ABSTRACT

Title of thesis: Development of a Research- Based Short Message Creation Tool for Wildfire Emergencies

Jessica Doermann,
Master of Science, 2019

Thesis directed by: Dr. James A. Milke, Chair
Department of Fire Protection Engineering

Wireless Emergency Alerts (WEAs) sent via the Integrated Public Alert and Warning System (IPAWS) are short message alerts that authorities can send to devices in specific geographical regions during times of imminent threat. These messages give authorities the ability to distribute important information in a timely manner to those who need it most. Effective May 2019, the Federal Communications Commission (FCC) increased the character limit of WEAs from 90c. to 360c. The extra 270c. available provide authorities with an opportunity to share additional and clarifying information in WEA messages.

Current research regarding best practices for creating short message alerts is available. However, the majority of information is vague and requires interpretation before implementation. This thesis reviews and analyzes research and evidence-based guidance currently available to those creating short message alerts. Using the research, evidence-based guidance, and subsequent analysis, fifteen user prompts were developed and implemented to build a message creation tool that generates wildfire evacuation messages. The result of using the tool is a wildfire-based evacuation message that auto-incorporates the research and guidance currently available. This thesis helps develop a foundation for the bridge between short message alert research and the practical generation of messages during imminent threat emergencies.

DEVELOPMENT OF A RESEARCH-BASED SHORT MESSAGE CREATION TOOL FOR WILDFIRE EMERGENCIES

by

Jessica L. Doermann

Thesis submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
of the requirements for the degree of
Master of Science
2019

Advisory Committee:
Professor James Milke, Chair
Dr. Erica Kuligowski
Professor Michael Gollner

Acknowledgements

The development of this thesis topic and the creation of an evidence-based emergency message creation tool would not have been possible without the help of many people. I would first like to thank Dr. Erica Kuligowski for the role she played as a mentor and advocate. It was her encouragement and leadership that helped me to push myself more than I thought possible.

I would like to thank Dr. Milke for being my advisor and always providing me with support and guidance. Dr. Milke always gave me the space I needed to be creative while simultaneously encouraging me to reevaluate my work and ensure I was meeting the goals and standards of a master's thesis.

Thank you to Dr. Michael Gollner for sitting as a member of my committee and for unintentionally bringing me into the FPE Department. It was his presentation in our Introduction to Fire Protection Engineering class that solidified my decision to transfer into the program.

Thank you to the National Institute of Standards and Technology, where I was brought on as an associate employee while I completed my work. I would like to thank them for providing me with the opportunity to participate in the pathways program in 2017. The research I completed in this program helped to inspire the development of my thesis topic.

I would like to thank my family and friends for their continuous love and support. There is no doubt in my mind I would not be have accomplished so many of my goals without them. Finally, to my fellow live-ins at the Hyattsville Volunteer Fire Department; thank you for always being there to crack a joke, lend a listening ear, or distract me when I was overwhelmed.

Extended Abstract

During imminent threat emergencies, authorities' ability to communicate with the public and provide them with timely and accurate information is imperative. Wireless Emergency Alerts (WEAs) sent via the Integrated Public Alert and Warning System (IPAWS) are short message alerts that authorities can send to devices in specific geographical regions during times of imminent threat. These messages give authorities the ability to distribute important information in a timely manner to those who need it most. Effective May 2019, the Federal Communications Commission (FCC) increased the character limit of WEAs from 90c. to 360c. The extra 270c. available provide authorities with an opportunity to share additional and clarifying information in WEA messages.

Current research regarding best practices for creating short message alerts is available. However, the majority of research results are vague and require interpretation before implementation. This thesis reviews and analyzes research and evidence-based guidance currently available to those creating short message alerts (i.e., message creators). While the research gathered is applicable to most imminent threat hazards, wildfire-based evacuation messages were chosen as the focus for the remainder of this thesis. Using the research, evidence-based guidance, and subsequent analysis, fifteen user prompts were developed that inquire relevant and important information about a wildfire-based evacuation. These fifteen prompts were used to build a message creation tool that generates wildfire evacuation messages. A message creator can use this tool by selecting or entering responses to each of the fifteen prompts. The result of the responses and the purpose of the tool is to generate a 360c. wildfire-based evacuation message that auto-incorporates the research and guidance currently available.

Case studies were completed to observe the validity and contributions of this tool. WEAs sent during the Thomas Fire, Lilac Fire, and Lake Spokane Fire were analyzed to identify potential problems/shortcomings with the original 90c. messages. Using the message creation tool, new 360c. messages were generated for each fire based off of the original message and additional research gathered on the fire. Through a comparison of the 90c. WEA and the tool-generated 360c. WEA, the benefits and limitations of the tool and new messages were discussed.

This thesis helps develop a foundation for the bridge between short message alert research and the practical generation of messages during imminent threat emergencies. Future research is proposed to further develop this tool for purposes other than evacuation, hazards other than wildfires, and systems other than WEA (e.g., mass notification systems).

Contents

1 Introduction and Motivation

Imminent threat emergencies are rapid onset events that pose immediate and grave danger to a specific region or group(s) of people. These hazards can be categorized as either natural (e.g., earthquakes, landslides, wildfires), human caused (e.g., active shooter, terrorism), or technological (e.g., biological/ radiological hazard, industrial accident). Incidents such as a hurricane or flood would not be considered rapid onset emergencies based on their extended warning timeline, however associated cascading events, such as a dam breaking as a result of a hurricane would fall into this category. During these events, providing information to the public is of the utmost importance. If people do not perceive that they have full and accurate information, they are likely to engage in milling behavior (Aguirre and Wenger 1998; Turner and Killian 1972) – i.e., searching for additional or clarifying information that they feel is necessary in order for them to make decisions and take protective actions. Milling behavior can delay movement to safety and increase the likelihood of encountering danger, which can lead to injuries and even death.

Short message platforms, such as Wireless Emergency Alerts and Twitter, is a channel that emergency personnel can use to quickly provide information to the public. These messages are defined as 'short' because they are limited in the number of characters allowed; where each letter, space, and punctuation mark is considered a single character. Two examples of short messages are Tweets (limit 280c.) that are sent on the popular social media site Twitter and Wireless Emergency Alerts (current limit 90c., future limit 360c.) that are sent via the Integrated Public Alert and Warning System (IPAWS).

The Wireless Emergency Alert (WEA) was created in 2012 by the Federal Communications Commission (FCC) as a way to warn the public about dangerous weather, missing children, and other critical situations (FCC Consumer Guide 2018). Pre-authorized national, state, or local government authorities have the ability to create and disseminate Wireless Emergency Alerts (WEAs) using this system (FCC Consumer Guide 2018). The messages are geo-targeted using the regions surrounding cellphone towers; meaning the authority selects the region of users that will receive the message, as long as the user's wireless carrier participates in the program and his/her device is WEA-enabled (FCC 2018). WEAs can be highly effective during times of emergency because they do not use the same channels as SMS messages for delivery (FCC Consumer Guide 2018). For instance, if an emergency occurs and mass amounts of people use to their cell phones to contact love ones, search for more information, etc., cell phone towers might become overwhelmed and decrease speeds or shut down entirely. If this situation occurs, WEAs would still have the ability to reach users' cell

phones.

According to the Federal Emergency Management Agency (FEMA), there are more than 1,100 federal, state, local, tribal, and territorial authorities that have the ability to send WEA messages (Witmer 2017). However, these authorities cannot directly send their message to WEA-capable devices. Authorities must use one of the twenty five currently available FEMA-approved alert origination software (FEMA 2019). These software use the free Integrated Public Alert and Warning System (IPAWS) for the message to be "authenticated, validated and delivered to FEMA's Alert Gateway" (FCC 2018). From the alert gateway, the message is disseminated to multiple public alerting systems, one of which is WEA.

Each alert origination software requires the user to enter the 90c. WEA he/she wishes to disseminate. Some software require the user to enter additional information such as alert type, duration, event category, urgency, severity, certainty, and URL. For the 3rd party software that require these additional details, it does not appear that their selections have an impact on the actual WEA message text.

Therefore, it is the responsibility of the alerting authority to create the WEA before it is entered into the alert origination software. Many jurisdiction have begun to create message templates for specific incidents that only require a few pieces of information to be added (e.g., date/time) before they are sent out. Others rely on people to gather the information and create the message from scratch while the incident is occurring. Issues arise in the first method because not all emergencies can fit into these "cookie cutter" situations for which the templates have been created. This may cause delays as writers are forced to stray from their templates and create new messages, something with which they might not have experience if they are only familiar with the prescript messages. The second method can be more effective because it allows for the personalization of each message based on the specific incident. However, emergencies can be very high stress situations which may alter the writers' decision making or cause him/her to make mistakes; both adding to the time it takes to send the information to the public and decreasing the public's understanding/ response to the messages.

In September 2016, the Federal Communications Commission (FCC) adopted multiple changes to WEAs in order to "promote the wider use and effectiveness of this lifesaving service" (FCC News 2016). One of the changes proposed and adopted was to increase the character limit of WEAs from 90c. to 360c. The proposed timeline for this change was within 30 months of adoption– i.e., May 2019 according to the FCC (2018).

The National Weather Service (NWS) is one organization that employs WEA templates that can

be quickly edited and disseminated during extreme weather events. Posted on their website are the legacy templates for their 90c. WEAs and the current 360c. message templates (NWS 2019). Both templates have been included below to demonstrate the length and content differences between the messages.

90c. Message:

NWS: TORNADO WARNING in this area til 12:15PM CST. Take shelter now. Check media.

360c. Message:

National Weather Service: TORNADO WARNING in this area until 12:15PM CST. Take shelter now in a basement or an interior room on the lowest floor of a sturdy building. If you are outdoors, in a mobile home, or in a vehicle, move to the closest substantial shelter and protect yourself from flying debris. Check media.

The shift from 90c. to 360c. messages poses a unique set of benefits and challenges. It has been observed many times that longer messages containing additional and specific information regarding an incident have a positive impact on the users' comprehension, personalization, and decision making (Wood et al. 2015, Bennett 2015, Endogmus et al. 2015, Daly 2014). However, if the user is presented with too many relevant or irrelevant details or conflicting information, it may cause them additional milling time. As agencies prepare for this shift in character limit, there are currently very few resources available that provide education or guidance on how to utilize these additional 270c. The shift from 90c. to 360c. messages was one of the catalysts for this thesis and was the reason WEAs were chosen as the short message alert of focus.

There have been many social science studies conducted that examine humans' perceptions and potential responses to short message alerts. These studies tend to produce findings and recommendations for specific hazards and conditions; very few take these findings and produce usable guidance. The guidance that has been produced for effective creation of short messages tends to be vague and requires interpretation from its user. Sutton and Kuligowski (2019) is one of the only publications found that not only provides guidance for effective message writing, but demonstrates the guidance through sample message templates.

The purpose of this research is to generate a message creation tool that will assist agencies in writing effective 360c. WEA messages. While the research and guidance gathered regarding best practices in short message alerts is applicable to all hazards, the tool will focus on generating mes-

sages for wildfire-based evacuations. The tool will gather information from the user through simple prompts, organize it, add additional verbiage and punctuation, and produce a 360c. WEA message. The tool is research-based and the supplemental information it collects ensures the additional 270c. are being effectively utilized. The potential applications of this tool are using it to generate message templates before an incident occurs or using it in lieu of 'free-form' message writing to generate messages right before or as an incident is occurring.

The purpose of this message creation tool is to help bridge the gap between fundamental social science research and short message alert creation by determining and implementing the research's practical applications. This base tool is expandable for hazards, purposes, and systems other than wildfire evacuation WEAs. Looking forward, messages generated by this tool should be tested and validated for each scenario and associated population.

2 Report Organization and Research Methods

The research methods for this M.S. thesis began in the summer of 2017 while collecting research for a publication titled *A Review of Public Response to Short Message Alerts under Imminent Threat.* This paper aimed to answer two main questions (Kuligowski and Doermann 2017):

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

The 2017 publication helped lay a foundational understanding of short message alerts and the public's response to them. The research gathered to complete this publication also provided the majority of the information necessary to complete the "Background and Literature Review" section of this thesis.

In the fall of 2017, a workshop on short message alerting was hosted by the Fire Protection Research Foundation (FPRF) and the National Institute of Standards and Technology (NIST). The purpose of this workshop was to present the preliminary research from the Kuligowski and Doermann (2017) publication as well as facilitate a discussion regarding the practicality and usability of the information presented.

This section first reviews the work that was completed in 2017, its application to the "Background and Literature Review", and how it helped develop the motivation for this thesis. Next, the limitation of this thesis project are discussed. The steps used for the development of the research-based message tool are provided along with details regarding key decisions and assumptions. Finally, the methods used to apply the message creation tool to wildfire emergency case studies in order to test its validity are provided. For each of the sections, key decisions and research methods are discussed.

Overall, this thesis combines knowledge of short message system limitations, human response and behavior, and research regarding best practices in short message alerts. This thesis presents the research, associated analysis, and a message creation tool that will help authorities to develop improved short message alerts for communities experiencing imminent threat from wildfire emergencies.

2.1 Publication- *A Review of Public Response to Short Message Alerts Under Imminent Threat*

The research collected for the 2017 publication aimed to give a review of the current status of short message alerts in the United States as well as provide insight into how the public responds to different short message alerts.

In order to give a review of the current status of short message alerts in the United States, Twitter and Wireless Emergency Alerts (WEA) were selected as the platforms to be investigated. For each of the platforms, an introduction to the system, its capabilities and limitations, and upcoming changes to character restrictions were discussed. Information regarding the usage of Twitter (everyday by the public and in times of emergencies by alerting authorities) and WEA (in times of emergencies by alerting authorities) was provided next as well as statistics about cell phone usage in the United States.

Several research databases were consulted to gather research regarding the public's response to short message alerts including Engineering Village, Web of Science, Web of Science: Social Science, and Google Scholar using the following keywords: *emergency, disaster, alert, message, notification, communication, social media, text, SMS, twitter, mobile, response, interpret, react, and understand.* The research gathered spanned the disciplines of sociology, psychology, communications, human factors, and engineering. During this search, over 60 potentially useful publications were collected for further review based on the relevance of their title and abstract to the main objectives of the publication.

In order to further review the publications and extract useful information, an organizational system was developed. For each of the publications, the following six types of information were extracted from each: the topic, objectives, research methods, research findings, recommendations based on the findings, and other information that was relevant/ potentially of use for introductory or background sections. If one of the articles reviewed did not contain information relevant to one of the sections listed above, that section was left blank during the review. The bulk of the information gathered from the collected literature fell under "research findings" and "recommendations based on the findings" sections. In order to organize the information gathered in each of these sections, a sub-organizational method was developed based loosely on the Protective Action Decision Model (PADM). This sub-organizational method required labeling each piece of information collected with one of the thirteen numbers below, allowing for easy reorganization later on. Also listed below are the categories or type of information associated with each number.

1 Readability: A users ability to physically read and understand a message.

2 Content: The types of information that should be included in a short message.

3 Style: The order of message content as well as grammar (i.e., capitalization and punctuation) and phrase structure.

4 Message Additions: Maps, pictures, URL links.

5 Salience: Information being passed online from one user to the next.

6 Monitoring/Feedback: Two-way communication after an initial short message alert is sent.

7 Rumor Mitigation: If/how user-generated rumors are addressed.

8 Risk Perception: Increasing a person's belief that the hazard will directly impact them.

9 Other/Introduction: Other relevant or introductory material.

10 Opt-in/Opt-out: Comments about opt-in vs out-out systems.

11 Experts: Names of content experts identified in the research (See section 2.1.1).

12 Public Trust: Factors that increase or decrease the public's trust of a message.

13 Public Action: Factors that promote or inhibit the public taking protective actions.

During further review, some of the originally gathered publications were eliminated based on irrelevance (i.e., they contained little to no information on the 13 topics described above). Information from 47 of the 60+ original publications was collected, organized, and included in the Kuligowski and Doermann (2017) review. These 47 publications included 25 peer reviewed journal articles, 5 government reports/books, 13 conference proceedings/bulletins, and 4 reports from companies/universities. Topics 1-8, 12, and 13 were included in the Kuligowski and Doermann (2017) report and discussed the methods of short message alerts that would both promote and inhibit public response. This review also aided in the development of 'preliminary guidance' and after vetting via the workshop discussed in section 2.2, a preliminary guidance report was generated (Sutton and Kuligowski 2019).

2.2 Workshop on Short Messages for Public Alerts

On September 7th, 2017, an 8-hour workshop was conducted at the National Weather Service Training Center (NWSTC) in Kansas City, MO. This workshop was hosted by the Fire Protection Research Foundation (FPRF) and the National Institute of Standards and Technology (NIST) with Kuligowski and Doermann as the main presenters/ discussion facilitators. The 17 workshop participants were considered to be "superusers" and demonstrated vast expertise using either social media and/or WEA messaging platforms during times of imminent threat emergencies (Kuligowski

and Doermann 2017). Some of the participants included were identified in the 'Experts' section of the publication discussed in section 2.1. The research methods regarding the reorganization of this information for the "Background and Literature Review" section can be found in section 2.5.

Prior to the workshop, individual phone calls lasting approximately an hour, were completed by Doermann with most of the workshop participants. During the call, participants were asked about their past and current usage and experience with different social media platforms/ WEA, personal views regarding challenges and benefits of short message alerts and different platforms, experience using short message templates, and workshop expectations. Participants were also asked if they or their organization had pre-written short message alert templates and/or social media policies and procedures for emergency situations. If they had either and were able to share them freely, a copy was requested for further review prior to the workshop. The templates and procedural documents were reviewed and information from them was shared with participants on the day of the workshop during the pre-workshop discussion.

During the workshop, Kuligowski and Doermann presented the information gathered regarding the current status of short message alerting in the United States and how the public responds to short message alerts. Finally, a discussion was facilitated with the superusers to discuss the practicality and feasibility of preliminary guidance. During this portion, some users also presented their current templates and improvements to them were discussed based on the research findings.

2.3 WEA- Process and Project Motivation

A basic knowledge of Wireless Emergency Alerts and how the Integrated Public Alert and Warning System (IPAWS) works is important to understand the implications of this thesis. A discussion begins with an introduction to WEA and Twitter and how they can be classified for use as 'short' message alerts. For this project, WEAs were the focus and therefore a more in depth discussion of their purpose, capabilities, and usage is provided. This is also paired with information on the logistics of the IPAWS system (i.e., the steps a message goes through from its originator until it is disseminated to the public's devices). A review of the message creation software currently available is provided to explain that messages must be generated completely by the message creator with little to no assistance from the alert origination software. For the message creator to generate a message, he/she has the option to create templates messages before an incident occurs or write the message 'free-form' while the incident is occurring/ about to occur. Both message creation options are explained and pros/cons are provided for each.

In September of 2016 the Federal Communications Commission (FCC) adopted changes to the IPAWS system. Of the changes, the adoption of increasing the WEA character limit from 90c. to 360c. by May 2019 (FCC 2018) played an integral role in the development of this thesis. Benefits and challenges of the shift are presented. The most influential challenge is the lack of educational materials currently available for message creators to learn to effectively utilize the additional 270c. available. Finally, a discussion of how this challenge led to the development of this thesis topic and the message creation tool is provided.

2.4 The PADM and Short Message Alerts

The Protective Action Decision Model (PADM) is a multi-stage theoretical model that helps describe the process a person goes through from the time a piece of external information (i.e., a short message alert) is received until the individual performs a protective action response based on that information (Lindell and Perry 2012). In this section, the model is broken down into it's pre-decisional and decisional steps and a separate discussion is provided for each.

First, information was extracted from Lindell and Perry (2012) to provide a general discussion about each of the pre-decisional and decisional steps. This section is followed by a discussion of how each of the steps relates to short message alerts in general and short message alerts in regards to this thesis project, i.e., the message creation tool. From these sections, key assumptions about the message receiver were also extracted.

The PADM has been used before to organize research discussing the best practices in short message alerts (Kuligowski and Doermann 2017, Sutton and Kuligowski 2019). This organizational method summarizes the PADM into four categories: attention, understanding, believability, and personalization. To increase the level of each of these within the message receiver, general guidance is provided on what to do and what not do for each category.

2.5 Current Knowledge of Best Practices in Short Message Alerts

Research shows that there are five types of information that need to be included in a short message alert in order for it to be effective: message source, guidance, hazard, timeline, and location (Sutton et al. 2014; Mileti and Peek 2000; Mileti and Sorensen 1990). Research also shows the best order for this information is source, hazard, location, time, guidance (Bean et al. 2014, Sutton and Kuligowski 2019) in cases where the messages are 280c. or more. In order to apply the research currently available to the message creation tool, reorganization of the information gathered for the

publication discussed in section 2.1 was required. The information previously organized based on the PADM steps needed to be reevaluated and re-categorized as it applied to each of the five content sections.

The research previously extracted from each source was reviewed and organized into six categories: general, source, hazard, location, timeline, guidance. Five of the categories aligned with the content types found necessary for an effective short message alert and research was filed into each accordingly. The final category, 'general', was used for information that pertained to the message as a whole or was applicable to all of the message content sections. Of the original 47 sources reviewed for the 2017 publication, research and information from 22 were included in this thesis including 5 Conference Proceeding, 4 Government Reports, 10 Peer Reviewed Journals, and 3 other Reports. Information and sources were excluded if they did not pertain to one of the six categories (e.g., research regarding maps for emergency communication). Annotations were created for each source in each content section to identify general information, problems/shortcomings, and key findings. The annotations also included comments about the information's relations to other sources, questions about the information found, and/or other general comments.

The research for each content section was reviewed as a whole and overlaps and discrepancies were identified. The information learned about each of the content sections was included along with examples presented by the research. The problems/shortcomings of each content sections as well as the key findings were extracted and included as a summarized list. The problems/shortcomings came directly from the research. For the most part, the key findings were also extracted directly from the research. In some instances, the key findings were assumed from the problems/shortcomings (i.e., confusion due to use of acronyms was listed as a problem, therefore, the need for exclusion of acronyms was included as a key finding). This process was completed for each of the six sections including the 'general' section.

2.6 Preliminary Tool Formation

The research discussed previous to this section is general and was not collected with a focus on any one hazard, therefore it is applicable to all hazard types. However, the message creation tool (described in detail in section 5) was formed for use during wildfire emergency based evacuations and is currently only applicable to this specific hazard-based situation.

For each of the five content sections: source, hazard, location, timeline, guidance, the research and multiple message examples were reviewed and a list of questions was created from the point

of view of the user. These questions were developed as a way to understand all points of potential confusion and clarification the message receiver might need when reading a short message alert. From this list of questions, eight were developed and regarded as the key questions a short message alert needs to answer. Throughout the tool development process, these questions acted as a reminder of the main purpose of each content section.

- Question 1: Who/which agency is sending this message?
- Question 2: What is the hazard people are being warned about?
- Question 3: What are the potential consequences of this hazard?
- Question 4: What is the current location of the hazard?
- Question 5: What direction is the hazard moving?
- Question 6: What region(s) of people should evacuate?
- Question 7: How long does the message receiver have until he/she needs to act?
- Question 8: What protective actions should the message receiver be following?

After the key questions were established and the research in each content section was summarized into a list of problems/shortcomings and key findings, the impact that each had on the message creation tool was determined. Next, a list of potential user inputs was created and refined into the fifteen user prompts that would be included in the final tool. For each of the prompts, the response type required from the message creator was determined: drop-down (list selection), Yes/No, fill-in. Considerations about character limits and potential user responses were taken into account when deciding the response category for each question. Questions were categorized as drop-down if they required responses that were limited to a certain scope (i.e., time: there is a finite number of hours to select from) or it was believed that the user would benefit from having predetermined options to pick from. Questions were categorized as fill-in if there was a direct need or benefit from having the message creator enter information. Once the questions were generated and their response type was categorized, a menu of potential responses was created and an organizational system for them was developed (i.e., User Response Headers).

Figure 1 illustrates the system that was used to identify each potential user response. The User Response Header for each Prompt refers to all of the possible user responses. For instance, 'User Response 3(a-c)' refers to Prompt 3 and the possibility of 3 different options in the drop-down menu, while 'User Response 3b' refers to a specific user response. This system was used through the development of tool logic for organizational purposes.

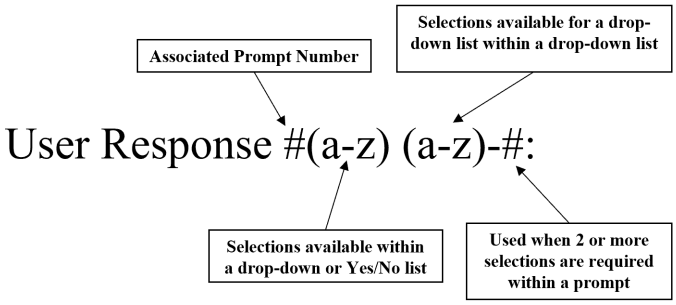


Figure 1: User Response Headers Diagram

The justification for each Prompt, response type required, and available user responses (if drop-down) is denoted in this thesis as *Prompt Justification*.

To develop the tool logic, determinations were made regarding how each User Response impacted the message output. Some of the responses were taken and directly entered into the message while others were used as leading questions to guide the message creator through the tool. For instance, a drop-down gives the options of well known landmark(s), town/city/county (all or portion), and major road(s)/ intersection(s) for the message creator to identify the current location of the hazard. The User Response to this question is not directly recorded in the message; however, requiring this response leads the reader to identify the location by one of these predetermined categories. The way some User Responses have a cascading impact on future Prompts and how others entered impact the final message is denoted in this thesis as *Response Algorithm*. The response algorithm for each section appears in paragraph form as well as a logic diagram.

Also included in the *Response Algorithm* are the punctuation, capitalization, organization, and additional words/phrases that are embedded in the tool in order to make the message flow properly. Justification and considerations for these and anything else not captured in one of the sections above is recorded in the *Other Justification* section.

Before employing the logic diagram/ Response Algorithm to build the message creation tool, it was necessary to convert the User Response Headers to a more user friendly form. This was done by converting the number/lettering system to phrases where the User Response Headers reiterated the Prompt and explained how the message creator should respond (e.g., 'select' or 'enter').

2.7 Tool Formation

Excel was used as the platform to build the short message creation tool. This program was chosen because it is user friendly and provided the capabilities necessary to build the tool without requiring extensive knowledge a complex programming language. Figure 2 displays a blank view of the message creation tool interface.

At the top of the document, a cell named 'Message:' appears and the adjacent cell is where the message is formed as the user enters his/her responses. At the commencement of message creation, this cell is blank. Directly below the 'Message:' cell is another titled 'Characters Left:'. The adjacent cell is used to inform the message creator of the number of characters they have remaining. This cell begins with the number 360 and decreases as the user responds to the prompts and the message is formed. This was done by taking =360-LEN(*message cell*) which takes the original 360 and subtracts the number of characters in the message cell resulting in the number of characters remaining.

The Response Algorithm and Justification sections described above acted as the logic for creating the tool. Data validation ranges (drop-downs) and 'IF' statements were the main logic methods that were used to create the tool. To begin, the prompt number and associated prompt were entered and a dedicated space for the user response was established. All of the prompts appear at all times except for those that only require answers if the user selects 'YES' on a previous prompt (e.g, Prompt 3 and Prompt 11). Next, all drop-down responses were created using data validation ranges. All text for the drop-downs is found in one column to the right of the prompts and user responses. In the case of character limited fill-in responses, the =LEN() (length of a specified string) function was used to inform the user of the number of allowable characters remaining.

A final column pulls the user responses by referencing the cells containing information that will be used to generate the message. This column contains a series of 'IF' statements in each cell to determine how the text will appear based on the user input. For instance, if a user has not selected a response yet, the cell will appear blank and if the user has entered a response, the cell will contain that response. In these cells, the capitalization, punctuation, and words/phrases necessary for the message to flow are also included. Once the user has completely filled out the prompts, this column will contain all of the pieces of the message. The final message is created by referencing all of these individual pieces in the original message cell.

	Message:		
	Characters Left:	360	
Guidance	Prompt 13	What is the main purpose of this message?	
		Select the main purpose of this message:	-
Source	Prompt 1	What agency should be listed as the source of this message?	
		Enter the agency sending this message:	
Source	Prompt 2	Does this agency use an acronym that is more common than its official title?	
		Select Yes or No:	-
Source	Prompt 3	Prompt not applicable. Continue to next prompt.	
Hazard	Prompt 4	What type of emergency is happening or about to happen?	
		Select the type of emergency:	-
Hazard	Prompt 5	What wildfire consequences should the public be aware of? "Wildfires can..."	
		Select consequence #1: *(you MUST select at least one consequence)*	-
		Select consequence #2: *(select 'none' if no other consequences should be included)*	-
			35
Location	Prompt 6	Which will be used to identify the current location of the hazard?	
		Select which will be used to identify the location of the hazard:	-
Location	Prompt 7	The hazard is located (in/near/between) which -?	
		Select the proximity of the hazard to the -:	(in/near/between)
		Enter the - the hazard is located (in/near/between): (separate multiple with 'and' or ',')	
Location	Prompt 8	Which will be used to identify the direction the fire is spreading?	
		Select which will be used to identify the direction the fire is spreading:	-
Location	Prompt 9	What is the name of the - that the fire is moving towards?	
		Enter the - that the fire is moving towards:	
Location	Prompt 10	Is there a specific region of people who should evacuate?	
		Select Yes or No:	-
Location	Prompt 11	Prompt not applicable. Continue to next prompt.	
			(in/near/between)
Timeline	Prompt 12	When should people take action?	
		Select when people should take action:	-
			-
			-
Guidance	Prompt 14	What specific actions should the person receiving this message take?	
		Select action #1: *(You MUST select at least one action)*	-
		Select action #2: *(select 'none' if no other actions should be included)*	-
			35
Guidance	Prompt 15	What should people do for update information?	
		Select action: *(select 'none' if no update information should be included)*	-

Figure 2: Blank Message Creation Tool Interface

2.8 Tool Demonstration

To show the tool's capabilities, three case studies were completed. Each of the case studies involved analyzing a Wireless Emergency Alert that was sent during a wildfire, creating a new message based on the original and additional information learned about the fire online, and providing a research-based explanation of why the 360 c. message created with the tool is valuable.

To select the messages that would be used for the case studies, a list of WEAs sent using IPAWS was obtained from FEMA (FEMA WEA FRW 2018) by NIST. While working at NIST as an associate researcher, access to this list was granted for its review. A total of 60 messages coded 'FRW' for 'Fire Warning' were extracted for potential usage. In the initial filter, messages were eliminated if they were not relevant, provided warnings of fire danger (i.e., 'red alert'), or were confusing/left

unfinished. This filter decreased the number of messages to 29. For the second filter, messages were eliminated that spoke about evacuations colloquially (i.e., 'level 1 evacuation'), only provided an 'in this area' fire warning, or only addressed one or two of the five messages content sections necessary for an effective short message alert. Of the 12 messages remaining, the three selected contained most if not all of the five content categories, stated the hazard was a fire or wildfire, and were evacuation-based.

The fire associated with each of the messages was researched for general information (i.e., dates, size, fatalities, etc.) and specific information was sought out that would be useful for generating a message with the tool. Next, the original message was broken down into the five content sections and were entered into a table. If the message did not address one of the sections, a '-' was entered instead. Additional comments regarding the message section were documented last. A summary list of problems/shortcomings of the original message was created from the table.

To generate a new message with the tool, user inputs to each of the prompts were generated based on the original message and additional research completed about the fire. It is unclear if during the fire incidents, message creators would have had access to this additional information. However, for the purpose of these case studies, the additional research was used as if it was accessible. Each of the inputs has comments justifying its inclusion and the source it came from. If any of the inputs needed to be assumed, justification for these were also included in the comments section. Finally, images capturing the tool interface as the inputs were entered and the final message generated were included.

A comparison of the original message and the tool-generated message using the 8 questions discussed in section 2.6 provided insight into the value of the tool and tool-generated message. Problems/ shortcomings of the tool and tool-generated message are also addressed.

2.9 Looking Forward

Finally, a section containing unanswered questions, topics available for further research, and 'next steps' for the tool are included in section 7. The questions and topics are included because there is little to no research available for them. The 'next steps' addresses ways the current tool could be expanded to broaden the scope of hazards, situations, and technologies it can be used for.

3 Background and Literature Review

This section begins with a review of the Protective Action Decision Model (PADM), a multi-stage model that describes how individuals make decisions based on gathered information. Next, for each stage of the model, a description of the stage is provided as well as how each stage applies to short message alerts and the short message creation tool developed in this thesis. This breakdown helped to identify key assumptions about the message receiver as well as discuss the limitations short messages are bound by. Following this review, guidance organized based on the PADM is provided on how to increase attention, understanding, believability, and personalization of short message alerts. Finally, the five necessary content types for an effective short message alerts are provided. A definition and research-based discussion that highlights problems/shortcomings and key findings is provided for each. These problems/shortcomings and key findings were used as the foundation for the message creation tool.

3.1 The Protective Action Decision Model

The Protective Action Decision Model (PADM) is a multi-stage model developed by Lindell and Perry (2012) that describes people's responses to environmental hazards and disasters. The model identifies the steps a person goes through from the time some external piece of information is learned (e.g., environmental cues, social cues, warning messages, etc.), to the time that individual makes a decision regarding a necessary protective action.

After receipt of the information, the model identifies three pre-decisional processes (exposure, attention, comprehension) and three core perceptions (threat, protective action, stakeholder) that influence an individual's decision making and overall behavioral response to an event. The model identifies three behavioral responses, information searching, protective response, and emotion-focused coping. If during the process at any stage an individual is unsure of the information they received or how to proceed, he/she will engage in milling and/or search for more information to fill the gaps (Woods et

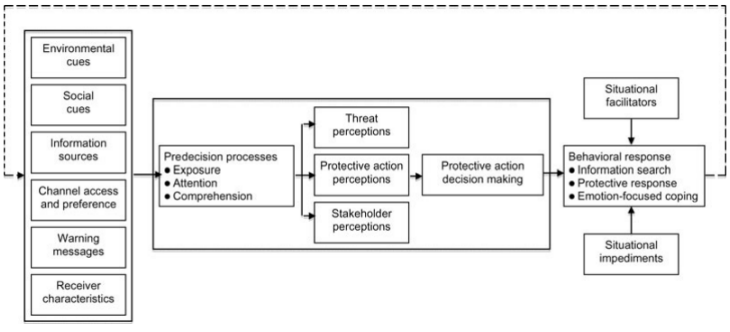


Figure 3: The Protective Action Decision Model. (Lindell and Perry 2012)

al. 2017). The PADM can be condensed into 2 major stages, pre-decisional and decisional.

3.2 The PADM for Short Messages

Short messaging impacts an individual's decision making process and is located the pre-decisional stage of the PADM. If a short message provides the message receiver with sufficient information, he or she may perform a protective action response without the need to seek additional information. The sections below provide insight into each stage of the PADM as explained by Lindell and Perry (2012), identified below as 'L&P'. The sections below labeled 'SM' refer to how each stage/ sub-stage of the PADM applies specifically to short messaging and the short message creation tool developed in this thesis. For the 'Cues' and 'Pre-Decisional Processes' Stages, this helps identify key assumptions about the message receiver that are summarized in section 4. The 'Key Perceptions' Stage addresses preliminary challenges that can arise due to different interpretations of the same information as well as the limitations that short messages are bound by.

Stage 0-Cues

Environmental Cues, Social Cues, and Warnings-

L&P- The cues that a person receives form the foundation upon which their decisional process occurs. Environmental cues (e.g., seeing flames or smoke from the wildlands), social cues (e.g., observing family or friends evacuating), and warnings (e.g., receiving a WEA) are key in the information gathering stage and impact a person's belief and behavior. Generally in decision making there is a feedback loop that occurs where a person is constantly gaining and/or re-evaluating sources of external information while making his/her decision.

SM- In an actual emergency, individuals receive information from many external sources and it is important that this information is consistent. This thesis was created under the assumption that the only external information a person would be receiving is a single short message alert. The overall goal of the message creation tool is to optimize this stand alone alert to be as impactful as possible. Therefore, for each of the additional stages, their influence was investigated as it applied only to the short message text.

Stage 1- Pre-decisional Processes

Stage 1.1-Exposure-

L&P- Exposure refers to a persons' ability to receive the external information available (e.g., Environmental Cues, Social Cues, and Warnings).

SM- For short messaging, exposure is impacted by an individuals' available technology and his/her location. For instance, is his/her device capable of receiving WEA messages?, is he/she in the area of impact? If so, he/she will receive the message to his/ her device. This stage poses little impact on this thesis because it is assumed that the message receiver has a WEA capable device and is in the area of impact/ area the message is being sent to.

Stage 1.2-Attention-

L&P- After an individual has received the external information, the next step is "whether or not they heed the information". Based on a person's personal expectations, external demands that are competing for his/her attention, and how intrusive the information is, an individual will either pay attention to the information or not (Fiske and Taylor 2013). Factors such as the individual's age have been shown to impact his/her ability to complete this step (Mayhorn 2005).

SM- Attention in short messaging refers to both an individual noticing he/she has received a message and choosing to read it as well as his/her noticing or concentrating on certain words/ phrases in the message more than others. The first portion of attention plays no role in the project because it is assumed that the receiver notices the message and reads it (i.e., the project does not focus on tones or vibrations that may accompany a message that are generally used to increase an individuals' awareness that a message has been received). The latter part of attention applies because there may be certain pieces of information in the message that can be emphasized based on grammatical or textual changes.

Stage 1.3-Comprehension-

L&P- Comprehension of the external information applies to an individual's ability to physically understand the cues or warnings they are being presented with.

SM- In terms of messaging, comprehension is two-fold. First, an individual must be able to understand all of the words in the message individually. Secondly, when the words are compiled in a message the individual must understand what the message is informing them

of and what it is instructing them to do. To comply with these requirements, this thesis assumes that the message receiver is English speaking and has a basic knowledge of the English language. This thesis was also created under the assumption that the message receiver does not have any physical or cognitive disabilities that would prevent him/her from reading and having a basic understanding of message.

Stage 2- Key Perceptions

Stage 2.1-Threat Perception-

L&P- The probability that a future event will occur and the personal consequences that may be the result of that future event are essential attributes for determining an individual's threat perception (Fischoff at al. 1978). Other factors that may influence risk perception of a future event are dread and unknown risks of the event (Fischoff at al. 1978). A person's perception of event probability and personal consequences is derived based on external cues and warnings, but can also characterized largely by his/her past personal experience with that hazard.

SM- An individual's threat perception is extremely subjective due to its large dependence on a person's personal, professional, and social standings (e.g., past experiences, education level, household roles and responsibilities, etc.). For instance, two individuals are living in the same community and receive word that there is a wildfire approaching. Person A decides to evacuate immediately based on their experience with a fire ten years ago that burned down their house, while person B does not because they feel that the fire is not a threat. This thesis assumes that messages are stand alone units and cannot rely on any additional external cues or an individual's attributes to help influence the message receiver's threat perception. In order to invoke a protective action, messages must ensure threat probability and establish clear and personal consequences for the receiver; regardless of his/her personal, professional, and social standings.

Stage 2.2-Protective Action Perception-

L&P- An individual's risk perception is dependant upon not only their perception of the hazard itself, but also of the hazard adjustments (i.e., the actions that must be taken because of a hazard). The attributes of a hazard adjustment have been separated into two categories, hazard-related and resource-related. Hazard- related attributes are characteristics directly related to the hazard that influence an individual's decisions. Effectiveness of an adjustment

in protecting people is an example of an attribute that has been shown to have a positive correlation with hazard adjustment. Resource-related attributes are traits or means that an individual has access to independent of the hazard. Cost and additional skill, time, and effort requirements, have been shown to have a negative correlation with an individual's protective action taking.

SM- Hazard adjustment perception is largely based on an individual or group's personal, professional, and social standings. Similar to threat perception, messages cannot rely on an individual's characteristics to influence his/her perception of hazard adjustments. Messages also should not be generated with the assumption that the reader has a specified skill set or uncommon resource available to them (i.e., a bomb shelter for sheltering in place). The hazard adjustments presented in a message must be easy to follow, effective, and minimize cost and skill requirements whenever possible. The message also must ensure the receiver that the guidance they are being presented with is the best possible option and the most important thing that they do.

Stage 3-Protective Action Decision Making-

L&P- There are a series of decisional stages that comprise this stage: risk identification, risk assessment, protective action search, protective action assessment, and protective action implementation. In the Protective Action Decision Making stage, the individual is assessing the information he/she has gathered and uses it to decide if he/she should preform an action or not. In risk identification and assessment, the individual uses his/her key perceptions to decide if there is a credible and personal threat. In protective action search and assessment, an individual assesses his/her options, weighs them against the hazard adjustment perceptions, and selects a final action(s). Finally, the individual implements the protective action.

SM- In order to aide the message reader in their decisional process, a message must do its best to convince the reader that the hazard being described is not only real but that it will also have significant and lasting consequences upon the reader, potentially negative if he/she does not act. The protective action desired by the message receiver will be included in the short message alert. An important characteristic of protective action search and assessment is convincing the reader that the protective action presented is the best option he/she has.

3.3 Recommendations and Guidance for Short Messages, based on the PADM

Recommendations and guidance on how to increase an individual's compliance with taking protective actions have been organized into four main categories; increasing attention, increasing understanding/readability, increasing believably/ credibility, and increasing personalization (Kuligowski and Doermann 2018, Sutton and Kuligowski 2019). The table below is adapted from the appendix of Sutton and Kuligowski 2019, guidance and recommendations not currently within the capabilities of WEA or within the September 2016 WEA updates were excluded.

Guidance on increasing attention to short messages for imminent threat:	-Use all caps, and/or bold letters to draw readers' attention to certain words or phrases in the short message, -Use language that conveys urgency (i.e., imperative sentences) -Provide complete information about the threat, its impacts and protective actions that the public should take. -Clearly identify the location of the hazards' impact
Guidance on greater understanding of short messages for imminent threat:	-Remove abbreviations and jargon; clearly spell out all words, including the source of the message and timing (i.e., time zones) -Eliminate spelling errors -Use clear language that leaves little room for interpretation -Identify specific locations of impact by including familiar landmarks
Guidance on increasing believability of short messages for imminent threat:	-Begin each message with a recognizable and trusted message source, spelled out completely -Order 90-character messages in the following way: source, guidance, hazard, location, and time -Order 280-character messages in the following way: source, hazard, location, timeline and guidance.
Guidance on increasing personalization of short messages for imminent threat:	-Use words that convey seriousness and urgency: e.g., "imminent danger", "immediate evacuation", "urgent", or "critical" -Use words that convey action: e.g., "take action now!" or "Evacuate immediately" -Use words that convey certainty about an event that is taking place (e.g., tornado has touched down). Use words, phrases, or imagery that place the receiver inside the risk area -Use words or phrases that discuss the consequences of the risk if the receiver does not act

Table 1: "Guidance for improving short messages for imminent threat." (Adapted from Sutton and Kuligowski 2019)

3.4 Content of an Effective Short Message

To generate an effective short message that increases the probability an individual will take protective action, the inclusion of five types of information have been found necessary (Sutton et al. 2014; Mileti and Peek 2001; Mileti and Sorensen 1990). The five types of information are:

- Source (i.e., the organization or entity who is sending the message),
- Guidance (i.e., the protective actions that the public should take in response to the message),
- Hazard/ consequences of the hazard (i.e., the event that has happened/ is about to happen as well as the threat this hazard poses to the public),
- Timeline (i.e., when the event will occur and when the public needs to act),
- Location (i.e., the region(s) the hazard is impacting or will impact and the region(s) of people who are at risk).

For messages of 280c. or greater, the following order has been found most effective in improving an individual's understanding, belief, and decision making: source, hazard, location, time, guidance (Wood et al. 2015, Sutton and Kuligowski 2019). Below, sections of the short message are addressed individually and for each a definition, problems/shortcomings, key findings/ recommendations, and supporting literature have been provided (section 3.4.1- 3.4.5) .

The final sub-section (section 3.4.6) identifies problems/shortcomings, key findings/ recommendations, and supporting literature for WEAs and short messages as a whole. These have not been identified as particular to a single portion of the short message and therefore are applicable to all sections (source, guidance, hazard, timeline, and location).

3.4.1 Source

The source is the agency/ person/ jurisdiction that is providing the information within the message. Source has been shown to impact an individual's level of understanding, decision, belief, and personalization of a message (Wood et al. 2015).

One of the largest challenges with the source of the message is that it is usually predetermined by whichever entity is sending the message. However, in cases where multiple jurisdictions or agencies are working together, the message creator may be able to select which will be listed as the message source. It has been observed that the public will have greater overall belief in a message when the message is sent by a source they perceive as most knowledgeable about a specific hazard. For instance, in the case of an active shooter, the local police department might be the best source, for a natural disaster or weather emergency it might be the National Weather Service, and for a terrorist

attack it might be the Federal Bureau of Investigation (FBI) or Department of Homeland Security (DHS) (Bean et. al 2015) (Liu et al. 2015). It has also been observed that when hazard-related agencies (e.g., National Weather Service for weather-related emergencies) are selected as the message source rather than elected officials (e.g., the mayor), substantially higher levels of message credibility have been reported (Wei et al. 2018).

Arguments have been made that favor national sources over local and vice versa. In general, it is most important that messages come from sources that are official and familiar to the receiver (Bean et al. 2015). Some studies have shown that nationally recognized sources such as NOAA (National Oceanic and Atmospheric Administration) proved to be highly effective in increasing an individual's level of decision making in regards to, understanding and belief of a message (Wood et al. 2015). Another study listed 'Denver PD' as the message source and believability increased because the receivers recognized the agency immediately and knew the message was coming from a credible source (Bean et al. 2016). In 2008, Sutton completed a study of the 2007 Southern California wildfires. In this study the majority of people identified local news as the best source of information because of its credibility and knowledge of the area and local affairs. Quotes from participants also identified significant levels of mistrust in major news sources all together:

- " 'What we learned... is that there is no 'they.' 'They' won't tell us if there is danger, 'they' aren't coming to help, and 'they' won't correct bad information. We (regular folks) have to do that amongst ourselves.' " (Sutton et al. 2008)
- " 'Most of the news media ... are utterly clueless about anything in rural areas. They constantly gave out bogus information, like locations and directions that made no sense at all.' " (Sutton et al. 2008)

Another study by Bean (2016) showed a comparison between a national source (US DHS) and a local source (Denver PD) where participants belief and understanding of the message increased when the source was switched from national to local. According to participants in this study, they believed "there was nothing saying it was coming from an official government agency [when 'US DHS']" was listed as the source (Bean et al. 2016). It appeared that this had more to do with people's misunderstanding of the acronym 'US DHS' than it did with their trust/mistrust of the message source. Due to source being located at the beginning of a message, it has the ability to either immediately establish credibility or immediately create confusion.

Problems/shortcomings of source within a short message:

- Lack of trust in the agency/ organization listed as the source.
- Confusion created due to individuals misunderstanding the source (i.e., due to use of acronyms or unfamiliar agencies).

Key findings for effectively messaging source:

- Place the source at the beginning of the message.
- Select a source for the message that is official and recognizable, if possible.
- If there are multiple sources available, select one that would be perceived as the most knowledgeable about the hazard.
- Neither national nor local sources are 'best' for all messages, choosing the most effective source may be hazard dependant.
- When possible, select a source from a hazard- relevant agency.
- Message source should be completely spelled out and avoid acronyms.

3.4.2 Hazard Identification

Identifying the hazard in a message involves naming the event that has occurred/ is about to occur as well as providing an explanation of the consequences (i.e., how dangerous these events will be and what threats they pose to the public). With the current character limits on short message platforms (90c. for WEA), it is common for messages to include the hazard but omit the consequences. With the 2016 WEA updates, an additional 270c. will be available for the message writer to use. Recommendations have been made to include the consequences of the hazard (Bean et al. 2015) in order to increase message personalization (Sutton and Kuligowski 2019).

When identifying the hazard, it is important to use words and phrases that are common and easily understood. In a study by Bean et al. (2016), the phrase 'Radiological Hazard' was used in a hypothetical 90c. WEA message. Participants found the phrase to be attention grabbing but scary and confusing because they did not know what a radiological warning was. There was an increase in the number of people who stated that they would take protective action when 'Radiological Hazard' was replaced with 'Nuclear Explosion', because it was easier for them to understand.

Jargon should also be avoided when explaining the hazard and naming its consequences. The National Weather Service (NWS) uses the terms 'watch', 'warning', and 'advisory' to describe different levels of immediacy, certainty, and danger during severe weather events. When used in short message alert studies, participants found these words to be unclear (Sutton et al. 2016) and had

confusion about the differences between them (Wood et al. 2015). These words are agency-specific and require some amount of prior knowledge to understand.

Using ambiguous statements can cause confusion and lead individuals to require additional and/or clarifying information. For instance, the phrases "tsunamis can seem to stop for long periods of time" and "damage has been reported" were used in a study about tsunami warning messages. These phrases caused confusion and led individuals to ask questions to clarify how long 'long periods' were and what the extent of the damage was (Sutton et al. 2016). Another message from the same study identified the tsunami's waves as being "2 to 4" feet. Participants found the specificity in this message to be calming and decreased their risk perception because they did not believe that waves that small would be able to cause any major damage. It was suggested instead to use a more ambiguous phrase such as 'the waves are dangerous'. Overall, the language chosen for the hazard and consequences explanation should convey the certainty, urgency, and severity of the event (Sutton and Kuligowski 2019).

Problems/shortcomings of hazard identification within a short message:

- Misunderstanding of the hazard/ name chosen to identify the hazard (e.g., what is physically happening or about to happen).
- Misconceptions about the severity and/or potential impacts/ consequences of the hazard.
- Confusion created by ambiguous/unclear statements and use of jargon.
- Confusion and fear created when an explanation of the hazard and/or its consequences was omitted from the message.

Key findings for effectively messaging hazard identification:

- Components to include: unambiguous and clear/familiar name of the hazard, potential impacts/ consequences of the hazard.
- Use language the accurately depicts the severity, urgency, and certainty of the event.
- Avoid using ambiguous/unclear statements and jargon.

3.4.3 Hazard Location

The hazard location portion of a short message identifies the physical and/ or geographical boundaries of the hazard (Wood et al. 2015). The location can and should also identify the areas/regions that are at risk to be impacted by the hazard (Sutton and Kuligowski 2019). For 90c. WEAs, the phrase 'in this area' is commonly used to describe the location impacted by the hazard

(e.g., often used by the National Weather Service). WEA messages are sent and received based on a specific geographical area, meaning if a WEA was received, the device is in the affected area that was selected by the message sender. If individuals are not aware of how this system works, the phrase may cause confusion because they may not know what area is being referred to. In a study completed by Bean et al. (2014) for the United States Department of Homeland Security, participants found the phrase 'in this area' to be insufficient and misleading. One participant asked " 'How do they [officials] know that you're there [in this area]?' ". If the message receiver has doubts or does not believe he/she is in the area of risk their personalization of the message may be decreased (Sutton et al. 2016, Sutton and Kuligowski 2019).

Naming specific cities/counties/regions/etc. is another way the location of a hazard can be identified. In a study completed by Bean et al. (2016), 'Denver' was used as the location of the hazard. Participants felt that using the city name was too broad of a geographic area, and they questioned whether the entire city or just a specific part of the city was actually at risk. When identifying the hazard location, those unfamiliar with the area must be taken into consideration. For instance, those local to an area might use county names to identify locations, while using the names of cities, towns, or even popular landmarks might be more helpful to a wider population (Sutton et al. 2016; Cao et al. 2016; Kuligowski et al. 2014; Hui et al. 2012).

Problems/shortcomings of hazard location within a short message:

- Confusion about the location of the hazard/ the location(s) that are at risk of being impacted by the hazard.
- Misunderstanding of location names used (e.g., by people who are new to the area or on vacation).
- Confusion created by ambiguous statements/locations (i.e., 'move to a *safe place*', 'in this area').

Key findings for effectively messaging hazard location:

- Use clear names that identify the hazard location and location of impact.
- Use names of cities/towns/major landmarks that are easily identifiable by a majority of people, including those not local to an area or region.
- Avoid using jargon or slang names [specific to a region] to identify location.
- Use words and phrases to inform the message receiver he/she is in an area of risk.

3.4.4 Event Timeline

The timeline given in a message can help inform the receiver of when the hazard will begin, when it may be over, and when he/she may need to take action (e.g., now). The time given in an event can also inform the receiver that a hazard has begun and can put them on 'stand-by' to wait for a a follow-up message (e.g., 'until further notice'). The inclusion of time in a message can help create urgency in the receiver (Bean et al. 2015). Including a 'time until impact' portion of the message has been shown to have a great impact on people's understanding and belief of the message, as well as if they decide to take protective action or not (Wood et al. 2015).

Overall, there is not a substantial amount of research investigating the timeline portion of short alert messages. One source of confusion regarding time that was identified however, was the use of acronyms; e.g., MDT (Mountain Daylight Time) (Bean et al. 2016).

The time portion of a message is hazard specific (i.e., not all hazards have the same timeline). For instance, a flash flood might have a timeline that begins when the message is sent and lasts until a specific time. While an active shooter emergency might have a timeline that begins immediately and lasts 'until further notice'. Wildfire messages do not often state the timeline of the hazard, but instead when message receivers need to take action. Due to the usage of these messages being during imminent threat emergencies, the timeline almost always begins when an individual receives the message and the timeline defines when he/she needs to take action.

Problems/shortcomings of timeline within a short message:

- Confusion about when the event started/when the message receiver needs to act.
- Confusion about when the event will be over and how they know it will be over.
- Confusion and misunderstanding of acronyms (i.e., time zones).

Key findings for effectively messaging timeline:

- The timeline of an event is hazard dependant and should be reflected in the 'start' and 'stop' times selected.
- The beginning and end of the event should be defined as clearly as possible. If the end of the event is unknown, information should be provided to the receiver that informs him/her of when/how they will know the hazard has ended (i.e., will they receive another message?).
- Acronyms should be avoided when identifying time (e.g., time zones).

3.4.5 Guidance

The guidance portion of a message should include three parts, the protective action that needs to be taken, how the message receiver should take it (Bean et al. 2015), and an explanation of why they should act (Woody and Ellison 2014). In traditional 90c. WEAs, often the guidance portion is short and includes only one or two of the three recommend parts listed above– the explanation of why the individual should act is usually not included (e.g., "Take shelter now. Check local media" (National Weather Service)). In a survey by Woody and Ellison (2014), compliance with the directions to stay indoors during a hypothetical hazardous-materials event increased when the reasoning of "to avoid chemical exposure" was added. The addition of this phrase provided the message receiver with the *why* portion of the guidance.

Guidance should be specific (Tyshchuk et. al 2012), actionable (National Academies 2013), and use imperative sentences to increase urgency (Sutton et al. 2015, Sutton and Kuligowski 2019). To increase the urgency of the reader to take protective action, the message should also include words and phrases that convey the severity of the event (e.g., "imminent danger", "immediate evacuation", "urgent", or "critical") and convey action (e.g., "take action now!") (Wood et al. 2015, Sutton and Kuligowski 2019). In another study completed by Sutton et al. (2016), the guidance provided in a hypothetical alert message "advised" people to stay off the beaches during a tsunami emergency. Participants interpreted this wording as "less risky"; one even stated, " 'It sounds optional, rather than ordered. Doesn't create a sense of urgency to get off the beach.' " In this case, the usage of the word "advised" did not convey the perceived severity of the event and did not prompt action. Participants stated that the phrase "people are ordered to stay off the beaches" would have been more effective.

In order for the guidance to be as clear as possible, simple words that are easily understood should be used. For instance, in a study that asked participants to review short message alerts and comment on them, participants recommend that the phrase "evacuations underway" be changed to "evacuations ongoing". They felt that the word "ongoing" was more understandable than "underway" (Temnikova et. al 2015).

Eliminating words and phrases that are ambiguous and require the reader to interpret them (e.g., declarative statements) (Sutton et al. 2014, Sutton and Kuligowski 2019) helps to improve understanding. In a study done by Bean et al. (2016), participants were exposed to hypothetical warning messages that instructed them to take 'shelter'. Many people were confused by this phrase because some thought it meant to seek refuge somewhere like a basement or tornado shelter, while

others associated this with the common phrase 'shelter-in-place' and thought it meant to stay where they were.

Problems/shortcomings of guidance within a short message:

- Confusion about the actions that message receivers were being told to take.
- Use of language that was uncommon/unfamiliar or confusing.
- Confusion about ambiguous terms that made the recommended protective actions sound optional.

Key findings for effectively messaging guidance:

- Items to include: the action that should be taken, how to take it, and why to take it.
- Use common words that are not ambiguous, easily understood, and require no interpretation.
- Use words and phrases that evoke a sense of urgency in the reader and prompt them to act (e.g., 'take action now!').
- Provide guidance that is as specific as possible and includes local context.

3.4.6 General Findings and Recommendations

The purpose of this section is to identify any findings and/or recommendations that were not captured in the sections above. The items below were not identified as particular to a single section of the message (source, guidance, hazard, timeline, and location), therefore it is being assumed that they are applicable to all sections of the message. A few of the themes identified below have already been addressed in previous subsections (e.g., eliminating the use of acronyms was addressed in source) but have been repeated here because other sources made the recommendation of eliminating acronyms throughout the entire message, not just in the source.

Key findings and recommendations for effective messaging:

- Confusion and misunderstanding are generated by the use of acronyms, abbreviations and jargon (Bean et. al 2016); therefore, they should not be used whenever possible. (Bennett 2015, Temnikova et. al 2015, Department of Justice 2012)
- Messages that are too vague are not helpful. (Bean et. al 2016) The information provided should be as specific as possible (Tyshchuk et. al 2012; Lindell et. al 1987).
- Messages should use words that are simple and familiar. (Temnikova et. al 2015)
- Messages should consist of fully-formed sentences. Incomplete thoughts or messages should be avoided. (Temnikova et. al 2015)
- ALL CAPS can be used in 2 ways: SIGNIFIER- specifies the content of the message, usually placed at the beginning. (e.g. "MANDATORY EVAC:..."). EMPHASIS- used in the middle of messages can draw the reader's attention to certain words (e.g. ...PLEASE...) (Sutton et. al 2014).
- Message compliance is directly related to understanding and emotional response (Liu et. al 2017).

4 Project Limitations

The scope of this project is limited by the number of characters in the short message alert. The research collected and implemented was done so under the assumption that the user would be generating messages with a length between 280 and 360c.

The research used to generate the tool as well as the problems/ shortcomings for each message portion are applicable to all imminent threat emergencies. The emphasis for defining these emergencies is in the time scale, they are events that are currently happening or are about to happen.

The message creation tool was generated specifically for creating wildfire evacuation-based WEAs.

The following key assumptions about the message receiver were also used when building the message creation tool:

- The message receiver will experience no external cues besides the warning message.
- The message receiver will receive a singular short warning message (no duplication of messages or multiple messages providing additional information).
- The message receiver is physically capable of receiving the warning message (i.e., he/she has a mobile device capable of receiving warning messages, he/she is part of the event and is in the proper area where a warning has been sent, the message reaches the user's device unaltered).
- The message receiver is aware that they have received the message, pays attention to it, and reads it.
- The message receiver has the ability to read and understand the message without translation or assistance (i.e., English speaking and full sighted).

5 Research Based Messaging Tool for Wildfire Emergencies

The research-based message creation tool, originally built in Excel, has been deconstructed below based on the five types of information necessary for an effective short message (i.e., source, hazard, location, timeline, guidance). The purpose of this deconstruction is for each content type to be discussed individually. The intent of this section is to provide the Promt(s), User Response Header(s), logic, and justification for building the message creation tool.

In this section, a 'Prompt' refers to the question begin posed to the message creator and a User Response Header (e.g., 'User Response 1:') identifies the user response for that Prompt. For each Prompt, the type of response required is denoted: fill-in, Yes/No, drop-down, or a combination of the three in parenthesis after the Prompt. Finally, the text that appears following the headers in *italics* is text the message creator would have either selected or entered.

First, each section lists the Prompt(s) and associated User Responses available in their text form. Following these, a section called 'Prompt Justification' includes the justification for why each prompt was included as well as the User Responses. Next, a 'Response Algorithm' is presented in paragraph form as well as a logic diagram to demonstrate how each User Response impacts the cascading Prompt[s] and potential Message Portions. Then, a section called 'Other Justification' is included to provide explanations for other decisions including, but not limited to, filler text, grammar, and punctuation.

The User Response Header system described in section 2 was employed in each of these sections. Examples of the system are listed below to show the numbering scheme.

If the Prompt is fill-in, the User Response is listed as *Response* followed by the associated Prompt number. For Example:

Prompt 1: What agency should be listed as the source of this message? (fill-in)

User Response 1: *Response 1*

If the Prompt is Yes/No or drop-down, the User Response available has been listed and can be identified by a letter following the associated Prompt number. For example:

Prompt 2: Does this agency use an acronym that is more common than its official title? (Yes/No)

User Response 2a: *No*

User Response 2b: *Yes*

If the Prompt requires the user to select multiple options, the User Responses are identified by the associated Prompt number, the associated User Response letter, then a dash followed by a number. The number following the dash identifies which option the response is for. In the following example, the user must select one option from the '-1' list and one from the '-2' list:

Prompt 5: What wildfire consequences should the public be aware of? "Wildfires can..." (drop-down, fill-in)

- **User Response 5a-1:** *burn down homes/other structures (32c.)*
- **User Response 5b-1:** *block roads/evacuation routes (30c.)*

- **User Response 5a-2:** *none*
- **User Response 5b-2:** *burn down homes/other structures (32c.)*

If the Prompt requires the user to respond to a drop-down within a drop-down, the User Responses are identified by the associated prompt number, the associated User Response letter, the User Response letter for the second drop-down, then a dash followed by a number. For example:

Prompt 12: When should people take action? (drop-down)

- **User Response 12a:** *Now (3c.)*
- **User Response 12b:** *Before ## (AM/PM) (11 or 12c.) (drop-down)*
  - **User Response 12b a-1:** *1*
  - **User Response 12b b-1:** *2*
  - **User Response 12b c-1:** *3* etc...

  - **User Response 12b a-2:** *AM*
  - **User Response 12b b-2:** *PM*

The next section, called 'Logic Diagram to Tool Interface' provides a table of how User Response Headers were changed in the message creation tool to make them more user-friendly. For example, 'User Response 1:' was changed to 'Enter the agency sending this message'. This portion also includes graphics of the user-interface for the message creation tool in its blank form.

Finally, in order to demonstrate the response algorithm and describe the tool completely, an example message was generated and used in each section (5.1-5.5):

Prince Georges County Fire Department (PGFD): WILDFIRE EMERGENCY located near East West Highway and 23rd Ave moving toward the Mall at Prince Georges. Wildfires can burn down homes/other structures, spread very fast. If you are receiving this message EVACUATE NOW. Do not delay to pack belongings. Check pgfdpio.blogspot.com for updates.

The user prompts and associated responses that were used to create the example message are shown in a graphic of the user interface for the message creation tool. Finally, the example message is listed and the portions of the message associated with the content section are highlighted.

5.1 Message Source

The source of the message identifies who/ which agency is providing the information and helps to establish credibility with the reader. Of the five sections necessary for inclusion, the source should be listed first. The main question that must be answered by the source portion of the message is:

Question 1: Who/which agency is sending this message?

To answer this question sufficiently, three user prompts were created. Prompt 1 and Prompt 2 will always appear in the message creation tool. Whether or not the user is asked to respond to Prompt 3 is dependant on his/her response to Prompt 2.

First, the prompts appear in their text form with their associated User Responses. Next, the response algorithm is written out to explain how the User Responses impact the cascading prompts as well as the final message portion. Following the algorithm is justification for why each of the prompts was included as well as other decisions regarding drop-down responses, punctuation, etc.

Prompt 1: What agency should be listed as the source of this message? (fill-in)

User Response 1: *Response 1*

Prompt 2: Does this agency use an acronym that is more common than its official title? (Yes/No)

User Response 2a: *No*

User Response 2b: *Yes*

Prompt 3: (If **User Response 2a:** *No*) Prompt not applicable. Continue to next prompt.

Prompt 3: (If **User Response 2b:** *Yes*) What is the acronym used by this agency? (fill-in)

User Response 3: *Response 3*

Prompt Justification:

Prompt 1 was included to establish the sender of the message because the message source has been shown as a necessary component of an effective short message.

Prompts 2 and 3 were included to determine if the message source uses an acronym that is more common than its official title, and if so, what the acronym is. The inclusion of these prompts contradicts the findings that stated that acronyms should never be included in message source, however there are some agencies that are more commonly known by their acronym than by their full name. In turn, these prompts were included to account for the portion of the public that would recognize an acronym over a full agency name. Acronyms alone can cause confusion, however with the inclusion of the full agency name and the agency acronym, there is a greater probability that

the source will be recognized. Therefore, if the message creator includes an acronym for the agency; both the full agency name and acronym would be included in the tool-generated message.

Response Algorithm:

The user will first be presented with Prompt 1 and his/her response is recorded as Response 1. Next, the user will be presented with Prompt 2. The user has an option of selecting User Response 2a or User Response 2b. If User Response 2a is selected, Prompt 3 will appear as 'Prompt not applicable. Continue to next prompt.' In this case, the Message Portion produced would appear as Response 1 followed by a colon (i.e., *Response 1:*).

If User Response 2b is selected, the user will be asked Prompt 3 and his/her response will be recorded as Response 3. In this case, the Message Portion produced would appear as Response 1, space, Response 3 in parenthesis, colon (i.e., *Response 1 (Response 3):*).

Figure 4 displays a logic diagram that is a visual representation of the response algorithm presented here. The use of '(or)' between two User Responses refers to a drop-down or Yes/No menu where the user has the option of selecting only one of the responses.

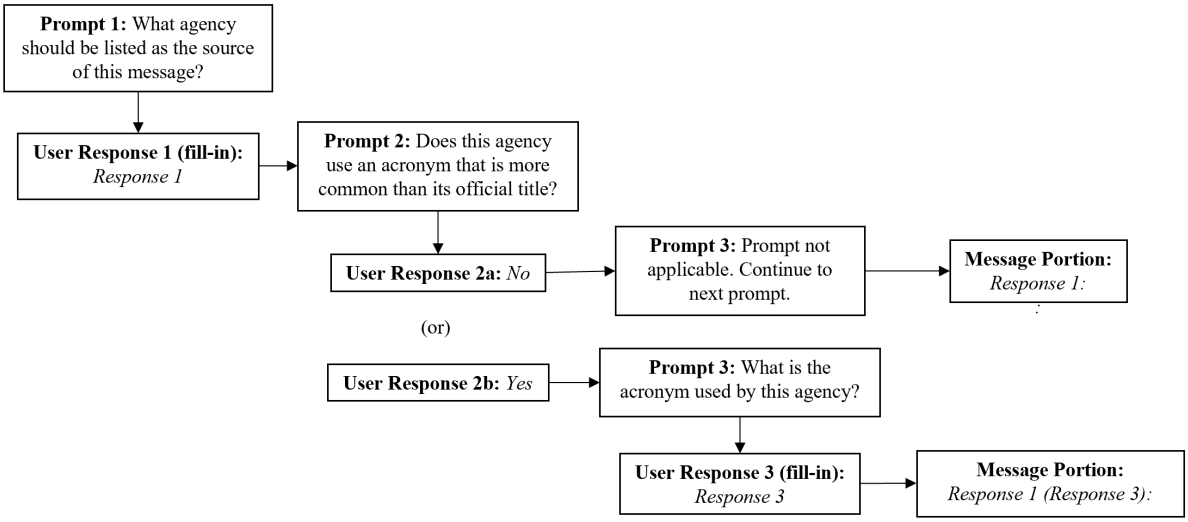


Figure 4: Logic Diagram for Prompts 1, 2, 3 based on the Message Source Response Algorithm

Other Justification:

Regardless of which is chosen, User Response 2(a or b), it was decided to have a colon following the agency or the agency and acronym to separate the message source from the next portion of the message (i.e., the hazard).

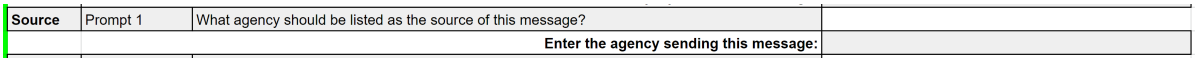
The formatting for User Response 3 was chosen because encasing the letters in parenthesis is a common designation for an agency acronym.

Logic Diagram to Tool Interface:

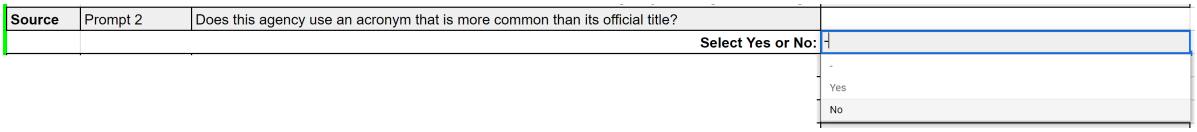
In an effort to make the tool user friendly, the User Response Headers were changed from their original form when entered in the tool. Table 2 contains a complete list of the changes that were made to the headers from the text/logic diagram form, to the form used in the message creation tool. The cascading images in Figure 5 illustrate the way each Prompt would appear in the interface of the message creation tool. Note: Prompt 3 has two different potential forms depending on the user response to Prompt 2, therefore, both are included.

User Response Header (as it appears in the text/logic diagram)	**User Response Header (as it appears in the message creation tool)**
User Response 1:	Enter the agency sending this message:
User Response 2(a-b):	Select Yes or No:
User Response 3:	Enter the acronym of the agency:

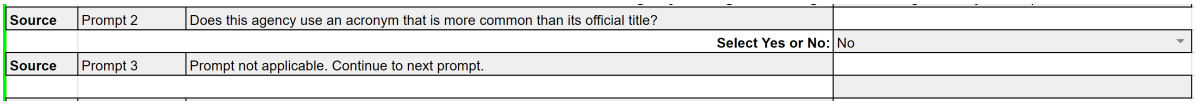
Table 2: User Response Headers for Message Source



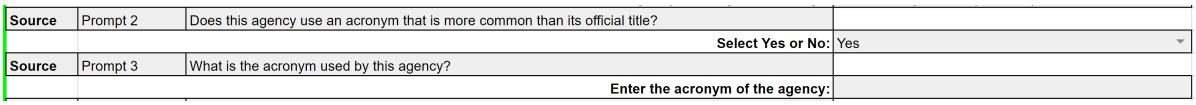
(a) Prompt 1.



(b) Prompt 2 and drop-down.



(c) Prompts 3 if User Response 2a: *No*



(d) Prompts 3 if User Response 2b: *Yes*

Figure 5: Prompts 1, 2, 3 as they appear in the message creation tool.

Example Message:

This section is used demonstrate the impact Prompts 1-3 have on an example message. Figure 6 shows the user interface of the message creation tool for Prompts 1-3. The User Responses that have been entered are those that were used to create the example message. Following Figure 6 is the example message with the Message Source portion highlighted.

Source	Prompt 1	What agency should be listed as the source of this message?	
		Enter the agency sending this message:	Prince Georges County Fire Department
Source	Prompt 2	Does this agency use an acronym that is more common than its official title?	
		Select Yes or No:	Yes
Source	Prompt 3	What is the acronym used by this agency?	
		Enter the acronym of the agency:	PGFD

Figure 6: Message Creation Tool: Example Source Responses

Prince Georges County Fire Department (PGFD): *WILDFIRE EMERGENCY located near East West Highway and 23rd Ave moving toward the Mall at Prince Georges. Wildfires can burn down homes/other structures, spread very fast. If you are receiving this message EVACUATE NOW. Do not delay to pack belongings. Check pgfdpio.blogspot.com for updates.*

5.2 Hazard Identification

The hazard identification portion of a message informs the reader of what hazard they should expect. Ideally, with a longer character count, the message will also contain the potential consequences of the hazard in order to increase threat and risk perception. The main questions that should be answered in the hazard identification portion of the message are:

Question 2: What is the hazard people are being warned about?

Question 3: What are the potential consequences of this hazard?

To answer these questions sufficiently two user prompts were created. Prompts 4 and 5 will always appear in the message creation tool. Prompt 5 contains 2 sets of user response options '-1' and '-2' because the user must select one response from each 'list' for this prompt.

Prompt 4: What type of emergency is happening or about to happen? (drop-down)

- **User Response 4a:** *Wildfire Emergency* (18c.)
- **User Response 4b:** *Tornado Emergency*
- **User Response 4c:** *Flash Flood*
- **User Response 4d:** *Active Shooter*
- **User Response 4e:** *Bomb Threat*

Prompt 5: What wildfire consequences should the public be aware of? "Wildfires can..." (drop-down, fill-in)

- **User Response 5a-1:** *burn down homes/other structures (32c.)*
- **User Response 5b-1:** *block roads/evacuation routes (30c.)*
- **User Response 5c-1:** *cause injury/death (18c.)*
- **User Response 5d-1:** *other (35c. limit) (fill-in)*
- **User Response 5d-1:** **(fill-in)** *Response 5d-1*

- **User Response 5a-2:** *none*
- **User Response 5b-2:** *burn down homes/other structures (32c.)*
- **User Response 5c-2:** *block roads/evacuation routes (30c.)*
- **User Response 5d-2:** *cause injury/death (18c.)*
- **User Response 5e-2:** *other (35c. limit) (fill-in)*
- **User Response 5e-2:** **(fill-in)** *Response 5e-2*

Prompt Justification:

Prompt 4 was included because the hazard that is occurring or about to occur needs to be clearly identified. This prompt has been included as a drop-down list because the options are predefined. Based on the limitation of this thesis (a focus on wildfires), User Response 4a is the only option that can be selected. User Responses 4(b-e) were included to demonstrate other options that could be included in the tool after it is developed further.

Prompt 5 was included because the consequences of the hazard have been shown to increase threat and risk perception. Prompt 5 provides the option for the message creator to select two User Responses (i.e., two consequences of the hazard). Prompt 5 was included as a drop-down because the consequences of wildfires for the most part, can be predefined.

User Response 5a-1 and 5b-2 (i.e., burn down homes/other structures) were included because the destruction of property is a major concern of wildfires that occur near communities. This response

includes the word 'home(s)' rather than houses because it was perceived that this word was more personal and would connect more with the message receiver.

User Response 5b-1 and 5c-2 (i.e., block roads/evacuation routes) were included because the main purpose of the message is evacuation. Including the consequence that fire could block the roads might create more urgency in the message receiver.

User Response 5c-1 and 5d-2 (i.e., cause injury/death) were included to inform the public that bodily harm is a concern in wildfire emergencies. Including this consequence might help the message receiver increase his/her sense of severity about the incident.

If User Response 5d-1 or 5e-2 (i.e., other (35c. limit)) is selected, the message creator has the option of typing in a consequence. It is not currently possible to select both of these User Responses and fill-in two consequences. This was included in case the message creator felt there was a consequence the public needed to be aware of other than those already listed. The character limit of the response option was set to 35c. because this allows a full phrase to be included without including so much that the message extends past 360c. This limit was also set to allow room for all message elements to be included.

Finally, User Response 5a-2 was included in case the message creator only wanted to include one wildfire consequence. There is no option 'none' for the first user response list because the message creator must include at least one consequence.

Response Algorithm:

The message creator will first be presented with Prompt 4. Even though there are multiple options, User Response 4a must be selected because limitations of this tool are for it to be used exclusively for wildfire emergencies. The Message Portion produced will read 'WILDFIRE EMERGENCY' in all capital letters. This phrase will appear after the message source colon.

Next, the user is presented with Prompt 5 where he/she has the option of selecting two consequences. If the user selected User Response 5d-1 or 5e-2, he/she will be asked to fill-in a wildfire consequence that is limited to 35c.

If the user selects User Response 5a-2 for the second option, only one wildfire consequence will be included and the Message Portion will read "Wildfires can" followed by User Response 5(a-d)-1 and a period (i.e., *Wildfires can Response 5(a-d)-1.*).

If the user selects an option from both lists other than User Response 5a-2, the Message Portion will appear as "Wildfires can" followed by Response 5(a-d)-1, comma, Response 5(a-e)-2, and a period (i.e., *Wildfires can Response 5(a-d)-1, Response 5(b-e)-2.*)

Figure 7 displays a logic diagram that is a visual representation of the response algorithm presented here. The use of '(or)' between two User Responses refers to a drop-down menu where the user has the option of selecting only one of the responses. The use of '(and)' refers to the message creator's ability to select one option from each drop-down list.

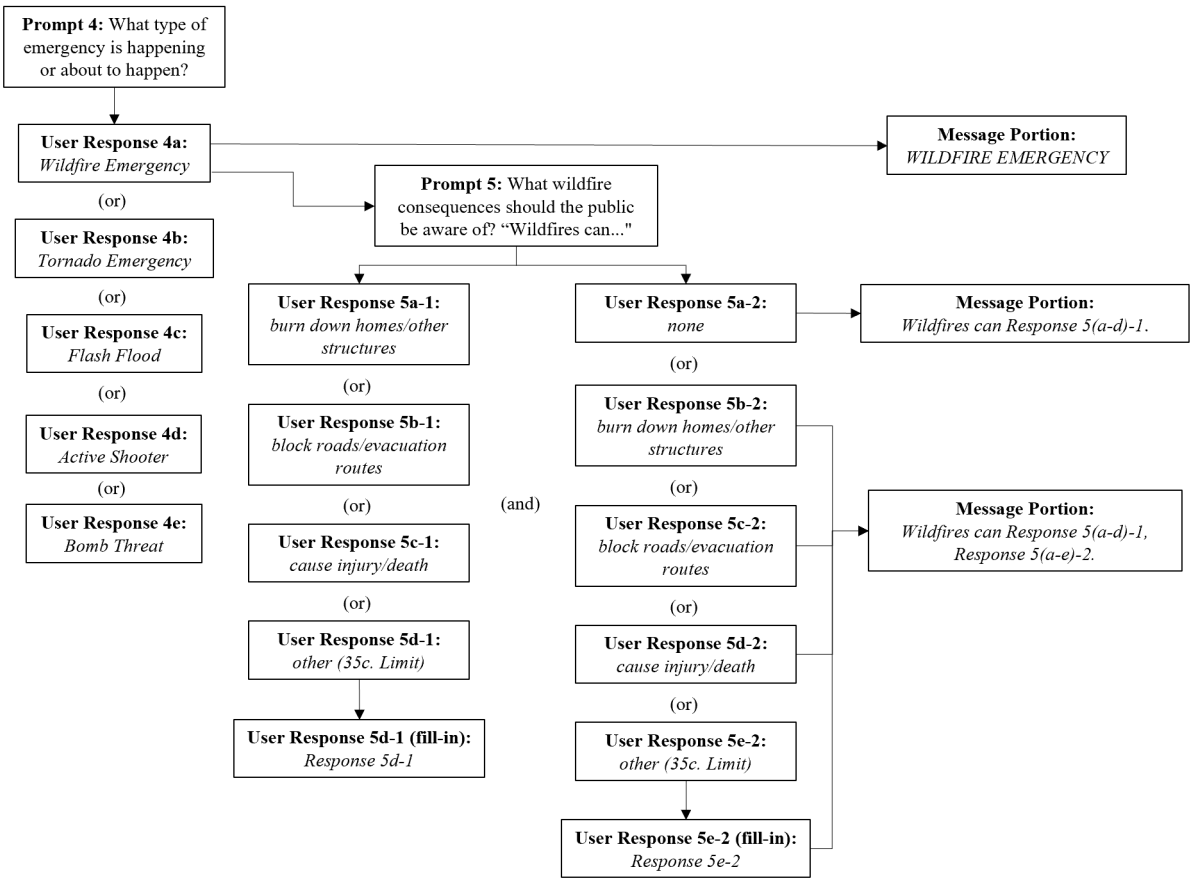


Figure 7: Logic Diagram for Prompts 4, 5 based on the Hazard Identification Response Algorithm

Other Justification:

The Message Portion for Prompt 4 appears in all capital letters in order to draw the readers attention to this phrase and emphasize it.

The phrase 'Wildfires can' was selected as the introduction for the consequences. 'Wildfires' was included to reiterate the hazard the public was being warned about. The word 'can' was chosen to describe the possibility of the consequences. Other words/phrases (e.g., 'have the ability to', 'will', 'might') were considered. These were not chosen because it was felt they were too wordy, expressed too much certainty the consequences would occur, or expressed an insufficient level of certainty, respectively. It was decided that 'can' expressed the possibility of the consequences occurring without over-defining the likelihood that they would occur.

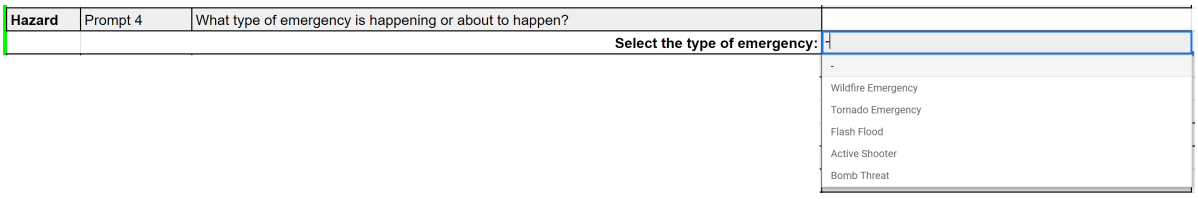
Logic Diagram to Tool Interface:

In an effort to make the tool user friendly, the User Response Headers were changed from their original form when entered in the tool. Table 3 contains a complete list of the changes that were made to the headers from the text/logic diagram form, to the form used in the message creation tool.

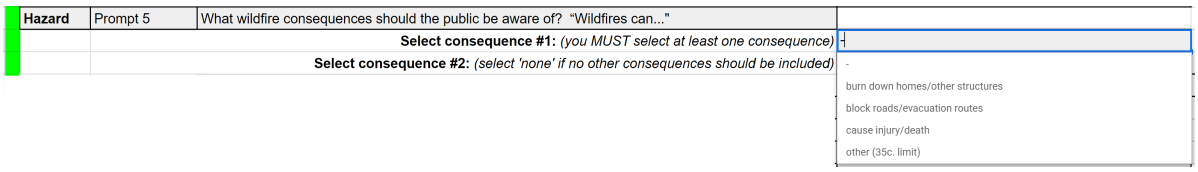
The cascading images in Figure 8 illustrate the way each Prompt would appear in the interface of the message creation tool. Note: Prompt 5 is included with the drop-downs for both consequence selections. It is also included with 'other (35c. limit)' selected to illustrate how the user is asked to fill-in the consequence. This is only shown for selecting 'other (35c. limit)' for consequence #2, but would appear in the same manner if it was chosen for consequence #1.

User Response Header (as it appears in the text/logic diagram)	**User Response Header (as it appears in the message creation tool)**
User Response 4(a-e):	Select the type of emergency:
User Response 5(a-d)-1:	Select consequence #1:
User Response 5(a-e)-2:	Select consequence #2:

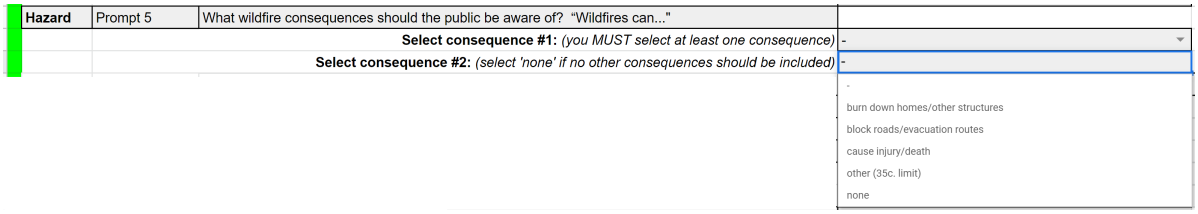
Table 3: User Response Headers for Hazard Identification



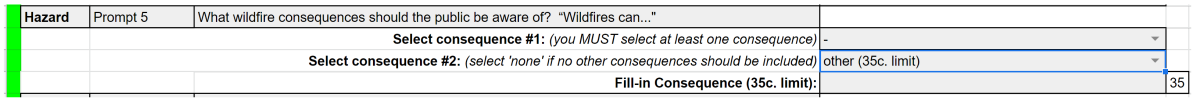
(a) Prompt 4 and drop-down.



(b) Prompt 5 and drop-down for Select consequence #1.



(c) Prompt 5 and drop-down for Select consequence #2.



(d) Prompt 5 after selecting 'other (35c. limit)' for consequence #2.

Figure 8: Prompts 4, 5 as they appear in the message creation tool.

Example Message:

This section is used demonstrate the impact Prompts 4 and 5 have on an example message. Figure 9 shows the user interface of the message creation tool for Prompts 4 and 5. The User Responses that have been entered are those that were used to create the example message. Following Figure 9 is the example message with the Hazard Identification portions highlighted. Note the '19' in the bottom right of Figure 9 refers to the number of characters the user has remaining for the fill-in response.

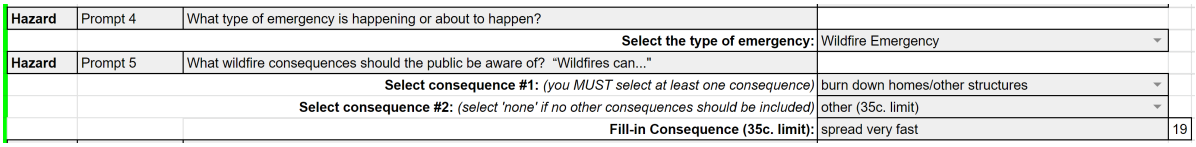


Figure 9: Message Creation Tool: Example Hazard Responses

Prince Georges County Fire Department (PGFD): *WILDFIRE EMERGENCY* *located near East West Highway and 23rd Ave moving toward the Mall at Prince Georges.* *Wildfires can burn down homes/other structures, spread very fast.* *If you are receiving this message EVACUATE NOW. Do not delay to pack belongings. Check pgfdpio.blogspot.com for updates.*

5.3 Hazard Location

The hazard location portion of the message should establish where the hazard is so that the user can determine that the hazard is a threat/risk to him/her. For a message with a longer character count, establishing the direction the hazard is moving can also help the receiver know if the area he/she is located in will be impacted next, potentially increasing threat perception and sense of urgency. Finally, if authorities have a known area of refuge for the evacuees, it can be included to help guide the receiver as he/she evacuates. The main questions that should be answered in the hazard location portion of the message are:

Question 4: What is the current location of the hazard?

Question 5: What direction is the hazard moving?

Question 6: What region(s) of people should evacuate?

To answer these questions sufficiently, six user prompts were created. The prompts can be separated into two categories; 1)hazard location and direction (Prompts 6, 7, 8, 9) and 2)evacuation location (Prompts 10, 11).

Prompt 6: Which will be used to identify the current location of the hazard? (drop-down)

- **User Response 6a:** *well known landmark(s)*
- **User Response 6b:** *town/city/county (all or portion)*
- **User Response 6c:** *major road(s)/ intersection(s)*

Prompt 7: The hazard is located (in/near/between) which *User Response 6(a-c)*? (drop-down, fill-in)

- **User Response 7a-1:** *in* (2c.)
- **User Response 7b-1:** *near* (4c.)
- **User Response 7c-1:** *between* (7c.)
- **User Response 7-2: (fill-in)** *Response 7-2*

Prompt 8: Which will be used to identify the direction the fire is spreading? (drop-down)

- **User Response 8a:** *well known landmark(s)*
- **User Response 8b:** *town/city/county (all or portion)*
- **User Response 8c:** *major road(s)/ intersection(s)*

Prompt 9: What is the name of the *User Response 8(a-c)* that the fire is moving towards? (fill-in)

User Response 9: *Response 9*

Prompt 10: Is there a specific region of people who should evacuate? (drop-down)

- **User Response 10a:** *No, everyone receiving this message should evacuate*
- **User Response 10b:** *Yes*

Prompt 11: (If **User Response 10a**) Prompt not applicable. Continue to next prompt.

Prompt 11: (If **User Response 10b**) People located (in/near/between) which region(s) should evacuate? (drop-down, fill-in)

- **User Response 11a-1:** *in (2c.)*
- **User Response 11b-1:** *near (4c.)*
- **User Response 11c-1:** *between (7c.)*

- **User Response 11-2: (fill-in)** *Response 11-2*

Prompt Justification:

Prompts 6, 7, 8, 9 focus on establishing the location of the hazard and the direction the hazard is moving. Prompt 6 was included to ask the message creator how the location of the hazard would be identified. User Responses 6(a-c) were included as a drop-down list because it was decided that these are the location identifiers that would be the most recognizable to a group of people. Having them in a drop down list educates the message creator that he/she should be identifying the hazard location by one of these three options.

Prompt 7 was included for the message creator to be able to express the exact location of the hazard. User Prompts 7(a-c)-1 allow the message creator to establish the proximity of the hazard to the location identifier. User Response 7-2 was included to allow the user to fill-in the name of the location identifier.

Prompt 8 was included to ask the the message creator which location identifier would be used to explain the direction the fire was spreading. The User Responses were included in the same way as User Response 6(a-c) to educate the message creator that he/she should be selecting one of these three location identifiers.

Finally, Prompt 9 was included as a fill-in for the message creator to establish the name of the location identifier the fire is moving towards.

Prompts 10 and 11 focus on the location of the people that are at risk (i.e., those who are being told to evacuate.) Prompt 10 was included to ask the message creator if there was a specific group of people who should be told to evacuate or if everyone receiving the message should evacuate.

User Response 10a was included because WEA messages are geo-targeted and the message creator could select this option if he/she wanted everyone to evacuate who was receiving it. User Response 10b was included for situations where a small population needs to be identified for evacuation, but the message is sent to a larger population that includes the affected and unaffected populations. Messages might be sent to larger populations intentionally (e.g., to provide them with information) or unintentionally (e.g., overshooting of the WEA geo-targeted area).

Prompt 11 was included for the message creator to identify the location of people who should evacuate, if not everyone receiving the message is being told to evacuate (i.e., the message is being sent to a large population but only a small population within is being told to evacuate). User Responses 11(a-c)-1 were included as a drop-down for the message creator to identify the proximity of the people who should evacuate to the location identifier. User Response 11-2 was included for the message creator to fill-in the location identifier for those being told to evacuate.

Response Algorithm:

The user is first presented with Prompt 6 where he/she will be presented with a three item drop-down list, User Response 6(a-c). The selection for Prompt 6 will be inputted into the *'User Response 6(a-c)'* portion of Prompt 7. When the user is presented with Prompt 7, he/she will need to make 2 selections. The first selection is User Response 7(a-c)-1 that will identify the proximity of the hazard to the location that the user will fill-in for User Response 7-2. The message portion produced will appear as "located" followed by the proximity word and then Response 7-2 (i.e., *located Response 7(a-c)-1 Response 7-2*).

Next, the user is presented with Prompt 8 that is included in the same way as the drop-down in Prompt 6. The selection for Prompt 8 will be included in the *'User Response 8 (a-c)'* portion of Prompt 9. Prompt 9 requires the user to fill-in the location identifier the fire is moving toward. The message portion produced by these prompts begins with "moving towards" and ends with User Response 9 followed by a period (i.e., *'moving toward Response 9.'*

Prompt 10 was included as a drop-down to establish who is being told to evacuate. If User Response 10a is selected, Prompt 11 appears as 'Prompt not applicable. Continue to next prompt.' In this case, the message portion produced would read 'If you are receiving this message'. If User Response 10b is selected, the message receiver would be presented with Prompt 11.

Prompt 11 requires the user to make 2 selections. User Response 11(a-c)-1 that will identify the proximity of the people being told to evacuate to the location filled-in for User Response 11-2. The message portion produced will read "If you are located" followed by Response 11(a-c)-1 then

Response 11-2 (i.e., *'If you are located Response 11(a-c)-1 Response 11-2'*.

Figure 10 displays a logic diagram that is a visual representation of the response algorithm presented here. The use of '(or)' between two User Responses refers to a drop-down menu where the user has the option of selecting only one of the responses. The use of '(and)' refers to the message creator's ability to select one option from each drop-down list.

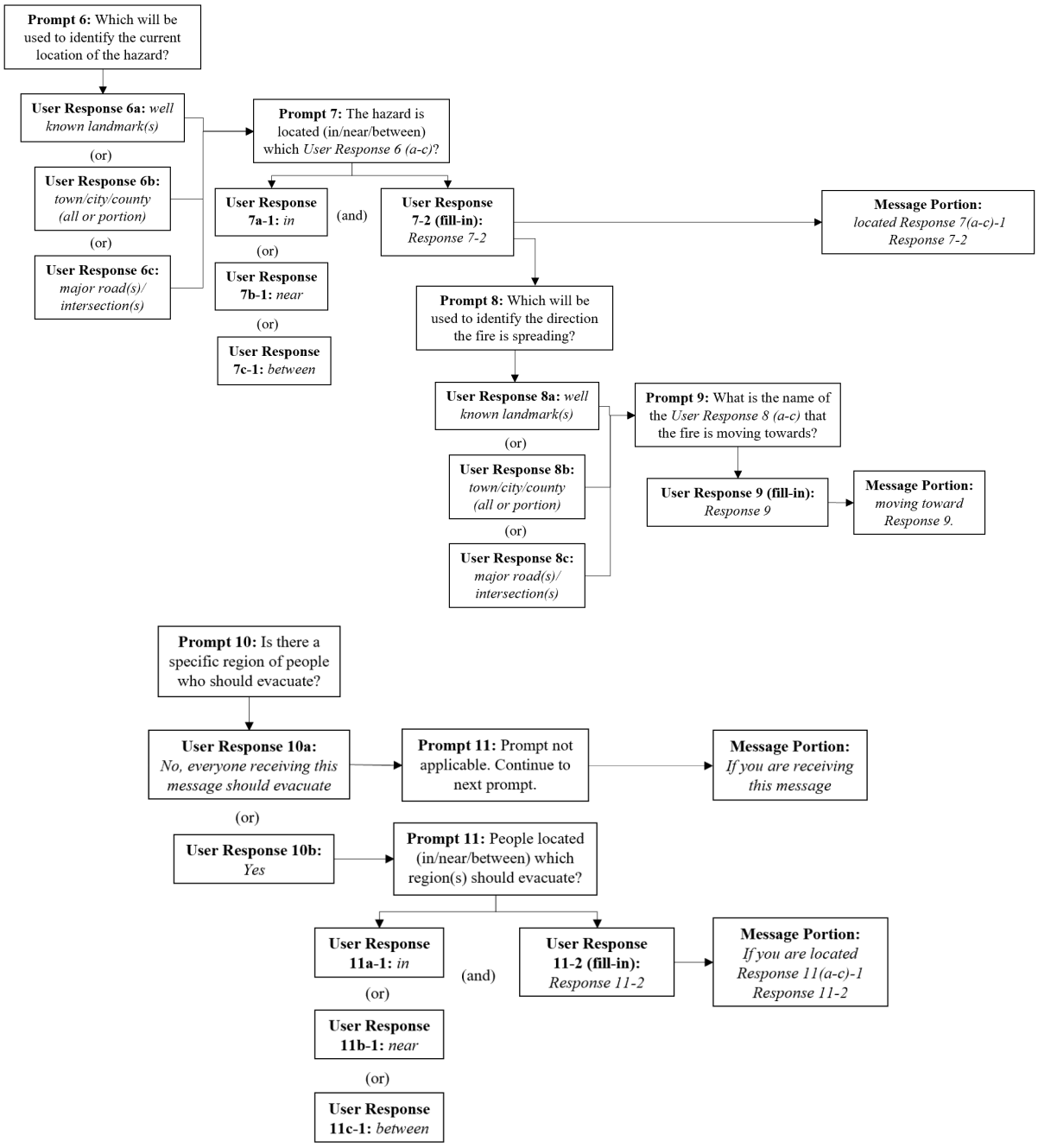


Figure 10: Logic Diagrams for Prompts 6, 7, 8, 9, 10, 11 based on the Hazard Location Response Algorithm

Other Justification:

Originally, the message portions produced after Prompt 11 read "Those" instead of "If you are". The first provided the benefit that it was used less characters; however, the portion was eventually switched to the latter. It was decided that the usage of the word 'you' made the message more personal and had the potential of increasing the message receiver's personalization and compliance.

Logic Diagram to Tool Interface:

In an effort to make the tool user friendly, the User Response Headers were changed from their original form when entered in the tool. Table 4 contains a complete list of the changes that were to the headers from the text/logic diagram form, to the form used in the message creation tool. Note some of the User Response Headers in the message creation tool interface include a '-'. This is because the text that will replace the '-' is dependant upon the selection in the previous prompt. Until the previous prompt is filled out, the text will continue to appear as a '-'.

Figure 11 is a graphic that illustrates the way each Prompt would appear in the message creation tool interface. Prompts that may have multiple appearances, such as those that are dependent on the responses or other prompts, appear in all forms. For instance, the text in Prompt 7 is dependant on the user selection in Prompt 6.

User Response Header (as it appears in the text/logic diagram)	**User Response Header (as it appears in the message creation tool)**
User Response 6(a-c):	Select which will be used to identify the location of the hazard:
User Response 7(a-c)-1:	Select the proximity of the hazard to the -:
User Response 7-2:	Enter the - the hazard is located (in/near/between):
User Response 8(a-c):	Select which will be used to identify the direction the fire is spreading:
User Response 9:	Enter the - the fire is moving towards:
User Response 10(a-b):	Select Yes or No:
User Response 11(a-c)-1:	Select the proximity of the evacuation area to the region:
User Response 11-2:	Enter the region(s) of people who should evacuate:

Table 4: User Response Headers for Hazard Location

Location	Prompt 6	Which will be used to identify the current location of the hazard?	

-
well known landmark(s)
town/city/county (all or portion)
major road(s)/ intersection(s)

(a) Prompt 6 and drop-down.

Location	Prompt 7	The hazard is located (in/near/between) which -?	
		Select the proximity of the hazard to the -:	(in/near/between)
		Enter the - the hazard is located (in/near/between): (separate multiple with 'and' or ',')	

(b) Prompt 7 as it appears before selections are made for Prompt 6.

Location	Prompt 6	Which will be used to identify the current location of the hazard?	
		Select which will be used to identify the location of the hazard:	well known landmark(s)
Location	Prompt 7	The hazard is located (in/near/between) which well known landmark(s)?	
		Select the proximity of the hazard to the well known landmark(s):	(in/near/between)
		Enter the well known landmark(s) the hazard is located (in/near/between): (separate multiple with 'and' or ',')	

(c) Prompt 7 with 'well known landmark(s)' selected for Prompt 6.

Location	Prompt 6	Which will be used to identify the current location of the hazard?	
		Select which will be used to identify the location of the hazard:	major road(s)/ intersection(s)
Location	Prompt 7	The hazard is located (in/near/between) which major road(s)/ intersection(s)?	
		Select the proximity of the hazard to the major road(s)/ intersection(s):	(in/near/between)
		Enter the major road(s)/ intersection(s) the hazard is located (in/near/between): (separate multiple with 'and' or ',')	

(d) Prompt 7 with 'major road(s)/intersection(s)' selected for Prompt 6.

Location	Prompt 6	Which will be used to identify the current location of the hazard?	
		Select which will be used to identify the location of the hazard:	town/city/county (all or portion)
Location	Prompt 7	The hazard is located (in/near/between) which town/city/county (all or portion)?	
		Select the proximity of the hazard to the town/city/county (all or portion):	(in/near/between)
		Enter the town/city/county (all or portion) the hazard is located (in/near/between): (separate multiple with 'and' or ',')	

(e) Prompt 7 with 'town/city/county (all or portion)' selected for Prompt 6.

Location	Prompt 8	Which will be used to identify the direction the fire is spreading?	

-
well known landmark(s)
town/city/county (all or portion)
major road(s)/ intersection(s)

(f) Prompt 8 and drop-down.

Location	Prompt 9	What is the name of the - that the fire is moving towards?	
		Enter the - that the fire is moving towards:	

(g) Prompt 9 as it appears before selections are made for Prompt 8.

Location	Prompt 8	Which will be used to identify the direction the fire is spreading?	
		Select which will be used to identify the direction the fire is spreading:	well known landmark(s)
Location	Prompt 9	What is the name of the well known landmark(s) that the fire is moving towards?	
		Enter the well known landmark(s) that the fire is moving towards:	

(h) Prompt 9 with 'well known landmark(s)' selected for Prompt 8.

Location	Prompt 8	Which will be used to identify the direction the fire is spreading?	
		Select which will be used to identify the direction the fire is spreading:	major road(s)/ intersection(s)
Location	Prompt 9	What is the name of the major road(s)/ intersection(s) that the fire is moving towards?	
		Enter the major road(s)/ intersection(s) that the fire is moving towards:	

(i) Prompt 9 with 'major road(s)/intersection(s)' selected for Prompt 8.

Location	Prompt 8	Which will be used to identify the direction the fire is spreading?	
		Select which will be used to identify the direction the fire is spreading:	town/city/county (all or portion)
Location	Prompt 9	What is the name of the town/city/county (all or portion) that the fire is moving towards?	
		Enter the town/city/county (all or portion) that the fire is moving towards:	

(j) Prompt 9 with 'town/city/county (all or portion)' selected for Prompt 8.

Location	Prompt 10	Is there a specific region of people who should evacuate?	
		Select Yes or No:	-

-
Yes
No, everyone receiving this message should evacuate

(k) Prompt 10 and drop-down.

Location	Prompt 10	Is there a specific region of people who should evacuate?	
		Select Yes or No:	No, everyone receiving this message should evacuate
Location	Prompt 11	Prompt not applicable. Continue to next prompt.	

(l) Prompt 11 with 'no, everyone receiving this message should evacuate' selected for Prompt 10.

Location	Prompt 10	Is there a specific region of people who should evacuate?	
		Select Yes or No:	Yes
Location	Prompt 11	People located (in/near/between) which region(s) should evacuate?	
		Select the proximity of the evacuation area to the region:	(in/near/between)
		Enter the region(s) of people who should evacuate: (separate with ',' if more than 1)	

(m) Prompt 11 with 'Yes' selected for Prompt 10.

Location	Prompt 10	Is there a specific region of people who should evacuate?	
		Select Yes or No:	Yes
Location	Prompt 11	People located (in/near/between) which region(s) should evacuate?	
		Select the proximity of the evacuation area to the region:	(in/near/between)
		Enter the region(s) of people who should evacuate: (separate with ',' if more than 1)	

(in/near/between)
in
near
between

(n) Prompt 11 and drop-down with 'Yes' selected for Prompt 10.

Figure 11: Prompts 6, 7, 8, 9, 10, 11 as they appear in the message creation tool.

Example Message:

This section is used demonstrate the impact Prompts 6, 7, 8, 9, 10, 11 have on an example message. Figure 12 shows the user interface of the message creation tool for Prompts 6, 7, 8, 9, 10, 11. The User Responses that have been entered are those that were used to create the example message. Following Figure 12 is the example message with the Hazard Location portions highlighted.

Location	Prompt 6	Which will be used to identify the current location of the hazard?	
		Select which will be used to identify the location of the hazard:	major road(s)/ intersection(s)
Location	Prompt 7	The hazard is located near which major road(s)/ intersection(s)?	
		Select the proximity of the hazard to the major road(s)/ intersection(s):	near
		Enter the major road(s)/ intersection(s) the hazard is located near: (separate multiple with 'and' or ',')	East West Highway and 23rd Ave
Location	Prompt 8	Which will be used to identify the direction the fire is spreading?	
		Select which will be used to identify the direction the fire is spreading:	well known landmark(s)
Location	Prompt 9	What is the name of the well known landmark(s) that the fire is moving towards?	
		Enter the well known landmark(s) that the fire is moving towards:	the Mall at Prince Georges
Location	Prompt 10	Is there a specific region of people who should evacuate?	
		Select Yes or No:	No, everyone receiving this message should evacuate
Location	Prompt 11	Prompt not applicable. Continue to next prompt.	
			(in/near/between)

Figure 12: Message Creation Tool: Example Location Responses

Prince Georges County Fire Department (PGFD): WILDFIRE EMERGENCY located near East West Highway and 23rd Ave moving toward the Mall at Prince Georges. Wildfires can burn down homes/other structures, spread very fast. If you are receiving this message EVACUATE NOW. Do not delay to pack belongings. Check pgfdpio.blogspot.com for updates.

5.4 Event Timeline

The event timeline portion of a message is used to establish when the hazard begins, when it will end, and when people need to act. In many messages, only the end time of the hazard is identified because it is assumed the hazard has already begun when the message is sent. For wildfires, there is no clear time when the hazard will be over and the commencement of the hazard has already been established by the message being sent. Therefore, the most important piece of information that needs to be determined is how long the public has until they should act. The main question that should be answered in the event timeline portion of the message is:

Question 7: How long does the message receiver have until he/she needs to act?

To answer this question sufficiently one user prompt was created. Prompt 12 will appear at all times in the message creation tool.

Prompt 12: When should people take action? (drop-down)

- **User Response 12a:** *Now (3c.)*
- **User Response 12b:** *Before ## (AM/PM) (11 or 12c.) (drop-down)*
  - **User Response 12b a-1:** *1*
  - **User Response 12b b-1:** *2*
  - **User Response 12b c-1:** *3*
  - **User Response 12b d-1:** *4*
  - **User Response 12b e-1:** *5*
  - **User Response 12b f-1:** *6*
  - **User Response 12b g-1:** *7*
  - **User Response 12b h-1:** *8*
  - **User Response 12b i-1:** *9*
  - **User Response 12b j-1:** *10*
  - **User Response 12b k-1:** *11*
  - **User Response 12b l-1:** *12*

  - **User Response 12b a-2:** *AM*
  - **User Response 12b b-2:** *PM*

Prompt Justification:

By identifying that there is a wildfire emergency, the start of the hazard has already been identified. Therefore, the purpose of the timeline is to tell people when they need to act. Prompt 12 was included to identify when people should take action. User Response 12a was included to identify that the message receiver should take action right away. User Response 12b was included to identify if there is a specific time before which the message receiver should take action. Because there are are a finite number of times that can be selected for User Response 12b, User Response 12b (a-l)-1 and User response 12b (a-b)-2 were included as drop-downs. AM/PM were chosen to identify the time rather than military time because it was felt the use of AM/PM is more common practice.

Response Algorithm:

The message creator will be presented with Prompt 12 and will have the option between selecting User Response 12a or User Response 12b. If User Response 12a is selected, the message portion produced will read 'NOW.'. If User Response 12b is selected, the message creator will be be presented

with drop-downs User Response 12b (a-l)-1 and User Response 12b 2(a-b)-2 and one option from each drop-down will be chosen to establish the time before which the message receiver must act. The message portion produced will read "BEFORE" followed by Response 12b (a-l)-1, Response 12b (a-b)-2, and a period (i.e., *BEFORE Response 12b (a-l)-1 Response 12b (a-b)-2.*).

Figure 13 displays a logic diagram that is a visual representation of the response algorithm presented here. The use of '(or)' between two User Responses refers to a drop-down menu where the user has the option of selecting only one of the responses. The use of '(and)' refers to the message creator's ability to select one option from each drop-down list.

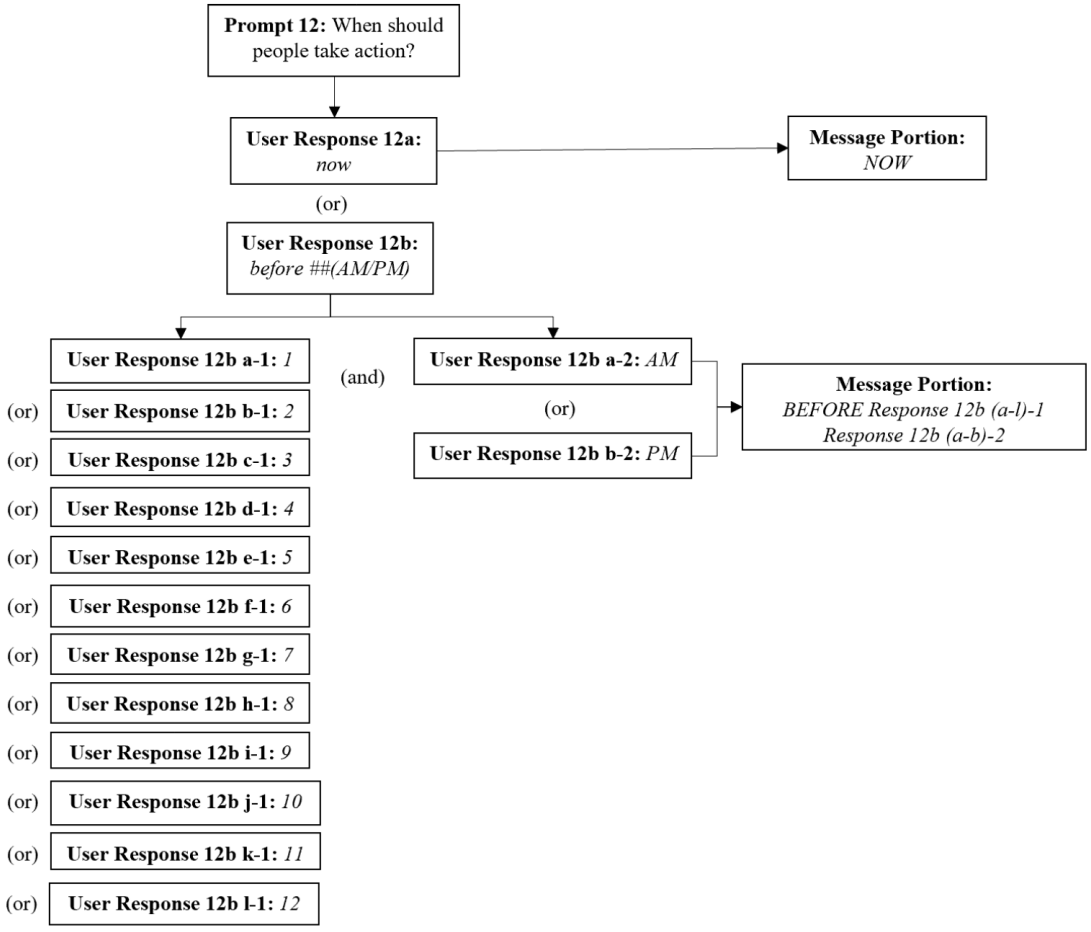


Figure 13: Logic Diagrams for Prompt 12 based on the Timeline Response Algorithm

Other Justification:

In some WEA messages, such as those from the National Weather Service (2018), the time is used in conjunction with the timezone. The decision was made to not include time zones in the message creation tool because they are acronyms that have the potential to be misinterpreted.

When displaying the time in the 360c. WEA message, it was chosen to have the 'NOW' and 'BEFORE' in all caps to emphasize they are important and the message receiver should pay attention to them.

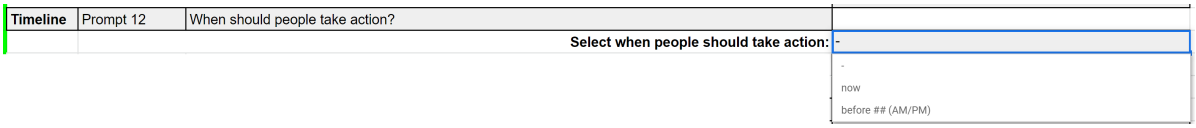
Logic Diagram to Tool Interface:

In an effort to make the tool user friendly, the User Response Headers were changed from their original form when entered into the tool. Table 5 contains a complete list of the changes that were to the headers from the text/logic diagram form, to the form used in the message creation tool.

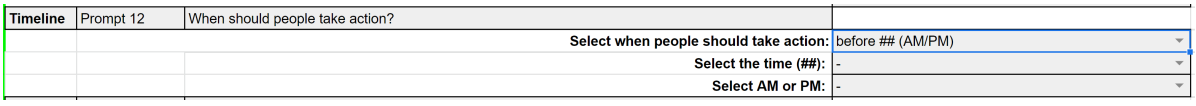
Figure 14 is a graphic that illustrates the way Prompt 12 would appear in the message creation tool interface.

User Response Header (as it appears in the text/logic diagram)	**User Response Header (as it appears in the message creation tool)**
User Response 12(a-b):	Select when people should take action:
User Response 12b (a-l)-1:	Select the time (##):
User Response 12b (a-b)-2:	Select AM or PM:

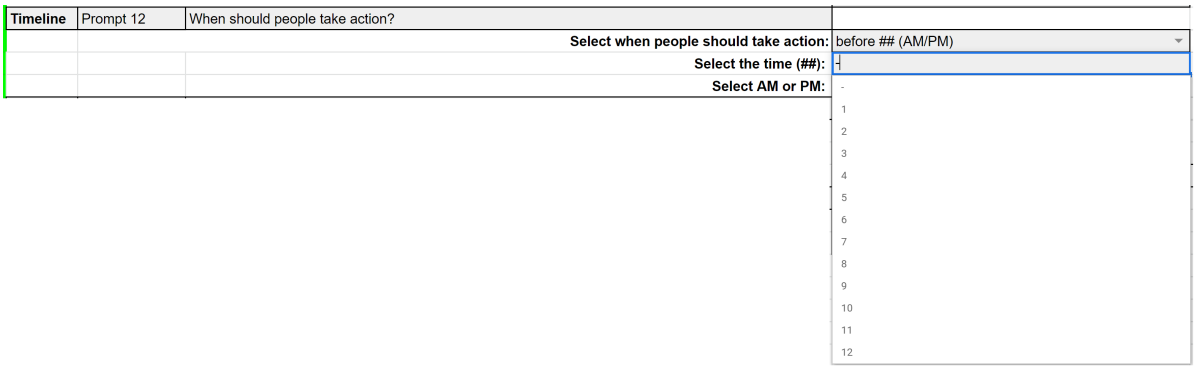
Table 5: User Response Headers for Timeline



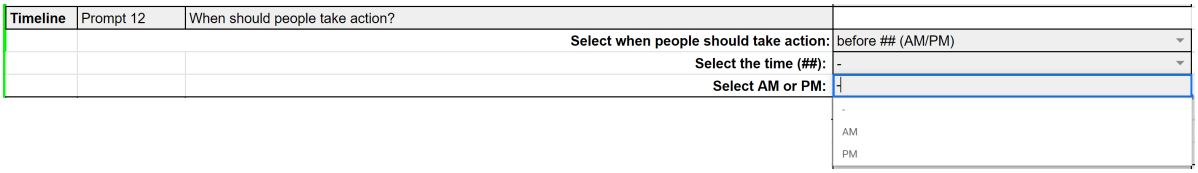
(a) Prompt 12 and drop-down.



(b) Prompt 12 if 'before ## (AM/PM)' is selected.



(c) Prompt 12 and drop-down for time selection.



(d) Prompt 12 and drop-down for AM/PM selection.

Figure 14: Prompt 12 as it appears in the message creation tool.

Example Message:

This section is used demonstrate the impact Prompt 12 has on an example message. Figure 15 shows the user interface of the message creation tool for Prompt 12. The User Response that has been entered is the one that was used to create the example message. Following Figure 12 is the example message with the timeline portion highlighted.

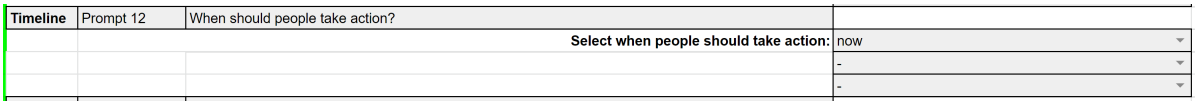


Figure 15: Message Creation Tool: Example Timeline Responses

Prince Georges County Fire Department (PGFD): WILDFIRE EMERGENCY located near East West Highway and 23rd Ave moving toward the Mall at Prince Georges. Wildfires can burn down homes/other structures, spread very fast. If you are receiving this message EVACUATE NOW. Do not delay to pack belongings. Check pgfdpio.blogspot.com for updates.

5.5 Protective Action Guidance

The protective action guidance portion of the message is used to instruct the message receiver of what he/she should do in response to the hazard. The guidance can be viewed as the 'goal' of the message (i.e., the message is being sent because authorities want the message receiver to take this/ these specific action(s)). The main question that should be answered in the protective action guidance portion of the message is:

Question 8: What protective actions should the message receiver be following?

To answer this question sufficiently three user prompts were created. Prompts 13, 14, 15 will appear at all times in the message creation tool.

Prompt 13: What is the main purpose of this message? (drop-down)

- **User Response 13a:** *Evacuation*
- **User Response 13b:** *Provide Information*
- **User Response 13c:** *Shelter-in-place*

Prompt 14: What specific actions should people receiving this message take? (drop-down, fill-in)

- **User Response 14a-1:** *Do not delay to pack belongings. (32c.)*
- **User Response 14b-1:** *Other (35c. limit)*
- **User Response 14b-1:** **(fill-in)** *Response 14b-1*

- **User Response 14a-2:** *none*
- **User Response 14a-2:** *Do not delay to pack belongings. (32c.)*
- **User Response 14b-2:** *Other (35c. limit)*
- **User Response 14b-2:** **(fill-in)** *Response 14b-2*

Prompt 15: Where should people go for updates?

- **User Response 15a:** *none*
- **User Response 15b:** *Check* $\{$*website*$\}$ *for updates. (19c. without website)*
- **User Response 15b:** $\{$*website*$\}$
- **User Response 15c:** *Call* $\{$*phone number*$\}$ *for updates. (30c.)*
- **User Response 15b:** $\{$*phone number*$\}$

Prompt Justification:

The majority of WEAs for imminent threat emergencies are for providing information or instructing people to either stay (i.e., shelter-in-place) or go (i.e., evacuate). Prompt 13 has a drop-down menu with these three options, User Responses 13(a-c). Presently for this tool, the only option that can be selected is User Response 13a (i.e., evacuation). User Responses 13(b-c) have been included to demonstrate the possible capabilities of the tool with further development.

Prompt 14 is included as a drop-down and asks what supplemental guidance should be provided to the message receiver. For Prompt 14, the user has the option of selecting two pieces of supplemental guidance. User Response 14a-1 and User Response 14b-2 were included because it was decided that informing the public that they did not have time to pack their belongings may evoke a sense of urgency. User Response 14b-1 and User Response 14c-2 were included so the message creator has the option to fill-in his or her own guidance. The character limit was set to 35c. because this allows a full phrase to be included without including so much that the message extends past 360c. This limit was also set to allow room for all of the other content elements of the message to be included.

Prompt 15 was included for the message creator to educate the message receiver about where he/she should go for update information. User Response 15a was included in case the message creator does not want to send a source of update information. User Response 15b and 15c were included if the message receiver wants to include a website or phone number, respectively. There is the possibility that including a website or phone number might cause extra milling time as message receivers search for additional information. However, it was decided that providing a specific location for individuals to search for more information would decrease the overall amount of milling time.

Response Algorithm:

The message creator is first presented with Prompt 13 and due to the limitations of the tool, only User Response 13a can be selected. The message portion that will appear reads 'EVACUATE' and is located before the timeline.

Next, the message creator is presented with Prompt 14 and has the ability to select two protective actions. If the user selects User Response 14b-1 or 14c-2, he/she will be asked to fill-in a protective action that is limited to 35c. It is not currently possible for the message creator to select both 14b-1 and 14c-2 and fill-in two protective actions. If the message creator wishes to include two consequences, one can be fill-in and the other must be one of the predetermined consequences.

If the user selects User Response 14a-2 for the second option, only one protective action guidance will be included in the message. Note the user MUST select at least one protective action guidance.

Finally, the message creator will be presented with Prompt 15 to determine if he/she wants to include a channel for the message receivers to go for update information. If the message creator selects User Response 15a, no update information will be included and the message portion will read either *'Response 14(a-b)-1.'* or *'Response 14(a-b)-1. Response 14(b-c)-2.'* depending on if one or two protective actions were selected.

If User Response 15b or 15c is selected, the message creator will be asked to fill in the {phone number} or {website}, respectively. In this case, the message will read *'Response 14(a-b)-1. Response 15(b-c).'* or *'Response 14(a-b)-1. Response 14(b-c)-2. Response 15(b-c).'* depending on if one or two protective actions were selected.

Figure 16 displays a logic diagram that is a visual representation of the response algorithm presented here. The use of '(or)' between two User Responses refers to a drop-down menu where the user has the option of selecting only one of the responses. The use of '(or)' between two message portions refers to only one of the portions being displayed depending on the previous User Responses. The use of '(and)' refers to the message creator's ability to select one option from each drop-down list.

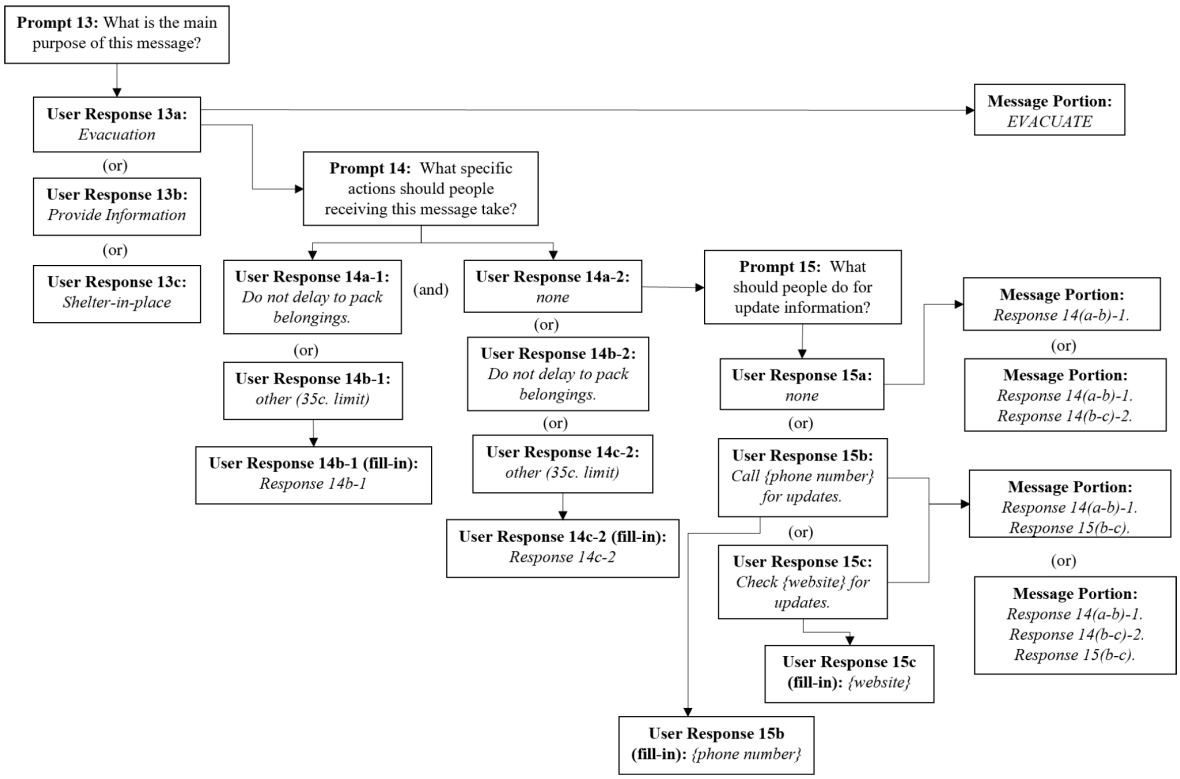


Figure 16: Logic Diagram for Prompts 13, 14, 15 based on the Protective Action Guidance Response Algorithm.

Other Justification:

User Response 13a identifies the main purpose of the message as "Evacuation". However, the message portion that is created when this is selected is 'EVACUATE'. This was done to change the purpose from a noun to a verb and to let people know this is an action they should be taking.

User Response 15b originally required the user to enter a phone number in the traditional 10-digit format (i.e., ###-###-####). However, this was changed to allow the message creator to enter the phone number with the number of digits and formatting of his/her choosing. This was done because the 10-digit formatting was not inclusive of the agencies that potentially used shorter phone numbers as information hot-lines (e.g., 2-1-1).

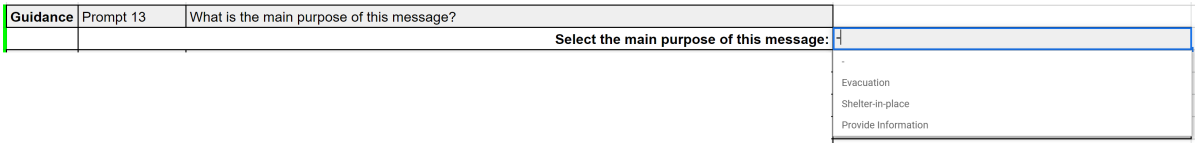
Logic Diagram to Tool Interface:

In an effort to make the tool user friendly, the User Response Headers were changed from their original form when entered in to the tool. Table 6 contains a complete list of the changes that were to the headers from the text/logic diagram form, to the form used in the message creation tool.

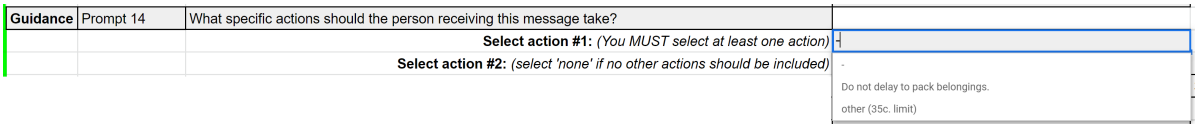
Figure 17 is a graphic that illustrates the way each Prompt would appear in the interface of the message creation tool. Note: Some prompts have multiple appearances, such as Prompt 15 that may require the user to enter additional information depending on his/her selection. If a Prompt has multiple forms, graphics of all interface options are included.

User Response Header (as it appears in the text/logic diagram)	**User Response Header (as it appears in the message creation tool)**
User Response 13(a-c):	Select the main purpose of this message:
User Response 14(a-b)-1:	Select action #1:
User Response 14(a-c)-2:	Select action #2:
User Response 15(a-c):	Select action:

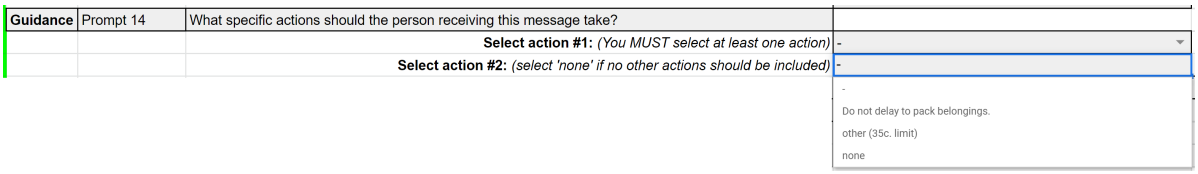
Table 6: User Response Headers for Protective Action Guidance.



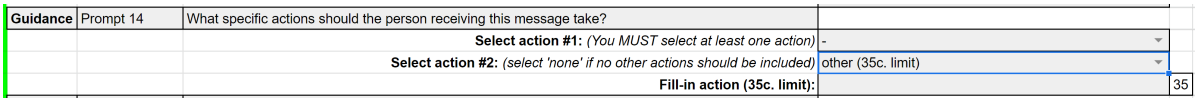
(a) Prompt 13 and drop-down.



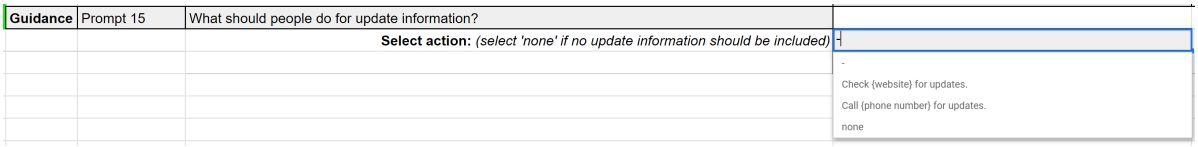
(b) Prompt 14 and drop-down for Select action #1.



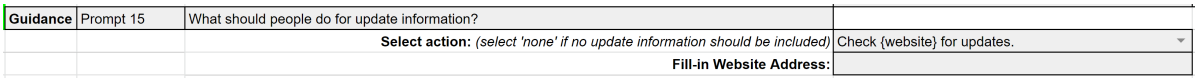
(c) Prompt 14 and drop-down for Select action #2.



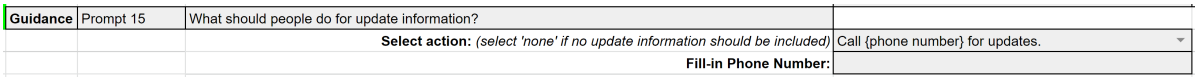
(d) Prompt 14 if 'other 35c. limit' was selected for either action #1 or action #2.



(e) Prompt 15 and drop down.



(f) Prompt 15 if 'Check {website} for updates.' is selected.



(g) Prompt 15 if 'Call {phone number} for updates.' is selected.

Figure 17: Prompts 13, 14, 15 as they appear in the message creation tool.

Example Message:

This section is used demonstrate the impact Prompts 13, 14, 15 have on an example message. Figure 18 shows the user interface of the message creation tool for Prompts 13, 14, 15. The User Responses that have been entered are those that were used to create the example message. Following Figure 18 is the example message with the Protective Action Guidance portions highlighted.

Guidance	Prompt 13	What is the main purpose of this message?	
		Select the main purpose of this message:	Evacuation
Guidance	Prompt 14	What specific actions should the person receiving this message take?	
		Select action #1: *(You MUST select at least one action)*	Do not delay to pack belongings.
		Select action #2: *(select 'none' if no other actions should be included)*	none
			35
Guidance	Prompt 15	What should people do for update information?	
		Select action: *(select 'none' if no update information should be included)*	Check {website} for updates.
		Fill-in Website Address:	pgfdpio.blogspot.com

Figure 18: Message Creation Tool: Example Protective Action Guidance Responses

Prince Georges County Fire Department (PGFD): WILDFIRE EMERGENCY located near East West Highway and 23rd Ave moving toward the Mall at Prince Georges. Wildfires can burn down homes/other structures, spread very fast. If you are receiving this message EVACUATE NOW. Do not delay to pack belongings. Check pgfdpio.blogspot.com for updates.

6 Case Studies

In order to demonstrate the validity and benefits of the message creation tool, three case studies have been completed. The messages being analyzed are the original 90c. WEA messages sent during the 2017 southern California Thomas Fire, the 2017 southern California Lilac Fire, and the 2014 Washington Lake Spokane Fires, respectively.

A message written with a 360c. limit vs a 90c. limit may be viewed as superior without investigation because of its extended length and ability to include more information and details. However, if used improperly, the additional information may confuse the message receiver and cause delays in their protective action taking (i.e., increase milling time). The extra 270c. available when the WEA character limit increases from 90c. to 360c. in May of 2019 allow for additional and clarifying information to be added to the messages. The message creation tool assists the message creator in generating an effective and useful message with 15 basic prompts. These prompts ensure the information being included addresses the 5 types of content necessary as well as supplemental information that is relevant and useful to the message receiver.

For each of the case studies these sections will be included:

- introduction and background information on the fire
- the original message sent as well as a table breaking down the message into the 5 content sections and comments about each
- a summarized list of issues and shortcomings of the original 90c. message
- each of the prompts included in the message creation tool along with the responses used to generate the new 360c. message and detailed explanations of why each was chosen
- the final 360c. tool-generated message
- an analysis of how the message created with the tool is an improvement over the original message
- potential issues/shortcomings of the tool and tool-generated message

6.1 Message #1: The Thomas Fire

The southern California Thomas Fire began on December 4, 2017 around 18:28 (CAL FIRE 2019) and is known as the largest wildfire in California history. According to Cal Fire data (2019), the Thomas Fire, believed to have been started by downed power lines, burned over 281,800 acres and destroyed over 1,060 structures before it was 100% contained. An estimated $177 million in damages were reported and the fire is responsible for 2 fatalities, 1 civilian during evacuation and

1 fire fighter battling the fire (Helsel 2017). According to a FEMA briefing on May 23, 2018, over 90,000+ people were under mandatory and voluntary evacuation orders throughout the course of the fire. Mandatory evacuation areas included parts of the City of Santa Barbara, Montecito, Summerland, City of Ventura, and unincorporated areas of Fillmore and Ventura Counties (Ferreira 2017). The majority of links available online with maps and lists of specific evacuation zones have been removed and are no longer available for review.

6.1.1 Original Thomas Fire Message Analysis and Research

For this case study, the following WEA message will be investigated:

> *"FAST MOVING BRUSH FIRE BETWEEN SANTA PAULA,*
> *VENTURA, OJAI - GO TO READYVENTURACOUNTY.ORG F"*

Figure 19 is a graphic found in an LA Times article that shows the original message sent as it would have appeared on a message receiver's device. Note that the original message is not in *italics*, but italics is being used in this thesis to distinguish the original message from other text.

Figure 19: Screenshot of the original WEA sent (St. John 2017)

The WEA message was sent to Federal Information Processing Standard (FIPS) Code 06111; a County FIPS code for Ventura County (USDA 2019). FIPS is a set of codes issued for the identification of specific geographic regions. This system is used by IPAWS as a way to identify a geographic warning area (FEMA 2016). This means that the message sent was issued to the geographic area of Ventura County. There is no other information available in the FEMA message directory to determine a smaller geographic range the message was sent to. Without access to specific maps and lists of evacuation areas, determining exactly which areas of Ventura County were under mandatory and voluntary evacuation orders is difficult. Therefore, it is being assumed in this thesis that the message was sent to all of the mobile devices in Ventura County.

The original message shown above contains the exact text listed in the FEMA WEA FRW (Fire Warning) message list (2018). The message was sent using all uppercase letters and is exactly 90c. (the character limit for WEA at the time the message was sent). The message has a seemingly random 'F' at the end that does not appear to have any meaning to the message. While researching

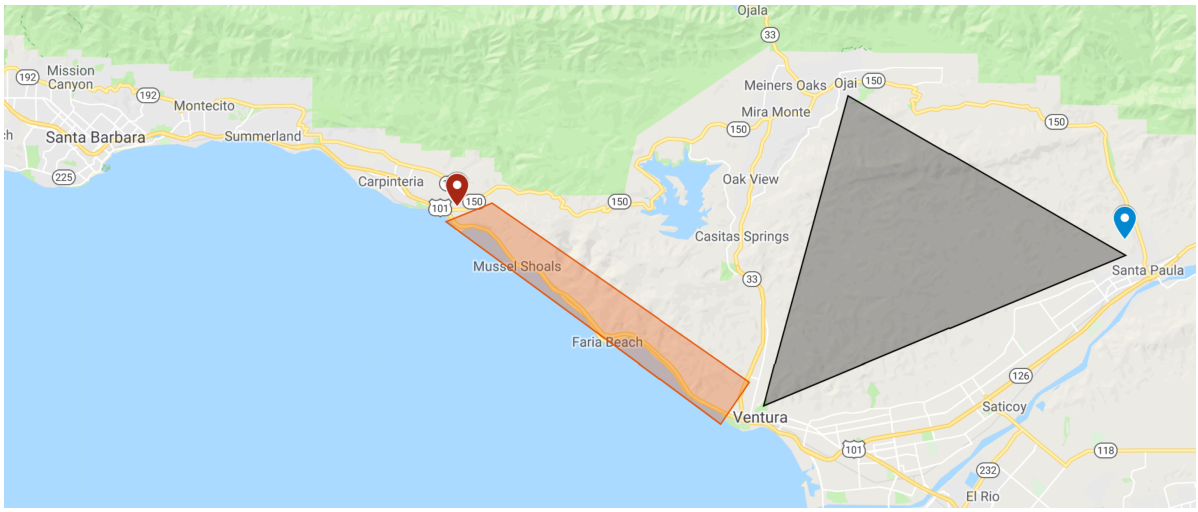


Figure 20: Map depicting areas of importance during the fire 6 hours of the Thomas Fire.

this message, a blog titled *IPAWS Non Weather* was found that compiles "IPAWS Public Alerts from Alerting Authorities except the National Weather Service". This blog confirms the WEA text that was sent and recorded in the FEMA list, including the 'F' at the end of the message. However, the description listed for the message in the blog reads, "FAST MOVING BRUSH FIRE BETWEEN SANTA PAULA, VENTURA, OJAI – GO TO READYVENTURACOUNTY.ORG FOR INFO." This 'description' is 98c.– 8 above the WEA limit. The messages match perfectly except for the final 8 characters of the 'description'. The inference can be made that the 'description' was the intended full message, but the IPAWS system eliminated the last 8 characters "OR INFO." prior to its distribution. One possible reason for this error is the message creator working quickly and mistakenly forgetting to check the character count before sending the message. If the WEA sent was not meant to contain the last two words of the description, it is more than likely the "F" would have been removed also. This blog also confirms the time, date, and geographical area code included in the FEMA WEA FRW list (2018).

According to the FEMA WEA FRW list (2018), this message was sent at 07:21 on December 5, 2017 approximately 12 hours after the start of the fire. The fire that began in an unincorporated area north of the City of Santa Paula (Thomas Fire AAR/IP 2018) grew west due to strong Santa Ana winds and spread over the Ventura County line into Santa Barbra county (KPCC 2017).

Figure 20 is a map graphic that can be used to visualize the ignition, spread, fire location at the time of the WEA, and one of the mandatory evacuation zones. The blue marker on the map indicates approximately the area where the fire began and the red marker indicates the border between Ventura County and Santa Barbara County, showing the fire moved west towards the

ocean. The black polygon triangulates the region identified by the WEA message as the location of the fire; "BETWEEN SANTA PAULA, VENTURA, OJAI". Finally, the red polygon approximates the southern coast of Ventura County, an area with a mandatory evacuation notice.

The website "READYVENTURACOUNTY.ORG" was established by the Ventura County Sheriff's Office of Emergency Services, the same entity recorded as the COGNAME for the WEA in the FEMA list (FEMA WEA FRW 2018). In searching the site, there is no information currently available regarding the Thomas Fire. However, using the Way Back Machine, a site that archives internet pages, the interface of readyventuracounty.com on December 5, 2017 at 13:50 was accessed. The only 2 closest time options to view the site for December 5th were 01:26 and 13:50, 13:50 was chosen because it was the first archive of the site after the WEA was sent at 07:21 on December 5th. The site provided information such as the location of the fire, the direction of spread, the resources being put in place to control the fire, the proclamation of a local emergency, the size and containment level of the fire, mandatory and voluntary evacuation zones, a map with an overlay of the fire and evacuation zones, road and school closures, shelter locations, and donation information specific to the Thomas Fire. While all of this information holds importance, some of it can be viewed as extraneous for those searching for what initial protective actions they should be taking (e.g., resources and personnel being deployed to contain the fire).

Table 7 breaks down the original message into the 5 categories of information found necessary for an effective short message alert. If one of the categories was not included in the message, a '-' has been entered in its place. The final letter "F" of the original message was not included in this table. The table also contains comments about each of the 5 categories.

Message Section	Thomas Fire Message	Comments
Source	-	The message did not contain a source to establish who the sender of the message was.
Hazard	*FAST MOVING BRUSH FIRE*	Uses the phrase "brush fire" to identify the hazard. Gives the description that the fire is "Fast-moving" but does not identify any personal consequences for the receiver.
Location	*BETWEEN SANTA PAULA, VENTURA, AND OJAI*	Triangulates the location of the fire between three cities. In viewing a map, this appears to be a fairly large unoccupied area that contains mostly desert land and brush. There is no mention of which direction the brush fire is heading (i.e., no information about what population is in danger).
Timeline	-	The message did not contain any kind of timeline about the fire. The phrase "Fast-moving" implies that the hazard is moving rapidly but does not give an exact time frame for when people should act.
Guidance	*GO TO READYVENTURA COUNTY.ORG*	Directs the receiver to the website listed, however there are no other directions given. In using the Way Back Machine the website was found to have useful and up to date information regarding the fire. However, some of the information was extraneous but still needed to be reviewed in full to collect all of the vital information. Providing only a website in lieu of a protective action forces people to mill and search for additional information online before taking any protective actions.

Table 7: Breakdown of the original Thomas Fire Message.

From the research and analysis earlier in this section, a summarized list of the problems and shortcomings of the original message has been compiled. The message:

- Does not identify the source.
- Does not identify which direction the fire is spreading.
- Does not include a timeline of the hazard or when the receiver needs to act.
- Provides guidance to visit a website; however it does not contain any protective actions that should be taken.
- Contains a random letter "F" at the end of the message that may create confusion.
- Uses capitalization for all words rather than to emphasize or signify specific words or phrases of importance.

6.1.2 Message Creation Tool Generated Thomas Fire Message

In order to use the message creation tool to generate a new message for Ventura County during the Thomas Fire, inputs for each of the user prompts needed to be selected. The inputs below were selected based on the original message and research that was completed about the fire. Below, each of the 15 user prompts used in the message creation tool are listed. For each of the prompts, the text used to indicate how the message creator should respond (i.e., select or enter) also appears exactly as it does in the message creation tool. Finally, the word/ phrase in **bold** following this text is the user-selected or entered response. Responses were chosen as if the message creator was generating a message to be sent to all of Ventura County during the Thomas Fire to prompt evacuation of those under imminent threat. Finally, for each of the prompts, an explanation for the user input is detailed. Note that the prompts are not in numerical order. This is purposeful so the order below matches the order in which the prompts are asked while using the tool. The prompt number is used to reference its order in this thesis. Following the prompt list, a graphic of the tool with all of the responses filled out and the final message created can be found.

PROMPT 13: What is the main purpose of this message?

Select the main purpose of the message: **Evacuation**

- User Input Explanation: The purpose of the message was selected as evacuation because this tool was designed specifically for wildfire emergency evacuation messages. Evacuation was chosen so the tool usage could be adequately demonstrated. Note that it is not clear if the intended purpose of the original 90c. WEA was for evacuation.

PROMPT 1: What agency should be listed as the source of this message?

Enter the agency sending this message: **Ventura County Sheriffs Office**

- User Input Explanation: According to the FEMA WEA FRW list (2018), the official name of the alerting authority was "CA Ventura County Sheriff's Office - Office of Emergency Services". By completing a Google search of this name, 'Ventura County Sheriff's Office' appeared to be the name used to identify the department as a whole with 'Office of Emergency Services' reserved for county wide emergencies. 'Ventura County Sheriff's Office' was selected as the source of the message because it is believed to be the most recognizable portion of the message sender. 'CA' and 'Office of Emergency Services' were omitted because it was not believed that these added additional useful information to the message. The apostrophe in "Sheriff's" was also removed for character limit purposes.

PROMPT 2: Does this agency use an acronym that is more common than its official title?

Select Yes or No: **No**

- User Input Explanation: In completing a Google search of 'CA Ventura County Sheriff's Office - Office of Emergency Services', web pages were searched for acronyms used in place of this agency. In some instances, 'Office of Emergency Services' was shortened to 'OES', but there was no acronym for this agency that appeared to be used more often than its full name. Therefore, the response selected was 'No'.

PROMPT 3: Prompt not applicable. Continue to next prompt.

- User Input Explanation: The response to Prompt 2 was entered as 'No', therefore, Prompt 3 is not applicable. If the response to Prompt 2 had been 'Yes', Prompt 3 would have appeared as, "What is the acronym used by this agency?".

PROMPT 4: What type of emergency is happening or about to happen?

Select the type of emergency: **Wildfire Emergency**

- User Input Explanation: This tool was created specifically for wildfire emergencies and the Thomas Fire was a wildfire emergency; therefore, this was selected as the emergency type.

PROMPT 5: What wildfire consequences should the public be aware of? "Wildfires can..."

Select consequence #1: (you MUST select at least one consequence):

burn down homes/other structures

Select consequence #2: (select 'none' if no other consequences should be included):

block roads/evacuation routes

- User Input Explanation: There were no hazard consequences mentioned in the original message; therefore, they needed to be selected/entered. The consequence of 'burn down homes/other structures' was chosen because this fire began in a fairly remote area and people needed to be warned that this was a possibility when the fire moved closer to town. The consequence of 'block roads/evacuation routes' was selected because the purpose of this message is evacuation and it is believed that this would increase the perceived urgency of those evacuating.

PROMPT 6: Which will be used to identify the current location of the hazard?

Select which will be used to identify the location of the hazard:

town/city/county (all or portion)

- User Input Explanation: In the original message, the location of the fire was triangulated by three cities,therefore it will be identified the same way in the tool-generated message.

PROMPT 7: The hazard is located (in/near/between) which town/city/county (all or portion)?

Select the proximity of the hazard to the town/city/county (all or portion): **between**

Enter the town/city/county (all or portion) the hazard is located between:

(separate multiple with ‘,’):

Santa Paula, Ventura, Ojai

- User Input Explanation: In the original message, the fire was described as being between these three cities, so it is being identified the same way in this message. Due to character limitations, there is not enough room in the message to include that the 3 locations are cities.

PROMPT 8: Which will be used to identify the direction the fire is spreading?

Select which will be used to identify the direction the fire is spreading:

town/city/county (all or portion)

- User Input Explanation: Research found online identified the fire was crossing from Ventura County to Santa Barbara County, so this was selected to identify the direction the fire was spreading.

PROMPT 9: What is the name of the town/city/county (all or portion) that the fire is moving towards?

Enter the town/city/county (all or portion) the fire is moving towards: **Santa Barbara County**

- User Input Explanation: Research found online stated that on Thursday (when the original WEA was being sent) the fire was moving from Ventura County into Santa Barbara County. This location was west of the fire origin and is east of Santa Barbara. There is no way of knowing when the fire crossed counties in comparison to when the WEA was sent; therefore it is being assumed that it was sent before the fire reached Santa Barbara County.

PROMPT 10: Is there a specific region of people who should evacuate?

Select Yes/No: **Yes**

- User Input Explanation: This was selected because the original message was sent to the FIPS code for the entire county. At the time of the fire, there were multiple areas under mandatory evacuation, but not all. Therefore, this was selected to identify the smaller population within the county that was under mandatory evacuation. If 'No, everyone receiving this message should evacuate' had been selected, the message would indicated that all people receiving it should evacuate. Because not all regions within Ventura County were under mandatory evacuation, 'Yes' was selected.

PROMPT 11: People located (in/near/between) which region(s) should evacuate?

Select the proximity of the evacuation area to the region: **in**

Enter the region(s) of people who should evacuate: (separate with ',' if more than 1)

the southern coast of Ventura County

- User Input Explanation: People in the southern coast of Ventura County were chosen as the example evacuation zone because they were under mandatory evacuation during the Thomas Fire. If desired, multiple evacuation zones could have been entered. The inclusion of the evacuation zone gives the potential for the message to be sent to a larger region while indicating the subset of people who need to evacuate.

PROMPT 12: When should people take action?

Enter when people should take action: **now**

- User Input Explanation: 'Now' was selected as the time for action because the original message indicated that the fire was moving fast, meaning there was little or no time to delay protective action taking.

PROMPT 14: What specific actions should the person receiving this message take?

Select action 1: (You MUST select at least one action): **Do not delay to pack belongings.**

Select action 2: (select 'none' if no other actions should be included): **none**

- User Input Explanation: The guidance of 'Do not delay to pack belongings.' was chosen because the original message indicating the fire was fast moving made it seem like there was no time for extraneous activities. 'None' was selected so a second action would not be included for character limit reasons.

PROMPT 15: What should people do for update information?

Select action: (select 'none' if no update information should be included):

Check {website} for updates.

Fill-in website address: **readyventuracounty.org**

- User Input Explanation: The guidance given in the original message was to to "Go to readyventuracounty.org". This is preserved in the tool-generated message by including this website as the location to search for additional information and updates.

The message (356c.) that was generated after all of the selections and inputs identified above were used in the message creation tool was:

> Ventura County Sheriffs Office: WILDFIRE EMERGENCY located between Santa Paula, Ventura, Ojai moving toward Santa Barbara County. Wildfires can burn down homes/other structures, block roads/evacuation routes. If you are located in the southern coast of Ventura County EVACUATE NOW. Do not delay to pack belongings. Check readyventuracounty.org for updates.

The following page provides an image that shows the user interface for the Thomas Fire message after all of the selections and inputs have been entered and the message was complete.

	Message:	Ventura County Sheriffs Office: WILDFIRE EMERGENCY located between Santa Paula, Ventura, Ojai moving toward Santa Barbara County. Wildfires can burn down homes/other structures, block roads/evacuation routes. If you are located in the southern coast of Ventura County EVACUATE NOW. Do not delay to pack belongings. Check readyventuracounty.org for updates.	
	Characters Left:	4	
Guidance	Prompt 13	What is the main purpose of this message?	
		Select the main purpose of this message:	Evacuation
Source	Prompt 1	What agency should be listed as the source of this message?	
		Enter the agency sending this message:	Ventura County Sheriffs Office
Source	Prompt 2	Does this agency use an acronym that is more common than its official title?	
		Select Yes or No:	No
Source	Prompt 3	Prompt not applicable. Continue to next prompt.	
Hazard	Prompt 4	What type of emergency is happening or about to happen?	
		Select the type of emergency:	Wildfire Emergency
Hazard	Prompt 5	What wildfire consequences should the public be aware of? "Wildfires can..."	
		Select consequence #1: *(you MUST select at least one consequence)*	burn down homes/other structures
		Select consequence #2: *(select 'none' if no other consequences should be included)*	block roads/evacuation routes
			35
Location	Prompt 6	Which will be used to identify the current location of the hazard?	
		Select which will be used to identify the location of the hazard:	town/city/county (all or portion)
Location	Prompt 7	The hazard is located between which town/city/county (all or portion)?	
		Select the proximity of the hazard to the town/city/county (all or portion):	between
		Enter the town/city/county (all or portion) the hazard is located between: (separate multiple with 'and' or ',')	Santa Paula, Ventura, Ojai
Location	Prompt 8	Which will be used to identify the direction the fire is spreading?	
		Select which will be used to identify the direction the fire is spreading:	town/city/county (all or portion)
Location	Prompt 9	What is the name of the town/city/county (all or portion) that the fire is moving towards?	
		Enter the town/city/county (all or portion) that the fire is moving towards:	Santa Barbara County
Location	Prompt 10	Is there a specific region of people who should evacuate?	
		Select Yes or No:	Yes
Location	Prompt 11	People located in which region(s) should evacuate?	
		Select the proximity of the evacuation area to the region:	in
		Enter the region(s) of people who should evacuate: (separate with ',' if more than 1)	the southern coast of Ventura County
Timeline	Prompt 12	When should people take action?	
		Select when people should take action:	now
			-
			-
Guidance	Prompt 14	What specific actions should the person receiving this message take?	
		Select action #1: *(You MUST select at least one action)*	Do not delay to pack belongings.
		Select action #2: *(select 'none' if no other actions should be included)*	none
			35
Guidance	Prompt 15	What should people do for update information?	
		Select action: *(select 'none' if no update information should be included)*	Check {website} for updates.
		Fill-in Website Address:	readyventuracounty.org

Figure 21: Thomas Fire Message Generated with the Message Creation Tool

6.1.3 Comparison of Original Message and Tool Generated Message

The purpose of this comparison is to explain the value added to the message with the additional 270c. available. Below is the summarized list of problems and shortcomings identified with the 90c. message. The 360c. message addresses each of these and also provides additional benefits.

The 90c. message:

- Does not identify the source.
- Does not identify which direction the fire is spreading.
- Does not include a timeline of the hazard or when the receiver needs to act.
- Provides guidance to visit a website; however it does not contain any protective actions that should be taken.
- Contains a random letter "F" at the end of the message that may create confusion.
- Uses capitalization for all words rather than to emphasize or signify specific words or phrases of importance.

The first four problems/ shortcoming identified have to do with missing content information. The original message is fully missing 2 of the 5 content sections necessary for an effective short message (source and timeline) and only partially addressed 2 of the other 3 (location and guidance). The tool-generated message includes information about all of the content sections. Below, the 5 content sections are listed and color coded. Following this key are the original message and the tool-generated message. The content of the messages is highlighted with its corresponding content section.

Color Key: Source Hazard Location Timeline Guidance

Original Message:

FAST MOVING BRUSH FIRE BETWEEN SANTA PAULA, VENTURA, OJAI - GO TO READYVENTURACOUNTY.ORG F

Tool Generated Message:

Ventura County Sheriffs Office: WILDFIRE EMERGENCY located between Santa Paula, Ventura, Ojai moving toward Santa Barbara County. Wildfires can burn down homes/other structures, block roads/evacuation routes. If you are located in the southern coast of Ventura County EVACUATE NOW. Do not delay to pack belongings. Check readyventuracounty.org for updates.

Along with containing the 5 necessary content types, the message generated with the tool also contains supplemental information to increase the message receiver's belief, understanding, and personalization of the message. The 8 questions displayed in the table below were developed to indicate major points of potential confusion and clarification the message receiver might need when reading a short message alert. The 5 questions without the '*' are associated with the 5 content types. The 3 questions with the '*' were developed to add additional or clarifying information to the message. In the table below, each of the questions has been applied to the original message and the tool generated message. The responses to each question have been written using only the information available in the original and tool-generated short messages, respectively.

Content Section	Question	Original Message	Tool Generated Message
Source	Who/which agency is sending this message?	-	Ventura County Sheriffs Office
Hazard	What is the hazard people are being warned about?	fast moving brush fire	wildfire emergency
Hazard*	What are the potential consequences of this hazard?	-	-burn down homes/other structures -block roads/evacuation routes
Location	What is the current location of the hazard?	between Santa Paula, Ventura, Ojai	between Santa Paula, Ventura, Ojai
Location*	What direction is the hazard moving?	-	Santa Barbara County
Location*	What region(s) of people should evacuate?	-	the southern coast of Ventura County
Timeline	How long does the message receiver have until he/she needs to act?	-	no time, act now
Guidance	What protective actions should the message receiver be following?	Go to readyventuracounty.org	-Evacuate -Do not delay to pack belongings. -Check readyventuracounty.org for updates.

Table 8: Chart of necessary and supplemental information comparing original and tool generated messages.

Another problem with the original message was the random letter 'F' that appeared at the end. It is believed that this is because the final characters of the message being truncated due to the character limit of WEAs at the time it was sent. With the message creation tool, the character limit is displayed and the message can be altered after answering all of the prompts if it happens to be over the character limit. This should eliminate the problem of messages accidentally being made too long.

Finally, the original message appeared in all capital letters. No research has been found that disputes the use of all capital letters and/or identifies this method as ineffective. However, research shows that it is effective to use certain words in capital letters to signify the content of the message (e.g, MANDATORY EVAC...) or emphasize certain words or phrases of the message (e.g., NOW) (Sutton et al. 2014). The message creation tool uses capital letters to signify (e.g., WILDFIRE EMERGENCY) and to emphasize (e.g., EVACUATE NOW). This method draws the readers attention to these two phrases and indicates they are of high importance.

The message generated with the creation tool addresses many of the problems and shortcomings discovered in the original 90c. WEA. The message also contains additional information that will help the message receiver understand, believe, and act upon the message quicker.

However, the tool-generated message contains its own shortcomings and this case study helped identify areas of future research and/or improvement for the tool. First, the apostrophe in 'Sheriff's' was omitted for character limit reasons. While a change like this might seem small and insignificant, it does alter the possession of the word. One of the largest challenges of the message was the inability to identify 'Santa Paula, Ventura, Ojai' as either cities or counties. This identification was also omitted due to character limit reasons and has the potential to increase the message receivers' confusion if there are regions that have the same base name but one is identified as 'city' and another as 'county' (e.g., Santa Paula City vs. Santa Paula County). Finally, in this scenario, the tool is only able to identify one evacuation zone. The tool does allow for more to be added. However, with the way the message is currently written, an additional evacuation zone identification would cause the message to go over the character limit restriction. Future research and tool development might be able to mitigate these problems.

6.2 Message #2: The Lilac Fire

The northern San Diego County Lilac Fire began on December 7, 2017 around 11:42 AM (Lilac Fire AAR 2018). At the time of the fire's origin, the region was experiencing strong Santa Ana winds and unprecedented drought. The fire consumed around 4,100 acres of land, destroyed over 200 homes and structures, and was responsible for 2 serious burn injuries and no fatalities (Lilac Fire AAR 2018). According to the Lilac Fire After Action Report (2018), more than 77,000 people received evacuation notices. Mandatory evacuation notices included parts of Bonsall, Vista, and Oceanside.

6.2.1 Original Lilac Fire Message Analysis and Research

For this case study, the following WEA message will be investigated: *"Dangerous fires in North SD County. Tune to local media. Call 2-1-1 for evac areas-SD OES".* According to the After Action Report (2018), this message was the region's first-ever use of WEA. The message was sent to 'all enabled cell phones in the region' to warn them about the fire. It is believed that the message was sent to over 2 million users. (Lilac Fire AAR 2018).

Figure 22 is a graphic found in the After Action Report that shows the original message as it would have appeared on a message receiver's device. Note that the original message is not in *italics,* but italics are being used in this thesis to distinguish the original message from other text.

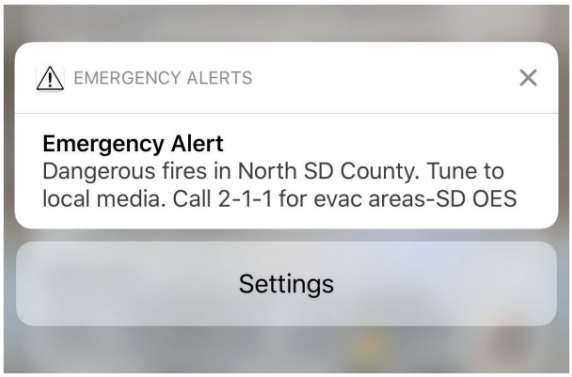


Figure 22: Screenshot of the original WEA sent (Lilac Fire AAR 2018)

The WEA was sent to FIPS code 06073; the FIPS code for San Diego County (USDA 2019). The FEMA WEA FRW list from which the message was pulled also gave the area description for the message as 'CA- San Diego' (2018). The After Action Report (2018) confirms that the Emergency Operation Center (EOC) 'Activated a Wireless Emergency Alert to all of San Diego County'. This means that all residents, including those in portions of San Diego County that are over 100 miles from the location of the fire, were receiving this message to their devices. The decision was made to send the WEA to the entire region because of the fire's potential for rapid spread into populated areas (Lilac Fire AAR 2018).

In reviewing evacuation information in the After Action report and KBPS, a local news source,

the majority of the evacuation zones were given by road names rather than sections of counties or cities (e.g., "East of the Camp Pendleton Eastern Fence Line and west of Green Canyon Road"). The lists of road sections under evacuation orders were extensive and potentially confusing to someone unfamiliar with the area.

The message notes that there were *"Dangerous fires"*, however, in the After Action Report, it indicates that the message was sent as a reaction to the Lilac Fire. There is the possibility that there were other smaller wildfires occurring at the same time as the Lilac Fire or the identification of multiple was due to the high likelihood of another beginning. If the Lilac Fire was the only wildfire message receivers knew about, the "s" might lead him or her to mill while looking for information about other fires.

The original message shown previously contains the exact text listed in the FEMA WEA FRW message list (2018). The message is 89c.– one character short of the 90c. limit. The message was sent at 21:56 on December 7, 2017 approximately 10 hours after the fire was initially reported (FEMA 2018). The fire began near the intersections of I-15 and highway 76. Due to the Santa Ana winds, the fire spread west toward the Pacific Ocean (Lilac Fire AAR 2018).

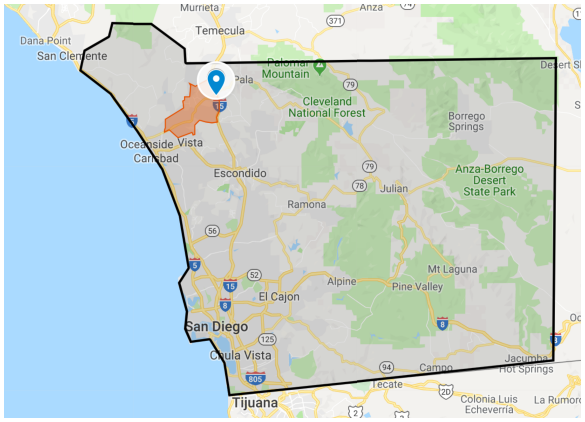


Figure 23: San Diego County during the Lilac Fire.

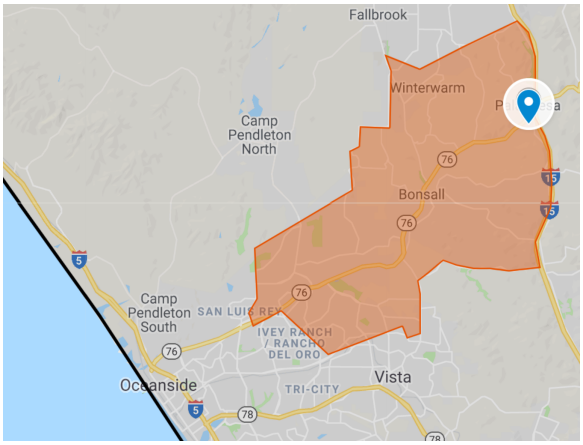


Figure 24: Fire Origin and Evacuation Zone.

Figures 23 and 24 are maps that detail information about the origin of the fire, evacuation zones, and the message distribution region. Figure 24 is a detail view of Figure 23. The black polygon outlines San Diego County (i.e., the region of devices that received the WEA). The blue marker is the area just south of the intersection of I-15 and Highway 76 and is the location of the fire origin. Finally, the orange polygon is the approximate region of people who were under mandatory evacuation during the fire.

The WEA instructs people to call 2-1-1. At the time of the fire, this number was established as an informational hot-line and included information regarding 'evac areas'. The purpose of sending this number and directing people to it was to preserve 9-1-1 for 'true emergencies' and the review found that this had its intended effect (Lilac Fire AAR 2018). According to the After Action Report (2018), there was a flood of calls to the hot-line and an unknown number of them failed due to the call volume overwhelming the system.

Finally, the last 6 characters of the original message are 'SD OES'. According to the FEMA WEA FRW list (2018), the COGNAME for the message was 'CA San Diego County Office of Emergency Services'. It is believed that the acronym included in the message is short for San Diego [County] Office of Emergency Services. In completing a Google search, it appears that 'Office of Emergency Services' is usually shortened to 'OES', but 'SD OES' does not appear to be a commonly used acronym.

Table 9 breaks down the original message into the 5 categories of information found necessary for an effective message alert, as well as comments about each. If one of the categories was not included in the message, a '-' has been entered in it's place.

Message Section	Lilac Fire Message	Comments
Source	*SD OES*	The source is an acronym that is believed to stand for 'San Diego [County] Office of Emergency Services'. The use of an acronym has the potential to create confusion if the message receiver is not familiar with it. If the reader does not understand that this is identifying the source of the message, the characters are not being used effectively.
Hazard	*Dangerous Fires*	The message uses the word "fire[s]" to identify the hazard. It gives the description that the fires are"dangerous" but does not identify any personal consequences for the receiver. The message also does not identify that the hazard is a wildfire. The message creator may be assuming that the message receiver will understand without clarification.
Location	*North SD County*	The message does provide a location for the fire; however, the message was sent to all of San Diego County and the 'north' part of the county is subjective. For instance, if the county was cut in half from East to West, technically everything higher than the line is North. This has the potential to confuse a lot of people and invoke action in those who are not affected by the fires. The use of 'SD' in the message may also be a point of confusion for message receivers. Research shows that the message was sent to all of San Diego County, but someone traveling might not know what county he/she is in, therefore potentially misinterpreting the 'SD' as something else (e.g., South Dakota).
Timeline	-	The message did not contain any kind of timeline about the fire or when people should act.
Guidance	*Tune to local media. Call 2-1-1 for evac areas*	The message directs the receiver to 'Tune to local media'. The message does not state what the receiver should check local media for and also does not indicate what it means by 'local media' (e.g., television, radio, etc.). If the message receiver does not feel he/she has a reason to check the media, he/she may not. The message also indicates that the receiver should call a phone number for 'evac areas'. The use of abbreviations such as 'evac' have the ability to be misinterpreted and can be a potential source of confusion. The message receiver may also believe he/she should only call the number for evacuation areas and may mill while trying to gather other information about the fire.

Table 9: Breakdown of the original 90c. Lilac Fire WEA.

From the research and analysis earlier in this section, a summarized list of the problems and shortcomings of the original message has been compiled. The message:

- Does not identify a timeline of the hazard or when the message receiver needs to act.
- Does not identify any personal consequences of the hazard.
- Gives the unspecific description of 'fire[s]' for the hazard identification.

- Provides a generic location description of the fire that is potentially subjective.
- Directs the receiver to 'local media', but does not clarify why or for what information.
- Uses acronyms (e.g., 'SD OES') and abbreviations (e.g., 'evac') that have the potential for misinterpretation that may confuse the message receiver.

6.2.2 Message Creation Tool Generated Lilac Fire Message

In order to use the message creation tool to generate a new message for San Diego County during the Lilac Fire, inputs for each of the user prompts needed to be selected. The inputs were selected based on the original message and research that was completed about the fire. Below, each of the 15 user prompts asked in the message creation tool are listed. For each of the prompts, the text used to indicate how the message creator should respond (i.e., select or enter) also appears exactly as it does in the message creation tool. Finally, the word/ phrase in **bold** following this text is the user selected or entered response. Responses were chosen as if the message creator was generating a message to be sent to the evacuation areas of San Diego County during the Lilac Fire. Finally, for each of the prompts, an explanation for the user input is detailed. Note that the prompts are not in numerical order. This is purposeful so the order below matches the order in which the prompts are asked while using the message creation tool. The prompt number is used to reference its order in this thesis. Following the prompt list, Figure 25 displays a graphic of the tool interface with all of the responses filled out and the final message created.

PROMPT 13: What is the main purpose of this message?

Select the main purpose of the message: **Evacuation**

- User Input Explanation: The After Action Report explains that the initial purpose of sending the WEA was both informational and for evacuations. The message was sent to all of San Diego County to warn them of the existence of the fire in case of sudden shifts in its direction. The message was also sent to inform people of where they could go for evacuation information. The message was extremely general and it is believed that in this case 2 messages would be more effective than 1. The first message would be for evacuation information and would be sent to those directly affected by the fire and evacuations orders. The second message would be informational and would be sent to those in the surrounding area and the rest of San Diego County. The tool is currently equipped to handle the creation of evacuation messages, therefore, this is being selected as the main purpose of the message. Future research could create a tool equipped to

generate an informational message.

PROMPT 1: What agency should be listed as the source of this message?

Enter the agency sending this message: **San Diego County Office of Emergency Services**

- User Input Explanation: According to the FEMA WEA FRW list (2018), the official name of the alerting authority sending the WEA was "CA San Diego County Office of Emergency Services". By completing a Google search of this name, 'San Diego County Office of Emergency Services' appeared to be the name used to identify the department, therefore, it was selected as the source of the message. The 'CA' was omitted from the source because it was not believed that it added additional useful information to the message.

PROMPT 2: Does this agency use an acronym that is more common than its official title?

Select Yes or No: **Yes**

- User Input Explanation: In completing a Google search of 'CA San Diego County Office of Emergency Services', web pages were searched for acronyms used in place of this agency. In some instances, 'Office of Emergency Services' was shortened to 'OES', but there was no acronym for this agency that appeared to be used more often than its full name. However, in the original message, 'SD OES' was used as the source of the message. It is possible that this acronym is commonly used, just not online.

PROMPT 3: What is the acronym used by this agency?

Enter the acronym of the agency: **SD OES**

- User Input Explanation: 'SD OES' was the acronym that was used to identify the source of the message in the original 90c. WEA. It is unclear if this acronym is used more commonly than the full agency name, therefore it is being preserved in the tool-generated message and used in conjunction with the full agency name.

PROMPT 4: What type of emergency is happening or about to happen?

Select the type of emergency: **Wildfire Emergency**

- User Input Explanation: This tool was created specifically for wildfire emergencies and the Lilac Fire was a wildfire emergency; therefore, this was selected as the emergency type.

PROMPT 5: What wildfire consequences should the public be aware of? "Wildfires can..."

Select consequence #1: (you MUST select at least one consequence):

block roads/evacuation routes

Select consequence #2: (select 'none' if no other consequences should be included):

other (35c. limit)

Fill-in Consequence (35c. limit): **change direction, and spread fast**

- User Input Explanation: There were no hazard consequences mentioned in the original message; therefore, they needed to be selected/entered. The consequence of 'block roads/evacuation routes' was selected because the purpose of this message is evacuation and it is believed that this would increase the perceived urgency of those evacuating. The consequence of 'change direction, and spread fast' was selected because the After Action report identified that there was a great potential and fear that the fire direction would shift dramatically and spread quickly due to the strong Santa Ana winds.

PROMPT 6: Which will be used to identify the current location of the hazard?

Select which will be used to identify the location of the hazard:

major road(s)/ intersection(s)

- User Input Explanation: In the original message, the location of the fire was given as 'North SD County'. It is believed that this is too general of a location to be useful to the message receivers. The fire originated near the intersection of 2 roads; therefore, the fire location is being identified by them.

PROMPT 7: The hazard is located (in/near/between) which major road(s)/ intersection(s)?

Select the proximity of the hazard to the major road(s)/ intersection(s): **near**

Enter the major road(s)/ intersection(s) the hazard is located near:

(separate multiple with 'and' or ','):

I-15 and Highway 76

- User Input Explanation: Sources identified the area near this major intersection as the location of the fire origin. Therefore, it is being used to describe the location of the fire. The location of 'North SD County' is a very large area and incorporates many people not impacted by the fire. By giving this more specific location and the direction of the fire spread, message receivers may more easily understand the location of the fire and if they are going to be directly or indirectly impacted by it.

PROMPT 8: Which will be used to identify the direction the fire is spreading?

Select which will be used to identify the direction the fire is spreading:

well known landmark(s)

- User Input Explanation: Research shows that at the time of the fire there were strong Santa Ana winds pushing the fire west. Because so many people were impacted by the evacuation orders across so many cities, a well known landmark was chosen to identify the spread of the fire because it was felt that it would be familiar to the most people.

PROMPT 9: What is the name of the well known landmark(s) that the fire is moving towards?

Enter the well known landmark(s) the fire is moving towards: **the Pacific Ocean**

- User Input Explanation: Strong Santa Ana winds were pushing the fire west at the time the original WEA was sent. Maps of the fire spread show the fire moving more of a south-west direction towards Oceanside. However, because of the fear that the fire would shift direction rapidly, it was felt that everyone needed to be warned that the fire was generally spreading west. If people were told the fire was moving south-west and began evacuating north, and the fire made a dramatic shift to north-west, then people might not be expecting the change. Keeping the direction of fire spread broad is purposeful so people are more alert and vigilant while evacuating.

PROMPT 10: Is there a specific region of people who should evacuate?

Select Yes/No: **No, everyone receiving this message should evacuate**

- User Input Explanation: In the user input explanation for Prompt 13 it was explained that the original intention of the message was both for evacuation and for information and it was sent to the entire county. Because the entire county was not under evacuation orders, the suggestion was made to send two message, one sent for evacuations only to those impacted by the orders and one for information sent to the rest of San Diego County. If this message was only sent to the devices in the regions with mandatory evacuation orders, everyone receiving the message should evacuate.

PROMPT 11: Prompt not applicable. Continue to next prompt.

- User Input Explanation: This prompt is not applicable because it was selected that everyone receiving the message should evacuate. If there was only a specific region of people who should evacuate, the prompt would have read 'People located (in/near/between) which region(s) should evacuate?'.

PROMPT 12: When should people take action?

Enter when people should take action: **now**

- User Input Explanation: 'Now' was selected as the time for action because of the harsh fire conditions and strong winds, there was little or no time to delay protective action taking.

PROMPT 14: What specific actions should the person receiving this message take?

Select action 1: (You MUST select at least one action): **Do not delay to pack belongings.**

Select action 2: (select 'none' if no other actions should be included):

Leave animals/livestock behind

- User Input Explanation: The guidance of 'Do not delay to pack belongings.' was chosen because the fire was moving quickly and there was no time for extraneous activities. The guidance of 'Leave animals/livestock behind' was entered manually after selecting 'other (35c. limit)'. This guidance was selected because the fire occurred in an area that contained many farms and ranches. It is possible that families or workers may have delayed their protective action taking to pack animals or livestock before evacuation. This guidance was included to instruct people not to do that. It also potentially increases a person's urgency because they are being told to leave everything behind, including their livelihood.

PROMPT 15: What should people do for update information?

Select action: (select 'none' if no update information should be included):

Call {phone number} for updates.

Fill-in Phone Number: **2-1-1**

- The original message gave the guidance to 'Call 2-1-1 for evac areas'. The new message is being sent to only those that are directly impacted by the evacuation orders. The message is clear that if they are receiving it, then they should evacuate, negating the need to call the number for 'evac areas'. However, during the Lilac Fire, the phone number was connected to a call center to provide people with information on the fire, not just the evacuation areas. This guidance was included so message receivers knew they could contact this number for update information on the fire.

The message that was generated after all of the selections and inputs identified above were used in the message creation tool was 357c. and read:

> San Diego County Office of Emergency Services (SD OES): WILDFIRE EMERGENCY located near I-15 and Highway 76 moving toward the Pacific Ocean. Wildfires can block roads/evacuation routes, change direction, and spread fast. If you are receiving this message EVACUATE NOW. Do not delay to pack belongings. Leave animals/livestock behind. Call 2-1-1 for updates.

Figure 25 provides an image that shows the user interface for the Lilac Fire message after all of the selections and inputs have been entered and the message was complete.

	Message:	San Diego County Office of Emergency Services (SD OES): WILDFIRE EMERGENCY located near I-15 and Highway 76 moving toward the Pacific Ocean. Wildfires can block roads/evacuation routes, change direction, and spread fast. If you are receiving this message EVACUATE NOW. Do not delay to pack belongings. Leave animals/livestock behind. Call 2-1-1 for updates.		
	Characters Left:	3		
Guidance	Prompt 13	What is the main purpose of this message?		
		Select the main purpose of this message:	Evacuation	
Source	Prompt 1	What agency should be listed as the source of this message?		
		Enter the agency sending this message:	San Diego County Office of Emergency Services	
Source	Prompt 2	Does this agency use an acronym that is more common than its official title?		
		Select Yes or No:	Yes	
Source	Prompt 3	What is the acronym used by this agency?		
		Enter the acronym of the agency:	SD OES	
Hazard	Prompt 4	What type of emergency is happening or about to happen?		
		Select the type of emergency:	Wildfire Emergency	
Hazard	Prompt 5	What wildfire consequences should the public be aware of? "Wildfires can..."		
		Select consequence #1: *(you MUST select at least one consequence)*	block roads/evacuation routes	
		Select consequence #2: *(select 'none' if no other consequences should be included)*	other (35c. limit)	
		Fill-in Consequence (35c. limit):	change direction, and spread fast	2
Location	Prompt 6	Which will be used to identify the current location of the hazard?		
		Select which will be used to identify the location of the hazard:	major road(s)/ intersection(s)	
Location	Prompt 7	The hazard is located near which major road(s)/ intersection(s)?		
		Select the proximity of the hazard to the major road(s)/ intersection(s):	near	
		Enter the major road(s)/ intersection(s) the hazard is located near: (separate multiple with 'and' or ',')	I-15 and Highway 76	
Location	Prompt 8	Which will be used to identify the direction the fire is spreading?		
		Select which will be used to identify the direction the fire is spreading:	well known landmark(s)	
Location	Prompt 9	What is the name of the well known landmark(s) that the fire is moving towards?		
		Enter the well known landmark(s) that the fire is moving towards:	the Pacific Ocean	
Location	Prompt 10	Is there a specific region of people who should evacuate?		
		Select Yes or No:	No, everyone receiving this message should evacuate	
Location	Prompt 11	Prompt not applicable. Continue to next prompt.		
			(in/near/between)	
Timeline	Prompt 12	When should people take action?		
		Select when people should take action:	now	
			-	
			-	
Guidance	Prompt 14	What specific actions should the person receiving this message take?		
		Select action #1: *(You MUST select at least one action)*	Do not delay to pack belongings.	
		Select action #2: *(select 'none' if no other actions should be included)*	other (35c. limit)	
		Fill-in action (35c. limit):	Leave animals/livestock behind	5
Guidance	Prompt 15	What should people do for update information?		
		Select action: *(select 'none' if no update information should be included)*	Call {phone number} for updates.	
		Fill-in Phone Number:	2-1-1	

Figure 25: Lilac Fire Message Generated with the Message Creation Tool

6.2.3 Comparison of Original Message and Tool Generated Message

The purpose of this comparison is to explain the value added to the message with the additional 270c. available. Below is the summarized list of problems and shortcomings identified with the 90c. message. The 360c. message addresses each of these and also provides additional benefits.

The message:

- Does not identify a timeline of the hazard or when the message receiver needs to act.
- Does not identify any personal consequences of the hazard.
- Gives the unspecific description of 'fire[s]' for the hazard identification.
- Provides a generic location description of the fire that is potentially subjective.
- Directs the message receiver to local media, but does not clarify why or for what information.
- Uses acronyms (e.g., 'SD OES') and abbreviations (e.g., 'evac') that have the potential for misinterpretation that may confuse the message receiver.

The first five problems/ shortcomings identified have to do with missing or confusing content information. The original message is missing one of the five necessary content sections (timeline). The message only partially addresses the hazard by not providing any personal consequences associated with it. The message content for the location and guidance is also extremely vague and could lead to misinterpretation and increased confusion. Finally, the message included abbreviations and acronyms that have the potential to decrease the message receiver's understanding. The tool-generated message includes information about all of the content sections. Below, the 5 content sections are listed and color coded. Following this key are the original message and the tool-generated message. The content of the messages is highlighted with its corresponding content section.

Color Key: Source Hazard Location Timeline Guidance

Original Message:

Dangerous fires in North SD County. Tune to local media. Call 2-1-1 for evac areas -SD OES

Tool-Generated Message:

San Diego County Office of Emergency Services (SD OES): WILDFIRE EMERGENCY located near I-15 and Highway 76 moving toward the Pacific Ocean. Wildfires can block roads/evacuation routes, change direction, and spread fast. If you are receiving this message EVACUATE NOW. Do not delay to pack belongings. Leave animals/livestock behind. Call 2-1-1 for updates.

Along with containing the 5 necessary content types, the message generated with the tool also contains supplemental information to increase the message receiver's belief, understanding, and personalization of the message. The 8 questions displayed in the table below were developed to indicate major points of potential confusion and clarification the message receiver might need when reading a short message alert. The 5 questions without the '*' are associated with the 5 content types. The 3 questions with the '*' were developed to add additional or clarifying information to the message. In the table below, each of the questions has been applied to the original message and the tool-generated message. The responses to each question have been written using only the information available in the original and tool-generated short messages, respectively.

Content Section	Question	Original Message	Tool Generated Message
Source	Who/which agency is sending this message?	SD OES	San Diego County Office of Emergency Services (SD OES)
Hazard	What is the hazard people are being warned about?	Dangerous fires	wildfire emergency
Hazard*	What are the potential consequences of this hazard?	-	-block roads/evacuation routes -change direction, and spread quickly
Location	What is the current location of the hazard?	North SD County	near I-15 and Highway 76
Location*	What direction is the hazard moving?	-	toward the Pacific Ocean
Location*	What region(s) of people should evacuate?	Call 2-1-1 to find out	Everyone receiving the message
Timeline	How long does the message receiver have until he/she needs to act?	-	no time, act now
Guidance	What protective actions should the message receiver be following?	-Tune to local media. -Call 2-1-1 for evac areas	-Evacuate -Do not delay to pack belongings. -Leave animals/livestock behind. -Call 2-1-1 for updates.

Table 10: Chart of necessary and supplemental information comparing original and tool-generated messages.

The original message addressed 4 of the 5 content section of the message. However, the majority of them were nondescriptive or included acronyms or abbreviations that were unclear. The tool-generated message addresses all of the 5 content sections and provides clear and concise answers for each of the 8 questions above. The decision to generate and send 2 messages allowed for the tool-generated message to include information specific and relevant to those evacuating.

The tool-generated messages contains its own problems and shortcomings. One of the problems identified in the original message is the use of acronyms due to the potential confusion they may

cause. The tool generated message uses the acronym found in the original message 'SD OES' in conjunction with its full name 'San Diego County Office of Emergency Services'. The hope is that using the acronym with the full name means that the source of the message will be recognized by most people. However, there is still the possibility for the misinterpretation of the acronym, leading to increased confusion. Another point of potential confusion is identifying the fire as 'near' the intersection. The word 'near' can be extremely subjective in terms of distance and also does not identify in which direction (i.e., North, South, East, West). Next, the choice to identify the location of fire movement by the Pacific Ocean was done so with the hope that it would be an easily recognized landmark and would keep evacuees alert for changing fire patterns. There is the possibility that this landmark choice was too large and it may generate confusion. The decision to have one message for evacuation and one for information was made so that more specific information could be given to its intended population. However, there is always the possibility of the message over-shooting (i.e., the message is delivered to a device outside of its intended polygon due to the location of cell towers). If this happens for the tool-generated message, there is the possibility of people being told to evacuate who are not in the intended evacuation zones and vice versa. Finally, including the guidance instructing people to leave their animals and livestock behind was included to hopefully create urgency and reiterate to message receivers that they had little to no time to act. However, because the community has a large number of ranches and farms, including this guidance may have an unwanted impact. It is possible that including this might cause message receivers to mill as they search for alternatives to leaving their animals or livestock behind.

Even with its own shortcomings, the tool-generated message is an improvement over the original 90c. WEA. The message contains information that is useful and clear for those who would be receiving it and taking protective actions.

6.3 Message #3: The Lake Spokane Fire

The Southern Stevens County Lake Spokane Fire was relatively much smaller than the Thomas Fire or the Lilac Fire. The Lake Spokane Fire began Wednesday July 9, 2014 and quickly consumed over 900 acres of land (Hill 2014). The fire began near the intersection of Highway 291 and Highway 231 (KHQ 2014). As of 23:30 on July 9, the fire was 0% contained. The fire was burning in a very heavily wooded area and flames could be seen over a dozen feet above the tree line (KHQ 2014). According to a local news source, 'Level 2' and 'Level 3' evacuations were in order for certain areas of Stevens County and about 60 homes were threatened (KXLY 2014). Before the fire was 100% contained on July 13, 2014 it burned over 1,010 acres (NWCC 2014). The fire resulted in no injuries, no fatalities, and no structural damage (Hill 2014).

6.3.1 Original Lake Spokane Fire Message Analysis and Research

For this case study, the following WEA message will be investigated: *"Please evacuate due to wildfire on Corkscrew between Happy Hills and Highway 291"*. Figure 26 shows a graphic found in a presentation prepared for the FEMA IPAWS info for Radiological Preparedness Conference (2017) with the original message as it would have appeared on a message receiver's device. Note that the original message is not in *italics,* but italics are being used in this thesis to distinguish the original message from other text.

Figure 26: Screenshot of the original WEA sent (Witmer 2017)

FIPS code 53065, the code for Stevens County (USDA 2019), was recorded for the WEA in the FEMA list (FEMA WEA FRW 2018). However, the area description is listed as "In this area" and there is a unique set of coordinates given as the message polygon. The use of the description "In this area" along with the coordinates means that the message was sent to a unique geographical range rather than an entire county.

According to the FEMA WEA FRW list (2018), the message was sent at 04:02 on Thursday, July 10 approximately 12 hours after the start of the fire and 5 hours after the last found report that the fire was 0% contained. At this time, 'Level 3' evacuations were in place for Highway 231 between Highway 291 and Corkscrew Canyon

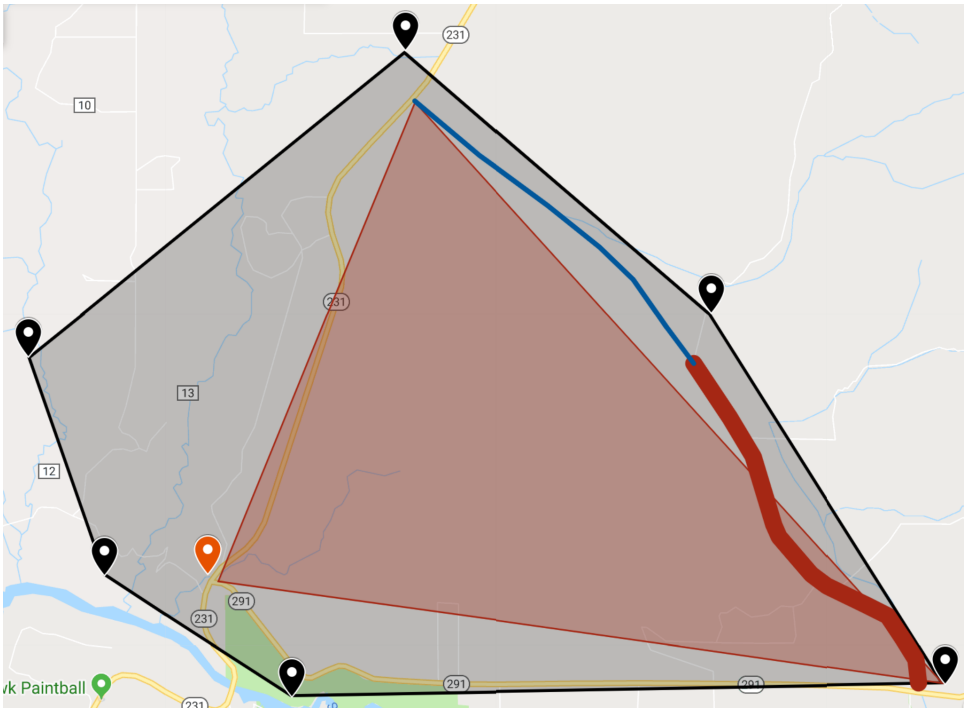


Figure 27: Map of southern Stevens County.

(KXLY 2014). According to Stevens County (2018), 'Level 3' "means danger is currently affecting your area or is imminent and you should LEAVE IMMEDIATELY".

The WEA identified the fire as being *"on Corkscrew between Happy Hills and Highway 291"*. According to Google Maps, the actual names of the roads are "Corkscrew Canyon Road" and "Happy Hill Road". The WEA does not use abbreviations for the road names, but completely omits pieces of them. According to a local news source, on Thursday the fire was triangulated between Highways 291, 231, and Corkscrew Canyon Road (Hill 2014).

Figure 27 is a graphic of the effected portion of southern Stevens County. The blue line is used to highlight Corkscrew Canyon Road and to make it more visible. The road continues all the way to Highway 231, but it is covered by the thick red line. The red marker on the left of the figure indicates where the fire began, near the intersection of Highways 291 and 231. The thick red line on the right of the image is the interpreted location of the fire based on the WEA message, *"on Corkscrew between Happy Hills and Highway 291"*. The red triangle in the middle of the image is the location of the fire on Thursday based on the news source, triangulated between Highways 231, 291, and Corkscrew Canyon Road. Finally, the black markers are the coordinates of the polygon recorded in the FEMA WEA FRW list (2018). Lines have been drawn between them and the inside shaded to identify the region of devices that would be receiving the WEA.

The location of the fire is unclear. The WEA could be interpreted that the fire is only in that very small region of road, however other reports indicate the fire is impacting a very large region. If someone received the WEA who was located in the left of the polygon, he/she might not think they will be impacted by the fire because they are miles from the location given. However, if the fire was actually burning in the entire red polygon, the fire could impact them sooner than expected.

Finally, the message begins with the word *'Please'*. The use of this word makes the message sound optional and less urgent. If message receivers are interpreting this word in a similar manner, he/she might not heed the message because their perceived threat may be decreased.

The following table breaks down the original message into the 5 categories of information found necessary for an effective message alert, as well as comments about each. If one of the categories was not included in the message, a '-' has been entered in it's place.

Message Section	**Lake Spokane Fire Message**	**Comments**
Source	-	The message does not contain a source to establish who the sender of the message was.
Hazard	*wildfire*	The message identifies the hazard. The message does not contain any personal consequences of the hazard for the receiver.
Location	*on Corkscrew between Happy Hills and Highway 291*	The message does provide a location for the fire; however,the location is confusing. The given location makes the fire sound small and concentrated to the location given when in actuality, the fire was larger and threatened more than just that small area. The message does not provide the receiver with any information about the location of people who should be acting upon the message (i.e., evacuating).
Timeline	-	The message did not contain a timeline for the fire or when people should act.
Guidance	*evacuate*	The message directs the receiver to 'evacuate'. The message does not give any other supplemental guidance to the message receiver. The message receiver might also not realize that he/she is located in a polygon selected specifically to receive the message. If he/she is far from the location of the fire, he/she might not take this protective action guidance personally and may delay or dismiss evacuation.

Table 11: Breakdown of the original Lake Spokane Fire Message.

From the research and analysis earlier in this section, a summarized list of the problems and shortcomings of the original message has been compiled. The message:

- Does not identify who is sending the message.

- Does not identify a timeline of the hazard or when the message receiver needs to act.
- Does not identify personal consequences of the hazard.
- Does not identify who should heed the message.
- Provides a potentially confusing location for the hazard.
- Does not provide any supplemental guidance to accompany the instruction to 'evacuate'.
- Truncates the names of roads (e.g., 'Corkscrew' for Corkscrew Canyon Road).
- Uses language that may not create urgency (e.g., 'Please').

6.3.2 Message Creation Tool Generated Lake Spokane Fire Message

In order to use the message creation tool to generate a new message for the identified polygon during the Lake Spokane Fire, inputs for each of the user prompts needed to be selected. The inputs were selected based on the original message and research that was completed about the fire. Below, each of the 15 user prompts asked in the message creation tool are listed. For each of the prompts, the text used to indicate how the message creator should respond (i.e., select or enter) also appears exactly as it does in the message creation tool. Finally, the word/ phrase in **bold** following this text is the user selected or entered response. Responses were chosen as if the message creator was generating a message to be sent to the evacuation area of southern Stevens County during the Lake Spokane Fire. Finally, for each of the prompts, an explanation for the user input is detailed. Note that the prompts are not in numerical order. This is purposeful so the order below matches the order in which the prompts are asked while using the message creation tool. The prompt number is used to reference its order in this thesis. Following the prompt list, a graphic of the tool interface with all of the responses filled out and the final message created can be found.

PROMPT 13: What is the main purpose of this message?

Select the main purpose of the message: **Evacuation**

- User Input Explanation: The purpose of the message was selected as evacuation because the originally intended purpose of the WEA was to tell people to evacuate.

PROMPT 1: What agency should be listed as the source of this message?

Enter the agency sending this message: **Stevens County Emergency Management**

- User Input Explanation: According to the FEMA WEA FRW list (2018), the official name of the alerting authority sending the WEA was "WA Stevens County". By completing a Google search of this name, 'Stevens County Emergency Management' appeared to have a fairly active online presence informing people about what was going on in the

county. The 'WA' was omitted from the source because it was not believed that it added additional useful information to the message.

PROMPT 2: Does this agency use an acronym that is more common than its official title?

Select Yes or No: **No**

- User Input Explanation: In completing a Google search of 'Stevens County Emergency Management', web pages were searched for acronyms used in place of this agency. There was no acronym for this agency that appeared to be used more often than its full name.

PROMPT 3: Prompt not applicable. Continue to next prompt.

- User Input Explanation: The response to Prompt 2 was entered as 'No', therefore, Prompt 3 is not applicable. If the response to Prompt 2 had been 'Yes', Prompt 3 would have appeared as, "What is the acronym used by this agency?".

PROMPT 4: What type of emergency is happening or about to happen?

Select the type of emergency: **Wildfire Emergency**

- User Input Explanation: This tool was created specifically for wildfire emergencies and the Lake Spokane Fire was a wildfire emergency; therefore, this was selected as the emergency type.

PROMPT 5: What wildfire consequences should the public be aware of? "Wildfires can..."

Select consequence #1: (you MUST select at least one consequence):

block roads/evacuation routes

Select consequence #2: (select 'none' if no other consequences should be included):

cause injury/death

- User Input Explanation: There were no hazard consequences mentioned in the original message; therefore, they needed to be selected/entered. The consequence of 'block roads/evacuation routes' was selected because the purpose of this message is evacuation and it is believed that this would increase the perceived urgency of those evacuating. The consequence of 'cause injury/death' was selected because the fire was growing extremely fast and people needed to evacuate quickly. It was thought that this consequence would increase peoples' risk perception making them act quicker.

PROMPT 6: Which will be used to identify the current location of the hazard?

Select which will be used to identify the location of the hazard:

major road(s)/ intersection(s)

- User Input Explanation: In the original message, the location of the fire was given by road names. This is being preserved in the new message by using road names again.

PROMPT 7: The hazard is located (in/near/between) which major road(s)/ intersection(s)?

Select the proximity of the hazard to the major road(s)/ intersection(s): **between**

Enter the major road(s)/ intersection(s) the hazard is located near:

(separate multiple with 'and' or ','): **Highway 231, Highway 291, Corkscrew Canyon Road**

- User Input Explanation: The original message gave a location for the fire that was geographically small and hard to interpret. Sources found online triangulated the fire between these three roads. Therefore, it was decided that the location of the fire was more easily understood by saying it was between these three major roads.

PROMPT 8: Which will be used to identify the direction the fire is spreading?

Select which will be used to identify the direction the fire is spreading:

major road(s)/ intersection(s)

- User Input Explanation: The original message as well as the evacuation areas given online were all identified using major road names. This is being continued by using major roads to identify locations in this message.

PROMPT 9: What is the name of the major road(s)/ intersection(s) that the fire is moving towards?

Enter the major road(s)/ intersection(s) the fire is moving towards: **Corkscrew Canyon Road**

- User Input Explanation: Although the research did not explicitly say that fire was moving toward Corkscrew Canyon Road, this was selected as the road the fire was moving toward. The fire began at the intersection of Highways 231 and 291, Corkscrew Canyon Road is the furthest point from this origin and is also identified in the original message as the location of the fire. Therefore, it is being assumed that this is the direction the fire is headed.

PROMPT 10: Is there a specific region of people who should evacuate?

Select Yes/No: **No, everyone receiving this message should evacuate**

- User Input Explanation: The original message was sent to a specific polygon on people who were being informed they should evacuate. This message will be used in the same way and only those who should be evacuating will be inside the polygon and receive the message.

PROMPT 11: Prompt not applicable. Continue to next prompt.

- User Input Explanation: This prompt is not applicable because it was selected that everyone receiving the message should evacuate. If there was only a specific region of people who should evacuate, the prompt would have read 'People located (in/near/between) which region(s) should evacuate?'.

PROMPT 12: When should people take action?

Enter when people should take action: **now**

- User Input Explanation: 'Now' was selected as the time for action because of the harsh fire conditions and strong winds, there was little or no time to delay protective action taking.

PROMPT 14: What specific actions should the person receiving this message take?

Select action 1: (You MUST select at least one action): **other (35c. limit)**

Fill-in action (35c. limit): **Do not wait to leave**

Select action 2: (select 'none' if no other actions should be included):

Do not delay to pack belongings.

- User Input Explanation: The guidance of 'Do not delay to pack belongings.' was chosen because the fire was moving quickly and there was no time for extraneous activities. The guidance of 'Do not wait to leave' was entered manually after selecting 'other (35c. limit)'. This guidance was selected because the original WEA was sent around 4am. If the unique tones woke the message receiver, it was important that he/she understood that they needed to leave right away and there was not time to waste. If the tones did not wake the message receiver and he/she did not read the message until they awoke, he/she might feel an increased sense or urgency because they feel like they are behind in their protective action taking.

PROMPT 15: What should people do for update information?

Select action: (select 'none' if no update information should be included):

none

- 'None' was selected because the original message did not contain any information for where the message receiver should seek more information. There was also no website or phone number indicated online as the best source of information during the Lake Spokane Fire.

The message that was generated after all of the selections and inputs identified above were used in the message creation tool was 324c. and read:

> Stevens County Emergency Management: WILDFIRE EMERGENCY located between Highway 231, Highway 291, Corkscrew Canyon Road moving toward Corkscrew Canyon Road. Wildfires can block roads/evacuation routes, cause injury/death. If you are receiving this message EVACUATE NOW. Do not wait to leave. Do not delay to pack belongings.

The following page provides an image that shows the user interface for the Lake Spokane Fire message after all of the selections and inputs have been entered and the message was complete.

	Message:	Stevens County Emergency Management: WILDFIRE EMERGENCY located between Highway 231, Highway 291, Corkscrew Canyon Road moving toward Corkscrew Canyon Road. Wildfires can block roads/evacuation routes, cause injury/death. If you are receiving this message EVACUATE NOW. Do not wait to leave. Do not delay to pack belongings.		
	Characters Left:	36		
Guidance	Prompt 13	What is the main purpose of this message?		
		Select the main purpose of this message:	Evacuation	
Source	Prompt 1	What agency should be listed as the source of this message?		
		Enter the agency sending this message:	Stevens County Emergency Management	
Source	Prompt 2	Does this agency use an acronym that is more common than its official title?		
		Select Yes or No:	No	
Source	Prompt 3	Prompt not applicable. Continue to next prompt.		
			SD OES	
Hazard	Prompt 4	What type of emergency is happening or about to happen?		
		Select the type of emergency:	Wildfire Emergency	
Hazard	Prompt 5	What wildfire consequences should the public be aware of? "Wildfires can..."		
		Select consequence #1: *(you MUST select at least one consequence)*	block roads/evacuation routes	
		Select consequence #2: *(select 'none' if no other consequences should be included)*	cause injury/death	
				35
Location	Prompt 6	Which will be used to identify the current location of the hazard?		
		Select which will be used to identify the location of the hazard:	major road(s)/ intersection(s)	
Location	Prompt 7	The hazard is located between which major road(s)/ intersection(s)?		
		Select the proximity of the hazard to the major road(s)/ intersection(s):	between	
		Enter the major road(s)/ intersection(s) the hazard is located between: (separate multiple with 'and' or ',')	Highway 231, Highway 291, Corkscrew Canyon Road	
Location	Prompt 8	Which will be used to identify the direction the fire is spreading?		
		Select which will be used to identify the direction the fire is spreading:	major road(s)/ intersection(s)	
Location	Prompt 9	What is the name of the major road(s)/ intersection(s) that the fire is moving towards?		
		Enter the major road(s)/ intersection(s) that the fire is moving towards:	Corkscrew Canyon Road	
Location	Prompt 10	Is there a specific region of people who should evacuate?		
		Select Yes or No:	No, everyone receiving this message should evacuate	
Location	Prompt 11	Prompt not applicable. Continue to next prompt.		
			(in/near/between)	
Timeline	Prompt 12	When should people take action?		
		Select when people should take action:	now	
			-	
			-	
Guidance	Prompt 14	What specific actions should the person receiving this message take?		
		Select action #1: *(You MUST select at least one action)*	other (35c. limit)	
		Select action #2: *(select 'none' if no other actions should be included)*	Do not delay to pack belongings.	
		Fill-in action (35c. limit):	Do not wait to leave	15
Guidance	Prompt 15	What should people do for update information?		
		Select action: *(select 'none' if no update information should be included)*	none	

Figure 28: Lake Spokane Fire Message Generated with the Message Creation Tool

6.3.3 Comparison of Original Message and Tool Generated Message

The purpose of this comparison is to explain the value added to the message with the additional 270c. available. Below is the summarized list of problems and shortcomings identified with the 90c. message. The 360c. message addresses each of these and also provides additional benefits.

The message:

- Does not identify who is sending the message.
- Does not identify a timeline of the hazard or when the message receiver needs to act.
- Does not identify personal consequences of the hazard.
- Does not identify who should heed the message.
- Provides a potentially confusing location for the hazard.
- Does not provide any supplemental guidance to accompany the instruction to 'evacuate'.
- Truncates the names of roads (e.g., 'Corkscrew' for Corkscrew Canyon Road).
- Uses language that may not create urgency (e.g., 'Please').

The first six problems/shortcomings identified have to do with missing or confusing content information. In the original message, only three of the five necessary content sections are included: hazard, location, and guidance. However, the location is potentially confusing, and the hazard and guidance are vague and lack useful supplemental information. The message does inform the receiver to 'evacuate' but is not clear about who should heed the message. A receiver that does not know this message was sent to a specific polygon of people might not think the message was intended for him/her. The message completely omits a source and a timeline of the hazard and/or when people should take protective action. Finally, the message uses language that may not create urgency and truncates the names of roads that are used to identify the location of the hazard. The tool-generated message includes information about all of the content sections. Below, the 5 content sections are listed and color coded. Following this key are the original message and the tool-generated message. The content of the messages is highlighted with its corresponding content section.

Color Key: Source Hazard Location Timeline Guidance

Original Message:

Please evacuate due to wildfire on Corkscrew between Happy Hills and Highway 291

Tool-Generated Message:

Stevens County Emergency Management: WILDFIRE EMERGENCY located between Highway 231, Highway 291, Corkscrew Canyon Road moving toward Corkscrew Canyon Road. Wildfires can block roads/evacuation routes, cause injury/death. If you are receiving this message EVACUATE NOW. Do not wait to leave. Do not delay to pack belongings.

Along with containing the 5 necessary content types, the message generated with the tool also contains supplemental information to increase the message receiver's belief, understanding, and personalization of the message. The 8 questions displayed in the table below were developed to indicate major points of potential confusion and clarification the message receiver might need when reading a short message alert. The 5 questions without the '*' are associated with the 5 content types. The 3 questions with the '*' were developed to add additional or clarifying information to the message. In the table below, each of the questions has been applied to the original message and the tool-generated message. The responses to each question have been written using only the information available in the original and tool-generated short messages, respectively.

Content Section	Question	Original Message	Tool Generated Message
Source	Who/which agency is sending this message?	-	Stevens County Emergency Management
Hazard	What is the hazard people are being warned about?	wildfire	wildfire emergency
Hazard*	What are the potential consequences of this hazard?	-	-block roads/evacuation routes -cause injury/death
Location	What is the current location of the hazard?	on Corkscrew between Happy Hills and Highway 291	between Highway 231, Highway 291, Corkscrew Canyon Road
Location*	What direction is the hazard moving?	-	toward Corkscrew Canyon Road
Location*	What region(s) of people should evacuate?	Everyone receiving the message	Everyone receiving the message
Timeline	How long does the message receiver have until he/she needs to act?	-	no time, act now
Guidance	What protective actions should the message receiver be following?	evacuate	-Evacuate -Do not delay to pack belongings. -Do not wait to leave

Table 12: Chart of necessary and supplemental information comparing original and tool-generated messages.

The original message addressed three of the five content sections and was vague and potentially confusing. The tool-generated message addresses all five of the content sections and provides clear and concise answers for each of the eight questions. The purpose of the original message, evacuation, is preserved and clarified in the too-generated message. The hazard is still identified as a wildfire and the location of the hazard is given in a way that is more clear.

Even though it is an improvement upon the original message, the tool-generated message contains its own problems and shortcomings. The original message did not identify a source. The source was selected based on the information available in the FEMA WEA FRW list (2018) and a Google search of the county. There is a possibility that the source selected is not the best or most recognizable and another should have been selected. The location identification for the hazard was also changed because it was felt that the original message was unclear. However, it is possible that the wording in the original message would have been clear to the message receivers and it did accurately portray the location of the hazard. It is possible that the new selected location is too large and ambiguous. Finally, the guidance instructing people to not wait to leave was included because the message was sent around 4am. This could potentially be a problem and could cause the message receiver distress if he/she did not read the message until they woke up. Shortcomings of the message creation tool

were also identified through this case study and provide feedback for potential improvements that could be made in the future. The way the hazard location was identified was changed because it was decided that the wording used in the original message was unclear. However, if the message creator had wished to identify the location the exact same way as the original message, he/she would not have been able to do so using the message creation tool. Currently the tool allows for the selection of '(in/near/between) location(s)', in turn, there is currently no way to enter 'on [location] (in/near/between) location(s)'. Future tool development might allow for more sophisticated location identification information to be used. The fire was also identified as moving toward Corkscrew Canyon Road. Based on the research gathered, the direction of the fire was assumed. In the current version of the tool, there is no way to enter that the fire is moving in multiple directions and, also, there is no way to omit directional information altogether. A future version of the tool might allow for these.

This case study aided in the identification of ways that the message creation tool could be improved. Even though the tool-generated message contained its own shortcomings, it was still an improvement over the original WEA.

7 Conclusion

Wireless Emergency Alerts (WEAs) are a form of short message alerts that can be sent using IPAWS during imminent threat emergencies. Currently, WEAs are written free-hand or by using fill-in-the-blank style templates that were created before an emergency occurs. As of May 2019, FEMA increased the WEA character limit from 90c. to 360c, meaning message creators will have an extra 270c. available to provide important, life changing information to the public. The majority of information available to message creators regarding best practices in writing short message alerts is potentially ambiguous and may require interpretation.

The message creation tool was designed to assist message creators in generating wildfire evacuation-based WEAs using 15 prompts. To construct the tool, the information currently available regarding best practices in short message alerts was collected, analyzed, and implemented into the tool. The message creation tool ensures that all necessary information is being included in the message as well as adding clarifying and useful supplemental information. The message creation tool sets a foundation for the bridge between social science-based short message alerting research and the practical generation of these messages for dissemination during imminent threat emergencies.

From this thesis, a summarized list of key contributions has been compiled. This thesis:

- Analyzes current research regarding best practices in short message alerts and discusses potential problems/ shortcomings as well as key findings.
- Uses the available research and subsequent analysis to develop fifteen user prompts that, when filled out, gather the information necessary to generate wildfire evacuation-based 360c. emergency alerts.
- Uses the fifteen prompts to develop a message creation tool that, when filled out, auto generate a 360c., or less, wildfire evacuation message.
- Ensures the tool-generated message includes information on the five necessary content sections– in order, as well as pertinent and useful supplemental information.
- Provides case studies of three different wildfires where WEAs were sent to demonstrate the practicality of the tool and the benefits of the tool-generated messages.
- Identifies topics for future research and potential improvements that could be made to future versions of the message creation tool.

8 Future Research and Tool Improvements

While completing this thesis, potential places for future research or tool improvements were identified and a list was compiled:

- **Development of the tool for purposes other than evacuation.** Prompt 13 has the message creator identify the main purpose of the message. In the tool, evacuation, shelter-in-place, and provide information are all options for the user to select; however, the tool was developed only for the message creator to select evacuation. Future versions of the tool could allow the message creator to select the other purposes and change the rest of the prompts depending on the purpose selected.
- **Development of the tool for hazards other than a wildfire.** Prompt 4 has the message creator identify the hazard that is occuring or is about to occur. The current selections available are wildfire emergency, tornado emergency, flash flood, active shooter, and bomb threat. Currently, the tool has only been developed for the message creator to select wildfire emergency. The other selections available are examples of the different types of hazards for which the tool could be developed in the future.
- **Development of the tool for systems other than WEA.** The message creation tool was developed for this thesis with the limitation that it would be used only to create 360c. WEA messages. Future research and tool improvements could expand this concept for other alerting systems, such as mass notification systems. In an alternate form, the tool could be used to develop templates for mass notification alerts where only a few pieces of information would need to be entered during an emergency. The tool could also potentially be used to generate messages in real time if a building had designated emergency communication personnel and/ or it is linked to building sensors. The concept of a tool that generates a message that auto-incorporates research and known best practices is endless.
- **Improvement of the tool and tool-generated messages wording and grammar.** It was identified in the case study that the tool currently limits the way certain portions of the tool-generated message can be worded (e.g., the hazard identification). Future versions of the tool might allow for more flexibility in wording, potentially through short free-hand responses that have guiding questions. Also, the current tool does not have a method for spell check. Future versions might have a pop-up after the prompts have been filled out to alert the message creator of misspelled words. Finally, the message creation tool has built in punctuation and does not account for repeats in punctuation marks. For instance, a message creator selects

'other (35c. limit) for Prompt 14 and enters 'Do not wait to leave.'. For this selection, the message creation tool automatically adds a period after the input. If the message creator also enters a period, the phrase would appear as 'Do not wait to leave..' Future versions of the tool may be able to account for this and ensure punctuation marks are not being repeated.

- **Validation testing of the tool's practicality.** The tool-generated messages were analyzed for the benefits they provided over traditional WEA messages. It is believed that the tool offers other benefits such as being able to generate messages quicker than writing them free-form. Validation testing would be needed in order to support this and determine other benefits the tool provides to the message creator.
- **Validation testing of the tool-generated messages.** The tool-generated messages were analyzed for their benefit by comparing them to 90c. WEA messages. They were also judged based on their ability to answer eight questions that were developed as the main questions a wildfire evacuation message should be able to answer. Validation testing of the messages created by the tool would be necessary to analyze other benefits of the message that are hypothesized such as increased readability and understanding.

9 References

Aguirre, B. E., Wenger, D., and Vigo, G. (1998). "A Test of the Emergent Norm Theory of Collective Behavior." Sociological Forum 13(2): 301-320.

Bean, H., Liu, B. F., Madden, S., Sutton, J., Wood, M. M., & Mileti, D. S. (2016). Disaster warnings in your pocket: How audiences interpret mobile alerts for an unfamiliar hazard. Journal of Contingencies and Crisis Management, 24(3), 136-147.

Bean, H., Sutton, J., Liu, B. F., Madden, S., Wood, M. M., & Mileti, D. S. (2015). The study of mobile public warning messages: A research review and agenda. Review of Communication, 15(1), 60-80.

Bennett, D. M. (2015). Gaps in Wireless Emergency Alert (WEA) Effectiveness.

CAL FIRE. (2019). "THOMAS FIRE", http://cdfdata.fire.ca.gov/incidents/incidents_details_info?incident_id=1922, Accessed April 1, 2019.

Cao, Y., Boruff, B. J., & McNeill, I. M. (2016). Is a picture worth a thousand words? Evaluating the effectiveness of maps for delivering wildfire warning information. International Journal of Disaster Risk Reduction, 19, 179-196.

City of Ventura Emergency Operations Center. (2018). "Thomas Fire After-Action Review/ Improvement Plan (AAR/IP)", https://www.cityofventura.ca.gov/DocumentCenter/View/16058/Thomas-Fire-After-Action-Review?bidId=, Accessed April 7, 2019.

County of San Diego. (2018). "Lilac Fire After Action Report (Lilac Fire AAR)", https://www.sandiegocounty.gov/dmpr/docs/LilacFireAAR.pdf, Accessed April 9, 2019.

Daly, B. K., Gerber, M., Anderson, W. B., Bhatia, K., Cox, C., Davis, J. S., ... & Hodan, C. (2014). Geographic Targeting, Message Content and Character Limitation Subgroup Report.

Department of Justice (2012). AMBER Alert Best Practices.

Erdogmus, H., Griss, M., Iannucci, B., Kumar, S., Falcão, J., Jauhri, A., & Kovalev, M. (2015). Opportunities, Options, and Enhancements for the Wireless Emergency Alerting Service. Carnegie Mellon University, Technical Report CMU-SV-15-001.

FCC News. (2016). "FCC Strengthens Wireless Emergency Alerts as a Public Safety Tool." News release. September 29, 2016. Accessed August 18, 2017. http://transition.fcc.gov/Daily_Releases/Daily_Business/2016/db0929/DOC-341504A1.pdf

Federal Communications Commission (FCC). (2018). "Consumer Guide: Wireless Emergency Alerts (WEA)", https://www.fcc.gov/sites/default/files/wireless_emergency_alerts_wea.pdf, Accessed March 10, 2019.

Federal Communications Commission (FCC). (2018). FCC 18-4 SECOND REPORT AND ORDER AND SECOND ORDER ON RECONSIDERATION. January 31, 2018. Accessed March 7, 2019. https://docs.fcc.gov/public/attachments/FCC-18-4A1.pdf

Federal Emergency Management Agency (FEMA). (2016). "Alert Origination Software Providers That Have Successfully Demonstrated Their IPAWS Capabilities", https://www.fema.gov/media-library/assets/documents/25916, Accessed May 21, 2019.

Federal Emergency Management Agency (FEMA). (2016). "Integrated Public Alert and Warning System (IPAWS) Glossary", https://www.fema.gov/media-library-data/1452627256761-baf3142e9efc593fe2e633ad53c0980f/IPAWS_Glossary_2016.pdf, Accessed April 1, 2019.

Federal Emergency Management Agency (FEMA). (2018). "THOMAS FIRE BRIEFING", https://www.fema.gov/media-library-data/1526574011770-6a3afb18c82beaf881650ae12cfe9891/ThomasFireBriefingNAC_508.pdf, Accessed April 1, 2019.

Federal Emergency Management Agency (FEMA). (2018). List of WEA FRW messages sent Mar 2014- Dec 2017. Accessed at NIST. Cited in this thesis as '(FEMA WEA FRW 2018)'.

Ferreira, Grabby. (2017). "Mandatory and voluntary evacuations for the Thomas Fire." THE TRIBUNE. https://www.sanluisobispo.com/news/state/california/fires/article190237219.html, Accessed April 3, 2019.

Fischhoff, B., Slovic, P., Lichtenstein, S., Read, S., & Combs, B. (1978). How safe is safe enough? A psychometric study of attitudes towards technological risks and benefits. Policy sciences, 9(2), 127-152.

Fiske, S. T., & Taylor, S. E. (2013). Social cognition: From brains to culture. Sage.

Helsel, Phil. (2017). "Southern California's Thomas Fire now largest in state history." NBC News. https://www.nbcnews.com/storyline/western-wildfires/southern-california-s-thomas-fire-now-largest-state-history-n832296, Accessed April 1, 2019.

Hill, Kip. (2014). "Lake Spokane wildfire now tops 900 acres." The Spokeman- Review. http://www.spokesman.com/stories/2014/jul/11/lake-spokane-wildfire-now-tops-900-acres/, Accessed April 15, 2019.

Hui, C., Tyshchuk, Y., Wallace, W. A., Magdon-Ismail, M., & Goldberg, M. (2012, April). Information cascades in social media in response to a crisis: a preliminary model and a case study. In Proceedings of the 21st International Conference on World Wide Web (pp. 653-656). ACM.

IPAWS NON WEATHER. (2019). "Alert: Fire Warning", http://ipawsnonweather.alertblogger.com, Accessed May 15, 2019.

KHQ. (2014). "Lake Spokane fire: 100% contained." https://www.khq.com/news/lake-spokane-fire-contained/article_f1bd4b3a-ee55-5da2-bd66-df671c636daf.html, Accessed April 15, 2019.

KPCC. (2017). "Thomas Fire grows to 115,000 acres, destroying 439 homes and buildings." Southern California Public Radio (SCPR). https://www.scpr.org/news/2017/12/07/78629/101-freeway-closed-as-thomas-fire-grows-to-96-000/, Accessed April 5, 2019.

Kuligowski, E. D., & Doermann, J. (2018). A Review of public response to short message alerts under imminent threat. US Department of Commerce, National Institute of Standards and Technology.

Kuligowski, E.D. and Omori, H. (2014). General Guidance on Emergency Communication Strategies for Buildings, 2nd Edition. NIST Technical Note 1827, National Institute of Standards and Technology: Gaithersburg, MD.

Lindell, M. K., & Perry, R. W. (2012). The protective action decision model: theoretical modifications and additional evidence. Risk Analysis: An International Journal, 32(4), 616-632.

Liu, B. F., Fraustino, J. D., & Jin, Y. (2015). How disaster information form, source, type, and prior disaster exposure affect public outcomes: Jumping on the social media bandwagon?. Journal of Applied Communication Research, 43(1), 44-65.

Liu, B. F., Wood, M. M., Egnoto, M., Bean, H., Sutton, J., Mileti, D., & Madden, S. (2017). Is a picture worth a thousand words? The effects of maps and warning messages on how publics respond to disaster information. Public Relations Review.

Mayhorn, C. B. (2005). Cognitive aging and the processing of hazard information and disaster warnings. Natural Hazards Review, 6(4), 165-170.

Mileti, D. S. and Peek, L. (2000). "The Social Psychology of Public Response to Warnings of a Nuclear Power Plant Accident." Journal of Hazardous Materials 75:181-194.

Mileti, D. S. and Sorensen, J. H. (1990). Communication of Emergency Public Warnings. ORNL-6609, Oak Ridge: National Laboratory.

National Research Council. (2013). Public response to alerts and warnings using social media: report of a workshop on current knowledge and research gaps. National Academies Press.

National Weather Service (NWS). 2019. "Wireless Emergency Alerts (360 characters)", https://www.weather.gov/wrn/wea360, Accessed April 20, 2019.

Northwest Interagency Coordination Center (NWCC). (2014). "Nothwest Annual Fire Report 2014", https://gacc.nifc.gov/nwcc/content/pdfs/archives/2014_Annual_Fire_Report.pdf, Accessed April 15, 2019.

Sevilla, Mario. (2017). "INTERACTIVE MAP: Lilac Fire rips through North San Diego County." abc 10 News San Diego. https://www.10news.com/news/interactive-map-lilac-fire-rips-through-north-san-diego-county, Accessed April 11, 2019.

St. John, Paige. (2017). "Alarming failures left many in path of California wildfires vulnerable and without warning." Los Angeles Times. Accessed May 15, 2019.

Starbird, K., & Palen, L. (2010). Pass it on?: Retweeting in mass emergency(pp. 1-10). International Community on Information Systems for Crisis Response and Management.

Stevens County. (2018). "Evacuation Levels", http://www.co.stevens.wa.us/EMS%20-%20Stevens%20County%20
Fire/ PDF%20docs/EvacuationLevels.pdf, Accessed April 15, 2019.

Sutton, J., & Woods, C. (2016). Tsunami Warning Message Interpretation and Sense Making: Focus Group Insights. Weather, Climate, and Society, 8(4), 389-398.

Sutton, J., Kuligowski, E. D., (2019). Alerts and Warnings on Short Message Channels: Guidance from an Expert Panel Process.

Sutton, J., League, C., Sellnow, T. L., & Sellnow, D. D. (2015). Terse messaging and public health in the midst of natural disasters: The case of the Boulder floods. Health communication, 30(2), 135-143.

Sutton, J., Palen, L., & Shklovski, I. (2008). Backchannels on the front lines: Emergent use of social media in the 2007 Southern California fire. proceedings of Information Systems for Crisis Response and Management Conference (ISCRAM), Washington DC. Washington DC.

Sutton, J., Spiro, E. S., Johnson, B., Fitzhugh, S., Gibson, B., & Butts, C. T. (2014). Warning tweets: Serial transmission of messages during the warning phase of a disaster event. Information, Communication & Society, 17(6), 765-787.

Tanaka, Y., Sakamoto, Y., & Honda, H. (2014, January). The impact of posting URLs in disaster-related tweets on rumor spreading behavior. In System Sciences (HICSS), 2014 47th Hawaii International Conference on(pp. 520-529). IEEE.

Temnikova, I., Vieweg, S., & Castillo, C. (2015, May). The case for readability of crisis communications in social media. In Proceedings of the 24th International Conference on World Wide Web (pp. 1245-1250). ACM.

Turner, R. H. and L. M. Killian. (1972). Collective Behavior. Englewood Cliffs, NJ: Prentice Hall, Inc.

Underwood, Christopher. (2017). "Lilac Fire: San Diego County Fire Evacuation Information". KPBS. https://www.kpbs.org/news/2017/dec/08/san-diego-county-fire-evacuation-information/, Accessed April 12, 2019.

United States Department of Agriculture (USDA). (2019). "County FIPS Codes", https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/home/?cid=nrcs143_013697, Accessed April 28, 2019.

Vieweg, S., Hughes, A. L., Starbird, K., & Palen, L. (2010, April). Microblogging during two natural hazards events: what twitter may contribute to situational awareness. In Proceedings of the SIGCHI conference on human factors in computing systems (pp. 1079-1088). ACM.

Wei, H-L, Lindell, M. K., Prater, C. S. Wei, J., Wang, F., Ge, Y. G. (2018). "Perceived stakeholder characteristics and protective action for influenza emergencies: A comparative study of respondents in the United States and China." Int. J. Mass Emerg. Disast., 36(1), 52-70.

Witmer, Wade. (2017). "Integrated Public Alert and Warning System (IPAWS)" prepared for the Radiological Preparedness Conference. Federal Emergency Managment Agency (FEMA). https://www.nist.gov/sites/default/files/documents/2017/08/24/5-ipaws_for_nacwir_mtg_24aug2017.pdf, Accessed April 12, 2019.

Wood,M., Bean, H., Liu, B., Boyd,M. (2015). Comprehensive testing of imminent threat public messages for mobile devices:Updated Findings. College Park: National Consortium for the Study of Terrorism and Responses to Terrorism.

Woody, C., & Ellison, R. (2014). Maximizing trust in the wireless emergency alerts (WEA) service.