Author's Note

The report is a summary of previously unpublished initial MIUS feasibility studies which were not originally intended for publication purposes. These studies were not published because the energy, cost, and environmental analyses were based on MIUS and conventional utility system conceptual designs. The author did not participate in this effort. This report is an accurate condensation of the documentation which was developed by NASA and NBS.

1.2 PRESENTATION OF THE RESULTS

1.2.1 Comparative Environmental Analysis

The information available for each of the five housing project sites evaluated did not permit a rigorous comparison of environmental considerations. This is principally due to the fact that only one of the five projects had reached a stage of planning sufficiently advanced to provide this necessary information except in conceptual terms.

A review of the findings indicates that, in terms of environmental consequences, the utilization of a MIUS is favored when considering the quality of wastewater discharges and is relatively equal in comparison to conventional utility services when considering land use.

1.2.1.1 Housing Project #1

MIUS is rated higher in regard to wastewater, since addition of a high-quality effluent to the nearby creek would be more desirable than sending the waste to the secondary treatment plant. MIUS also rates higher in regard to solid waste because of the reduction in the volume which must be sent to landfill. MIUS rated slightly higher than conventional in terms of land which must be devoted to utility services.

1.2.1.2 Housing Project #2

Solid waste disposal favors MIUS; but to a lesser extent because of the small size of the project and the probable ease of finding landfill sites. MIUS is favored when wastewater disposal is considered because of the problems which might be required in adapting a septic tank system to a community of this type, especially when the water table may reach to near the surface in times of flooding. Land use is considered to favor the MIUS slightly, primarily because of the area which will have to be devoted to the septic system.

1.2.1.3 Housing Project #3

The rating for wastewater is about even. There is no advantage associated with the high quality of the MIUS effluent if disposed of by spray irrigation. Solid waste disposal is becoming a problem in the metropolitan area. There is no advantage for either utility system in terms of land use.

1.2.1.4 Housing Project #4

The use of MIUS would be favored based on wastewater as a high quality effluent to the river rather than to discharge a secondary effluent to the river. The reduction by MIUS in the amount of solid waste which must be transported to landfill is an advantage. However, solid waste disposal sites are not scarce. In terms of land use there would seem to be no advantage to either option.

1.2.1.5 Housing Project #5

With spray irrigation of the wastewater effluent for both systems, there is no advantage to either system. If permission could be obtained to discharge into the river, MIUS would have a considerable advantage because of the higher quality of its effluent. Because of the scarcity of suitable sites for sanitary landfill, the smaller amount of solid waste from the MIUS is a significant advantage. In terms of land use, MIUS is penalized slightly because of increased requirements for the environmentally desirable forest land.

1.2.2 Comparative Energy Analysis

Energy values were calculated for MIUS and conventional utility service by both NASA and NBS teams for each housing project. In some cases, site assumptions used by NASA and NBS were somewhat different. No effort has been made to reconcile differences in site assumptions and systems designs on which energy calculations are based.

The NASA MIUS and conventional systems designs were fairly standardized for all sites. The MIUS system used diesel engines with heat recovery from the exhaust, water jacket, and lube oil. Solid waste was incinerated and the heat recovered. Heating was accomplished with recovered heat and supplemented by boilers when required. Cooling was accomplished by a floating compression/absorption split. Thermal storage was used where applicable. The NASA conventional design was a standard system not tailored to individual sites, but providing a standardized comparison for different MIUS installations. It assumed a power generation efficiency of 30% and uses central heating and cooling systems for all buildings except single-family dwellings.

The NBS-MIUS design was similar to NASA's with some exceptions. Heat was not recovered from the lube oil and, in some cases, from the incineration process. The conventional systems were tailored to each site and, for instance, used natural gas when available. Natural gas was also used in the NBS-MIUS when it was available and more efficient.

The energy requirements resulting from these designs are presented in Table 1.2.2.1. First the NASA MIUS and NASA conventional (CONV) systems are compared, then the NASA MIUS and NBS conventional systems, and finally the NBS MIUS and NBS conventional systems. Although there are differences in the numbers as derived by NASA and NBS due principally to the variations

Table 1.2.2.1

Energy Comparisons

(All energy numbers in 10^9 Btu's)

Housing Project #	NASA MIUS	NASA CONV	%Savings
1	115	168	32
2	52	60	13
3	417	514	19
4	327	460	29
5	81	121	33

Housing Project #	NASA MIUS	NBS CONV	%Savings
1	115	302	62
2	52	33	-58
3	417	496	16
4	327	485	33
5	81	217	63

Housing Project #	NBS MIUS	NBS CONV	%Savings
1	144	302	52
2	36	33	-9
3	398	496	20
4	461	485	5
5	106	217	51

in assumptions as described above, a trend for significant MIUS energy savings relative to conventional utility service is clearly demonstrated.

1.2.3 Utility System Design and Cost Analysis

The analysis was based on the comparison of the differential costs between MIUS and conventional including the O & M costs and debt service on the capital. Cost data are summarized in Table 1.2.3.1. The elements involved in the analysis are: the capital costs of MIUS and conventional utility systems; the annual operating and maintenance costs for MIUS and conventional utilities; and cost projections of fuel, capital goods, labor and the cost of capital. The capital costs are for 1976; O & M costs for 1977. In general, there is good agreement between the basic cost numbers determined by NASA and Hittman/McClure.

1.3 CONCLUSIONS

1.3.1 Comparative Environmental Analysis

This study indicates that there is little or no difference in the magnitude of the environmental impact attributable to the installation and operation of a MIUS in lieu of conventional utility services.

The treated wastewater discharged from the MIUS for each of the five housing project sites will be of higher quality than that achieved by the off-site waste treatment plant which will be used by the community if there is no MIUS. The specifications for water quality that the MIUS must meet assure the validity of this conclusion. An evaluation of the receiving stream when using a MIUS versus the municipal waste treatment plant was made for each housing project. Three of the projects will discharge into the same receiving stream regardless of which of the alternative treatment plants is employed. Housing Project #4, however, will discharge into a river if the regional wastewater treatment plant is used, and to a second river if a MIUS is employed. The first is much larger; however, the minimum flow of the second is approximately 1,000 gpm, which is three times the volume of treated wastewater to be discharged by the MIUS. The high quality of the discharge would therefore not be expected to exceed the assimilative capacity of the river. Housing Project #3 would in all probability employ spray irrigation for the discharge of the MIUS. The site had not yet been selected for the regional treatment plant that would be used as the eventual alternate to the MIUS. Summarized, in terms of water discharges, the environmental quality for each project would be improved rather than reduced if a MIUS is utilized for the treatment of the wastewater generated by the proposed community.

It has been decided that the sanitary sludge generated by MIUS will not be incinerated, due to potential problems associated with the performance of incineration equipment if sanitary sludge was included with the solid waste. This restraint dictated conventional landfill. The alternative wastewater treatment facility available to each of the five housing project sites apparently would have also employed landfill as the means of disposal of the sanitary sludges. The information made available does not indicate

Table 1.2.3.1

Cost Summary

	Housing Project				
	#1	#2	#3	#4	#5
Capita Cost ('75 $ x 10^{-3})					
MIUS (H/M)*	5532	2776	10171	11862	5029
MIUS (NASA)	5058	1961	10373	13546	5169
CONV (H/M)	1220	699	1461	2461	1444
CONV (NASA)	4643	1672	10573	12665	4640
Annual Cost ('77 $ x 10^{-3})					
MIUS (H/M)	1011	399	2240	2648	906
MIUS (NASA)	548	240	1276	1343	446
CONV (H/M)	975	204	2330	2911	902
CONV (NASA)	545	193	1207	1425	418
Annual Savings('77 $ x 10^{-3}) (w/o plant amort.)					
H/M	-36	-195	90	263	- 4
NASA	- 3	- 47	-69	83	-28
Annual Savings ('77 $ x 10^{-3}) (w/plant amort.)					
H/M	-471	-405	-790	-686	-366
NASA	45	-76	-49	-6	-81

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* Legend:
H/M - Hittman Associates/Charles J.R. McClure Associates
NASA - Urban Systems Project Office, Johnson Space Flight Center, National Aeronautics and Space Administration

that any of the municipal treatment plants incinerate sludge. Therefore, since the disposal technique and site employed as are the same for the sanitary sludge generated by the proposed communities, the environmental degradation attributable to this disposal method will be essentially equal whether or not the community utilizes a MIUS.

The facilities planned for the five housing projects to accommodate and control storm water drainage and run-off would have been installed regardless of which alternative was employed to provide utilities. Three of five housing projects planned to create two small ponds on the development site to provide storage for run-off control which would have represented an improvement in the environmental quality in carefully designed and maintained facilities. Housing Projects #1 and #2 planned to provide storm water run-off drainage out-falls to the streams that are on the site property lines. The detailed information necessary to evaluate the environmental effects of these run-off facilities was not available. However, due to the proximity of the receiving streams, careful design and planning can produce effective results with minimal undesirable environmental consequences.

Each project provided for potable water supply employing the same facilities regardless of the presence or absence of a MIUS. The water supply was on-site or adjacent to the site for all projects except the one located at Housing Project #1. At this site a water supply appeared to be available within 1,000 to 1,500 feet of the development property line. The land area required to provide a right-of-way for a pipeline would be approximately one acre, and would have probably paralleled existing roads. The environmental effects would have therefore been minimal.

1.3.2 Comparative Environmental Analysis

The methods of providing heating and cooling had a significant effect on energy consumption on both the MIUS and conventional utilities. In particular, the use of strip heaters required considerably more energy than heat pumps or gas heating. This factor can be as large as 20% of the energy savings.

The recovery of heat from incineration can provide approximately 15% of the total energy requirement of a housing project. The utilization of this energy varied significantly with the heating and cooling requirements of the site which varies considerably with the season. Various heat values and amounts of trash produced affected the availability of recoverable incinerator heat. Better data on these variables are needed.

The recovery of lubrication oil thermal energy provided approximately 10% of the total energy requirement of a building site; the feasibility of this concept required further demonstration. Thermal storage could also benefit MIUS in several situations.

1.3.3 Utility System Design and Cost Analysis

The density of dwelling units served affected the MIUS cost in the distribution of services, particularly HVAC. Also, the percentage of single family dwellings (SFD's) affected the energy balance in that it was not cost effective to serve all SFD's with central hot and chilled water; therefore, electricity produced for SFD's did not provide for the use of recovered heat. Use of air-to-air heat pumps on a site powered by a MIUS was about the same in energy usage and was, therefore, not energy conserving in contrast to individual fuel-fired systems.

Fuel availability affected energy savings and costs. In general, natural gas used in a conventional system was relatively cheap and constrained the viability of a MIUS. Fuel oil prices and relative growth rate of fuel prices was a strong influence on fuel use and its cost. The escalation rates for oil and gas can change the relative order of energy savings and costs for the housing projects.

Institutional factors such as sewage treatment plant installation constraints can be a strong influence on cost. The dis-economy of scale was less favorable for the sewage treatment portion of MIUS than for the total energy portion of MIUS.

1.3.4 Individual Housing Projects

Housing Project #1 presented a desirable site in terms of density, thermal loads and number of dwelling units. Up to sixty-two percent of the raw energy required to provide utilities to the site could have been saved by use of the MIUS. This is due, in large part, to the fact that natural gas was unavailable to the site, resulting in an all-electric installation for the conventional case. Seventy percent of the the site was within a 100-year flood plain with poor bearing soil, but the developer planned to develop the site in a manner to eliminate these problems. The only serious technical drawback of the site was the high (greater than 65 dBA) noise level due to truck traffic on a nearby interstate highway.

Housing Project #2 presented an undesirable site in terms of density, thermal loads and number of dwelling units. The least energy savings were possible, since both MIUS and the conventional alternative used natural gas for heating. The MIUS wastewater and solid waste treatment processes were more energy intensive than conventional. Less efficient engines intensified the already high site electrical/thermal load ratio. The annual cost (excluding capital recovery) would be three times that of the conventional alternative due to significant diseconomies of scale. In addition, with the exception of Housing Project #4, a poor capacity factor (again due to the purely residential load), small project scale, and low density required a plant amortization cost more than twice as high as that of any other site. Projected housing demand and land use plans for the area did not suggest any viable alternatives to the present site. Housing Project #2 had the most favorable MIUS environmental impact.

Housing Project #3 was undesirable in terms of density, thermal loads, and construction timing. Further commitment to all-electric homes was not compatible with MIUS utility services. These factors resulted in a modest 20% energy savings (little use for recovered heat) and a small annual operating deficit when compared to conventional dwelling unit utility expenses.

Housing Project #4 suffered greatly from low density and the availability of natural gas for small scale (residential) users. An energy savings of only eleven percent could be shown against this most efficient conventional energy system. A moderate annual cost (excluding capital recovery) for MIUS services resulted in a projected annual savings excluding the overcost of the MIUS plant. Possible improvements in energy savings and economics could result from a reduced service area. A reduced solid waste load and improved wastewater treatment favored the MIUS approach to utility services.

Housing Project #5 presented a desirable site in terms of density, but the high thermal loads and modest project scale (500 townhouses) had negative effects. Again, 57% of the raw energy required to serve the project could have been saved due largely to the unavailability of natural gas in the area. An annual cost saving (excluding capital recovery) was projected using the MIUS. A poor capacity factor and high peak demands explain why this annual savings was insufficient to capitalize the second most expensive plant in terms of initial cost. The most significant feature of this building site was that the conventional alternatives are hypothetical. The developer cannot build without a MIUS due to lack of a sewer connection. The developer's problems and Housing Project #5 typify the market MIUS is likely to serve. The need for housing was evident, but the means to provide water and sewer to new suburbs is often not available.

2. COMPARATIVE ENVIROMENTAL EVALUATION

The objective is to provide information concerning the environmental suitability of each housing project site in such a manner as to assist the identification of typical land use parameters to be encountered in MIUS replication and to determine how such parameters impact utility design--MIUS and conventional. Special attention has been paid to those items which were particularly outstanding in either a positive or a negative sense.

2.1 EVALUATION METHODOLOGY

Section 2. represents the efforts of Wapora Inc., under contract to NBS, to evaluate the environmental suitability of each of the five housing project sites.

2.1.1 Before Development

The environmental status of the housing project sites before development is evaluated taking the following into account: (1) terrestrial biota; (2) aquatic biota; (3) water quality; and (4) noise.

2.1.1.1 Terrestrial Biota

Vegetation is assessed on a quality and quantity basis. Quality of vegetation, when viewed from the local perspective, is the degree to which vegetation approaches conditions natural to that area. Quantity of vegetation is again a function of local natural conditions. For example, a desert landscape has considerably less vegetation than a densely wooded area, but if each is consonant with its natural condition it is of highest environmental quality.

This assessment must account for both natural and domesticated animals. Because of the growing scarcity of the former in the vicinity of urban areas, their presence is taken as an indication of higher EQ (Environmental Quality). EQ is also related to area natural conditions. Small animal presence is measured indirectly, using project area and surrounding habitat as a guide. Pest species are indicators of the degree of disturbance of system. They include large areas of weeds, plant diseases, excessive insect populations, etc.

Rare and endangered species include an evaluation of species for both local, regional and would-wide scarcity. Species diversity was estimated in the field visit.

2.1.1.2 Aquatic Biota

Aquatic vegetation includes phytoplankton, rooted aquatic wetland vegetation. Fish are estimated from on-site observations coupled with stream data. Fish include resident and migratory species in wetlands and aquatic areas. Pests are viewed as aquatic plants and species which are harmful or annoying to man, fish, waterfowl and aquatic vegetation.

Rare and endangered species can be aquatic biota as well as waterfowl. An estimate is made from available data and the field survey. Species diversity is estimated from literature and direct observation, using water pollution as an indicator.

2.1.1.3 Water Quality

In the absence of on-site monitoring, EQ of biochemical water quality is estimated from past records. Nutrient level is estimated using the symptoms of elevated nutrient levels as a guide such as enrichment and eutrophication. Fecal coliforms are a direct indication of pollution by human and animal wastes when the concentration exceeds normally low natural levels, below 10^2 MPN/100 mL.

Hazardous materials include pesticides, heavy metals, and some organic compounds. Hazardous materials are toxic materials which produce acute effects in biological systems. pH is a measure of acidity or alkalinity of a stream and is commonly most affected by industrial discharges or mine drainage. Because natural pH varies from location to location, this parameter is measured in terms of deviations from the natural.

In urban areas, paving affects water run-off patterns. In extreme cases, flooding may become common after a water shed is urbanized. Because the direct land area involved is small, the evaluation of the physical water environment required exercise of engineering judgment for the building alternatives. For the no-build alternative, EQ is rated as a function of the presence of development-induced flow variation on local streams. Temperature is significant from the standpoint of its deviation from natural condition in the water body. Turbidity measures the loss of transparence in a water body due to suspended solids. It is of major concern to aquatic organisms.

2.1.1.4 Noise

Noise impact is a function of three parameters - the frequency, the intensity of disturbing noise, and the time of day. The parameter used will be the L_{10} level (the noise level exceeded 10% of the time). Two tables are to be used (each rated 30 minimum) - one for daytime levels and the other for nighttime. If no nighttime data is available, the daytime table should be used and the appropriate points described. The L_{10} level is in dBA.

2.1.2 Site Engineering Suitability

The objective is to present the principal areas of concern as to soil suitability for land use application. The engineering features evaluated are related to erosion, contour of the land, bearing capacity, and permeability. The potential for erosion is related to the type of soil and the slope of the area, and is estimated from information available from various agencies. However, even with an erosive soil, various soil conservatiion methods can often be applied to stabilize or reduce the full impact.

The contour of the land is also of importance in other aspects of site usage. The steeper slopes may increase construction costs and problems of drainage, and hence lead to problems such as local flooding and erosion. Permeability is an important site factor because it is related to surface drainage, and hence to problems such as local flooding and erosion. The bearing capacity of a soil is considered in relation to the type of structure which can be economically put on the site. The sites are considered for frequency of devastating parameters, such as flooding, seismic risk, tornados, etc.

2.1.3 Social and Economic Evaluations

The objective is to evaluate each site socially and economically. Two perspectives are assumed. First, the suitability of the site itself for development is evaluated. The converse suitability of the development for the site is also evaluated.

2.1.3.1 Site Suitability for Development

Specific criteria for judging site suitability for development are: land use; social resources; proximity to present or planned developed areas; and community attitudes. Present land use and planned future land use are taken as a measure of compatibility of potential site development with institutional norms established to control and direct growth in conformance with societal goals. Nonconformance with a local land use plan is not necessarily an absolute bar to development, since land use planning is partially a political process, and classification of land for future land use is subject to revision and change.

Certain sites, because of unusual terrain characteristics such as steep slopes, may not be suitable for the construction of new projects. Compatibility asks the question "is the proposed new land use compatible with existing land use on site and bordering the site?" For example, is this a high density residential development adjoining an industrial area? Is this development on previously undeveloped land? Undeveloped land is felt to have a minimum impact on the environment and therefore has a high environmental quality.

Soil erosion is a broad indicator of environmental impacts on land use and varies with topography, rainfall, type of soil, etc. Consequantly, this parameter is evaluated subjectively. If no provisions are made for the disposal of solid waste from a project, the impact of a project can be significant. Due to the fact that these controls can vary significantly according to local conditions, a subjective judgment is required again. Controls could range from complete incineration with air pollution control (extensive) to open burning (no control).

Social resources indicate in an approximate way the attributes in a region that contribute to a varied and interesting environment. Included under this heading are recreational opportunities available to area residents, in-door, out-door, participant or spectator. Impact will vary with the degree of development in area. Undeveloped areas should be examined to see if the potential exists for any or all of these. Developed areas should be examined to see whether any of them actually do take place (within a reasonable traveling distance in both cases).

Natural features of scientific or educational interest in the local area also are deemed to be social resources. Certain aspects of project sites may be of certain educational and/or scientific value to people. This can apply to people in the locality, to the region where the project is located, or to a national interest. For example, Niagara Falls would be a site of national interest, while a stream may be of just local interest. The third component of social resources is historical or archeological significance. Certain project sites also may have aspects which are of historical and/or cultural value. These aspects will be rated as in the educational-scientific case.

Another site attribute that effects the social suitability for development is the relative proximity of site to existing or planned developments. A site that is more distant from present or future development is considered to contribute more to "sprawl" type development than is one adjacent to development. Additionally, such a site may involve greater cost in providing utilities and other social services. If the relative isolation of a development reduces the level of services provided to its residents, a social cost is incurred both by the project residents and, to a leser extent, by society in general.

The last aspects of site suitability to be considered are community attitudes. These are defined and measured as the extent of public interest in issues of local growth and development and the level of participation by public officials or the general population in project planning.

2.1.3.2 Suitability of Development for a Particular Site

Project suitability is judged on the following criteria: aesthetics; impact on community services; induced secondary development; and regional economic impact. While aesthetics tends to be a subjective assessment, there are elements which can be used to make the assessment more objective.

Aesthetics

Surface configuraton measures the deviation of surface configuration from natural conditins, caused by man's activities. Land appearance assesses the impact of man-caused changes and usage on the "tidiness" of the land, as reflected in litter and degree of erosion. The geological surface impact is related to the presence of unique out-croppings and formations which add interest, color, and texture to the land area.

Odor conditions at a site, or due to human activity, affect aesthetic values. Visual aesthetics measures EQ as impacted by visible air pollution. Sound measures the aesthetic impact of man's activities as well as those of nature.

Water courses derive considerable aesthetic impact from their flow characteristics. Fast moving white water is normally considered more aesthetically interesting. Aesthetically, water bodies are considered to be of greater value when they are clear. Clarity measures the aesthetic assets of water clarity.

In general, with more animals present, the interest and aesthetic pleasure will be higher. Aquatic life evaluates aesthetic pleasure derived from aquatic life. A subjective rating is based on the amounts of game fish and other forms of aquatic life.

Architectural style is evaluated in terms of its compatibility with the area, of the degree to which it reflects regional of historical styles, and of its funcitonalism. Site design refers to the arrangement of housing units, to commercial and service areas, and to open space. Site design considers the topography and vegetation of the site. Compatability refers to arrangement of land uses within the development as well as those land uses adjacent to the development. Architectural aesthetics are subjective. Styles differ greatly and evoke diverse response from various observers. Projects and community developments can be styled and located in such a manner as to blend, rather than clash, with their surroundings (compatibility). Planting and site design reflect the survey teams assessment of the aesthetic assets of the proposed site plan.

Composition quantifies the overall effect upon the senses and emotions of the interplay of land, air, water, biota, and man-made structures. The criterion is like, dislike, or neutrality to the aesthetic impact of the site. Unique composition identifies rare or unique physical and biological elements in aesthetic composition of site. Uniqueness is the principal criterion.

Impact on Community Services

The second criterion of suitability of the proposed project is its expected impact on community services. Under this criterion the effect of the development on such community srvices as transportation facilities, fire and police protection, provision of educational, recreational and health care facilities, and water and sewer must be estimated. The magnitude of the expected impact is determined at least in part by project size and the proximity and extent of development of existing services. In some areas, for example, schools may be adequate to handle additional students but sewers may be inadequate to handle additional new loads.

Induced Secondary Development

Induced secondary development is a third standard for evaluating development suitability. This criterion attempts to estimate the potential for additional unplanned development in the area stemming from the project development. This potential is again a function of project size, the existing commercial infrastructure, and planned commercial development associated with the site development.

Virtually all construction projects cause some form of induced secondary development. If this growth occurs in a planned manner, it is not necessarily bad. Serious problems can arise when such growth occurs in an unplanned manner. If a residential development occurs in an area where there is a significant infrastructure of retail stores, food stores, ovie theaters, etc., the amount of secondary development will be miniized. However, if the development occurs in an undeveloped or underdeveloped area there will be a significant degree of secondary development. The percent of undeveloped or underdeveloped land within 1/2 mile of the project site is used as a parameter to measure secondary development.

Regional Economic Impact

All projects will have some degree of economic inpact on the community in which they are situated. This will vary with the extent to which the region is developed. Regional economic impact is an approximation of the positive or negative effect the project will have on the region's economy. The scale of the project relative to the area's economy is one determinant of its impact. Also of importance is the relative timing of the project, i.e., whether it is the opening wedge of future development in the area or whether it is absorbing existing demand for housing in a developed, relatively stable area.

2.1.4 Federal, State and Local Regulations

The objective is to analyze the compatibility of MIUS and conventional utilities at each site with various local, regional, and state regulations.

This category includes the compatibility of the MIUS installation and site with various local, regional, and state regulations regarding zoning, approvals and permits, licensing, planning, and water and air pollution. Such considerations include applicable regulations concerning required construction and operating permits; instrumentation, testing, and records; operator training and certification; compatibility with local and regional zoning and planning; and applicable air and water regulations.

2.1.5 Comparison of MIUS and Conventional Utilities

The objective is to identify the environmental consideratons associated with the utilization of a MIUS in lieu of conventional utilities to provide all the utility services to each of five housing project sites.

The five housing projects were carefully reviewed to determine the source and means by which each community would be provided with power, heating, cooling, water supply, wastewater treatment, solid waste disposal, and storm water drainage facilities. In addition, an evaluation was made of the relative quality of wastewaters discharged to the environment and the quantity of sanitary sludge and solid waste generated by utilization of conventional utility services or the MIUS.

2.2 PRESENTATON OF RESULTS

2.2.1 Housing Project #1

2.2.1.1 Before Development

Refer to Figure 2.2.1.1. The plant and animal species diversities are low on this site because most of the area is being used for agriculture. The major portion of the site is flat land devoted to corn; the northeast corner is a rolling pasture. Plants other than agricultural species were found in fence rows, along the edges of fields, or along the deep eroded drainage ditch which appears to drain most of the site into a creek. No natural or native stands of vegetation were present on the site. The lack of natural vegatation and the simple structure of the plant communities makes this site a potentially poor habitat for birds and other terrestrial animals. The presence of the creek does furnish a habitat for muskrats and migratory waterfowl. Deer and raccoons appear to use the creek as a food or water source, but these animals would have to be regarded as transients because the vegetation simply does not provide adequate food and shelter or materials for home construciton. Most of the plants present in the area are weedy species that are characteristic of disturbed sites. The probability of the site containing rare plants or animals is extremely low.

The creek is fast-flowing at the north portion of the site, becoming slower and with more pools further to the south. It is obviously subject to wide fluctuations in level, being normally about 35 feet below the level of the surrounding ground, but rising to near the surface during floods. While not obviously polluted, the creek had a large algae population, indicating good nutrient supply, which is not surprising in this agricultural area.

There appeared to be considerable run-off entering the site from the community to the north. This and the run-off from the site have eroded a long, deep ditch near the center of the site, draining into the creek. Further indication of erosion problems was supplied by several portions of the fence which borders the field having fallen into the creek bed. The run-off, entering the site and from the site itself, will have to be conveyed by storm sewer to the creek. Consideration should be given to the possibility that this will increase the already-present flooding problems downstream. Local residents say it has not flooded within memory (about 50 years), but that flooding does occur downstream. A smaller creek, the southern boundary of the site, is similar to the larger creek,

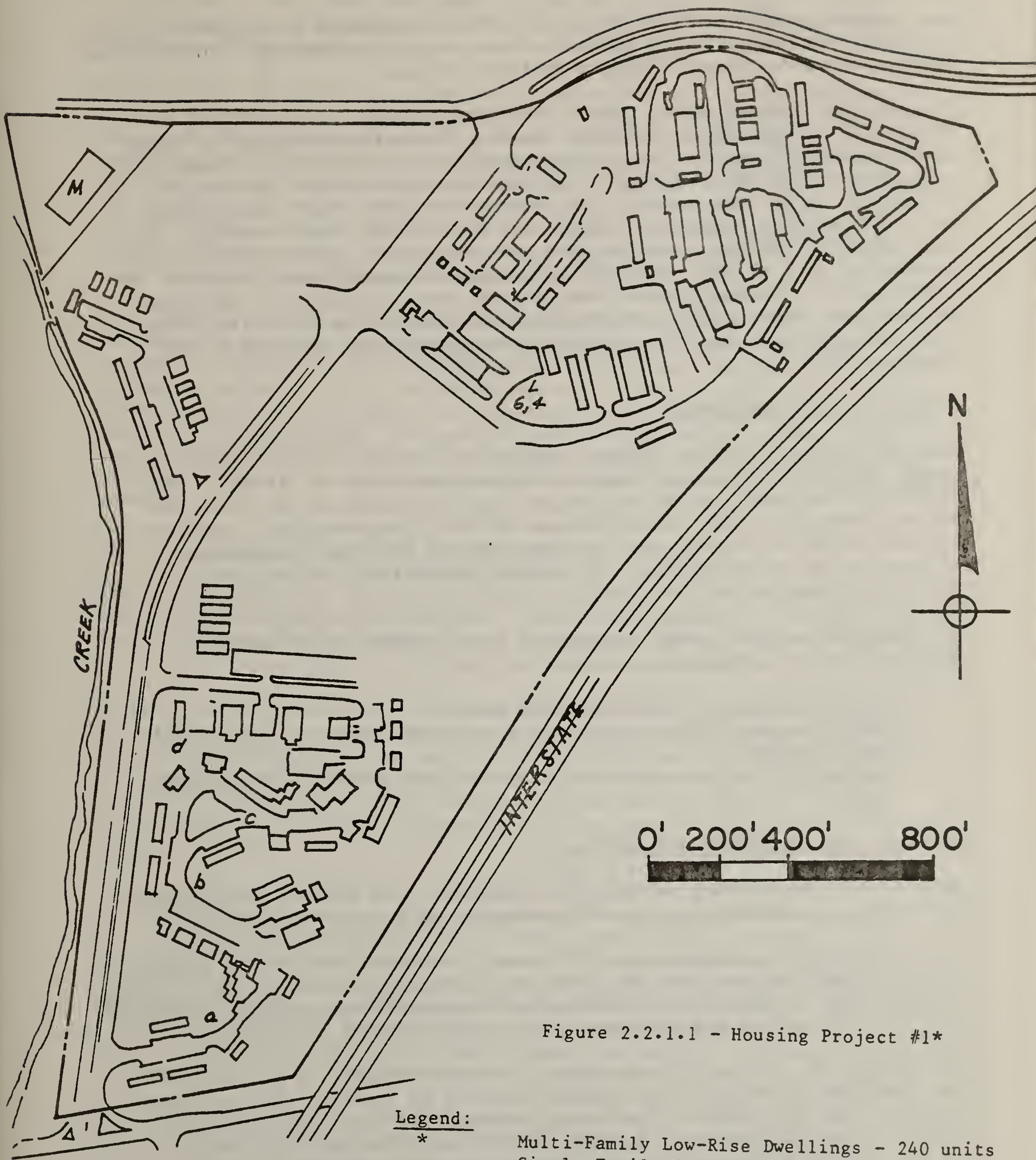


Figure 2.2.1.1 - Housing Project #1*

Legend:
* Multi-Family Low-Rise Dwellings - 240 units
Single-Family Attached Dwellings - 527 units

and somewhat higher in nutrient level. Neither appeared to be grossly polluted, and neither would appear to have any special aesthetic or sporting value; both were typical flatland drainage creeks.

The site is bordered on the west by the larger creek. The west bank of this creek is occupied by railroad tracks. The eastern boundary is interstate highway. Onsite noise readings show the railroad trains producing the highest readings (75-78 dBA) for three minutes. Trains were noted to pass by three times a day. The interstate highway has a noise level of 52-58 dBA with automobile traffic and 74 dBA with trucks passing. At approximately 600 feet into the site from the highway, readings on trucks passing by were 68 dBA. Aircraft were observed passing near the site. No readings were obtained because they did not pass directly over the site. An extensive noise study is recommended on this site as the noise levels obtained show some conflict with HUD noise regulations outlined in HUD Circular 1390.2.

2.2.1.2 After Development

This agricultural site is already completely altered from its natural state, so the environmental impact of development will be minimal. The field will be taken out of cultivation, but the impact on the plant and animal communities will be low because of their low diversity. Most of the plants in the project area are weed species that have naturalized in much of the United States. The animal populations are confined to the creeks that border the site.

As discussed earlier, there are several site problems which must be addressed in the development design:

- °Locaton within the 100-year flood plain;
- °Channelization of the runoff could increase downstream area flood severity; and
- °Susceptibility to erosion will require good erosion and siltation control

2.2.1.3 Site Engineering Suitability

Several site engineering suitability parameters need special consideration before the installation of the MIUS community in Housing Project #1.

The total area is approximately 102 acres. Presently half of the acreage is being used for crops and the other half for cattle grazing. The majority of the trees at this site are located on the western and southern boundaries with up to 20 walnut and oak trees scattered throughout the interior.

The contour of the land is relatively flat on two-thirds of the site with the remaining northeast third having slopes of 18 to 22%. This existing contour marks the limits of potential flooding due to a 100 year storm. The State Natural Resources Council clearly qualifies that two-thirds of the site is a flood plain resulting from creek water overflows. In the middle of the flood plain area on the southern half there appears a drainage ditch approximately 1,650 feet long by 90 to 100 feet wide and 35 to 40 feet deep.

The soil has the following properties as reported by the U.S. Department of Agriculture, Soil Conservation Service. The soil throughout the site is a dark silty loam. On the two-thirds which is in the flood plain area the slope is 0% to 2%. The remaining third of the site slopes from 5% to 20%. The soils permeability in general is qualified as being moderate. The depth of the water table on the flatter land is 3 to 5 feet, while on the rolling terrain depths of greater than 5 feet are necessary to reach the water table. The report indicates that the surface soil is a good topsoil material but not suitable for other uses.

The flatland area is generally qualified as having severe limitation for building, principally because of the poor bearing capacity and shear strength. As for a septic tank disposal field, the same area is qualified as having moderate to severe limitation due to the occasional high water table, moderate permeability and vulnerability to flooding. For a sewage lagoon or effluent pond, the area is severaly limited by flooding and water table problems. The rolling terrain has the same qualities as discussed for the flatlands except that the septic tank disposal field conditions improve.

2.2.1.4 Social and Economic Evaluations

Land use on this site is primarily agricultural. The area immediately to the north is occupied by a College. The site is bounded on the west and east by transportation corridors - a railroad to the west and an interstate highway to the southwest. Farther west is a compact residential development.

Revised land use and zoning maps are currently being prepared so current projections of land use of the site are not available. The previous land use plan showed the site as mostly "other Public and Semi-public" with the remainder as "Open Space and Conservation" (the former presumably referred to ownership to this site by the community college). In the text, however, the report recommends that the area be maintained as a conservation area because of its position on the flood plain of the two creeks.

The recreational opportunities reflect the urban character of the SMSA and the rural area surrounding it. Parks, golf courses, swimming pools and other recreational facilities normally found in an urban area are found in Housing Project #1. There are 19 parks, three golf courses, and two swimming pools, in addition to playing fields, playgrounds, and school facilities. Fishing, hunting, and boating are available in the surrounding rural areas. Opportunities for water-based recreation requiring large bodies of water are limited somewhat, however, as are most winter sports.

There are no natural features of scientific or educational value on the site. A small non-public wildlife refuge located a few miles north of the site, is one point that may be of educational interest.

The housing project site is within the corporate limits of a city. Although it is located in an area that is relatively undeveloped as yet, the site is proximate to the residential areas. Additional development is occurring adjacent to the community college campus north of the site.

The architectural design of the proposed development is a rather conventional two-story garden apartment complex. Exterior finish of stucco and wood will creat an interesting effect. Lack of trees and shrubs initially will create a rather bleak appearance although the amount of planting shown on the site plan will remedy this in time.

The compositional effect of the development, expecially in its early years, will be hindered by the relatively flat terrain of most of the site, and the lack of trees to soften building profiles and to create an impression of cohesion. The existance of interstate highway along the eastern edge of the site also is detrimental.

Transportation routes, expecially the interstate highway, are the major difficulties with land use compatibility. Noise pollution may be a problem along the eastern portion of the site, along with potential air quality problems.

The impact of this housing project on community services is expected to be minor because of its relatively small projected population and its location in an area where utilities and other services are already available. Sewers would be the major exception at the present time if MIUS were not used. A sewer line paralleling the interstate highway has inadequate capacity at peak periods to accommodate further development in the area. Several bond issues which would have increased sewer capacity for this area have failed in recent years.

A new elementary school is scheduled for construction adjacent to the project site. Also a declining school population has created capacity to absorb an increase from the housing project.

Induced secondary development resulting from this housing project also is expected to be negligible. A projected population of approximately 2,500 will not create much demand for additional commercial development. The site also is located within city limits with its existing commercial area. In addition, a major new commercial area is planned within a mile of the site at the interchange of interstate highway and a state highway.

Regional economic impact of the project will be minimal. Its small scale, its residential character and its location rule out major effects. Short-term construction-related employment and its net effect on local government finances are the only expected effects, and these should be minor.

2.2.1.5 State and Local Regulations

The State does not have any laws, rules, or regulations governing the integrated utility system, but it does regulate the components of the modular integrated utility system. These components are: potable water treatment, wastewater treatment, solid waste disposal and electric power generation including heat dissipation from cooling towers.

Electric Power Generation

There is no State agency that deals with construction and operation of a power plant and of a cooling tower. Environmental concerns in utility operation fall within the realm of the State Environmental Quality Department.

The State Commerce Council has rate setting responsibilities and regulates distribution systems as specified by the State Code. As far as it could be determined, the State does not have any certification or operator training programs.

Space Heating and Air Conditioning

Since the blowdown from the cooling tower is treated by the wastewater treatment plant of MIUS, the treatment requirements will be the same as specified in the National Pollutant Discharge Elimination System (NPDES) Discharge Permit which will be required.

Solid Waste Disposal

The Division of Solid Waste of the State Department of Environmental Quality has jurisdiction over solid waste management in the State. The state laws do not permit disposal of hazardous materials in a landfill. The State has an annnual inspection program for landfills. Certification of

landfill operators is not required. Residues from incinerators will have to be chemically analyzed prior to disposal in a landfill. Wastes from a potable water treatment plant should be spread on agricultural land, instead of landfill disposal. The State is requiring the general area to have a landfill in operation by July 1, 1975. Hence, a new landfill for a MIUS project will not be required.

The State Department of Environmental Quality, Division of Air Quality has control over permits to construct incinerators. Manufacturers information must be submitted for review prior to application for the permit. There are no operator's permit requirements at this time. For incinerators which burn under 1,000 lbs/hr, particulate emissions must not exceed 0.35 grains per standard cubic foot dry corrected to 12% CO_2; to burn over 1,000 lbs/hr, 0.2 grains per standard cubic foot dry corrected to 12% CO_2.

Wastewater Treatment

The Division of Water Quality has the responsibility over design, construction and operation of wastewater treatment plants. The Division issues construction and operation permits after review of plans and specifications of the proposed facility. The Division certifies wastewater treatment operators and the type of certification is dependent on the size of the treatment facility and population served. The degree of treatment required will be high because the effluent from the treatment plant will be discharged into a creek, which has definite water-quality requirements. Combination of cooling tower blowdown and municipal wastewater may require adjustments in treatment in order to meet applicable water quality standards. The best practical treatment will have to be provided.

The rules and regulations for testing and records are being revised at present. In general, monthly operating reports are required by State. These reports include data on: BOD, suspended solids, fecal coliform. The type of certificate depends on the population served. The State conducts operator training courses once a year.

Potable Water Treatment

The Division of Water Quality has the jurisdiction over issuing construction and operation permits for potable water treatment plants. The Division will review the application and supporting documents and then issue the permits upon satisfactory review. It also certifies potable water treatment plant operators.

The State Council of Natural Resources has legal jurisdication over water withdrawal from any source and water use. Application to the Council for the necessary permit must indicate amount of water withdrawn, water use, legal ovnership of the land and a map showing water storage, point of water withdrawal and point of water diversion, if from a surface source of supply. The applicable standards are those specified in 1962 U.S. Public Health Service Drinking Water Standards. The Division reviews plans and specifications for treatment if the source of water supply is surface. The Division recommended connecting to the existing water supply system. However, plans for connection and distribution system, will have to be submitted for approval prior to construction.

The State requires two samples for bacteriological analysis per month for populations up to 2,000 people and three samples per month for populations up to 2,500 people. The State certifies potable water treatment plant operators for water supply from a surface source. A Grade III Plant Operator will be required for the project if a surface source of water supply is used. The operator training courses are conducted by the State on a once-per-year basis.

Planning and Zoning

In general, there are no conflicts with any plans for future development of the area. The site is zoned as "open-space" area, which means that the area is being held open for a systematic development. According to the County Zoning and Planning Office, the area is primarily classified as suburban and industrial area. If a shopping center is built, as a part of the project, then the area will have to be rezoned to include commercial clasification. The City has jurisdiction over areas up to two miles from the city limits and city approvals will be needed for any development within this area. The County requirements include approval of subdivision, streets, water, and sewer lines. As far as the City is concerned, it will rule on the application for rezoning. This application will have to include all supporting documentation regarding plans for development of the area and the reasons for the development. As far as environmental standards are concerned, both the City and County require that the appropriate State and Federal standards be met.

The State Council of Natural Resources has legal jurisdiction over any construction in a flood plain area. The development has to be protected from a 100-year flood of creek or river. The construction has to be carried out in a manner that will not increase the flood stage by one foot or more. The Council has to give consideration to equal and opposite encroachment in reference to any future construction. The development has to be located landward or out of the floodway. The floodway of the creek has not yet been delineated, but will have to be developed prior to any construction. The developer must apply to the Council of Natural Resources to issue permits for building and construction in the flood plains of the Creek. The application for the permits must be accompanied by the engineering plans for the development (to include locations of buildings, streets and utilities and to show the extent of flood plain obstructed) and by data on cut and fill involved.

2.2.1.6 <u>MIUS/Conventional Utilities Comparison</u>

The land occupied by the MIUS Plant will be approximately two and a half acres located at the northwest corner of the development. The physical plant will occupy slightly less than one acre. The excess land will be used to promote the use of architectural landscaping techniques to create a plant site that is aesthetically compatible with the architecture utilized throughout the site area. The land acreage required for installation of a MIUS equates reasonably well to the land required to provide the utility services needed if a MIUS is not utilized. The environmental trade-offs in terms of land-use appear to be equal or to favor the utilization of a MIUS.

Electrical Generation

The source of electrical power to supply the needs of Housing Project #1 has not been described in available information. However, the college located on the adjacent property north of the site has an electric power source which may be of adequate capacity. Based on this probability it would be necessary to install and maintain approximately fifteen hundred to two thousand feet of power supply line. The necessary right-of-way required would involve two or three acres of land that would be subject to environmental degradaton. The impact might well be minimal since the right-of-way would, in all probability, coincide with the right-of-way of existing roads. Thus the major environmental assault has already taken place and, following construction, the restoration of the land to its present state would be a relatively rapid process. If a MIUS were employed for this project, the need for this power supply line, the right-of-way, and the environmental consequences associated with it would be avoided.

Solid Waste Disposal

The City provides for solid waste collection and disposal by landfill. The housing project will add approximately six tons/day of solid waste to that presently generated by the area, a relatively small part to the total waste load. Thus, in the immediate future, little or no additional land would be subject to environmental degradation attributable to this activity. However, over the long term, there is a land-use loss that is due to the solid waste generated by the housing project representing an environmental impact. The utilization of incineration by MIUS will achieve a reduction in the ultimate volume of solid waste by 80 to 90 percent. The land requirements and the attendant environmental impact attributable to the disposal of solid waste will be reduced proportionately.

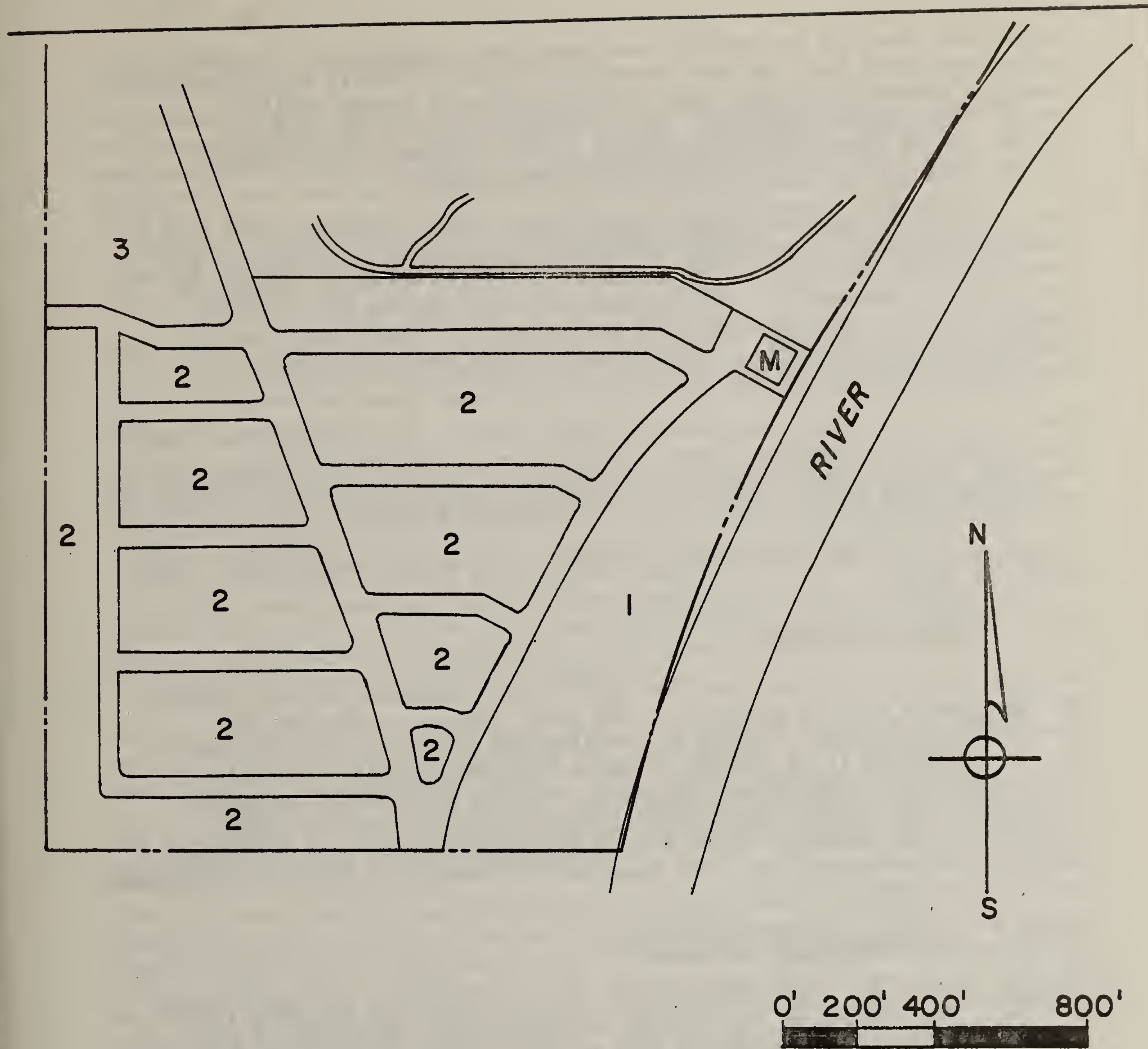
Wastewater Treatment

A new 30-inch sewage pipeline is presently under construction along the west bank of creek which is the west property line of Housing Project #1. This line serves the college to the north and will terminate at a new 13 Mgd waste treatment plant. A sewage transport pipe from Housing Project #1 to this 30-inch line will be three to five hundred feet long. It will span the creek and probably be supported on one of the two existing bridges. The amount of land required for the right of way for this pipeline will be less than one acre, and would probably coincide with the existing right of way for the bridge and the 30-inch sewage pipeline. This would tend to minimize the envoronmental impact attributable to the sewage transport line required. The utilization of a MIUS for this project would eliminate this environmental consequence since the treated wastewater would be discharged directly to the creek.

2.2.2 Housing Project #2

2.2.2.1 Before Development

Refer to Figure 2.2.2.1. Most of the area that would be occupied by the housing project is used for some form of agriculture. A Bayou-like old river bed on the north side of the project area supports a natural plant community. Bald cypress and sourgum grow in the shallow water. Elms, pecan, oaks, and sweet gums were growing on the banks. Deer and beaver



Legend:
1 - Mobile Homes - 200 units
2 - Single Family Detached Dwellings - 104 units
3 - Multi-Family Low Rise Dwellings - 40 units

Figure 2.2.2.1 - Housing Project #2

signs were observed and several wood ducks were sighted in the waters. It was concluded that the site supports a relatively large bird population based on numerous sightings and information from a nearby wildlife refuge with similar habitats. The probability of Housing Project #2 containing rare plants and animals is not considered high because of the small size and the uniformity of the habitat.

The river is good-sized, fast-flowing, fairly turbid and saturated with oxygen. The site is partially within the floodplain of the river. A local resident stated that the pasture forming the southern portion of the site was covered by a shallow sheet of water in the floods of the spring of 1973. This was the only time water had reached the site in memory (about five years). The passage through east of the site was passible to trucks, but not cars.

The water in the bayou is typical of swamp water. It is covered with duck-weed, and has a dissolved oxygen content of only 1.9 ppm. Phosphate and coliform levels are also high. Both the bayou and the river are typical of their type, and do not appear to be of outstanding aesthetic or other value.

There appears to be no problem with noise. All on-site measurements were below 55 dBA_{10}.

2.2.2.2 After Development

Much of the site has been used for agricultural purposes, so that impact of development will be minimized. The bayou area is by far the most interesting ecological feature of the site and little ecological impact is expected since it is planned to leave this undistrubed. The noise from construction may disturb waterfowl but this disturbance should be temporary. The plants and animals of this area should not be greatly affected. Care should be taken not to disturb the bayou area by run-off patterns and sedimentation. The floodplain problem will have to be addressed with this in mind.

2.2.2.3 Site Engineering Suitability

Housing Project #2 is located directly west of a city on the east side of a river. The contour of the land is relatively flat with fair to poor drainage qualities. Drainage is into a river. The site is at an elevation of about 130' MSL (mean sea level), while the river is at elevation 100' MSL. Part of the site is in a flood plain near the banks of the river, which can be expected to reach levels of 131' MSL.

The depth to the water table from the surface is 125 feet for a shallow strata and 800 feet for a deeper strata. The soil permeability is generally moderate to rapid. The soil is a silty sandy material. Referring to the Unified Soil Classification System, the soil bearing capacity would generally be limited to 0.5 to 1.5 tons/sq. ft.

2.2.2.4 Social and Economic Evaluations

The existing land use is approximately 60 percent agricultural, with the rest being mostly wooded. Row crops - cotton and soybeans - are the dominant agricultural activities. The area surrounding the site also shows the same land use patterns. A city is located east of the site with some light industry. Future land use of the site was projected to remain the same (Planning and Development District). The State has selected this site for the development of a state park, so the use will change somewhat.

Recreational opportunities in the area are somewhat limited both in variety and number. Several small lakes to the north provide major recreational sites. A number of county parks provide playing fields and courts, picnic and other facilities.

The state park being developed adjacent to the site will probably be the major educational or scientific resource in this area. As a re-creation of a mid-nineteenth century plantation, this park will provide some understanding of plantation farming and domestic life of this period. A Wildlife Laboratory, another educational asset, is used as a nature center and outdoor study area by the County schools. It is located adjacent to the site to the west. There are a number of historic houses and other sites in the County area including two Civil War forts - one located downstream from the site, the other upstream.

Housing Project #2 is a development that is sponsored by a public agency, in this case the local city government. No information is available describing the architectural design. Site design segregates land uses (i.e., single family, multi-family, or commercial dwellings) but provides for a conventional extended system of dwelling units rather than cluster development or some other arrangement.

Composition suffers for several reasons in this housing project. The floor-plain type of terrain and the agricultural character of the area impose limits by restricting the potential for variety in topography or in utilizing mature wooded areas. Moreover, in the preliminary plot of the area, much of the existing wooded area will be lost, especially in the single-family residence area. The sub-division arrangement of houses also lends monotony to the expected area which is compounded by houses arranged in rows along straight streets.

Adjacent land use presents few problems at the site. It is bounded on the west and south by areas of agricultural and wooded land, and the state park is a low intensity use whose major impact would be possibly high levels of auto traffic at certain times. The commercial area to the north will presumably be separated from the residential areas and the state park by the wooded bayou area.

Community services in the country area will not be impacted appreciably by this housing project. With an expected year-round population of approximately

1,000 and a peak population of less than 2,300, the expected demands on the various community services should not be appreciable. The rather small populaiton projected for the housing project will in itself have little impact on potential commercial development, expecially in view of the proximity of a city and the commercial services located there. A commercial area located along a nearby interstate highway should be adequate for the peak population projected for the site.

Induced secondary development may be more significant. Housing Project #2 could easily serve as an opening wedge of development to the south and west of the state park. Such development depends in large part on the growth in the area and the resulting demand for housing. Given sufficient demand, the development of this housing project, especially with a four-lane highway extending from the nearby interstate highway to the southern edge of the site, may well serve as an initiating force for future development of the area. The terminus of this thoroughfare and an access street at the southern edge of the site strongly suggests future development in this direction. While this further development is not necessarily a determinant, it will have an additional environmental impact, and the appropriateness of extensive development on this flood plain should be questioned.

The anticipated regional economic impact of the housing project should be minor in itself. A relatively small year-round population and the mostly residential character of the housing project are the principal reasons for this. Short-term employment effects, longer-term employment in the commercial area and the effect on local government finances are the major regional impacts that are expected.

2.2.2.5 State and Local Regulations

The State has no regulations or guidelines specifically designed to accommodate an integrated utility system. It does, however, have regulations affecting the components of the MIUS system. There are no operator certificatin requirements at the present time. Instrumentation, testing and records would be defined once the plans were reviewed by the agencies.

Electric Power Generation

The State Public Service Commission has granted franchised service areas to privately owned electrical generating companies. They do not have authority over municipally owned systems. Municipally owned systems, such as local utilities which are owned and operated by the city by agreement with the Public Service Commision, can serve an area including the municipality and one mile out from the corporate limits. The area covered by the housing project is not in the city utilities' service area. The majority of the area is in a private electric power company's franchised area and a small portion is in another. These companies would normally plan to serve this housing project. Any plan by the city utilities to serve the area would have to be legally agreed upon. One of the two private electric power companies had suggested that they would resist giving up their franchised portion. Emisions from the prime movers are exempt under the Commissions "Permit Exclusion List."

Space Heating and Air Conditioning

Since the blowdown from the cooling tower is treated by the wastewater treatment portion of MIUS, no additional discharge permits are required.

Solid Waste Disposal

The State Environmental Health Department has authority over solid waste disposal. There are no permit requirements other than for incineration. The submission of plans for comment and approval are the only requirements. The State Air & Water Pollution Control Commission has control over construction permits for incinerators. A permit to construct must be applied for. The incinerator must meet State emisssion standards. For an incinerator to be located in a "developer" area, the particulate emsission limit is .01 grains per standard cubic foot dry, corrected to 12% CO_2. Visible emissions must be no greater than #2 on the Ringleman Scale.

Wastewater Treatment

The State Air and Water Pollution Control Commission has regulatory powers over the construction and operation of a sewage treatment facility. The general requirement is a NPDES discharge permit which can be obtained through the Commission. The proposed discharge will enter a river, which is classified as "Fish and Wildlife," and required a minimum of secondary treatment of sewage prior to discharge. Testing requirements would be determined by the Commission.

Potable Water Treatment

The accepted potable water source in the area is deep wells. Chlorine injection is the only form of treatment. The State Environmental Health Department has authority over potable water treatment facilities although there are no regulations or permit requirements. The submission of plans to the Regional Engineer in the city for comment and approval is the only requirement for construction. The County Sanitary Engineer examines samples monthly for bacteria counts. The only other testing requirement may be residual chlorine analysis.

Planning and Zoning

The area for MIUS and the surrounding development is planned for a State Park to be known as the "Living Historical Plantation." This will encompass approximately 104 acres.

2.2.2.6 MIUS/Conventional Utilities Comparison

The land to be occupied by the MIUS plant and landscaping will be approximately two acres of which the physical plant will occupy slightly less than half an acre.

The land acreage required for installation of a MIUS is much less than that required if a MIUS is not utilized for the project. Therefore, the environmental trade-offs in terms of land-use weigh heavily in favor of the utilization of a MIUS.

Electric Power Generation

There is a power line that runs along the northern boundary of the site which makes it unnecesary to install offsite power supply lines if MIUS is not utilized. Thus the environmental considerations are the same regardless of whether or not a MIUS is used to provide electrical power.

Solid Waste Disposal

A solid waste disposal area (located 2-1/2 miles to the west of the site) would be utilized by the housing project. The housing project will add approximately two ton/day of solid waste to that presently generated by the town, a relatively small contribution to the total waste load. However, any environmental impact associated with landfill disposal will be reduced considerably if MIUS incinerates project refuse.

Wastewater Treatment

The municipal sanitary water treatment plant is located approximately five miles west on the far side of the nearby town. The cost of installing a sewage transport line from the site to the treatment plant appears to be prohibitive and therefore Housing Project #2 would not be undertaken if a MIUS were not utilized. The use of a MIUS would eliminate the need for sewage transport pipeline and the attendant environmental degradation that would be associated with its installation and maintenance. The treated effluent generated by a MIUS would be discharged to the river located on the eastern boundary. Therefore, without a MIUS approximately fifteen acres of land along the banks of the river would be subject to environmental impact attributable to the installation of a sewage pipeline, which would be completely eliminated with the installation of a MIUS or some form of septic tank system.

2.2.3 Housing Project #3

2.2.3.1 Before Development

Refer to Figure 2.2.3.1. The forests have a relatively high plant species diversity. The most important tree species are white oak, black gum, red maple, and pin oak. The dense understory is dominated by cucumber trees, American holly, and blueberries. The site is a relatively mature forest with a large number of mature trees. Other parts of the forest had been logged in recent years and the trees were in the sapling stage with white oak being the dominant species. Birds were seen in the forest as were numerous squirrel, raccoon, and deer signs. The forest could serve as a home for many mammals and birds.

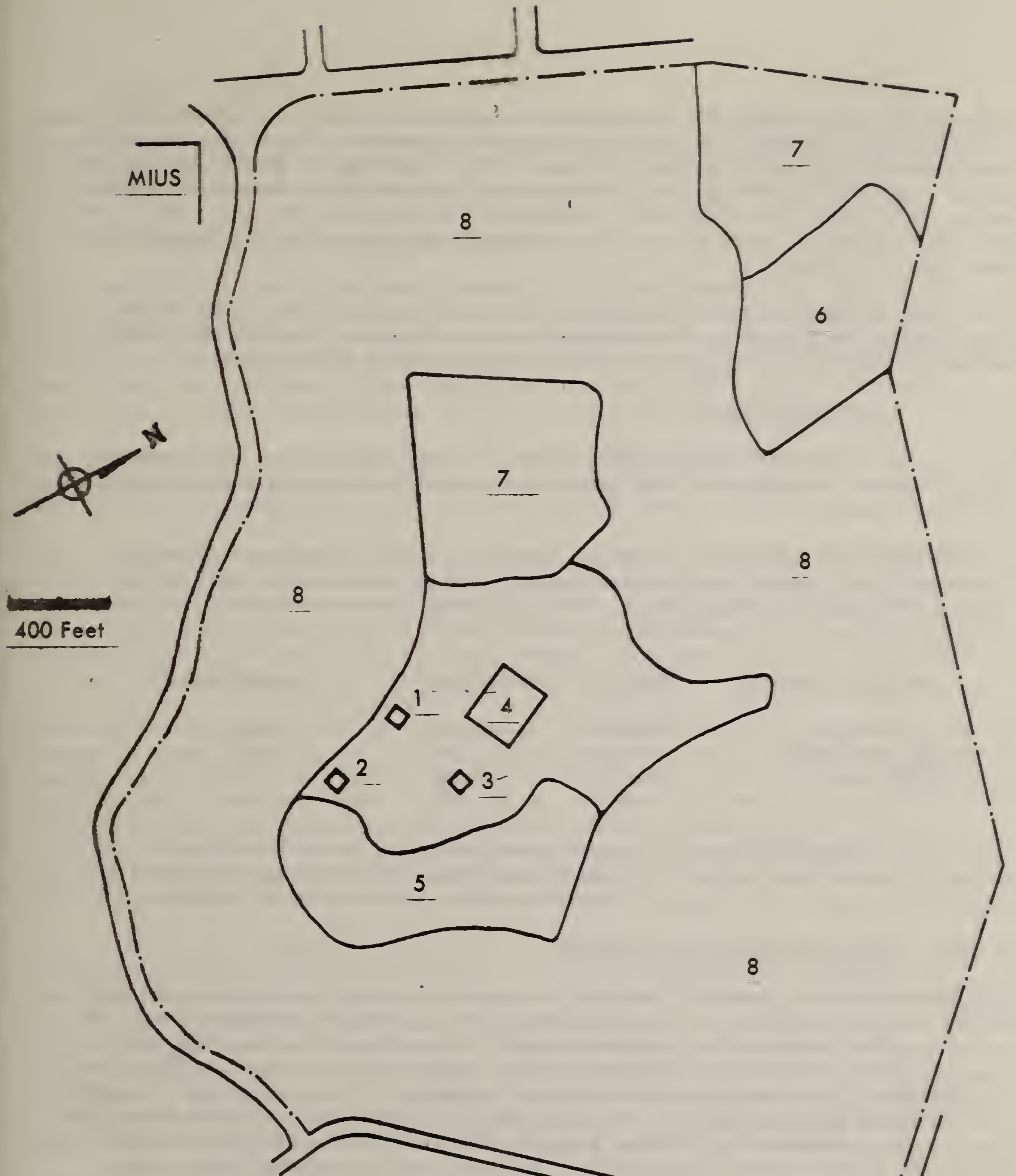


Figure 2.2.3.1 - Housing Project #3

Legend:

1 - Seven/Eleven store
2 - Service station
3 - Community center
4 - Elementary school
5 - Triplexes
6 - Apartments
7 - Townhouses
8 - Single family units

There is no natural aquatic habitat on the site; only intermittent drainage streams cross the site. A portion of the site appears to drain to the northeast, eventually draining into a swamp. This is an area of unique ecological value. It is protected by regulations which prohibit point-source discharges which would drain into the site. The balance of the site drains to the south into another small swamp across the road from the site, which in turn drains into the first swamp.

This site is well screened with trees and the only sounds were from vehicular traffic in the area. The present site plan states that the site would be surrounded by a thick belt of trees to effectively block noise.

2.2.3.2 After Development

There will be an environmental impact due to development since this area was wooded before development. The relative magnitude of such an environmental impact is unknown.

The developer is creating a settling pond, which will later be used as a permanent small lake. This is desirable; however, maintenance will be required to prevent eutrophication. The following values show the water quality in the area during the site visits in October 1974.

Sampling Location	Nitrate	Phosphate	Clorophylla
Creek, Southwest	(mg/1)	(mg/1)	(mg/m)
Settling Pond, South	.61	.04	.32
Protected Swamp	2.92	.02	23.2
	.22	.02	2.3

None of the samples indicated coliform contamination and all had near-saturated dissolved oxygen. It can be seen that the south settling pond is high in nitrate and in algae, indicating dangers in this type of pond.

2.2.3.3 Site Engineering Suitability

The contour of the land is generally flat and occurs in the highest and most level area of the county. Mean sea level (MSL) elevation ranges between 190 to 215 feet. The soil is composed largely of sands and gravels with minor amounts of clay-like and silty materials. Sixty percent of the soils are well drained while the remaining 40% are poorly drained. This runoff is collected in the swamp drainage basin. The permeability of the area soils is very high due to the substrate of sand and gravel. The water table generally ranges from 4 to 10 feet below the surface. However, due to seasonal rains, the water table can rise to 1-1/2 to 2-1/2 feet below the surface.

The structural stability for the contemplated design loads will be ample as the soil has a bearing capacity ranging from 1 to 2.5 tons/sq. ft. Presently there exists an elevated 2.5 million gallon water storage facility. The site is not in a flood plain.

Devastating parameters which should be considered are tropical storms and hurricanes, which occur about once per year, and have caused minor damage in the past. Winds from these storms may reach 50 mph or higher. Thunderstorms and winter storms will occasionally have comparable wind velocities.

2.2.3.4 Social and Economic Evaluations

Land use on this site is primarily wooded. This has changed recently with the construction of garden apartments as part of the planned growth of Housing Project #3. The site is currently under development to medium density residential with single family dwellings predominant throughout the site and several townhouses and triplexs, either completed or under construction. The site will have a neighborhood center, service station, and elementary school.

The proposed land use for the area is for the area is for medium density residential with emphasis on cluster development and new towns according to the latest available edition of the County Comprehensive Plan.

The recreational opportunities are complete in concept and some areas devoted to recreation are already developed. Since the housing project is part of a HUD-sponsored planned community, recreation was planned and ought to meet the projected needs of the inhabitants. Open space planning is a key factor in recreational activities. The planned community has approximately 1,516 acres of recreational and open space land providing a variety of opportunities.

The educational and scientific resource of importance is the swamp. The swamp is quite close to the housing project and was recently rated the most ecologically significant tract of land in the general area by the Smithsonian Institution's Center for Natural Resources. It has diverse forms of life inhabiting the area including beaver, mink, osprey, wood ducks and heron. It is also home for some rare and endangered species such as bald eagles, red-bellied woodpeckers, Maryland diamondback terrapin and the stonefly. There are no historical or archeological sites known.

The architectural design of the garden apartments is generaly pleasing. Very standard building designs are used. The site is essentially a conventional subdivision with curved atreets and rows of houses. While compositional effect of the development is not particularly stimulating, it does have gently rolling topography and much of the site will remain wooded. During construction, drainage ditches and retention ponds will be utilized and will be somewhat of an eyesore, although this will eventually recover due to vegetation regrowth. The planned community atmosphere is not uncommon in the general Metropolitan area and needs to be examined very closely for social implications.

The impact of this development on community services is expected to be minimal as the development is planned to include all necessary services. The sewage system may present some problems, though the area is to be tied in with regional plant when it is constructed. An elementary school is planned for the neighborhood and will be constructed within five years.

Induced secondary development is expected to be small, again due to the total planning of the community. The surrounding commercial areas will absorb the needs of the community. In addition, the provisions of neighborhood centers and village centers should satisfy immediate residential needs. Additional residential development due to MIUS is not expected.

Regional economic impact of the project will be minimal. The small scale, the character of the garden apartments in comparison with community, and its location close to a large metropolitan area rule out any major effects. Short-term construction-related employment and its net effect on local government finances are the only expected effects, and these will be a positive net change, although minor.

2.2.3.5 State, and Local Regulations

There are no guidelines, rules, or regulations to accommodate the MIUS concept in its whole form at this time. The components of the MIUS system do, however, fall under authority of several jurisdictions of the state and counties. It has been indicated by the State regulatory agencies that consideration will be given to the MIUS concept as a complete system. Due to the uncertainty of its status with the agencies involved, it is not clear what will be needed in terms of operators' training and certification. The state does have requirements for operators and operation of utilities which comprise MIUS, but individual utility systems best fit these requirements.

Electric Power Generation

The State Public Service Commission (P.S.C.) has regulatory powers over any electrical generating utility (either public or private) operating within the state. Since service areas within the State are franchised, any application of MIUS which generates electricity must be incorporated with an existing utility, or apply to the P.S.C. to operate as a separate utility and develop an agreement with the existing utility serving that area. The locally franchised utility has indicated interest in the project and that it is likely they would have responsibility over the generation and distribution of electricity from the MIUS unit.

Space Heating and Air Conditioning

There are no State regulations governing airborne pollutants originating from cooling towers, but there are regulations concerning a blowdown from the cooling tower. If the blowdown waste is treated by a wastewater treatment plant prior to discharge to the receiving stream, the discharge permit for the treatment plant satisfies the requirement.

Solid Waste Disposal

The Division of Air Quality Control of the State Department of Health and Mental Hygiene has authority over issuance of permits for construction of incinerators. In general, any brand of incinerator will be approved if it has a venturi scrubber an dhas a minimum pressure drop equivalent to 20" of water across the scrubber. Particulates from an incinerator should not exceed .03 grains per standard cubic foot of dry exhaust gas adjusted to 12% CO_2. A general requirement states that no person shall cause, suffer, allow, or permit the use of any flue-fed or chute-fed single chamber incinerator unless it has a burning capacity greater than two tons per hour and is used to burn at least five tons of refuse per day.

Wastewater Treatment

The State Department of Health and Mental Hygiene (D.H.M.H.) has authority over the construction of wastewater treatment plants. There is a chain of events which must take place prior to construction of any facility which is to operate in the State. First, the plan for a treatment plant must be incorporated in the county water and sewer plan. The amendment must be sent to the Environmental Health Administration of the D.H.M.H. for study, and to the State Planning and Zoning Office for their approval. Next, application must be made for a discharge permit, and to the State Water Resources Council for a study of the effluent. Finally, application can be made for a construction permit. Regulations surrounding a wastewater treatment plant include the fact that any facility-built unit is termed an "interim plant" and within five years from the date of operation must be included in the regional treatment system. In addition, an agency of the State or County must operate the plant, excluding any piping. The State or County provides manpower while the developer pays the cost of such manpower.

A State Discharge Permit is required for disposal of sanitary effluents on land, as in a spray irrigation system. The housing project has plans to discharge the liquid effluent in this manner. Should this method change for disposal to water (i.e., stream, pond, etc.) a NPDES permit will be required.

Planning and Zoning

The area designated for site is zoned for residential use.

2.2.3.6 MIUS/Conventional Utilities Comparison

The land occupied by the MIUS Plant and associated landscaping will be approximately four acres of which the physical plant will occupy about one and a half acres. The existence of power and waste treatment facilities eliminates the need of acquiring right-of-way land in order to provide these facilities. However, the four acres allocated to the MIUS represents an environmental impact not encountered if a MIUS is not utilized. The magnitude of the impact will be minimized if the landscaping design is successful. However, the environmental trade-offs in terms of land use appear to slightly favor the use of conventional utilities for this proposed project.

Electric Power Generation

Housing Project #3 is only a part of a larger development program which is already partially built and occupied. A power substation is located onsite providing service to the developed portion of the development. The proximity of this substation eliminates the need for providing power supply lines or a right-of-way as a result of their installation. Thus, the environmental impact associated with the installation and maintenance of power supply lines for this housing project is equivalent to that experienced when the electric power is supplied by an on-site MIUS.

Solid Waste Disposal

A 200-ton-per-day landfill operation for solid waste disposal is planned to serve the entire region in which the housing project is to be located. The housing project will add approximately 13 tons per day of solid waste to that projected for the entire region, a relatively small contribution to the total waste load. Whatever land use impact is attributable to the landfill operation will be much smaller if MIUS incinerates solid waste.

Wastewater Treatment

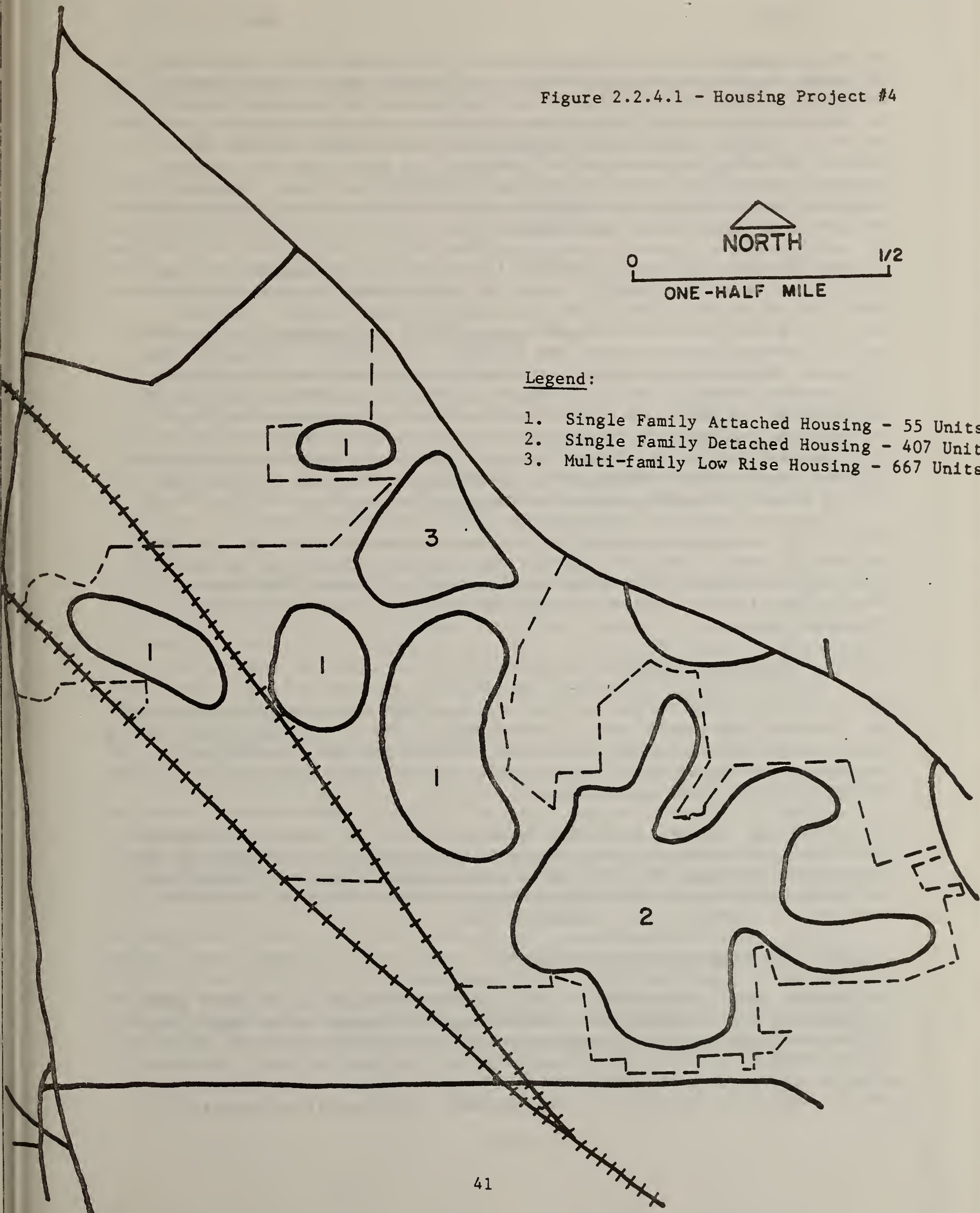
A wastewater treatment system is already in operation at this site with a capacity of 1.2 Mgd utilizing settling and storage lagoons followed by spray irrigation. This system may have the capacity to accept the sewage generated by the housing project and, if so, there would be minimal piping required to transport this sewage to the existing wastewater treatment plant. The presence of this on-site treatment system eliminates any significant difference in the amount of land area required for sewage transport, whether or not a MIUS is utilized. If a MIUS is employed, the relative high quality effluent will probably continue to be discharged to the spray irrigation facility due to the absence of an acceptable receiving stream in the area. The alternative of discharging this treated effluent to an existing natural drainage system should be avoided since the area drains into swamp. The environmental implications attending this alternative are sufficient to indicate that a permit for such a discharge would not be granted. Based on design information available and present plans for the development, it appears that no additional land for sewage transport will be required whether a MIUS or existing wastewater treatment facilities are utilized for this project.

2.2.4 Housing Project #4

2.2.4.1 Before Development

Refer to Figure 2.2.4.1. Three different vegetational zones exist within the boundaries of Housing Project #4. These are a marsh, an evergreen

Figure 2.2.4.1 - Housing Project #4



Legend:

1. Single Family Attached Housing - 55 Units
2. Single Family Detached Housing - 407 Units
3. Multi-family Low Rise Housing - 667 Units

forest, and a deciduous hardwood forest. The dominant tree species in the marsh are red maple, paper birch, and quaking aspen. White pine is the dominant tree in the coniferous forest while the deciduous forest is dominated by several oak species. Evidence indicates that the area supports a fairly large animal population. Several bird species were sighted including approximately 40 ducks on the marsh near the sanitary landfill. Deer signs were observed and wildlife lists from a nearby swamp and neighboring areas indicate that the area has the potential for supporting a large animal population.

The most interesting aquatic feature is the marsh-pond located in a depression south of the landfill area. It appears that the depth of this pond fluctuates about one to two feet with the water table. The pond which has a good dissolved oxygen content and a good algae crop, appears to be a favored site for birds and animals. The swamp, a protected area, lies near the the site to the south, but drainage from the site appears to be to the north and west into a river. This river, which lies off the site, is a typical small river with neither any gross pollution or outstanding aesthetic value. A small swampy area lies along the west boundary of the site by railroad tracks. This would receive run-off from adjacent wooded areas scheduled for development. The soil is sandy and several natural run-off channels showed signs of erosion.

Noise level measurements taken for one hour showed readings up to 65 dBA. The site is near a sanitary landfill and some vehicular noise is expected from there, although the housing development is screened from that by trees. The site is bordered on one side by a railroad, which is in infrequent use.

2.2.4.2 After Development

The location of MIUS to the north of the landfill will preserve the marsh and its waterfowl populations. Several wood ducks use the marsh for nesting. Construction would probably cause them to leave the site, as well as the deer and other animals. It is hoped that the pond area will be preserved in the development plans.

The balance of the site is divided between forest and field, with development causing considerably less impact in the latter. The portions of the development completed to date show a considerable interest in maintaining the wooded character of the site after development, which is desirable from both an aesthetic and ecological view.

2.2.4.3 Site Engineering Suitability

The general slope of the site is 15%, commonly represented by short steep slopes. The soil is sandy with coarser gravelly layers occurring within 30 inches of the surface. Complete gravel layers begin at depths of greater than 42 inches. The permeability of the site is rapid. The depth at which ground water is available at 20 feet or less. This general soil area is suited for most uses: recreational, high density residential, industrial, and commercial. The latter use was favorable because of the well drained soil which would provide good drain fields for septic tanks, plus the access to two large-volume ground water supplies. The bearing capacity of the site is adequate for the structures that may be placed there. The report indicates capacities ranging from 1-5 tons/sq. ft.

Flooding at the site is a concern only at the extreme northern boundaries where the river crosses. The flooded area would be expected to occur at elevation of 160 MSL and lower. Consideration of devastating parameters must include forest fires. The species of trees present, combined with the type of soil that is well drained, create woodlands that are particularly susceptible to forest fires.

2.2.4.4 Social and Economic Evaluations

Land use in the area adjacent to the site is largely agricultural, vacant and wooded with scattered residences. Development of a medium density residential area across the road, which is on the east side has occurred within the recent past. In addition, development surrounding the site has begun with a number of units completed. According to the land use plan published by the regional planning agency, this area was classified as "prime agricultural" and undeveloped land was projected to remain in this use. The area immediately to the north-west between the site and a nearby town has been classified as a major industrial site.

Recreational opportunities for most outdoor activities exists through the different seasons of the year. Playing fields and other indoor facilities are present at the local colleges. Access to these facilities is somewhat restricted. A publication by the Corps of Engineers discusses the relative need for additional development of water resources and adjacent land areas. It also mentions the need for increased public access to these resources throughout the basin.

The housing project also contains a swamp and a pond. The pond is a natural kettle hole (a glacially formed pond) which is progressing naturally to a bog-like condition, and, although not unique, it is of interest. The swamp, located roughly one mile south of the development, is held as a conservation area by the nearby town. The area contains many sites of historical significance. Among the more well-known sites is that of an Indian massacre which occurred in 1704. No sites of historical or archeological significance are recorded within the housing project.

The aesthetics are very good to excellent. Architectural design is a modern interpretation of traditional New England styles. Colors have been selected that blend into the trees and other vegetation, much of which has been retained in the residential areas. Cluster development is utilized, creating small local areas of human activity, thus allowing the retention of more of the existing vegetation and a feeling of a rural area.

Compositional aspects of this development are good also. Several small streams and ponds are interspersed among the trees and residential areas, creating a varied and pleasing effect. A caveat is that the evaluation of site aesthetics applied primarily to the initial development in a wooded area. Part of the site is vacant land and future development in this area may not create so pleasing an effect.

Land use contiguous to the development is varied, with wooded, agricultural, vacant, and residential areas found adjacent to the site. An old sand and gravel quarry is partially surrounded by the development area. This quarry is currently being used as a sanitary landfill site. A commercial development of about 35 acres is proposed for the northeast corner of the site along the road on the site's east perimeter. In addition, a parcel of approximately 20 acres immediately to the west of the development is zoned for industrial use.

The impact on community services in the adjacent area is expected to differ with the type of service. Potable water is being supplied by the nearby town and will continue to be. While the demand for water in the service area is approaching the safe yield of the supply source (4.54 Mgd), the incremental demand from the site will have little impact at present. Futher, the projected water demand of 0.53 Mgd will not be realized presumably before new sources of supply have been found.

The wastewater flow of 0.42 Mgd is projected from the housing project. When the new sewage treatment plant for the nearby town is completed, this wastewater flow will be pumped into that system, utilizing roughly five percent of the expanded capacity of 8.0 Mgd.

A new fire station had already been planned for the south side of the nearby town, thereby reducing the response time in this area and increasing the overall fire-fighting capacity within the town and surrounding service area. The ultimate addition of over 1,600 dwelling units with an approximate population of 4,800 people and 35 acres of commercial land will have some impact on the provision of fire and police services, <u>and</u> on educational and health care facilities. This increment will require up to 20 years to reach its full size, however, so whatever impacts do occur will be spread over a number of years.

Induced secondary development is expected to be minimal because of its relatively small size, because of a fairly high degree of commercial and other development in the general area, and because of the planned commercial development associated with the housing project. With a total population of less than 5,000 people to be attained over a 30 year span, there will be little pressure for additional commercial development. This is reinforced by an expected slowing of growth in the general area because of stabilization of college enrollment and employment, and the prospect of little industrial growth. In addition, there are two regional shopping centers nearby and the planned commercial area adjacent to the housing project.

The regional economic impact will be relatively minor. The moderate population and long time span involved minimze the expected impact. Employment and income effects will be limited to construction-related jobs in the short-run and to employment related to the commercial center after it is constructed. There may also be additional employment related to the industrial site, but the small size of this area limits the regional impact. There probably will be a favorable impact on the local tax base and local government tax yield. The projected selling price and the size of the cluster development relative to existing single family housing, commercial, and industrial development are the factors indicating the probable greater increment to local government revenues than to their costs.

2.2.4.5 State, and Local Regulations

The State has no rules, regulations, or guidelines at the present time to accommodate MIUS. Various state and local agencies would be involved in permits and operation of the components and sub-systems of MIUS.

Electric Power Generation

The electrical generating portion of the MIUS is discussed by the private utility in Appendix A in terms of being sold or leased to them for operation. The site falls in the franchised distribution area of a wholly-owned subsidiary of this utility. The MIUS would be interconnected with the electric utility system for back-up purposes and thus would not have to apply for permission to operate as a separate public utility to generate and distribute electricity.

Space Heating and Air Conditioning

The delivery of space heating and/or cooling would be treated as another municipal utility and would be subject to the construction standards for utilities within public ways.

Solid Waste Disposal

The State Department of Public Health has jurisdiction over incineration of solid waste. There are no minimum operation requirements at this time. There are no operator training or certification requirements at present. Plans and specifications would be reviewed by the public health board, the Air Pollution Control District and the State Department of Public Health. The site must be approved by the local public health board.

Wastewater Treatment

The State Department of Public Health has jurisdiction over the construction and operation of sewage treatment facilities. Evidence of performance is required prior to permits and operation. The developer would operate the plant with a certified operator. Effluent discharge falls under the jurisdiction of the Water Pollution Division of the Public Health Department. The existing wastewater treatment plant is not large enough to handle the entire housing project

The State has a law which is very similar to the Federal law requiring environmental impact statements, and although there are some exemptions. This may prove to be an additional requirement.

Potable Water Treatment

The Public Utilities Department requires the incorporation as a private water company and licensing for treatment and delivery of potable water. The Division of Environmental Health of the State Health Department examines applications from a health standpoint.

Planning and Zoning

The Town Planning Board has zoned the area of the housing project as Low Density Residential, and in granting development put certain constraints on the builder to meet environmental quality levels which are described in the site plan.

2.2.4.6 MIUS/Conventional Utilities Comparison

The land to be occupied by the MIUS plant and associated landscaping will occupy five acres; the physical plant, slightly less than two acres. The five acres of land allocated to the installation of a MIUS equates reasonably well to the net land subject to environmental assault in order to provide power and sewage transport facilities if a MIUS is not used. The environmental trade-offs in terms of land-use appear to be equal or to favor the utilization of a MIUS.

Electric Power Generation

Available information indicates that a substation located approximately two miles northwest of site will be used to serve this housing project if a MIUS is not utilized. The power supply cable would be installed from the onsite distribution point adjacent to an existing interior secondary road located in the middle of site out to the east perimeter road. The cable would then follow this road northwest to the substation. The total distance involved is 10,000 to 12,000 feet. The principal environmental impact associated with this action will be the installation and maintenance of the cable. The action will fall within the right of way of existing roads; therefore, the environmental degradation can be expected to be minimal, affecting perhaps 8 to 9 acres of land. This conclusion seems valid since the major environmental assault took place when the roads were constructed, and the restoration of land to its present state would be relatively rapid process.

The utilization of a MIUS will completely eliminate the impact associated with the installation of a power cable along the east perimeter road.

However, it will be necessary to install distribution cable that will carry the power generated at a MIUS, located on the north side to the distribution point. This will involve a few hundred feet of land to provide a right of way that will be subject to environmental degradation. Therefore, the net environmental consequence if a MIUS is not employed is the 10,000 feet of right of way along existing road which would be avoided if a MIUS were installed.

Solid Waste Disposal

The town nearby provides for solid waste collection and disposal by land-fill which is located adjacent to the site. Housing Project #4 will add approximately 16 tons/day of solid waste to that presently generated by the region. This is a relatively small contribution to the total waste load, and will be smaller if a MIUS incinerates refuse.

Wastewater Treatment

If a MIUS is utilized, the treated effluent will have to be transported for discharge to the river at the road crossing to the east. This pipeline would be approximately 6000 feet long of which 4000 feet would be within the right of way for the road. The environmental consequences of this activity would be similar to that encountered by the installation of a power supply cable along the same road. In this instance, the length of the right of way would be about half that required for the power supply cable. If a MIUS is not used, the sanitary waste will be transported to an existing pumping station on a street to the south. This will require the installation of perhaps 1200 feet of force main from the end of an existing 12-inch force main now discharging to the river to the east. The right of way required for the new sewage pipeline will require perhaps one acre of undeveloped land. The loss of trees and the destruction of shrubs and vegetation will attend the construction phase. The long term environmental impact will be the loss of this land to natural growth.

2.2.5 Housing Project #5

2.2.5.1 Before Construction

Refer to Figure 2.2.5.1. This location is a very well developed forest. The forest has a high plant species diversity and little evidence of recent disturbance. The dominant trees are beech, white oak, black gum, and tulip tree. The important understory shrubs are mountain laurel, magnolias, and rhododendrons. A large number of small, woody plants and herbaceous species were also observed.

One rare plant was observed on the site. This plant is the cranefly orchid (Tipularia discolor) known in the eastern half of the United States. It is highly likely that other rare plants or animals could be found due to the natural state of the forest.

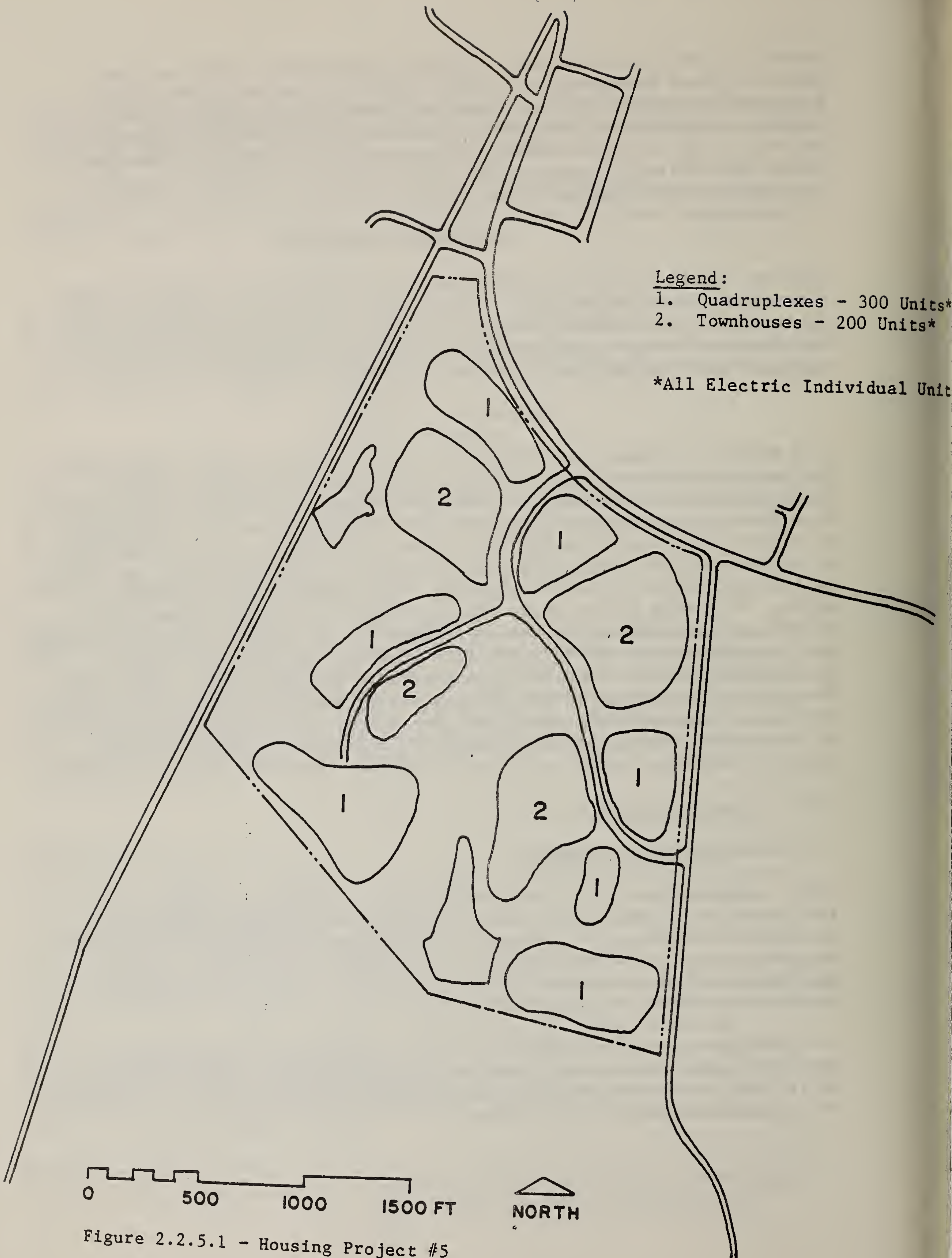


Figure 2.2.5.1 - Housing Project #5

There are no aquatic features of interest. There are only intermittent drainage streams present. The site is bordered by a nearby river. This is a quite scenic river, and is the subject of considerable interest in terms of improving its quality. It receives the discharge of several municipal wastewater treatment plants, both upstream and downstream of the development.

Approximately one hour of noise level measurements were taken and at no time did the readings exceed 65 dBA. The site is wooded and effectively screened from the nearby railroad and highway.

2.2.5.2 After Development

The major environmental effect would be the destruction of high-quality natural forest by the housing project. In addition, a settling pond and a MIUS pond would also remove some forest. Careful erosion and sedimentation control practices will be required.

The plans to dispose of the wastewater treatment plant effluent on a wooded area along the river will result in the loss of a considerable land area for other uses, but may be necessary when the only receiving stream is already enriched. The problem can be seen in the nitrate content of the area waters:

Sampling Location	Nitrate, mg/l
Stream on Site	0.10
Stream by railroad	0.85
STP* at development	3.26
River, above STP	2.70

*STP - sewage treatment plant

The proposed location for the spray disposal area is in the flood plain of the nearby river, and hence would be unsatisfactory.

2.2.5.3 Site Engineering Suitability

The contour of the land, as interpreted from the soil survey, is moderately steep. Slopes have grades of 5% to 15%. The soil, sand and gravel, with the given slopes is severely erodable. The soils permeability is generally moderate to rapid. The depth of the water table varies with seasonal change. At its seasonal high, it is approximately 4 feet.

The soil survey makes no direct reference to soil bearing capacity. The engineering properties refer to AASHO rating of A-2 to A-4 which have two individual qualities. A-2 soil classification is generally a granular material which can be compacted and provides good drainage. The A-4 soil classification is moderately plastic silty soil which is difficult to compact properly.

The soil survey does give an indication of the degree and kind of limitations for community development. The area is considered to have slight to moderate limitation for onsite disposal of sewage effluent (septic tank). The moderate limitation is principally due to the sloping terrain. For the use for a sewage lagoon, moderate to severe limitations are specified, due to the permeability and slopes. The report indicates that homes in this area would have but slight limitations.

2.2.5.4 Social and Economic Evaluations

Site is completely wooded. The larger area surrounding the site is wooded with some area in agricultural use and with scattered residences. Projected land use for the area of the housing project is medium to high density residential.

Recreational opportunities in the area are somewhat limited. The county tends to be water oriented, but facilities to realize this orientation do not exist in proportion to the demand. Opportunities for other recreational activities exist, but need development. There are no significant features of educational or scientific interest in this immediate area. There are no historical and archeological sites of importantance.

Architectural styles chosen for the development seem confined to conventional garden apartment buildings. Information on exterior appearance is somewhat limited, but the buildings could blend into the existing trees to create a pleasing effect. The housing project has been organized in large scale clusters by housing type. Sufficient information is not available concerning building location within the subdivisions to evaluate the design in more detail. Similarly, composition can only be examined in a broad context. Retaining mature trees and the suitable location of buildings could create a good compositional effect, the more so if the pond is utilized properly. Failure on one or more of these points will detract from the overall effect.

Land use adjacent to the site is compatible. Areas adjacent to the project are agricultural or wooded while there is development of single-family residential areas north of the site. Future development adjacent to the housing project would transform wooded and vacant areas to residential. A light industrial site is proposed adjacent to the railroad tracks. This will be somewhat separated from the residential neighborhoods by a highway when it is extended.

Impact on community services should not be significant. A relatively small population of less than 1,800 people will not exert sufficient incremental demand for services. Population growth is expected in this area and expansion of services is planned. Extension of the highway south from its intersection with other state highway will provide access and minimize impact on the existing transportation system. There will be little induced secondary development associated with the site because of its small population. Further future development of the housing project will absorb the housing demand. The area will continue to grow because of its location in a major growth center. The regional economic impact will be extremely small. The only expected impacts, which this relatively small housing project will have on the regional economy, are short-run employment effects and á minor increase in local government revenues from real property taxes.

2.2.5.5 State, and Local Regulations

There are no guidelines, rules, or regulations to accommodate the MIUS. The components of the MIUS system do, however, fall under authority of several jurisdictions of the state and counties. It has been indicated by the State regulatory agencies that consideration will be given to the MIUS concept as a complete system. Due to its status with the agencies involved, it is not clear what will be needed in terms of operators' training and certification. The state does have requirements for operators and operation of utilities which comprise MIUS. Individual utility systems best fit these requirements.

Electric Power Generation

The State Public Service Commission (P.S.C.) has regulatory powers over any electrical generating utility; either public or private, operating within the state. Since service areas within the State are franchised, any MIUS generating electricity must be incorporated within an existing utility, or apply to the P.S.C. to operate as a separate utility and develop an agreement with the existing utility serving the housing project.

The utility company, which serves the area of housing project, is acting as the developers' electric utility advisor. At the present, no position has been taken by the private utility concerning MIUS.

Space Heating and Air Conditioning

There are no State regulations governing airborne pollutants originating from cooling towers, but there are State regulations concerning blowdown from the cooling tower. If the blowdown waste is treated by a wastewater treatment plant prior to discharge to the receiving stream, the discharge permit for the treatment plant satisfies the requirement.

Solid Waste Disposal

The Division of Air Quality Control of the State Department of Health and Mental Hygiene has authority over issuance of permits for construction of incinerators. In general, any brand of incinerator will be approved if it has a venturi scrubber and has a minimum pressure drop equivalent to 20 inches of water across the scrubber. Particulates from an incinerator should not exceed 0.03 grains per standard cubic foot of dry exhaust gas adjusted to 12 percent CO_2.

Wastewater Treatment

The State Department of Health and Mental Hygiene (D.H.M.H.) has authority over in the construction of wastewater treatment plants. There is a chain of events which must take place prior to construction of any facility. The treatment plant must be incorporated in the county water and sewer plan. This amendment must be sent to the Environmental Health Administration of the D.H.M.H. for study and sent to the State Planning and Zoning Office for their approval. Application must be made for a discharge permit and to the State Water Resources Council for a study of the effluent. Application must be made for a construction permit. Regulations surrounding a wastewater treatment plant include the fact that any facility built is termed an "interim plant" and within five years from the date of operation must be included in the regional treatment system. An agency of the State or County must operate the plant, excluding any piping. The developer of the treatment plant is responsible for the construction, and maintenance of the facility. The operating agency provides manpower while the developer pays the cost of such manpower.

A State Discharge Permit is required for disposal of sanitary effluents on land, as in a spray irrigation system. Should the method change for disposal in water (i.e., stream, pond, etc.) a NPDES permit will be required.

Planning and Zoning

The housing project site is zoned R-5. The site is planned for high density residential development.

2.2.5.6 MIUS/Conventional Utilities Comparison

The land to be occupied by the MIUS Plant and its attendant landscaping will be approximately two acres; the physical plant, two-thirds of an acre. The environmental consequences associated with the provision of power supply and sewage transport facilities are equivalent for this project whether or not a MIUS is utilized. Therefore, the four acres to be allocated for a MIUS plant facility represents an environmental impact not encountered if a MIUS is not employed. The magnitude of the impact will be minimized if the landscaping design is successful. The environmental trade-offs in terms of land-use may favor the use of conventional utilities.

Electric Power Generation

Housing Project #5 would have obtained its electric power supply from an existing power line installed along its west property line. The proximity of this power supply line eliminates the need for providing additional power supply lines or the right of way attending their installation. Therefore, the environmental impact associated with the installation and maintenance of power supply lines for this project is equivalent to that experienced when the electric power is supplied by an onsite MIUS.

Solid Waste Disposal

The nearby town provides for solid waste collection and disposal by landfill. It is planned to expand this service to include the housing project which will add approximately five ton/day of solid waste, a relatively small contribution to the total total waste load. Little or no additional land would be subject to environmental degradation.

Wastewater Treatment

If a MIUS is not utilized, the housing project will require the use of an existing wastewater treatment plant for treatment of the sanitary wastes generated by the community. There is an existing gravity sewer off site. Therefore, in order to transport the sanitary wastewater generated to the waste treatment plant, it will be necessary to use 3 to 40 acres of land to provide the right of way for the transport line from the site to the sewer trunk line. The environmental degradation associated with the installation of this pipeline will be minimal since it will, in all likelihood, be placed in the right of way of an existing secondary road (western perimeter). The long term environmental degradation is similarly reduced since the existing road precludes the use of the land for other purposes whether or not the pipeline is installed.

If a MIUS is employed, the treated effluent will very likely require the installation of 6000 feet of transport pipe to carry it to the nearby river to avoid discharging the treated effluent to a natural storm drainage ditch. This ditch would also carry the effluent to the river, as it does the storm run-off for the entire site area. However, during dry weather, the effluent would be the only flow in the ditch and the quality of the resultant stream may not be in compliance with state regulations. The right of way for this pipeline would also involve four acres of land; therefore, the environmental degradation associated with the installation of this pipeline equates to that experienced by the installation of the transport pipeline required if a MIUS is not used. In the former case the impact may be more severe since the MIUS effluent pipeline will be installed in undeveloped woodlands, and trees and shrubs would be removed during construction. However, it appears that the path to be followed for the pipeline would be the same as that required for a proposed road extension that would run north and south along the western border. If this road were constructed before the effluent pipeline to the river, the environmental degradation attributable to the pipeline would equate to that experienced if a MIUS were not utilized.

3. COMPARATIVE ENERGY ANALYSIS

The purpose of Section 3. is to present the methodologies and results of a comparative energy analysis of MIUS and conventional utilities for each of five housing projects described in Sections 1. and 2. The methodologies and results are those developed for NBS by NASA-USPO, and by Hittman Associates and Charles J. R. McClure Associates.

3.1 EVALUATION METHODOLOGY

Section 3.1.1 is a description of subroutines in the Energy Systems Optimization Program utilized by NASA-USPO to complete the comparative energy analyses. Section 3.1.2 describes the comparative energy analysis methodology utilized by the collaborative efforts of Hittman Associates and Charles J. R. McClure Associates. These NBS technical consultants utilized the ENVIRON and MEDSI software programs to perform the comparative energy analyses. ENVIRON and MEDSI are two proprietary software programs of Mechanical Engineering Data Services, Inc.

3.1.1 NASA Methodology

Section 3.1.1 represents the efforts of NASA-USPO as documented in NASA Technical Memorandum 4084 - "Energy Systems Optimization Program (ESOP) Users Guide - Update IV (Volume I)". The ESOP software program was developed for NASA - USPO by Lockheed Electronics Company. Mr. A. E. Brandli of Systems Engineering was the project manager.

3.1.1.1 Energy Systems Optimization Program (ESOP)

The ESOP was written for the purpose of calculating facility load requirements and then evaluating the yearly operational characteristics of MIUS designed to satisfy these loads. Based on these average hourly, daily, monthly, seasonal and yearly loads, the energy analysis predicts the fuel requirements for a MIUS and a conventional system to satisfy these loads.

Figure 3.1.1.1 presents a generalized schematic of a typical ESOP energy analysis. Building utility loads are computed as a function of outside ambient, desired inside conditions, building construction and geometry, building power usage, occupancy rate, and occupant metabolic rate. Each parameter is updated each hour of a twenty-four hour day. The load calculations are performed for each building type. These results are summed for all the buildings of the same generic type. The loads for each generic building type are again aggregated to obtain the total load profile for a twenty-four hour day. From the calculations, the housing project energy requirements are obtained. This total energy requirement can be aggregated on hourly, daily, seasonal, and yearly bases.

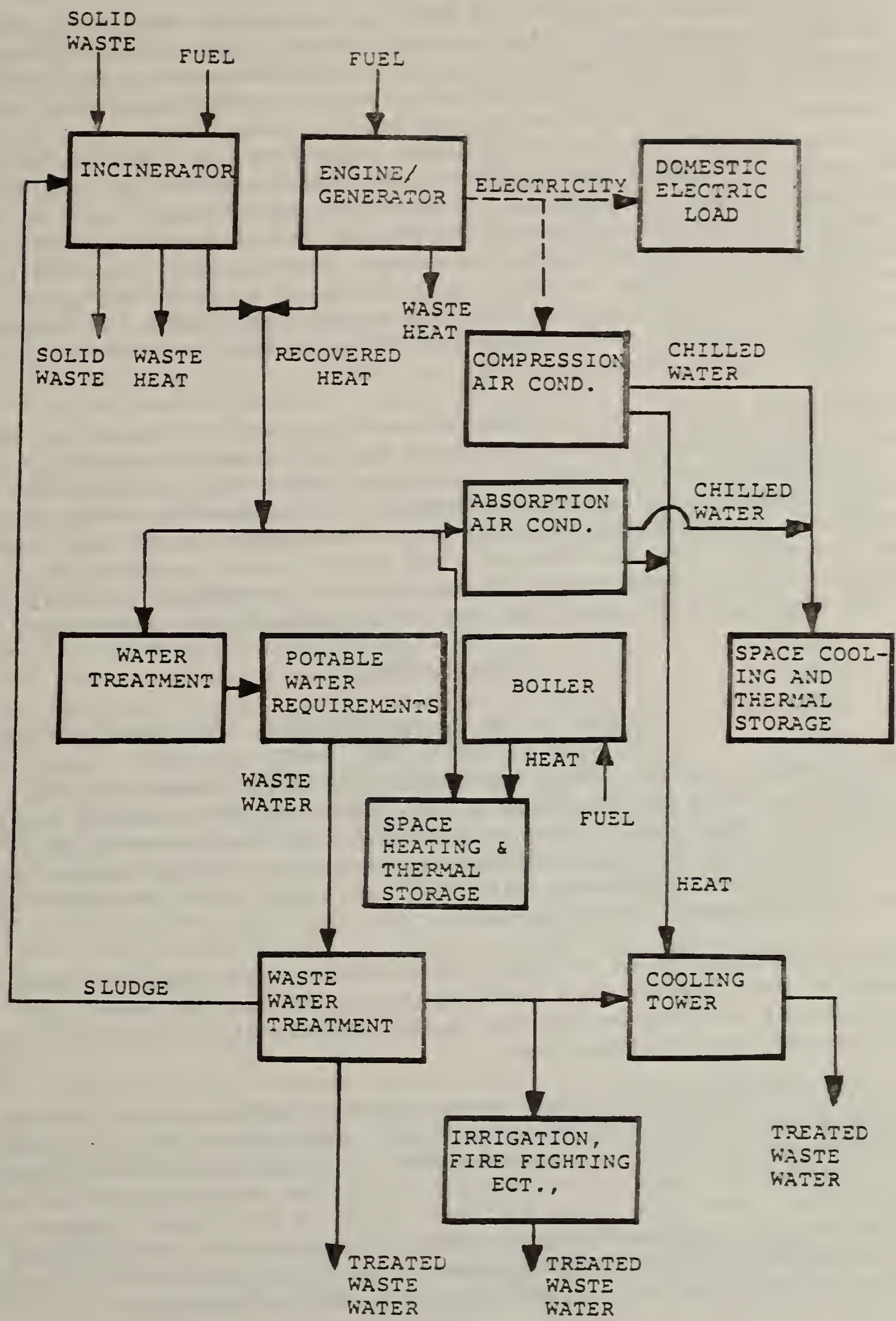


Figure 3.1.1.1 Generalized ESOP energy analysis schematic

The power generation section of ESOP calculates the energy required by specific, user-selected prime movers to deliver the electrical energy. The amount of usable waste heat which can be recovered from the prime movers is also calculated. The solid waste disposal section of ESOP predicts the daily solid waste load and the energy required to operate a specific user-selected solid waste disposal system. The daily quantity of usable waste heat energy which can be recovered from the solid waste disposal system is determined. The wastewater treatment section computes the wastewater load and tracks the changes in wastewater quality as it passes through each wastewater treatment process. The sludge is recovered and is transferred to the solid waste disposal system. The conventional utility system section calculates the energy requirements of a commercial utility system that meets the same heating/cooling, hot water and domestic/ auxiliary power demands as MIUS.

ESOP energy data output, in general, consists of: the operating characteristics and recoverable heat energy of the solid waste disposal system; all components of the heating and cooling loads; the load demands, operating characteristics, and energy requirements of the specific prime mover being analyzed; an indication of degree of utilization of waste heat energy; and a summary of daily, seasonal, and yearly energy requirements of the specific MIUS configurations (twenty-four in the case of diesel/turbine prime movers and twelve in the case of the steam power plant prime mover).

Program Input

All input data to the ESOP is in namelist format. The data consists of six namelists: INPUT, ENVRHR, BLDGD, WWT, WASTE and CONST. Each run of ESOP requires one WWT, WASTE and CONST namelist. In addition, each type of building being served requires its individual INPUT, ENVRHR and BLDGD namelists. Generally, a case study consists of four separate runs, each run representing a typical 24 hour day of winter, spring, summer or fall. All input parameters will remain unchanged from one run to the next unless changed by new input.

Namelist INPUT contains variables which define: the number of buildings; number of dwellings in each building; hot water heating demand per building (if not residential-type building); all-electric option flag; and basement option parameters.

Namelist ENVRHR contains input variables which define twenty-four hour profiles of: inside and outside dry bulb temperatures and air enthalpies; domestic and auxiliary electric demands; occupancy rate profile; metabolic rate profile; hot water fraction profile (if not residential-type building); ventilation rates; number of different types of buildings; temperature variation and corresponding coefficient of performance for both heat pump and compression air conditioning (for the all-electric option); total number of occupants in each building; and residential-type.

Namelist BLDGD provides the definition of the building exterior surfaces, the building surroundings and the building location. The surfaces are defined by areas, tilt angles, azimuth angles, transmission coefficients, and solar absorptance of the surfaces. The surroundings and location are defined by the solar reflectance of the ground, cloud cover, atmospheric clearness number, longitude, latitude and time zone.

Namelist WWT contains the parameters which defines the various wastewater treatment processes and the order in which these processes are to be used. There are two categories of input variables, general and specific. General input variables are relevant to all processes. Specific input variables are relevant only to the indicated processes. SERIES, TOTAL, WFLOW, and WTEMP are general input variables. SERIES sequences the processes and identifies the specific process manufacturer. TOTAL identifies the number of processes chosen. WFLOW is the influent wastewater flow in gallons per day. WTEMP is the temperature of the influent wastewater in degrees Fahrenheit. Other general variables are influent wastewater quality in miligrams per liter, sludge flow in gallons per day, and sludge quality in miligrams per liter. The specific variables specify the maximum influent particle size, the maximum loading factor, and minimum detention times of the influent wastewater in the individual wastewater treatment processes identified by the general variables.

Namelist WASTE contains input variables which define: the amount of solid waste to be disposed of; its heating value; the cost of the required fuel; capacity of the incinerator unit; the total quantity of recovered waste heat; the waste heat usage profile; the operating characteristics of the pyrolysis process (if used); and heat recovery efficiencies of both the incineration and pyrolysis processes (if used).

Namelist CONST contains variables which define:diesel/generator or turbine/generator rated loads; boiler efficiencies; heating value of fuel; coefficients of performance for air conditioning systems; percentage absorption/compression for the fixed ratio mode; boiler operating characteristics (for the steam power plant - if used); program logic flags for season; prime mover system low-grade heat utilization selection; lowgrade heat recovery and usage characteristics; water cooling tower operating characteristics; and thermal storage parameters.

Subroutine SWDP

Subroutine SWDP calculates operating parameters and daily total energy input required for three types of solid waste disposal systems: incineration, pyrolysis, and combination incineration/pyrolysis. Process byproducts and recoverable waste energy are also calculated. The incineration process is utilized for this study.

The total daily waste (lbs) generated is a function of input values of the waste generation rate per person (lbs/day), the total number of occupants and the sludge input from the wastewater. The total moisture (lbs) and non-organics (lbs) are calculated from percent (of total waste) values of moisture and non-organics. The total weight (lbs) of organic trash material (combustibles) is then calculated

Organics (lbs) = Total Trash (lbs) - (Moisture + Non-Organics) (lbs)

The daily fuel energy requirement (BTU's) for the incineration process is composed of start-up fuel energy and supplementary fuel energy (required to sustain combustion). The total fuel energy requirement is calculated by

Total Energy Reqd. (BTU's) = Start-up (BTU's) + Supp. Energy Rate (BTU's/HR) x Operating Time (HRs)

where start-up and supplementary energy requirements are input values.

The heat generated by combustion of the trash is a function of the input trash heating value (BTU/lb). The total amount of heat (BTU's) generated by the incineration process is the sum of the fuel energy requirements, the trash combustion heat generation, and the energy available from sludge material. The heat recovered from the incineration process is a function of an input "recovery efficiency" factor.

Subroutine HEAIR

Subroutine HEAIR calculates the heating or cooling loads on a specific building with given internal and external environmental conditions for each hour of a 24 hour day. Input variables define the location, geometry and construction of the building and the internal and external environments.

The total heat gain or loss of the building is calculated as the sum of the six distinct sources. The total building heat gain or loss is:

$$\dot{Q}_{GAIN} = \dot{Q}_{ELEC} + \dot{Q}_{MET} + \dot{Q}_{VENT} + \dot{Q}_{COND} + \dot{Q}_{RAD} + \dot{Q}_{HW}$$

The building domestic electricity usage is totally dissipated within the building. Auxiliary electricity usage is not considered to be a heat load source.

$$\dot{Q}_{ELEC} = \text{domestic usage } \left(\frac{\text{KW-HR}}{\text{HR}}\right) * 3414 \text{ BTU/KW-HR} = \text{BTU/HR}$$

The sensible and latent heat loads are calculated by empirical equations with metabolic rate per occupant and inside dry bulb temperature as independent variables. When the building is being cooled, both the sensible and latent gain are considered. In the heating mode only sensible is considered.

$$\dot{Q}_{MET} = (Q_{SENS.} + Q_{LAT}) * \text{No. of occupants}$$

Sensible and latent heat loads from ventilation air are calculated the following manner for the heating and cooling modes.

Cooling Mode:

$$\dot{Q}_{VENT} = \omega \, (H_{OUTSIDE} - H_{INSIDE})$$

Heating Mode:

$$\dot{Q}_{VENT} = C_p \, \omega \, (T_{OUTSIDE} - T_{INSIDE})$$

Where:

ω = mass flow

H = specific enthalpy

T = dry bulb temperature

C_p = specific heat

Conduction heat transfer load from the walls, roof, and windows is:

$$\dot{Q}_{COND} = Q_{ROOF_{COND}} + Q_{WALLS_{COND}} + Q_{WINDOW_{COND}}$$

$$Q_{ROOF_{COND}} = UA\Delta T$$

$$Q_{WALL_{COND}} = UA\Delta T$$

$$Q_{WIND_{COND}} = UA\Delta T$$

U = heat transfer coefficient

A = area

ΔT = temperature differential

Radiation heat transfer load from the building window glass is:

$$\dot{Q}_{RAD} = A_{WINDOW} \text{ (DIRSOL + DIFSOL) where}$$

A = window area

DIRSOL = direct solar radiation flux passing through the glass

DIFSOL = diffuse solar radiation flux passing through the glass

Provision is made for calculation of the heat gain from the use of hot water in the building. The heat gain due to domestic hot water is:

$$\dot{Q}_{HW} = HWF*Q_{HWD}$$

Q_{HW} = Heat gain from the use of hot water in the building

HWF = Fraction of hot water demand that becomes a heat source

Q_{HWD} = Hot water demand

The above process is repeated for each building type. The calculated total heating/cooling demand profiles, the hot water demand profiles, and the input domestic and auxiliary electrical demand profiles are then summed to comprise the total 24-hour load demand profile.

Subroutine AIRHT

Subroutine AIRHT calculates, on an hourly basis, the required energy output of the MIUS energy systems (thermal storage, boiler, diesel/generator, and/or turbine/generator). For this study diesel/generators are utilized.

The hot water heating demands are initially met by low-grade waste heat energy recovered from the lubrication oil cooling system and water jacket cooling system (if not ebullient cooling) of the diesel/turbine prime mover. If there is low-grade heat left over after meeting the hot water demand, it is used for the space heating demand. If there is enough low grade heat to satisfy both of the above demands, none of the high grade heat recovered from the prime mover (exhaust and water jacket - if ebulliently cooled) and the incineration process will be used for these demands. If there is not enough low-grade heat to meet both the domestic hot water and space heating demands, the high grade recovered heat will be used. If there is not enough high-grade (plus low-grade) heat to satisfy these demands, the boiler is fired to meet the necessary remaining demands. The absorption chillers use the high-grade heat until it is all used or until the total air conditioning demand is met. The compression air conditioning system is used, if the absorption chiller can not meet the total air conditioning demand.

The air conditioning load demands are met by an air conditioning system that has four modes of operation: compression refrigeration; absorption refrigeration; fixed ratio - compression/absorption; and floating ratio - compression/absorption. The "Floating Ratio" system operation is determined by an iterative method that maximizes usage of available waste heat by the absorption system and minimizes electrical consumption by the compression system for each hourly period. Thus, the ratio between compression/absorption air conditioning varies hourly. The iterative method for the "floating ratio" system uses a technique involving up to 25 iterations to ensure that the sum of the absorption A/C load plus the compression A/C load comes within 2 tons of the total air conditioning demand for the particular hour being considered.

The coolant water flow from the MIUS system to the cooling tower is determined by the heat rejection rate of the A/C condenser system, miscellaneous heat rejection requirements, and the cooling capacity of the cooling tower. Coolant water is lost through drift, evaporation, and blow-down processes. This loss is made up with wastewater effluent flow. Requirement for the waste heat and wastewater effluent flow are input to the program. Recovery, utilization, and disposal of the heat and water are summarized in the program output. The total MIUS electric power load demand is comprised of the domestic and auxiliary demands (program input) and the calculated electric power required to drive the compression-type air conditioning system.

Subroutine GENRAT

Subroutine GENRAT calculates the hourly energy requirements for prime mover/generator units as a function of electrical load demands imposed by subroutine AIRHT. The program user may specify the engine/generator to be used or the program will select the engine/generator which will require the minimum fuel during a mean year. GENRAT also calculates the hourly rate of waste heat energy that is recovered from prime mover heat exchanger systems. The operating characteristics as a function of percent full rated load operation of ten diesel and two turbine generator units are currently programmed into GENRAT. Among these operating characteristics are the specific fuel consumption in Btu/kWh and the recovered waste heat from the engine exhaust, water jacket, and lubricating oil, all in Btu/h.

When a Thermal Storage System is not included in MIUS the number of specified prime mover/generator units required to meet the electrical load demand is determined by the criteria that a unit can only be loaded to a maximum of 90% of its rated full load capacity. Thus, when one unit is loaded to 90% capacity, another unit is brought into operation and the two units operate at 45% load.

When a thermal storage system is included in MIUS, the number of generators will be the minimum number required to meet the day's maximum auxiliary and domestic electric demand without exceeding 110% of generator rated output. Each hour's total electric demand (auxiliary, domestic and compression air conditioning) is evenly distributed among the generators.

Conventional Utility System

ESOP also calculates the energy required by a conventional utility system to provide the same services provided by MIUS. The conventional system modeled in the program consists of a central power generation facility, all compression air conditioning, and a gas-fired boiler for space heating and hot water heating. The program does provide sufficient information such that the energy requirements of other types of conventional systems (e.g., heat pumps for single family dwelling units) can be calculated.

3.1.2 Hittman/McClure Methodology

ENVIRON was utilized to compute individual building heating and cooling loads. Section 3.1.2.1 describes the ENVIRON software program. Information concerning ENVIRON can be found in "Heating and Cooling Loads Calculations" by National Computer Service, Inc. NCS is a service organization providing computer services to architectural and engineering firms. MEDSI was utilized to size individual building HVAC and utility equipment and to compute energy balances for both MIUS and conventional utilities. Section 3.1.2.2 describes the MEDSI software program. Information concerning MEDSI can be found in "Shared Time System Computer Programs for Heating and Cooling Energy Analysis of Building Air Conditioning Systems" by C. J. R. McClure and J. C. Vorbeck.

3.1.2.1 ENVIRON

The ENVIRON Heating and Cooling Load Program calculates heating and cooling loads for structures. There are 3 input forms. Form 01, DESIGN CONDITIONS FOR ENTIRE BUILDING, consists of master design data (such as design indoor dry bulb temperature and number of cooling months) and is filled-in only once for each job. Form 02, MASTER LOADS FOR ENTIRE BUILDING, consists of construction data (such as typical wall, roof, and floor sections) and is also filled in only once for each job. Form 03, INDIVIDUAL SPACE CONSTRUCTION DATA, is used for each space for which loads are desired. A space may be an individual room, group of rooms, a zone or a whole building. A job may be a building or a whole development with the same HVAC design constraints and same wall, roof and floor construction.

Design Conditions For Entire Building (Form 01)

The program automatically creates an outside temperature profile which correctly adjusts the outside temperature for each hour being considered (Summer Outdoor Design, Winter Outdoor Design). This is accomplished by taking the outside design temperature and the daily range specified and fitting these values to a 10-year average weather distribution curve. Then when the load calculations require the outside air temperature, as in ventilation loads, the program goes to the temperature profile and uses the correct outside temperature for each hour as it makes it's hourly calculations. The user need never refer to the psychrometric chart because this has been fully programmed and stored. The outdoor load and indoor humidity ratios for every hour (needed for ventilation load calculations) are determined automatically from the design entries for dry bulbs, wet bulb, relative humidity, and from the temperature profile.

The user may, at his option, have the instantaneous thermal loads averaged over a specified number of hours in order to consider the thermal storage effect of the building. Some engineers wish to base the maximum cooling load on the peak instantaneous heat gain for a given building. On other jobs, they may wish to account for a difference between instantaneous heat gain and instantaneous cooling load caused by thermal storage effects of the building. When thermal load averaging is used, the program averages the following loads in accordance with recommendations of the ASHRAE Guide: window solar, walls, roofs, lights and the sensible portion of the occupancy loads.

Master Loads For Entire Building (Form 02)

The description of walls, windows, roofs and floors is entered only one time, using Input Form 02. For example, a building may have three different types of wall construction. Each type is described on a separate line on Form 02. These are then described as Wall Type 1, Wall Type 2, Wall Type 3 etc. Later, when individual room data is being input, outside walls for a room are simply described as a Type 1 or 2 or 3 etc. This eliminates much repetitive input which is customary in load calculations and results in a great saving in time.

Eight general types of wall construction are described in Table I in the instructions. It is recognized that many walls which will not fit exactly into one of these types, but the user selects the closest to his actual condition, paying particular attention to the time-lag hours shown on Table I. Each set of published equivalent wall temperature differentials is intended to cover a range of construction. Within each of the eight brackets, ENVIRON will correctly select the equivalent temperature differential for any hour and orientation. In addition, the wall load calculation is made even more precise, because the program will accept any U-value entered by the user. The program will calculate loads for systems with return air plenums under roofs or between floors, by providing entries for percentage of loads to return air. Also, provision is made to consider heat-of-light systems where part of the lighting load goes directly to return air. These entries affect the psychrometrics of the space and building loads.

Shading coefficients are pre-stored and need not be entered if the user does not wish to do so. These coefficients are given in Table III of the instructions. The user may enter any optional shading coefficient if he elects to do so. Any window U-value may be entered for use by the program in calculation of conduction loads.

Internal loads for the number of people, heat gain per person, and lighting, in addition to ventilation loads, may be input one time as master entry. These loads will then apply to all spaces in the building unless the user overrides the master internal loads or master ventilation loads; the user need only make an entry on the appropriate line on Form 03 for the room involved. Outside air ventilation may be input in any one of three ways (a master entry or for any individual space): CFM per person, percent of supply air, or air changes per hour. Infiltration is input as air changes per hour.

Individual Space Construction Data (Form 03)

The user need not make any area, volume or air change calculations. The program automatically makes all calculations for floor area, roof area, net wall areas (windows automatically deducted), air changes etc., using the space dimensions input by the user on each Form 03. The program recognizes the difference between room units and central systems.

The program calculates loads for any orientation and construction type. The program first determines the equivalent temperature differentials for the wall by deriving the correct solar heat gain factors, solar temperatures, decrement factor, and time lag for any construction type, for any hour, and for any orientation. The program calculates both solar and conduction loads for windows. Correct solar heat gain factors are determined for any hour, for any month, for any latitude, and for any orientation. Since straight-line interpolation of tabular solar data is not correct, all calculations are made from basic formulae.

3.1.2.2 MEDSI

MEDSI heating and cooling energy calculations were made by time-share computer programs using Weather Data taken from Air Force Manual 88-8 and U.S. Weather Bureau Climates of the States covering 218 areas in the United States. Charles J. R. McClure and Associates, Inc. was the developer of the computer program system. Reheat, Heat-Cool-Off, and Multizone (or Double-Duct) are three basic routines which produce net requirements of ton-hours and Btu x 10^5. In addition to the weather file, these routines require 91 data to describe building heat gains and losses, the heating and air conditioning system, and building use. HC ENERGY converts the output file of these routines to the total fuel and electrical energy of equipment selected to satisfy Reheat, Heat-Cool-Off or Multizone Loads. HCENERGY requires an additional 32 data such as efficiencies and auxiliary plant loads.

The basic procedure common to all programs is illustrated in the logic diagram (Figure 3.1.2.1). As indicated in the diagram, each of the 36 time periods that make up the weather year are printed after the influence

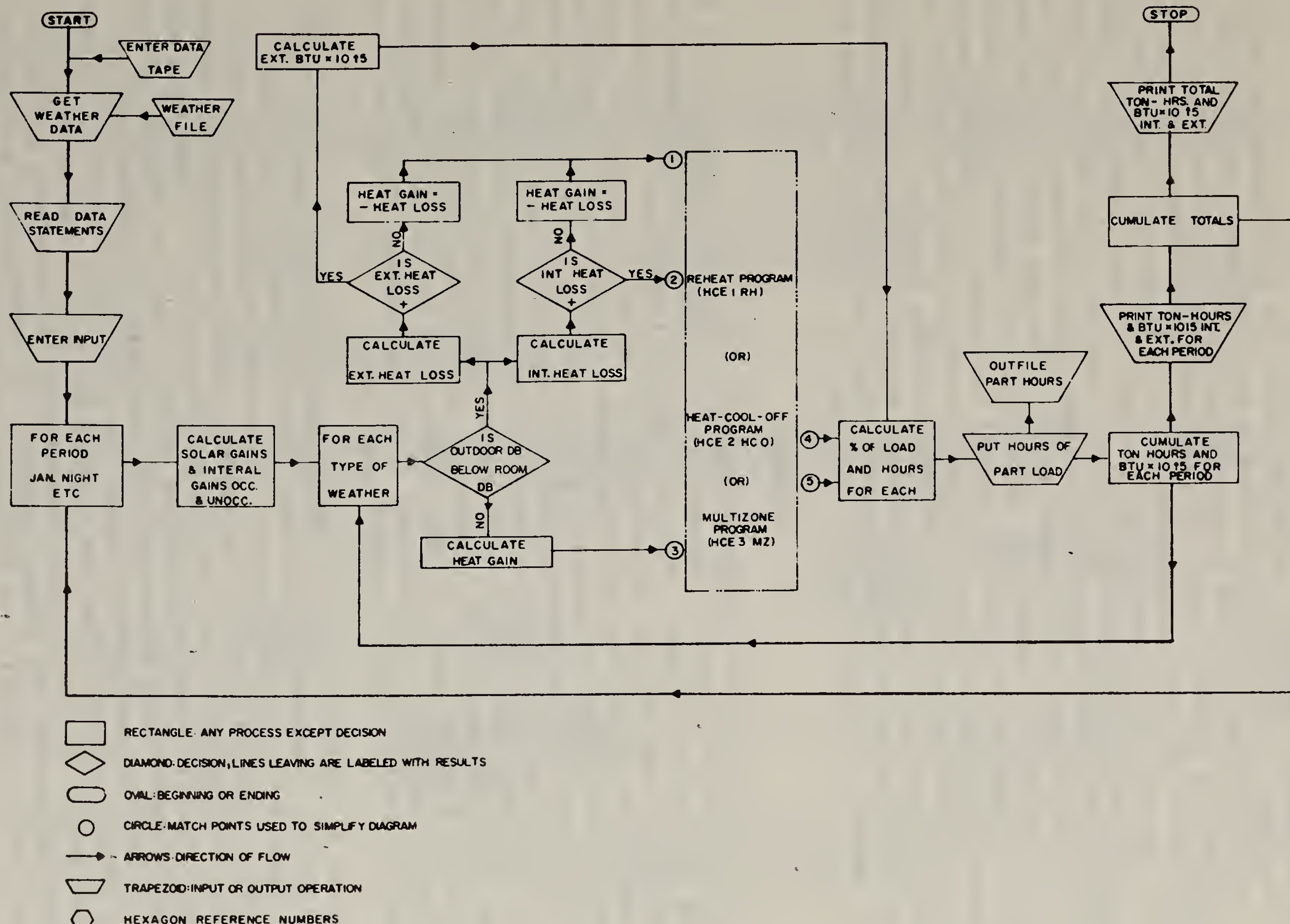


Figure 3.1.2.1 Basic logic diagram common to all programs.

of each weather incident is calculated with the input data. The programs determine solar heat gains, external heat losses and gains, and internal gains and losses, process the raw building load in the unique features of the selected system program, calculate part load hours and accumulate the totals of the various output information.

Programs HCE1RH, HCE2HCO, and HCE3MZ model the performance of reheat, heat-cool-off, and multizone or double duct systems, respectively. The weather files have been created from Air Force Manual 88-8, Chapter 6, Engineering Weather Data. In this manual, the number of hours of occurrence of dry bulb temperatures in 5° F ranges for night, day and evening periods of all months are recorded for many locations. Each weather file contains this information for its location, along with monthly mean coincident wet bulb temperatures for each range, and with monthly factors which relate average solar gains to July peaks and monthly cloud cover factors. Using the information in the data and weather files, each system program calculates the building thermal loads for each weather and occupancy occurrence and then simulates the performance of the specific HVAC system which is to meet these loads. All three system programs recognize such features as economizer, with or without enthalpy control, night setback, system specified on or off during unoccupied cooling periods, and different summer and winter room temperatures.

Reheat

The logic diagram of the reheat program (*HCE1RH) in Figure 3.1.2.2 illustrates the analysis used to reflect the performance of this system in meeting the building loads. When the outdoor temperature is lower than room dry bulb, the program accounts for the effect of economizer cycle. A determination of the mix air temperature is made, based on input data concerning reset range of mix air if used, and, if the outdoor air temperature is lower than the adjusted mix air temperature then the cooling effect of the outdoor air is calculated. The quantity of reheat is calculated for conditions when the space needs additional heat and added to the heat required to preheat outdoor air and to humidify. This program allows for a 3 degree shift in room temperature before the reheat load is figured to account for thermostat throttling range. These calculations are done for each different weather condition.

If there is no economizer cycle, the program calculates required reheat for the mix air temperature resulting from the introduction of the minimum quantity of ventilation air. The refrigeration load required to cool the supply air down to the design supply temperature is adjusted to reflect the cooling effect of minimum outdoor air. If the space does not require the full available cooling effect, then the program calculates the necessary reheat and determines required heat for humidification. A separate loop is provided to account for a special control cycle that will use 100% outdoor air when the outdoor wet bulb temperature is below return wet bulb. When the outdoor temperature is above room dry bulb, the program calculates the reheat needed in the same manner as with the economizer cycle. However, the refrigeration requirement is determined

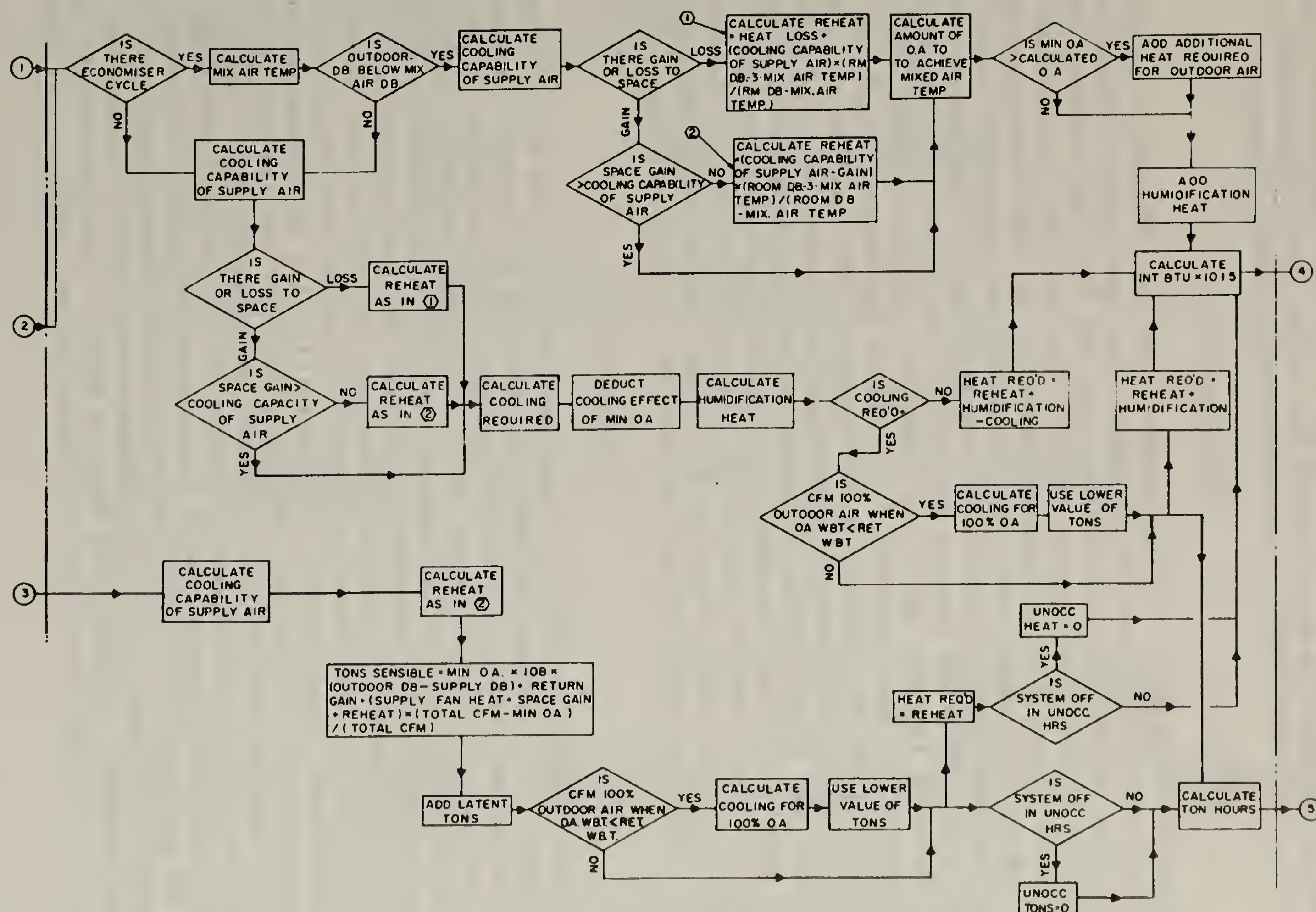


Figure 3.1.2.2 Logic diagram for reheat program.

as the sum of the minimum outdoor air sensible cooling, return air heat gain, supply fan heat, space heat gains and the heat added as reheat plus the latent heat load from internal loads and outdoor air dehumidification. The same loop as above is available to reflect 100% outdoor air when outdoor wet bulb is below return wet bulb. The program also accounts for the scheduled mode of operation during occupied hours.

Heat-Cool-Off

The logic diagram of the heat-cool-off program (*HCE2HCO) in Figure 3.1.2.3 illustrates the calculation procedure for this system. When the outdoor air is below dry bulb temperature, and the building internal gains exceed the heat losses, the program accounts for the cooling, heating and humidification required for minimum outdoor air and then determines if the system is in occupied mode and if there is an economizer cycle. The heating needs for humidification and building refrigeration loads are calculated. When the outdoor temperature is below room temperature and the building internal gains are less than the heat losses, the program calculates the heat required for treating the minimum fresh air and supplying heat to offset the losses. When the outdoor dry bulb is not lower than room dry bulb, the computer determines the cooling required to offset sensible and latent gains, including minimum outdoor air and then adjusts this value to reflect a reduction in latent load proportional to the ratio of total load to the size of the cooling system. A loop of computer operations will take account of a special control cycle that provides 100% outdoor air when the outdoor wet bulb is below return wet bulb.

Multizone

The logic diagram or the multizone program (or Double Duct System - HCE3MZ) in Figure 3.1.2.4 shows the analysis employed to account for special considerations inherent with this system. Separate modes of calculation are used to reflect the system performance when the relationship of outdoor air temperature to room temperature changes as in *HCE1RH and *HCE2HCO. Bypass factor is the percentage of supply air that goes through the heating coil and this value is determined for each weather condition. The influence of the economizer cycle on cooling and heating energy use is calculated. Heat required for humidification is determined for each new condition of outdoor air quantity, enthalpy and internal latent gain. The influence of 100% outdoor air when outdoor wet bulb is lower than return wet bulb is calculated. The refrigeration requirement is calculated using the adjusted bypass factors and including the latent heat load of outdoor air. Use of the recalculated bypass factor reflects the changing conditions of face and bypass control and is valid when the bypass is merely untreated mix air, as when no heat is added to a hot deck in the summer cycle, and when there is heat added to the bypassed air.

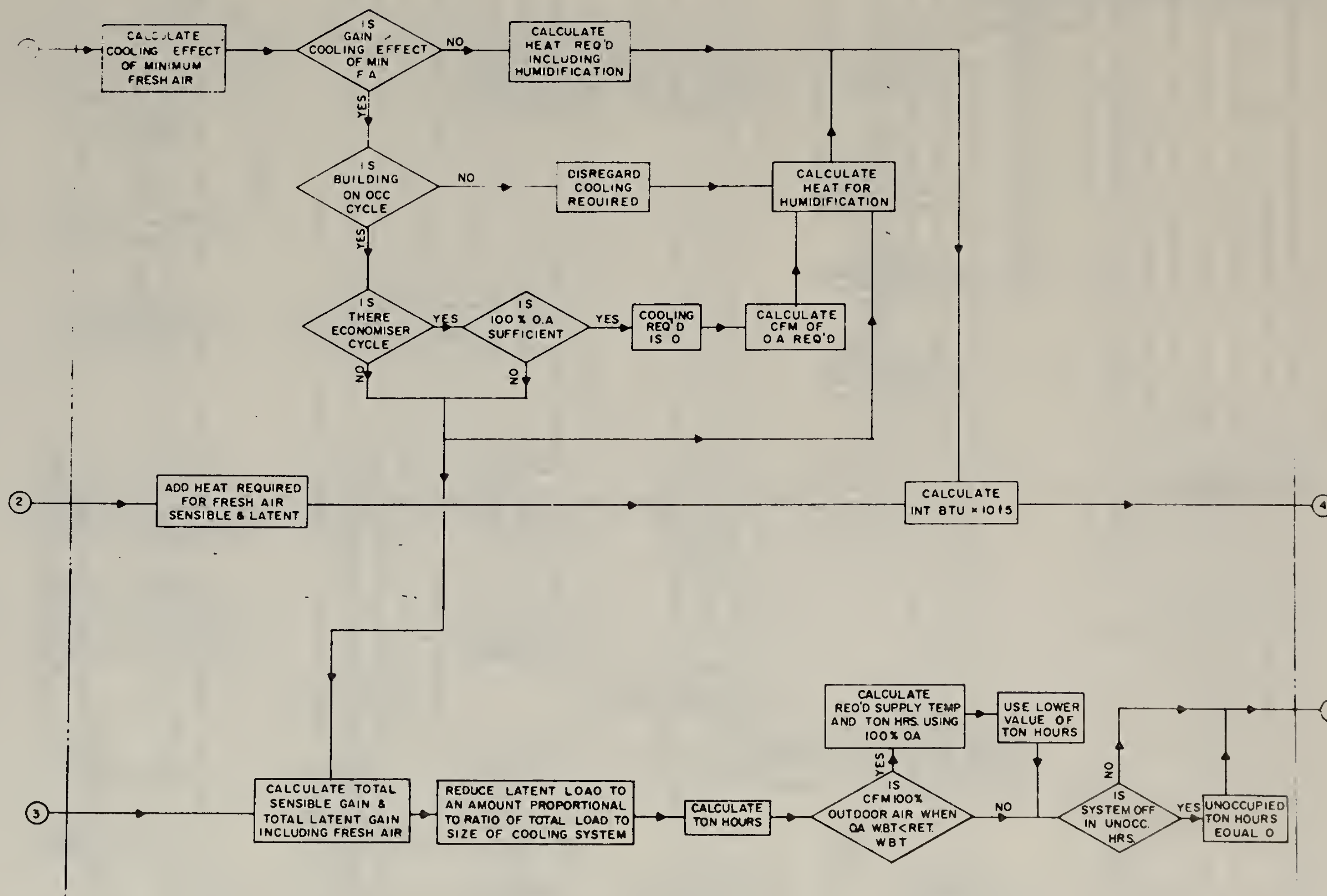


Figure 3.1.2.3 Logic diagram for heat-cool-off program.

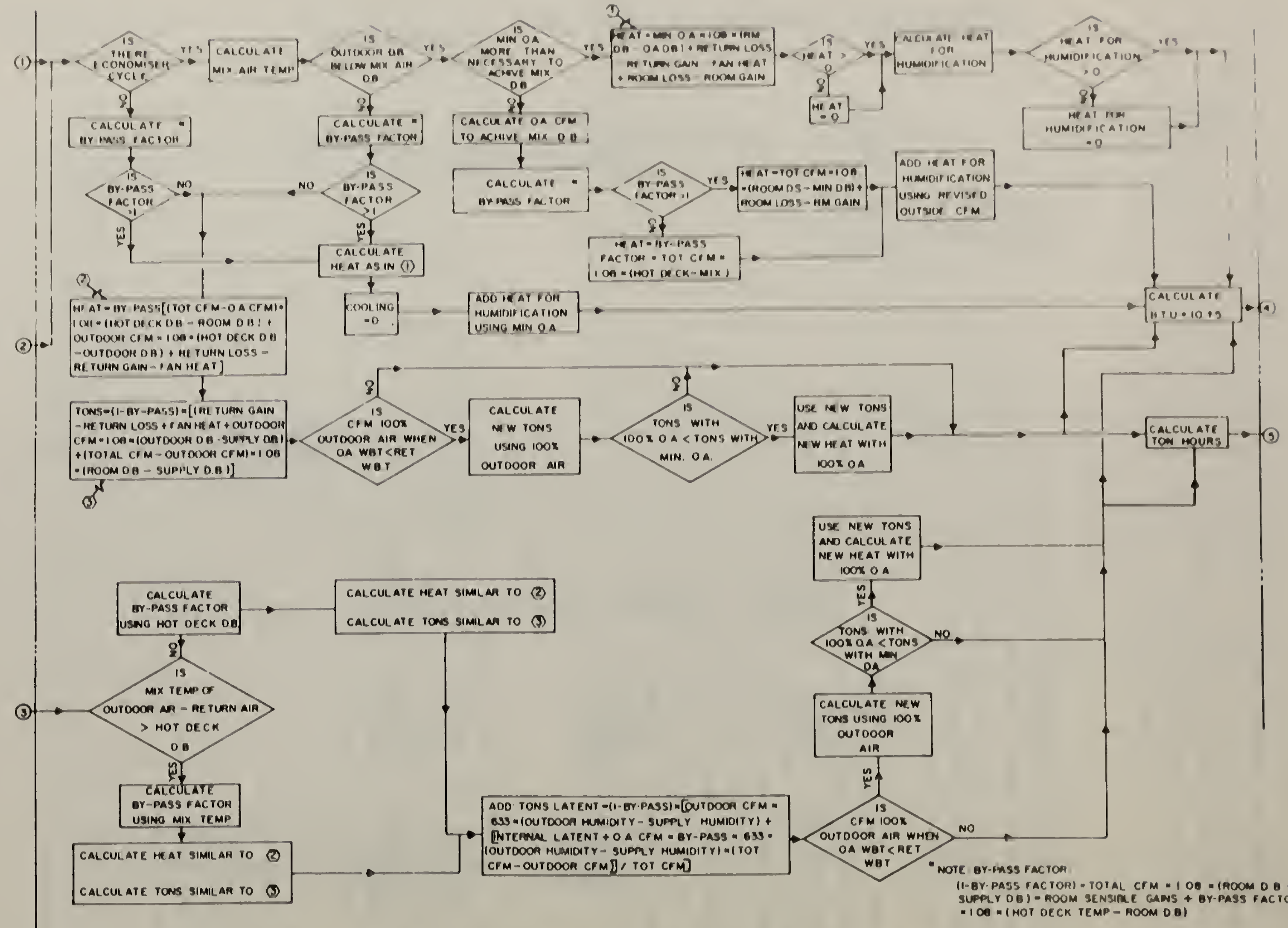


Figure 3.1.2.4 Logic diagram for multizone program.

*HCENERGY produces the total fuel and electrical energy input required for the apparatus selected for the project. Output of this supplementary program facilitates comparative analysis of several alternatives of equipment and fuel source. Additional input information describing the characteristics of the apparatus to be used in serving the building loads must be entered. The reduced load performance characteristics, capacity and quantity of boilers, of chillers, towers, and of pumps are related to the part load hour calculations made in the program to account for variable energy conversion efficiency.

3.2 PRESENTATION OF RESULTS

Section 3.2 presents the detailed results of the NASA and NBS comparative energy analyses summarized in Section 1.2.2. Section 3.2.1 details the results developed by NASA; Section 3.2.2, those by Hittman Associates and McClure Associates in behalf of NBS.

3.2.1 NASA Evaluation

The purpose of Section 3.2.1 is to present detailed background data developed by NASA-USPO which is the basis for data presented in Section 1.2.2. The more significant aspects of ESOP input information, the generic MIUS and conventional utilities models, and energy computation procedures are identified.

Section 3.2.1.1 describes the manner in which utility load profiles were developed for the five housing projects. Section 3.2.1.1 describes the individual building simulations and site specific assumptions used in conjunction with ESOP. Information for Section 3.2.1.1 is found in "Preliminary Design Study of a Baseline MIUS System"[2], a community study[3], and additional work by a NASA-USPO technical group headed by Mr. H. E. Benson. Section 3.2.1.2 presents the MIUS and conventional utility systems developed by NASA-USPO. Tables have been added which summarize the major aspects of these designs for the five housing projects. Information for Section 3.2.1.2 is found in the community study and a MIUS design study[4].

3.2.1.1 Utility Loads

The loads (electrical power, HVAC, potable water, sewage and solid waste) were defined by determining the utility requirements of each building and the housing project. Refer to Table 3.2.1.1.

Analysis of the energy utilization and other consumables was accomplished primarily with the ESOP. The ESOP was first used to determine peak

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[2] This and other similar superscripts represent individual citations of REFERENCES located at the end of this document.

Table 3.2.1.1

NASA Utility Load Data
(Plant + Site)

	Housing Project				
	#1	#2	#3	#4	#5
Electric Power Generation:					
Peak, MIUS (kW)	1912	1828	8617	9848	1434
Peak, CONV (kW)	2679	1828	9554	9848	1959
Average, MIUS (kW)	1099	554	3567	3612	792
Average, CONV (kW)	1168	582	3695	3776	855
Annual, MIUS (kWh x 10^{-6})	9.63	4.86	31.16	31.64	6.94
Annual, CONV (kWh x 10^{-6})	10.23	5.10	32.37	33.07	7.49
Load Factor, MIUS (%)	57.5	30.3	41.3	36.7	55.2
Load Factor, CONV (%)	43.6	31.8	38.7	38.3	43.6
Space Heating:					
MIUS (Btu/h x 10^{-6}	15.08	5.30	40.18	43.16	10.54
CONV (Btu/h x 10^{-6}	15.08	5.30	40.18	43.16	10.54
Air Conditioning:					
MIUS (tons)	1357	604	4015	3580	1166
CONV (tons)	1357	604	4015	3580	1166
Solid Waste Disposal (av):					
MIUS Refuse (lb/d)	12340	4460	26000	32855	10000
CONV Refuse (lb/d)	12340	4460	26000	32855	10000
MIUS Sludge (lb/d)	8630	1900	17100	20550	7000
CONV Sludge (lb/d)	8630	1900	17100	20550	7000
Wastewater Treatment (av):					
MIUS (kgpd)	168	36	316	385	130
CONV (kgpd)	168	36	316	385	130
Potable Water Treatment (av):					
MIUS (kgpd)	169	36	322	392	130
CONV (kgpd)	198	55	381	467	154

equipment loads for equipment sizing. This was done by performing analyses for the summer and winter seasons with hourly weather data which was two standard deviations above and below the mean, respectively. Data for January are used for the winter season and July data for the summer season. Mean data for January, April, July, and October are used, respectively, for winter, spring, summer and fall seasonal analyses.

Electric Power Generation

Each building and individual dwelling unit was analyzed, and a 24-hour profile of the domestic load was developed. The domestic load is defined as lights, electric oven (where applicable), other appliances, and all other electrical loads except environmental conditioning loads. Where necessary, MIUS-peculiar loads were added. To develop the electrical profiles for the dwelling units, the diversity among units was considered.

Some electrical loads within the community were not associated with a particular building. Houston Lighting and Power Company standards were used for the streetlighting loads of the various sections of the community. The electrical loads for the lighting in the parking areas of the community were based on parking-area lighting levels from McGuiness and Stein.

The environmental conditioning of the site used excess heat from electrical power generation equipment and from incineration for absorption air conditioning in the summer. However, it was necessary to provide additional compression air conditioning at various times in the summer. The absorption/compression split of the total cooling load varies so that the amount of absorption air conditioning is maximized to use all available heat energy. The electrical power load is a function of the amount of compression air conditioning required.

The MIUS does not directly supply environmental conditioning to the single-family detached houses. Each house had standard electric central air conditioning unit. The total electrical power load was a result of the amount of compressive air conditioning required by the MIUS itself and the additional electrical load to cool the single-family houses. Additionally, the HVAC auxiliary loads, pump motors, etc. were included.

Space Heating and Air Conditioning

HVAC requirements were derived as a function of HVAC loads developed over a 24-hour period. For air conditioning, the loads were based on a 2-sigma (two standard deviations above and below the mean) hot summer design day; for winter, the heating loads are based on a 2-sigma cold winter design day.

The calculation of the community heating and air conditioning loads used basic HVAC load determination techniques from the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) supplemented by design manuals from commercial environmental conditioning firms. The actual calculation of the loads on the various building types within the community was performed by a computer program, the Energy Systems Optimization Program (ESOP). The design is required to maintain an inside temperature of 74°F dry bulb with a 50-percent relative humidity. Material "U" factors, solar factors, and other constraints that were used are obtained from ASHRAE.

Solid Waste Disposal

The generation of solid waste was estimated for each building based on published reports, generally in terms of pounds per day per capita.

Potable Water/Wastewater Treatment

Potable water demands were determined from published surveys. For a residential unit, water uses included kitchen, laundry, bath and toilet demands, as well as exterior demands such as recreation (e.g., pools) and car washing. Average daily demands and hour-by-hour profiles were developed for both hot and cold water. The outdoor demand varied with season and averages were determined for each of the four seasons.

The loads on the wastewater system were the same as the potable water loads with the exception of that used for exterior demands. Blowdown loads of the MIUS processes, particularly from the heat rejection system were treated. The MIUS treated wastewater was reused for irrigation, MIUS process water makeup (especially for heat rejection), and could be used for fire protection. This reuse thus reduces the potable water requirements. Irrigation requirements were based on area and climatic conditions and varied per season. Fire protection storage requirements were based on the National Board of Fire Underwriters Handbook.

Site Specific Assumptions

The purpose of this section is to identify some additional NASA assumptions used in the energy evaluation of housing projects, #1 through 5. Refer to Table 3.2.1.2 and to Table 1.1.4.1.

Housing Project #1 consisted of 240 apartment units and 527 townhouse units. After analyzing the square footage, NASA concluded that the LOW-RISE SINGLES would be the appropriate model for the apartment units. NASA adjusted the unit count to allow for any differences in floor area. NASA utilized their TOWNHOUSE model for the remaining units. The unit count was adjusted as for the apartment units. This adjustment reduced the wall area by a small percentage. The incinerator supplementary fuel rate was 0.825×10^6 Btu/h. The incinerator start-up fuel requirement was 0.4×10^6 Btu/day.

For Housing Project #2, the single-family detached and apartment unit numbers were based on percentages given in the developer's descriptive text. The motel, maintenance area, historical buildings, and trailer park annual energy utilization and consumables were not calculated. The total commercial space utilized for the energy analysis has 35,000

Table 3.2.1.2

	Housing Project				
Model	#1	#2	#3	#4	#5
Low Rise Family:					
Bldg		1	1	1	
Units		40	208	667.5	
Sq Ft		44,689	231,495	744,810	
Low Rise Singles:					
Bldg	1			407	
Units	240			1	
Sq Ft	174,960			1500	
Townhouse:					
Bldg	1		1	1	1
Units	527		362	553.5	500
Sq Ft	685,100		459,148	719,550	791,120
Single Family House:					
Bldg		105	700		
Units		1	1		
Sq Ft		1,500	1,500		
Commercial:					
Bldg		1	1	1	
Units		3.53	3.25	8	
Sq Ft		35,000	32,787	79,200	

square feet. The incinerator supplementary fuel rate was 1.2 x 10^6 Btu/hr. The incinerator start-up fuel requirement was 0.6 x 10^6 Btu/day.

For Housing Project #3, NASA considered the Village Center as a whole. The school was modeled as a COMMERCIAL AREA of 10,000 square feet for a total of 32,000 square feet. NASA utilized their SINGLE FAMILY HOUSE model. Seven hundred units were assumed. SINGLE FAMILY HVAC is all electric. NASA used the LOW-RISE FAMILY model for the 208 apartments. The triplexes were modeled as TOWNHOUSES. Triplexes were to have pitched roofs; the TOWNHOUSES were flat. Triplexes were to have an 8 foot floor to ceiling dimension; TOWNHOUSES were nine. The TOWNHOUSES were served by district HVAC. Furnaces were shown for triplexes in some developer drawings. The incinerator supplementary fuel rate was 1.5 x 10^6 Btu/h. The incinerator start-up fuel requirement was 0.6 x 10^6 Btu/day.

For Housing Project #4, the developer did not supply any building construction detail other than the percent of each building type and the total number of buildings. The LOW-RISE FAMILY model was utilized to simulate the apartment units. The model unit count was adjusted to 667.5. The TOWNHOUSE model was utilized and the number count was adjusted to 553.5. NASA also used LOW RISE SINGLES to simulate 407 single-family detached units. No consideration was given to the light industrial space. It was decided that the commercial area is representative of a typical villge center. Based on NASA's previous work in community design, NASA assumed 60,000 square foot of commercial space. The developer indicated a recreational complex. NASA assumed 20,000 square feet of floor area and modeled this space as commercial. The recreational complex was not included in the solid waste loads. The incinerator supplementary fuel rate was 1.91 x 10^6 Btu/h. The incinerator start-up fuel requirement was 0.8 x 10^6 Btu/day.

For Housing Project #5, there are three generic TOWNHOUSE models - 8 unit, 7 unit, and 4 unit. To make 300 total units (as stated by the developer) NASA assumed 19 each of the 8 unit model, 16 each of the 7 unit model and 9 each of the 4 unit model. NASA calculated the wall, roof, and glass areas for each unit type. The number of NASA 8-unit Townhouse models were determined. Only a small decrease in wall area occurs. The developer's townhouse roofs were pitched. Flat roofs were assumed for the study. The four-plexes were modeled as 4 unit TOWNHOUSES. The incinerator supplementary fuel rate was 0.64 x 10^6 Btu/hr. The incinerator start-up fuel requirement was 0.4 x 10^6 Btu/day.

The SINGLE-FAMILY HOUSE model was selected to characterize the low-density housing. The dwelling design conformed to the uniform building code (UBC) classification I standards (dwellings and lodgings). The TOWNHOUSE model was selected to represent this dwelling type in the medium-density housing areas. The SINGLE-FAMILY HOUSE and TOWNHOUSE models were developed from a statistical survey of multi-family housing in the Baltimore-Washington, and DC area. The TOWNHOUSE had the same UBC classification as the SINGLE-FAMILY HOUSE model.

The size of the COMMERCIAL AREA was based on a combined regional and local marketing approach. It was designed on a 5 foot planning module or grid in a 30 by 30 foot structural bay format to allow for structural efficiency and compatibility. This area was typical of the lease space for many national chain supermarkets. The adjacent 30 x 60 foot lease spaces are typical small-shop spaces and professional offices. The model design complied with UBC classification I-2 standards.

Each HIGH RISE APARTMENT had 22 floors, 21 of which contain apartment units, 10 units on each floor, for a total of 210 units/building. The HIGH-RISE APARTMENT model building design was based on the center corridor concept, which was well suited to such a structure. The plan for the building reflected a high-density ratio common to high-rise apartments. Structural efficiency, privacy, elevator core location, and the parking ratio were important design and arrangement considerations. The structural design complied with UBC classification H standards (high rise residential).

There were two LOW RISE APARTMENT models: singles and families. Both LOW-RISE apartment models had three floors. LOW-RISE SINGLES had twelve dwelling units per floor. There were four each of efficiency, one and two bedroom apartments. LOW-RISE FAMILY had six dwelling units per floor. There were two each of one, two, and three bedroom apartments.

3.2.1.2 Utility Resource Consumption

Table 3.2.1.3 is the resource consumption of MIUS and conventional utility systems determined by NASA serving the same five housing projects as Hittman/McClure. The MIUS alternative included energy flows for the water and wastewater utilities. These were not incorporated in the conventional utility computation. Table 3.2.1.3 demonstrates the energy conservation possible through MIUS implementation. Further a significant amount of potable water can also be conserved as shown by these tables if treated wastewater is recycled as cooling tower make-up.

Modular Integrated Utility System

An overview of the MIUS system is illustrated by the schematic in Figure 3.2.1.1. The power generation subsystem consisted of diesel generators, with heat recovery and one stand-by generator without heat recovery.

The generators were ebulliently cooled with recovery of water jacket and exhaust heat in the form of 15 psi, 250°F steam and lube oil heat recovery in the form of 180°F water. Solid waste management was incinerated with heat recovery from the exhaust gas in the form of 15 psi, 250°F steam which was tied to the steam header from the prime movers.

The steam was used in three ways. First, it was routed to a heat exchanger which was used to heat a 200°F hot water loop that had been preheated by another heat exchanger using the heat recovered from the engine lube oil. This 200° hot water provided heating of the domestic hot water and space

Table 3.2.1.3

Utility Resource Consumption (NASA)

Housing Project	Utility Type	Fuel (10^9 Btu)	Potable Water (10^6 Gal)	Wastewater Effluent (10^6 Gal)	TRASH (Tons)	Sludge (Tons)
#1	CONV	16.8	72	61	2250	1575
	MIUS	1.5	62	51	450	1575
#2	CONV	60	20	13	810	347
	MIUS	52	13	6	160	347
#3	CONV	405	139	115	4750	3121
	MIUS	321	117	94	950	3121
#4	CONV	460	170	140	5910	3750
	MIUS	327	143	113	1182	3750
#5	CONV	121	56	47	1830	1278
	MIUS	81	47	38	366	1278

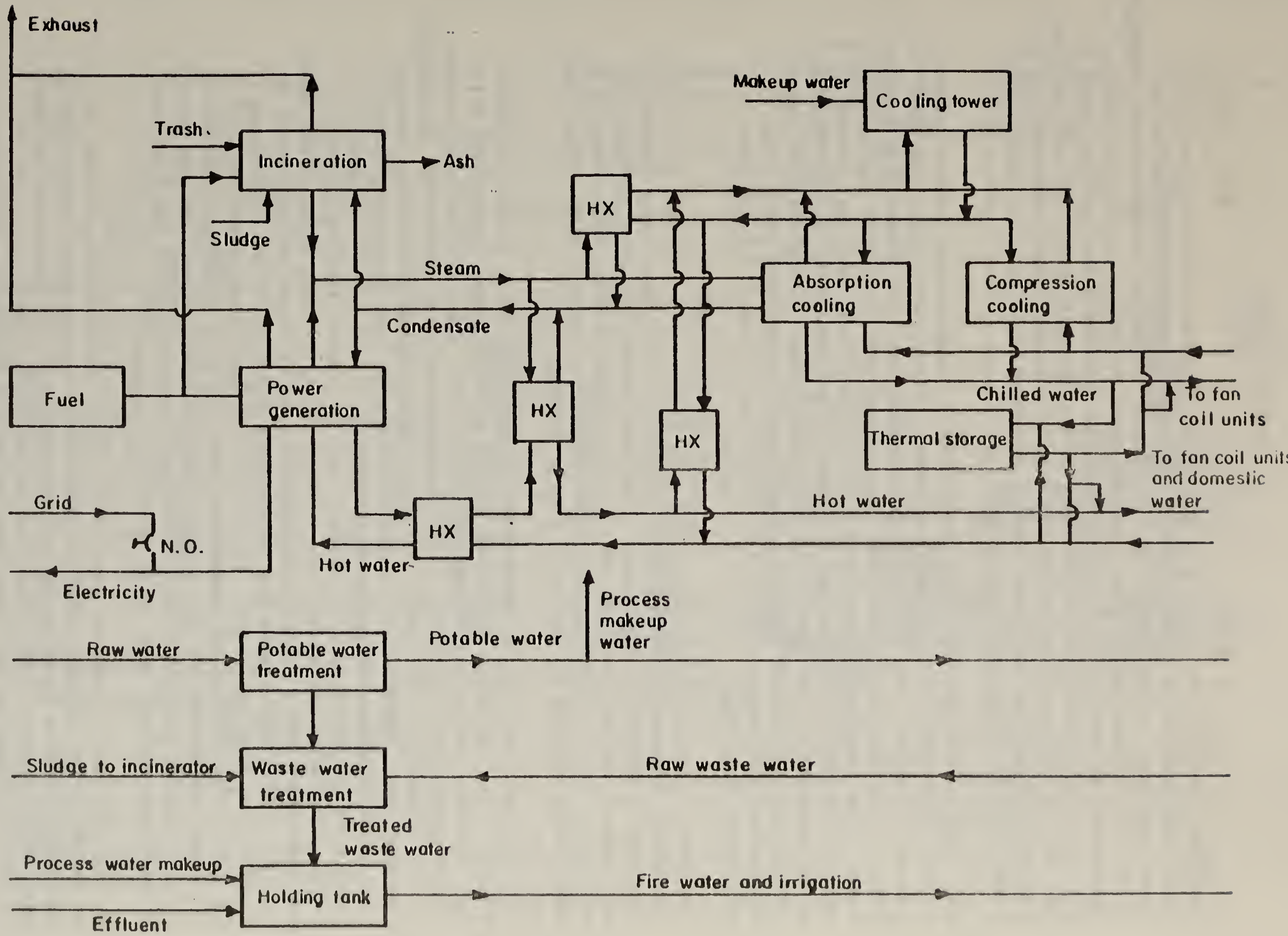

Figure 3.2.1.1 MIUS overview

heating. Second, the steam was routed to the absorption chillers which were supplemented by compression chillers to provide chilled water for space cooling. Third, the unused steam was rejected through a heat exchanger to a cooling tower which also provided heat rejection for the chillers. Provision was made to store thermal energy from both the chilled water and hot water loops by a water tank. The principal effect of such storage was that it allows reduction of the peak electrical load required for compression cooling and thus reduced the required electrical generating capacity that needs to be installed.

The prime movers for the power generation subsystem were selected based on the peak electrical energy requirement calculated through the ESOP computer program. The inputs to the program were the domestic electrical loads, auxiliary electrical loads (excluding chiller power) and cooling loads. The program considered all of the electrical and heat energy required by all subsystems and iterated to an electrical demand profile to be produced by the power generation subsystem. The electrical demand profile was calculated for a 2 sigma summer day and its demand peak represented the maximum electrical demand anticipated for the power generation subsystem.

The number and size of prime movers were chosen such that the part-load electrical conversion efficiency decreased no more than three percent from that achieved at full load. The prime movers selected offered the best energy savings possible over a conen ional system, while being consistent with good reliability and commercial availability. Electrical power was generated at 460 volts (rms), 3-phase 60 Hz.

The configuration for the electrical power subsystem is given in Figure 3.2.1.2. The subsystem consisted of two or more diesel generators with heat recovery units on the exhaust and the lube oil circuits. The backup diesel/generator was included as a standby to provide additional redundancy for the generation of electricity only. Heat recovery equipment was not used with this prime mover. For the units with heat recovery, the wat jackets and exhaust boilers were integrated into a pressure forced-circulated hot water cooling system, with hot water leaving the water jackets at 230°F feeding into the exhaust boiler. This pressurized water was flashed to steam in the exhaust boiler. The steam was regulated at 15 psig, 250°F and, mixing with steam from the incinerator, provided steam to the HVAC subsystem. When there was more steam than required, the excess was reduced to cndensate through a heat exchanger and held in a tank for recirculation through both the prime movers and the incinerator. Makeup water for the entire heat recovery system was provided through this holding tank using treated wastewater.

The lube oil was circulated through an oil to water heat-exchanger which exited hot water at about 180°F. This water loop provided space heating and also through a water to water heat exchanger provided heat for the domestic hot water. When there was no demand for this heat, the oil was routed through an air-blast heat exchanger for heat rejection.

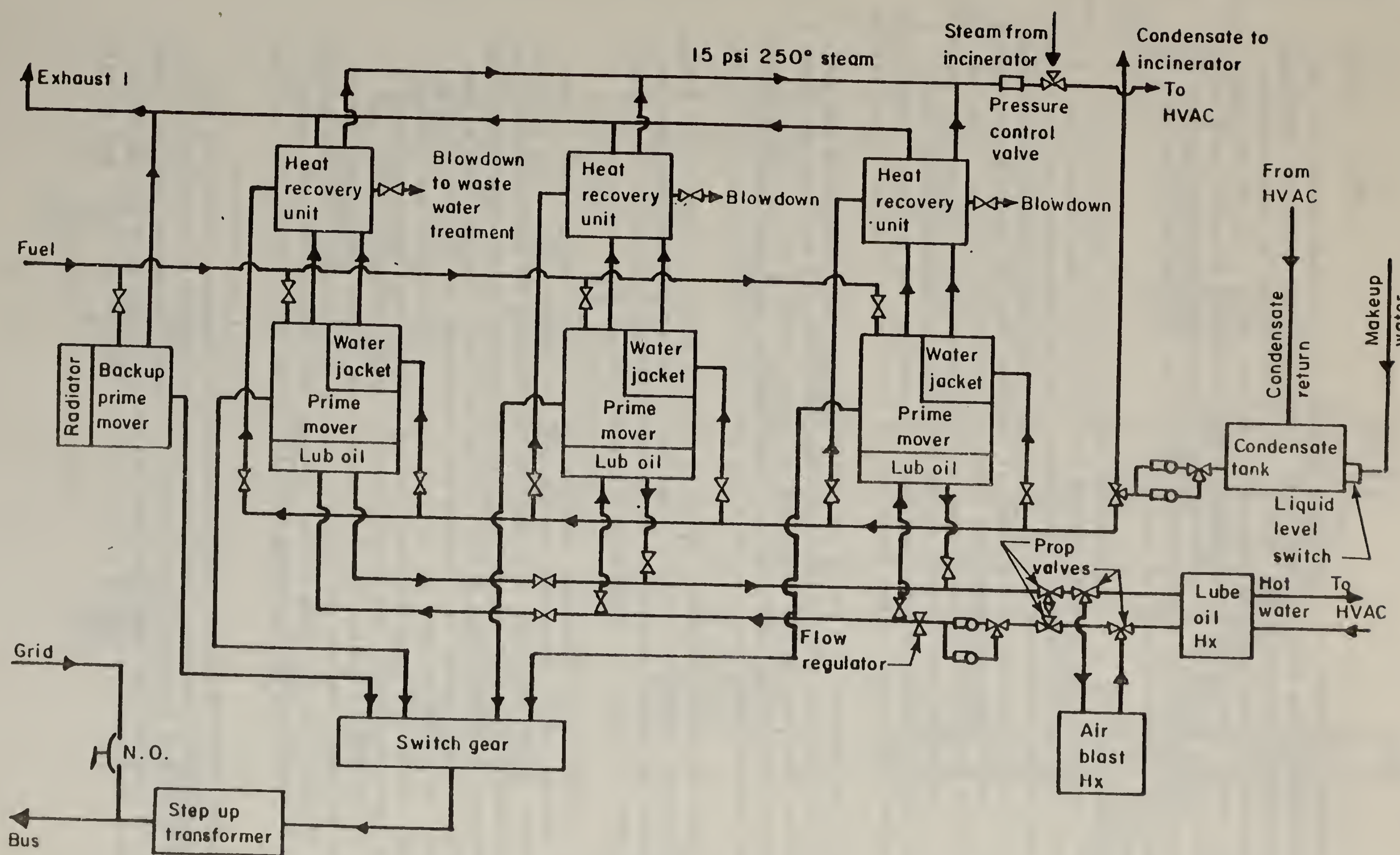

Figure 3.2.1.2 Electrical power subsystem

An economic tradeoff was conducted between the Fairbanks-Morse and the Caterpillar prime movers. The total subsystems cost using the Fairbanks-Morse diesels increased the capital cost of the MIUS by approximately five percent over what the Caterpillar engine would cost. At the same time, fuel consumption was decreased by ten percent annually with an undetermined reduction in maintenance. It was decided that the ten percent annual energy savings over the life of the system offset the penalty of increased initial costs.

The HVAC subsystem is illustrated in Figure 3.2.1.3. Shown are the major components of the HVAC system and interfaces with other MIUS systems and typical building equipment. The #1 designated heat exchanger allowed steam supplied from the incinerator and each prime mover's stack and jacket to supplement the lube oil heat for the hot water distribution loop. The #2 heat exchanger was used to transfer excess heat from the hot water distribution loop during moderate seasons to the cooling tower loop. Similarly, the #3 heat exchanger delivered excess heat to the tower loop. Thermal storage was used for heating and cooling. Connection to either hot or cold water distribution loops was accomplished by valving.

Energy for domestic hot water and space heating was supplied by the hot water distribution loop which delivered water to each building at about 200°F and returned it for reheating at about 140°F. This energy came primarily from prime mover lube oil heat and was supplemented from the higher energy steam loop and from the pre-stored thermal storage system.

The absorption chillers were supplied 15 psig steam from the prime movers and from the incinerator after domestic hot water requirements were met. Distribution losses were added to the chiller requirements to determine equipment selected on the peak requirement during the design day.

HVAC equipment selection was based on the following assumptions. Most HVAC systems would use total compression air conditioning. The moderate increase in initial costs necessary to incorporate an absorption chiller was compensated for by significant energy savings achieved by using high-grade heat from the prime movers and incinerator. The addition of the thermal storage system for storing heat minimized the need for boilers or fuel firing provisions on the incinerator. The use of the thermal storage system for supplementing cooling reduced the number of prime mover generator sets. The generators were sized to satsify the peak non-air conditioning electrical demands. The excess generator capacity during off-peak periods was used to produce chilled water for use during peak periods. In the case of hot storage, all unused heat was stored up to the volume of the storage facility which was sized for the cooling load.

The solid waste management subsystem included storage, collection and transportation, processing and disposal of solid wastes generated within the complex and disposal of wastewater treatment subsystem sludge. Each low-rise, medium-rise and high-rise building was equipped with gravity chutes. There was one solid waste charging station per floor per gravity

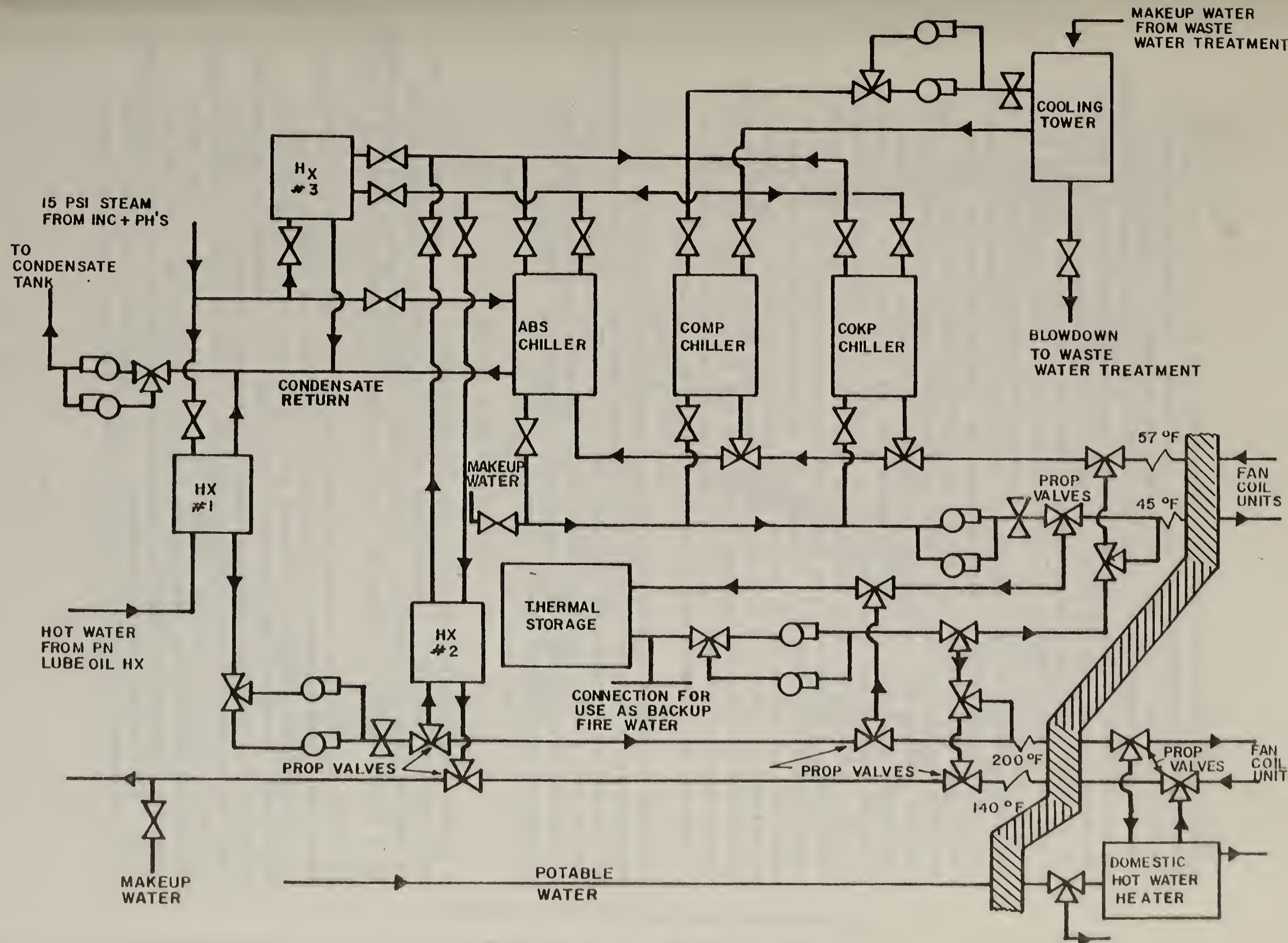

Figure 3.2.1.3 HVAC Subsystem

chute. Solid waste was directly deposited into 37.5 cubic ft. capacity wheeled cart located at the base of each chute. Collection was made every other day. Each cart collected was replaced by an empty cart. Carts were transported to the incinerator by a tractor capable of pulling up to six carts simultaneously. Spare carts were available to provide replacement for full carts, and to provide total storage capacity for three days solid waste generation. Three days storage was chosen to allow for 5-day operation if seven days were not desirable and to compensate for system failures. The storage carts were compatible with the incinerator loader. The capability was provided to mechanically transfer the solid waste from the storage container to the incinerator loader. The choice of a starved air incinerator with a stack heat recovery boiler was made because it was the lowest price off-the-shelf system available to both dispose of solid waste and recover the energy from the waste. The incinerator was operated 12 hours per day (8 a.m. to 8 p.m., seven days per week). Ash was stored in a 10 cubic yard container to be picked up once per week by truck and hauled to a remote landfill. Bulk waste was collected on as-required basis and was transported with the ashes to remote landfill. The heat produced by the incineration of the solid waste was recovered at 15 psi as 250°F steam in a boiler. The recovery efficiency was 60 percent of the input fuel and solid waste heating value. Wastewater treatment subsystem sludge was fed to a holding tank with a 3-day capacity and then auger-fed into the incinerator. A mixture of 60 percent solid waste and 40 percent sludge was maintained.

Sewerage treatment capacity was accomplished using a biological system supplemented by a tertiary physical/chemical system. The treated wastewater was stored in a retention tank and used in cooling tower makeup, fire protection, and irrigation. Disposal of the unused wastewater was to a stream. Water treatment systems were designed with capacities of 130 percent of the average annual demand.

Conventional Utility System

A conventional utility services network was defined for comparison with the MIUS (Figure 3.2.1.4). Conventional utilities serviced a housing project through independent networks. Conventional utility systems provided services in a manner similar to those of the "MIUS Community Conceptual Design Study[2]".

The conventional power generation and distribution system for the community study was a 1300-megawatt, diesel-fuel-oil-fired steam powerplant with an average plant thermal efficiency of 32.7 percent. The plan was grid connected. Condenser cooling was accomplished by a combination of reservoir water and natural-draft cooling towers. The power transmission system was a conventional 700 kilovolt system (grid) with stepdown to 230 kilovolts at a main substation in the vicinity of the housing project. The transmission conductors were composed of noninsulated aluminum. Within the community, there were satellite substations serviced by overhead transmission lines. The average power transmission efficiency was 95 percent. Power was distributed through 13.2-kilovolt primary feeders (insulated copper

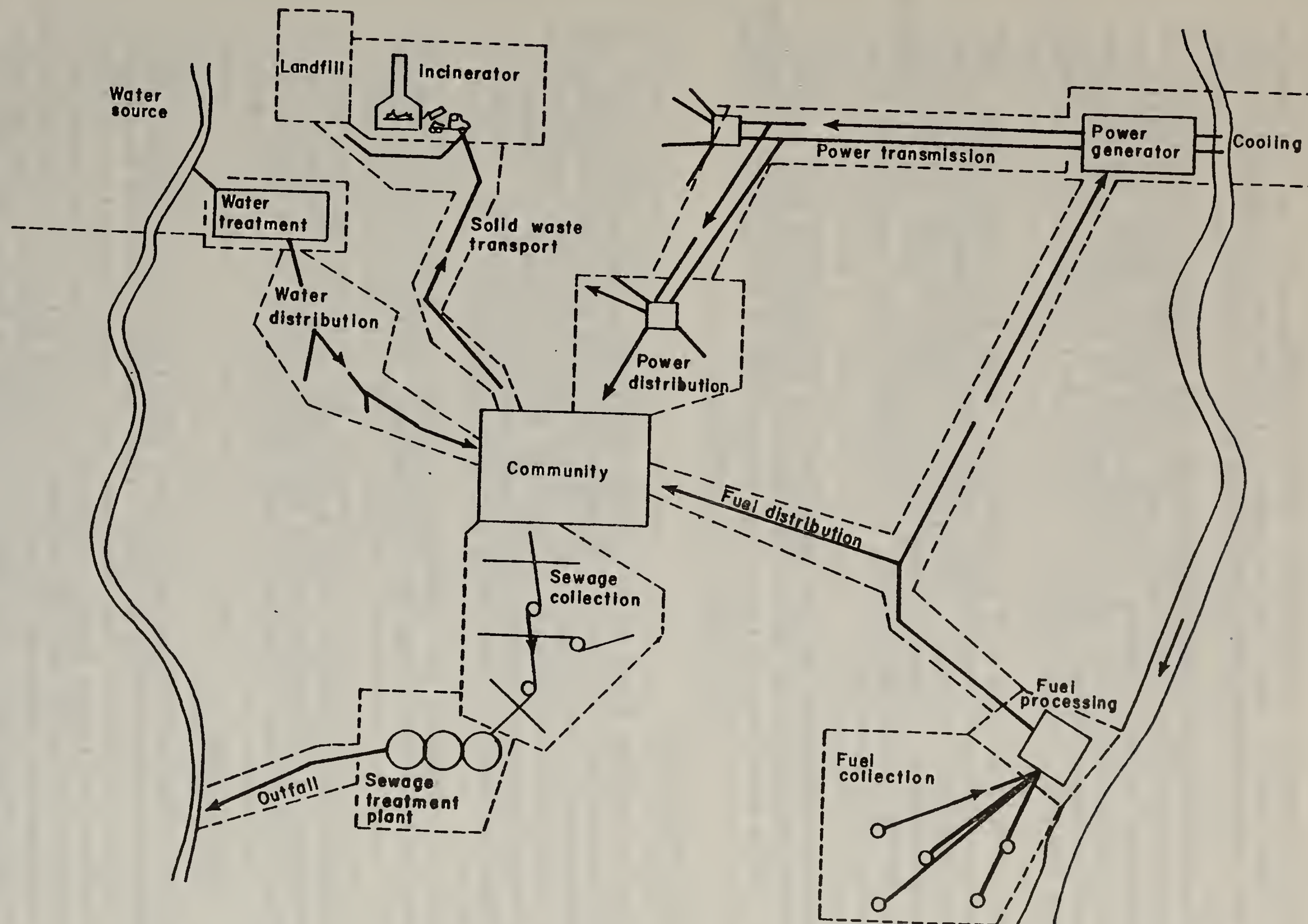

Figure 3.2.1.4 Conventional utility services

conductors) installed underground. Local transformers (50 to 80 kilovolt-amperes) were used to step down voltage to 120/240 Vac for domestic use. The average distribution efficiency was 97 percent.

All structures except SINGLE-FAMILY HOUSES were served by a district HVAC system. Hot and chilled water were transported through the site by a four-pipe system. Heating and cooling in SINGLE FAMILY HOUSES were by electric heat pump. Air distribution was provided by a single air duct with single zone control. There was no return air duct. Electric hot water heaters were utilized.

For both conventional and MIUS alternatives, water for potable water use and firefighting comes from surface source water 24 kilometers (15 miles) from the community. The water was piped to a central treatment plant, treated, and then distributed to the community users. Water for firefighting was distributed in the same manner, with elevated water towers used to meet storage requirements.

The wastewater treatment for the community was accomplished in a central plant. The wastewater was fed to the central plant by trunk and interceptor sewers. Solid waste was collected and transported 24 kilometers (15 miles) to a central incinerator facility and landfill.

3.2.2 NBS Evaluation

The purpose of Sectin 3.2.2 is to present detailed background for data presented in Section 1.2.2 and to document how this data was determined by Hittman Associates and Charles J. R. McClure Associates under contract to NBS. Section 3.2.2 presents the general method utilized to compute utility loads, the more significant assumptions and the manner in which the ENVIRON and MEDSI software programs were implemented.

Section 3.2.2.1 presents how individual building hot water, electrical power, and potable water loads were determined. Section 3.2.2.2 presents how MEDSI forecasted the energy consumed by MIUS and conventional utilities to satisfy utility loads. Information for Section 3.2.2 is found in two contract deliverables: "MIUS Review Site Four" by Charles J. R. McClure Associates, January 29, 1976, and "Draft MIUS Case Study Report (Rough Draft) by Hittman Associates, February 1976.

3.2.2.1 Utility Loads

A detailed cooling and heating design load calculation was conducted for each building of each housing project. These calculations were based upon the information provided by the developer, the needed assumptions generated, and the weather and indoor design conditions established. The loads for other energy requirements were determined for each building, such as domestic hot water, lighting, appliances, and miscellaneous machinery. Energy calculations were conducted to determine the profile of energy need for the categories space heating, space cooling, lighting, and other. Table 3.2.2.1 presents the design loads for each housing project.

Electric Power Generation

The design electrical load was the maximum kilowatt demand which was likely to be experienced under normal operation. This load was composed of lighting, air handling, electric refrigeration, space heating and domestic hot water heating (where applicable), refrigeration and heating auxiliaries, appliances, cooking, and outdoor lighting. Analysis of refrigeration, space heating, domestic hot water heating, and air handling needs was made in a manner indicated for MEDSI. Determination of the lighting and other electrical loads was made by interfacing the connected residential loads with a use profile. The connected lighting and other demand loads were determined by selecting lighting fixtures, washers, dryers, television sets, and kitchen appliances in sizes consistent with standard practices for commercial and residential applications. A use profile was then developed using hours of specific types of occupancy each having a related maximum kilowatt demand. By interfacing this data with applicable demand and diversity factors existing between the mix of buildings on the site, the anticipated maximum kW demand was determined. This maximum kW demand profile, when integrated with demand profiles for space heating, domestic hot water heating, refrigeration, and air handling yielded the maximum anticipated kilowattt demand.

Space Heating and Air Conditioning

The design heating and cooling loads were calculated for each structure in the building site. The design space heating load was the rate of heat loss from the building when that loss was at the maximum anticipated level under the temperature differentials selected, with given construction materials and selected ventilation rates. The design heating load did not account for credits due to heat gains from the sun, lights, appliances and people. The design space cooling load was the rate of heat gain to the building from the surroundings and internal generation. That gain was at the maximum anticipated level under temperature and moisture differentials selected, with no cloud cover, with given construction materials, selected ventilation rates, and selected building use.

With the data established, the loads were calculated in accordance with the procedures of ASHRAE, Handbook of Fundamentals, 1972. To perform the calculations, a computer program based upon these procedures, ENVIRON, developed by National Computer Service, St. Louis and available on the timesharing network of United Computing Systems, Inc. was utilized. Indoor design dry bulb temperature was selected at 75°F summer and winter, during occupied hours for all buildings. No control of humidity was assumed for winter operation, and summer indoor design relative humidity is selected at 50%.

For the calculation of cooling loads and heating loads, the gains to the space resulting from the use of domestic hot water were assumed to be negligible. This assumption was justified by the reasoning that available load calculation techniques do not adequately quantify building thermal storage, and any sensible load resulting from the use of hot

Table 3.2.2.1

H/M Utility Load Data
(Plant + Site)

	Housing Project				
	#1	#2	#3	#4	#5
Electric Power Generation:					
Peak, MIUS (kW)	2330	599	11137	7908	1704
Peak, CON (kW)	7257	753	12451	9438	5444
Average, MIUS (kW)	1891	535	8776	6084	1518
Average, CONV (kW)	5074	530	9318	6835	3493
Annual, MIUS (kW x 10^{-6})	3.66	0.74	33.0	14.6	2.32
Annual, CONV (kW x 10^{-6})	25.16	1.36	41.1	16.06	18.04
Load Factor, MIUS (%)	81.2	89.3	78.8	76.9	89.2
Load Factor, CONV (%)	69.9	77.0	74.8	72.4	64.2
Space Heating:					
MIUS (Btu/h x 10^{-6})	29.28	5.00	36.90	72.79	15.70
CONV (Btu/h x 10^{-6})	29.28	5.00	36.90	72.79	15.70
Air Conditioning:					
MIUS (tons)	1494	391	2752	4400	1226
CONV (tons)	1494	391	2752	4400	1226
Solid Waste Disposal (av):					
MIUS Refuse (lb/d)		1200	10800	13800	4200
CONV Refuse (lb/d)		1200	10800	13800	4200
MIUS Sludge (lb/d)	2700	357	4838	6350	1747
CONV Sludge (lb/d)	2700	357	4838	6350	1747
Wastewater Treatment (av):					
MIUS (kgpd)	195	34	350	493	141
CONV (kgpd)	195	34	350	493	141
Potable Water Treatment (av):					
MIUS (kgpd)	257	46	507	633	238
CONV (kgpd)	257	46	507	633	238

water would be absorbed by building mass, imposing no measurable load on the apparatus. The latent load, although possibly instantaneously significant, was of such short duration and was assumed negligible.

The load from cooking was developed by constructing a typical meal requirement, with burner requirement and duration to prepare the meal. This resulted in a gross heat contribution to the space (instantaneous) of 7,271 Btu over a duration of four hours. The contribution of this gain to the space load was reduced by a factor of 2 and divided evenly over a four hour overall. The resulting load contribution was thus 910 Btu/h. This gain was then applied to the load calculation for each dwelling unit.

Residential buildings were grouped for the load analysis. Diversification resulting from any noncoincident loads was accounted for in the logic (weather and solar) inherent in the programs. Heat-Cool-Off control mode was selected because this mode is generally accepted state-of-the-art in domestic systems. Although the residential systems do not employ a classic economizer cycle, the homeowner will generally not operate mechanical cooling systems when the outdoor air temperature is below the normal "economizer" deck temperatures. Thus, an open window is similar to that with economizer and Heat-Cool-Off control. For this reason, the simulation employed the "economizer" feature. The occupancy schedule had three basic functions in the program logic. Occupancy provides data on load (gains) values due to occupant heat dissipation. Occupancy assisted the simulation of consumer-dependent loads such as lights and appliances. Occupancy also facilitated the cycling of systems components such as fans when the building was occupied.

Since residential systems do not cycle off during unoccupied times and since the gains due to occupants are minimal as an instantaneous contributor, the occupancy schedule was set up to more accurately reflect the profile of energy consuming devices other than space heating and cooling. The occupancy schedule established was: 0.25 for night (0-8 hours); 1.00 for day (8-16 hours); and 0.75 for evening (16-24 hours). Since all individual residences, with the conventional systems, were to have electric space heat, the boiler efficiency input was set at 100%. The program converted the electric space heat load energy requirements directly to kWh. The supply fan power demands and refrigeration kW/ton were obtained by the actual selection of good quality residential equipment for each dwelling unit. The fan power inputs were then summed for the dwellings included, and the average kW/ton input for the specific machinery selected was used.

Lighting, appliance, and cooling energy requirements for residential buildings were developed from the developer data and assumptions of coincident demand and diversity factors applicable to each housing project. For each attached and detached residence, a maximum demand load of 8 kW was used, this representing the maximum coincident demand for kitchen appliances, washer and dryer, lighting, television, air handling, and other miscellaneous appliances. The lighting coincident demand was computed to be 298 watts per dwelling unit. The validity of the diversity and demand factors used are quantitively substantiated from various literature sources* and from experience on similar total energy system applications.

Since a school inherently has a different use and occupancy from either the residential spaces or the commercial facilities, a separate analysis was made. Assumptions were made to facilitate input data for the analysis. A Heat-Cool-Off system was assumed for two reasons. The Heat-Cool-Off system, regardless of energy source, uses less primary and control energy than either multizone or reheat. Secondly, current design trends have leaned heavily to individual space systems employing Heat-Cool-Off or variable volume systems. The variable volume systems, in turn, have primary energy characteristics similar to Heat-Cool-Off. An economizer system was assumed, as it is commonly used in school systems, and when coupled with a Heat-Cool-Off system minimizes primary energy requirements.

The occupancy schedule of a school varies with the calendar months, and adjustments were necessary to facilitate holidays, weekends, and vacations. The schedule employed with 100% occupancy as unity was:

Month	Night	Day	Evening
January	.089	.714	0
February	.089	.714	0
March	.089	.714	0
April	.071	.576	0
May	.089	.714	0
June	.043	.345	0
July	0	.535	0
August	0	.535	0
September	.071	.576	0
October	.089	.714	0
November	.089	.714	0
December	.046	.368	0

For the purposes of the energy calculations, the boiler efficiency of both full load and reduced load was assumed to be unity. This assumption was made to provide an output relating to the energy to the building system rather than to the conversion systems. The input energy is then the direct requirement to the building from the MIUS Plant, and the subsequent conventional analysis applies the appropriate conversion losses.

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* EHA Case Histories, Electric Heating Association, Inc., 750 Third Avenue, New York, N.Y. 10017.

All Electric Homes in the United States Annual Bills - January 1, 1973, Federal Power Commission, Washington, D.C.

For a school, the cooling energy rate was 1.6 kW per ton based upon an approximate average kW/ton rating of package equipment including compressor and condenser fans from the ARI Directory of Certified Unitary Air Conditioners, July 31, 1971. Since part load information was not available, the same value was used for the reduced load operation. It was recognized that this assumption could cause minor errors in the results. The supply fan kW requirement was based upon 1 cfm/ft^2 for 40,000 usable square feet, 80% building efficiency @ 2.25 in total pressure, 70% fan efficiency and 90% motor efficiency. The lighting load assumption was based on an average of 3 watts per gross square foot. This was an average value based upon experience with well lighted but, conservatively designed school buildings. Other electrical loads were also based upon experience with school buildings. These loads included constant and intermittent exhaust fans, vending machines, water coolers, etc.

Heat-Cool-Off was utilized to compute building HVAC loads of commercial buildings. The assumption of Heat-Cool-Off was made on the basis that this would result in minimal energy use. The economizer assumption also was made on the same basis. The open doors operation of quick food shops, department stores, and service stations have essentially the same energy use impact as a classical economizer cycle. For lack of better information, the occupancy schedule was assumed not to vary seasonally. The night-day-evening schedule, for a seven day week was set at:

Night	0.250
Day	1.000
Evening	0.750

The quantative values of thermal conversion efficiencies and refrigeration power rates were assumed at the same values as for the school. The supply fan power requirement was based on a total air circulation rate, 2" total pressure, 65% fan efficiency, and 90% motor-drive efficiency. Lighting power for commercial buildings was based upon an average of 3.0 watts per square foot of building plus outdoor parking lot and security lighting. Other electrical loads included miscellaneous exhaust fans, food coolers, and display boxes, vending machines, fuel dispensers, and air compressor drives.

Solid Waste Disposal

The monthly quantity of solid waste was calculated by assuming that each dwelling unit generated 8.4 pounds of solid waste per day (approximately 1.5 cubic feet per day, per dwelling unit). This factor was multiplied by the number of dwelling units to obtain the quantity of solid waste generated per day. The quantity of solid waste per day was converted to pounds per month by multiplying by a factor of 365/12. Solid waste was assumed to the following percent composition by weight: paper - 48 percent; garbage - 16 percent; leaves and grass - 9 percent; wood - 2 percent; synthetics - 2 percent; cloth - 1 percent; glass - 6 percent;

metal - 8 percent; and ashes, stone and dust - 8 percent. The economics of heat recovery was the controlling factor whether heat recovery was employed. A 70% boiler efficiency was utilized.

Potable Water/Wastewater Treatment

The loads on the wastewater system were the same as the potable water system with the exception of that for external uses. Potable water requirements were calculated by use of equations given in Volume II of HIT-413 entitled Forecasting Municipal Water Requirement - The Main II System. The potable water requirement was the sum of two components calculated separately: mean annual domestic usage and the mean annual sprinkling usage.

To calculate mean annual domestic usage equations (1) and (2) of Appendix B in HIT-413 were used. The use of two equations was required because most of the MIUS sites had more than one type of dwelling unit. The significant difference between the types of units was the manner in which they are billed for water and sewer service. Townhouses and single-family detached houses were metered while apartments were billed at a flat rate included in the rent. The meter-sewered equation used for townhouses and single-family detached units was:

$$(q_D)_{ms} = (206 + 3.47\ V/F_a - 1.3\ \bar{p})\ N_r \qquad (1)$$

where $(q_D)_{ms}$ = mean annual domestic water usage in gallons per day

V = average home value in a range of values in thousands of dollar

F_a = assessment factor

$\bar{p}$ = mean annual price of water in cents per thousand gallons

N_r = the number of residences in the range with average value V

The flat-rate sewered equation used for apartment was:

$$(q_D)_{fs} = (28.9 + 4.39\ V/F_a + 33.6\ D_p)\ N_r \qquad (2)$$

where $(q_D)_{fs}$ = mean annual domestic water usage in gallons per day

V = average home value in a range of values in thousands of dollars

F_a = assessment factor

D_p = population density in dwelling units in persons per unit

N_r = the number of residences in the range with average value V

The values of residences were determined from data furnished by the developer. In cases where the values of the residences were not given, values were than determined by multiplying the floor area in square feet by a factor of $35 per square foot. When the values of all residences were determined and appropriate value ranges are chosen, the set of values for V and N_r were computed. The ranges were usually $5,000 each, starting at values $20,000. The factor F_a was set equal to 1. The mean annual price of water, $\bar{p}$, was established by a calculation based on the water and sewage rate schedule. The local utility company providing water and sewer service was contacted obtain the rate schedule and an estimate of the average bill. The average quantity of water used per billing was the amount needed to produce the average bill according to the rate schedule. To obtain $\bar{p}$ the average bill was divided by the average quantity of water. The factor D_p in equation (2) was set equal to 3.3.

Equation (1) was used to determine domestic water usage for the meter-sewered dwelling units in each value range by substituting the values of V and N_r successively into the equation. Total domestic usage for all meter-sewered units was obtained by summing the contributions from units in individual value ranges. Equation (2) was similarly used to determine domestic water usage for all flat-rate sewered units and was the sum of the contributions from individual value ranges. The mean annual domestic usage for all dwelling units, q_D, was the sum of the total usage for meter-sewered units and total usage for flat-rate sewered units:

$$q_D = (q_D)_{ms} + (q_D)_{fs}$$

The second component of the potable water requirement was the mean annual sprinkling usage. It was assumed that lawn sprinkling usage occurs only for meter-sewered dwelling units. Two equations were available for use in determining mean annual lawn sprinkling usage in meter-sewered dwelling units. One equation was used for housing projects east of the 100th meridian; the other, for housing projects west of the 100th meridian. The equation for site west of the 100th meridian was:

$$(q_s)_{ms,w} = (0.48 \times 1130\ p_s^{-0.703})\ (V/F_a)^{0.429}\ N_r \qquad (5)$$

where $(q_s)_{ms,w}$ = mean annual sprinkling usage for meter-sewered units west of the 100th meridian in gallons per day

P_s = summer price of water in cents per thousand gallons

V = average home value in a range of values in thousands of dollars

F_a = assessment factor

N_r = the number of residences in the range with average value V

The equation used for sites east of the 100th meridian was:

$$(q_s)_{ms,e} = (0.39 \times 0.164\ B^{-0.783})\ (E - 0.6R)^{2.93}\ P_s^{-1.57}\ (V/F_a)^{1.45}\ N_r \qquad (6)$$

where $(q_s)_{ms,e}$ = mean annual sprinkling usage for meter-sewered units east of the 100th meridian in gallons per day

B = irrigable land per dwelling unit in acres per unit, determined from formula given below

E = total summer evapotranspiration in inches

R = total summer precipitation in inches

P_s = summer price of water in cents per thousand gallons

V = average home value in a range of values in thousands of dollars

F_a = assessment factor

N_r = the number of residences in the range with average value V

The value used for P_s was the same as the value used for $\bar{p}$ in computing mean annual domestic usage since none of the utility companies reported a seasonal differential in the rate schedule. The values used for V and N_r were the same as those determined for the purpose of computing mean annual domestic usage. The assessment factor F_a was set equal to 1. The numerical value of B was determined by another equation from Appendix B of HIT-413:

$$B = 0.803\ H_d^{-1.26} \qquad (10)$$

where H_d = housing density in units per acre

In calculating H_d, the gross residential area of the site, including streets, was used. Total summer evapotranspiration E and total summer precipitation R were determined from Figure D-2 of Appendix D in HIT-413. Figure D-2 was a table of values for E and R as a function of the site latitude and longitude.

The potable water requirement, q, was the sum of the mean annual domestic usage, q_D, calculated from equations (1) and (2), and the mean annual law sprinkling usage, q_s, calculated from equations (5) or (6): $q = q_D + q_s$. Since water usage calculated from these equations was in units of gallons per day, the sum of domestic usage and lawn sprinkling usage was multiplied by 365/12 to obtain an answer in units of gallons per month.

Maximum daily sprinkling usage was determined from one of two equations. As in the calculation of mean annual lawn sprinkling usage, one equation is used for housing projects east of the 100th meridian; the other, for for housing projects west of the 100th meridian. The equation used sites west of the 100th meridian was:

$$(q_{mxs})_{ms,w} = (3400\ E_m{}^{2.06}\ (V/F_a)^{0.413})N_r \qquad (11)$$

where $(q_{mxs})_{ms,w}$ = maximum sprinkling usage per day for meter-sewered units west of the 100th meridian in gallons per day

E_m = maximum evapotranspiration per day which is 0.25 inches for the west

V = average home value in a range of value in thousands of dollars

F_a = assessment factor

N_r = the number of residences in the range with average value V

The equation used for sites east of the 100th meridian was:

$$(q_{mxs})_{ms,e} = (0.0106\ B^{0.118}\ E_m{}^{-10.4}\ p_s{}^{-1.25}\ (V/F_a)^{0.931})\ N_r \qquad (12)$$

where $(q_{mxs})_{ms,e}$ = maximum sprinkling usage per day for meter-sewered units east of the 100th meridian in gallons per day

B	=	irrigable land per dwelling unit in acres per unit, determined from equation (10)
E_m	=	maximum evapotranspiration per day which is 0.29 inch for the east
P_s	=	summer price of water in cents per thousand gallons
V	=	average home value in a range of values in thousands of dollars
F_a	=	assessment factor
N_r	=	the number of residences in the range with average value V

The set of values for V and N_r was the same as for the calculation of mean annual domestic usage. The assessment factor F_a was set equal to one. The value used for P_s was the same as the value used for $\bar{p}$ in computing mean annual domestic usage since none of the utility companies reported a seasonal differential in the rate schedule. The value of B was determined by another equation from Appendix B of HIT-413:

$$B = 0.803\ H_d^{-1.26} \quad (10)$$

where H_d = housing density in units per acre

In calculating H_d, the gross residential area of the site, including streets, was used.

Mean annual domestic usage and maximum day sprinkling usage were substituted into the following equation to determine peak hour demand:

$$q_{pkhr} = 334\ N_r + 2.017\ (q_D + q_{mxs}) \quad (16)$$

where

q_{pkhr}	=	peak hour demand in gallons per day
N_r	=	total number of dwelling units at the site
q_D	=	mean annual domestic usage in gallons per day
q_{mxs}	=	maximum sprinkling requirement per day calculated from either equation (11) or (12) in gallons per day

The peak hour demand was changed from units of gallons per day to gallons per hour by dividing q_{pkhr} from equation (16) by 24.

Computation of hot water energy requirement per month was based on consumption of hot water in three uses: laundry, bath, and dishwasher. The percentage of mean annual domestic usage consumed by each category was obtained from Volume I of HIT-409 entitled "Main C," Computerized Methodology for Evaluation of Municipal Water Conservation Research Programs. Figure II-5 on page II-19 of that report gives the percentage of total domestic use consumed in seven categories of domestic usage. For the three categories of interest, the figure shows the following percentages for both meter-sewer and flat-rate sewer connections (rounded off to the nearest percent): dishwasher - 8 percent, laundry - 13 percent, and bathing - 35 percent. These percentages can be applied to the mean annual domestic usage, q_D, to determine the quantity of hot water use (q_{use}) in each category.

To determine the energy requirement of each category it was also necessary to know the temperature of the water in use. The following temperatures were used for hot water in the three categories: dishwater - 150°F, laundry - 120°F, and bath - 100°F. It was assumed that the hot water heater would take incoming water a temperature of 50°F and heat it to 150°F. Water from the hot water heater would then be mixed with cold water to obtain the desired temperature in actual usage. In order to determine the quantity of water heated to 150°F in order to produce the desired amount of water at some other temperature, the following equation was used:

$$q_{hot} \Delta T_{hot} = q_{cold} \Delta T_{cold}$$

Where q_{hot} = quantity of water that must be heated to 150°F by hot water heater

ΔT_{hot} = change in temperature of hot water initially at 150° F when it comes to equilibrium after being combined with the cold water

q_{cold} = quantity of cold water that must be combined with q_{hot} to produce desired temperature

ΔT_{cold} = change in temperature of cold water initially at 50° F when it comes to equilibrium after being combined with hot water

This equation can be put into another form:

$$q_{use} = q_{hot} + q_{cold}$$

where q_{use} = the quantity of water used in a given application. Substituting $q_{use} - q_{hot}$ for q_{cold} yielded the equation:

$$q_{hot} = \frac{\frac{\Delta T_{cold}}{\Delta T_{hot}}}{1 + \frac{\Delta T_{cold}}{\Delta T_{hot}}} q_{use}.$$

This equation was used to compute the quantity of hot water needed for each application. The total quantity of hot water required was the sum of the quantities needed for all three uses:

$$q_{hot} = q_{hot(laundry)} + q_{hot(bath)} + q_{hot(dishwasher)}$$

The hot water energy requirement was computed from the total quantity of hot water required by the following equation:

$$E = \frac{Q_{hot} \left(\frac{365\ \text{days}}{12\ \text{months}}\right) 100°F \left(\frac{1\ \text{Btu}}{\text{lb}\ °F}\right) \frac{8.33\ \text{lb}}{\text{gal}}}{.85}$$

where E = energy requirement for hot water in Btu/month

Q_{hot} = total quantity of hot water required in gallons per day

The factor 365 days/12 months was included to adjust Q_{hot} to units of gallons per month. The factor 100°F represents the change in temperature of the water that is heated. The factor 8.33 lb/gal. was included to adjust Q_{hot} to units of pounds per month. The factor of .85 in the denominator represents an assumed hot water heater efficiency of 85 percent. The factor 1 Btu/lb°F is from the definition of a Btu.

The peak hour demand for hot water, $Q_{hot(pkhr)}$, was determined by use of the equation:

$$Q_{hot(pkhr)} = .154\ q_{pkhr}$$

The factor .154 represents the percentage of cold water that would be consumed in hot water uses during a peak-hour flow. It was obtained by adding the percentages of cold water that would be consumed by three uses of hot water: dishwater, laundry, and bathing. The percentages of peak hour demand for these three uses were taken from Figure II-7 on page II-22 of Volume I of HIT-409, "Main C" Computerized Methodology for Evaluation of Municipal Water Conservation Research Programs. The percentages given in that figure are dishwasher - 2.3 percent, laundry - 3.5 percent, and bathing - 9.6 percent. The multiplying factor is thus .023 + .035 + .096 = .154.

Peak hour energy demand for hot water was computed from the peak hour demand for hot water and the following equation:

$$E_{pkhr} = \frac{Q_{hot\ (pkhr)}\ (100°F)\ \frac{1\ Btu}{lb\ °F}\ (\frac{8.33\ lb}{gal})}{.85}$$

where

E_{pkhr} = peak hour energy demand for hot water in Btu per hour

$Q_{hot\ (pkhr)}$ = peak hour demand for hot water

The sewage treatment requirement was assumed to be equal to the mean annual domestic usage q_D. The value of q_D, calculated in units of gallons per day, was multiplied by a factor of 365/12 to express it in units of gallons per month. The monthly maximum demand for sewage treatment was assumed to be equal to the mean annual domestic usage q_D.

3.2.2.2 Utility Resource Consumption

The input energy requirement for each building classification was modeled mathematially, integrated for the entire community on a monthly basis, and aggregated to an annual requirement in the subdivisions of the form the energy is purchased. The input housing project energy needs were then used to calculate the resource energy requirement by the application of distribution system losses and by conversion plant heat rates. This calculation resulted in the "Conventional System" community energy resource requirement. Considering the current status of construction and planning, and the energy forms available from a MIUS plant and the practicalities of metering and hardware, assumptions were made to establish the most favorable alternative method of serving the community energy needs from MIUS. These assumptions, coupled with the load data were used to design a MIUS plant. The plant performance characteristics were then used in conjunction with the energy calculations above, to determine MIUS input energy, waste energy, and product energy to the community.

Table 3.2.2.2 is the energy flow diagram for the conventional utility systems serving the five housing projects investigated by Hittman/McClure. Table 3.2.2.3 is the energy flow diagrams for the MIUS alternative for these same five housing projects. Notice that the MIUS energy flow diagram includes that for the "sewage treatment module". The energy flow diagram for the conventional utility system for the same site does not.

To provide conventional energy consumption for each housing project, program HCENERG prints out the equipment energy input requirements for each building. The system programs give the ton hours of cooling and 10^5 Btu heating to meet the building loads. HCENERG tells the Btu

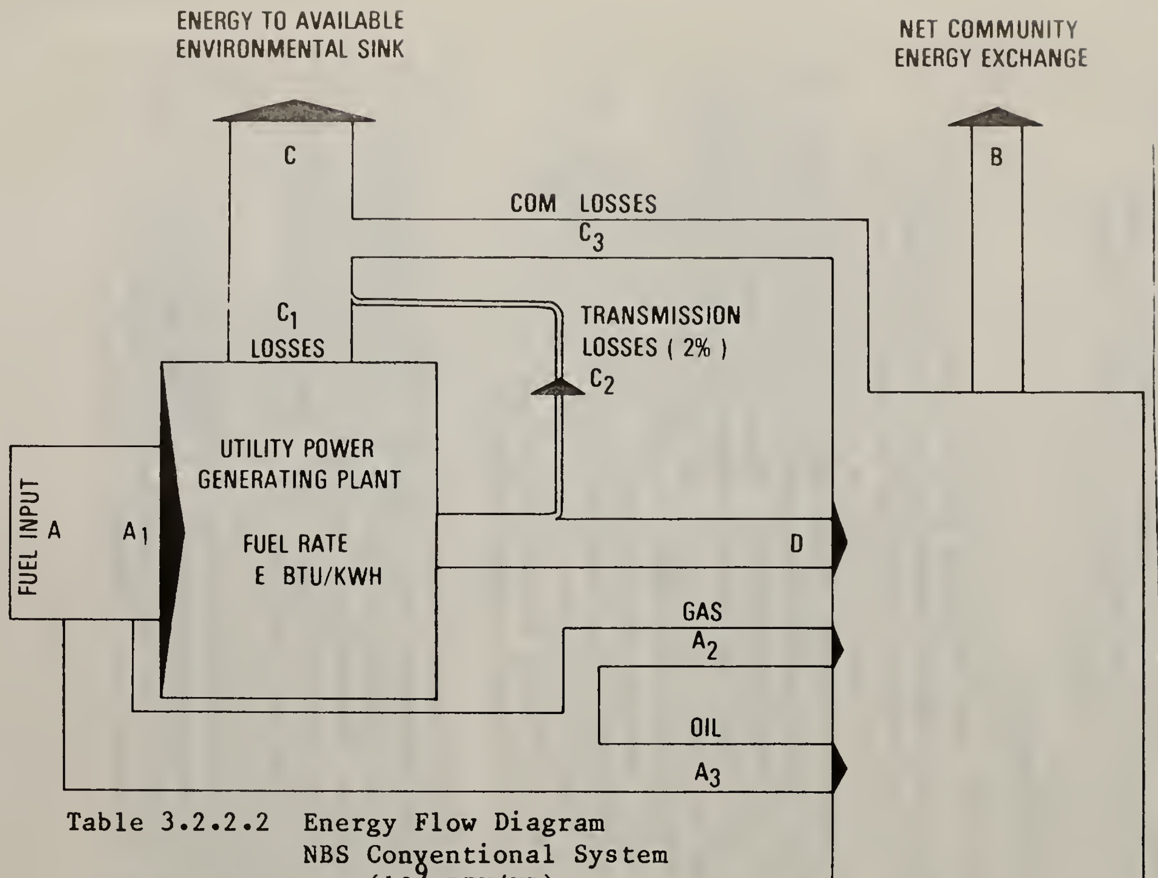
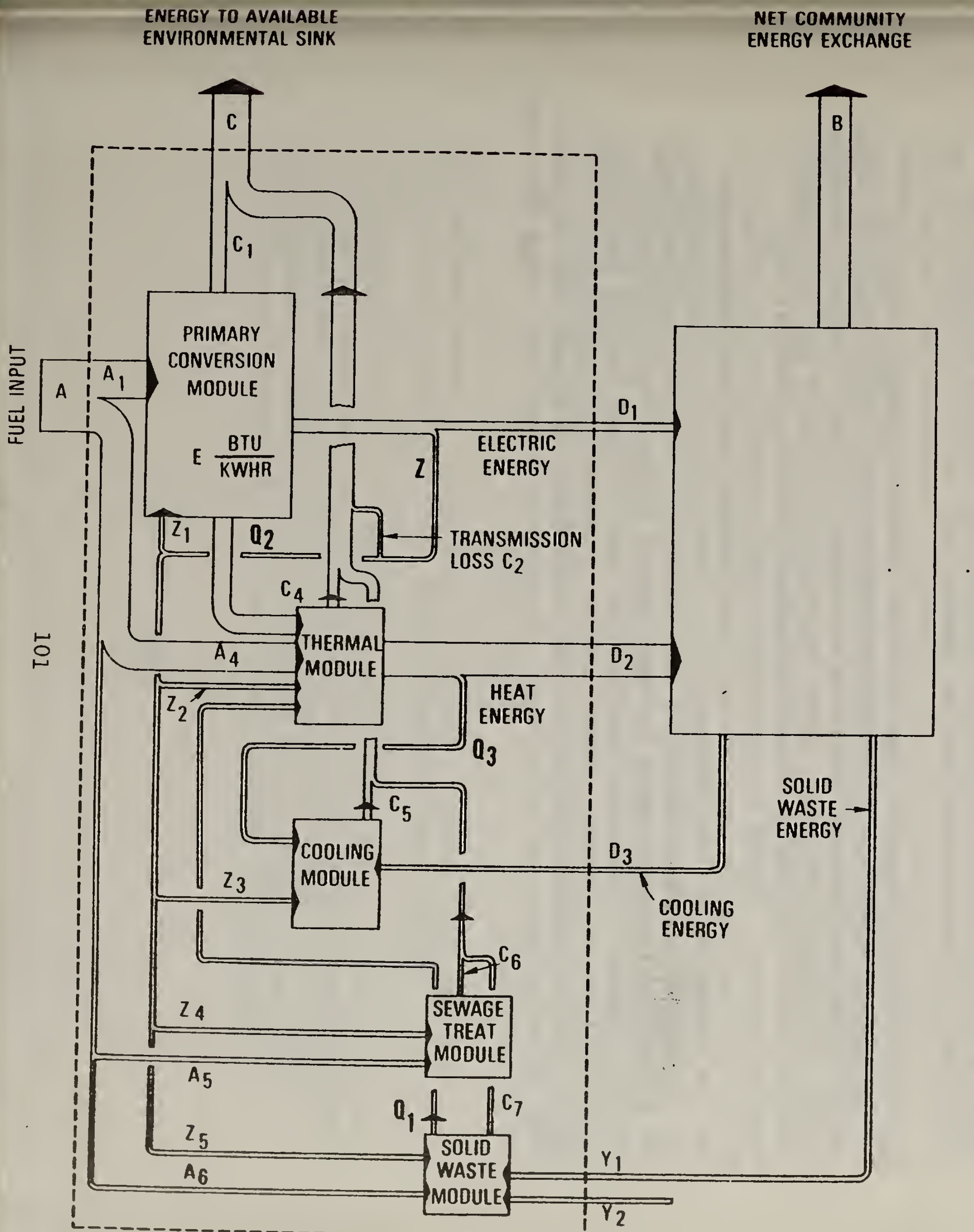


Table 3.2.2.2 Energy Flow Diagram
NBS Conventional System
(10^9 BTU/YR)

Housing # Project	A_1	A_2	A_3	A	B	C_1	C_2	C_3	C	D	E
1	302			302	86	214	2.0		216	86	11748
2	16.28	16.6		32.88	15.86	11.55	0.1	5.37	17.02	4.63	11748
3	492		3.9	496	143	349	3.0	1.3	353	140	11748
4	193	292		485	267	137	3.0	80	218	55	11748
5	217			217	62	154	1.0		155	62	11748



Housing Project

	1	2	3	4	5
A	144	35.85	398	467	106
A_1	80	28	391	196	58
A_2				195	
A_3					
A_4	60	6.69		67	44.3
A_5	2.16	0.31	3.43	5.5	1.26
A_6	1.62	0.85	4.0	3.5	2.0
B	67	9.15	131	237	45
C	76.76	27	267	230	61
C_1	29	10.56	208	85	21
C_2	0.25	.05	2.0	1.0	0.16
C_3				58	
C_4	20.5	2.75	30	36	17
C_5	18	9.3	9	32	15.4
C_6	6.16	3.18	7	9	5
C_7	2.85	0.88	11	9	2.5
D_1	12.5	2.53	111	50	8
D_2	69	11.22	30	74	49
D_3	10	4.6	3	11	9
E	12986	13217	10933	10947	12372
Q_1	3.29			7	2.6
Q_2	31	10.59	64	52	22.7
Q_3	6	3.62	5	17	4.4
Y_1	4.37		7	12	3
Y_2					
Z_1	.71	0.38	3.0	2.0	1.27
Z_2	1.16	0.31	1.0	1.0	0.84
Z_3	2.23	1.06	1.0	3.5	2.0
Z_4	4	2.87	3.37	3.5	3.58
Z_5	.15	.03	0.13	0.17	0.15
Z	8.21	4.65	8.5	10.17	7.84

Notes: 1 All units are 10^9 BTU/YR
2 A3 and C3 refer to Table 3.2.2.2

Table 3.2.2.3 Energy flow diagram : MIUS fuel input to a boiler is necessary to meet space and domestic hot water heating and absorption cooling needs. HCENERG also prints out kWh of electricity needed for lighting, heating pumps and accessories, cooling pumps, fans and accessories, electric compression refrigeration, space and hot water heating. There are provisions for specifying numbers of heating pumps, chilled water pumps, condenser water pumps, and tower or condenser fans which are staged to come on as heating or cooling loads increase. Additionally part load boiler, absorption chiller, and electric compression chiller efficiencies or figures of merit were considered in determining equipment energy input requirements. A new separate computer program summed up the HECENERG equipment input requirements. A listing of the program is located in Appendix B.

To project MIUS energy consumption for each housing project, program XTOTEN was written to model a total energy plant. XTOTEN performs the same functions as the existing program TOTEN with the following additions. XTOTEN sums up to four LFILE's with different occupancy schedules. TOTEN requires that all occupancy schedules be the same. XTOTEN allows a mix of electric compression and absorption refrigeration; TOTEN has only absorption. The logic of XTOTEN calls for the heat recovered from the engines to be used first for domestic hot water heating, then for either space heating or absorption cooling as needed, up to the limit of recovered heat. If the recovered heat is insufficient for domestic hot water or space heating, supplemental heat is added.

If more cooling is required than recovered heat can provide, electric refrigeration is added. The additional electric load on the plant increases the recovered heat and the available absorption cooling. Several iterations of the compression/absorption split were made. Only when the compression machine reached its full load cooling capacity was supplemental heat used for cooling. XTOTEN was tailored to each specific site to include heat recovered from the incinerator, plant burden, electric requirements for the sewage plant, area lighting, etc. XTOTEN adds an engine whenever the electrical load exceeds 80% of the capacity of the machines operating and totals the operating hours on each engine, assuming that they were added in sequence. Since calculations are made for each weather occurrence, it is possible to have some conditions for which supplemental heat is needed, while at others within the same month there is excess heat recovered. These normally cannot be offsetting. The program output totals this recovered but unusable heat.

4. UTILITY SYSTEM DESIGN AND COST ANALYSIS

The purpose of Section 4. is to present the methodologies and results of a comparative cost analysis of MIUS and conventional utilities for each of five housing projects described in Section 1. and Section 2. These methodologies and results were developed by NASA-USPO and by Hittman Associates and Charles J. R. McClure Associates under contract to NBS.

4.1 EVALUATION METHODOLOGY

Section 4.1.1 presents the methodology utilized by NASA-USPO to perform their comparative cost analysis. Section 4.1.2 presents the methodology utilized by Hittman Associates and Charles J. R. McClure Associates.

4.1.1 NASA Methodology

The purpose of Section 4.1.1 is to identify the NASA evaluation methodology utilized to generate cost data found in Section 4.2.1 for five housing projects described in Section 1.1.4. The NASA cost methodology was developed by the Aerospace Division of Lockheed Electronics Company under a contract to NASA-USPO. Mr. Harold E. Benson (Chief of Subsystems Engineering) was the overall project director. The ESOP software program was developed jointly by personnel of Lockheed and USPO. Mr. A.E. Brandli (Systems Engineering) was the overall project director. Information for Sections 4.1.1.1 and 4.1.1.2, is found in an internal December 4, 1974 correspondence entitled "Cost Evaluation of MIUS Services and Conventional Utilities Services (Preliminary Methods Documentation) from Mr. R. V. Monzingo (Lockheed) to Mr. H. E. Benson (NASA-USPO). Information for Section 4.1.1.3 is found in Energy Systems Operation Program (ESOP) User's Guide - Update IV, Economic Base, Volume III.

4.1.1.1 Initial and Annual Costs

How the MIUS owner conducts his business with the residents of the site and what profit he must have are related but different problems are not considered in this evaluation. The principal discrepancy in such a comparison is in the profits and taxes which are included in the rate structure for conventional electrical power. This factor was not possible to assess.

Common Costs

There exists common costs for both the MIUS and conventional equipment within the buildings which were omitted from the cost analyses.

For single-family detached dwellings, building equipment to the lot line or utility easement was considered identical unless district heating and/or hot water was provided. Building equipment and O & M costs were not evaluated unless these latter MIUS services were provided. The cost differences were treated in a manner identical to MIUS townhouses.

Townhouses were generally provided with district heating and cooling, and domestic hot water. Equipment within buildings was evaluated as to initial and annual O & M cost. The cost analysis excluded ductwork, controls, and domestic hot water plumbing. An equivalent and similar comparison was made of building equipment if less than three MIUS services were provided or where natural gas or fuel oil was used for conventional equipment.

It was assumed that there were no differences between conventional and MIUS services in the electrical power service, water supply, sewage and solid waste collection to the lot line or utility easement. This assumption was not strictly true, particularly for electrical power because of HVAC load differences, but for this exercise, the difference was not evaluated.

Apartments, Duplexes, Commercial and Community buildings were compared in a similar manner as MIUS townhouses.

Conventional Utilities

Single-family detached dwellings were assumed to be owned by individuals who pay conventional utility charges in the conventional manner. Each dwelling unit had an individual water connection, individual solid waste pickup, an individual hot water heater, and individual space heating and cooling units. The utilities available were those which the developer has indicated that he had made arrangements for and would have installed. If no such information was provided by the developer, logical and reasonable assumptions were made. Residential rates and taxes applied. Townhouses were considered in an identical manner as single-family detached dwellings. Residential rate and taxes applied.

Apartments were considered in terms of apartment complexes. A housing project may have had one or more apartment complexes. If one group of apartments was separated from another group by individually owned dwellings i.e., single-family detached dwellings or townhouses, then more than one apartment complex was assumed. The apartments were assumed to have an owner who provided all utilities with the rent. Each apartment complex was assumed to have one water connection, one sewer connection, and one electrical meter. (Individual electrical metering costs for each apartment were used if this was stated by the developer). Each apartment complex had a single solid waste pickup point for each building. HVAC equipment was that stated by the developer. A central chilled water and heating system for an entire housing project had the greatest initial cost and the least annual O & M cost. Individual apartment systems had the least initial cost and the greatest annual O & M cost. Domestic hot water service was provided by inidividual hot water heaters in each apartment or a central system for each building with continuously circulating hot water in each apartment. The latter equipment facilitated cost comparison with MIUS equipment. Commercial rates and taxes applied.

Duplexes and other similar multi-family buildings were considered in an identical manner as single-family detached dwellings. These units were owned or rented by the residents. In either case, individual dwelling unit metering was provided. Residential rates and taxes applied.

For commercial and community buildings, each separate building was considered to have conventional utility connections similar to that of the apartment buildings. Commercial rates and taxes applied.

MIUS

Single-family detached dwellings were identical to those for which conventional utilities were provided. If district heating, chilled water, and hot water were provided to these units, the cost assessment was made in an identical manner as for MIUS townhouses. MIUS initial costs were adjusted in either case to include the cost of metering equipment for electricity and water (and hot and chilled water if these services were provided). Meter reader and clerical billing help were costed in the composite MIUS crew.

Townhouses were generally provided with district heating and cooling and domestic hot water. Metering costs were assessed for the services provided. If none of these services were provided, the townhouse equipment was identical to that of the conventional townhouses.

Apartments were treated in a manner identical to the conventional apartments except that district space heating, chilled water and domestic hot water energy were supplied from the central MIUS plant. Equipment arrangement (ducting, controls, fan coil units) within the buildings was considered identical to that of the conventional apartments if central HVAC equipment was costed for the conventional apartment. If conventional apartment equipment was assumed to be individual heating and cooling units for each apartment, then the total cost of the equipment for both the conventional case and MIUS case were evaluated because ducting, controls and fan coil units were different. Metering costs were considered.

Duplexes and other similar multi-family buildings were considered in a manner identical to MIUS townhouses. Metering costs were considered. Commercial and community buildings were treated in a identical manner as the MIUS apartments. Metering costs were considered. Since ownership considerations affect the cost comparison of conventional utilities and services, a cost for the MIUS grounds was added to the MIUS cost analysis. It is asssumed that the developer provided the onsite utility easements at no cost.

4.1.1.2 Utility Systems Compared

The MIUS had a single owner, either an individual, company, corporation, municipal government, or some such other organization. The owner operates and maintains the MIUS. The MIUS was defined as a complete set of subsystems including electrical power, water, wastewater, hot water, HVAC, and solid waste. The MIUS included all the supporting components of electrical power distribution, water distribution, sewage collection, heating, hot water and cooling distribution, and solid waste collection. The MIUS stopped at the lot owner's property line (or at the limits of the utility easement). The equipment from that point, to and within the buildings served, was the property of the property owner. The initial cost and annual operating and maintenance cost of this individually owned equipment was assessed and compared to the initial and annual operating and maintenance cost of conventional equipment which would typically be owned by individuals. This cost differential was considered in the cost comparison of MIUS services and conventional utilities.

The water supply and fire protection was provided by conventional means. The conventional water costs were evaluated as to initial cost (connection fees, front foot benefits, other) and annual owning and operating expenses (rate structure and taxes) for the requirements of both the MIUS installation and the conventional installations. It has been determined that for some or all of the five housing projects, there exist institutional restrictions as well as restrictions due to previous and planned development progress. MIUS costs were developed without regard to these conditions. The differing time frames of the developments were compensated for in the cost comparison.

MIUS

The MIUS design (Table 4.1.1.1) provided five services. Electrical power was supplied at 120/208-volt three-phase ac power to all occupied spaces. Domestic hot water of potable quality was heated to 150°F. Heating and air conditioning was provided to meet the particular heating and cooling loads of the particular locale. Wastewater treatment was consistent with the requirements of recycling for non-potable use and/or disposal to the external environment. Solid waste disposal consisted of transportation and incineration consistent with applicable EPA regulations. The optimization approach used was that of the MIUS Community Conceptual Design Study[2] to minimize the discounted cash flow. The alternative having the lowest present cost was selected. The reliability requirement determined the redundancy provided in the design of the system. Reliability also influenced the selection of equipment and the decisions concerning interconnection of systems. The MIUS reliability was comparable to that of conventional systems. A design goal for all subsystems was to obtain maximum commonality of subsystem components without decreasing efficiency and without violating the optimization criterion.

Power was generated at 60 hertz, three-phase only. Minimum-heat-rate engines were used in power generation. Heat-recovery equipment was compatible with the HVAC system. Fuel oil was the basic energy source. A fuel storage capability (adequate for 24 hours of normal operation) was provided at each MIUS housing project. Replenishment of the fuel oil was from offsite storage through an underground pipeline. The electrical power subsystem operates independently of, but compatibly with, the offsite power system.

Table 4.1.1.1

NASA MIUS Design

	Housing Project				
	#1	#2	#3	#4	#5
Fuel					
Electric Power Generation:	#2 Oil	Nat. Gas	#2 Oil	#2 Oil	#2 Oil
Capacity (kW)	2870	2400	9500	10500	1900
Engines (#)	3	5	10	11	4
Heat recovery	E,J,L	E,J,L	E,J,L	E,J,L	E,J,L
(stand-by)					
Capacity (kW)	800	400	800	800	400
Engines (#)	1	1	1	1	1
Heat recovery	None	None	None	None	None
Space Heating:					
Boilers (#)	1	0	0	2	1
Rating (hp)	490	0	0	460	350
Thermal Storage (kgal)	340	0	0	0	205
Air Conditioning:					
Comp. Chiller (#)	2			2	2
Rating (ton)	425			425	400
Abs. Chiller (#)	1	1	2	2	1
Rating (ton)	422	160	650	725	325
Solid Waste Disposal:					
Rating (tpd)	6.2	1.3	12.2	16.2	5.0
Incinerator (#)	1	1	2	2	1
heat recovery	Yes	Yes	Yes	Yes	Yes
sludge (tpd)	4.3	1.3	9.4	10.3	3.5
Wastewater Treatment:					
Capacity (kgpd)	226	48		516	174
Potable Water Treatment:					
Capacity (kgpd)	Conv	45	Conv	Conv	164

NASA Conventional Design

	#1	#2	#3	#4	#5
Space Heating:					
Boiler (#)	2	1	1	2	1
Rating (hp)	300	350	450	465	430
Air Conditioning:					
Comp. Chiller (#)	2	1	2	3	2
Rating (ton)	680	160	650	720	585

The HVAC subsystem was designed to maximize the utilization of waste heat for both summer cooling and winter heating. If necessary, supplemental boilers were used to meet the winter space-heating peaks. Compression refrigeration was used if supplemental cooling capacity was required. Circulating hot-water and chilled-water systems were used for the high-density regions of the housing project. Where possible, heat was rejected directly to the environment so that water can be conserved.

The solid waste was disposed of by incineration. Energy, in the form of heat, was recovered from the wastes. The heat-recovery equipment used was compatible with the HVAC subsystem. The burning schedule of the solid wastes conformed to the requirements of the HVAC subsystem. The utilization of supplemental fuel in the incineration process was minimized. The stack emissions complied with EPA guidelines. All solid waste used was from the community itself; solid wastes were not imported to the housing project. Alternate disposal or storage was provided for protection against possible subsystem failure. The ultimate disposal (in the form of ashes) was to a remote offsite landfill.

All water produced by the potable water subsystem met the 1962 U.S. Public Health Service standards for drinking water. Only such potable water was used for human consumption. Prime mover waste heat was used wherever possible to heat domestic hot water. Wastewater treatment produced an effluent that was of sufficient quality for use in heat exchangers and cooling towers. Human contact with treated effluent was minimized. Surplus treated wastewater was used for lawn watering. Throughout the potable and wastewater portions of the subsystem, alternate means of disposal or storage were provided in case of subsystem failure. Adequate pressure and storage of water existed for firefighting purposes at any location within the housing project.

Electric Power Generation

Electrical power loads for both MIUS and conventional service were developed for each housing project in terms of building type, direct consumption, and auxiliary loads. The auxiliary loads in both cases included HVAC consumption, building exterior lighting (street lighting), water supply power, sewer system power, and incinerator system power. The domestic loads include all loads developed within each dwelling unit excluding the mentioned auxiliary loads. For the MIUS, the initial costs and production costs for this power were evaluated for the entire site without regard to individual building type consumption. For conventional power, an assessment was made of consumption by building type because of conventional rate structure and then compared to the MIUS costs for the entire site. Electrical power was metered by the MIUS owner as conventional electrical power. Street lighting power costs were distributed proportionately between the individual consumers for both the MIUS and conventional systems.

For conventional electrical power initial costs, it was determined whether or not: (a) there are any initial costs to be imposed on the developer such as for bringing power to the site, or establishing one or more transformer stations; (b) there are any initial costs imposed on the developer for providing underground distribution (underground distribution costs run 1-1/2 to 3 times the cost of typical overhead distribution); (c) there is an initial one-time electrical connection fee. A one-year deposit was required for a singlefamily dwelling unit in some cases. While this deposit was not be considered an initial expense, the interest on the deposit was considered an initial expense. MIUS initial capital and annual (O & M and annualized initial costs) costs were adjusted to include meters and metering reading. The personnel costs were included in the MIUS composite crew. Conventional annual costs were developed from appropriate rate schedules using average consumption values. Initial and annual costs of equipment within buildings were considered to be the same in both the MIUS and conventional cases and were not evaluated.

Space Heating and Air Conditioning

MIUS and conventional costs include the central plant, hot and chilled water distribution (including trenching, metering and isolation valves) and individual building equipment. Building equipment includes central heat exchangers for domestic hot water and for heating and cooling. It does not include ducting, controls, piping and building space. Annual costs (other than annualized initial costs) for both MIUS and conventional are labor, fuel, materials and individual building maintenance.

Solid Waste Disposal

Generally, neither the developer nor property owner incur any initial costs relative to the disposal of solid waste in the conventional case. The responsibility for this activity is assumed directly by a local government or by private contractors who are licensed by the local government. Charges may include taxes as well as periodic payments in either case. Unless so specified, it was assumed that none were applicable in the conventional case. The cost analysis for offsite disposal of residual solid waste for MIUS were adjusted to reflect local conditions at each site.

Wastewater Treatment

The MIUS initial cost included the treatment plant, collection system (including trenching which terminated on the utility easement), the outfall, and fire protection if MIUS provided a potable water subsystem. MIUS annual O & M costs were chemicals, labor and miscellaneous materials. Electrical power was not assessed separately. The initial conventional costs were connection fees, permanent deposits, interest on non-permanent deposits and front foot benefit charges. Annual charges for other than annualized first costs were based on applicable tax and rate structures.

For comparision to the MIUS, in order to assess initial as well as annual costs, the period of financing of the conventional system was ignored. Current interest rates and an assumed 20-year period for MIUS financing made this comparison reasonable. The conventional system will typically be financed for a longer period at a lower rate of interest than will be possible with MIUS.

Potable Water Treatment

If a water supply subsystem was not provided with the MIUS, the applicable tax/rate structure was applied to both the MIUS and conventional system costs. A MIUS installation, without a water subsystem still used less water than the conventional system because of the tertiary treated wastewater used in the cooling tower and the treated wastewater used for irrigation. This irrigation was assumed to be accomplished from the fire protection system and credit for this savings was not taken unless a wastewater-fire protection system was installed. If the MIUS had a water subsystem, then fire protection was provided by a MIUS wastewater subsystem. If the MIUS did not have a water subsystem, then fire protection was provided by the conventional water supply system.

For the conventional water supply system, the initial costs cannot be clearly separated from those of wastewater and storm water. If MIUS does not provide a water supply subsystem, MIUS and conventional systems were costed the same. Initials cost were connection fees, front foot benefits (proportionalized between water, wastewater and storm water as necessary), installation of supply line, interest on non-permanent deposits and permanent deposits.

Other Condersiderations

A cost for the MIUS building and grounds were included in total MIUS costs. An acreage was specified for this and the developer and/or local tax authorities were contacted for an estimate of this value.

4.1.1.3 ENERGY SYSTEMS OPTIMIZATION PROGRAM

ECOBAS determined the capital and operating and maintenance cost for both MIUS and a conventional system based on the energy analysis performed by ESOP.

ECOBAS

The economic data base consists of approximately 130 tables of costs for various components and operating/maintenance expenses. ECOBAS is programmed for utility systems consisting of ten basic pieces. These ten pieces are: electrical power generation (engine/generator sets, heat exchangers, fuel storage); electrical power distribution (wire, transformers, switchgear); potable water supply (plumbing, pumps, valves, tanks, chlorination); domestic hot water (tanks, pumps, heat exchangers, plumbing); wastewater management which includes collection, processing and residual disposal (plumbing, pumps, lift stations, manholes, package plants); HVAC (pumps, plumbing, chillers, cooling towers, boilers, valves, heat exchangers); solid waste management (incinerators, material handling equipment, pumps, blowers, plumbing, heat exchangers); control system; equipment building space; and miscellaneous. Each of these ten pieces includes costs for internal controls/instrumentation, consumables, O & M rates, and miscellaneous.

ECOBAS is a four-step computation. From the ESOP energy analysis ECOBAS develops the required capacities of each piece of equipment and the usage rates of consumables (fuel oil, electricity, natural gas) for MIUS and conventional utilities. MIUS or conventional utility systems need not contain all the cost items mentioned in the previous paragraph. The converse is true. The miscellaneous item in one of the other nine pieces or miscellaneous itself may be used to input additional cost items. ECOBAS interpolates within the cost tables and determines the cost of each cost item. Both the capital cost and the operating/maintenance cost are available. ECOBAS prints out a cost data summary. This cost data summary includes yearly operating/ maintenance costs for both MIUS and conventional, and a listing of the capital cost of each constituent cost item.

Program Input Data Discussion

The program input format is basically Fortran V namelists. The required namelists are MAINT, and SIZE. MAINT inputs information concerning the housing project (location, population, dwelling unit number, per capita utility consumption, cost index), utility equipment (annual consumables, O & M costs) and utility equipment consumables (cost). SIZE has four variables: CPCTY, UNITS, DIRCOS, and RATE. CPCTY is the capacity of each component in the equipment inventory. UNITS is the number of CPCTY units. DIRCOS is the direct cost of each CPCTY unit. RATE is labor required to install each CPCTY unit.

4.1.2 Hittman/McClure Methodology

The purpose of Section 4.1.2 is to identify the evaluation methodology of Hittman Associates and Charles J. R. McClure Associates which generated the cost data found in Section 4.2.2 for the five housing projects described in Section 1. and Section 2. Information for Sections 4.1.2.1 and 4.1.2.2 is found in "MIUS Review Site Four" by Charles J. R. McClure Associates, January 29, 1976 and "Draft MIUS Case Study Report" (Rough Draft) by Hittman Associates, February 1976.

4.1.2.1 Initial and Annual Costs

Detailed identification of affected subsystems, developer design constraints, local construction cost factors, pertinent details of terrain and other site specific characteristics were evaluated. It was determined that differential costs would be evaluated. Only those project features directly influenced by system design options were analyzed. No monetary consideration was given so desirability or preferences as seen from the stand point of the developer, contractor, owner, or tenant. A cost comparison was developed of initial construction costs. A cost comparison was made of maintenance and operating costs for the first full year of operating. The first full year was January through December 1977.

The cost of the conventional system energy to each of the user buildings in the community was calculated by applying appropriate utility and product costs. These costs were then summed to establish a "value" of the product from the MIUS, which was then applied in the analysis as the potential MIUS revenue. The MIUS investment cost was calculated by preparing a detailed construction cost estimate of the plant, distribution systems, and terminal systems costs of the user buildings. System diagrams and equipment lists were developed in the design of the utilities for the conventional and MIUS for each housing project (Table 4.1.2.1). The costs developed were limited to services provided up to the dwelling units but do not include terminal or distribution apparatus within the buildings. Construction costs were determined on the basis of unit prices for components of subsystems and included: vendor selling prices for principal apparatus, installation expenses peculiar to the location and system design, cost of buildings and other site improvements incident to the subsystems, utility connection charges, engineering designs, contingency allowances, contractor overhead charges, sales taxes, and start-up expenses.

Annual operating expense of the utility services systems on each housing project were developed from the data generated in the system design. Energy charges, including demand and commodity cost and taxes, were computed for each utility service purchased: electricity, water, sewer, steam, chilled water, etc. Local utility rates were verified; the expense of solid waste handling and disposal, calculated. Annual operating labor costs, parts and supplies expenses, contract services, replacement parts allowance, insurance costs, and property taxes were estimated. Operating schedules for utility service functions were determined. Hours of use for each apparatus were estimated. Replacement and overhaul intervals, and costs were obtained from suppliers and contractors.

Site-specific characteristics significantly affect both the construction costs and the energy consumption. Comparative costs for distribution supply system vary significantly with length of main per service entrance, service entrances per unit area of development, topographical characteristics of the site, location of MIUS with respect to user builders, geological characteristics of site, etc. Investment cost of the plant relates not only to the segregated product demands (electric, heat, and cooling), but to the full load balance of these products from an integrated plant. For example, the full load balance between electrical and thermal requirements dictates the type of prime mover, the salvage heat systems necessary for the prime mover, the need for supplemental heat, the method for generating chilled water for cooling, and the need for thermal storage systems.

Housing Project

	#1	#2	#3	#4	#5
Fuel					
Electrical Power Generation:	#2 Oil	Nat Gas	#2 Oil	#2 Oil	#2 Oil
Capacity (kW)	3250	900	1400	10400	2500
Engines (#)	5	4	5	4	5
Heat recovery	E,J	E,J	E,J	E,J	E,J
(stand-by)					
Capacity (kW)	NA	NA	NA	NA	NA
Engines (#)	NA	NA	NA	NA	NA
Heat recovery	NA	NA	NA	NA	NA
Space Heating:					
Boilers (#)		2	None	2	
Rating (hp)		60	0		
Thermal Storage	None	None	None	None	None
Air Conditioning:					
Comp. Chillers (#)	2	2	None	None	2
Rating (ton)	4325	100	0	0	350
Abs. Chillers (#)	1	1	3	3	1
Rating (ton)	665	200	174	365	500
Solid Waste Disposal:					
Rating (tpd)	3.3	0.6	5.4	6.9	2.1
Incinerator (#)	1	1	1	1	1
Heat recovery	Yes	No	No	Yes	No
Sludge (tpd)	LndFl	LndFl	LndFl	LndFl	LndFl
Wastewater Treatment:					
Capacity (kgpd)	190				195
Potable Water Treatment:					
Capacity (kgpd)	Conv	46	Conv	Conv	24

H/M Conventional Design

Space Heating:					
Source	Elect Furn	Gas Furn	Elect Furn	Gas Furn	Elect Furn
Cop	1.0	0.75	1.0*	0.75	1.0
Air Conditioning:	Elect Comp	Elect Comp	Elect Comp*	Elect Comp	Elect Comp.
Source	1.6	1.6	1.6	1.6	1.6
EER					

4.1.2.2 Cost Projections

The regions for which costs were projected (Table 4.1.2.3) are: West North Central (Housing Project #1); East South Central (Housing Project #2); South Atlantic (Housing Project #3, and #5) and the New England (Housing Project #4). The specific cost variables that were projected are indices for labor, equipment, fuel, and selected utilities.

Capital

The wholesale price index for machinery and equipment on an annual basis is reported by BLS[a], though only on a nationwide basis. For the U.S. as a whole, the annual growth rate for the wholesale price index for machinery and equipment was calculated to be 2.55 percent.

Labor

Average hourly earnings are undoubtedly the relevant variable for estimating labor costs. Data for average hourly earnings in manufacturing are available for each state in Employment and Earnings: States and Areas which is reported by the Bureau of Labor Statistics (BLS). Data for average hourly earnings in electric companies and systems are tabulated by the BLS only for the nation as a whole. Earnings in electric companies and systems were estimated on a state by state basis for the electric companies and systems in the U.S. as a whole on data for average hourly earnings in manufacturing as a whole (BLS). The resulting relation was then used to generate the appropriate series for average hourly earning in electric companies and systems for each state.

Once the four data series were estimated, the four index growth rates were calculated according to the autoregressive method described above. The rates thus obtained are: 5.51 percent (West North Central); 5.18 percent (East South Central); 5.00 percent (South Atlantic); and 4.81 (New England).

Fuel

Chase Econometrics' special long-term forecasts provided specific long-term annual forecasts for the prices of oil, electric utilities, and gas utilities through the year 1980 for the U.S. as a whole. The imputed annual growth rates for these projected indexes from 1975 to 1980 were calculated to be 6 percent for all oil, 10 percent for electric utilities, and 10 percent for gas utilities. Allowances for regional variations in fuel costs were made by an examination of past trends. Annual data on national wholesale prices for refined petroleum products, gas fuels, and electric power for the past dozen years were obtained from Business Statistics, while

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[a] Bureau of Labor Statistics, "The Biennial Supplement to the Survey of Current Business," of Business Statistics.

Table 4.1.2.3 - Price Indices Projections (By Area)

(1974 = 100)

Cost Indices	Year	West North Central	East South Central	South Atlantic	New England	United States
Capital: Industrial	1975					102.55
Commodities	1976					105.16
(Wholesale)	1977					107.84
Labor: Average	1975	105.59	105.21	105.10	104.78	
Hourly	1976	112.27	111.47	111.23	110.56	
Earnings	1977	119.31	118.05	117.67	116.63	
Fuel: Coal	1975	106.89	111.24			108.50
(Wholesale)	1976	114.25	123.74			117.72
	1977	122.13	137.64			127.73
#2 Fuel Oil	1975			107.10	105.10	105.82
(Wholesale)	1976			113.53	111.41	111.94
	1977			120.34	118.09	118.43
#6 Fuel Oil	1975			118.72	127.72	105.82
	1976			125.84	135.38	111.94
	1977			133.39	143.51	118.43
Gas	1975	134.33	135.10	134.02	129.49	
(Utilities -	1976	147.76	148.61	147.42	142.44	
Wholesale)	1977	162.54	163.47	162.16	156.68	
Electricity	1975	115.17	126.40	126.40	129.71	
(Utilities -	1976	126.69	139.04	139.04	142.68	
Wholesale)	1977	139.39	152.94	152.94	156.95	
Potable Water:	1975					102.06
(Utilities -	1976					104.16
Wholesale)	1977					106.31

regional data for these same variables were obtained from "Energy Prices," 1960-1973 (Foster Associates, Inc.).[a] The mean deviation of the wholesale price index for each region from the national wholesale price indexes on a year by year, region by region, and source by source basis, and then dividing by the number of years. The mean deviations thus calculated were then incorporated into the forecasts as an adjustment for regional discrepancies in cost structures by incorporating them at the beginning of the series and thereafter applying the imputed constaint growth rate to project the series forward. Hence, fuel cost projections of each region for oil, gas, and electricity are trends that differ from the past national trend by a constant percentage that reflects past trends in regional cost differences.[b]

Unlike other fuel sources, the trend of past coal prices was judged to be a reasonable predictor of future trends. Over the past decade or so, coal prices have displayed a steady and strong upward trend. Regression analysis, used as before, yielded the following growth rates for the f.o.b. mine wholesale price of coal: 8.50 percent (U.S.); 6.89 percent (West North Central); and 11.24 percent (East South Central).

Potable Water/Wastewater Treatment

Data for water and sewerage services were not presented as separate tabulations or by regions, but were included nationally under the category of consumer prices for "Housing Fuel and Utilities" by "Business Statistics Supplement" to the Survey of Current Business. This was judged to be the relevant index to use for water utilities. Regression analysis yielded a growth rate of 2.06 percent for the consumer prices index of fuel and utilities over the past two decades. The series has been projected forward at this constant rate.

4.2 PRESENTATION OF RESULTS

Section 4.2.1 presents the cost data developed by NASA-USPO for the five housing projects described in Sections 1.1.4 and with the methodology described in Section 4.1.1. Section 4.2.2 presents the cost data developed by Hittman Associates and Charles J. R. McClure Associates for the same five housing projects with the methodology described in Section 4.1.2.

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[a] It should be pointed out that regional data were not available here or elsewhere for fuel oil in the West North Central or East South Central areas, while price indexes for coal in the South Atlantic and New England areas were unavailable as well. In these particular cases, the average national trend was used as a proxy for regional rates.

[b] The identical projections for electric utilities in the East South Central and South Atlantic areas are not a result of identical data. It is a mere coincidence of the data that the mean deviation form the national trend was the same in, both cases.

4.2.1 NASA Evaluation

4.2.1.1 MIUS

MIUS cost evaluation was originally intended to be made using the data developed for 496 apartments in the summer of 1974. These data have been published by the NASA Urban Systems Project Office in a report entitled, "Preliminary Design Study of a Baseline MIUS System," dated April 1974, reprinted July 1974.[3] The baseline study was for a very high population and dwelling unit density housing project of 11.18 acres, and 496 dwelling units, 106.5 residents per acre. The five housing projects in Section 1.1.4 possess generally far more dwelling units and considerably less residents per acre density than the baseline system. As a result, a combination of the cost data developed for the baseline MIUS and for the community study, which was conducted by NASA in the summer of 1973 and which had a population density of 9 residents per acre, are used for the cost estimates for the five housing projects. Costs for the community study are documented in a report entitled, "Cost Methods and Cost Analysis Results for the Community Study MIUS Concepts," dated December 7, 1973.[2]

In both studies, initial costs were developed excluding general contractor profit and overhead which would add between 15% and 40% to the published costs. No engineering costs were included, nor adjustments made for construction time, construction loan costs, architectural fees, or similar real expenses. No land, right-of-way, or site preparation costs were included. Provisions for storm water drainage and the costs for disposal of the treated wastewater were not included in the studies. No costs had been included for laboratory facilities for testing the quality of the water and wastewater. Operating and maintenance costs were exclusive of overhead or fixed costs such as for taxes, interest and principal on initial capital, insurance, and administrative and clerical costs. Maintenance cost figures were averages which would occur over a period of several years.

An elementary "turnkey cost" estimate (Table 4.2.1.1) has been made for each housing project to partially compensate for the omissions discussed. The 19.2% added to the base cost of materials and labor for general contractor overhead was taken from the 1974 Building Construction Cost File and details of this estimate are given in that reference. The 7.5% estimate for architectural fees for the MIUS building is from the same source. Engineering costs and general contractor profit are estimates based on engineering judgement. While each general contractor will develop his estimates in much greater detail as it relates to his unique costs and conditions, the total turnkey cost provides a reasonable estimate of the additional costs over materials and subcontractor costs which should be expected. For total annual outlay, an insurance estimate and an annual payment of principal and interest were added to the base O & M cost.

Costs for the baseline MIUS (Preliminary Design Study) were developed using primarily either Chicago or U.S. average costs (Table 4.2.1.2). While Chicago costs do not represent a U.S. average, this combination was the

Table 4.2.1.1

NASA MIUS Turnkey Cost

(10^3 $)

	Housing Project				
	#1	#2	#3	#4	#5
Turnkey Cost:					
Material, Sublabor Profit, Overhead	3447	1336	7071	9234	3524
Gen. Cont. Overhead (@ 19.2% M&L)	662	257	1358	1773	677
Engineering (@ 10% M&L)	345	134	707	923	352
Architecture (@ 7.5%)	259	100	530	693	264
Gen. Cont. Profit (@ 10% M&L)	345	134	707	923	352
Total	5058	1961	10373	13546	5169
Annual Cost:					
O&M	514	227	1205	1251	411
Insurance (@ 10% M&L)	34	13	71	92	35
Total	548	240	1276	1343	446

best available for developing cost data from which location variations could be studied. This approach is used for evaluation of the five housing projects. Three indices have been used to assess the variation in cost from one location to another with Chicago being 100 in each case. Operating personnel costs are varied according to the construction labor indices given in the 1974 Building Construction Cost Data published by Robert Snow Means Company, Inc. Construction labor and materials are related to the total construction indices from the same reference. O & M costs are also varied by the same relationship. Fuel costs are related to Chicago and the housing project locations through use of the variation in the price of gasoline, exclusive of state taxes, as reported in "The Oil and Gas Journal," as of July 30, 1974. Table 4.2.1.3 illustrates the indices used to effect the cost variations because of location. The indexing method used for these variations is not for absolute costs of a particular component or subsystem and is intended only to provide the proper trend for the major variations in total system cost with location.

Electric Power Generation

The engine-generator sets with all local controls, heat recovery equipment, interconnecting steam and lube oil piping, primary switchgear and transformers, wiring, day tank, installation, warranty, manuals, and initial oil fill had a single value. The costs were based on Fairbanks-Morse-type engine and were estimated to be approximately 10% to 15% more per kW than a comparable Caterpillar installation. A Caterpillar-type engine-generator set without heat recovery and with a minimum of accessories was costed separately as a standby auxiliary. There were no switchgear and transformer costs associated with this standby engine-generator.

Fuel storage and supply equipment consisted of underground fuel storage tanks with capacities up to 40,000 gallons each. The tanks were coated steel similar to those used for gasoline service stations. A four-pump distribution system with underground copper piping was included. Distribution external to the MIUS building included underground wiring (but no trenching cost), transformers, and switchgear. No costs were included for wiring from the terminal transformers to the dwelling unit buildings. No metering equipment was included. In the case of the very high density (106.5 residents/acre), distribution costs were $3,390/acre, $76.50/dwelling unit, or $26.40/kW of installed capacity with heat recovery. In the less dense neighborhood of the community study (9 residents/acre), distribution costs were $2,010/acre, $524/dwelling unit, or $81.70 per kW of installed capacity. For the cost evaluation of the five housing projects, a cost per acre (linear) as a function of residents/acre (log scale) has been used with the two points of 9 residents/acre at $2,010/acre and 106.5 residents/acre at $3,390/acre.

A total cost of maintenance of the engine-generator sets, heat recovery equipment, and MIUS building transformers and switchgear is 4.02 mils/kWh. Distribution equipment maintenance was at 2%/year of the initial equipment costs. The lube oil value used was .75 mils/kWh. Fuel costs were based on the requirments generated by the ESOP program, the fuel

Table 4.2.1.2

NASA MIUS Cost

(10^3 $)

	Housing Project				
	#1	#2	#3	#4	#5
Materials, and Subcontractor Costs:					
Electrice Power Generation	1125	521	2640	3318	1281
Space Heating and Air Conditioning	638	67	1043	1364	662
Solid Waste Disposal	136	52	280	321	120
Wastewater Treatment	622	326	1337	1912	630
Potable Water Treatment	428	90	810	989	330
Controls	127	104	134	135	154
MIUS Bldg	158	72	231	275	143
Miscellaneous	213	104	596	920	204
Total	3447	1336	7071	9234	3524
Annual Operating and Maintenance Costs:					
Electric Power Generation	301	135	914	906	209
Space Heating and Air Conditioning	40	2	19	28	30
Solid Waste Disposal	20	5	37	45	16
Wastewater Treatment	28	11	49	61	25
Potable Water Treatment	16	3	31	37	12
Controls	16	14	17	17	17
MIUS Bldg	2	1	3	4	2
Miscellaneous	0	0	1	1	1
Operating Crew	91	56	134	152	99
Total	514	227	1205	1251	411

Table 4.2.1.3

Cost Indices
(By Area)

	Housing Project					
	#1	#2	#3	#4	#5	Chicago
1974 MEANS Building Construction Cost Data:						
Labor	91	68	99	99	99	110
Materials and Labor	91	75	96	97	96	104
Labor*	82.7	61.8	90.0	90.0	90.0	100
Materials and Labor*	87.5	72.1	92.3	93.3	92.3	100
Oil and Gas Journal (July 1974):						
Gasoline	44.4	40.9	42.9	41.9	42.9	45.6
Gasoline*	97.5	89.7	94.0	92.0	94.0	100

*Related to Chicago @ 100

indices of Table 4.2.1.3, and a delivered cost of 34.2¢/gallon for the Chicago area. Operating labor is based on the composition of the operating crew.

Space Heating and Air Conditioning

Only the central chilled and hot water plant costs and the cost of distribution to individual buildings were assessed. No costs for equipment within the dwelling unit and commercial buildings were evaluated because this equipment is assumed to be the same for both the MIUS and conventional system. This equipment included fan coil terminal units, thermostats, ducting, and piping. No costs were included for single-family dwelling unit HVAC equipment on the assumption that this equipment was required even if a MIUS was not installed. Power loads were considered for the single-family dwelling units in sizing the power plant.

The cost elements for the MIUS HVAC and domestic hot water equipment included: for example, absorption and centrifugal chillers; cooling tower(s); chilled water pumps; hot water pumps; interconnecting plumbing, valves, and heat exchangers within the MIUS building; and hot water and chilled water distribution piping from the MIUS building up to but not including individual buildings. Some MIUS designs also included low pressure steam boilers, thermal storage pumps, and a thermal storage tank. Installed costs for chillers, boilers, and cooling towers were taken directly from standard cost references. Plots for chilled and hot water pumping equipment were also developed from standard cost references. The thermal storage tank costs (where required) were based on the detailed cost analysis for the 496-apartment baseline MIUS and cost trend data for underground concrete tanks taken from Richardson's. The MIUS building interconnect plumbing, valves, and heat exchangers were related to the 496-apartment baseline MIUS costs on an installed chiller capacity basis and this value is used for all systems.

The hot and chilled water distribution piping was related to the dwelling unit density per acre in a special study. The special study was made for regular distribution patterns for 4, 16, and 64 dwelling units per acre. Results of the study agreed reasonably well with the community study data and the 496-baseline MIUS data. This type of estimate was necessary because building locations were not defined for all five housing projects. The area or areas being served by the central hot and chilled water were estimated and the cost was interpolated from the special study data. For the housing projects where the MIUS building was not located adjacent to the site being served, separate estimates were made for the primary piping required to deliver service to the high density areas.

O&M costs, exclusive of labor (one-half the maintenance labor was assumed to be provided by the operating crew), were evaluated for each component or subassembly. Fuel costs were evaluated for the quantities developed from the ESOP program data, the fuel index, and the 34.2¢/gallon for diesel fuel in Chicago.

Solid Waste Disposal

For solid waste disposal, there was one (or more) incinerator with a heat recovery boiler, interconnecting steam and water piping, ash removal equipment, and other related accessories. The 496-apartment baseline system data were scaled based on the cost trend of incinerators without heat recovery and the other peripheral equipment. The sizing of the incinerator was based on burning the average daily solid waste load in twelve hours.

Collection equipment costs were related to the number of dwelling units served. Collection equipment cost was taken from the 496-apartment baseline MIUS. This cost agreed quite closely with the community study data.

Operating costs (excluding labor) for the solid waste subsystem included incinerator fuel, collection equipment fuel, and an estimate for the cost of offsite disposal of ash and non-combustibles. Offsite disposal cost was related to the community study data (adjusted to mid-1974 $). The offset disposal cost was $21.64/ton. From this total cost, the cost of collection and cost for incinerator fuel were subtracted because these costs were included in the MIUS operating costs. As in many other areas of this preliminary costing, the actual cost of disposal of residual solid waste depended on the local conditions at each housing project.

Maintenance costs for the solid waste equipment were developed for individual components of the 496-apartment baseline MIUS. Maintance costs from this study were related to the total initial costs of the MIUS building and the collection equipment.

Wastewater Treatment

No costs were included for the disposal of treated wastewater since this represented a unique cost for each particular housing project. In the MIUS studies conducted by NASA, fire protection equipment costs were included with the wastewater subsystem. Because it was assumed that the conventional potable water supply system provided for fire protection, this element of cost was omitted from the wastewater subsystem.

Primary and secondary treatment costs were scaled from the detailed cost analysis made for the 496-apartment baseline MIUS. Vendor cost data for the Three-Stage Autotrol Bio-Disk Process equipment were used to establish the cost trend with the assumption that the other auxiliary equipment required followed the same cost trend. The bio-disk process equipment was the major cost item of the primary and secondary treatment. Auxiliary equipment included pumps, tanks, and interconnect plumbing. Costs for this process were based on the peak capacity requirements.

Tertiary treatment plant costs were scaled from the detailed cost analysis for the 496-apartment baseline system using vendor cost data for the Met-Pro IPC Advanced Treatment equipment as the cost trend indicator. This equipment was the major cost element of the tertiary treatment. Auxiliary supporting equipment included plumbing. Costs for this process were also based on the peak capacity requirements.

Wastewater collection cost was the third element of the cost evaluation and was related to both the community study and the 496-apartment baseline MIUS. The Option I MIUS of the community study included 29 450,000-gpd wastewater treatment plants, one typically serving a neighborhood on 365 acres with 713 single-family dwellings, 324 townhouses, 324 apartments, and several miscellaneous neighborhood buildings. Nine residents per acre represented the neighborhood population density. For this system, the collection equipment costs included lift stations, manholes and piping (but not trenching costs), and came to $1,825/acre (1974 $). The 496-apartment baseline had 106.5 residents/acre and a collection equipment cost of $2,485/acre. A cost per acre (linear) as a function of residents per acre (log) was used, based on these values, to estimate collection equipment costs.

Potable Water Treatment

An independent MIUS potable water supply and treatment plant was not to be developed for any of the five housing projects. Because a water supply presented a unique situation for any housing project, the conceptual water supply system costs developed for the community study were used in the MIUS base cost analysis without any adjustment for the different locations.

MIUS Control Subsystem

A comprehensive study of the requirements and costs for control and monitoring equipment for the 496-apartment baseline MIUS was conducted and was documented in the "Preliminary Design Study of a Baseline MIUS System," dated April 1974 and reprinted July 1974[3]. Costs for the Baseline MIUS System were used in cost evaluation for each housing project. While some variation was expected in the cost for equipment for the different housing projects because of numbers of pieces of equipment requiring control and monitoring, no satisfactory approach was developed for determining this variation in cost. The same cost for this element was used for each of the five housing projects with the only variation resulting from the construction cost index. The equipment costed under this category included only the control room equipment, sensors, and transducers. Costs for control valves was included with the subsystem costs. Costs for pilot valves, pneumatic equipment, and piping was included in Miscellaneous.

MIUS Central Equipment Building

The MIUS building, which houses the MIUS subsystems, was sized according to the equipment installed. A value of $\$16.69/ft^2$ excluding general contractor profit and overhead site work, engineering and architectural costs, was used. A description of the building being costed was included in both the community study cost documentation and the 496-apartment baseline MIUS documentation.

Miscellaneous

Miscellaneous trenching costs were related to both the community study and the 496-apartment baseline MIUS. In both of these studies the site area was assumed to be flat and costs were based on "unclassified" soil. Wastewater trenching, which was separate from all other service trenching, was related to the population density of each site. The trenching (adjusted to mid-1974 $) for a community study neighborhood of 365 acres with 9 residents/acre came to $1,015/acre (Chicago). The trenching costs for the 496-apartment baseline MIUS with 106.5 residents/acre came to $2,180/acre. A plot of these two cost values (linear) against residents/ acre (log) was used to estimate the wastewater trenching costs. Trenching costs for all other services, based on the community study data, were set at $413/acre independent of population density. The initial fuel load was charged to miscellaneous costs. The fuel tank capacity was sized to accommodate a 30-day fuel supply.

Operating Crew

The operating crew for each MIUS included as a minimum, one skilled employee and three semi-skilled employees. Service workers were added as necessary to cover the estimated manhours per week required to operate the system. A base annual Chicago cost of $22,880 for the skilled employee, $12,430 for each of the seim-skilled employees, and $8,283 each for the service workers was established from the Bureau of Labor statistics. Social security tax, unemployment tax, 3% of the base for overtime, and an additional 5% for other costs set the Chicago costs at $26,532 for the skilled employee, $14,731 for each semi-skilled employee, and $9,827 for each service.

Forty hours per week were allotted for the one skilled employee who was the Engineer-Supervisor. An engine-generator required five man-hours per week. Man-hours per 24 hours for the wastewater equipment were based on the average daily processing load where 18 man-hours per 24 hours were required to operate a plant processing an average of 88,000 gpd and 25 manhours per 24 hours are required to operate a plant processing an average of 338,000 gpd. Manhours per week for the HVAC equipment were set a 7.7 manhours per major component (chiller, boiler, and cooling tower). Manhours per week for the solid waste subsystem were related to: the tons per week to be collected; the collection cost per ton as a function of residents per acre (based on the community study and the 496-apartment baseline studies); and the average hourly rate for the service workers. The manpower estimate obtained in this manner can be improved. The method did provide a consistent, relative set of cost values for comparison.

4.2.1.2 Conventional Utilities

An elementary "turnkey cost" estimate (Table 4.2.1.4) was made for conventional utility costs at each housing project. Refer to Section 4.2.1.1.

Costs for conventional utilities (Table 4.2.1.5) were based on the community study conducted by NASA in the summer 1973. The purpose of evaluation of costs for conventional utilities was to obtain a point of reference for comparison. These costs did not represent the costs which would be incurred by a developer. The community study costs, documented as, "Cost Methods and Cost Analyses Results for the Community Study MIUS Concepts," dated December 7, 1973[2], were originally developed for the Washington, D.C. area. No attempt was made to adjust these costs for each different location. All 1973 costs were adjusted to reflect mid-1974 replacement costs.

Electric Power Generation

It was assumed that capital costs for the conventional electrical power plant were based on 2σ peak load plus 6% of the values generated by the ESOP program. The electrical power plant costs were based on the East Central Power Region using the Homer City, Pennsylvania coalburning plant as a cost reference point. Transmission and general plant facilities costs were related to the generating plant costs according to the total capital. Distribution equipment costs were related to the distribution equipment costs for the MIUS in order to make a more reasonable comparison.

The heat rate of the Homer City power plant, as reported by the Federal Power Commission and as used in the ESOP program, was 11,360 Btu/kWh delivered. In order to provide a consistent comparison for all five building sites, it was assumed that conventional system fuel costs would be 80% of the cost of fuel for the MIUS. Table 4.2.1.6 lists the local power plants for each housing project for electrical power cost comparison with that assumed. Other O&M costs for the generating, transmission, and general plant facilities were also related to the Homer City plant and the East Central Power Region.

Distribution equipment costs for the conventional system were not taken from the East Central Power Region values but rather are related to the distribution costs for the MIUS. The conventional system distribution costs was related to the MIUS distribution equipment costs by the ratio of the 2σ peak power load plus 6% of the conventional requirements. Two percent of the initial cost of the distribution equipment was for O&M costs. This was an approximate average value obtained from several sources which agrees well with the data reported by the Federal Power Commission, generally given in mils/kWh.

Space Heating and Air Conditioning

The HVAC equipment costs used for the community study could not be used for a conventional equipment cost comparison. A conventional HVAC system (including domestic hot water) of similar design to that of the MIUS

Table 4.2.1.4

NASA Conventional Turnkey Cost

	Housing Project				
	#1	#2	#3	#4	#5
Turnkey Cost:					
Material, Sub. Labor, Profit, Overhead	3335	1201	7595	9098	3334
Gen. Cont. Overhead (@ 19.2% M&L)	640	231	1458	1747	640
Engineering (@ 10% M&L)	334	120	760	910	333
Architecture (@ 7.5%)					
Gen. Cont. Profit (@ 10% M&L)	334	120	760	910	333
Total	4643	1672	10573	12665	4640
Annual Cost:					
O&M	512	181	1131	1335	385
Insurance (@ 1% M&L)	33	12	76	91	33
Total	545	193	1207	1426	418

Table 4.2.1.5

NASA Conventional Cost

(10^3 $)

	Housing Project				
	#1	#2	#3	#4	#5
Materials, and Subcontractor Costs					
Electric Power Generation	1186	721	3784	4262	1250
Space Heating and Air Conditioning	666	83	997	1344	928
Solid Waste Disposal	156	55	327	407	126
Wastewater Treatment	710	149	1323	1622	548
Potable Water Treatment	617	193	1164	1463	482
Controls					
MIUS Bldg					
Miscellaneous					
Total	3335	1201	7595	9098	3334
Annual Operating and Maintenance Costs:					
Electric Power Generation	259	130	813	839	191
Space Heating and Air Conditioning	138	7	103	224	101
Solid Waste Disposal	49	18	102	128	39
Wastewater Treatment	32	7	60	73	25
Potable Water Treatment	21	6	40	49	16
Controls					
MIUS Bldg					
Miscellaneous					
Operating Crew*	13	13	13	22	13
Total	512	181	1131	1335	385

*HVAC only

Table 4.2.1.6

Electrical Power Cost Comparison
(¢/10^6 Btu)

	1971 Fuel Costs		
	Coal	Oil	Gas
Site #1			
° Power Plant A	39.31		29.38
° Power Plant B	32.62		29.13
Site #2			
° Power Plant A		31.14	28.80
° Power Plant B		30.68	29.27
° Power Plant C		27.41	29.00
° Power Plant D		26.48	27.54
Site #3	(No Plants Identified)		
Site #4			
° Power Plant	54.65	64.85	49.45
Site #5			
° Power Plant A	46.23	70.05	
° Power Plant B	52.32	71.31	40.66
° Power Plant C		70.11	
° Power Plant D	49.74	69.91	
° Power Plant E	78.06	70.57	

was costed. This system did not use absorption refrigeration machines. Chilled and hot water pump costs were the same as for the MIUS. The distribution piping costs were also. This equipment cost was also adjusted to the Washington, D.C. area to provide a consistent set of data As in the case of the MIUS the cost of single-family dwelling HVAC and hot water equipment was not costed since these costs were the same whether a MIUS was used or not.

Solid Waste Disposal

For conventional solid waste disposal, NASA utilized the results from their community studies. The conventional solid waste system for the community study consisted of local collection equipment, transport equipment for hauling the solid waste to a central incinerator facility and to a landfill area located offsite, incinerators, and landfill equipment. O&M costs included operator labor, fuel, and maintenance materials and labor for the equipment. Capital and fuel costs have been adjusted to reflect mid-1974 costs. The capital cost of the community study equipment came to $25,150/ton of capacity and $21.64/ton for O&M costs.

Wastewater Treatment

Conventional wastewater costs were based on collection system costs and treatment plant costs. Provision for outfall from the treatment plant was not considered. In the community study, the treatment plant was located at the edge of the community and was assumed to be installed in 2,000,000-gpd stages as the requirements of the community increased. The total capacity at the end of the study period was 14,000,000 gpd. Capital cost and O&M costs for the treatment plants were developed from data obtained from numerous operating facilities and EPA reports.

The collection system was comprised of concrete sewer pipe in sizes ranging from 8" to 66" in diameter, lift stations, and manholes. The gravity system was assumed to have been installed in a flat area and consequently required more lift stations than a typical system. Operation and maintenance costs for the collection system were taken as one-fourth the O&M labor costs for the treatment plants. The total O&M costs for the wastewater system, including electricity, came to 51.9¢/1000 gallons (adjusted to reflect mid-1974 costs). The mid-1974 capital cost of the system, not including land, came to $2.62/gallon capacity. A proportional part of the capital cost of the above system was used based on peak daily requirements. O&M costs for the system were based on annual usage.

Potable Water Treatment

The community study conventional water supply was assumed to be from a natural source located 15 miles from the community. Like all the conventional systems of the community study, the water supply system was assumed to have been built up over a period of 20 years. The completed system consisted of pumping station, installed in two phases, a pipeline to the community, 28,000,000-gpd treatment plant installed in 4,000,000-gpd stages, elevated storage, and distribution throughout the community. There were no fire hydrants, a relatively small cost, which was inadvertently omitted. Electrical power costs, not assessed independently in the community study, were taken at 2.41¢/kWh. Mid-1974 costs for the system were: $2.01/gallon of capacity; an operating cost of 84¢/1000 gallons delivered, and maintenance costs (derived from the community study data and other related data) of 2% of the initial cost of the system. A proportional part of the capital cost of the above system was used based on peak daily requirements. O&M costs for the treatment plant were based on the annual requirements and the average operating costs of the 28,000,000-gpd plant. Maintenance costs for use of the distribution system were also a proportional part of the above community system costs based on average usage.

Operating Crew

Costs for operating and maintenance personnel were included in the system O&M cost for each of the systems except for HVAC. For consistency of the comparison, the HVAC operating crew was assessed in the same manner as was the MIUS crew. It was assumed that one semi-skilled employee would be required in any case, and any additional help would be costed at the service worker's rate. A full-time service worker was added for total weekly hours over 53. Manhours per week have been estimated based on 7.7 manhours per week per chiller, boiler, and cooling tower.

4.2.2 Hittman/McClure Evaluation

Information for Section 4.2.2 is found in "MIUS Review Site Four" by Charles J. R. McClure Associates, January 29, 1976 and "Draft MIUS Case Study Report" (Rough Draft) by Hittman Associates, February 1976.

4.2.2.1 MIUS

Construction costs were developed. (Table 4.2.2.1) Itemized costs of materials and labor were determined. Total cost impacts were calculated. Individual building terminal subsystems considered were: heating (energy source, controls, primary distribution unit, wiring, fuel storage and building space); air conditioning (energy source, piping, wiring heat transfer equipment and controls); domestic hot water (energy source, wiring and controls); and electricity (service entrance and distribution panel). Electrical distribution on the housing project in conventional design was considered as having no investment expense to the project since the electric utility rates charged to the users included installation expenses and the maintenance of the primary distribution system, transformers and service entrances. For the MIUS design, the costs of the land on which the plant was sited, all costs of building and equipment in the plant, and the mechanical and electrical distribution systems were identified and were calculated for the specific design selected for the housing project. Construction costs were developed by obtaining quotations on specific makes and models of apparatus from nationally distributed manufacturers

Table 4.2.2.1

H/M MIUS Cost

(10^3 $)

	Housing Project				
Materials, and Subcontractor Costs:	#1	#2	#3	#4	#5
Electric Power Generation + Space Heating and Air Conditioning	3560	1901	7241	8054	3156
Solid Waste Disposal	125	27	86	186	113
Wastewater Treatment	530	293	1334	1472	518
Potable water Treatment	137	190	161	721	327
Fire Protection	110	101	183	369	544
House Appliances	838	164	605	618	138
Working Capital	223	97	550	431	225
Land	9	3	11	11	8
Total	5532	2776	10171	11862	5029
Annual Operating and Maintenance Costs:					
Electric Power + Space Heating and Air Conditioning	691	168	1664	1288	580
Solid Waste Disposal	65	42	60	75	52
Wastewater Treatment	136	108	209	220	162
Potable Water Treatment + Fire Protection	78	70	118	142	88
Natural Gas				731	
House Appliances	41	11	189	192	24
Total	1011	399	2240	2648	906

and suppliers and by calculating manhours of labor for installation from labor data from the Mechanical Contractors Association of America, Inc., Washington, D.C.

Annual operation expenses were developed as a composite of: fuel consumption; plant staff personnel expense; plant supplies (parts, overhaul/and replacement allowances); plant management (engineering, insurance, taxes); and terminal equipment (parts, supplies, replacement allowance). The fuel consumption estimate (generated in the Medsi Energy Analysis, with allowance for the requirements of the solid and liquid waste systems) was priced at costs obtained from major oil suppliers in the area.

The power plant operating and maintenance staff size and technical skills were determined from extrapolation of experience at other total energy plants. The staff was planned to provide all required labor and management for onsite repairs, maintenance, operating and replacement for all in-plant equipment and customer's terminal equipment (other than conventional all-electric dwelling unit customers). Some special service skills for plant apparatus were to be provided by outside contractors. The plant staff was sized for 24 hour attendance with the capacity to provide emergency and routine service to the electrical and mechanical distribution systems.

Power plant supplies, overhaul and replacement allowances were developed principally from recent cost studies of two existing total energy plants with central heating and air conditioning systems serving dwelling units and a large commercial facility. Provisions were included for contracted services to service automation components and refrigeration machinery. Engine generator overhaul periods and costs were developed in conference with the manufacturer.

A substantial annual allowance was provided for management and engineering services in addition to the plant operating staff. The scope of services to be provided included: the business of billing customers for services; receiving and disbursing funds; purchasing supplies; evaluating performance of personnel and equipment; design of alterations to the plant and distribution systems; and customer relations. Annual costs for boiler and machinery insurance were from vendors. Real estate taxes on the power plant building and ground were from local tax rates.

The annual allowances for parts and supplies to service and maintain all the customer's terminal apparatus were developed in the same manner as for the conventional system. In addition, an estimate was included of man hours to service the heat exchange apparatus in each customer's premises that was connected to the MIUS central heating and cooling circuits. Customer's terminal equipment replacement allowance was developed in the same manner as described for the conventional system with the addition of staff man hours estimated for replacement labor of those items connected to the central plant heating and cooling circuits.

Basic to this study was the assumption that the customers would pay no more for the same services regardless of the source. Therefore, the initial step was to calculate the MIUS plant revenue earned by providing electricity to the customers served. Again, the individual customer consumption estimate was priced with prevailing utility company electric rates with appropriate escalation and tax factors. The totals were extended to develop the total annual revenue to the MIUS from the sale of electricity.

Individual MIUS items costed were: central equipment building site property; central equipment building (foundations, ventilation systems, accoustical isolation, illumination, automation with indicators and controls); compressed air (compressors, tanks, piping, air filter drier, controls); engineering (design, testing, start-up and preparation of operation and maintenance program); administration of construction program (site preparation, insurance, permits, zoning approval, and legal requirements); construction financing; and facilities management of operations (bookkeeping, customer relations, operations and maintenance staff training, accounting, taxation, legal, purchasing of supplies and services).

Electric Power Generation

Cleanable tube heat recovery mufflers were selected, which reduce the exhaust gas temperature from 600 F to 350 F, providing approximately 1800 Btu recovered heat per kilowatt hour. One reason for the selection of muffler recovery, in lieu of jacket heat recovery, was that the muffler heat could be recovered in the form of medium pressure steam (60 psi).

Steam recovery systems had advantages over water systems in that:

1. Higher temperatures and pressures were available;

2. Greatly increased reliability of the plant was achieved (A failure in the fluid reserve or pressure of one unit did not affect the other units);

3. Minor pressure losses did not result in vapor binding which could cause complete plant shutdown; and

4. Inherent advantages of a constant-temperature, two-phase system were available.

The non-recovered heat included: stack exhaust (from 350°F. down to ambient) which was rejected directly to the atmosphere; heat from engine jacket, from oil coolers, and from aftercoolers which were cooled with cooling tower water (heat rejected as latent heat to the atmosphere); and heat lost by radiation and by convection to the room for removal and by the room ventilation system.

Coolant water for the aftercooler, oil cooler and engine jacket circulated through a closed circuit on each prime mover. The heat was then transferred to the lower temperature cooling tower circuit through a water/water heat exchanger. Separate cooling tower pumps were provided for each unit on the basis of reducing interdependence, improving reliability, and reducing plant burden. The cooling tower water after circulating through the three engine heat exchangers was then piped to waste heat condensers where excess steam was condensed. This surplus heat is also dissipated to the cooling tower.

The voltage class of the distribution system between the power plant and these building transformers could have been either 600 volt, 5000 volt or 15,000 volt. An economic study was made from which 5,000 volt class was selected. The use of the 600 volt class, specifically 480 volts, resulted in poor regulation, the use of many 500 MCM cables and a premium for outdoor type distribution transformers. The use of the 5000 volt classs proved most economical and allowed the selection of generators rated 4160V/2400V and the use of unshielded cables. The use of the 15,000 volt class would have resulted in special generators and circuit breakers (or a step-up transformer arrangement to obtain the 15,000 volts), the use of shielded cables with more expensive splices and terminators, and more expensive distribution transformers. A 480 volt step down transformer was used to obtain a utilization voltage for the MIUS Plant loads.

MIUS electrical power generation cost items were central equipment building equipment, site distribution, and individual building equipment. Individual building equipment cost items were: distribution system transformers, space, and pad; low voltage distribution, switchboard, and distribution cable; meter installations; and dwelling unit distribution centers. Site distribution cost items were: high voltage transformers, distribution cable, conduit, trenching, and manholes. Central equipment building equipment cost items were: heat recovery (heat exchangers, controls, piping, pumps, insulation); fuel (fuel storage, pumps, piping); lube oil (make-up and waste oil tanks, piping, controls, heat exchangers); engine exhaust (heat recovery mufflers, exhaust piping, insulation, accoustical control); power distribution (feeders, main switch board, isolating breakers, grounding network, metering, generator control, subfeeders, switchboard, transformers, power branch circuits, motor control centers, indicators, and controls); diesel enginers (governors, starters, lube filters, pumps, vibration isolators, safety and alarm sensors); generators (voltage regulators, exciters, safety and alarm sensors); and apparatus installation/connection.

Space Heating and Air Conditioning

The thermal system was designed to convey heat to the community in the form of hot water. The water system was selected for the inherent simplicity of terminal apparatus which permits the plant to operate independent of terminal maintenance. To hold piping sizes and pumping capacities to a minimum, efforts were made to maximize the temperature differential at the terminal apparatus. A 50°F temperature range was achieved by arranging several terminal connections in series. The temperature also was dictated by the need for 140°F domestic hot water.

The distribution system temperature was set at 240°F which, with a saturation pressure of approximately 10 psig, enabled the use of low pressure piping in the distribution system and avoided temperature ranges of excessively active electrolytic action. To retain a reasonable LMTD (loop mean temperature differential) for the domestic water heat exchangers, the minimum loop temperature of 190° was selected. A steam pressure of 60 psig (308°F) was selected to heat the distribution water from 190° to 240°. The LMTD would have been considerably reduced had the engine jacket heat been needed, since the jacket temperatures are limited to approximately 15 psig (250°F).

The Central Equipment building distribution system was pumped as a primary loop to hydraulically isolate the terminal systems from the plant system. Two primary pumps were used. Both were needed to provide the design loop flow. In the event of failure of one pump, reduced flow (of approximately 70% design) was still available to serve the community, which would be sufficient for the vast majority of the operating hours. Each terminal connection was pumped from the loop, circulating first to the domestic hot water heating load then to the space heating load. This always provided for the highest temperature water available to heat the 140°F domestic water.

The two phase heat transfer system was designed as a complete closed system to minimize corrosion and chemical treatment costs. The only vent point provided was the deaerator vent, and the only point for air entrance was at the main condensate receiver. The concept was that this singular connection could be used for the controlled injection of inert gas when the system pressure dropped beyond a predetermined value into the vacuum range. Although this latter concept had not been commercially proven to date, recent advances in state-of-the-art in two phase systems appeared to be rapidly approaching this technology.

The chilled water distribution system was arranged for variable flow in response to load variations to improve source control response and minimize plant energy burdens. The chillers, in turn, were arranged as secondary pumped loops in series such that the chillers could be staged with flow variations.

MIUS HVAC cost items were: central equipment building equipment; site distribution; and individual building equipment. Individual building equipment cost items were: service entrance space and circulating pump room for hot and chilled water; air handling units (heating and cooling coils, piping, and controls); pump room piping, pumps, and controls; domestic hot water heat exchanger and control; and electrical power and connections to pumps. Site distribution cost items: chilled water and hot water mains, valves, manholes, insulation, trenching, backfill, chilled and hot water building run-outs, and connections. Central equipment building cost items were: heat rejection (cooling towers, heat exchangers, pumps, piping, controls, water treatment); auxiliary heating (supplementary boilers, stacks, fuel piping, pumps, controls, insulation); and water chilling (chillers, pumps, piping, controls insulation).

Solid Waste Disposal

The MIUS performance specification stated that refuse must be reduced 65 percent by weight and that the subsystem must generate an element of value or the subsystem was not to be considered a MIUS subsystem. The only commercially available process for reducing the weight of refuse by 65 percent was incineration. To obtain an element of value from incineration, heat was recovered in a form compatible with the MIUS thermal subsystems. Heat recovery economics must, therefore, be such that enough fuel to the MIUS plant can be saved to pay for the incinerator and waste heat boiler.

The incinerator and waste heat boiler utilized for the individual housing project cost evaluations were those of Environmental Control Products Inc. The equipment was guaranteed by the manufacturer to meet or exceed all EPA and state emission standards. The units could be purchased separately if heat recovery was not desired. The requirements were that the equipment be as automatic as practicable to minimize labor requirements. Refuse was not be stored for periods exceeding 24 hours, where practicable.

All loads were determined on the basis of 8.4 lbs per dwelling unit per day (approximately 1.5 cu. ft. of refuse per day per unit). This factor was multiplied by the number of dwelling units to obtain the quantity of solid waste generated per day. The quantity of solid waste generated per day was converted to tons and then expressed as tons per month by multiplying by 365/12. Solid waste was assumed to have the following as-received percentage composition by weight: paper - 48 percent; garbage - 16 percent; leaves and grass - 9 percent; wood - 2 percent; synthetics - 2 percent; cloth - 1 percent; glass - 6 percent; metal 8 percent; and ashes, stone, and dust - 8 percent.

The economics of refuse incineration and heat recovery was a controlling factor in determining whether an element of value was generated by the subsystem. In the case of Housing Project # 3, the thermal and electrical subsystems required no supplemental heat; therefore, only an incinerator was designed. The heat recovery economics were studied for the value of the heat as follows:

$$\text{Annualized Equipment Costs} + \text{Annual Recurring Costs} + \text{Annual Operating Costs} \quad \text{must not equal}$$

or exceed the value of supplemental heat requirements in terms of fuel (oil or natural gas) and equipment costs saved. This analysis was used to determine the value of heat recovery from the refuse incineration. Because of suspect reliability of refuse incineration, small refuse load relative to supplemental heat requirements, and low utilization rate (eight hours daily, Monday through Friday), the MIUS used supplemental heat boilers. Heat recovered from refuse incineration was used when available. The analyses show that Housing Project #4 was the only housing project having sufficient refuse load to warrant incineration and heat recovery.

Incineration and heat recovery was also employed, however, at Housing Projects 1 and 5. Incineration only was employed at Housing Projects 2, and 3.

Wastewater Treatment

The sewage treatment requirement was assumed to be equal to the mean annual domestic usage (q_D). Refer to Section 3.2.2.1 for mean annual domestic usage (q_D). The value of q_D (gallons per day) was multiplied by a factor of 365/12 to obtain the monthly sewage treatment requirement (gallons per month). The monthly maximum demand for sewage treatment was assumed to be the same as the average monthly sewage treatment requirement.

The MIUS performance specifications[1] called for the liquid waste treatment system to process and "renovate liquid wastes to levels adequate for final disposal or non-potable reuse." The MIUS sewage treatment system was a biological and tertiary wastewater treatment system designed to meet the above specifications.

The incoming liquid wastes were macerated and pumped to an aeration tank. The extended aeration tank had a design retention time of 24 hours rather than the typical six. Here, an activated-sludge process biologically degraded the liquid wastes under aerobic conditions. Air was continuously bubbled through the tank. The extended aeration subsystem significantly reduced the sludge volumes, and allowed the primary sedimentation to be omitted. The extended aeration tank also acted as a flow equalizer to smooth out fluctuations in the input, thus reducing the size of the clarifier. The mixed liquor from the aeration tank was then put through a mechanical clarifier which concentrated the suspended solids. The sludge was sent to a thickener while the effluent overflowed to anaerobic denitrification.

In anaerobic denitrification, methanol was bubbled as a source of carbon. Here the nitrate was converted into nitrogen gas biologically. The effluent from anaerobic denitrification was then mixed with lime and sent to a phosphate flocculation and settling subsystem with a designed detention time of 10 minutes. The calcium of the lime reacted to remove phosphorous as flocculant calcium phosphates; the resulting high pH permited the stripping of any ammonia in the liquid. The precipitated solids were sent to a sludge thickener while the liquid was charged with CO_2 in a recarbonation chamber to reduce the pH. The recarbonated liquid was passed through fine filtration and was sent to a chlorination chamber.

The flow from the chlorination chamber was retained in an effluent storage tank for 48 hours. This allowed sufficient time to conduct the necessary chemical water quality tests. Some of the final effluent was piped to the fire main while some was used as cooling and makeup water for the MIUS thermal subsystem. The rest of the effluent was discharged to the environment.

The sludge was thickened in a thickener and then vacuum dewatered. The resulting sludge was sent to the MIUS solid waste disposal subsystem while the liquid supernate was recirculated with the incoming wastewater.

Potable Water Treatment

For most housing projects, off-site conventional utilities supplied the potable water. Potable water was utilized also for fire protection. Local regulations necessitated a separate fire protection system. The major potable water cost item other than fire protection was the housing project connection and distribution mains.

4.2.2.2 Conventional Utilities

Conventional construction costs were developed in the same manner as for MIUS. Refer to section 4.2.2.1. Annual operating costs were determined for each class of building in two major steps: energy cost and maintenance/ replacement cost. Operating labor expense for conventional systems was considered not significant and was not costed.

Electric energy costs were calculated using the output of the Medsi energy analysis and applying current utility company rate schedules, fuel escalation charges and taxes. Oil-using customers' costs were established in a similar fashion with fuel prices obtained from sales agencies in the housing project area.

Maintenance and replacement expenses were determined for each item considered relevant to the differential cost analysis. Annual maintenance allowance for each item was estimated from McClure Associates' service experience of similar customers and apparatus. Costs were based on custodial personnel providing basic servicing and cleaning with contracted services on a periodic seasonal basis. Replacement costs for a 20-year life cycle were estimated from the estimated present cost of the replacement divided by the estimated service life expectancy of the component. Estimated service life, initial cost per dwelling, and annual maintenance and repair expense factors were verified with HUD information on this topic. The sum of all the customer's total owning and operating expenses was then identified for comparison with the MIUS alternative.

Conventional system cost items (Table 4.2.2.2) varied. When a unitary building system was compared with MIUS, the conventional system cost items were the individual building electrical distribution and mechanical subsystems. Individual building electrical distribution cost items were: utility distribution tranformer; space and concrete pads; low voltage distribution switchboard and distribution cable; meter installations; and individual dwelling unit distribution centers. Individual building mechanical cost items were: power wiring to heating; air conditioning; building openings; framing; and weather-proofing for air conditioning units; air conditioning condenser units; concrete pads; piping connections; air handling units; vaporators; resistance heaters; contactors; electrical hot water heaters; storage tanks; and controls. When a district heating/cooling

Table 4.2.2.2

H/M Conventional Cost

(10^3 $)

Materials, and Subcontractor Costs:	Housing Project #1	#2	#3	#4	#5
Electric Power + Space Heating and Air Conditioning					
Solid Waste Disposal					
Wastewater Treatment	174	293	689	804	518
Potable Water Treatment	137	209	161	721	340
Fire Protection	8	8	20	22	9
House Appliances	901	188	591	914	572
Working Capital					
Land		1			5
Total	1220	699	1461	2461	1444
Annual Operating and Maintenance Costs:					
Electric Power + Space Heating and Air Conditioning	700	50	1691	1170	587
Solid Waste Disposal	15	6	66	64	18
Wastewater Treatment	61	43	199	148	117
Potable Water Treatment + Fire Protection	76	43	139	141	100
House Appliances	123	29	211	293	80
Natural Gas		33		1095	
Fuel Oil			24		
Total	975	204	2330	2911	902

systems was compared with MIUS, the cost items for heating portion of the district system were: fuel storage and piping; boilers; burners; chimneys; boiler room space and ventilation; heating pumps; boiler room piping; electrical power distribution and connections; and domestic hot water heater (tank, controls, and fuel systems). The cost items for the air conditioning portion of the district systems were: refrigeration machines; condensers; evaporators; controls; cooling towers; pumps and piping; chilled water pumps; electrical power distribution; and connections.

Wastewater Treatment

In two cases, Housing Projects, #2 and #5, offsite wastewater treatment was not available. All (capital operating and maintenance) cost items were developed for these two, housing projects in the same manner as MIUS. Refer to Section 4.2.2.1.

Potable Water Treatment

Potable water supply was from an offsite municipal plant. Housing project water distribution mains, fire hydrants and connection to the off-site system were the initial capital costs. A separate fire water distribution system was required for MIUS only. Coventional O&M costs were front-foot benefits assessment and the water bill determined by the local water rates.

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3. Wolfer, Barry M. et. al., Preliminary Design Study of a Baseline MIUS, National Aeronautics and Space Administration, Johnson Space Flight Center, Urban Systems Project Office, NASA TMS-58193, April 1977.

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APPENDIX A

MEMORANDUM OF POINTS AND AUTHORITIES

DATE: August 12, 1974

RE: THE ACQUISITION OF AN INTEREST IN A MODULAR INTEGRATED UTILITY SYSTEM BY A SUBSIDIARY OF AN ELECTRICAL UTILITY.

FACTS

The Office of Policy Development and Research of the Department of Housing and Urban Development is investigating the construction and operation of a Modular Integrated Utility System (hereinafter a "MIUS"). A MIUS is an improved means for providing five previously separate services, space heating and air conditioning, solid waste processing, liquid waste processing, water purification and electricity, in an integrated package. The electricity from the MIUS generators provides power and is used to operate the solid and liquid waste processing facilities and the air conditioning facilities. The heat from the generators and the solid waste processing facilities provides space heating and is used to operate the water purification & the liquid waste processing facilities. The integration of these services saves energy and minimizes any adverse environmental impact associated with them.

One of the primary goals of the Department of Housing and Urban Development for a MIUS is to determine whether a MIUS is a commercially feasible alternative for providing the five basic services involved.

The electric utility, through one of its wholly-owned subsidiaries (hereinafter "Subsidiary"), is contemplating submitting a proposal in conjunction with a Developer and a Designer. The Developer is constructing an essentially residential community (hereinafter the "Community") of approximately 1600 living units and a few small commercial units. Some of the residential units will be purchased by the residents, and some will be leased. The Designer will design and construct the MIUS Plant for the Community. The plant will then be sold or leased to Subsidiary for operation.

The Community is located in the distribution area of a wholly-owned subsidiary of the electric utility. The MIUS will be physically interconnected with the electric utility system for back-up purposes. The cost of the MIUS Plant and its operating revenues will be minimal in comparison to the book value of the assets and the operating revenues of Subsidiary.

ISSUE

Does the Public Utility Holding Company Act of 1935 permit Subsidiary to acquire an interest in a MIUS?

SHORT ANSWER

I. SUBSIDIARY SHOULD OBTAIN SECURITIES AND EXCHANGE COMMISSION CONCURRENCE BEFORE ACQUIRING AN INTEREST IN A MODULAR INTEGRATED UTILITY SYSTEM.

II. THE SECURITIES AND EXCHANGE COMMISSION SHOULD CONCUR IN SUBSIDIARY'S ACQUISITION OF AN INTEREST IN A MODULAR INTEGRATED UTILITY SYSTEM.

DISCUSSION

I. SUBSIDIARY SHOULD OBTAIN SECURITIES AND EXCHANGE COMMISSION CONCURRENCE BEFORE ACQUIRING AN INTEREST IN A MODULAR INTEGRATED UTILITY SYSTEM.

The electric utility is a registered holding company under Sec. 5 of the public Utility Holding Company Act of 1935 (hereinafter the "Act"), c. 681, Title I, 49 Stat. 803, 15 U.S.C. Secs. 79 *et seq*. Moreover, because Subsidiary is wholly-owned, it is defined in the Act to be a subsidiary company. Sec. 2(a) (8).

Sec. 9(a) of the Act requires any registered holding company and any subsidiary company to obtain the approval of the Securities and Exchange Commission (hereinafter the "Commission") before acquiring any new business interests. Sec. 9(a) states:

> "Unless the acquisition has been approved by the Commission under Section 10, it shall be unlawful -
>
> (1) for any registered holding company or any subsidiary company thereof, by use of the mails of any means of instrumentality of interstate commerce, or otherwise, to acquire, directly or indirectly, any securities or utility assets or any other interest in any business;"

The term "to acquire" is defined in the Act to include *inter alia* to purchase or to acquire by lease. Sec. 2(a) (22). The term "utility assets" is defined to mean:

> "facilities, *in place*, of any electric utility company...for the production, transmission, transportation, or distribution of electric energy..." Sec. 2(a) (18) (emphasis added).

Because the facilities of the MIUS Plant to be used for the production of electric energy are not yet in place, they are not utility assets. They are also clearly not securities. Thus, Subsidiary is required to obtain the Commission's approval of the lease or purchase and the operation of the MIUS Plant only if those actions constitute acquisition of "any other interest in any business."

The phrase "any other interest in any business" has been held to have a narrow meaning. The Commission has stated:

> "Although this elusive phrase is not defined by the Act and although there is little legislative history to guide us, we think that the word "business" means something more than property as such, whether real or personal." New York State Natural Gas Corporation, 35 S.E.C. 480 (1953).

In fact, all the cases in which the Commission has specified addressed the question of the propriety of the acquisition or retention of "any other interest in any business" have involved interests in enterprises organized and operated for the purpose of either directly or indirectly making a profit. See, e.g., General Public Utilities Corporation, 32 S.E.C. 807, 840-42 (1951); Engineers Public Service, 12 S.E.C. 41, 54-55 (1942).

In the present case, on the other hand, the lease or purchase and the operation on of the MIUS Plant are not being undertaken for the purpose of making a profit. The Plant is experimental. Its purpose is to determine whether a MIUS is an economically feasible alternative to the present methods of providing the five services involved. Consequently, neither the lease or purchase of the MIUS Plant nor its operation by Subsidiary should be considered an acquisition of "any other interest in any business," requiring the Commission's approval for it to be lawful.

However, if Subsidiary were not to obtain the Commission's approval of such an acquisition and it were subsequently deemed to be an acquisition of "any other interst in any business," the acquisition would not be lawful, and all contracts entered into by Subsidiary for the acquisition would be void under the Act. Sec. 26(b). Therefore, the prudent course of action would be for Subsidiary to obtain the Commission's concurrence in the proposed acquisition, either by obtaining a decision from the Commission that it need not approve the acquisition or if the acquisition were deemed to be an acquisition of "any other interest in any business," by obtaining the Commission's approval of the acquisition.

II. THE SECURITIES AND EXCHANGE COMMISSION SHOULD CONCUR IN SUBSIDIARY'S ACQUISITION OF AN INTEREST IN A MODULAR INTEGRATED UTILITY SYSTEM.

As is discussed in Section I above, the Commission should concur in Subsidiary's proposed acquisition by finding that it need not approve the acquisition for it to be lawful. Even if the Commission were to find that its approval of the acquisition was required, it should grant its approval for the reasons discussed below.

Sec. 10(a) of the Act provides that a person may apply for approval of an acquisition of "any other interest in any business" by filing an application, which must include certain information, in the form provided by the Commission.

Sec. 10(b) provides, insofar as is here relevant, that the Commission will approve any such acquisition that complies with state law unless the Commission determines that:

"(1) such acquisition will tend toward interlocking relations or the concentration of control of public utility companies, of a kind or to an extent detrimental to the public interest or the interest of investors or consumers;

* * *

(3) such acquisition will unduly complicate the capital structure of the holding-company system of the applicant or will be detrimental to the public interest or the interest of investors or consumers or the proper functioning of such holding-company system."

The proposed acquisition by Subsidiary of an interst in a MIUS does not complicate, or in any way change, the capital structure or control of the holding company system or of any subsidiary company. Therefore, the Commission should under this criterion approve the acquisition.

However, Sec. 10(c) of the Act states:

"Not withstanding the provisions of subsection (b), the Commission shall not approve -

(1) an acquisition of securities or utility assets, or of any other interest, which is...detrimental to the carrying out of the provisions of section 11;"

Sec. 11 of the Act contains narrow restrictions on the type of interest that can be acquired or retained by a registered holding company or any subsidiary company.

Sec. 11(b) provides that it is the duty of the Commission:

"To require..., that each registered holding company, and each subsidiary company thereof, shall take such action as the Commission shall find necessary to limit the operations of the holding-company system of which such company is a part to a single integrated public-utility system, and to such other businesses as are reasonably incidental, or economically necessary or appropriate to the operation of such integrated public-utility system:

* * *

The Commission may permit as reasonably incidental, or economically necessary or appropriate to the operations of one or more integrated public-utility systems the retention of an interest in any business (other than the business of a public-utility company as such) which the Commission shall find necessary or appropriate in the public interest or for the protection of investors or consumers and not detrimental to the proper functioning of such system or systems."

Section 2(a) (29) of the Act defines the term "integrated public utility system," as applied to electric utility systems, as follows:

"(A) system consisting of one or more units of generating plants and/or transmission lines and/or distributing facilities, whole utility assets, whether owned by one or more electric utility companies, are physically interconnected or capable of physical interconnection and which under normal conditions may be economically operated as a single interconnected and coordinated system confined in its operations to a single area or region, on one or more States, not so large as to impair (considering the state of the art and the area or region affected) the advantages and the localized management, efficient operation, and the effectiveness of regulation;"

In New England Electric System, 38 S.E.C. 193, 198 (1958), the Commission concluded that the requirement that a system's utility assets be interconnected or capable of interconnection and be capable of economic operation as a single interconnected and coordinated system was met if one group of utility assets were connected to another primarily for back-up purposes.

Also, in Mississippi Valley Generating Company, 36 S.E.C. 159, 187-188 (1955), the Commission held that physical interconnection of utility assets primarily for the purpose of supplying back-up power met the requirement of an interconnected and coordinated system. Because the MIUS will be physically interconnected with the electric utility system for back-up purposes, the two systems meet the requirement that they be physically interconnected and coordinated.

In order to be an "integrated public utility system," a system must also be "confined in its operations to a single area or region, in one or more States,..." The Commission, in Mississippi Valley Generating Company, 36 S.E.C. 159 (1955), concluded that if a new generating facility was located within the applicant's present service area, the single area or region requirement was met. The Commission stated:

"We think it clear that no problem with respect to the 'single area or region' test is presented." 36 S.E.C. at 187.

In the present case, because the Community and the MIUS Plant are within the electric utility's distribution area, the electric utility portion of the MIUS and the electric utility's electric utility system constitute an integrated public utility system.

Thus, the question presented here is whether the lease or purchase and the operation of the MIUS Plant to provide space heating and air conditioning, liquid and solid waste processing, and water purification meet the requirement of Sec. 11(b) for "the retention of an interest in any business (other than the business of a public-utility company as such)..."

Sec. 11(b) has been interpreted by the courts to impose a twofold requirement. The court in Michigan Consolidated Gas Co. v. S.E.C., 444 F. 2d 913 (D.C. Cir. 1971), stated:

> "The Commission in construing this section has adopted what has been referred to as the 'functional relationship' test in order to determine whether the retention of a particular business is permissible under the Act. To pass this test the holding company or its subsidiary must clear two hurdles. First, the company must show that its 'other business' is 'reasonably incidental, or economically necessary or appropriate to the operations of such integrated public-utility system.' (Id.) Once a company has cleared this hurdle, the Commission then looks to see whether the retention of the 'other business' is 'necessary or appropriate in the public interst.' (Id.)
>
> * * *
>
> We think that prior judicial decisions, the principles of statutory construction, and the legislative history call for adoption of the Commission's interpretation." 444 F2d at 916.

See North American Co. v. S.E.C., 133 F2d. 148 (2nd Cir. 1943), aff'd on other grounds 327 U.S. 686 (1946).

Thus, the first requirement imposed by Sec. 11(b) is that Subsidiary's operation of the MIUS Plant be "reasonably incidental or economically necessary or appropriate" to the operation of the electric utility's integrated electric utility system. Past cases indicate that if each of two tests are met a business will be held to be "reasonably incidental..." to an electric utility system. The first test that must be met is that the business must be subordinate in size to the electric utility system.

> "In general, the pattern of the statute and the context of the relevant statutory provisions seems to indicate that the other business tests are not to be applied to operations grossly out of proportion to the utility business with respect to which they are claimed to be reasonably incidental, or economically necessary or appropriate. In the ordinary case, therefore, we believe the statute contemplates that after compliance with Section 11(b) (1) the integrated systems retainable by a registered holding company will constitute its primary business and that retainable nonutility interests will occupy a clearly subordinate position. (The North American Company and its Subsidiary Companies, 11 S.E.C. 194 (1942) aff'd. North American Company v Securities and Exchange Commission, 133 F.(2d) 148 (C.C.A. 2d, 1943).)" Cities Service Company, 15 S.E.C. 962, 976 (1944)

Also, in Lone Star Gas Corporation, 12 S.E.C. 286 (1942), Commission expressly found that each business that was retainable was "clearly subordinate in size to public utility operations." 12 S.E.C. at 289-299.

The second test that must be met if a business is to be "reasonably incidental..." to an electric utility system is the test of whether a functional relationship exists between the business and the utility system. Thus, it is not sufficient that there is a relationship between the business and the utility system if the relationship is not a result of their functions. The test is not met by the business and the utility system sharing common management. See Philadelphia Company, 28 S.E.C. 35 (1948), aff'd 177 F2d 720 (D.C. Cir. 1949).

There is a functional relationship, however, if the business uses the by-products from the electric utility system's production of electricity. For example, in General Public Utilities Corporation, 32 S.E.C. 807, 840-841 (1951), the Commission concluded that the sale of waste steam, steam that had been used to drive the electric utility system's generators, was a business that was functionally related to the electric utility system. The same result was also reached in Philadelphia Company, 28 S.E.C. 35 (1948), aff'd 177 F.2d 720 (D.C. Cir. 1949).

In the case of a MIUS, the space heating and air conditioning, liquid and solid waste processing, and waste purification services are all functionally integrated with the generation of electricity. The heat from the MIUS generators is used for space heating and to operate the water purification and liquid waste processing facilities. Consequently, the operation of the MIUS Plant to provide these services is "reasonably incidental..." to the integrated public utility system.

The second requirement imposed by Sec. 11(b) of the Act is that the acquisition or retention of a business be in the "public interest or for the protection of investors or consumers and not detrimental to the proper functioning of such (utility) system..." The requirement that the acquisition or retention be in the "public interest..." refers to the public affected by the operation of the business. Philadelphia Company, 28 S.E.C. 35 (1948), aff'd 177 F2d 720 (D.C. Cir. 1949).

In a number of cases the requirement that the acquisition or retention of a business be in the "public interest..." has almost automatically been found to be satisfied if the requirement that the business be "reasonably incidental..." to the utility system was met. See, e.g., North American Company, 32 S.E.C. 168, 182 (1950).

In the cases that discuss the requirement that the acquisition or retention of a business be in the "public interest...", one measure of public interest that has been used is the savings to be business that would result from its retention as part of the utility system. E.g., Philadelphia Company, 28S.E.C. 35 (1948), aff'd 177 F.2d 720 (D.C. Cir. 1949)

There can be no question in this case that the cost of operating the MIUS Plant will be lower if the Plant is operated by Subsidiary rather than someone else. Common management for the operation of the Plant and the electric utility system and Subsidiary's experience in the production and distribution of utility services will both contribute to low costs in the operation of the MIUS Plant. Consequently, both requirements of Sec. 11(b) of lthe Act are met.

SUMMATION PROGRAM

```
PROGRAM PRNT (INPUT,OUTPUT,TAPE1)
DIMENSION E(4,9,13),D(4,9,13),DSUM(9,13),ESUM(9,13)
DIMENSION EKWH(13),DKW(13),EBTU(13),EBTUC(13)
DIMENSION 1MONTH(13),OIL(13),PDMND(13),PLOAD(13),QSALV(13)
DIMENSION QSUP(13)
DATA 1MONTH/3HJAN,3HFEB,3HMAR,3HAPR,3HMAY,3HJUN,3HJUL,3HAUG,
+3HSEP,3HOCT,3HNOV,3HDEC,3HTOT/
PRINT,*DATA FILE NAME,NUMBER OF DATA SETS,PRINT PARTS 1,2,3,4 *,
PRINT,*(0=NO)*
READ,NFILE,NDATA,N1,N2,N3,N4
PRINT 20
20 FORMAT(////*MIUS SITE 4, ST.CHARLES, MARYLAND*//)
CALL PFUR(3HRET,5HTAPE1,NFILE,0,ISTA)
DO 100 I=1,NDATA
DO 100 J=1,6
READ(1,) NLINE,(E(I,J,K),K=1,6)
READ(1,) NLINE,(E(I,J,K),K-7,12)
READ(1,) NLINE,(D(I,J,K),K=1,6)
IF(D(I,J,2)) 60,40,60
40 DO 50 K=2,12
D(I,J,K)=D(I,J,1)
GO TO 70
60 READ(1,) NLINE,(D(I,J,K),K=7,12)
E(I,J,13)=0.
70 DO 80 K-1,12
80 E(I,J,13)=E(I,J,13)+E(I,J,K)
100 D(I,J,13)=0.
IF(N1.EQ.0) GO TO 142
DO 130 J=1,6
DO 110 K-1,12
110 PRINT 120,(D(I,J,K),E(I,J,K),I-1,NDATA)
120 FORMAT(4(F5.0,1X,F10.0,2X))
130 PRINT 140,(E(I,J,13),I=1,NDATA)
140 FORMAT(4(6X,F10.0,2X)////)
142 CONTINUE
DO 145 J=1,6
DO 145 K=1,13
ESUM(J,K)=0.
DSUM(J,K)=0.
DO 145 I=1,NDATA
IF((I.GE.3).AND.(J.EQ.5)) GO TO 145
ESUM(J,K)=ESUM(J,K)+E(I,J,K)
DSUM(J,K)=DSUM(J,K)+D(I,J,K)
145 CONTINUE
DO 150 K=1,13
EKWH(K)=0.
DO 150 J=1,6
EKWH(K)=EKWH(K)+ESUM(J,K)
150 DKW(K)=DKW(K)+DSUM(J,K)
OSUM=0.
DO 172 K-1,13
EBTU(K)-0.
DO 165 I=3,NDATA
165 EBTU(K)=EBTU(K)+E(I,5,K)
EBTU(K)=EBTU(K)*34.3.E-9
IF(EBTU(K)-.05) 166,167,167
```

```
166 EFF=.6
GO TO 170
167 IF(EBTU(K)-.3) 168,169,169
168 EFF=.65
GO TO 170
269 EFF=.7
170 OIL(K)=EBTU(K)/(EFF*1.44E-4)
OSUM=OSUM+OIL(K)
172 CONTINUE
OIL(13)=OSUM-OIL(13)
IF(N2.EQ.0) GO TO 195
PRINT 175
175 FORMAT(10X,*LIGHTING*,11X,*AIR HANDLING*,7X,*OTHER ELECTRICAL*
+/3(7X,*KW*,9X,*KWH*)
DO 185 K-1,12
185 PRINT 180,1MONTH(K),(DSUM(J,K),ESUM(J,K),J=1,3)
180 FORMAT(A3,3(1X,F6.0,1X,F12.0,1X)
PRINT 190,IMONTH(13),(ESUM(J,13),J=1,3)
190 FORMAT(A3,3(8X,F12.0,1X)/////)
195 IF(N3.EQ.0) GO TO 225
PRINT 200
200 FORMAT(*CONVENTIONAL SYSTEM*//10X,*ELECTIC*,17X,*OIL*/
+33X,*HEATING*/7X,*KW*,9X,*KWH*,8X,*BTU*,6X,*GALLONS*)
200 FORMAT(11X,*ELECTRIC*,18X,*OIL HEATING*/5X,*KW*,14X,
+*KWH,20X,*BTU/YR*)
DO 205 K-1,12
205 PRINT 210,IMONTH(K),DKW(K),EKWH(K),EBTU(CK),OIL(K)
210 FORMAT(A3,1X,F6.0,1X,F12.0,2X,F7.3,*E09*,2X,F7.0)
PRINT 220,IMONTH(13),EKWH(13),EBTU(13),OIL(13)
220 FORMAT(A3,8X,F12.0,2X,F7.3,*E09*,2X,F7.0///)
IF(N4.EQ.0) GO TO 360
PRINT 230
230 FORMAT(*MIUS PLANT*//10X,*CUSTOMER*,8X,*HOT WATER*,2X,
+*CHILLED WATER*/10X,*ELECTRIC*,9X,*HEATING*,6X,*COOLING*/
+7X,*KW*,9X,*KWH*,8X,*BTU*,10X,*BTU*)
195 CONTINUE
DO 250 J=1,6
DO 250 K=1,13
ESUM(J,K)=0.
DSUM(J,K)=0
DO 250 I=1,4
C=1.
IF((I.EQ.1).AND.(J.GE.5)) C=.1943
IF((I.EQ.1).AND.(J.EQ.4)) C=.6852
ESUM(J,K)=ESUM(J,K)+C*E(I,J,K)
DSUM(J,K)=DSUM(J,K)+C*D(I,J,K)
250 CONTINUE
DO 260 K-1,13
EKWH(K)=0.
DKW(K)=0.
DO 260 J=1,6
EKWH(K)=EKWH(K)+ESUM(J,K)
260 DKW(K)=DKW(K)+DSUM(J,K)
DO 280 K-1,13
EBTU(K)=0.
EBTUC(K)=.3148+.75E-5*E(1,4,K)
```

```
DO 275 J=5,6
275 EBTU(K)=EBTU(K)+.8057*E(1,J,K)
280 EBTU(K)=EBTU(K)*3413.E-9
DO 290 K=1,12
290 PRINT  300,IMONTH(K),DKW(K),EKWH(K),EBTU(K),EBTUC(K)
300 FORMAT (A3,1X,F6.0,1X,F12.0,2X,F7.3,*E09*,3X,F7.3,*E09*)
PRINT 301, IMONTH(13),EKWH(13),EBTU(13),EBTUC(13)
301 FORMAT(A3,8X,F12.02X,F7.3,*E09*,3X,F.3,*E09*)
302 CONTINUE
PRINT 305
305 FORMAT (///*MIUS PLANT BURDEN*//7X,*KW*,9X,*KWH*)
PLOAD(13)=0.
DO 310 K-1,12
PDMND(K)=460.+DKW(K)/154.+.6852/17.*D(1,4,K)
PLOAD(K)=235060.+EKWH(K)/154.+.6852/17.*E(1,4,K)
PLOAD(13)=PLOAD(13)+PLOAD(K)
310 CONTINUE
DO 312 K=1,12
312 PRINT 315,IMONTH(K),PDMND(K),PLOAD(K)
315 FORMAT(A3,1X,F6.0,1X,F12.0)
PRINT 320,IMONTH(13),PLOAD(13)
320 FORMAT(A3,8X,F12.0)
325 CONTINUE
DO 330 K=1,13
DKW(K)=DKW(K)+PDMND(K)
EKWH(K)=EKWH(K)+PLOAD(K)
OIL(K)=10947./144000.*EKWH(K)
OSALV(K)=1.15*(EBTU(K)+1.5*EBTUC(K))
330 QSUP(K)=QSALV(K)-1800.E-9*EKWH(K)
PRINT 335
335 FORMAT(///*MIUS PLANT TOTALS*//39X,*ENGINE HEAT*,2X,
+*SUPPLEMENTAL*/26X,*ENGINE FUEL*,3X,*SALVAGED*,3X,*HEAT REQUIRED*
+/7X,*KW*,9X,*KWH*,7X,*GALLONS*,8X,*BTU*,10X,*BTU*)
DO 340 K-1,12
340 PRINT 345,IMONTH(K),DKW(K),EKWH(K),OIL(K),QSALV(K),QSUP(K)
345 FORMAT(A3,1X,F6.0,1X,F12.0,2X,F10.0,4X,F7.3,*E09*,3X,F7.3,
+*E09*)
PRINT 350,IMONTH(13),EKWH(13),EKWH(13),OIL(13),QSALV(13),QSUP(13)
350 FORMAT(A3,8X,F12.0,2X,F10.0,4X,F7.3,*E09*,3X,F7.3,*E09*)
360 CONTINUE
END
```

RUN COMPLETE.

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15. SUPPLEMENTARY NOTES

[ ] Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

This report highlights the collaborative efforts of the National Bureau of Standards, the National Aeronautics and Space Administration and their contractors in the analysis of a Modular Integrated Utility System (MIUS) and conventional utilities for five separate housing projects. The collaborative efforts consist of three separate tasks:

1. Comparative Environmental Analysis
2. Comparative Energy Analysis
3. Utility System Design and Cost Analysis

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Energy conservation; environmental impact; feasibility study; integrated utilities; MIUS; on-site utilities.

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