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Abstract

The National Institute of Standards and Technology (NIST)'s Technical Investigation of the 2011 Joplin, MO tornado identified that no widely accepted standards exist for emergency communications in tornado events and more specifically, policies involving the use of communication systems to alert the public in advance of tornadoes.

This study is designed to develop evidence-based guidance for communities on the creation and provision of public alerts, including both alerts provided by outdoor siren (warning) systems and "short messages" sent by social media or other short message service (SMS) platforms. It is the hope that this guidance can eventually be used as input for standardization, through codes and standards, of the procedures and practices for outdoor siren systems and short message alerts used by communities across the United States. Standardization of emergency communication policies and procedures could occur at multiple levels, including among multiple jurisdictions, state-wide, regionally, or even nationally.

This document focuses on short message alerts, specifically presenting a review of platforms, usage and public response. First, an overview is provided on the current status of short message alerts in the United States, i.e., the current short message technology available and the ways in which this technology is used in communities across the United States. Second, a review of the literature is presented on the ways in which people respond to short message alerts and the current limitations of these systems in light of these findings. This document concludes with a discussion on the key findings and recommendations from the literature on the ways in which to improve current short message alerts, based on the methods by which people receive and process these types of alerts. Following this work, a document will be developed to provide the overall evidence-based guidance for communities on the creation and provision of public alerts.

Keywords: alerts, disasters, emergency communication, mass communication, short messages, Twitter, Wireless Emergency Alerts, IPAWS, public response, emergency warnings

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1. Introduction

Tornadoes pose a significant threat to life and property in the United States. In an average year, these windstorms are responsible for the most fatalities and insured losses of any natural hazard in the U.S. For example, in the ten years from 2001 to 2010, the U.S. averaged nearly $1B in insured losses and 56 fatalities per year from tornadoes according to the National Oceanic and Atmospheric Administration (NOAA 2014). One of the deadliest U.S. tornadoes on record was one that struck the city of Joplin, MO and surrounding areas on May 22, 2011.

The tornado that occurred on May 22, 2011 in a populated area, Joplin, Missouri was rated as a National Weather Service (NWS) EF-5 tornado on the Enhanced Fujita tornado intensity scale (NOAA 2011). This tornado touched down just to the west of Joplin and proceeded to cut a swath across the entire city. The tornado directly affected 41 percent of the city's population (20 820 people, out of the 50 175 estimated), damaged or destroyed nearly 8 000 structures and caused nearly $2B in insured commercial and residential property losses, and generated approximately 2.29 x 10^6 m^3 (3M yd^3) of debris (Kuligowski et al. 2014). More importantly, the structural damage and associated windborne debris were responsible for the majority of the 161 fatalities, the most caused by a single tornado since the NWS started keeping records in 1950. Windborne debris was also a major factor in the over 1 000 injuries reported from the tornado, which also included a large number of debris impacts.

Given the unprecedented number of fatalities and injuries, as well as the scope and extent of structural damages caused by the May 22, 2011 Joplin, MO tornado, the National Institute of Standards and Technology (NIST) formally established a team to investigate the disaster under the National Construction Safety Team (NCST) Act (Public Law 107-231). The team consisted of the four NIST researchers – with expertise in structural and fire engineering, wind science and engineering, and sociology – and a researcher from the National Oceanic and Atmospheric Administration's National Severe Storms Laboratory (NOAA's NSSL) with expertise in meteorology, severe storms and warnings.

The NIST Investigation's goals were to: (1) study the wind environment and conditions associated with fatalities and injuries, the performance of emergency communications systems and public response to such communications, and the performance of residential, commercial, and critical (e.g., hospital) buildings, designated safe areas in buildings, and lifelines; and (2) develop findings and recommendations that serve as the basis for potential improvements to public safety in tornadoes, including:

- Potential improvements to requirements for design and construction of buildings, designated safe areas, and lifeline facilities in tornado–prone regions;
- Potential improvements to guidance for tornado warning systems and emergency response procedures; and
- Potential revisions to building, fire, and emergency communications codes, standards, and practices.

Several findings from this investigation focus specifically on emergency communications (Kuligowski et al. 2014). First, there were the multiple ways in which individuals in Joplin, MO were made aware and received further information about the May 22, 2011 tornado emergency. Joplin's outdoor siren system, which could generally be heard indoors as well as outside, was the primary means by which individuals were alerted to a tornado event. Radio, television, and word of mouth were the primary means by which individuals were provided with warning information. Second, functioning as an alerting system only, the outdoor sirens prompted many Joplin residents and visitors to seek further information. However, the multiplicity of information sources, and the conflicting information provided by those sources, added to the public's confusion about the true hazard as additional information was sought. In turn, responses to the approaching tornado among members of the public, in many cases, were delayed or incomplete, as was evidenced by the fatalities that occurred among individuals located outdoors, in vehicles, or en route within buildings to safer refuges when the tornado hit. The two main factors that contributed to delays in or incomplete response to the Joplin, MO tornado were: 1) a lack of awareness of the tornado, and 2) an inability to perceive personal risk due to a) receiving conflicting or uncertain information about the tornado, b) holding pre-existing beliefs about Joplin's immunity to direct tornado strikes, or 3) distrust or confusion about Joplin's emergency communications system.

Another significant finding was that no widely accepted standards exist for emergency communications in tornado events. In response to these findings from the investigation, NIST recommended "the development of national codes and standards and uniform guidance for clear, consistent, recognizable, and accurate emergency communications, encompassing alerts and warnings, to enable safe, effective and timely responses" (Kuligowski et al. 2014).

With the extensive use of outdoor siren systems in tornado prone areas and the rising use of social media and other platforms that can provide information via mobile devices, this study focused on developing evidence-based guidance for communities on the creation and provision of public alerts. Here, public alerts include both alerts provided by outdoor siren (warning) systems and "short message alerts" (i.e., messages with a specific character restriction sent by social media or other short message service [SMS] platforms). It is the hope that this guidance can eventually be used as a basis for standardization, through codes and standards, of the procedures and policies for public alerting used by communities across the United States. Standardization of emergency communication policies and procedures could occur at multiple levels, including among multiple local jurisdictions, state-wide, regionally, or even nationally.

In 2017, a NIST Technical Note was published on outdoor siren systems (Kuligowski and Wakeman 2017). This Technical Note provided an overview on the current status of siren systems in the United States, as well as a review of the literature on the ways in which people respond to alerting signals (including siren systems) and the current limitations of siren systems in light of these findings.

The current document focuses on short messages alerts, also known as "terse messages". Short message alerts are messages with specific character restrictions – e.g., 90 or 140 characters in length – that are meant to alert individuals (under imminent threat) that something is wrong and that more information is available (elsewhere) on the emergency. Short or terse messages can be delivered via multiple channels, including short message service (SMS) or text messaging, wireless emergency alerts (WEAs) disseminated via the Integrated Public Alert & Warning System (IPAWS), or Twitter.

The purpose of this document is to provide an overview on the current status of short message alerting, focusing on Wireless Emergency Alerts (90 characters in length) and Twitter alerts (140 characters in length); i.e., where most of the research has focused. Additionally, this report provides a review of the literature on the ways in which people respond to short message alerts during emergencies and the current limitations of these types of alerts in light of these findings. This document concludes with a discussion on the key findings and recommendations from the literature on the possible ways in which to improve current short messages, based on the methods by which people receive and process alerts.

In a future document, both the findings from Kuligowski and Wakeman (2017) on outdoor siren system alerting and the findings discussed in this document on short message alerts will be used to develop the overall evidence-based guidance for communities on the creation and provision of public alerts.

A more detailed discussion on this current report's organization is included in the following section.

2. Report Organization and Methods

Overall, this report presents research that will eventually help to inform communities on the creation and provision of short message alerts. The report provides insight into the following two main questions regarding short messages:

1. What is the current status of short message alerting in the U.S., including usage and potential limitations?
2. How does the public respond to different short message alerts?

2.1 Current Status of Short Message Alerts in the U.S. – Organization and methods

The first question asks what is the current state-of-the-art of short message alerts for use during emergencies in the U.S. While other short message alerting systems may be available at the local level and/or through third-party vendors, this review has focused solely on two widely available systems in the U.S. used to disseminate short message alerts to the public in times of imminent threat; i.e., Twitter and Wireless Emergency Alerts (or WEA) disseminated via IPAWS. For each type of alerting system, a brief section provides a general introduction of the messaging platform. As part of this introduction, the capabilities of each system are discussed, as well as upcoming changes to character restrictions.

An additional discussion is provided on the use of short messages in the U.S., both in times of emergencies (for WEA) and in general (for Twitter). For WEA, since it is part of IPAWS, through which Federal, state, territorial, and local alerting authorities[1] can disseminate alerts via multiple channels, a discussion is provided on the organizations throughout the U.S. that have or are in the process of obtaining IPAWS "Public Alerting Authority". The number of alerting authorities in various states throughout the U.S. will give a broader sense of IPAWS usage, which in turn, can provide some measure of WEA usage (since WEAs sent to mobile phones is one of the ways to disseminate alerts via IPAWS). Additionally, statistics are provided on cell phone and smart phone usage in the U.S., to help to identify the likelihood that individuals will receive WEAs that are relevant to them if/when an emergency occurs.

For Twitter usage, both alerting authorities and the general public can use this platform to disseminate information about disasters. Therefore, it was difficult to single out Twitter usage only by alerting authorities in disaster events. Additionally, since Twitter is an opt-in system, it is arguably more important to understand it popularity among general users in the U.S., to determine its feasibility for use

[1] Alerting Authorities are those entities authorized by FEMA to access IPAWS, and in turn, send out alerts/warnings through multiple channels. Section 3.1 will provide more detail on alerting authorities.

in information dissemination before/during disasters. For these reasons, statistics published by the Pew Center on social media usage in the U.S. will be presented (in which Twitter is included).

Overall, Section 3 provides an introduction to WEA and Twitter emergency-based alerts, including capabilities of these systems; updates on character restrictions; and a discussion on their usage among alerting authorities (in the case of WEA) and the general public (in the case of Twitter).

2.2 Public Response to Alerts – Organization and methods

The second question focuses on how the public responds to short message alerts. To answer this question, a literature review has been carried out that addresses how people respond to short messages alerts in the context of emergencies. To begin the review process, a general search for research was performed, and sources were included or not based on their relevance to short messages and human response to emergency-based alerts. More specifically, material was selected based on whether or not it provided background on the response of the public to short message alerts (specifically focused on WEA and Twitter), the limitations of current systems in alerting the public during disasters, and/or key findings or recommendations that would improve or advance the current methods used to alert people of impending disasters.

A total of 47 relevant sources were collected and reviewed as part of this report. The selected material is intended to present a representative – as opposed to exhaustive – view into research and best practices. All material was drawn from publicly available resources, published in English. Sources of information were found using several databases: Engineering Village, Web of Science, Web of Science: Social Science and Google Scholar. The databases were searched using the following keywords: *emergency, disaster, alert, message, notification, communication, social media, text, SMS, twitter, tweet, mobile, response, interpret, react,* and *understand.* The disciplines from which literature was collected included communication, crisis management, emergency management, disasters, psychology, sociology, geography, meteorology, and public health.

Once articles were identified, each of the articles' abstracts were reviewed for relevance. Articles deemed relevant were collected and analyzed. The purpose of this review was to identify the findings and/or recommendations made about public response to short message alerts, with a specific focus on findings from research on WEA and Twitter alerts. As with any research on disasters and human behavior, research and publications were analyzed that used hypothetical scenarios to study public behavior related to alerts/warnings. This type of research can be problematic when attempting to identify/predict how the public is likely to behave in an actual alerting or real event (National Research Council 2013). Additionally, the research documented in the publications collected contained varying methods from one report to the next. Therefore, as part of this review, each article underwent an extensive review of its objectives, methods, findings, and recommendations. Objectives were checked for their relevance to the overall project objective. Methods were scrutinized primarily based on sample size, demographic/ locations represented, time period of data collection, and the presentation of a survey or exercise to subjects, if one was included. From all reviews, each article's findings and recommendations were collected and then categorized based on their relevance to five topics of interest. These topics were the following: comprehension and readability, credibility, personalization of the message, providing additional information, and salience. If an article was reviewed and determined to have questionable methods, its findings and/or recommendations were included in this review only if they were confirmed by other reviewed publications.

The 47 sources collected and reviewed fell into a variety of source types and time periods. Tables 1 and 2 show the count of how many sources fell into each division. The majority of the sources included in this review consisted of peer reviewed journal articles and conference proceedings. A limited number of publications were categorized as government reports, books, and other types of reports. Also, all of the articles included in this review were published in 2008 or later. This was particularly important since short message alerting and technology is a growing field, and it was found that most articles published before 2008 were already out of date. As shown in Table 2, a majority of the articles reviewed were published in between 2014 and 2017.

Count	**Type of Source**
25	Peer Reviewed Journal Articles
5	Government Reports, Books
13	Conference Proceedings/Bulletins
4	Reports (companies/universities)

Table 1: Count based on publication type

Count	**Year Published**
12	2016-2017
20	2014-2015
8	2012-2013
7	2008-2011

Table 2: Count based on year published

Research on short message alerts, related to public response, is provided in Sections 4 and 5 of this report. Section 4 begins by first presenting the method by which people respond to any type of cue or information, including short message alerts. The method presented, known as the Protective Action Decision Model[2] or the PADM (Lindell and Perry 2004), is a decision-making process by which people receive, interpret, and respond to short message alerts. Each stage of the PADM is described in the context of alerting messages presented in a disaster scenario. Then, based upon the PADM, Section 4 also presents research on the potential limitations associated with short message alerts and their use that can inhibit the various stages of the PADM, leading to a delayed or incomplete response of the public to an impending emergency. Research findings are presented as evidence for the four main limitations identified in Section 4.

Based upon these limitations, Section 5 presents evidence-based findings and recommendations to improve short message alerts to better meet the needs and requirements of the responding public. The key findings and recommendations presented in this section will inform the later stages of this research project; i.e., the development of specific guidance on short message alerting. Finally, Section 6 details the "unanswered questions" on which little or no research was found on potential improvements to short messages.

[2] The PADM is a model that describes the decision-making process that occurs before taking protective action, which was used as a method to organize the literature review.

The following section begins the discussion of the current status of short message platforms in the U.S. This discussion includes a review of currently available technology as well as the usage of these technologies across communities in the U.S.

3.Current Status of Short Message Alerts

In the event of community-wide emergencies, such as tornadoes, tsunami, wildfires, or hazardous chemical spills, alerts and warnings are issued with the goal of initiating protective action among the public. Sheltering in place or evacuating to safety are two examples of protective actions. The main purpose of alerts is to capture the attention of the public in preparation for a subsequent warning message. Warnings are then used to provide *information* about the emergency, such as emergency type, when it will manifest, and the forms of protective action that should be taken (Kuligowski et al. 2014; National Research Council 2013).

A confusion with short message alerts is whether they serve as alerts or warnings during disasters. Short messages, or terse messages, are limited-character messages (e.g., 90 to 140 characters) provided via various platforms and channels, e.g., mobile technology. While short message platforms contain the ability to alert the public, especially if pushed out to devices or placed on "notification mode", the current character limits are insufficient to include all necessary warning information. For that reason, they are often referred to as "alerts" rather than warning messages/systems.

Short message alerts can be disseminated for all hazards. Additionally, they may be pushed out to individuals via mobile technology based on geographic location of nearby cellular towers (i.e., Wireless Emergency Alerts or WEAs) or disseminated via social media or mobile applications only to those who subscribe to and/or follow specific platforms and accounts within those platforms.

Overall, there are different types of short message platforms. The focus of this study has been on short message alerts provided via IPAWS as WEAs (90 character limits) and short messages provided via Twitter (140 character limits). This section will provide introductory information on WEA and Twitter messages used as short message (or terse message) alerts for those under imminent threat.

3.1 Wireless Emergency Alerts (WEAs)

Wireless Emergency Alerts (WEAs) is a free nationwide program that began in 2011, whereby emergency messages (restricted to 90 characters in length) are sent to individual mobile devices by "authorized government alerting authorities". IPAWS, or the Integrated Public Alerting and Warning System, allows alerting authorities to write their own message using open standards. The alert message is then authenticated by the IPAWS open platform for emergency networks so that it can be delivered simultaneously via IPAWS-compliant public-alerting and warning channels (e.g., television, radio, cell phone, etc.). Each WEA contains various types of information within the 90-character limit, which can include the five main types of information identified as effective in prompting protective action (Sutton et al. 2014; Mileti and Peek 2001; Mileti and Sorensen 1990). These five types of information are the following:

- Source (i.e., what entity/organization/person is sending this message?),
- Guidance (i.e., what actions should the public take in response to the message?),

- Time (i.e., what hour/day did/will this event occur? Or, by when do people need to act?),
- Location (i.e., which areas are at risk?),
- Hazard/consequence (i.e., what event has/will take place and how dangerous will these events be to the public?).

An example of a WEA of a flash flood warning is shown in Figure 1.

Figure 1: Example of a WEA of a flash flood warning (https://www.weather.gov/wrn/wea)

WEAs can be written using two methods, the Common Alerting Protocol (CAP) and free-form. CAP is a form of message creation where the user has a 'fill-in-the-blank' interface. Users input information on the message sender, time/date, urgency, type of event, etc. and a message is automatically generated. Free form message creation is comparable to writing a text message. The message sender, such as the NWS, might require the message have specific information in a certain order, but free-form messages are generated entirely by the Alert Originator (AO).

WEAs are sent through a wireless channel, so they are unaffected by network congestion before, during and after disasters. There are three main types of alerts that can be disseminated through this system, including alerts for extreme weather (or other disasters), AMBER alerts (i.e., urgent bulletins alerting individuals about child-abduction cases), and Presidential Alerts during a national emergency. WEA messages are always accompanied by a special tone and vibration, which are both repeated two times as the message is first displayed on the mobile device.

WEA alerts are disseminated via IPAWS by authorized alerting authorities. Authorized alerting authorities can include officials from Federal, state, territorial, tribal and local government entities. For example, the National Weather Service is considered an “authorized government alerting authority” and can send WEA messages for tsunami, tornadoes, flash floods, hurricanes, typhoons, dust storms and extreme winds. Alerting authorities must complete FEMA training before being authenticated for access to IPAWS. Once authenticated, they can then use common alerting protocol compliant emergency and incident management tools to create location-specific alerts (scaled to the needs of the emergency event).

As of August 2017, there were over 400 U.S. counties, cities, emergency management agencies, police departments or Sherriff's offices, and other local government entities with "alerting authority in progress" for IPAWS, and another ≈900 U.S. entities of similar type with "alerting authority completed" for IPAWS. These numbers were assessed to attempt to estimate the popularity and/or usage of WEAs. However, it should be noted that IPAWS is used to disseminate alerts and warnings via many channels (e.g., EAS, NOAA Weather Radio, etc.), of which WEA is only one of these alerting outlets. No sources were found that documented the number of U.S. entities that used WEAs to alert during disasters and/or their frequency of use by these entities.

An individual can receive these alerts directly to his/her mobile device, without the need to download an app or subscribe to a particular service. WEA messages are sent to individuals based upon their geographical location (i.e., WEAs are broadcast from area cell towers to mobile devices in the area), their type of device (i.e., it needs to be a WEA-capable phone), and their wireless carrier (i.e., the carrier must participate in the program). This is an opt-out program, in that if individuals do not wish to receive WEAs, they can opt-out of the system via settings on their mobile devices.

To better understand usage of WEA from a users' standpoint, it is important to understand the trends in ownership of cell phones in the U.S. According to a study conducted by the Pew Research Center (Anderson 2015), 92 % of U.S. adults own a cellphone. Aggregating the data further, the research shows that 68 % of U.S. adults have a smartphone, which is up from 35 % in 2011. When data is aggregated by socio-demographic factors, like age, race/ethnicity and household income, the Research Center found that cell phone ownership was common across all major demographic groups. With that said, older adults tended to use cell phones less frequently (78 %) than those younger in age (98 %).

It should be noted that high levels of cell phone usage do not always equate to higher levels of knowledge about WEAs or short message alerting. Studies have found that as of 2015, the public was still largely unaware that government officials could send them warning message to their mobile devices (Bean et al. 2015).

On September 29, 2016, the Federal Communications Commission (FCC) adopted six new WEA guidelines aiming to “promote the wider use and effectiveness of this life saving service” (FCC News 2016, p. 1). Taken directly from the FCC announcement, the new rules are listed below, along with timelines for each guideline in parentheses (Piett 2016):

1. Increase the maximum length of WEA messages (from 90 to 360 characters) for 4G LTE and future networks (within 30 months of adoption);
2. Require participating wireless providers to support inclusion of embedded phone numbers and Uniform resource locators (URLs) in all WEA alerts, including WEA AMBER alerts, which will enable the public to click to see a photo or to call authorities (within 12 months of adoption);
3. Require participating wireless providers to support transmission of Spanish-language alerts (within 24 months of adoption);
4. Require participating wireless providers to deliver the alerts to more granular geographic areas (within 60 days of adoption);
5. Create a new class of alerts (“Public Safety Messages”) to convey essential, recommended actions that can save lives or property (e.g. emergency shelter locations or boil water orders) (within 30 days of adoption);
6. Make it easier for state and local authorities to test WEAs, train personnel, and raise public awareness about the service.

Of these new regulations, the three that are most relevant to this study are the first three listed; i.e., expanding the length of WEA messages, support for embedded URLs and phone numbers, and support of Spanish-language alerts. First, the FCC provided an explanation for expanding WEA messages to 360 c (FCC 2016). The FCC cites much of the research reviewed for this study as support for the lengthening of short messages (Wood et al. 2015, Erdogmus et al. 2015, CSRIC 2014). The FCC also notes that while research exists that supports a 1000+ character limit (Wood et al. 2014); other sources suggest that 1000+ character messages may hinder readers' attention paid to the entire message. In turn, the FCC decided upon 360 characters as the newly extended message length due to the following: 1) the Wireless Emergency Alerts Notice of Proposed Rule Making (WEA NPRM) and Communications Security, Reliability and Interoperability Council IV (CSRIC IV) recommendations for a 280-character limit; and 2) feasibility testing that found that messages up to 360 characters could be supported without delays in delivery or draining devices' battery life. Even with these increases in length, the FCC notes the importance for legacy networks to continue to receive 90-character messages until they are retired (FCC 2016).

Second, the FCC's requirement for providers' support of the inclusion of embedded phone numbers and URLs in all WEA alerts is seen as a positive change. Embedded reference materials were originally omitted from WEA messages for the fear that their inclusion would add to network congestion during an emergency. The FCC states in their Amendments that: "Participating CMS Providers who claim that embedded references will result in harmful network congestion have offered no network models, or any other form of rigorous network analysis, to support their proposition that allowing embedded references in WEA would cause or contribute to network congestion" (FCC 2016). The FCC also supports claims by FEMA, NWS, and disaster experts that having embedded reference materials could reduce congestion because the public's search for information will be directed through a single "authoritative and comprehensive resource". Overall it is believed that these reference materials are integral because they provide information that is omitted in character-limited messages (FCC 2016).

Finally, the FCC also requires providers to support Spanish-language messages. Research supports the inclusion of different languages for WEAs because of their ability to reach a broader audience (Woody and Ellison 2014, Bennett 2015). The FCC disputes the suggestions that using a "'translate' button/link" is sufficient, since current automatic translation technologies can be inaccurate when translating emergency messages. The FCC ensures that these messages will be "processed and displayed properly" and that they will only appear on devices where Spanish has been set as the preferred language (FCC 2016).

It should be noted; however, that even with these new FCC regulations, alerting authorities will still be responsible to include/implement these important features into their WEA messages. Evidence-based best practices are included in Section 5 of this document, to assist in the development of the most effective WEA messages in various emergencies scenarios.

3.2 Twitter

Twitter is a free news and social media site launched in 2006 that allows users to post "tweets" (i.e., messages) of up to 140 characters. Non-users of this site have the ability to read but not post. Users in Twitter create a unique profile name (e.g., @username) and in their account, have information such as their followers, the accounts they are following and their past tweets. Twitter is an opt-in system meaning that a user can choose to "follow" another account and receive their tweets, and if they do not wish to receive tweets from an account, they simply do not follow that account. Tweets can be accessed through two portals. Users have the ability to access these messages at www.twitter.com or have the messages sent directly to their cell phones in the form of a text message. Users can customize what messages are sent to them based on specific accounts, i.e., a user might choose to have messages from NWS (i.e., @NWS) come to their phone as text messages and access all other tweets online. Users also have the ability to customize the tones and vibrations that occur when they receive messages.

There are three “conventions” used in messages/tweets that make Twitter unique from other short message platforms. The first convention is a mention, denoted by an '@' symbol, which identifies a specific user within the message. This convention can simply be used to “call on someone” or can start an interactive dialogue between multiple users. The second feature is the hashtag, represented by a '#' symbol, e.g., #LAfire or #SanDiegoFire. This feature is usually placed at the end of a tweet and is used to signify overall topics or themes of the tweet. Users also have the ability to search for tweets based on a certain hashtag (Mills et al. 2009). The final convention is the shortened URL, such as 'bit.ly'. These shortened URLs are used in place of traditional ones to aid in keeping the character count under maximum limits. These links can stand alone (as the message, itself) or accompany a message and when clicked on, take the user to an image or another webpage.

Using Twitter for emergency communication can offer quick dissemination of information, especially when accounts have large numbers of followers (Hughes and Palen 2012). Users disseminating an emergency message will create a message free-form that must adhere to the 140-character limit. However, as of September 2017, Twitter announced that they were testing out messages with longer character limits (i.e., 280 characters) with a small group of users in select languages.

Twitter, like other social media platforms, provides the ability for message providers to monitor public response, allowing them to craft messages that are appropriate for the current emergency as well as to provide follow-up messages that are relevant to the affected population. Additionally, message providers can disseminate messages meant to correct or redirect public actions, if necessary. However, to do this, agencies may be required to spend a significant amount of time filtering and verifying incoming information both before and during a disaster (Hughes and Palen 2012; Humphrey 2011; Latonero and Shklovski 2010; White et al. 2009). Depending upon the duration of the disaster, the size of the affected community, and the staffing resources of the alerting agency, two-way communications may not always be feasible.

Additionally, and similarly with other social media sites, Twitter users may be concerned with the perpetuation of false information, which can be detrimental to public response during an emergency. However, research has found that users often correct false information, such that social media (e.g., Twitter) in emergencies frequently becomes self-correcting (Mileti and Sutton 2009). Another benefit of social media, including Twitter, is its facilitation of the milling or confirmation process. In any emergency, individuals are likely to spend time discussing the event and proposing next steps with others before taking action themselves. By posting information on Twitter, the milling process takes place in a virtual forum, which can reduce the time spent in this process and allow individuals to respond in a quicker manner (National Research Council 2013; Mileti and Sutton 2009).

Twitter also can provide a very fast, cheap, and relatively easy way for mass distribution of communications (White et al. 2009). However, before one can make a claim of mass distribution, it is important to understand more about overall use of Twitter in the U.S. As stated earlier, for Twitter usage, both alerting authorities and the general public can use this platform to disseminate information about disasters. Statistics published by the Pew Center on social media usage can provide insight on how far of a reach Twitter can provide before, during and after disasters.

Overall, social media usage among adults (18 years old and above) is increasing. However, discrepancies in social media usage do exist among various age groups in the U.S. Young adults (ages 18 to 29) are the most likely to use social media – approximately 90 % do. However, studies have shown that these discrepancies are decreasing. For example, usage among those 65 years old and older has more than tripled since 2010 and two-thirds of American adults (65 %) are using social networking sites (Perrin 2015).

Additionally, the Pew Center has monitored social media usage among other socio-demographics, including gender, race/ethnicity, and socio-economics (Perrin 2015). These studies show that men and women use social networking sites at similar rates. Similarly, no differences were found among racial or ethnic groups related to social media usage. Also, while previous trends showed that people with higher education levels and household income were more likely to use social media; more recent trends show that more than half (56 %) of those living in the lowest-income households use social media sites. Similar patterns have been found for education levels (Perrin 2015). One difference was found for usage across communities. People living in rural areas (58 %) are less likely than those living in suburban (68 %) or urban areas (64 %) to use social media. The Pew Center notes that this trend has been consistent over the years.

An update was published by the Pew Research Center in 2016, which provided statistics on social media usage by platform; e.g., Facebook, Instagram, Pinterest, LinkedIn, and Twitter (Greenwood, Perrin, and Duggan 2016). While Facebook remains the most popular social media platform (with 79% of *online* adults using this platform), other platforms account for approximately one-quarter to one-third of the usage (e.g., 24 % of *online* adults use Twitter). These percentages decrease slightly when accounting for all U.S. adults (e.g., 21 % of all Americans are Twitter users). Also interesting are the reasons why individuals use social media sites. A majority of Americans now say that they get their news from social media, while some are using it in the context of work (e.g., to take a mental break on the job or to seek out employment) (Greenwood, Perrin, and Duggan 2016).

At the time that this document was published, the most recent statistics released by the Pew Center were 2015 and 2016 statistics. It is likely that these usage percentages have increased significantly, even within the past year.

Now that short message platforms have been introduced, the next section will discuss how the public responds to alerts and warnings in emergencies, with a focus on response to short message alerts. The first section will describe the general method or model by which people receive, process and respond to emergency alerts. The second section (Section 4.2) will identify the limitations of short message alerts in aiding public response.

4. Short Message Alerts and the Public

The previous section outlined the ways in which short message alerts are currently used in the U.S. to alert/warn individuals under imminent disaster threat. While we understand how the technology is used, it is also important to understand how the public interacts with and responds to these types of alerts. This section describes public response to short message alerting, including the limitations of short message alerting systems in light of this understanding.

4.1 How people Receive, Process and Respond to Emergency Alerts

Over the last 50 years, numerous empirical studies have sought to systematically chart the social processes involved in human responses to emergency incidents (Tierney, Lindell and Perry 2001; Mileti and Sorensen 1990; Drabek 1986). Of these, the Protective Action Decision Model (PADM) is selected here as a model to understand how individuals respond to external alerts and information (Lindell and Perry 2004; Kuligowski 2011). The PADM provides a framework that describes the information flow and decision-making that influences protective actions taken in response to natural and technological disasters (Lindell and Perry 2004).

The PADM asserts that the process of decision making begins when people are first presented with any type of environmental cue (including physical and social cues and information). The introduction of these cues initiates a series of processes that must occur in order for the individual to perform protective actions, split into pre-decisional processes (PRE-DEC, which determine whether a decision-making process commences), and decisional processes (DEC – the key components of the decision-making process itself). A simplified version of this process is presented below (with examples from short message alerting):

- PRE-DEC_1: the individual must perceive or receive the cue(s); e.g., the alerting sound that accompanies the short message alert must be heard or felt (in the case of vibration)
- PRE-DEC_2: the individual must pay attention to the cue(s); i.e., given that it is possible for the alerting sound to be heard, the individual/receiver actually takes note of the sound and pays attention to the accompanying short message.
- PRE-DEC_3: the individual must comprehend the cue(s) and the information that is being conveyed; i.e., given that the short message is paid attention, that the meaning of the message is understood.
- DEC_1: the individual must feel that the incident suggested by the short message is a credible threat.
- DEC_2: the individual must personalize the threat (i.e., feel that the incident is a threat to them) and feel that protective action is required; i.e., something needs to be done.
- DEC_3: the individual searches for what this action might be and establishes options.
- DEC_4: the options identified are assessed (given the information available) and a final action selected.
- DEC_5: the individual determines whether the protective action needs to be performed immediately.

Initially, the individual needs to receive a cue, pay attention to it, and comprehend the meaning associated with the cue (e.g., an alerting signal and accompanying information). These represent the three pre-decisional stages of the PADM (PRE-DEC_1-3) – the stages that determine whether external information is processed such that it can inform the decision-making process (Lindell and Perry 2004). Given that this information is processed, it then needs to be assessed to determine whether the information provided is credible (DEC_1). At this stage, the individual decides if there is actually something occurring that may require action. If the individual's answer is yes, then he or she is said to believe the threat, and subsequently moves on to consider the next question in the process.

The individual next tries to determine whether the threat is relevant to him/her (DEC_2), known as personalizing the threat (or risk). Research has shown that a person's perception of personal risk, or "the individual's expectation of personal exposure to death, injury, or property damage" is highly correlated with taking protective action (Lindell and Perry 2004:51). In this stage, also known as personalizing risk (Mileti and Sorensen 1990), the individual determines the likelihood of personal consequences that could result from the threat and asks the following: "Do I need to take protective action?" Essentially, at this point, which is also discussed in human factors research as "situation awareness" (Groner 2009), the individual tries to gain insight on the potential outcomes of the disaster and what those potential outcomes mean to his or her safety. The more certain, severe, and immediate the risk is perceived to be, the more likely the individual is to perform protective actions (Perry, Lindell and Greene 1981). If the cues are deemed to relate to him/her, the individual then determines whether it is relevant and pressing. This then requires the individual to determine the nature of the response required at that point in time.

At this stage, the individual engages in a decision-making process to identify 1) what can be done to achieve protection, and 2) the best available method for achieving protection. This consists of a search for protective actions, and the outcome of this stage is a set of possible protective actions from which to choose. After establishing at least one protective action option, an individual engages in protective action assessment. This involves assessment of the potential option(s), evaluating the option(s) in comparison with taking no action and continuing with normal activities, and then selecting the best method of protective action.

If at any stage the individual is uncertain about the answer to a question and if there is perceived time to do so, the individual engages in additional information-seeking actions. Information seeking can involve searching for other sources of information (e.g., websites, media, etc.) and/or reaching out to other people, e.g., the family unit or work colleagues, to discuss the situation and what to do (also known as the milling process or confirmation behavior) (Aguirre, Wegner and Vigo 1998; Turner and Killian 1972). The greater the ambiguity involved in the situation, the more likely that individuals will search for additional information that can guide their actions (Mileti and O'Brien 1992; Mileti and Beck 1975). Information seeking is especially likely to occur when individuals think that time is available to gain additional insight on the question at hand. If information seeking is successful, in that the person at risk judges he or she has obtained enough information to answer the question, then the individual moves on to the next stage or question in the decision-making process. However, if the information-seeking action is unsuccessful, there will be additional searching for information as long as he or she is optimistic that other sources or channels can help (Lindell and Perry 2004). If the individual is pessimistic regarding future information seeking success, he or she is likely to attempt to decide on a protective action based solely on whatever information is available.

Passage through the stages of the PADM is often problematic. For example, as previous disasters have shown, information received can be incomplete, ambiguous, or contradictory, causing uncertainty in what is going on and what do to about it (Kuligowski et al. 2014; Sutton 2008). In these cases, progress in the stages of the PADM can be significantly delayed and/or promote inefficient or unsafe protective action behavior. It is important to understand what role short message alerts can have in limiting the decision-making process, which is presented in Section 4.2, before best practices can be presented on how to improve the effectiveness of short message alerts (Section 5).

4.2 Potential Limitations of Short Message Alerts

Research has shown that there are certain limitations associated with short messages alerts that can inhibit the various stages of the PADM, leading to a delayed or incomplete response to the impending emergency. These limitations are organized by the steps in the PADM and discussed in the following sections.

4.2.1 Perception and Attention (Pre-Decisional Steps 1 and 2 of the PADM)

Short messages are limited in effectiveness if they are incapable of reaching and/or grabbing attention of their targeted receiver. First, short message alerting systems that require the public to seek out the information (i.e., pull technology), rather than having the information sent directly to them (i.e., push technology), has been shown to reach a smaller audience (Woody and Ellison 2014; Chandler 2010). Various short message systems, including WEA and Twitter, do provide the capability of pushing (or sending) messages as notifications directly to wireless devices. As long as the public is carrying these devices, the short messages are more likely to be received.

Second, short message systems can be limited based on opt-in versus opt-out subscription policies. Twitter, for example, requires individuals to sign-in to the system, create an account, and follow particular emergency-based Twitter accounts, before receiving important short message alerts. WEAs, on the other hand, do not. As mentioned earlier, WEA is an opt-out system that sends information to individuals' phones, without requiring pre-event subscription. Receivers are sent WEA messages depending upon geographic location, type of device and wireless carrier. However, research has shown that the public may view WEA messages as spam if they are not expecting to receive a message to which they did not previously subscribe (Bean et al. 2016). Additionally, for both WEA and Twitter short message alerts, the public is more likely to opt-out of a system that uses the account to disseminate messages outside of the original scope of the alerting system (National Research Council 2013). One example is a Twitter account originally created to send out emergency-related information only, that over time, begins to send out public service announcements or non-emergency related informational messages. In these cases, research has shown that members of the public can become frustrated with receiving off-topic messages, causing them to opt-out of the system.

Another potential issue with short message systems, particularly Twitter, relates to public expectations. The two-way nature of the platform, which is positive in many aspects, may present potential issues related to unrealistic expectations of its users in times of imminent threat. For example, research has found that the public would request assistance via social media sites, with the assumption that there is someone on the other end monitoring public response and life safety needs (National Research Council 2013). These expectations pose significant challenges to message providers, especially for those organizations with limited staffing resources before, during and after disasters.

4.2.2 Comprehension (Pre-Decision Step 3 of the PADM)

Simply because a message gains attention, does not necessarily mean that the message is written in a way that will prompt safe and effective public response. Research has identified cases where the short message is written in such a way that the public becomes confused about the event and/or what they are required to do in response to the message. Take, for instance, research that studied messages in the event of a radiological hazard. A message labeled as a "radiological warning" was deemed ineffective; while it grabbed people's attention and even scared them, participants admitted that they were more scared of what they did not know (or understand) rather than the event itself (Bean et al. 2016). This example helps to illustrate that there are aspects of short message alerts that may inhibit comprehension (or understanding of the meaning) of the short message alerts (PRE-DEC_3).

First and foremost, there is very little information that can be provided via messages with the current character limits; e.g., 90 or 140 characters, often times, leaving receivers of these messages wanting additional information to clarify the situation and their safest response (Sutton et al. 2016). Additionally, the short message character limits often require message providers to shorten or abbreviate words or phrases in ways that are difficult to understand. Research has shown that participants are often unfamiliar with the meaning of a variety of abbreviations and acronyms (Temnikova, Vieweg, and Castillo 2015). Acronyms like "US DHS" to refer to the U.S. Department of Homeland Security or "MDT" to refer to Mountain Daylight Time were unfamiliar to study participants, making the short messages difficult to understand (Bean et al. 2016).

Difficulties with the readability of short messages was also identified as an issue in some studies (Temnikova, Vieweg, and Castillo 2015). While acronyms are likely used to shorten certain words in WEAs and tweets, potentially leaving room within the character limits for additional information, they also made short messages more difficult to read. Also, in Twitter, the inclusion of "user mentions", as well as hashtags at the beginning of tweets, negatively impacted the readability of the message.

Short messages also provide little room to clarify potentially confusing statements and terminology. Research provides evidence that short messages containing certain terminology (where expanded explanations of the terms could not be provided) were confusing to the readers (Temnikova, Vieweg, and

Castillo 2015). Additionally, messages were found to be wrought with ambiguous statements that invoked additional questions from the study participants (Sutton and Woods 2016), left room for potentially incorrect interpretations of the hazard of its consequences (Bean et al. 2016), and lacked specificity on important topics, such as locations of risk areas, potential evacuation routes, and other places of safety (Wood et al. 2015). A clear example of message ambiguity was found in Sutton and Woods (2016), who conducted focus group research on longer tsunami messages (and whose findings are relevant to short message alerts). To alert study participants of an impending tsunami and in an attempt to provide information about the hazard characteristics, part of an emergency message stated that: “tsunamis can seem to stop for long periods of time”. However, this statement left participants with additional questions, such as: how long is a “long period of time”? Similarly, studies showed that participants can interpret the same phrase in very different ways. An example message from Sutton and Woods (2016) stated that the impending tsunami could produce “2 to 4 ft waves”. This example range of wave height caused some participants to feel anxious (and at risk); while others noted that this range signified a safe, and particularly fun, day at the beach.

Also found to negatively influence comprehension were short messages that lacked personal location in relation to the disaster event. Research found that people unfamiliar with an area may become frustrated with the use of county names; whereas city, towns, and popular landmarks were more familiar to them (Sutton and Woods 2016). Additionally, when members of the public were told that something had occurred in a larger city, for example Denver or Washington, DC, they were left wondering if the event had affected the entire area or one specific part of the city. In this case, the larger geographical area affected was too broad for individuals to truly understand where the disaster event was taking place and if they were personally affected (Bean et al. 2016). Finally, WEAs are often created and disseminated with the statement “in this area”. An example of an older style WEA disseminated by the National Weather Service (NWS) is shown in Figure 2. The circled area of the figure shows the use of “this area” to identify the location of the flash flood event. However, issues with comprehension can arise if the recipient of the message is unclear on how the WEA system works, in that messages are sent based on the receiver’s geographical location in relation to the disaster event (Wood et al. 2015). Thus, if an individual receives a WEA, he/she is personally at risk.

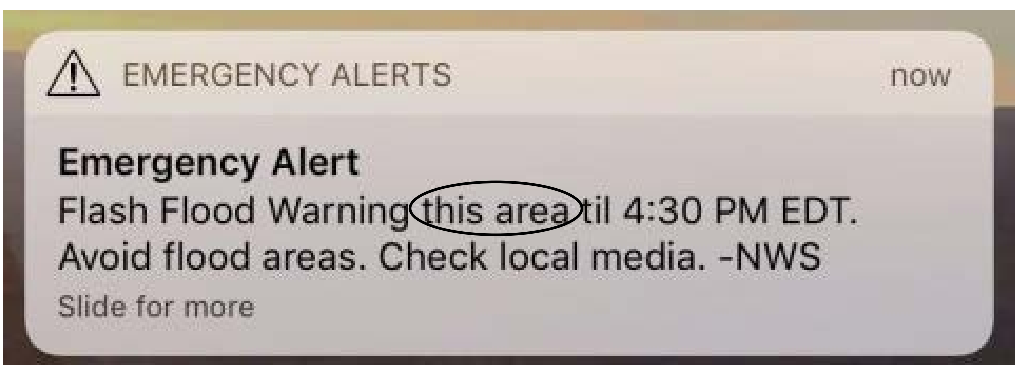

Figure 2: Example of a flash flood warning disseminated by the NWS through IPAWS as a WEA.

Research has also been performed on short messages that are accompanied by maps. While maps can significantly aid in comprehension of the short message (Liu et al. 2017), research has shown that comprehension can be impaired if the maps are too small, unclear, unreadable, or in gray scale (Bean et al. 2016; Wood et al. 2015). Additionally, maps with confusing graphics (displayed without a legend or accompanying text), as well as maps that did not show the location of the recipient in relation to the disaster event, were also labeled as confusing (Bean et al. 2016; Wood et al. 2015). Figure 3 provides an example of a map tested in Wood et al. (2015) to alert the public of an impending tsunami threat. Issues identified with this map included confusion over the meaning of the blue dot with a small circle surrounding it, as well as the red/orange shading along the coast. Some thought that the blue dot was their location; while others thought that it was the impact point of the tsunami.

Figure 3: Example from Wood et al. (2015) of a map tested to alert of an impending tsunami disaster.

4.2.3 Credibility of the Message/Threat (Decisional Step 1 of the PADM)

There are some aspects of short message alerts that inhibit the ability for receivers to trust the message and perceive that there is a credible threat to which they must respond (DEC_1). First, message and threat credibility are decreased if the message is disseminated without a source (Bean et al. 2016). Similarly, if the source listed is confusing and/or mistrusted, credibility of the message, and in turn, the perceived threat is decreased (Bean et al. 2016). Before the message can be trusted, people often need to verify that the message/information is coming from a source that they trust. Additional factors that can decrease trust in short message systems are the following: receiving too many alerts; receiving inaccurate, insufficient, or confusing information; perceiving excessive delays between the disaster event itself and the receipt of the alert; and receiving bogus (or invalid alerts) (Woody and Ellison 2014).

In addition to the factors that increase or decrease trust by the public, it is also important to acknowledge the importance of trust by the alert originators in the short message alerting systems they use to reach the public. Because the public can use social media platforms to create and disseminate inaccurate information (Hughes and Palen 2012), some alert originators are concerned about the potential to spread misinformation via these platforms, and in turn, compromise public safety (Sutton, Palen and Shklovski 2008). This misinformation, or rumors, spread via social media may be inevitable (National Research Council 2013). If these rumors perpetuate, it could cause individuals to take actions that place them in harm's way, rather than away from it, risking the life safety of themselves, their families, their neighbors/friends, and first responders. Ways to reduce and mitigate rumors or misinformation involve some form of monitoring and/or responding to these rumors in real-time (National Research Council 2013). Additionally, experts claim that an even better way of mitigating misinformation spread via social media is to lead the conversation as the official information source, rather than allowing any non-official, mis-users to do so.

4.2.4 Personalization Risk (Decisional Step 2 of the PADM)

Finally, short message alerts have shown difficulty in facilitating the perception or personalization of risk (DEC_2), the last step in the PADM process before protective actions are considered. First, the insufficiency in character space provided by short message alerts makes it almost impossible to create a sense of urgency for the receiver (Bean et al. 2016; Bean et al. 2015). Additionally, the use of phrases or statements that create doubt; for example, “may develop” or “has been spotted” may not necessarily lead directly to protective action by message recipients (Wood et al. 2015). Similarly, using phrases or terms that sound less risky, for example, being “advised” to take an action, rather than ordered to do so, has been shown to lack the appropriate level of urgency to prompt protective action (Sutton and Woods 2016).

Overall, the limited character length exacerbated by the use of unclear or ambiguous terminology has been shown to hinder the public’s perception of risk. Without sufficient space to describe the intensity of the disaster event, in addition to its consequences and the actions that should be taken, the short message can do little in the way of prompting safe and effective action in the face of imminent disaster (Bean et al. 2016; Wood et al. 2015).

This section has discussed many research studies that identify limitations with current short message alerts, specifically those factors that inhibit the receipt, processing, and response of the public to these types of alerts. When the public does not receive, pay attention to, or understand the alert, or trust the message/system and neglects to perceive risk, their responses will likely be delayed or incomplete (Kuligowski et al. 2014). Delays have been shown to include calling 9-1-1 centers asking for clarification and/or additional information before taking action (Hughes et al. 2012). Delayed or incomplete responses can lead to serious injuries and even deaths.

In contrast, improvements can be made to short message alerts that can increase public awareness, decrease confusion, increase credibility and perceived risk, and subsequently enhance human response in disaster events. The following section outlines these potential improvements to short message alerts, based on research findings.

5. Key Findings from the Literature on Improvements to Short Message Alerts

All key findings and recommendations identified from the 47 sources of the literature review were collected, organized and reviewed to discover what insights they provided on potential improvements to the current short message alerts – mainly focusing on the creation of the 90- or 140-character message, itself. The goal is that evidence-based findings and recommendations for short message alerts could be identified that would improve decision-making and response of those under imminent disaster threat.

Findings and recommendations from the literature are provided in the three sections below. The first section will discuss findings and recommendations from the literature to improve short messages, so that these alerts reach a wider audience. The second section will discuss findings and recommendations for improvements to short messages that could increase comprehension of the alert. Finally, the third section will discuss findings and recommendations for improvements to short message alerts that could increase the perceived credibility of the message (and in turn, the threat), as well as aid individuals in personalizing the risk associated with the impending disaster. After those three sections are presented, an additional discussion is provided on providing additional information as accompaniments to short message alerts, including maps and URLs. Finally, a discussion is provided on the message features that increase its salience; i.e., the likelihood that the message is passed onto others who might also be at risk.

Before any specific improvements are discussed, it is important to identify message features that transcend all short message types and platforms and can aid in increasing the likelihood of perception, comprehension, perceived credibility, personalization of risk, and protective action compliance. Research has shown that any effective message should contain specific information about the hazard, including the physical characteristics of the threat, its potential effects, and an explanation of why the hazard threatens public safety. Also necessary to include is guidance on what the public should do in response to the hazard (i.e., protective action guidance) (Sutton and Woods 2016; Mileti and Peek 2000). Other important message features have been identified, including the timing and location of the hazard as well as the source of the message. Please revisit Section 3.1 for a bulleted list of the five main types of information identified as effective in prompting protective action.

The following section focuses on the evidence-based findings and recommendations for short message alerts that can improve their likelihood of being received and paid attention. A discussion on reaching a wider audience is presented.

5.1 Reaching a Wider Audience (Perception and Attention)

Research shows that increasing the likelihood that the public will receive and pay attention to the short message can be achieved through systems and message improvements. As mentioned earlier in the limitations section of this report, push technology is more successful at reaching a wider audience than pull technology (Chandler 2010). Additionally, systems that are opt-out, in that they do not require pre-event subscription, or mandatory, rather than (voluntary) opt-in systems are also more effective at reaching a wider audience (Sullivan, Hakkinen and Piechocinski 2009). Opt-out systems, like WEA, do not rely on members of the public to take time and subscribe or seek out the system and enroll; instead, they are enrolled in the system automatically until they manually opt-out of the system. Research has shown that opt-out systems are more likely to obtain a wider audience, since individuals have been shown to persist with "defaults" and/or the social norm, since they assume that that is what they are supposed to do (Fischoff and Kadavny 2011).

With that said, it is still important for users to understand opt-out systems, like WEA, because if they opt-out, it is potentially more difficult to prompt them to return. Techniques like avoiding too many messages and/or educating the public on why and how they are receiving these types of alerts will aid in maintaining their participation on the WEA system (Erdogmus et al. 2015). Additional methods involve creating and disseminating messages that are well aligned with the original purpose of the short message system (National Research Council 2013). In other words, if the original short message system or account was created to disseminate emergency-based messages only, it will be important to refrain from sending non-emergency short messages via this same system or account.

Research also provides examples of ways to increase the public's attention to short message alerts. First, the use of emphasis (e.g., ALL CAPS) of a particular word or statement within the short message can draw the readers' attention to the message, especially to those words in particular (Sutton et al. 2014). Messages have been tested with capitalization of such words as "NOT", "PLEASE", etc. Also, the use of bold letters or different colors for certain words, like "emergency" has been shown to grab the recipients' attention to the messages (Wood et al. 2015). In addition to changes to words within the short message text, research has found that tones or accompanying sounds (Kuligowski and Wakeman 2016) as well as images attached to short messages can grab attention (Vos et al. under review).

5.2 Increasing Comprehension

Short messages that are more effective are those that are easier to understand by the general public. Research suggests multiple methods to increase comprehension, or the understanding of the meaning behind the alert messages. First and foremost, research suggests the reduction, if not the removal of abbreviations and jargon from short message alerts, as much as possible (Cao, Boruff and McNeill 2016; Bean et al. 2016; Bennett 2015; Temnikova, Vieweg and Castillo 2015; Department of Justice 2012). Clearly spelling out the source and/or all other information with the short message will aid in higher comprehension of the message, and in turn, increase likelihood of safe and effective response.

Research also shows that eliminating spelling errors (Sutton and Woods 2016; Woody and Ellison 2014) and using clear language that leaves little room for interpretation will also help to increase comprehension (Bean et al. 2016; Temnikova, Vieweg and Castillo 2015). The use of language that is perceived as "clear" and comprehendible by a particular population will need to be developed and tested for that particular population (Wood et al. 2015). In addition, short messages can undergo language and readability testing that would improve the public's ability to comprehend in disaster events (see Kuligowski and Omori 2014; Omori et al. 2017 for more information on language and readability testing for messages).

Research has identified specific guidance for Twitter message creators to increase the readability of alert messages. First, specifically focused on Twitter messages, is the avoidance of "user-mentions" and placing a limit on the number of hashtags listed in the message (Temnikova, Vieweg and Castillo 2015). While there can be a benefit to the use of "user-mentions" (i.e., the reader can obtain further information from the source), it can interrupt the natural flow of the message as well as suggest that the short message is actually only directed at one person or organization mentioned in the message. Additionally, research suggests that no more than two hashtags are listed in any one message, and these should be listed at the end of the Twitter message. The lower number of hashtags listed at the end of the message helps to both improve readability and focus and coordinate the readers' search for additional information to only the hashtags provided.

Another method of increasing comprehension is to make the information provided in the short message more accessible to the receivers. Research has found that when identifying hazard location, providing information that is more familiar to the receivers will aid in understanding; for example, using local community/city names over county names (which are often less familiar to the public) (Bean et al. 2016). Additionally, the use of local context aids in comprehension with the inclusion of well-known landmarks, such as national parks, road names, and suburbs, to help identify the location of hazards and/or safe zones (Cao, Boruff and McNeill 2016; Kuligowski et al. 2014; Hui et al. 2012). A good example of this is provided in Figure 4. Figure 4 shows a tweet posted by the Warning Coordination Meteorologist (WCM) in the NWS Norman, OK Weather Forecast Office, alerting the affected population of Moore, OK about the impending tornado. In the tweet, the WCM notes that the tornado is approaching the area near the "Warren Theater", a well-known landmark among residents and tourists within Moore, OK.

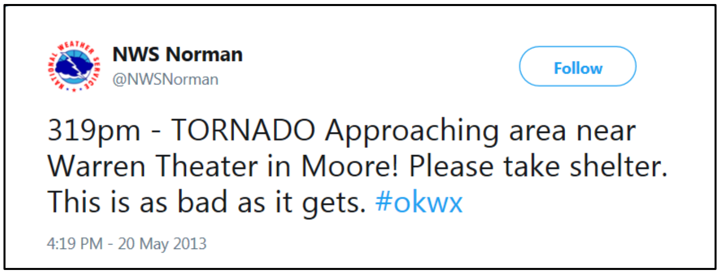

Figure 4: An example of a Tweet posted by the Warning Coordination Meteorologist in the NWS Norman, OK Weather Forecast Office during the 2013 Moore, OK tornado [Note: the Twitter time stamp and the time referenced in the message text are different since the tweet was accessed Sept 4, 2017 from the East Coast Time Zone, rather than the Central Time Zone, in which this hazard took place]

However, it is important to note that identifying areas along the path of the disaster may be difficult to do with some types of disasters (e.g., tracking the tornado's path [Kuligowski et al. 2013]).

5.3 Increasing the Credibility and Ability to Personalize the Risk

Short messages that are more effective than others in prompting public response are those that invoke credibility. The research literature provides insights on ways to improve the credibility of the message, and in turn, the credibility of the threat invoked by short message alerts. The findings to increase credibility focus on the source of the message.

First, it is important to list the source of the message at the beginning of the short message alert (Bean et al. 2016). Since source is a crucial element of a short message, it is also important that the source's name is fully recognizable to all audiences (e.g., without the use of abbreviations or acronyms) (Bean et al. 2016). After the source is clearly provided, the rest of the message order that increases message and threat credibility is as follows (for 280-character messages): the hazard, location, timeline, and guidance (on protective actions that should be taken in response to the hazard) (Wood et al. 2015).

Another important aspect of the message source is that it should be linked with hazard type (Wood et al. 2015). The research has found that credibility increases if the message source is one that is perceived as most knowledgeable or having credible information about that particular hazard type (Liu, Fraustino and Jin 2015). Examples of credible sources linked to hazard type are the following: local police may be perceived as more credible for an active shooter event, the National Weather Service (NWS) may be perceived as more credible for a natural disaster (more specifically, a severe weather event), and the US Department of Homeland Security or the Federal Bureau of Investigation may be perceived as more credible in the event of a terrorist attack (Bean et al. 2015).

Credibility has also been shown to increase when the message source was changed from the Federal or state government to a local government source (Bean et al. 2016). Research has found that people may have more trust in local agencies than Federal (Steelman et al. 2015; Sutton et al. 2008). One example of this is with local news when compared with national news, which has been known to provide misinformation on disasters and/or sensationalize the event. On the other hand, local news has been perceived as a credible source and more knowledge of the area and its local affairs (Sutton et al. 2008). With that said, it should be noted that some well-known federal sources, e.g., the NWS, can be just as, if not more, effective as a credible source in disaster alerting (Wood et al. 2015).

Short messages that evoke urgency are also more effective in influencing safe and effective public response in imminent disasters. Research has also been conducted on the ways to increase the perceived urgency prompted by the short message alert. In the same way that source mattered for credibility, the wording/language of the short message matters for risk perception.

Research findings suggest the use of “more serious” or action words to increase recipients’ levels of risk perception (Cao, Boruff and McNeill 2016). Phrases or words that convey an emergency situation can include “imminent danger”, “immediate evacuation”, “urgent”, “critical”, and “now”, to name a few (Wood et al. 2015). One example of this is using phrases that provide assurances or certainty about the threat (e.g., “will hit shore” in the event of a tsunami [Wood et al. 2015]). Research has also found that moving the words “emergency alert” or “tornado” or “tsunami warning” to the beginning of the message can elevate levels of perceived risk (Wood et al. 2015).

There are benefits to phrases or graphics that help to place the receiver “inside” the risk area as well (Sutton and Woods 2016). Specifics about receivers’ locations in relation to the actual disaster event can be accomplished in text as well as with graphics/maps. Another way of placing the receiver “inside” the risk areas is to describe the consequences of the disaster event, should the receiver find themselves in the affected area (Sutton and Woods 2016). For example, Sutton and Woods (2016) show that when warning of a tsunami event, simply describing the hazard (i.e., expect 2 to 4 foot waves) can be insufficient. A more effective short messaging strategy suggests discussing the consequences of these types of waves, e.g., making statement like the following: “life threatening storm surge capable of flooding the first story of a house in a matter of minutes”.

5.4 Providing Additional Information

Research has shown that short message alerts that are most effective in prompting public response are those that provide additional information to the receivers. Here, the alert originator could provide specific and more detailed information on all five important features of a message: i.e., the hazard, location, guidance, time, and source. Research has found the following benefits of providing additional information on the five elements of a message:

- In relation to the ***source***, additional space or graphics could allow the alert originator to provide more details about the source, including spelling out the entire name and even the individuals responsible for crafting the message. Providing additional details about the source can increase the credibility of the message, an in turn, the threat (as discussed earlier in Section 5.3).
- For the ***hazard***, additional information would provide the opportunity to not only state the hazard type (which is the current method), but also provide additional details about the hazard (e.g., wind speed and surge effects for a hurricane) as well as explaining why it is a threat by discussing the consequences of the hazard (Sutton and Woods 2016; Wood et al. 2015). As discussed earlier, in Sections 5.2 and 5.3, discussing the consequences associated with the hazard can increase an individual/group’s comprehension as well as perceived risk associated with the event.
- Additional information can be provided on the ***location*** of the hazard, including where the receiver is in relation to the event. Maps can be particularly helpful in displaying physical and geographical boundaries of hazard (Bean et al. 2016; Wood et al. 2015). It is important to note as well that hazard location can change over time, and because of this, providing additional, follow-up information on the changing location is also beneficial (Vieweg et al. 2010).
- Receivers would also benefit from specific information on ***timing*** (or a timeline) of the event, including when individuals need to take specific actions (Wood et al. 2015). Additionally, as discussed in Section 5.2, spelling out abbreviations that are currently used to express timing and

time zones will also aid in message comprehension, and the inclusion of a timeline helps to create urgency (Section 5.3).

- Finally, for ***guidance***, additional information would benefit the recipients of short message alerts by providing specific information on what do to; i.e., the protective actions that need to be taken so that they can protect themselves and their loved ones (Wood et al. 2015; Corley et al. 2016). Additional information can expand upon current methods; e.g., “shelter in place” or simply “to shelter”, by instructing individuals using imperative or instructional message style exactly how and where to take shelter (Sutton et al. 2015a). Similarly, instead of instructing individuals to evacuate (only), additional information could be provided to recipients on evacuation routes and/or methods for evacuation (e.g., “move 50 feet above the shoreline and at least 6 blocks inland [Wood et al. 2015]).

Overall, the provision of additional information can aid in further comprehension, perceived credibility of the threat, and an increase in levels of perceived risk. All of these outcomes can aid in safe and effective public response for those under imminent threat.

There are multiple ways available to provide additional information. These methods include providing a link (or URL) to other websites within the short message, linking to or associating the message with maps or other graphics[3], and/or extending the length of the short message to hold a larger number of characters. Links to other websites are often provided within the short message and allow the message recipient to be directed to a new source of information. In the case of a weblink, the recipient is directed to a website, which can provide an unlimited amount of information, including text, graphics, and maps. The short message can also link or be accompanied by a map, which can offer visual displays of the recipient’s and/or hazard’s location (Liu et al. 2017). Finally, short messages can be extended in length either by extending system requirements, as the 2016 FCC requirements outline for WEA, or allowing for the attachment of text-based graphics (in the case of Twitter), whereby additional information can be provided to the recipient within the message, itself.

One additional method of providing information has been recently studied in the literature. This method is known as “threading the message” (Sutton et al. under review). Threading the message involves providing short message recipients with a sequence of short messages (in series), all at one time, about a particular event. An example of this was tested with WEA messages; whereby study participants were provided with a series of 90 c messages (text only). The threaded messages were numbered to identify the order in which the messages were disseminated (and should be received). Based on this study, participants were willing to receive a series of messages, and rated this method as more informative than receiving only one 90-character message for the same event. However, when asked if they would rather receive threaded messages instead of expanded messages (i.e., 360 characters in length) or messages with maps or pictures; participants more frequently chose the latter (i.e., the extended or graphic-based short message alerts).

The provision of additional information provides multiple benefits for both alert originators and message receivers (i.e., those under imminent threat). Additional information can fill in the potentially significant gaps in information left by current short message alerting techniques. In addition, research has shown that before individuals take action, they must confirm the presence of a threat with others and/or additional information on the disaster event (Wood et al. 2017). This need for confirming the threat is an important and vital part of the milling process – whereby individuals spend time discussing the emergency with

[3] There are requirements that graphics disseminated via short message technology or posted to the web be 508 compliant (Please see: General Services Administration, Government-wide Section 508 Accessibility Program, https://www.section508.gov/).

others to decipher what is going on and what should be done about it (originally discussed in Section 3.2 of this report). Since the milling process takes time and can delay the public's action to reach safety, it is in the best interest of any alert originator to work to decrease time spent confirming the threat and milling about the event (National Research Council 2013). The provision of additional information through many of the methods described above can aid in confirmation, and in turn, reduce milling and delay time associated with any disaster event (Wood et al. 2017; Bean et al. 2016; Wood et al. 2015; Sutton et al. 2014). Added benefits of providing additional information include a decrease in call volume to 9-1-1 centers (St. Denis, Palen and Anderson 2014) as well as an increase in "myth-busting" or rumor control (Bird, Ling and Haynes 2012).

The following two sections include research findings on the inclusion of maps and external web links, or URLs.

5.4.1 Research Findings on Maps

Social science research discusses the many benefits and potential disadvantages associated with using maps in short message alerting. The use of maps with short message alerts can lead to a higher level of understanding, when compared with text-based messages alone. Additionally, maps can aid in increasing levels of perceived risk, and in turn, public response (Erdogmus et al. 2015). Finally, visualizations, such as maps, can be more effective at representing information involving individuals'/hazards' location and space, which is one of the key elements of effective short message alerts (Cao, Boruff and McNeill 2016). On the other hand, there may be some technological constraints associated with the inclusion of maps with short message alerts, particularly for the WEA system. Working Group 2 of the Communications Security, Reliability, and Interoperability Council (CSRIC 2014) questioned whether the inclusion of maps would require two separate WEA messages to be pushed out; i.e., one with text and one with the map, itself, potentially causing issues for the system as well as for older wireless devices. Another question that arose was whether "location services" would be required for messages with maps (i.e., the user would be required to have "geo-location" activated on their mobile device), which has been known to drain battery power on cellular devices (CSRIC 2014).

Now that the advantages and disadvantages of accompanying maps has been discussed, the following section provides research findings on the use of maps with short message alerts. It should be noted that there is an entire field within the Geography discipline dedicated to maps and the usage of maps during emergency and non-emergency time periods. The research discussed in this section focuses exclusively on the use of maps with short message alerts. Therefore, the research findings discussed here will focus only on the types of information that are beneficial for maps/short messages to include, rather than findings on the design, graphics, features, and layout of maps in general. The reader is directed to other literature for research on effective map design.

Overall, research has shown that maps can provide additional information that short message text cannot (Liu et al. 2017; Bean et al. 2016; Wood et al. 2015). However, research suggests an important synergy between the maps and text (Wood et al. 2015). For maps to be most successful, one cannot assume that any graphics or objects included in the map are common knowledge. Therefore, research suggests that the map be accompanied by a legend or text boxes that stand out from the rest of the map (Liu et al. 2017; Bean et al. 2016; Cao, Boruff and McNeill 2016; Wood et al. 2015). The purpose of the legend or text boxes would be to clearly label objects leaving little room for incorrect interpretations of the graphics. Not only can maps provide clear information on the hazard location, but also can help "place" people within the risk, which, in turn, can increase their risk perception and their response (Liu et al. 2017; Wood et al. 2015). Research has shown that "high information maps"; i.e., maps that provide information on the affected area, the non-affected area, and the receiver's location among them, can increase message relevance to receivers (Wood et al. 2015; Erdogmus et al. 2015).

Research also suggests that maps are best if the alert originator is using a platform that can be constantly updated, especially for hazards that evolve over hours or days, e.g., wildland fires (Cao, Boruff and McNeill 2016). Information, such as evacuation zones, will also require constant updating. Even more, interactive, animated maps (i.e., maps that people can interact with, for example, to zoom in to specific areas and/or click on icons that provide additional information) can provide added benefits to short message alert recipients (Wood et al. 2015; CSRIC 2014).

5.4.2 Research Findings on URLs

Social science research also focuses on the use of weblinks or URLs within short message alerts, including discussions on advantages and disadvantages. However, where the research is fairly clear on the benefits of maps that accompany short messages, the discussion from the research community on the benefits of URLs is mixed. A weblink could direct message recipients to detailed, important, and vital information about the hazard event; however, research trends are mixed on whether or not message recipients are likely to click on that link, especially under imminent threat.

The main question to consider here is should alert originators prompt the public to search for more information (via the URL provided in the short message alert) or should alert originators provide all of the necessary information to the public in the alert message (or sequence of messages) sent directly to them?

On one hand, some suggest that since the public is likely to engage in the milling process anyway (to confirm the message delivered to them), that it would be a good idea to direct people to one vetted, trusted, and official information source of information or website (Erdogmus et al. 2015; CSRIC 2014). As a follow-up, research has found that people may be unlikely to download a special app to their mobile devices (pre-event) that provides additional information, takes up storage, and may be unreliable; therefore, they are more likely to support websites for additional information over apps (Wood et al. 2015).

On the other hand, it is unknown if the use of weblinks would create more or less network congestion compared with people milling on their own (CSRIC 2014). Additionally, it would be important for alert originators to ensure that their website is constantly updated with useful and relevant information, as well as is prepared for the influx of people affected by the disaster event (Bird, Ling and Haynes 2012). It is unclear how feasible these requirements are for communities/organizations already lacking in disaster response staffing and economic resources.

In addition to the features of short messages that prompt safe and effective response, presented in Sections 5.1 to 5.4, research also identifies the features of short message alerts that prompt its transmission to others (referred to as message salience). Research studies on message salience are presented in the following section.

5.5 Increasing Message Salience

Message salience or "serial transmission" is the passing on of received information from one person or organization or another (Sutton et al. 2014). While message salience is most relevant to Twitter (i.e., retweets), the features of a message that are most likely to increase message salience may also prompt receivers to contact and pass information onto informal networks in other ways, e.g., phone calls, texts, etc. A discussion on message salience is important because informal channels (e.g., people in your social network) are good ways to disseminate information as "trusted sources" to the receiver (Bird, Ling and Haynes 2012). Additionally, receiving a message from a member of your social network can aid with confirmation, possibly reducing milling and delay time (Sutton et al. 2014).

This section will outline the features of short messages that have been found to increase the likelihood that the receiver will pass the messages onto others. Since the focus of this project is on development effective messages for individuals under imminent threat, the research findings on message salience can be categorized in two ways: a) research findings that align with those already presented (in Sections 5.1-5.4), therefore supporting both the purpose of prompting effective public response <u>and</u> salience and b) research findings that are "new", in that they were not previously identified in the literature as prompting safe and effective response for those under imminent threat. The research findings that align with those previously presented will be discussed first.

Many features of short message alerts were identified by research findings as those more likely to increase message salience. In research studies, messages that included the following features were more likely to be passed onto others, including the most up-to-date and relevant information (Vieweg et al. 2010); geo-location on what is happening (e.g., location of road closures) (Vieweg et al. 2010); information about protective action guidance, hazard impact and hazard location (Sutton et al. 2014); and disaster information (within the message) rather than information sent as a webpage only (Liu, Fraustino, and Yin 2015). Also, messages that used imperative voice (Sutton et al. 2014), clear and specific statements (Sutton et al. 2014), and "ALL CAPS" for the signifier[4], rather than for emphasis of words throughout the text (Sutton et al. 2015b), were also more likely to be passed on to others.

Other important features that lead to increased message salience focused on the source of the message (Snoeijers, Poels, and Nicolay 2014). Messages from sources and accounts whose purpose it was to cover the emergency event were more likely to be passed on to others (Starbird and Palen 2010). Also, messages from official accounts as well as accounts that were often retweeted (or passed onto others) and/or had a larger number of followers had higher salience (Suh et al. 2010; Corley et al. 2016). These findings highlight the importance of establishing a short messaging account/system and obtaining followers for these accounts before the disaster event occurs.

Research also found that the unique microstructures of Twitter can affect message salience. Messages with hashtags were more likely to be passed on (Suh et al. 2010); however, including all three microstructures, e.g., URLs, hashtags, and mentions, had a negative effect on message salience (Sutton et al. 2015b). Taking this one step further, the use of external links did not necessarily increase saliency (Sutton et al. 2014). The reason for this is because during high threat situations, individuals choose to pass along messages with complete information over messages that require people to search for additional information elsewhere (as is the case with messages that include URLs). Additionally, of the three microstructures, user mentions were found to be the least successful in prompting message salience, relatively (Suh et al. 2010). The reasoning here is that user-mentions can be interpreted as directed to a specific person or organization, potentially making it less likely to be interpreted as a broader message to a larger population.

Additional or "new" features were highlighted in research on message salience. Blanford et al. (2014) found that including a request to "retweet" (or to send to others) could facilitate wider dissemination of the short message alert. Also, inclusion of emotive or evaluative content can increase the likelihood of

[4] A signifier is a statement used to specify the message content, usually used at the beginning of the message.

"retweet". Emotive or evaluative content includes content that encourages or restores confidence in receivers. Finally, in addition to important message features like accuracy, fluency, anxiety-producing (i.e., urgency), familiar, and informative (Li et al. 2014), receivers who have first order exposure to the message (i.e., receive and read the message directly from the source) are more likely to resend (Sutton et al. 2014). This highlights the importance of alert originators getting the first message out to as many people as possible.

6. Unanswered Questions

Despite a review of the literature, there were several unanswered questions, some that focus solely on Twitter, that arose in the process of performing this literature review. These questions are listed below, as bullets, to provide some ideas to readers on future research needs and potential future guidance. Where research has suggested these questions, appropriate references are provided.

- How frequently should alert originators send these short message alerts? How can an alert originator make it clear that the message (most recently disseminated) is the most up-to-date?
- How do alert originators reach at-risk or vulnerable populations?
- What are the best mechanisms for alert originators to test the effectiveness of their messages, especially with new additions, such as URLs and maps (Wood et al. 2015; Erdogmus et al. 2015)?
- What should/can be done as far as public educational campaigns for public alerting; i.e., to clearly state the capabilities and reasonable expectations of short message alerts (Erdogmus et al. 2015; Bennett 2015; Woody and Ellison 2014; Sullivan et a. 2009; National Academies 2013)? The following list of questions provide the breadth of inquiry into informational campaigns and setting realistic expectations of the public:
  - From whom does the public want to receive messages? (whom do they trust, or let the public know who might be non-governmental trustworthy sources)
  - Does the alert originator have the capability to monitor responses via two-way short messaging systems? Will someone be available to respond; and if so, after how long? If not, what should the public do in various scenarios?
  - How many messages is the public likely to receive (*how many is <u>too many</u>* because "too many" is a negative [Schroeder, Whitmer and Sims 2017; Erdogmus et al. 2015])
  - Can the public opt-out and if so, what does that mean for them (as far as information/consequences)? How do alert originators keep people engaged?
  - Can the public (and would alert originators like the public to) retweet? (Note: this will help with confirmation)
  - What would alert originators like the public to do if they want to opt-out of a system? *(Provide feedback or opt-out?)*
  - Should alert originators issue a final communication ("**all clear**" or "remain alert" notice); Note: An all-clear may be more useful for some types of disasters than others (Woody and Ellison 2014)
- How does an alert originator balance the benefits provided by salience with the requirements for compliance? If there is a good balance, is there feasibility and/or interest to "share" WEAs with receivers' contact lists?

Twitter only:

- What is the appropriate, official, and most effective use of hashtags, mentions, and other Twitter features to promote safe and efficient public response? (Rajdey et al. 2015)

7. Summary

This report presents the research that will eventually inform guidance for communities on the creation and provision of public alerts, specifically short message alerts. The report answers the following two main questions regarding short message alerts:

1. What is the current status of short message alerting in the U.S., including usage and potential limitations?
2. How does the public respond to different short message alerts?

First, a review was conducted of the current status of short message alerting, including capabilities and limitations in alerting and warning the public. While other short message alerting systems may be available at the local level and/or through third-party vendors, this review has focused solely on two major systems widely used in the U.S. to disseminate short message alerts to the public in times of imminent threat; i.e., Twitter and Wireless Emergency Alerts (or WEA) disseminated via IPAWS. For each type of alerting system, a brief introduction was provided on each of the short messaging systems as well as the capabilities of the systems. Also discussed was the use of short messages in the U.S., both in times of emergencies (for WEA) and in general (for Twitter).

Next, a literature review was conducted to address how people respond to short message alerts. A total of 47 sources were collected and reviewed. Based upon the PADM, presented as the framework for this literature review, research on the potential limitations associated with short message alerts and their use was presented. Overall, research found that certain features of short message alerts can inhibit various steps in the decision-making process, including receipt, attention, comprehension, credibility, and perception of risk. In turn, public responses can be delayed or incomplete, which can lead to serious injuries and even deaths.

Based on these limitations, key findings and recommendations from the 47 sources were presented as potential improvements to current short message alerts. These potential improvements would allow the messages to reach a wider audience (i.e., increase perception and attention), increase comprehension, invoke credibility, evoke urgency, provide additional (and necessary) information, and increase salience. Research-based key findings and recommendations presented in this report will inform the later stages of this research project; i.e., the development of specific guidance on the most effective usage of public alerting systems, including outdoor siren systems and short message alerts.

This report ends with a discussion of “unanswered questions” that will likely be of interest to researchers and other interested parties who might wish to continue to fill in the research and practical gaps identified by this project.

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