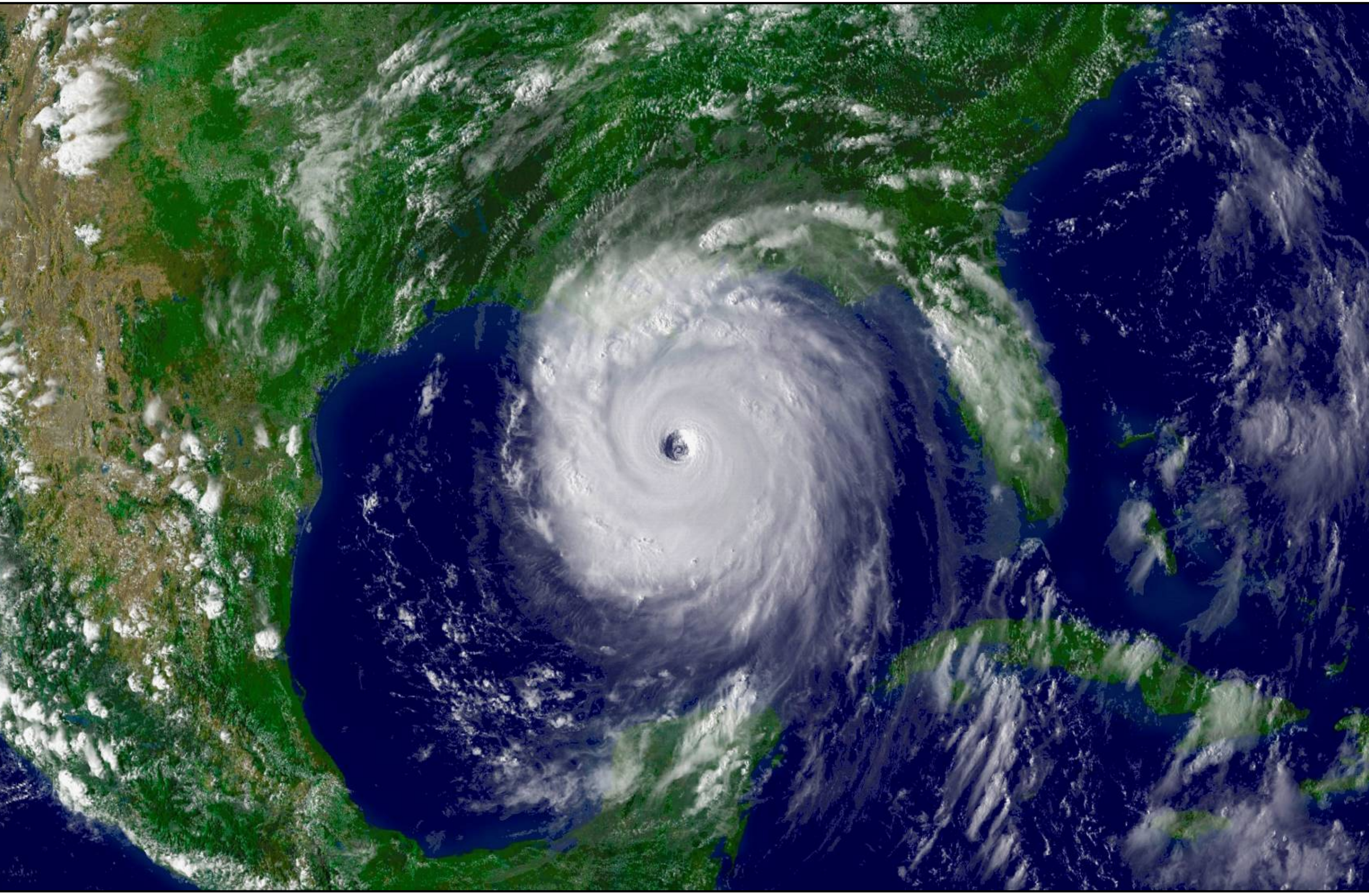

Final Report: An Integrated Approach to Geo-Target At-Risk Communities and Deploy Effective Crisis Communication Approaches

May 2016

Homeland Security

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Preface

The purpose of this research, performed for the Department of Homeland Security, Science and Technology Directorate, was to identify effective alert and warning technologies, and to determine effective alert message format and content to maximize coverage among the ethnically and culturally diverse population of the Mississippi Gulf Coast. The main objectives of this research were to: (i) examine public perception of and responses to different types of communication technologies used for alert and warning message dissemination; (ii) investigate the impact of socioeconomic and cultural characteristics of at-risk populations (i.e., people who are highly susceptible to coastal hazards because of their physical location along the Mississippi Gulf Coast boundary) on their responses to alert and warning messages received by specific devices and from specific information sources; and (iii) offer recommendations to improve the availability and coverage of existing communication devices for communities with ethnically and culturally diverse populations, both on the Mississippi Gulf Coast and elsewhere in the United States.

The intended audience of this report includes: federal, state, local and tribal alert originators, first responders and emergency management agencies; decision makers; wireless providers; local communities and community organizations; and academic and research communities. Each of these audience groups has an important role to play in deciding the most effective way to implement Wireless Emergency Alerts and to expand its use.

Contents

Figures

Tables

Executive Summary

The Science and Technology Directorate of the Department of Homeland Security (DHS) established the Wireless Emergency Alerts (WEA) Research, Development, Testing and Evaluation (RDT&E) Program within the First Responders Group's (FRG) Office for Interoperability and Compatibility (OIC) to facilitate systems research, technology development, testing and evaluation related to public alerts and warnings. The WEA RDT&E Program faces the organizational challenge of aligning efforts of a diverse research community in the public and private sectors to specific legislative mandates and national goals. This research project identified effective warning device(s) based on their performance and usability from agency and household perspectives, and effective alert message format and content in relation to socioeconomic and cultural characteristics of the public so as to provide maximum coverage to the culturally and ethnically diverse populations of the Mississippi Gulf Coast.

A variety of technologies are currently used to disseminate alert and warning messages. The traditional command and control, hierarchical communication approach used Emergency Alert System (alert and warning messages are disseminated via TV and radio), National Warning System (automated telephone system disseminates messages), Commercial Mobile Alert System (currently known as WEA uses mobile phones and devices to send text alerts), the National Oceanic and Atmospheric Administration (NOAA) Weather Radio All Hazards (NWR) (uses radio stations to broadcast alerts), and local systems (use sirens) to reach the public during a hazard event (Sorensen 2000). Following the Public Alert and Warning System Executive Order of 2006,[1] the Federal Emergency Management Agency (FEMA) established the Integrated Public Alert and Warning System (IPAWS). This system is designed to integrate these different alert systems so standardized messages can be sent out to a broader community in a timely manner (FEMA 2012). The standardized message length for WEA messages remains at present limited to no more than 90 characters, however, and sirens simply provide sounds with limited geographical coverage, thereby requiring the public to seek out more information about a hazard and its associated risks (FEMA 2015). An alternative to this top-down approach is a network communication approach that allows both the public and agencies to share information in near real time before, during and after a disaster event (Sutton et al. 2008). With advancements and growth in information and communication technologies (ICT), social media sites along with networking applications (e.g., Facebook, Flickr, MySpace, LinkedIn), messaging services (e.g., Twitter) and social mapping applications (e.g., Google Maps) have become popular sources of information that use network communication (Sorensen 2000; Sutton et al. 2008; Palen et al. 2009).

Although these communication technologies provide a broader coverage by informing everyone of the adverse consequences of a disaster, studies have indicated that their

[1] White House (2006). Retrieved May 2, 2016 from Executive Order: Public Alert and Warning System: https://georgewbush-whitehouse.archives.gov/news/releases/2006/06/20060626.html.

effective usage and acceptability is influenced by socioeconomic, cultural and psychological (risk perception) characteristics of at-risk populations (Mileti and Peek 2000; Sorensen 2000). With present restrictions associated with message length, it is crucial to understand the impact of message content and format with regard to public responses. Such knowledge will not only help frame alert and warning messages in relation to the socio-cultural and psychological characteristics of the public, but will also help disseminate messages using multiple technologies to maximize response.

This project focused on examining the effectiveness of the public response subsystem by undertaking the following six tasks: (i) determine the coverage area and accessibility of existing emergency alert and warning devices; (ii) determine local emergency management agency (EMA) perspectives of available alert and warning devices; (iii) determine socioeconomic and cultural characteristics of at-risk populations; (iv) examine the perceptions of at-risk populations regarding alert and warning devices; (v) explore the perceptions and reactions of at-risk populations with regard to alert and warning messages; and (vi) investigate the effectiveness of alert and warning messages with regard to public participation in message preparation and dissemination.

To answer the research questions identified under each task, a combination of spatial and statistical techniques were implemented. Participatory, action-oriented ethnographic surveys were administered to individuals and emergency management agency personnel in the study counties to collect primary data about alert/warning devices; perceptions of agency personnel and households regarding the usability and performance of these devices; format, and content of messages; public perceptions and responses to warnings; and public perspectives about their participation in message preparation and dissemination. A number of secondary datasets — socioeconomic information, administrative boundaries, transportation networks, hydrology data, coast boundary, digital elevation models (DEMs), land use/cover, and location and spatial coverage of alert and warning devices — were collected from local, state and federal agencies to undertake each task.

This study was conducted in the three Gulf Coast counties of South Mississippi (Hancock, Harrison and Jackson), all of which are susceptible to tropical cyclones and coastal flooding. In addition to its physical risk to natural and human-made hazards, the Mississippi Gulf Coast is heavily-populated and home to socioeconomically and culturally diverse communities. The high risk areas of the Mississippi Gulf Coast are also occupied by vulnerable population groups, which include immigrant communities comprised in part of older generation individuals with limited knowledge of English. Its coastline is also a complex mosaic of rural and urban landscapes.

EMAs use a variety of technologies for message dissemination, which, based on the results of this research, together provide almost 100 percent spatial coverage. Messages are generally sent out in English, however, hindering non-English speaking residents from obtaining information about a disaster and appropriate mitigation actions. Both agencies and households indicated that conventional devices (i.e., TV, radio, NWR and Reverse 911) along with cell phones/WEA messages offer accurate and updated messages in a timely manner, and hence, they prefer using these devices to receive alerts and warnings. Agency

personnel prefer not to use sirens because they (i) provide limited spatial coverage, (ii) are expensive to install, and (iii) are available in only few cities; however, they continue to believe that sirens are effective in motivating the public, specifically immigrant communities, to take positive actions. Local residents indicated that they place more trust in family and friends than conventional devices with regard to receiving up-to-date and accurate information, and they are more inclined to respond positively to warnings if their family and friends are also responding accordingly. This situation is cause for some concern; despite the prevalence of different devices, ultimately, peer communication and familial relationship seems to be a deciding factor in public response to warnings.

Despite considerable progress in implementing the WEA system, a sizable minority of survey respondents indicated they know little or nothing about it. Likewise, both agencies and local residents were skeptical of its effectiveness in increasing public response. The socioeconomic and cultural characteristics of local residents did not seem to influence their choice of devices or response to messages received from those devices, but it is clear that their response is influenced to some degree by the information originator. For instance, a certain group of people indicated their willingness to evacuate if they received messages from traditional media while another group — older and younger generations, as well as lower income residents — mentioned that they would take action only if their family and friends were also doing so. The lack of confidence in WEA messages appears to be related to a persistent lack of knowledge and understanding among the public, although this cannot be verified based on the findings of this research.

Both local EMAs and communities displayed inclinations towards using social media (SM) to disseminate risk information, but both groups expressed reservations as well. Discussion with agency personnel highlighted that they (i) prefer using SM following the hierarchical risk communication approach, such that messages are disseminated without feedback from the public, and (ii) do not consider it effective in increasing response in comparison to other warning devices. Local residents on the other hand like using SM to reach out to their family and friends and to receive alerts and warnings, but they do not prefer using SM over other technologies. SM nevertheless provides quick access to information and creates an atmosphere where local stakeholders can interact with each other in the communication process. Therefore, it has the potential to foster public participation in risk communication.

Based on these findings, the following recommendations should be considered to increase effectiveness of existing risk communication approaches and bridge research gap.

(i) Risk Communication:

a. In 2015, almost two-thirds of Americans owned a smart-phone irrespective of their socioeconomic and cultural background.[2] With the ubiquity of cell phones that allow reception of WEA messages anywhere and anytime, it is becoming increasingly easier to disseminate alerts and warnings to everyone. This research found that both the public and agencies have a higher confidence in alerts and

[2] Smith, A. (2015). Retrieved May 2, 2016 U.S. Smartphone Use in 2015: http://www.pewinternet.org/2015/04/01/us-smartphone-use-in-2015/.

warnings received via conventional devices than in WEA messages, however. One reason for this was lack of knowledge among many local residents about WEA before our study. Given how common cell phones are at present, policy makers and EMAs should work together to increase public knowledge and awareness of WEA messages, what they mean and what information can be disseminated by them.

b. The research also indicated that the public still seeks additional information from social media that provides a venue for information sharing and peer-to-peer communication. To increase public response to warnings, policy makers and EMAs should strive to collaborate with the public in message dissemination and increase their own social media presence.

(ii) Resilience and Emergency Management: According to this research, family and friends appear to be more influential in the public's decision to take mitigation actions. In some cases, family and friends are considered the source of more accurate information than alerts and warnings from local EMAs and other government sources. In other cases, such as with younger generations and lower incomes, the decision to evacuate is influenced by what family and friends do. In light of this finding, local EMAs in communities with socio-cultural diversity should work with community organizations and local stakeholders to (i) increase the public's acceptance of alerts and warnings coming from government sources, and (ii) reduce rumors that are present in information generated by social media.

(iii) Technology: Social media is considered a potential source for alerts and warnings as it enables the public to share and receive risk information. Risk information is generally not available from social media in a streamlined and consistent manner similar to WEA messages, however, thus resulting in the propagation of rumors that render it ineffective for risk communication. Increasing social media usage for risk communication will likely require establishing a science gateway, or "a community-developed set of tools, applications and data that are integrated via a portal or a suite of applications, usually in a graphical user interface."[3] Building a science gateway on the premise of social media would allow EMA personnel to supervise the sharing of risk information publicly in a streamlined, consistent manner.

(iv) Local EMAs and organizations should work together to increase awareness of risk and risk communication to maximize public response to alert and warning messages.

(v) Longitudinal analysis of the questions explored in this research project need to be conducted to determine how public response changes over time. Such information will aid with ongoing research in risk communication.

[3] XSEDE (2016). Retrieved May 4, 2016 Science Gateways: https://www.xsede.org/gateways-overview.

1. Background

With increased risk and financial impacts from different hazards in recent years, building community resilience through public and private stakeholder participation has become a priority for researchers and policy makers (Cutter et al. 2008; NRC 2012). Risk communication has been identified as a crucial component of community resilience-building efforts, and a precursor to undertaking disaster risk reduction initiatives during different phases of emergency management (Mileti and Peek 2002; Morgan et al. 2002; Hooke and Rogers 2005; Fischhoff 2009). The *Sendai Framework for Disaster Risk Reduction 2015—2030*, a recent United Nation's initiative to build resilience and a successor to the *Hyogo Framework for Action (HFA) 2005—2015*, has also identified the need to develop, maintain and strengthen a multi-hazard, multi-cultural and people-centered forecasting and early warning system for disaster risk communication (UN 2015).

Risk communication, as defined by U.S. federal policy, "is any purposeful exchange of scientific information between interested parties regarding health or environmental risks" (Covello et al. 1987, p. 222). In essence, risk communication is an interactive process that allows for multi-faceted and multi-directional exchanges of information about a hazard event and its associated risks among stakeholders (Plough and Krimsky 1987; NRC 1989). The focus of risk communication is to provide accurate information about a hazard, its potential risks and possible consequences, and required mitigation steps in a timely manner to individuals and communities so that all can take preparatory actions to mitigate the hazard's impacts.

A hazard warning system is essential for effective risk communication. Hazard warning systems are comprised of three main components: (i) a detection subsystem (which focuses on detecting and/or predicting the location and time of a hazard event); (ii) emergency management subsystem (which focuses on determining the threat posed by the hazard and the necessity to formulate alert and warning messages to be disseminated to members of the public who are at risk from the hazard); and (iii) a public response subsystem (which focuses on public receipt and understanding of messages, and public responses in the form of appropriate preparatory actions) (Sorensen et al. 1987; Grabill and Simmons 1998; NRC 2012). Although significant advances have been made to accurately predict a hazard, the effectiveness of a warning system is still a research challenge from the perspective of the public response subsystem (PRS). The PRS is influenced by two main factors: (i) warning messages — message content and style, message source, message delivery approaches and devices (Mileti and Sorensen 1990; Mileti and Peek 2000; NRC 2012); and (ii) message recipient characteristics — social and psychological characteristics of the public (Mileti and Sorensen 1990; Mileti and Peek 2000).

A number of devices and channels (voice, electronic signal, text) are used to alert at-risk populations of impending disasters so as to enable them to take effective and efficient remedial actions. The most common devices include outdoor sirens, Tone Alert Radio (TAR) that broadcasts messages tailored for at-risk populations, and televisions that broadcast alert messages via the National Weather Service (NWS) (Sorenson 2000). With

advancements in information and communication technologies (ICT), Wireless Emergency Alerts (WEA), which were previously known as Commercial Mobile Alert System (CMAS), are now disseminated via cellular networks to cell phones and other mobile devices as text messages with the help of commercial mobile service providers (FEMA 2012). These communication technologies follow a hierarchical or a linear approach such that alerts and warnings are delivered from recognized sources (e.g., NWS) to emergency responders and ultimately to at-risk populations.

Risk communication in the 21st century not only relies on information from traditional sources (hierarchical and vertically-integrated organizations), but also from social media and word-of-mouth sources (i.e., families and friends) that are typically non-hierarchical and horizontally integrated across society (Liu et al. 2011). With the growth of ICT, social media has become a popular source of risk information before, during and after an emergency situation (Lindsay 2011). During the 2014 Oso mudslide in Washington State, for example, county emergency officials used social media sites to update the public about the event, its impacts and actions underway to reduce adverse impacts (CDG 2015).

Social media builds upon *crisis informatics,* a concept that "views emergency response as an expanded social system" (Palen et al. 2009, p. 3). It also encourages stakeholder (i.e., the public and emergency managers) participation in generating and sharing disaster-related information to a broader audience (Shklovski et al. 2008; Sutton et al. 2008; Palen et al. 2009). Furthermore, because social media uses a decentralized, collaborative and network communication approach, it allows both impacted and interested populations to share and access information in near real time, irrespective of the geographic location and time of a hazard event, and it potentially enables public participation in the decision-making process (Taylor and Perry 2005; Krimsky 2007; Palen and Liu 2007; Palen 2008; Shklovski et al. 2008; Sutton et al. 2008; Palen et al. 2009; Vieweg et al. 2010).

Although the conventional, authority-based, hierarchical risk communication approach provides accurate information, it fails to incorporate viewpoints of at-risk populations or to encourage community response and participation (Wenger et al. 1990; Sorensen 2000; Gladwin et al. 2007). By contrast, social media is widely accepted as a risk communication approach, and both agencies and the public are becoming increasingly inclined towards using social media to disseminate and receive alerts and warnings (Lindsay 2011). Nonetheless, social media has its own limitations, including a tendency to proliferate rumors and hoaxes and a potential to violate the privacy of its users. In light of these concerns, it is crucial to examine how the public responds not only to message content and style, but also to sources of information and the technology used to disseminate messages.

As indicated before, the public's socio-psychological characteristics influence response to emergency warnings. Variations in perceived risk across the scientific community, emergency responders and at-risk populations result in ineffective message deliverance and message content, which in turn contribute to a disorganized or potentially chaotic public response. Prior experience partly influences how an impacted population perceives risk and responds to warning messages. Likewise, socioeconomic, cultural and political factors all contribute to differences in public response to alert and warning messages. The established

top-down, hierarchical approach to risk communication can potentially inhibit public response and acceptance as opposed to more interactive and participatory approaches. Finally, the public at large sometimes lacks general understanding of disasters and their associated risks (Cronin et al. 2004; Carter-Pokras et al. 2007; Kalkstein and Sheridan 2007; Spence et al. 2007; Taylor et al. 2007; De la Cruz-Reyna and Tilling 2008; Gaillard et al. 2008). In view of these factors, it is crucial to understand how risk perceptions and prior experiences of the public influence its response to warnings.

Executive Order 13407 of 2006 established the Integrated Public Alert and Warning System (IPAWS) to update and integrate the alert and warning infrastructure of the U.S. in response to the failure of the alert systems to increase public response during Hurricane Katrina (2005) (FEMA 2012). The mission of IPAWS is to "provide integrated services and capabilities to local, state and federal authorities that enable them to alert and warn their respective communities via multiple communications methods" (FEMA 2012). IPAWS is designed to standardize alert messages and deliver them via multiple communication technologies to a broader audience before, during and after an emergency situation in a timely manner to reduce risk (FEMA 2012).

The Mississippi Gulf Coast, the focus of this study, was the landfall location for Hurricane Katrina. Tropical cyclones are an inherent part of the Mississippi Gulf Coast and the occurrence of future cyclones is inevitable. The population of the Mississippi Gulf Coast consists of an increasingly diverse number of ethnic groups, including Anglo-Americans, African-Americans, and Vietnamese and Hispanic immigrants. Given the socioeconomic and cultural diversity of the Mississippi Gulf Coast, examining the effectiveness of communication technologies and warning messages based on public responses will help form policies and guidelines to increase public participation in mitigation activities.

2. Methodology

This chapter introduces the study site and discusses the: (i) geographic scale used for spatial analysis and modeling; (ii) survey instruments used to collect primary data from emergency management agencies and local residents of the Mississippi Gulf Coast; (iii) secondary data sets obtained as part of this research or created during analyses; and (iv) techniques used for data analyses.

2.1. Study Site

This study was conducted in the three counties of the Mississippi Gulf Coast (Hancock, Harrison and Jackson) (Figure 1), which together comprise a region that is annually susceptible to tropical cyclones during the Atlantic Basin hurricane season (June 1 to November 1). Due to the availability of offshore fossil fuels nearby in the northern Gulf of Mexico, the region is also prone to anthropogenic hazards, as was demonstrated with the 2010 Deepwater Horizon Oil Spill.

In addition to its physical vulnerability to natural and anthropogenic hazards, this coastal region is densely settled and contains an ethnically and socioeconomically diverse population. According to the 2010 U.S. Census, the combined population of the three coastal counties totaled 370,680 people; this increased to an estimated 386,144 people in 2014 (Table 1). A majority of the tri-county population is located in relatively dense urban areas situated on or near the coast. Inland areas, on the other hand, especially north of Interstate 10, contain sparsely populated and expansive rural areas through which infrastructure and communication coverage remains inconsistent (Figure 2).

Table 1: Demographic Distribution in the Three Study Counties in 2010 and 2014

	2010				2014			
County	Caucasian	African-American	Other	Total Population	Caucasian	African-American	Other	Total Population
Hancock	38,842 (88.4%)	3,139 (7.15%)	1,949 (4.45%)	43,930	40,343 (87.8%)	3,860 (8.4%)	1,746 (3.8%)	45,949
Harrison	130,365 (69.7%)	41,393 (22.1%)	15,346 (8.2%)	187,104	138,942 (69.8%)	47,773 (24%)	12,343 (6.2%)	199,058
Jackson	100,720 (72.1%)	30,034 (21.5%)	8,893 (6.4%)	139,647	102,453 (73.3%)	31,191 (22.1%)	6,492 (4.6%)	141,136

2.2. Scale of Analysis

Spatial analysis and modeling, along with ethnographic and survey-based research, were implemented to identify communities that are at risk to future coastal hazards, but may have restricted access to risk communication devices (e.g., TV, cell phones, radio) due to the variable spatial coverage of these devices. These research methods were also used to identify which risk communication devices are most commonly used by the study area communities to receive alert and warning messages, and to determine the overall effectiveness of WEA

messages based on their content and their format of delivery. Because both spatial and non-spatial data used in this study are available at multiple spatial scales, the spatial models can be implemented at varying geographic units of analysis (e.g., census tract versus census block), thereby producing different results at different scales (Mandelbrot 1967; Clark and Avery 1976; Kar and Hodgson 2012a). To increase the accuracy of modeled outcomes and to determine the optimal granularity at which analyses should be conducted, the following scales were used based on a comparative analysis of error variance at multiple geographic units and spatial resolutions.

2.2.1. Geographic Unit of Analysis

The census block is the finest scale at which socioeconomic data are available from the U.S. Census. The finest resolution at which elevation data is available from the United States Geological Survey (USGS) is 3m x 3m (Digital Elevation Model). Taking these geographic units into account, all analyses in this study was conducted at the block level using a raster model at 10m x 10m resolution (a more detailed discussion about the selection of this spatial resolution and about granularity analysis is presented in Section 3.3.2. Results and Discussion). In cases of varying resolutions, a nearest neighbor re-sampling and a dasymetric mapping areal interpolation was implemented to convert datasets to one resolution and avoid data loss arising from the Modifiable Areal Unit Problem (MAUP) outlined by Openshaw and Taylor (1979).

2.2.2. Social Unit of Analysis

Social scale can be measured through observable demographic or cultural differences (e.g., income or racial composition) or more fine-grained characteristics to identify subtle variations. Social scale does not simply conform to preconceived orders, such as local, regional or national, but is the outcome of interactions between societal structures and human agency (Marston 2000). For this study, primary data about public perception of and responses to WEA messages and risk communication devices were obtained at the household level. Agency perception of risk communication devices and policies were obtained at the individual level from emergency management agency (EMA) personnel. To maintain privacy and anonymity of research participants, household survey data were aggregated to the zip-code level before being integrated with other spatial data for analysis. Likewise, privacy and anonymity of agency personnel were ensured by removing agency affiliation from analysis.

2.3. Data and Variables

Both primary and secondary data were collected as part of this study. While questionnaire-based surveys were used to obtain primary data, secondary data containing both spatial and non-spatial information were gathered from a number of local, state and federal agencies. A discussion of survey instruments, sampling techniques, survey administration process, variables for which data were collected, and sources and types of secondary data collected is presented in the following sections.

2.3.1. Survey Instruments

(i) The first survey instrument (Appendix 1 – Agency Perceptions of Alert and Warning Devices) was created to obtain responses from agency personnel and first responders working in EMAs in the study counties. The instrument contained questions based on five-choice Likert scales, yes/no statements and factual statements with one or more answers.

The primary data obtained through this survey included an inventory of alert and warning technologies that are widely used by local agencies; perceptions of EMA personnel regarding the usability of these technologies; message accuracy; the frequency with which messages are updated and delivered; the ease of using these technologies and their availability during power outages; the effectiveness of the technologies in motivating the public to take positive preparatory actions based on their trust in the source of information; the main languages in which messages are delivered; and socioeconomic and cultural factors influencing public response to warnings from the agency perspective.

(ii) The second survey instrument (Appendix 2 – Household Perceptions of Alert and Warning Devices) was created to obtain data about local households' perceptions of and responses to available alert and warning technologies. A series of yes/no questions, factual questions with one or more choices, and Likert-scale questions were used to obtain data about the following variables:

a. Socioeconomic-Cultural Characteristics: *Demographic Profiles* (e.g., age, gender, educational attainment); *Economic Conditions* (e.g., household income, employment status); *Cultural Traits* (e.g., languages spoken fluently); *Household Characteristics* (e.g., access to TV, radio, weather radio, cell phone, Internet and landline phones at home; cell phone ownership and type); and *Location of Residence* (e.g., city, subdivision).
b. Perceptions: *Perception of Risk Based on Prior Experience* (Do respondents believe there will be future cyclones similar to Hurricane Katrina? Do respondents think they will be impacted by such a tropical cyclone?) and *Alert and Warning Technologies* (Which are currently in use? Which do respondents prefer? Do respondents use social media for risk communication? Why do respondents use a specific device?).
c. Experience: *Prior Experience with Tropical Cyclones* (Have respondents ever been impacted by a tropical cyclone?) and *Prior Experience with Warning Devices* (Which warning devices are used in study counties? How accurate are messages? What is the frequency of message delivery? Which technologies do respondents trust based on prior experience, and which do they consider to provide reliable messages? Which technologies are easiest to use?).
d. Responses: *Public Response to Alert and Warning Technologies* (How do respondents react to a specific device or channel? For instance, if the message is received via NOAA/Weather Radio, do they rely on it more than other devices?

Would respondents evacuate if they receive a message from a specific device or channel?).

(iii) The third survey instrument (Appendix 3 – Household Perceptions of Alert and Warning Messages) was created to obtain data about local households' perceptions of and responses to alert and warning messages. As with the other surveys, a series of yes/no questions, factual questions with multiple choices, and Likert-scale questions were used to obtain data about the following variables:

a. Socioeconomic-Cultural Characteristics: *Demographic Profiles* (age, gender, ethnicity, education level); *Economic Conditions* (household income, employment status); and *Cultural Traits* (languages spoken fluently).
b. Message Format and Content: *Respondent Preferences* (What length do respondents expect the message to be? In what languages do respondents prefer the message to be delivered? What specific contents do respondents expect to be included in a message? What is the sequence in which message content should be presented?).
c. Response to Messages: *Prior Experience* (How does public response to alert and warning messages differ based on prior experience with a tropical cyclone and perceptions about tropical cyclone risk?); *Message Source* (How does the public respond to messages delivered via social media versus traditional media (e.g., TV, radio, sirens) vs. word-of-mouth communication? What is the public's reaction to WEA messages and specifically to its character limitations? How does public trust in message source influence their response to messages?); *Respondent Participation* (Do respondents want to participate in message preparation and dissemination? Have they participated in message preparation and dissemination?).

2.3.2. Sampling Technique and Survey Administration

To obtain a representative sample in each of the three study counties, a non-probability sample comprising at least 0.05 percent of all households in the three counties was obtained. To meet the targeted sample size, a combination of sampling techniques was implemented.

(i) **Targeted Sampling:** A targeted sampling approach was used during the administration of all three surveys. The first survey instrument (for agencies) specifically targeted EMA personnel. The second and third (for households) survey instruments targeted households and individuals residing anywhere on the Mississippi Gulf Coast. Agency surveys were administered face-to-face as well as via an online survey link that was emailed directly to EMA personnel. Household surveys were administered in part via online links that were posted through regular emails to students, staff and faculty of the University of Southern Mississippi (USM) living on the Gulf Coast, and through Reddit, Facebook and Twitter to Gulf Coast communities. Likewise, with the help of personnel from Boat People–NAVASA (Advocacy Organization for the Vietnamese Immigrant Community) and El Pueblo/Seashore Mission (Advocacy Organization for Hispanic Immigrants and the Homeless Community), Hispanic and Vietnamese immigrants and homeless populations were targeted to participate in the household survey.

(ii) **Snowball Approach:** A snowball sampling approach was deployed to increase online participation during the household and agency surveys. Online links to the household surveys were distributed among personnel from local community organizations and private agencies (e.g., Red Cross and Gulf of Mexico Alliance) who distributed these links to their household contacts throughout the Mississippi Gulf Coast. With the help of agency personnel, online links and hard copies of the agency survey instrument were distributed to first responder groups via email and during monthly emergency operation center (EOC) meetings.

(iii) **Stratified Random Sampling:** A multi-stage, spatially stratified random sampling technique was used during administration of the warning message survey. This process involved a series of steps. The first strata of this technique encompassed the three counties — Hancock, Harrison and Jackson — of the Mississippi Gulf Coast. The second strata was the area located between the coastal boundary and Interstate 10 (I-10). Areas south of I-10 are at high risk from coastal hazard events as a result of their proximity to the coast and the surrounding low-lying terrain. The third strata included parcel or property boundaries south of I-10 in the three study counties. The fourth strata consisted of individuals and households residing in the extracted parcel boundaries.

The following steps were implemented to select a final sample of residential properties (proxy for 1 percent of households) for administration of the warning message survey:

(i) All parcels with areas between 0.1 and two acres were extracted. Parcels with areas larger than two acres were found to be occupied by storage sheds, parking lots and non-residential land-use types. Likewise, parcels with areas less than 0.1 acres are too small to be usable as residential lots.

(ii) The extracted parcels from Step 1 (between 0.1 and two acres in area) were then overlaid with spatial data sets pertaining to the following land uses within the study area: Community and Civic Centers, K-12 School Facilities, College and University Campuses, Hospitals, Churches, Storage Tanks, Recreational Facilities, Mississippi Public Broadcasting Towers, Forest Industry Lands, EPA-Designated Sites, Cemeteries, Casinos and Brownfields. A point-in-a-polygon spatial query was conducted to further refine the sample. Any parcels that coincided with land-use features from the aforementioned land-use types were removed from the study.

(iii) A visual photo interpretation technique was implemented in which color infrared imagery of the study counties was overlaid onto the extracted residential parcel boundaries. This step ensured that vacant lots and blighted properties were eliminated from the sampling process as much as possible.

From this final list of properties, a random sample was extracted. To get *n* (100) number of surveys, a total sample of *4n* (400) was randomly selected. The purpose of increasing the random sample was to ensure the final survey sample could be collected in case (i) some houses were unoccupied, (ii) some households were reluctant to participate in the survey or (iii) some houses were inaccessible.

Student surveyors were hired to administer the survey instruments in English from individuals residing in the sampled properties through face-to-face visits. Vietnamese and Spanish-speaking surveyors hired with the help of Boat People–NAVASA and El Pueblo/Seashore Mission administered the survey to Vietnamese and Hispanic residents as well through face-to-face visits.

2.3.3. Secondary Data Sets

Both spatial and non-spatial secondary data were obtained from a number of sources. The socioeconomic data was collected from the U.S. Census Bureau and the American Community Survey (ACS). The jurisdictional boundaries — county, census tract, block group and block — were obtained from the Environmental Sciences Research Institute (ESRI). The transportation networks, hydrology layers (e.g., streams and water bodies) and coastal boundary information were obtained from the Mississippi Automated Resource Information System (MARIS) and NOAA. The floodplain data for the study counties was obtained from the Federal Emergency Management Agency (FEMA). The Digital Elevation Model (DEM) data depicting the topographic variation in feet in the study counties was obtained from the USGS at 1/9 arc second (3.23m x 3.23m) spatial resolution. The DEM was derived from Light Detection and Ranging (LiDAR) data acquired after Hurricane Katrina. The spatial data pertaining to the coverage of communication devices that are used by EMA personnel in the study counties and their location data were collected from the local EMAs, Mississippi Emergency Management Agency (MEMA), NOAA and the Federal Communication Commission (FCC). Table 2 lists the secondary data sets that were used in this study, their sources and the scale of analysis at which they were obtained and used.

Table 2: Demographic Distribution in the Three Study Counties in 2010 and 2014

Data Sets	Sources	Scale of Analysis
Socioeconomic	US Census Bureau and ACS	Block, Block Group, Tract, County
Jurisdictional Boundary	ESRI and US Census	Block, Block Group, Tract, County, Zip Code, City
Parcel Boundary, Tax-Roll	County Tax Assessors	Parcel Boundary
Transportation Network	MARIS	State
Hydrology	MARIS	State
Mean High Water Boundary (Coastline)	NOAA	State
Q3 Flood Plain	FEMA	State
DEM	USGS	3m x 3m
Land Use/Cover	NOAA C-Cap	30m x 30m
Siren	MEMA	Harrison and Hancock Counties
Reverse 911	County EMA	County
NOAA Weather Radio and Coverage	NOAA	State
National Weather Channel	NOAA	State
Cell Tower	FCC	State

2.4. Data Processing and Techniques

Given that this study involved spatial analysis and modeling, a raster model at 10m x 10m spatial resolution was implemented to create a continuous surface for a specific variable and for easy implementation of models. To maintain compatibility of data sets for analysis and accuracy, all spatial data sets were projected to the same spatial reference system: the North American Datum (NAD 1983), UTM Projection Zone 16N.

2.4.1. Multi-Criteria Evaluation

Multi-Criteria Evaluation (MCE) is a tool used to simplify decision-making tasks involving numerous stakeholders, diverse sets of possible outcomes, and numerous qualitative and quantitative criteria (Proctor and Drechsler 2003; Drobne and Lisec 2009). Although rooted in mathematics and operations research, it is widely used in decision-making tasks involving social/economic and environmental criteria, such as site selection, site suitability, resource management and evaluation analysis (Drobne and Lisec 2009).

Weighted Linear Combination (WLC) is a type of MCE that allows stakeholders to weight a set of criteria influencing the final outcomes, which can be a subjective process (Kar and Hodgson 2008; Drobne and Lisec 2009). Each criterion is also rated (classified into different classes) before being multiplied with its corresponding weights and all weighted layers are added to determine a ranked spatial distribution of final scores (Equation 2.1) (Malczewski 2000; Kar and Hodgson 2008; Drobne and Lisec 2009).

$$Score = (\sum_{j}^{n} FR_j * w_j) \qquad \textbf{Equation 2.1}$$

where *Score* = total score for the location, FR_j = factor rating for factor j, n = total number of factors/criteria, w_j = weight assigned to factor j such that $\sum_{j}^{n} w_j = 100.$

3. Task Results

In this chapter, the results of the six tasks that were undertaken to fulfill the goals of this research are presented along with a discussion of these results. The chapter also presents the architecture used to deploy the Spatial Decision Support System (SDSS) and discusses its different components.

3.1. Availability of Warning Devices

Access to accurate information about a hazard and its potential risks is essential in geo-targeting the communities that must be notified of an impending disaster and recommended preparatory actions. Considerable advancements have been made in accurately determining the probability of occurrence of a hazard and the potential threats it poses to society through risk assessment — a precursor to activating the emergency response system to disseminate warning messages (Sorensen 2000). Multiple channels (e.g., voice, electronic signals and print) are also used to deliver messages via multiple devices (e.g., television, radio, telephones, cell phones and other mobile devices) to increase public understanding and improve response (Mileti and Peek 2000). An individual must still hear the risk information before processing it and responding appropriately, however, which is generally influenced by the areal extent of a warning and the spatial coverage of devices used for dissemination (Mileti and Peek 2000). Although multiple technologies are used to disseminate alert and warning messages, they may not necessarily cover the entire at-risk population and the population may not have access to an appropriate device. Thus, determining the effectiveness of a warning system should begin with determining the coverage area of available devices and accessibility of the public to all or specific devices, which is the goal of this task. The main questions that were answered as part of this task include:

- (i) Which devices are used by local EMAs for risk communication?
- (ii) What is the spatial coverage of these devices?
- (iii) What percentage of the population has access to different devices?

3.1.1. Data Analysis

To determine the spatial coverage of existing devices, a list of the devices currently in use was created with help from local EMAs and all spatial data were collected for each device. At the time of the survey there were four devices in use on the Mississippi Gulf Coast: sirens, radio, TV and mobile phones. To create the spatial coverage of sirens, the geographical locations of all sirens in the study area were obtained from a statewide spatial data set. Assuming the impacted population is outside, and ambient noise (e.g., wind, rain, hail) is minimal, the maximum area for a siren in which everyone can hear the signal is a circle of 0.5 mile radius (~300 meters) (Langham 2013). Using this stipulation, circular buffers of 0.5 mile radius were created for all sirens to determine their spatial coverage.

Unlike sirens, a radio can receive an alert message, provided it is within a maximum distance of a radio tower and the strength of the radio-wave signals is strong enough to reach the

radio. To determine the spatial coverage of NOAA Weather Radio (NWR), NWR propagation maps were used. The propagation maps identify spatial coverage offered by all radio towers in a location based on the Longley-Rice model — a terrain model that uses signal strength of the radio wave, topographic elevation and distance from the radio tower, among other parameters, to determine the coverage (ITS 2013). Likewise, TV coverage is impacted by the electromagnetic strength used for transmission. Furthermore, every cable TV subscriber has access to the National Weather Channel, which is one of the few channels that is available as part of standard cable TV packages. The FCC maintains a database of the TV stations providing digital and analog channels, and the coverage provided by digital TV for the coterminous U.S., which is also created by using the Longley-Rice model (ITS 2013). This TV location and coverage information was used to determine the spatial coverage of TV in the study counties and to determine the percent of the population that is able to receive warning messages via TV. The FCC maintains a list of all functioning cell towers and the coverage provided by each tower. The coverage area is comprised of cellular service area boundaries based on aggregated call signs (FCC 2015). The cell tower location and coverage data were used to determine the area within which all cell phones will receive WEA messages. A simple visibility analysis was also conducted to determine the locations within a cell coverage area that may be impacted by signal strength based on their distance from cell towers and topographic variation.

3.1.2. Results and Discussions

From the four main devices that were used to disseminate alert and warning messages, sirens are the oldest form of communication that use electronic signals to inform the public of an impending disaster. Because the installation and maintenance of sirens is expensive, they are only used in Bay St. Louis (Hancock County) and Biloxi (Harrison County) for risk communication (Figure 3). Sirens also do not provide wide spatial coverage, so the vast majority of Gulf Coast residents would never hear them during a hazard event, which understandably makes them ineffective for risk communication.

NWR broadcasts cover the three study counties, except for 177,498 acres in Jackson County which correspond to the mostly uninhabited Pascagoula River basin (Figure 4). According to the FCC, the National Weather Channel currently provides almost 100 percent coverage (Figure 5). Cell towers are distributed throughout the study area with a higher density along the coastline (Figure 6), and the study counties have almost 100 percent spatial coverage from Cellular South (the leading cell service provider) (Figure 6). A discussion with EMA personnel indicated that the private company First Call Network is responsible for Reverse 911 service, which also disseminates warning messages via text or voice mail to landline phones or older cell phones that are not WEA-enabled (MPB 2013).

Among the four devices, sirens provide the least amount of coverage — only 1.46 percent of the total study county — while all other devices (cell phones, radio and TV) provide almost 100 percent coverage (Table 3). Reverse 911, which is supposed to provide 100 percent coverage, requires users to register their phone numbers to receive messages. With increased usage of mobile devices, especially WEA-enabled phones, landline service is

becoming obsolete, although the 911 and Reverse 911 systems will continue to be used. Further analysis of the usability of Reverse 911 from the household perspective was conducted, which is reported in Section 3.4. Evidently the entire population has access to multiple devices and multiple channels (text messages, electronic signals and voices) to receive risk information from traditional media. The next task of the study focused on investigating which devices are used by emergency personnel and how that might impact the accessibility of users to timely alert and warning messages.

Table 3: Spatial Coverage of Available Alert and Warning Devices

Communication Platform	Covered	Not Covered	Rank
Siren	1.46% (36,772 acres)	98.54 % (2,478,407 acres)	4
Radio/NWR	92.94% (2,337,681 acres)	7% (177,498 acres)	3
Cell Phone Coverage	99.4% (2,498791 acres)	0.6 % (16,388 acres)	2
TV/National Weather Channel	100% (2,515179 acres)	0%	1

3.2. Warning Device Usage by EMA Personnel

Following the detection of a hazard, the emergency management subsystem is mobilized so as to formulate warning messages and enable emergency managers to disseminate alerts to at-risk populations. Extensive research has been undertaken to accurately detect hazards, to determine what socio-psychological characteristics of the public influence the effectiveness of warnings, to develop new technologies to increase the coverage of warning messages and geo-target message dissemination, and to identify message content and format to make warnings more informative. Very little research has focused on the emergency response subsystem, however, particularly regarding agency perspectives about preferences and usability of alert and warning technologies. Despite the availability of cell phones, county emergency personnel still have doubts about WEA messages, in part because they are unaware of their geo-targeting capabilities.

A number of devices are used in the Mississippi Gulf Coast for alert dissemination, which together provide 100 percent spatial coverage. What is unclear, however, is how the different agencies view the effectiveness of these devices and their preferences regarding certain technologies. This task sought to rank available warning and alert devices from an agency perspective by answering the following questions:

(i) Which devices are used by local EMAs for alert message dissemination?
(ii) Which devices are considered more effective based on message accuracy, frequency of message delivery and frequency at which a message is updated?
(iii) In which language(s) are messages disseminated?

3.2.1. Data Analysis

The questionnaire survey "Agency Perceptions of Warning Devices" (Appendix 1) was administered to EMA personnel using a targeted sampling approach between January 2014 and June 2014. Paper questionnaires of the survey were distributed to the county EMA

personnel in the three study counties and the city of Ocean Springs during face-to-face meetings, and to first responders during monthly meetings of the Red Cross – Coastal Resilience Network and the monthly meetings of the EMA personnel in Jackson County. An online version of the survey was also emailed to the county EMA personnel in three study counties. By the end of June 2014, a total of 51 questionnaires were collected, which went through quality control before data analysis. Both descriptive and inferential statistics (ANOVA and T-test) were used to explore the distribution of agency personnel's responses about the usability and availability of alert and warning devices. Finally, the WLC approach (discussed in Section 2.4.1) was employed to rank the devices using the survey responses to the questions pertaining to the usage of a device, accuracy of information, and the frequency at which a message is updated and delivered.

3.2.2. Results and Discussion

In addition to the devices identified in Section 3.1.2, the agencies also use social media, posters/pictures and door-to-door visits to inform the public about an emergency situation. From an agency perspective, the following devices are always used for alerts and warnings: TV, radio/NWR, Reverse 911, WEA and text messages, and social media (Figure 7). By contrast, sirens, posters/pictures and door-to-door visits are generally not used. As indicated by the responses, however, these devices are used in some cases, which could be related to hazard type or the location where the message is disseminated. For instance, Biloxi and Bay St. Louis are the two cities where sirens are available and, therefore, must be used for warnings, especially during tornadoes. Respondents reported that 90 percent of the time, alert messages are distributed in English (Figure 8), which means sirens, posters/pictures and door-to-door visits must be used to reach out to the Vietnamese and Hispanic residents, who are mainly located in Harrison County.

When asked about overall performance of the devices they use, agency personnel indicated that messages sent out via TV, radio, NWR, Reverse 911, the WEA system and social media sites are most frequently updated (Figure 9). In terms of the accuracy of message content, EMA personnel indicated that messages are very accurate when received from TV, radio, NWR, Reverse 911, WEA, Internet/social media and during door-to-door visits made by first responders (Figure 10). Messages sent via sirens, pictures/posters and even door-to-door visits are generally less to up-to-date, and sirens and pictures/posters tend not to have accurate messages, possibly due to infrequent updating.

The EMA personnel were asked to rank the devices based on their effectiveness in motivating the public to take preparatory actions (Figure 11). It is surprising to note that although sirens do not disseminate textual messages, they are deemed very effective in encouraging public to take responsive actions. TV, radio, NWR, Reverse 911 and WEA messages received via cell phones, on the other hand, were regarded as being ineffective by some respondents in terms of their capability to increase public response to warnings. This could be influenced by risk perception and experience of the at-risk population with regard to the hazard event rather than their confidence in the message received via these devices. Although social media sites provide accurate message when the message is disseminated by EMA personnel, they are

often ineffective as they suffer from effects of rumors and hoaxes. Pictures and posters are generally ineffective as they do not have wide coverage nor are they regarded as up to date.

The EMA personnel were also asked to rank the devices based on their overall performance in delivering accurate information and motivating the public to take positive actions. The agency personnel believe that TV, radio, NWR and sirens are most effective during a hazard event (Figure 11). The EMA personnel in the study counties did not believe that Reverse 911, WEA messages and social media sites are always very effective in motivating the public. Pictures/posters are found to be not very useful during a hazard event. Even door-to-door visits were seen as not very effective, which could be attributed to the socio-psychological characteristics of the message recipients.

3.3. Socioeconomic Condition of At-Risk Population

With the increasing frequency and severity of hazards, every nation is required to undertake Disaster Risk Reduction (DRR) initiatives as part of the United Nation's initiatives in the *Hyogo Framework for Action* of 2005 and the recent *Sendai Framework for Disaster Risk Reduction 2015—2030* (UN 2004, 2005, 2015). These frameworks advocate for the need to conduct periodic assessments of the risk and vulnerability of communities to hazard events. Such assessments are considered helpful in developing preparedness, mitigation and response guidelines that will minimize disaster impacts to society and will help develop people-centered, multi-hazard warning systems that enhance the capacity of communities to prepare, respond and recover from hazard events (UN 2005, 2015).

At-risk populations cannot be viewed as single entities, but rather as collections of multiple stakeholders from socioeconomically and culturally diverse groups. For instance, the Mississippi Gulf Coast counties are occupied by Hispanic and Asian immigrant populations, many with English language deficiencies. Ethnic minorities in the U.S. have been found to often reside in areas of higher risk, which exacerbates their vulnerability and exposure to disaster impacts (Ueland and Warf 2006). To reach culturally and linguistically isolated stakeholder communities in a crisis, it is imperative to develop culturally-specific communication avenues and protocols well in advance of a disaster. From the public response subsystem of a warning system, it is paramount to delve into the socio-cultural diversity of at-risk communities to determine the vulnerable populations and their spatial distribution in areas prone to coastal hazards such that actions can be taken to disseminate messages to these populations and increase their response to warning messages. This task sought to determine socio-economic characteristics of at-risk populations. The main questions that were answered in this task included:

(i) What is the spatial extent of areas susceptible to coastal hazards?
(ii) What is the spatial distribution of social vulnerability and vulnerable populations in the coastal counties?
(iii) What are the socioeconomic and cultural conditions of people residing in at-risk zones?

3.3.1. Data Analysis

Risk is defined as the “probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions” (UN 2004). Risk is therefore expressed as a product of *hazards x vulnerability*, which is a dynamic condition that changes with location and time, and is an inherent part of a place and a community (UN 2004). A number of models and indices have been developed to assess physical risk, such as the Disaster Risk Index (DRI) (determines losses experienced by a country due to multiple hazards) and the Disaster Deficit Index (DDI) (determines economic losses and coping capacity of a country due to exposure to a major disaster) (Cardona 2005; UNDP 2004). Despite their popularity, these indices are criticized because: (i) they are implemented at a coarse scale of analysis (country level) and fail to account for local variability and (ii) there is no consistency in variables used in them.

Vulnerability is a pre-existing condition of a community that changes with time, location and among social groups (Cutter et al. 2000; UN 2004). Vulnerability is generally described as *the potential and degree of susceptibility of an individual, group or community to experience adverse impacts of hazards due to socio-cultural, physical, economic and environmental conditions* (Burton et al. 1993; Cannon 1994; Kasperson et al. 1995; Hewitt 1997). A number of conceptual models and indices have been developed to assess vulnerability, which include the Hazards of Place framework; Risk-Hazard Framework; Pressure and Release Model, Environmental Vulnerability Index; the United Nations Development Program's Human Development Index; Human Well-Being Index (HWI); Social Vulnerability Index (SoVI); and Prevalent Vulnerability Index (Birkmann 2006). Like risk assessment indices, the operationalization of these indices suffers from the need for accurate and reliable data, large numbers of variables and their implementation at coarse scales of analysis (Birkmann 2006).

Choropleth mapping can be used to assess vulnerability, but it does not account for the presence of non-residential zones and variations in populations along jurisdictional boundaries. To eliminate this problem, a dasymetric mapping technique was implemented to distribute socio-economic variables in residential zones within a jurisdictional boundary (Kar and Hodgson 2012). Generally, land use/cover data is used for dasymetric mapping. However, the dasymetric technique derived population distribution at block level using 2010 Census data and NOAA produced land use/cover data resulted in a 50 percent loss of total population in comparison to actual 2010 census data. The reason for this data loss could be because the land-use data is from 2006 when most of the areas was abandoned following Hurricane Katrina in 2005. For this study, therefore, the following steps, similar to a Pass/Fail screening technique (a type of MCE technique), were implemented to create an ancillary layer for dasymetric mapping: (i) a binary layer representing habitable (population > 0) and non-habitable (population = 0) zones was created at the block level; (ii) the habitable zones were assigned a value of “1” and the non-habitable zones were assigned a value of "0"; (iii) 30 feet buffer zones surrounding the primary and secondary roads, the rail roads, and the streams, water bodies, and other hydrology features were created, and all the areas within the buffer were assigned a value of “0” (non-habitable) and areas beyond the

buffer were assigned a value of “1” (habitable); and (iv) finally, all layers were multiplied to determine habitable zones.

Due to the availability of data at multiple scales, to address the issue of MAUP and determine the granularity at which the spatial analysis should be conducted, the total population in the three study counties was distributed at the block, block group, census tract and county level in three spatial resolutions: 3m x 3m, 10m x 10m, and 30m x 30m using the ancillary layer developed from the steps above. The aggregated total population at block group, tract and county, and each spatial resolution was then compared with the reference data (total population at census block level) to determine the finest resolution and spatial scale of analysis.

Tropical cyclones are the most frequent and costliest events impacting the Mississippi Gulf Coast. For this task, the physical risk and impact areas from a tropical cyclone induced storm surge was modeled. Instead of analyzing historical tropical cyclone data available from NOAA, the physical characteristics — inland distance and topographic elevation — that increase the risk of a location to storm surge were used for risk assessment.

Using the DEM, a slope layer was created, which represented the topographic surface for the coastal counties. Instead of computing Euclidean Distance (the straight line distance between two locations), the three-dimensional surface distance was computed for the coastal counties using the Path Distance function in ArcGIS and the following data sets: coast boundary, slope layer (accounts for 3-D earth surface), DEM layer and an Inverse Linear parameter representing the vertical difficulty of moving from one location to another that increases with higher distance and slope.

The following ratings (Table 4) were used to classify distance and elevation. A higher rating for distance signifies high risk to storm surge because of the location’s proximity to the coast. Likewise, a higher rating for elevation represents low-lying areas susceptible to storm surge impact irrespective of a tropical cyclone's category. It was assumed that both elevation and distance are equally responsible for storm surge impact at a location. Therefore, both layers were given equal ranking of 50 percent. The maximum storm surge depth and inland distance that was inundated during Hurricane Katrina were used as thresholds for the model. Using the equation for WLC (equation 2.1), physical risk was determined. The numerical values for physical risk were converted to low (<= 30), medium (>30 and <= 70) and high risk zones (> 70 and <= 100).

Table 4: Rating Schedule for Distance and Elevation Layers

Distance Distance from the Coast (max 12.5 mile)		**Elevation** Elevation from the Coast (max 25 feet)	
Factor	**Rating**	**Factor**	**Rating**
1 mile (1,609 m)	10	<0 feet	10
2.5 mile (4,022.5 m)	8	0 – 2.5 feet	9
5 mile (8,045 m)	6	2.5 – 5 feet	8
10mile (16,090 m)	4	5 – 7.5 feet	7

Distance Distance from the Coast (max 12.5 mile)		**Elevation** Elevation from the Coast (max 25 feet)	
12.5mile (20,112.5 m)	2	7.5 – 10 feet	6
>12.5mile	0	10 – 12.5 feet	5
		12.5 – 15 feet	4
		15 – 17.5 feet	3
		17.5 – 20 feet	2
		20 – 25 feet	1
		>25 feet	0

The Q3 flood-plain layer represents the extent of flooding a location will experience in case of coastal and riverine flooding events. This layer was classified into four categories: (i) the areas that will experience 100-year flooding or have 1 percent flooding chance (symbolized as *A, AE, AH, AO, VE* by FEMA) were assigned a value of 100 (high risk); (ii) the areas that will experience 500-year flooding or have 0.2 percent flood chance (symbolized as *X-500* by FEMA) were assigned a value of 10 (moderate risk); (iii) the areas that may experience possible flooding (symbolized as *ANI, D* by FEMA) were assigned a value of 1 (low risk); and (iv) the areas that will not experience any flooding (symbolized as *X* by FEMA) were assigned a value of 0. The reclassified Q3 flood-plain layer was multiplied with the physical risk layer (discussed above) to determine the final risk zones.

Instead of incorporating all variables used in SoVI, the following were used to determine social vulnerability based on a literature review and personal communications with local EMA personnel and community leaders: total population density (p_i) (higher population concentration increases exposure); people below 18 years ($a18_i$) and above 65 years ($a65_i$) (the population in these age groups generally lack funding, lack a vehicle to evacuate during a hazard event, and can also suffer from health problems, thereby, requiring aid with evacuation); Asian population (ra_i) and African-American population (rb_i) (these two ethnic groups suffered the most during Hurricane Katrina); single parent households with children ($sphh_i$) (these households may lack resources due to absence of a partner/a spouse); income1 ($inc1_i$) (income less than $25,000) and income2 ($inc2_i$) (income between $25,000—$50,000) (people in these incomes groups are considered to have low affordability to take preparatory actions and/or recover from an event); income3 ($inc3_i$) (people with income $50,000—$75,000); income4 ($inc4_i$) (people with income $75,000—$100,000); income5 ($inc5_i$) (people with income > $100,000) (people with income above $50,000 are considered financially stable and to be able to recover fast and take preparatory actions); people with boats, RVs, and vans (rv_i) (these people can evacuate easily if needed); and owner occupied housing units (oh_i) (these people may experience financial loss if they are in risk zones) (Cutter et al. 2000; Gabe et al. 2005).

To assign a rank to a social variable, Cutter et al. (2000) divided the value of the variable (X) at a block (b_i) by the total of that variable for the entire county (C_j) in which the block belongs. The derived ratio (r) was then divided by the maximum ratio (r_m) to determine a standardized index ranging from 0 to 1. Higher index value represented higher vulnerability. This approach compared the significance of each social variable among the blocks rather

than with each other. Given that one variable might have higher influence on vulnerability than another variable, the following equations were used to rank the variables with each other.

For block (b_i) where i = 1 to the total number of blocks present in a county (C_j) where j = 1 to 3 (total number of study counties),

$$r_{ik} = b_{ik} / p_i \qquad \textbf{Equation 3.1}$$

where r_{ik} = ratio for one variable k, k = 1 to the total number of social variables used in this study in block b_i, b_{ik} = the value of a social variable k in block i, p_i = the total population of block i. For this block, the index was computed by using equation 3.2 where IN_{ik} = rank for a variable k in block b_i, r_{im} = the maximum ratio value (r_{ik}) in block i.

$$IN_{ik} = r_{ik} / r_{im} \qquad \textbf{Equation 3.2}$$

These equations were used to compute the rank for income variables and the variable representing people owning a boat/RV/van that were available at the census tract level. Implementing the same steps to determine a rank for total population would result in a value of 1 for all the blocks, however. Therefore, the p_i of a block was divided by the total population (p_l) of a tract (t_l) to which the block belongs to get the ratio r_{il}. Finally, the ratio for each block (r_{il}) was divided by the highest ratio (r_{ilm}) to get a standardized rank ranging from 0—1. After computing the rank for each variable, a raster layer was created for each social variable, which was then multiplied with its corresponding rank (computed above). Finally, all the multiplied layers were summed together using WLC model to generate a social vulnerability score (Equation 3.3).

$$\forall\, i \in I: SV_i = (p_i * IN_{pi}) + (a18_i * IN_{a18i}) + (a65_i * IN_{a65i}) + (ra_i * IN_{rai}) + (rb_i * IN_{rbi}) + (sphh_i * IN_{sphhi}) + (inc1_i * IN_{inc1i}) + (inc2_i * IN_{inc2i}) - (inc3_i * IN_{inc3i}) - (inc4_i * IN_{inc4i}) - (inc5_i * IN_{inc5i}) - (rv_i * IN_{rvi}) + (oh_i * IN_{ohi})$$

Equation 3.3

3.3.2. Results and Discussion

For the granularity analysis, the 2010 population was first distributed at 3m x 3m, 10m x 10m, and 30m x 30m spatial resolutions within each jurisdictional boundary. The distributed population was then aggregated and compared with actual population, and also with population at the block level to determine the error difference (Table 5). Evidently, the lowest error resulted when the analysis was conducted at 3m x 3m and 10m x 10m spatial resolutions and at the census block level. Because 10m x 10m resulted in faster processing of large data sets, all spatial analysis and modeling in this study were conducted at the granularity of 10m x 10m resolution.

Table 5: Error Associated with Each Spatial Resolution and Scale of Analysis

Jurisdictional Boundary	Spatial Resolution (m)	Beginning Population	Final Population	Percent Error
Block	3x3	372875	372562.0001	-0.08
	10x10	372875	372084.0004	-0.21
	30x30	372875	374972.3364	0.56
Block Group	3x3	392653	389148	-0.89
Tract	3x3	410017	403264.0018	-1.64
County	3x3	370702	370701.9844	4.20823e-6

An analysis of topographic conditions of the study counties based on inland distance and elevation was conducted to determine physical risk zones (susceptible to flooding) (Figure 13). Not surprisingly, near the coastline, all three counties are expected to encounter severe flooding. Based on location, almost 50 percent of Hancock County will be subjected to moderate or severe flooding from future storm events. During a Category 3 tropical cyclone, about 25 percent of Jackson County and 35 percent of Harrison County will be subjected to moderate or severe flooding. The combination of the physical risk zones with Q3 floodplain categories (discussed above) resulted in physical risk zones that are susceptible to both coastal and riverine flooding events (Figure 14). Although the spatial extent of high risk areas is the same in both Figure 13 and Figure 14, using Q3 floodplain reduced the extent of moderate-risk zone, but increased the extent of low-risk zone. This could possibly be attributed to how FEMA classifies flood zones based on flood extent.

An analysis of the population density distribution in areas susceptible to coastal flooding indicated that moderate to severe risk zones have high population density (Figure 15). This is particularly true in the mostly urban Harrison County. Densely populated areas in Jackson County are mostly situated in moderately risky zones, which otherwise appears not to be risky as per the Q3 flood plain data (Figure 14). The majority of the population of Hancock County is concentrated in low to moderate risk areas (Figure 15). Social vulnerability scores (Figure 16) indicate that moderately and highly vulnerable populations are present in moderate to high risk zones. Spatial analysis of sociocultural groups indicates that moderate-to high-risk areas are occupied by high concentration of vulnerable groups (Table 6).

Table 6: Concentration of Socioeconomic Variables in Physical Risk Zones

	Physical Risk Zones		
	Low	**Moderate**	**High**
White	112612	126900	32244
African American	16552	48324	9697
Asian	2291	5118	1357
Hispanic	4277	10814	2695
Male	68085	93867	22655
Female	68621	96430	22902
Below 18	36388	45057	10745
Above 65	14890	25070	6215
Female Household	6986	13409	2816

	Physical Risk Zones		
Male Household	2837	4187	1037
Owner Occupied Housing Unit	38812	44428	12323
Household Living Alone	9675	21120	4839

3.4. Public Perceptions of and Responses to Warning Devices

Despite advancements in warning systems, risk communication is still criticized for its inability to increase public response or to incorporate public viewpoints (Gladwin et al. 2007; Sorensen 2000). For risk communication to be effective in motivating the public to take mitigation actions, it is essential to deliver clear and concise messages about a hazard and its possible impacts to at-risk populations, and to ensure these populations have access to multiple technologies to receive warnings (Krimsky 2007). However, extensive research conducted in psychology and social science has revealed that to a great extent, socio-psychological conditions of the public including their risk perception, past experience and familial relationships influence the success and failure of risk communication (Mileti and Peek 2000; NRC 2012).

Although a number of social, economic and cultural factors have been found to influence the public's use of different technologies and their response to warnings, these factors are not always consistent. For instance, during the rebuilding process after Hurricane Katrina, the federal government made little effort to facilitate a multilingual communication plan, which forced the Vietnamese Americans to rely on grass roots organizations from within their community to help them receive federal aid (Rosa 2010). Older citizens, mostly immigrants, in these communities have a poor understanding of the English language, which makes them less responsive to warnings. As Ulmer et al. (2011) pointed out, the risk communication approach used during Hurricane Katrina was culturally neutral and did not account for socioeconomic conditions, language or ethnic difference among local populations. Cultural barriers create a wall – a demarcation where communication breaks down and large segments of stakeholders are neither heard nor reached. To reach culturally and linguistically isolated stakeholder communities in a crisis, it is imperative to develop culture-oriented communication avenues and protocols well in advance of any future disaster. The purpose of this task was to examine the role of sociocultural characteristics of local residents in their decision to use specific warning devices. The specific questions that were examined in this task included:

(i) Which devices are used by local residents?
(ii) Which devices do the local residents trust because of message accuracy, frequency of updated message delivery, ease of use and source of information?
(iii) Which devices are effective in motivating local residents to take preparatory actions?
(iv) How do the socioeconomic and cultural properties of local residents influence their trust and usage of a specific device?

3.4.1. Data Analysis

The survey "Household Perceptions of Warning Devices" (See Appendix 2) was administered from August 2013 to September 2014. To obtain statistically significant survey responses from the major ethnic groups, the questionnaire was translated into Spanish and Vietnamese. A number of sampling techniques were used to collect primary data for this task. First, booths were set up at the Ocean Spring Art Market[4] (August 31, 2013) and Peter Anderson Festival[5] (November 2, 2013) where paper questionnaires were administered to participants in face-to-face meetings. With the help of NAVASA - Boat People and El Pueblo – Sea Shore Mission, surveyors were recruited to administer questionnaires to Vietnamese and Hispanic communities. An online version of the survey was made available to local communities with the help of United Way and Red Cross. Finally, a snowball approach was implemented via mass emailing of the survey to USM faculties, staff and students who are residents of the Gulf Coast counties. At the end, these approaches resulted in 422 completed questionnaires, of which 399 were used after quality control for analysis. Both descriptive and inferential statistics (ANOVA, T-test and linear regression) were used to answer the questions identified in this task.

Of the survey respondents, 3.8 percent (11) resided in Hancock County, 76.1 percent (223) in Harrison County and 20.1 percent (59) in Jackson County. The ethnic diversity of the respondents included 43.8 percent Caucasian (Non-Hispanic), 3.8 percent African-American, 51.4 percent Hispanic, 0.3 percent Asian, and 0.5 percent other. In terms of gender, 30.8 percent of respondents were male and 41.4 percent were female with the remaining 27.8 percent providing no response in terms of gender. Respondents were fairly evenly represented by age: 18-25 years (13.5 percent), 26-35 years (22.8 percent), 36-45 years (20.1 percent), 46-55 years (11.8 percent), 56-65 years (10.8 percent) and 66 years and above (3.0 percent), with 18.0 percent of respondents providing no response with regard to age. Approximately 33.9 percent of respondents reported having an annual income under $25,000 (below poverty line); 14.5 percent had an income between $25,000 and $45,000; 12.0 percent had an income between $45,000 and $75,000; and 10.5 percent had an income over $75,000, with 29.1 percent providing no information about annual income. Educational attainment was fairly low with 18.0 percent having no high school diploma and 64.2 percent having a high school diploma or equivalent. Those with an associate or bachelor's degree (26.5 percent), master's degree (6.6 percent), or professional or doctoral (2.6 percent) degrees comprised about a third of survey respondents. Despite the prevalence of low incomes and low educational attainment, 83.7 percent reported owning a smart phone (e.g., Android or iPhone).

3.4.2. Results and Discussion

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4 Ocean Springs Chamber of Commerce. Retrieved May 2, 2016 Festivals: http://www.oceanspringschamber.com/index.php/festivals.

5 Peter Anderson Festival. Retrieved May 2, 2016 http://www.peterandersonfestival.com/.

Figure 17 illustrates the technologies that are frequently used by local residents to receive alerts and warnings. All devices are used to receive warnings except for pictures/posters that are apparently used only by a small group. The residents were asked to rank each device and channel based on the ease of using them, accuracy of message content and the frequency at which a message is updated and delivered to the residents. From the responses (Table 7 and Figure 18—20), it is evident that all respondents trust family/friends along with TV and radio to receive accurate and updated messages frequently followed by NWR, siren, Reverse 911 and WEA message. Social media and door-to-door visits are less trusted by respondents followed by pictures and posters. Basically, the devices can be grouped by their source of information into traditional media (TV, radio, NWR, siren, door-to-door visits, WEA message and Reverse 911), word-of-mouth (family/friends) and social media. A comparison of public trust in these sources indicated that in general, residents trust family and friends followed by traditional media to receive accurate and frequently updated messages.

The respondents were also asked to identify the devices that are effective in motivating them to take positive actions following warnings (Figure 21). Not surprisingly family and friends were found to be more effective in encouraging local residents to take actions followed by TV, visits from first responders, siren and radio. Social media and pictures/posters are not effective in motivating the public to take actions though they are widely used by both agencies and public to receive messages. The ineffectiveness of social media could be because the messages disseminated by it are not updated frequently, which means the social media sites fail to provide updated information about a hazard event and its associated risks. Finally, one-way and two-way ANOVAs were implemented to examine the impact of socioeconomic characteristics of local residents on their trust of a specific device. Although there were some differences in terms of usage of a specific device based on ethnicity, age groups and income, the differences are not significant. For instance, posters and pictures are generally used by Vietnamese communities, but they are not considered effective in terms of disseminating updated messages or motivating the public to take action. Younger generations prefer text messages to a greater extent than older generations (above 35), but because everyone has access to a cell phone, they will be able to receive WEA messages. Overall, socioeconomic characteristics of the local residents did not influence their decision to use specific technology to receive warning messages.

Table 7: Ranking of Devices Based on Weighted Mean of Positive Responses

	Weighted Mean Based on Positive Responses			
TV	4.41544118	4.48275862	0.91769547	0.92561983
Radio	4.09734513	4.20853081	0.86772487	0.82812500
NWR	3.84974093	4.05978261	0.75722543	0.73170732
Siren	3.92718447	3.96891192	0.72222222	0.73333333
Reverse 911	3.93364929	3.81500000	0.67338710	0.75126904
WEA Message	3.94117647	3.83962264	0.75121951	0.76884422
Internet	3.98095238	3.99024390	0.74242424	0.75252525

	Weighted Mean Based on Positive Responses			
Social Media	3.60189573	3.80597015	0.66836735	0.70618557
Pictures/Posters	2.85365854	2.92546584	0.42045455	0.44318182
Door-to-door Visit	3.68062827	3.61878453	0.66666667	0.69354839
Family/Friends	4.37190083	4.45258621	0.81531532	0.89041096

3.5. Public Perceptions of and Responses to Warning Messages

The first factor influencing public response to warnings encompasses characteristics of the sender — message content and style (accuracy, consistency, specificity and clarity), message source, message frequency, message delivery — as well as timing, language, devices and channels used to disseminate messages (Mileti and Sorensen 1990; Mileti and Peek 2000; NRC 2012). Hammond et al. (2003) indicated that using graphic pictorial warnings on tobacco products was more effective in motivating public to reduce tobacco consumption compared to textual warnings about adverse health impacts of tobacco.

Although message content and style is important, how the public reacts to messages is influenced by their socioeconomic, cultural and psychological conditions. For example, the coastal counties of Mississippi are inhabited by small, but growing Hispanic and Asian populations, many with limited or no English-language proficiency. Warning messages, however, are predominantly sent out in English. This language barrier prohibits people from understanding and responding to messages, and undermines the effectiveness of the messages. A variety of devices and information sources are also used to disseminate alert and warning messages, some of which are prone to producing misleading information (e.g., Twitter), or are limited to emitting simple sounds (e.g., sirens), requiring the public to seek out more information about a hazard and its associated risks (FEMA 2015). Given that the Mississippi coastal counties are inhabited by residents of diverse socioeconomic and cultural backgrounds and the restrictions associated with WEA message length (customarily 90 characters in length, although action is underway to expand this to 360 characters (FCC 2016)), it is essential from policy and public perspective to identify effective message contents, styles and information sources.

This task examined *public perceptions and responses to alert and warning messages* by focusing on the following questions:

- (i) How much do people know about WEA messages?
- (ii) Do the socioeconomic and cultural characteristics of survey respondents influence their response to warnings?
- (iii) Does the source of a message influence public response to it?
- (iv) Does the primary language of a recipient influence his/her response to an alert or warning message?
- (v) Does message format and content influence public response to warnings?

3.5.1. Data Analysis

Primary data was collected through a survey instrument, "Public Perceptions of Warning and Alert Messages" (see Appendix 3), which was administered to the local residents in English, Spanish and Vietnamese between January and July of 2015. Through a combination of stratified and targeted sampling, a total of 304 surveys were collected. After quality control, 281 surveys were used for analysis. Inferential statistical techniques, including ANOVA and Chi-Square, were implemented along with standard frequency graphs and descriptive statistics to answer the research questions.

Of the survey respondents, 13.2 percent (37) resided in Hancock County, 68.7 percent (193) in Harrison County and 11.4 percent (32) in Jackson County. Respondent ethnicity included 33.5 percent Caucasian (Non-Hispanic), 16.7 percent African-American, 18.5 percent Hispanic and 24.9 percent Asian. Males represented 45.9 of respondents and 47.7 percent were female, with the remaining 6.4 percent providing no response in terms of gender. Respondents had a median age of 45.5 years and were fairly evenly represented by age: 18-25 years (13.5 percent), 26-35 years (18.5 percent), 36-45 years (19.9 percent), 46-55 years (15.7 percent), 56-65 years (12.8 percent) and 66 years and above (10.3 percent), with 9.3 percent of respondents providing no response with regard to age. Approximately 60 percent of respondents reported having an annual income under $25,000 (below poverty line); 24 percent had an income between $25,000 and $50,000; 7.5 percent had an income between $50,000 and $75,000; and 6.4 percent had an income over $75,000. Median household income was about $37,500 with 17.4 percent providing no information about annual income. Educational attainment was fairly low, with 25.6 percent having less than a 9th grade education and 35.9 percent having a high school diploma or equivalent. Those with an associate or bachelor's degree (29.6 percent), master's degree (4.3 percent), or professional or doctoral (1.4 percent) degrees comprised about a third of survey respondents. Despite the prevalence of low incomes and low educational attainment, 59.1 percent reported owning a smart phone (e.g., Android or iPhone).

3.5.2. Results and Discussions

Figure 22 illustrates responses of survey respondents to two different sources of information: county EMAs and the NWS. Respondents clearly trust warning messages received from these sources. Respondents also indicated high levels of agreement regarding the likelihood of their following an official evacuation notice from these traditional sources. On the other hand, a smaller, yet sizable number of respondents indicated that their decision to evacuate depended upon the actions of friends and family or on their own perception of risk rather than the information received from official sources as alert and warning messages. A small number of respondents indicated they would not follow any evacuation notice. The results of one-way ANOVA tests indicated that most of these respondents were young adults less than 35 years of age ($p = .000$) and individuals without a high school degree ($p = .000$). The unwillingness among individuals of both of these groups to evacuate might have to do with their lack of experience with coastal hazards (as in the case of young adults)

and their lack of awareness of their risk (for both young adults and low education groups) with regard to coastal hazards.

A series of one-way ANOVA tests revealed that respondents' socioeconomic characteristics significantly impacted their responses regarding warning messages: (i) for those younger than 35 and older than 56, the decision to evacuate is influenced by the actions of family and friends ($p = .000$); (ii) older respondents (56 years and above) are less unwilling to evacuate than other age cohorts if recommended to do so by alert or warning messages ; (iii) risk perception impacts decisions to evacuate for respondents of all cohorts above 36 years or age ($p = .000$); (iv) although individuals with the least education are more trusting of alert and warning messages, they are least likely to respond to an evacuation notice; it is likely that individuals with the highest levels of educational attainment are also unlikely to evacuate ($p = .000$); (v) female respondents are slightly more inclined than males to evacuate if they receive notice to do so ($p = .069$); and (vi) residents with incomes lower than $35,000 will evacuate if they receive a notice, but their decision to evacuate will be somewhat influenced by family and friends ($p = .007$).

The third question examined public response based on message source, traditional source (i.e., emergency management agency) or social media, and how survey respondents might like to use social media during a hazard event. This question also sought to determine variations in public response to social media and traditional media based on socioeconomic and cultural characteristics of respondents. The public would like local EMAs to use social media to disseminate alert and warning messages (Figure 23). Social media (i.e., Facebook and Twitter) and word-of-mouth (i.e., family and friends) are important sources of information through which the public shares disaster-related information. Although Twitter appears to be popular among respondents, it is clear from Figure 23 that the public most prefers Facebook during a hazard event for communication. The results of a one-way ANOVA and an independent sample T-test that examined the impact of socioeconomic characteristics on using social media during hazard events revealed that: (i) local residents below 35 years and above 46 years prefer using Facebook to receive alert messages; (ii) gender and income do not influence preference of social media usage during disasters either for receiving alert messages or for sharing disaster-related information; (iii) all residents, irrespective of educational qualification, prefer local EMAs to disseminate alert and warning messages through social media; and (iv) residents with a high school diploma and higher levels of education prefer using Twitter to receive alert messages, to contact family and friends, and to share disaster-related information.

The fourth research question focused on the degree to which the primary language of a recipient influences his/her response to an alert or warning message. A series of ANOVA tests indicated that there were no significant differences between these respondents and the mainstream English-speaking respondents in terms of their response to alert or warning messages. Approximately 46 percent of the 127 respondents indicated that they would like to receive alert messages in other languages, however.

The fifth research question assessed whether message format and content influence public responses to alert and warning messages, and particularly WEA messages. With current

efforts to expand and transform WEA messages to achieve greater coverage of at-risk populations, this question gauged knowledge of the WEA system and the degree to which perceptions towards it vary according to the socioeconomic and cultural characteristics of respondents. Almost 40 percent of survey respondents indicated that they had known about WEA message before the survey and had received WEA messages on their phones. To address the issue of WEA message length, the survey contained questions about whether or not 90 characters were sufficient for alert and warning messages. Approximately 53.7 percent responded that 90 characters are not enough for a message to be informative while 42.6 percent indicated 90 characters was an appropriate length. When asked about the content that should be included in a WEA message and the sequence in which they must appear in a message, the participants ranked the following contents in the order they are presented here: nature of the disaster, impact zone of the disaster, time frame and duration of the disaster, recommended actions, evacuation routes, when to take action, shelter location, how to obtain additional information, and a map showing features such as evacuation routes, shelters and nearby hospitals (Figure 24).

3.6. Public Participation in Message Preparation and Response to Messages

Public participation in disaster management is not new. Research has revealed that the vertical and horizontal integration of communities and individuals creates social networks and bonds of trust among the public and EMAs, increases public acceptance of policies and has a generally positive effect on recovery efforts and resilience building (Berke et al. 1993; Putnam 1993; Kweit and Kweit 2004; Duval-Diopa et al. 2010). Local residents are, in a sense, among the first responders to a disaster, providing first aid and assistance with search and rescue operations (Tierney and Quarantelli 1989; Palen and Liu 2007; Tierney et al. 2011). Whereas social media and word-of-mouth provides a venue for citizens to collaborate in sharing information about risks and disaster impacts, traditional media has a tendency to inhibit citizen participation and response. The overly concise, 90-character length of WEA messages, for example, might encourage *milling behavior*, which can prompt citizens to take time to seek out additional information rather than follow the recommendations of the message itself (Wimberly 2015).

Public response to warnings and public inclination to seek out information about a disaster is influenced by sociocultural and political factors, message content and message source. Studies have revealed that the command and control based top-down risk communication approach is less effective and less accepted by the public compared to more participatory approaches, such as social media that allows citizen communication in near real time (Gladwin et al. 2007; Taylor et al. 2007; Ockwell et al. 2009). In light of these facts, implementing a collaborative risk communication approach that involves *peer-to-peer communications* during and after a disaster will help reduce uncertainty in information available from social media, increase public trust in warnings disseminated by traditional media and enable information exchange among stakeholders (NRC 1989; Grabill and Simmons 1998; Palen and Liu 2007).

This task examined the social construction of risk by exploring public responses to alert and warning messages based on the extent of their participation in risk communication. The specific research questions explored in this task included:

(i) How does the public respond to messages in terms of undertaking positive actions (notably to evacuate) if they participated in message preparation and dissemination?

(ii) To what extent is the public willing to participate in message preparation and dissemination?

Given the hierarchical model of the current IPAWS system, in which local residents receive warning and alert messages, but have no official role in their formulation and dissemination, the research questions for this task focused on public use of social media, which currently represents the most coherent and widespread channel through which local residents can involve themselves in risk communication.

3.6.1. Data Analysis

Primary data for this task was collected through the survey instrument, "Public Perceptions of Warning and Alert Messages" (See Appendix 3). Data collection associated with this survey and the statistical analysis performed on the survey responses was outlined in the section focusing on the previous task.

3.6.2. Results and Discussions

The research questions examined the extent to which survey respondents were inclined to take positive actions (i.e., evacuate) if they participated in warning message preparation and dissemination. It is evident from Figure 25 that there is a strong agreement (about 60 percent) among survey respondents with regards to their (i) willingness to collaborate with local EMA in disseminating alerts and warnings, and (ii) potential to take positive actions in response to alert and warning messages if they were more involved in message dissemination and preparation. Given the hierarchical nature of risk communication in the United States, it is no surprise that a majority (60 percent) of survey respondents indicated that they had never participated in message dissemination and preparation with the local EMA.

An ANOVA analysis based on age, income, education, ethnicity and gender on sub questions 7—10 of question 17 (Appendix 3) and frequency distributions based on cross-tab analysis revealed that (i) survey participants' age and gender do not influence their willingness to participate in message dissemination and their subsequent response to warnings, and (ii) survey participants' educational qualification and income displayed a negative relationship (Figure 26 and Figure 27), which indicates that individuals with higher education, specifically with an associate degree or higher, and individuals with incomes above $50,000 are less inclined to participate in message dissemination, and their responses to alert and warning messages are not influenced by their extent of participation. Although all ethnic groups are willing to participate in message dissemination, individuals who are Hispanic and

Asian indicated their positive response to alert and warning message is influenced by their extent of participation in message dissemination.

3.7. Spatial Decision Support System

As part of this project, a Web-based SDSS was developed to: (i) enable visualization of spatial distribution of at-risk populations, spatial coverage of warning devices and usage of warning devices based on public confidence and preference; (ii) be used as a training tool by public and first responders with regard to emergency preparedness and risk communication; and (iii) allow data collection by using the Rapid Assessment Surveys developed in this study about public perception and use of different devices, and responses to messages received from specific devices. The SDSS also contains a science gateway —CyberInfrastructure for GeoInformatics and Community Resilience (CIGIR). This gateway is built on the social construct of risk communication that incorporates citizen science to evaluate warning message sources, message content and dissemination channels, and designed to increase public responses to warnings by increasing citizen communication. The gateway can be used to maximize citizen participation in risk communication by allowing them to provide information about specific contents as part of a warning message in a streamlined manner, which could then be used by EMA personnel and the local public to undertake emergency management and preparedness activities. The SDSS houses a central data repository of spatial and non-spatial data sets generated in this project, and provides access to python based spatial tool boxes that were developed in this project.

A *thin-client* environment was deployed for the SDSS so that most processing (e.g., geo-targeting of at-risk communities, determination of economically vulnerable locations and their distributions, and map creation) could be undertaken on the server side to maximize performance. The server side programming is done in ASP .NET/MVC under the Microsoft .NET framework 4.0. The *client-side* or the front end of the SDSS is built in HTML 5, CSS and JavaScript. The *server-side* consists of a data server (deployed in SQL/ArcSDE to store spatial and non-spatial data), a Web server that is deployed in Microsoft Internet Information Service (IIS) to distribute maps and data, and a map server that is deployed in ArcGIS Server and .NET to generate maps and implement geo-processing models (Figure 28). Figure 28 illustrates the architecture and main components of the SDSS (http://ghrldev.st.usm.edu/).

The main site (home page) (Figure 29) provides information about the lab and links to other pages of the site including the research team, current projects, and mapping component — CIGIR. The page also provides access to all maps that have been created in this project and has a link to the social media sites that constantly provide an updated news feed. The *Data and Tools Portal* (Figure 30) allows users to download tools and data from the data server. The page requires users to register and log in prior to downloading data sets as zip files. This portal contains a number of pages that allows for collection of data using an online version of survey instruments about socioeconomic characteristics, perceptions of risk, trust, and use of different alert and warning devices and message sources, among others. This information is stored on the server along with survey data collected for different tasks to allow longitudinal analysis of these tasks.

The mapping component is part of the science gateway CIGIR (Figure 31), which allows users to visualize spatial data sets; undertake attribute queries (criteria based searching (e.g., transportation, physical risk or loss estimation)), and spatial queries (searching for shelters, hospitals, evacuation routes and risk zones within a specified distance of a user's location or user provided address); and compare features (e.g., compare number of shelters available per zip code to help individuals prepare for evacuation during a tropical cyclone and for mitigation planning). The gateway also contains a page that allows citizens to participate in risk communication by providing information about an ongoing hazard event. This information is stored on the server to be used for other analyses, which is also visualized on the map based on the user's current location information. This page in essence works on the precept of social media (i.e., Twitter), but ensures that specific information provided by users is used to create the message and visualize the information.

4. Conclusions and Recommendations

The findings of this study indicate that the culturally and ethnically diverse communities of the Mississippi Gulf Coast still trust and rely on alert and warning messages received from traditional media using conventional devices. Communities do use social media to communicate with families and friends, however, and have indicated that they would like emergency management agencies to use social media to disseminate alert and warning messages. Despite considerable progress in the development and implementation of WEA, its usage remains varied across communities of the study area. Although a majority of respondents claimed to have known about WEA prior to this research, a sizable minority did not, which suggests that more focus is needed on the dissemination of information about WEA to specific segments of the population.

This chapter summarizes the findings of the tasks performed in this study and includes a set of recommendations to increase the effectiveness of WEA messages, as well as risk communication in general. This section also identifies a number of challenges still existing in risk communication research in the era of Web 2.0 that could potentially impact the public's use of certain devices and trust in sources of information.

4.1. Available Warning Devices

In light of the available devices and their spatial coverages (Table 3), the three Mississippi Gulf Coast counties are fully covered by different warning devices that receive information from traditional media. Together, at least one device covers any location in the study area, which means that the issue of inaccessibility of a specific demographic group to risk information does not exist. However, discussions with county EMAs indicated the following limitations:

(i) Despite their usability, sirens are only available in two cities (Biloxi and Bay St. Louis), and the vast majority of the population is unable to hear them due to their limited spatial coverage.

(ii) The Reverse 911 system is available to everyone, but few residents in the study counties have bought into it to date. For instance, discussions with the EMA personnel indicated that only 400 people in Hancock County had signed up as of 2015 for receiving alert messages through this system on their cell phones.

(iii) According to the existing cell providers (C-Spire, AT&T, Verizon), there is 100 percent cell coverage in the study counties. The successful use of WEA service is dependent upon users owning WEA-enabled phones, however. Persistent lack of knowledge among stakeholders about WEA also restricts its usage in some communities.

(iv) The cell signal strength is pivotal for a person to receive alert messages on his/her cell phone. Signal strength is assumed to be consistent across the cell coverage area, but in fact, it varies with regard to elevation and topography (surroundings of a cell phone), capacity (number of callers using the same cell tower at a given time) and network architecture (presence of a cell tower) (FCC 2015). From a geo-targeting perspective, it

is essential to understand the variability of signal strength across space and over time so that appropriate actions can be taken to increase WEA usability.

4.2. EMA Perception of Warning Devices

Agencies use a variety of technologies to disseminate alerts and warnings. Survey results indicated that the local EMA personnel prefer using conventional devices that receive alerts and warnings from traditional media (i.e., government sources) which include TV, radio, NWR, Reverse 911 and WEA messages. Also, these devices provide updated and accurate messages in a timely manner.

English is the only language in which messages are disseminated in the study counties. Given the language barrier that exists among Vietnamese immigrants, other devices, specifically sirens and posters/pictures, must be used to disseminate messages to non-English speaking residents. These devices do not provide up-to-date or accurate messages as indicated by the EMA personnel, however (Figure 9 and Figure 10). Furthermore, sirens have limited spatial coverage, but are seen by EMA personnel as more effective in motivating the public to respond to warnings in addition to TV and door-to-door visits, followed by other device usage. This situation indicates a certain degree of conflict with regard to agency and household preferences towards alert and warning devices. Also, agencies are limited in reaching the broader community due to limited access to non-English modes of risk communication. An alternative might be to use social media, which is favored by both agencies and local residents, despite the fact that EMA personnel considered social media to be less effective in increasing public response to warnings.

4.3. Socio-Cultural Distribution of At-Risk Population

The coastal counties of Mississippi are at high risk from coastal flooding and storm surge events, but it is alarming to note that these areas are also heavily populated by socially and economically vulnerable groups. Although multiple warning devices provide almost 100 percent spatial coverage, the problem lies with the presence of vulnerable groups, specifically low-income, Vietnamese, elderly and younger populations. The Vietnamese population is concentrated in Biloxi (Harrison County) and a majority of this population suffers from a language barrier as they are unable to communicate in English. According to the community organization, NAVASA-Boat People, Vietnamese rely upon specific TV channels to receive warning messages. Given that warning messages are disseminated in English, despite having access to multiple devices, this population group cannot respond effectively to these messages. Similarly, low income and elderly populations may not be able to respond effectively to warning messages because of financial or physical limitations rather than access to available warning devices.

4.4. Public Response to Alert and Warning Devices

Mississippi Gulf Coast residents are aware of available warning technologies, but trust only a few of these devices based on their perceptions of the accuracy, frequency and timely delivery of messages. They indicated that they rely on messages received via TV, sirens, radio, NWR, WEA messages, Reverse 911 and from agency personnel directly during personal visits. Despite this trust in conventional warning systems, survey respondents exhibited a higher trust in family and friends with regard to receiving accurate and up-to-date information. Family and friends were also found to be more influential than conventional technologies in motivating positive responses to warnings.

Both agencies and local residents indicated that sirens are effective in encouraging the public to take appropriate mitigation actions. Sirens are expensive to install, however, and provide a very limited coverage. Specifically, during inclement weather such as tropical cyclones, siren sound cannot be heard by the public if they reside more than 1 mile away from the sirens. Furthermore, sirens also do not provide up-to-date, verbal messages which seems to be the major disadvantage of using them for alerts and warnings.

Although social media and pictures/posters are used to disseminate warnings, they were found to be less trustworthy and effective in motivating public to take positive actions. Agencies prefer using social media to send out warnings following the one-way communication approach without utilizing the feedback and participatory mechanisms of these sites (e.g., Twitter and Facebook). Local residents also use and prefer receiving messages via social media, but they like using social media to be in contact with family and friends, and in sharing information through these sites about a disaster. It was also evident that the public has a high level of trust in word-of-mouth media (i.e., family and friends). This is one of the main factors influencing public's motivation to using social media as it allows them to be in contact with family and friends. Furthermore, this familial relationship was found to be crucial in an individual's decision making process in response to warning rather than socioeconomic characteristics or warning message delivery system. While this situation can mobilize positive responses, the lack of EMA presence during the decision-making process undermines the effectiveness of the warning technologies in general. Therefore, it is critical for EMA personnel to use social media in sharing feedback responses with local residents so that milling behavior and rumors can be eliminated, and the reliability of warning messages can be enhanced.

Pictures/posters, like sirens, have a low spatial coverage, and fail to provide up-to-date verbal messages. They are also used to reach out specific population groups who do not use English language for communication. Although this is very useful in disseminating risk information to older generation Vietnamese and Spanish individuals who neither read nor speak English, the failure of this device to provide accurate and up-to-date information renders it ineffective. It also necessitates personal visits from EMA personnel in motivating these groups to take any response action.

4.5. Public Response to Alert and Warning Messages

Ownership of smart phones is not restricted to specific age groups or income levels. Although a large percentage of respondents is at or below the poverty level, most own a smart phone and will be able to receive WEA and text messages and use social media during hazard events. More than 50 percent of residents stated that the 90-character length of WEA messages is too short to be informative, however. English is the only language used for disseminating alert and warning messages at present, though some participants have indicated that they would like to receive messages in other languages.

When it comes to relying on messages, respondents indicated that they rely more on those received from authorities and would take appropriate action as recommended by these messages. The majority of respondents, and specifically female respondents, claimed they would evacuate if they received alert and warning messages from their local EMA or the NWS. By contrast, older (56 years and above) and younger (below 35 years) respondents, and respondents with lower incomes (below $35,000) indicated that they would not evacuate unless they perceive danger or their family and friends were evacuating. Respondents with higher education appeared to rely on their own judgment and awareness of risk rather than the information received from messages about a hazard event to take actions. Respondents also indicated the need to include more information in WEA messages. Evidently, local residents rely on warning messages, but there is a need to take actions to motivate certain population groups in responding to warnings.

4.6. Public Participation in Message Preparation and Response to Warnings

Local residents indicated their inclination to participate in message dissemination (rather than preparation) and to collaborate with local EMAs regardless of their age, gender or ethnicity. Individuals with low educational qualifications and lower income are willing to participate in message dissemination as opposed to people with higher education and higher income. Survey respondents also indicated that they will be more inclined to take positive actions in response to alerts and warnings if they were involved in the message dissemination process. This trend does not apply to individuals with higher education and higher income, or to Anglo-American and African-American respondents, however. Overall, it is evident that individuals with higher education and income make their own decisions in terms of following evacuation notices or responding to alert or warning messages regardless of their gender, age, ethnicity, prior experience with similar hazard events, or the decisions of family and friends regarding evacuation. These individuals are also less inclined to participate in hierarchical risk communication though they may be involved in participatory risk communication through social media.

4.7. Recommendations

Based on these findings, the following are some suggested actions that should be undertaken by local EMA, FEMA/DHS and NOAA/NWS offices to increase the overall effectiveness of alert and warning messages.

(i) With increasing social media presence and use of smart phones, the public is becoming increasingly involved in recovery and response activities following a disaster. They also are involved in risk communication using non-traditional media throughout a disaster event. To increase the public's response to WEA messages, actions should be taken to increase public participation in the message dissemination process.

(ii) Although many people are aware of WEA messages, knowledge is not universal. Local EMAs should work with community organizations (for instance, the Gulf of Mexico Alliance) to increase public knowledge of WEA messages and how, when and why they are disseminated.

(iii) Despite wide acceptance of WEA messages, their character length limitation prevents public from getting detailed information. The recent changes undertaken by FCC to increase the character length will help. The English language barrier needs to be addressed either by disseminating messages via language neutral devices (i.e., sirens) or in other languages, however.

(iv) Social media is preferred for risk communication by both agencies and the local public. Based on our interview with local agencies, local EMAs prefer to use Facebook for alert and warning message dissemination. Based on Task 5, the public also prefers Facebook to receive risk information. Local EMAs therefore should strive to increase their Facebook presence.

(v) Twitter is preferred by the public for sharing disaster-related information that could be used during emergency management. To capture valuable data and information available on Twitter, local EMAs should increase their Twitter presence and work with community organizations to increase information sharing.

(vi) Although many people will evacuate in response to evacuation notices, some segments of the population (people with higher education, high income and belonging to specific ethnic groups) are neither inclined to participate in message dissemination nor to take appropriate actions in response to valid alerts and warnings. Furthermore, family and friends of local residents influence their decision to undertake actions in response to warnings. Therefore, local EMAs should work with community organizations to increase public awareness of risk and to communicate the reasons and importance of evacuations, and discuss the effectiveness of devices other than TV.

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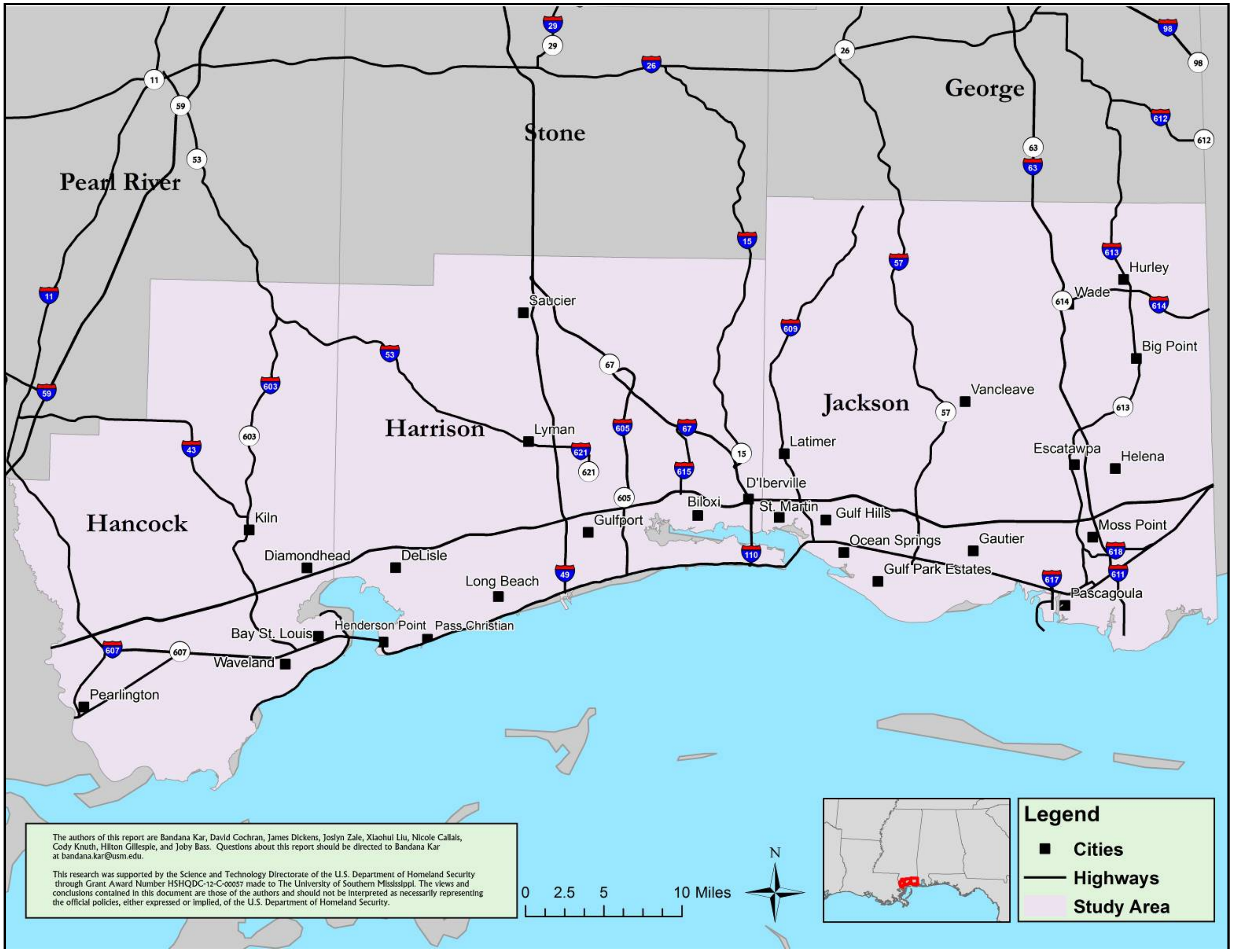

Figure 1: Location of Study Counties (Hancock, Harrison and Jackson from Left to Right)

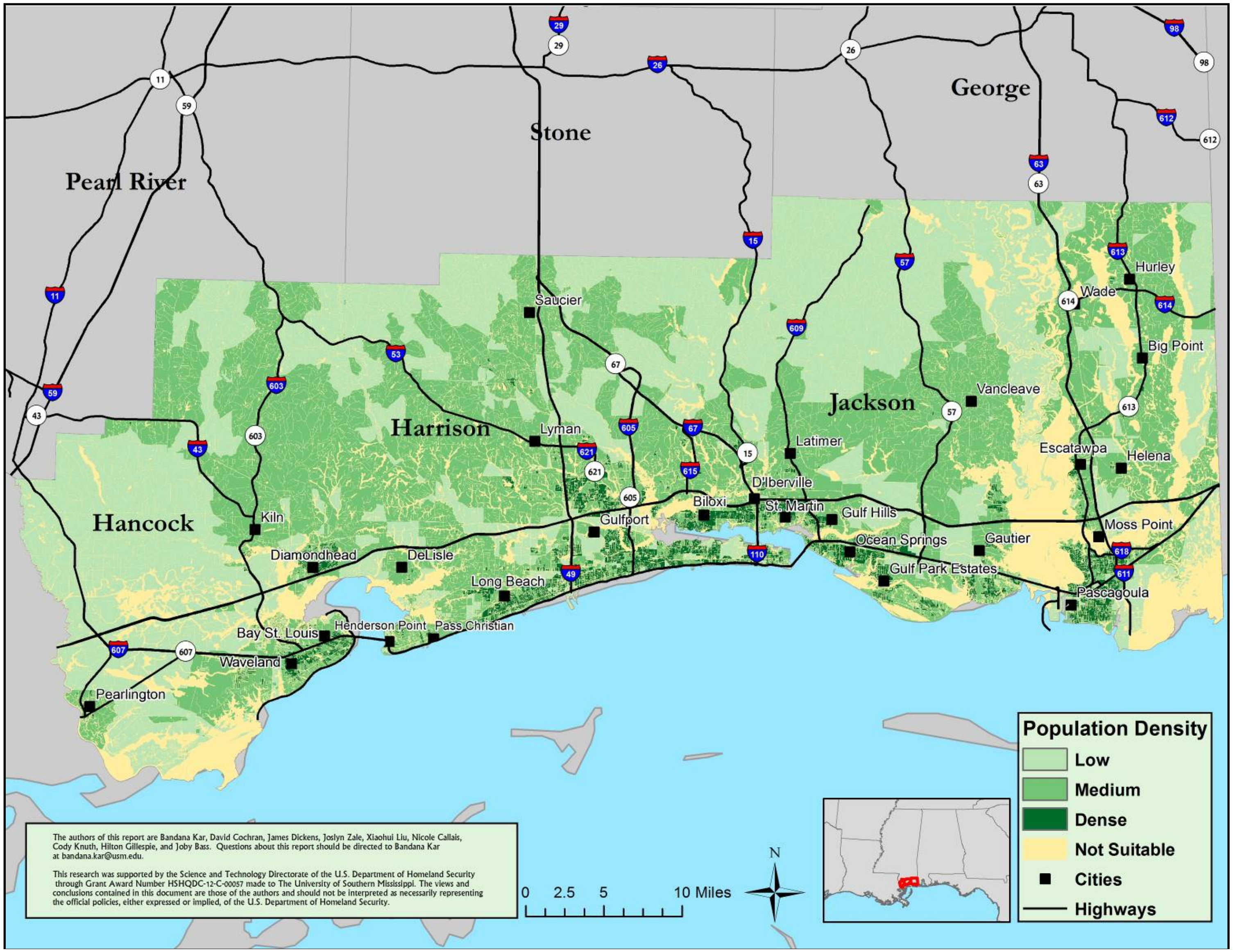

Figure 2: Population Density Distribution in Study Counties

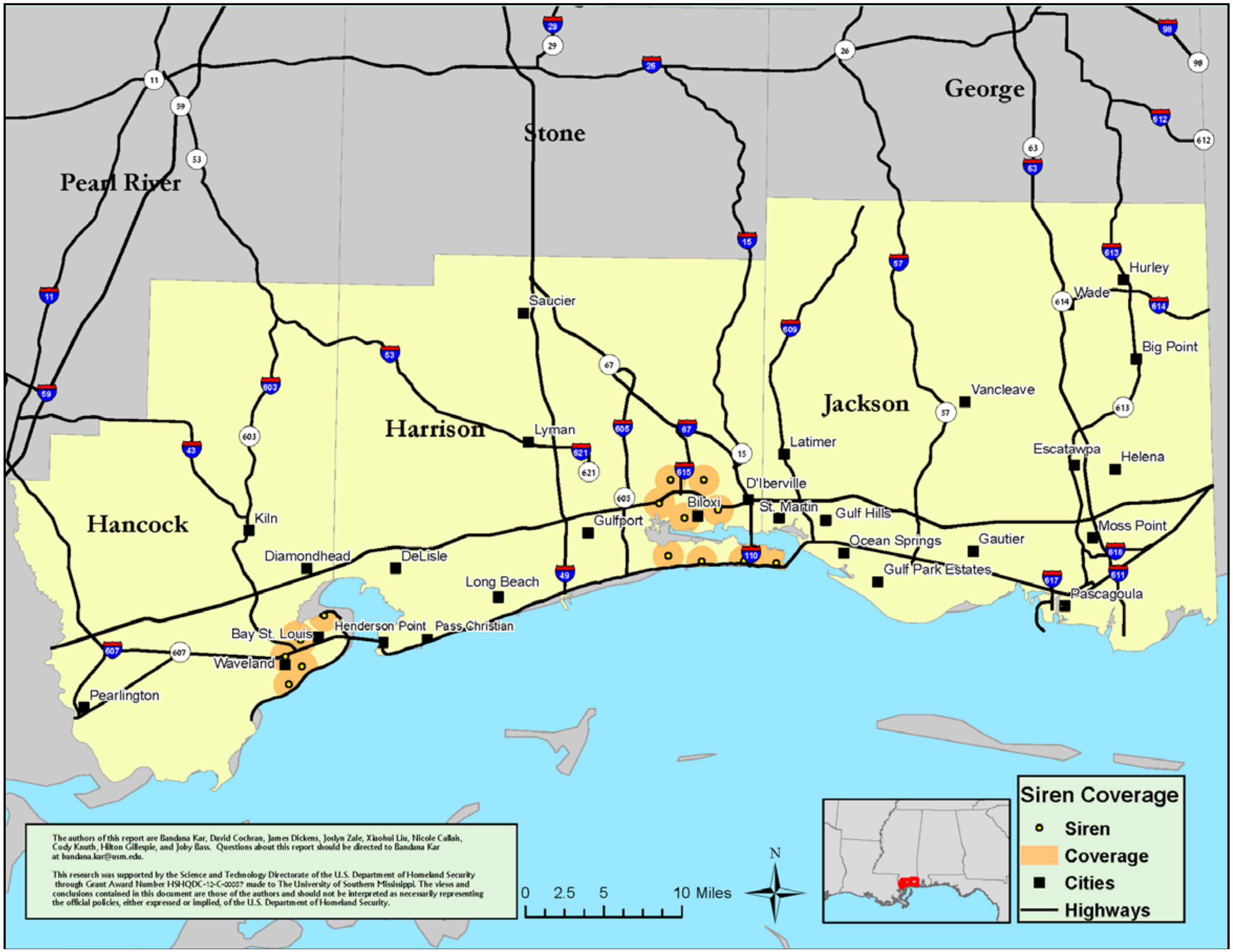

Figure 3: Spatial Coverage of Warning Sirens in Bay Saint Louis and Biloxi

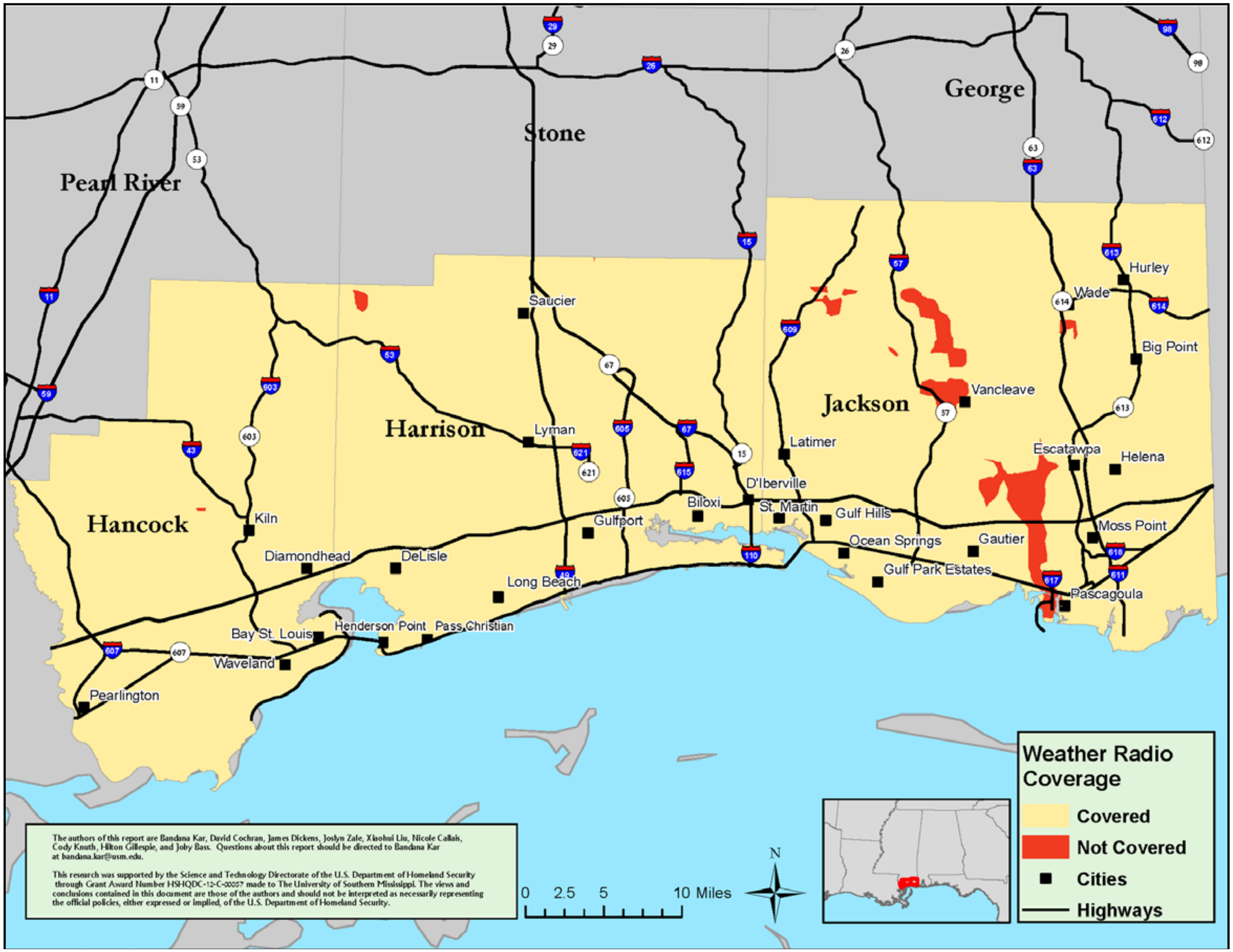

Figure 4: Spatial Coverage of NOAA Weather Radio

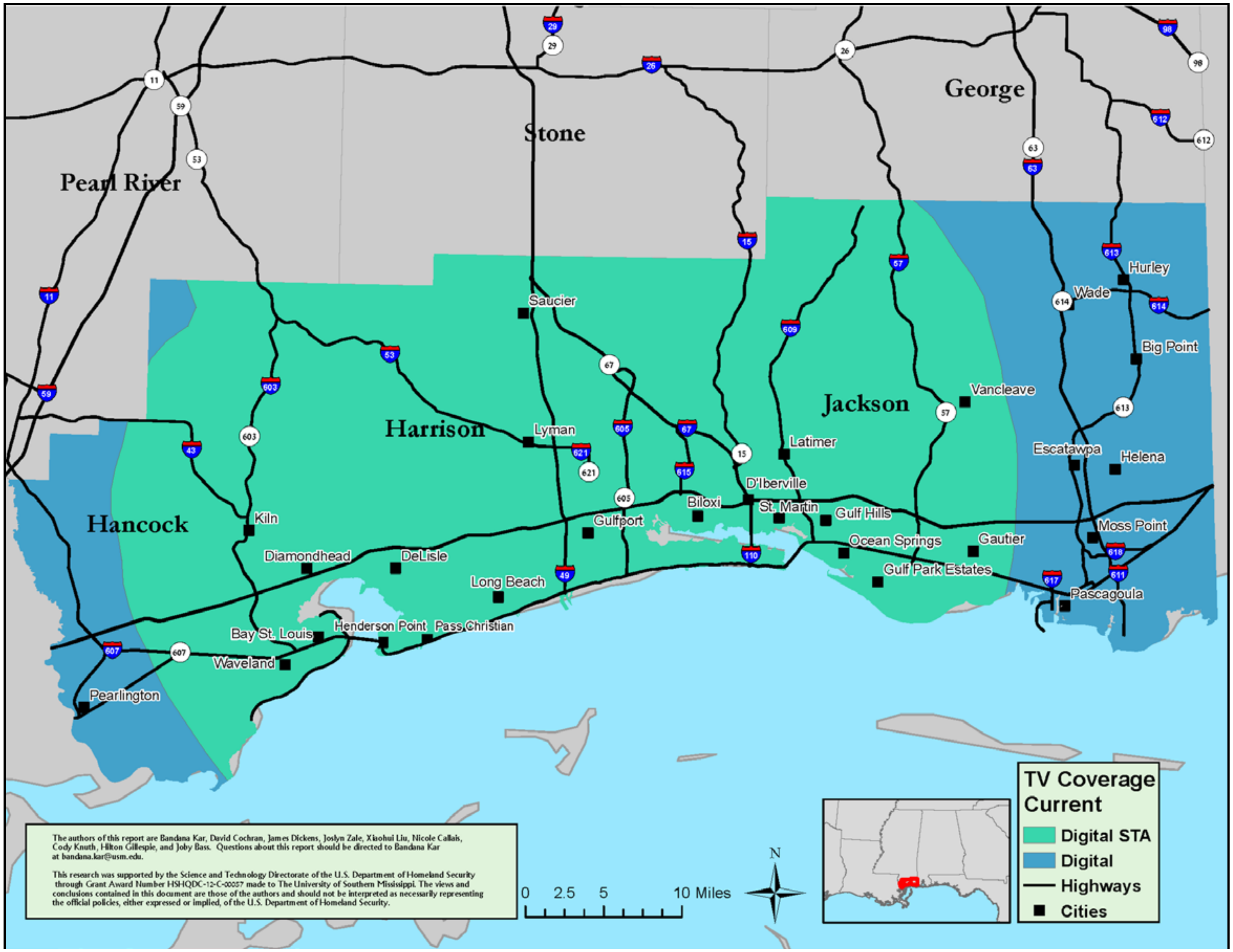

Figure 5: Spatial Coverage of Digital Television

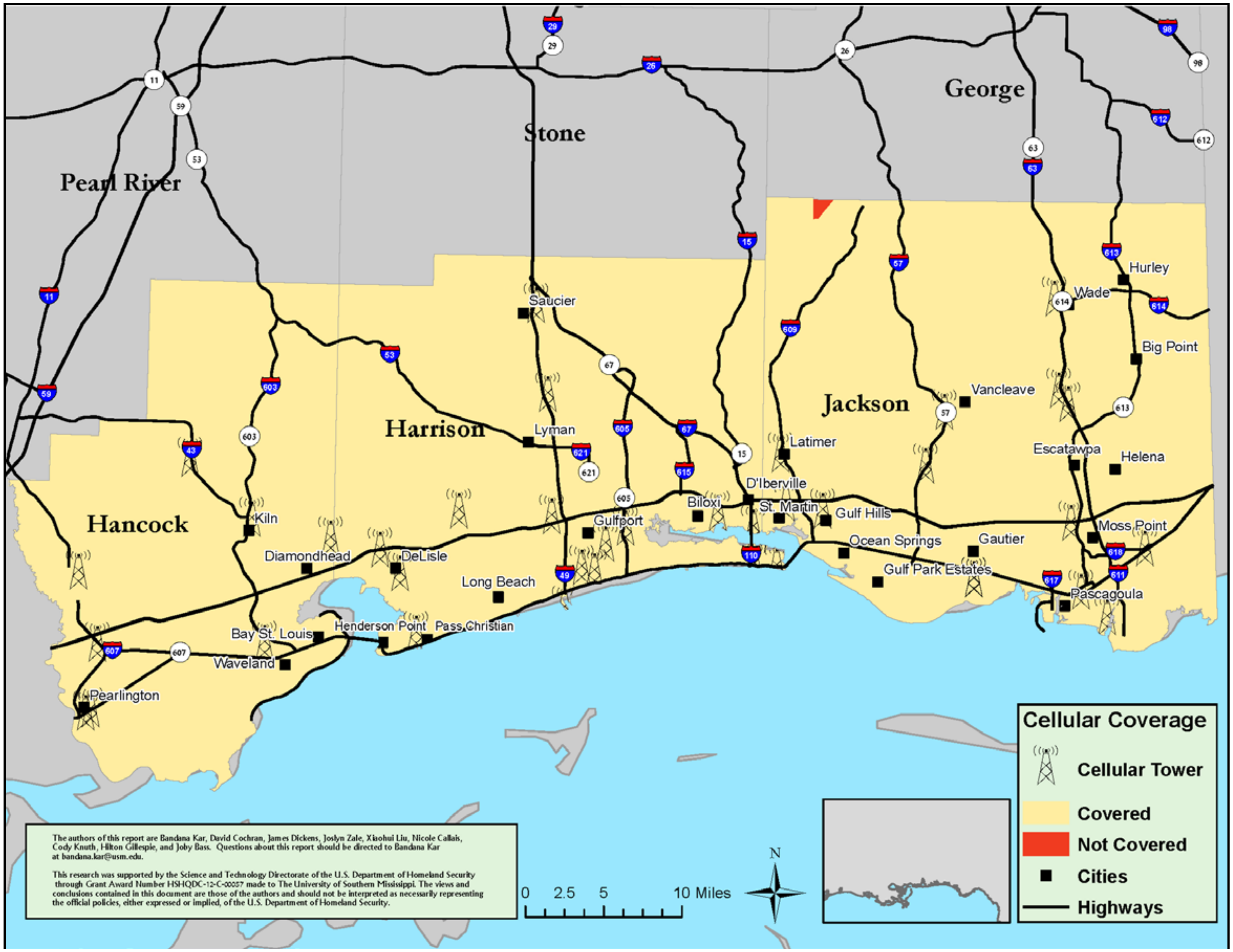

Figure 6: Spatial Distribution of Cell Towers and Their Spatial Coverage

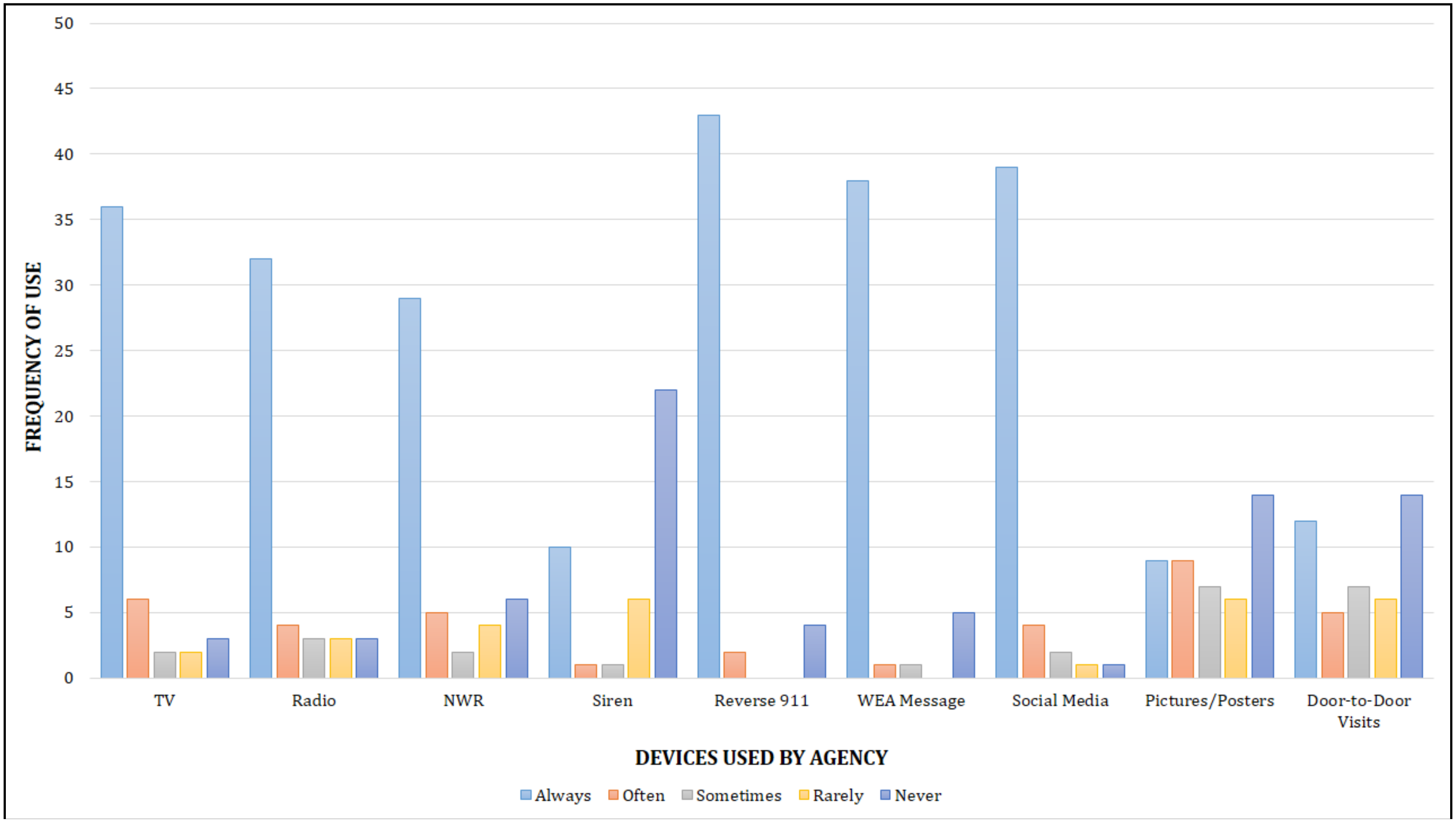

Figure 7: Alert and Warning Devices Frequently Used by County EMAs

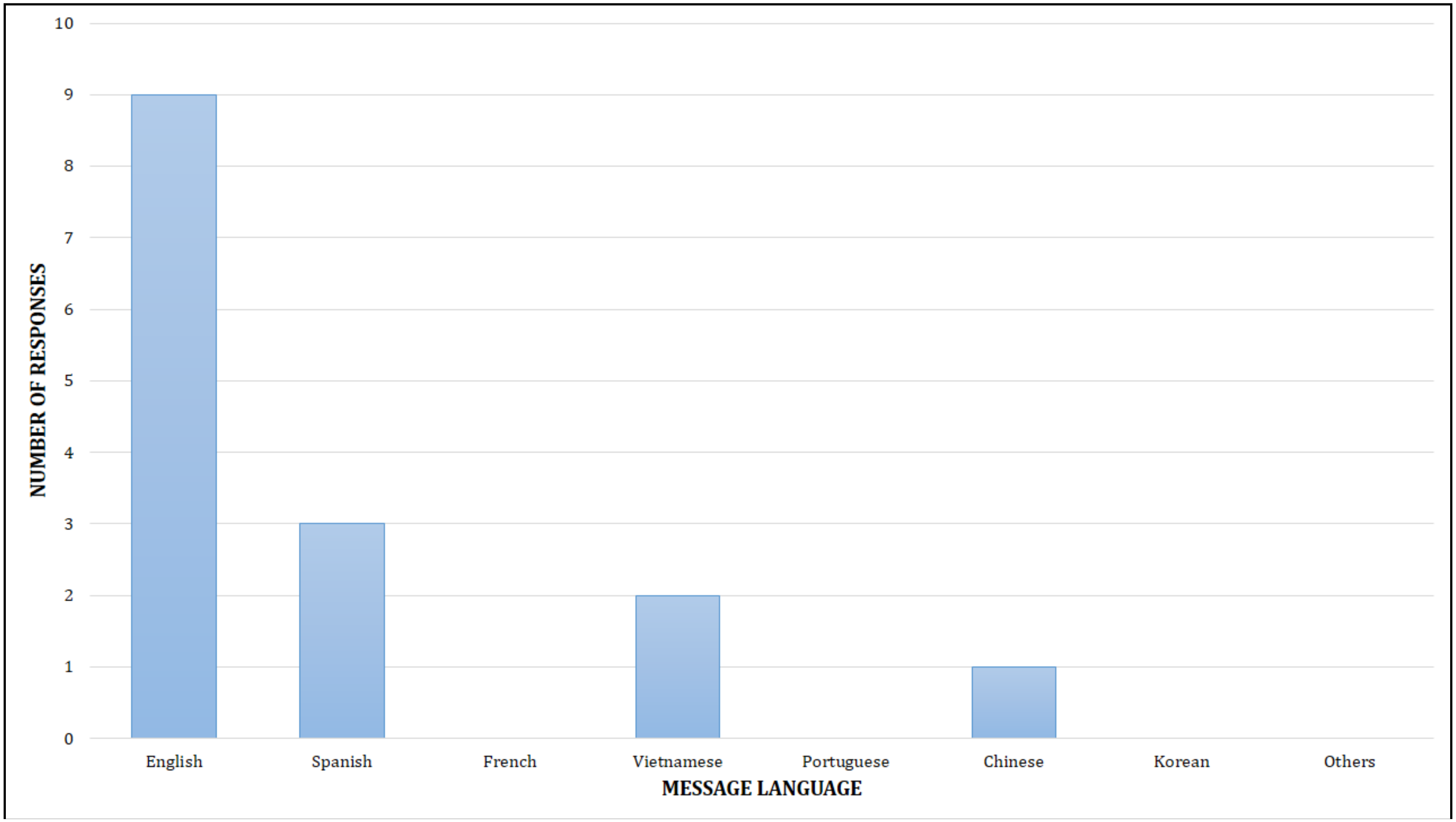

Figure 8: Languages Used by County EMA to Disseminate Alert and Warning Messages

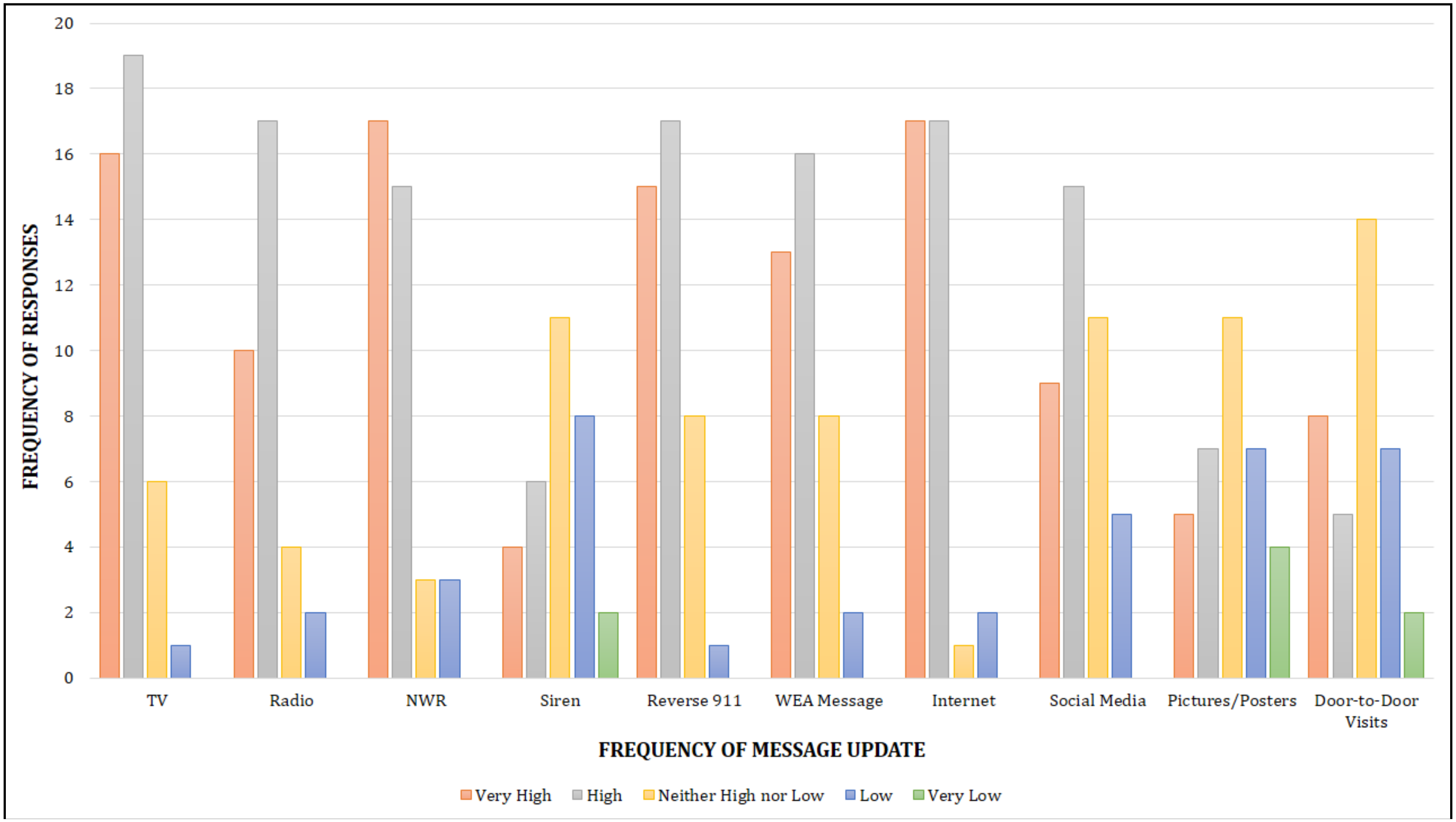

Figure 9: Frequency at Which Warnings Are Updated by Different Devices/Channels

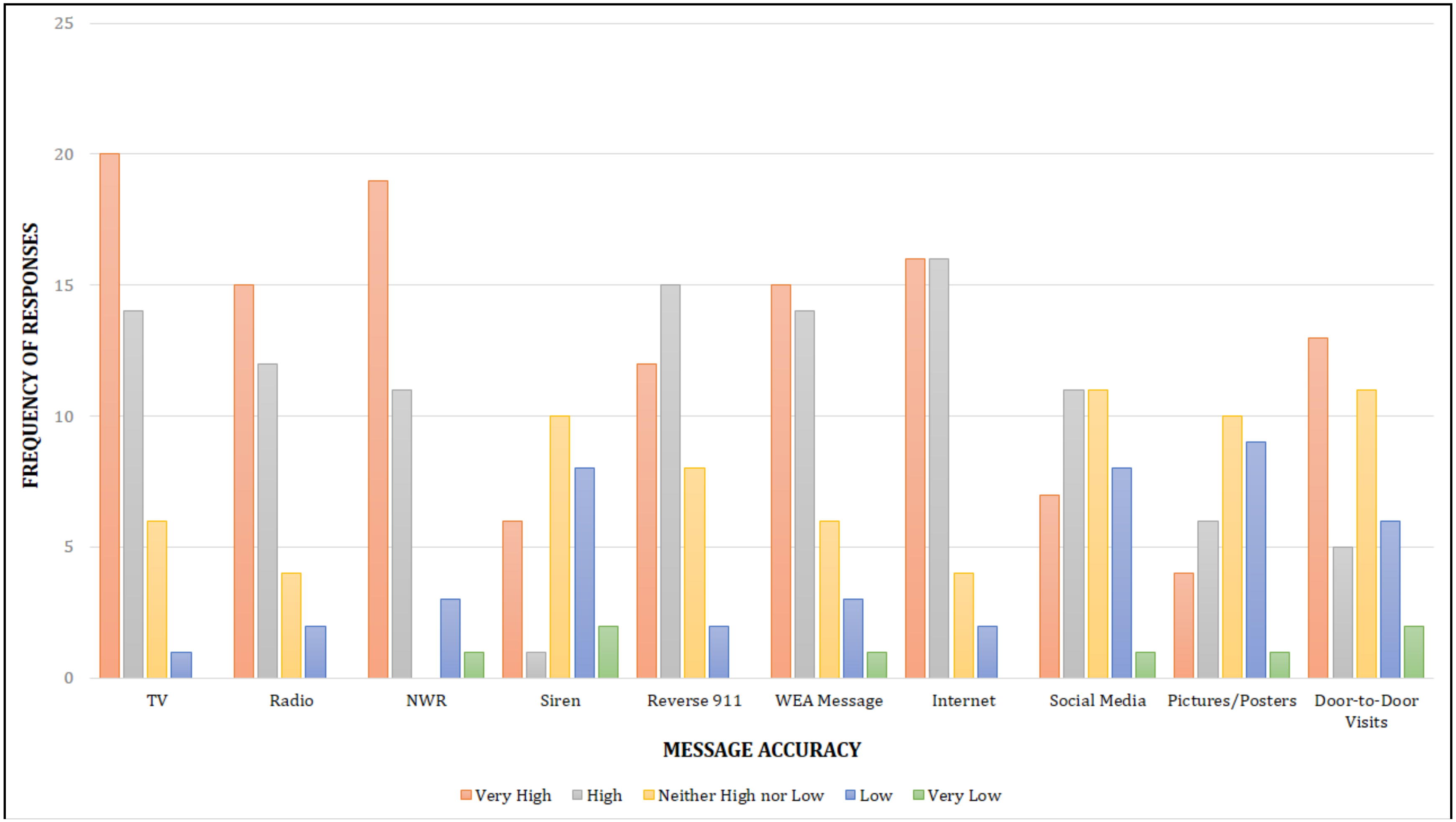

Figure 10: Accuracy of Warnings Disseminated by Different Devices/Channels

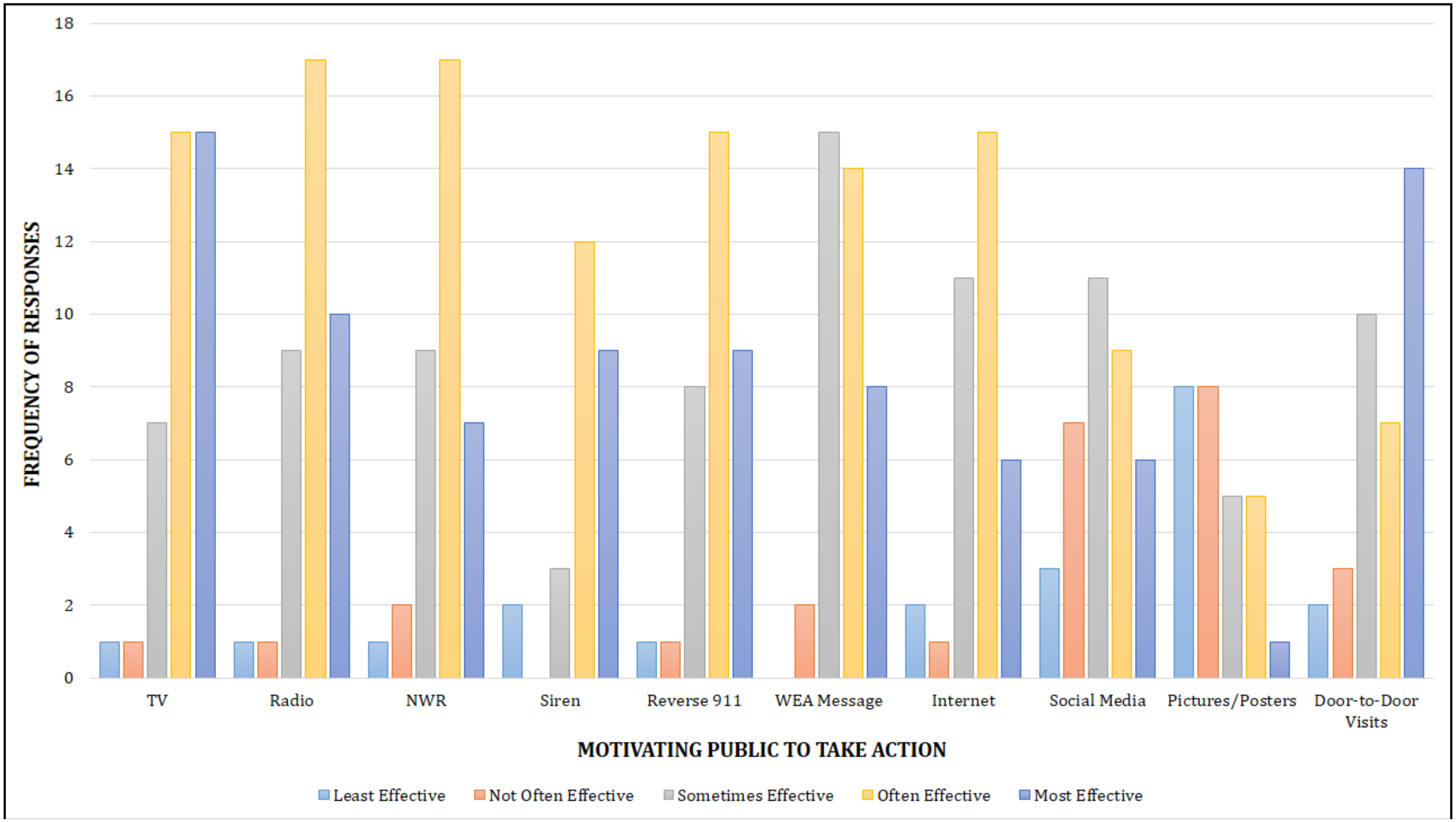

Figure 11: Effectiveness of Warnings Disseminated by Different Devices in Motivating Public to Take Preparatory Actions

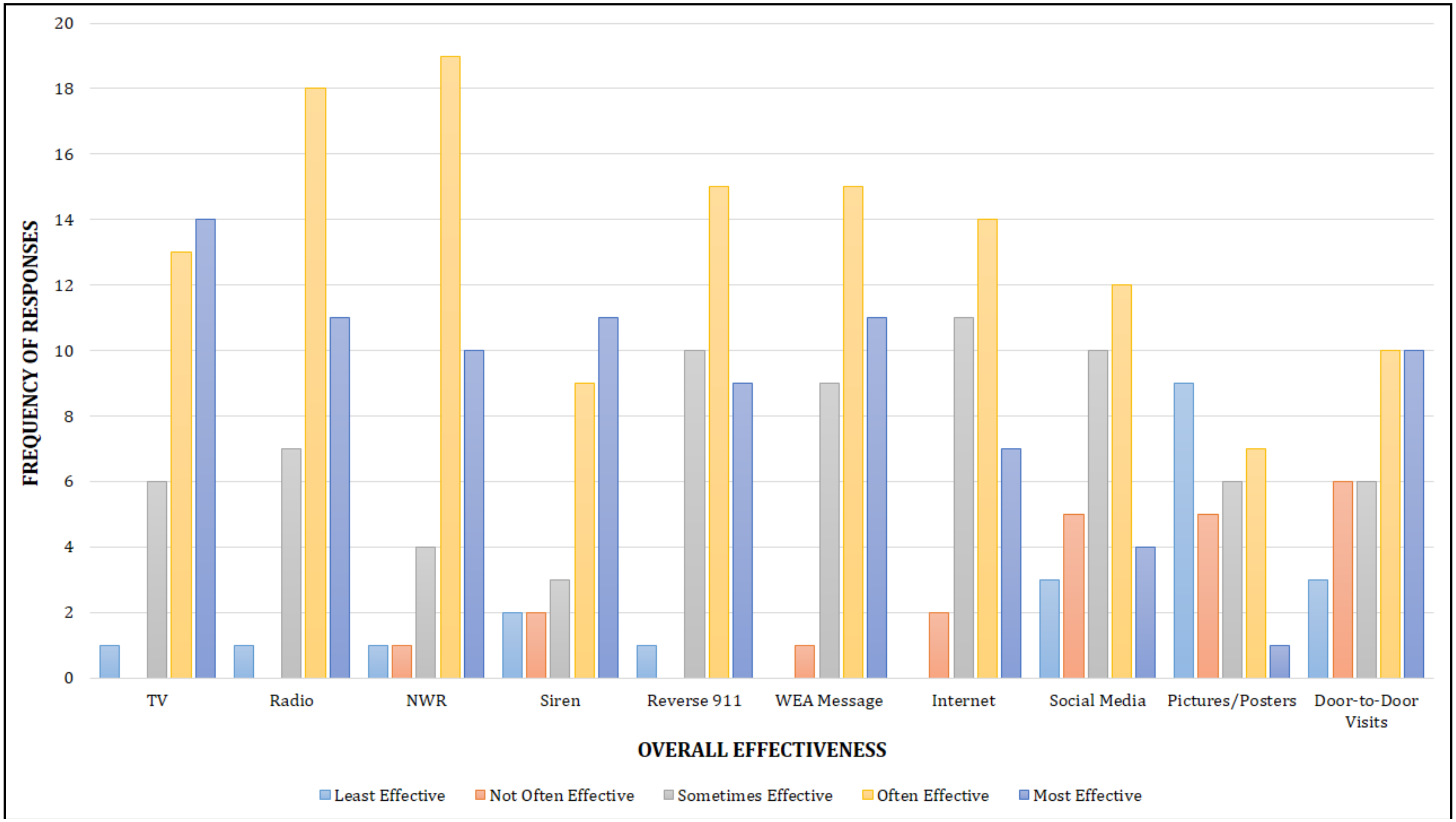

Figure 12: Overall Effectiveness of Each Device/Channel Used by County EMA

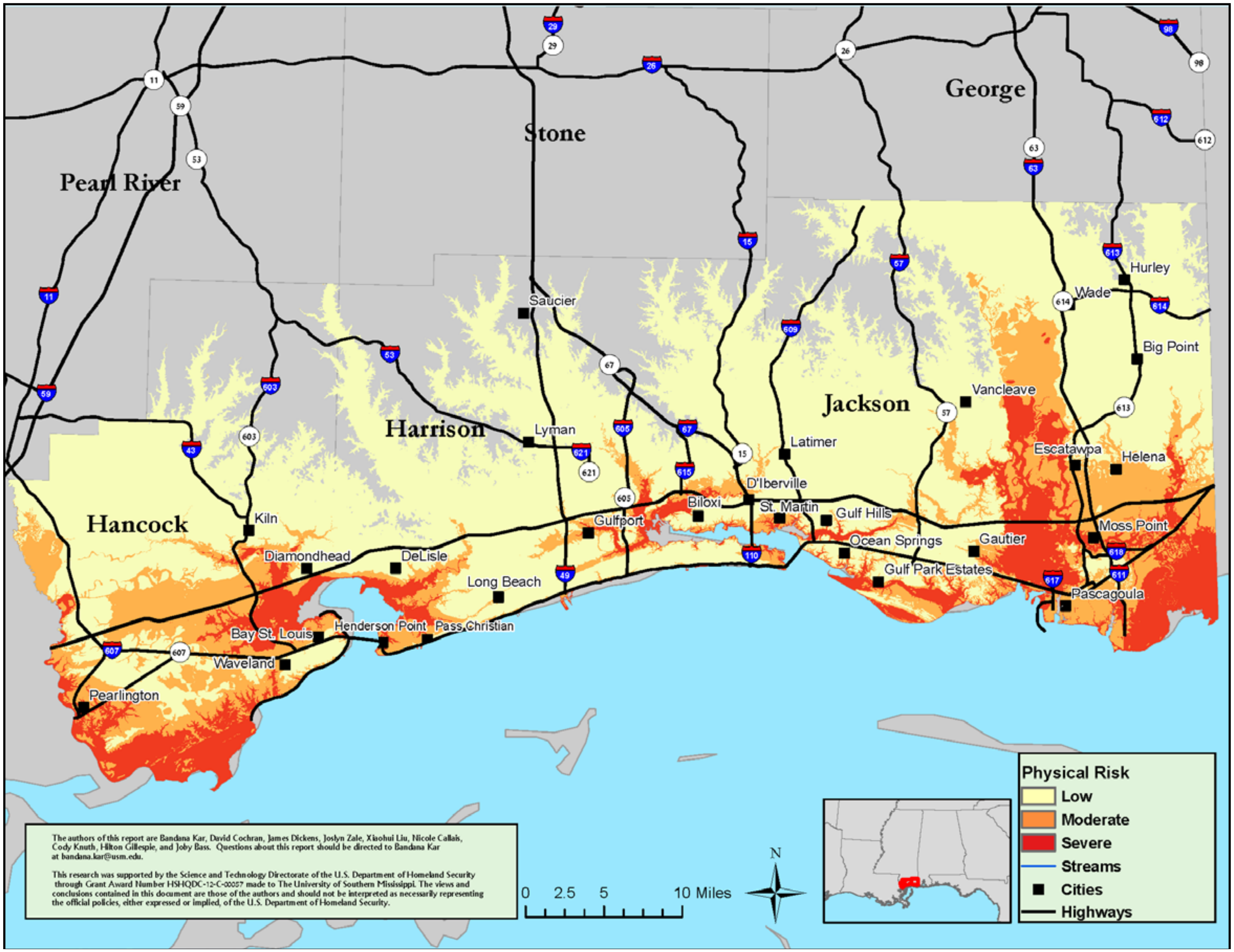

Figure 13: Spatial Distribution of Physical Risk Due to Storm Surge

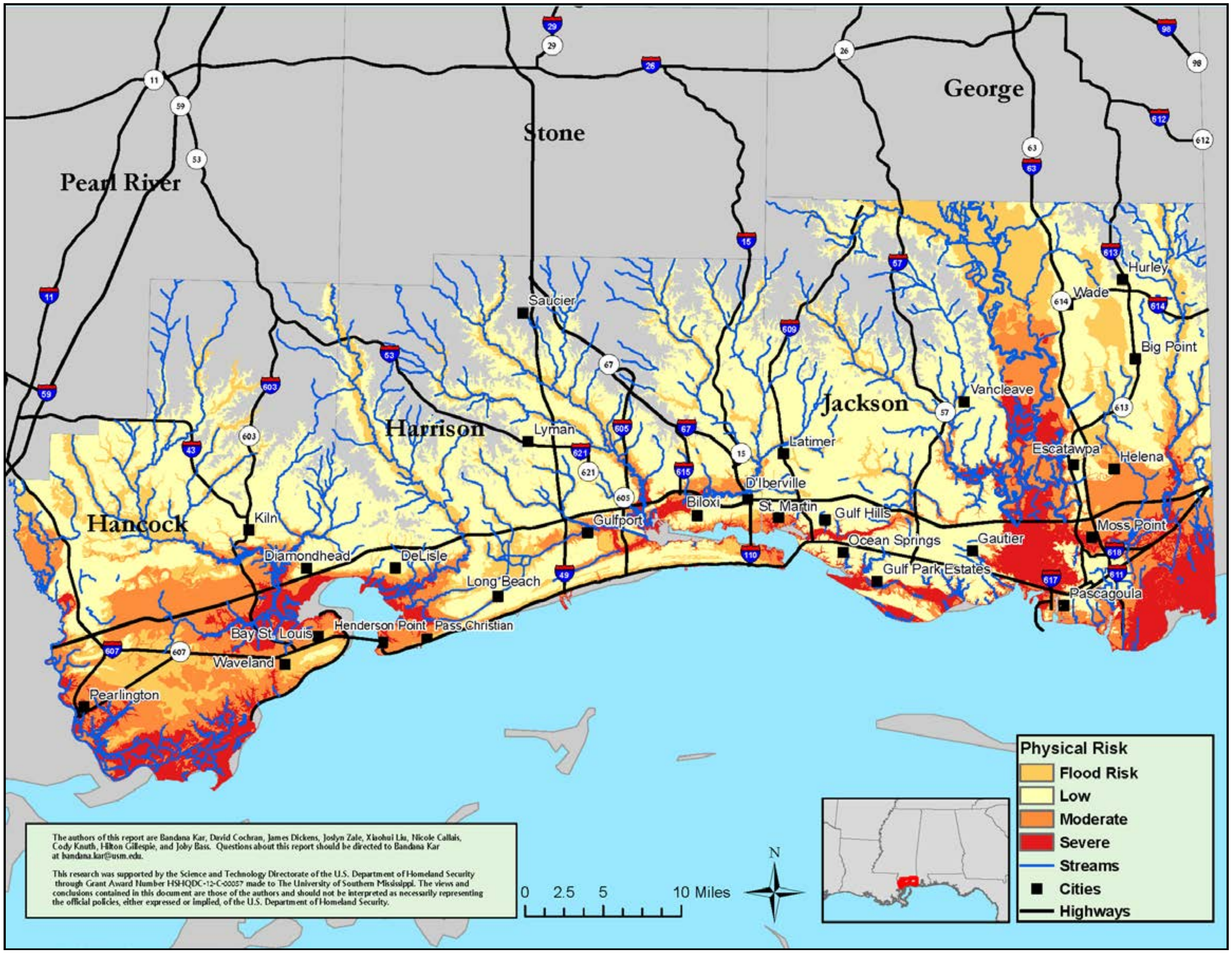

Figure 14: Spatial Distribution of Physical Risk Due to Storm Surge and Flooding

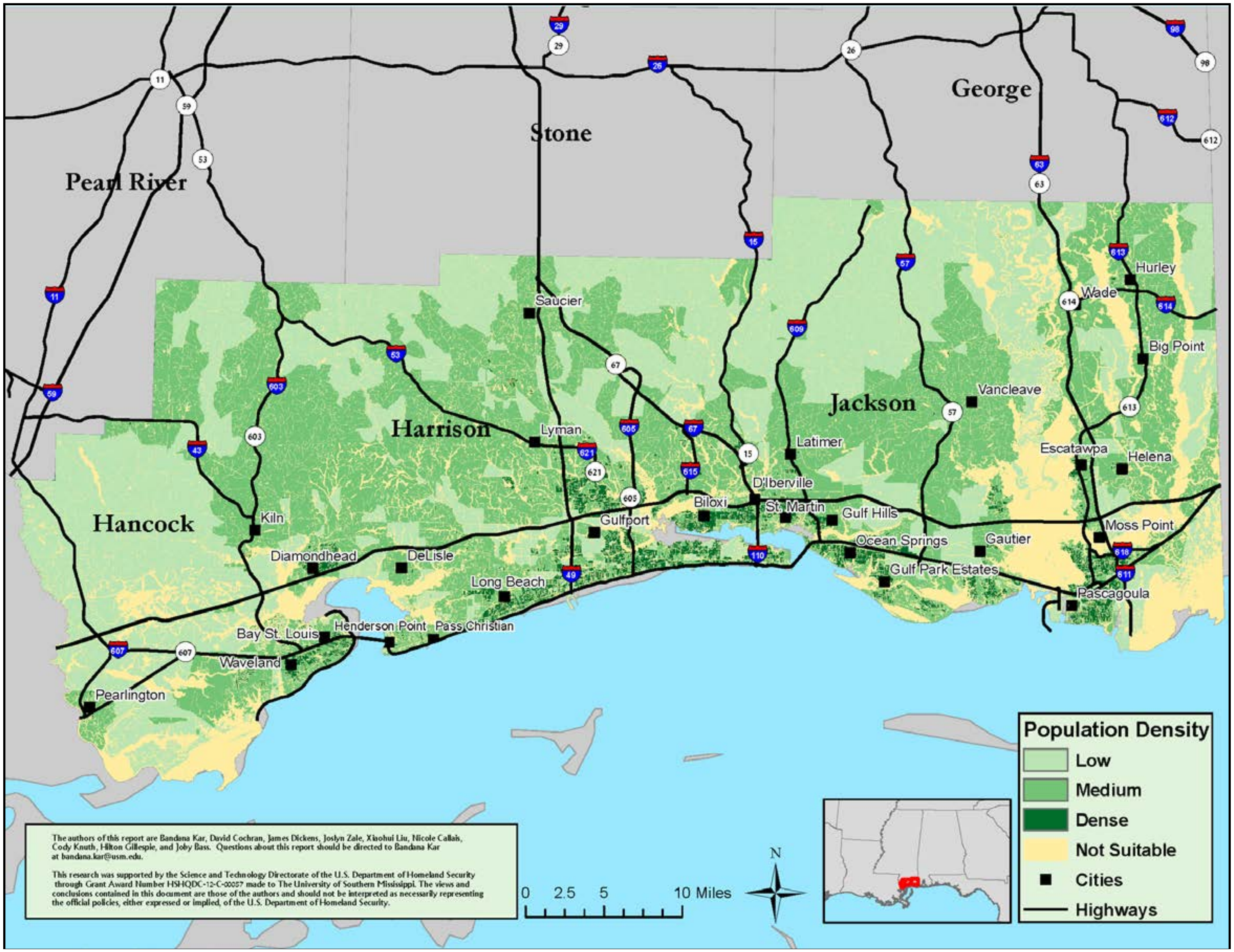

Figure 15: Spatial Distribution of Population Density in the Study Counties

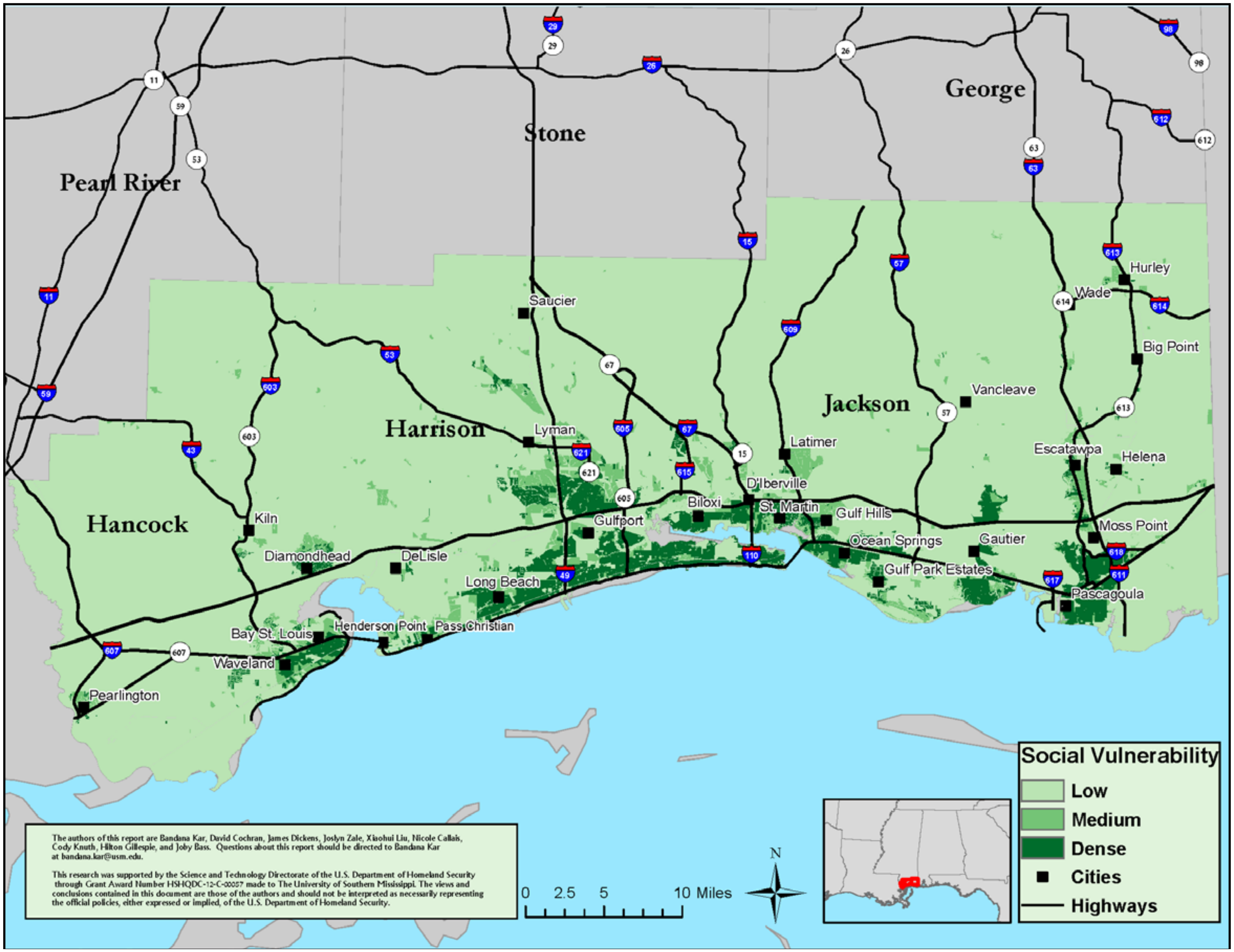

Figure 16: Spatial Distribution of Social Vulnerability (High Concentration of Socially Vulnerable Populations)

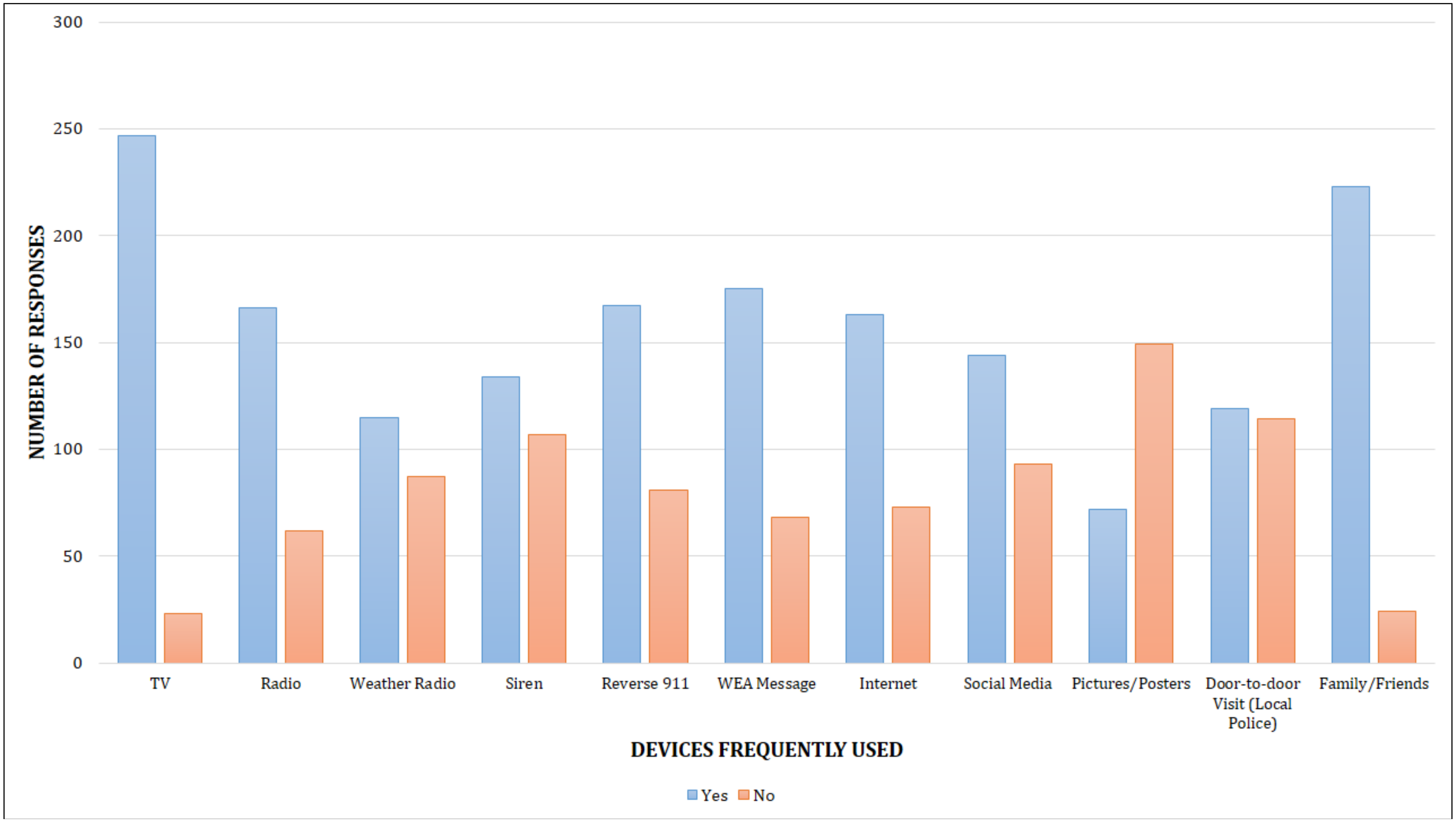

Figure 17: Alert and Warning Devices Frequently Used by Local Residents

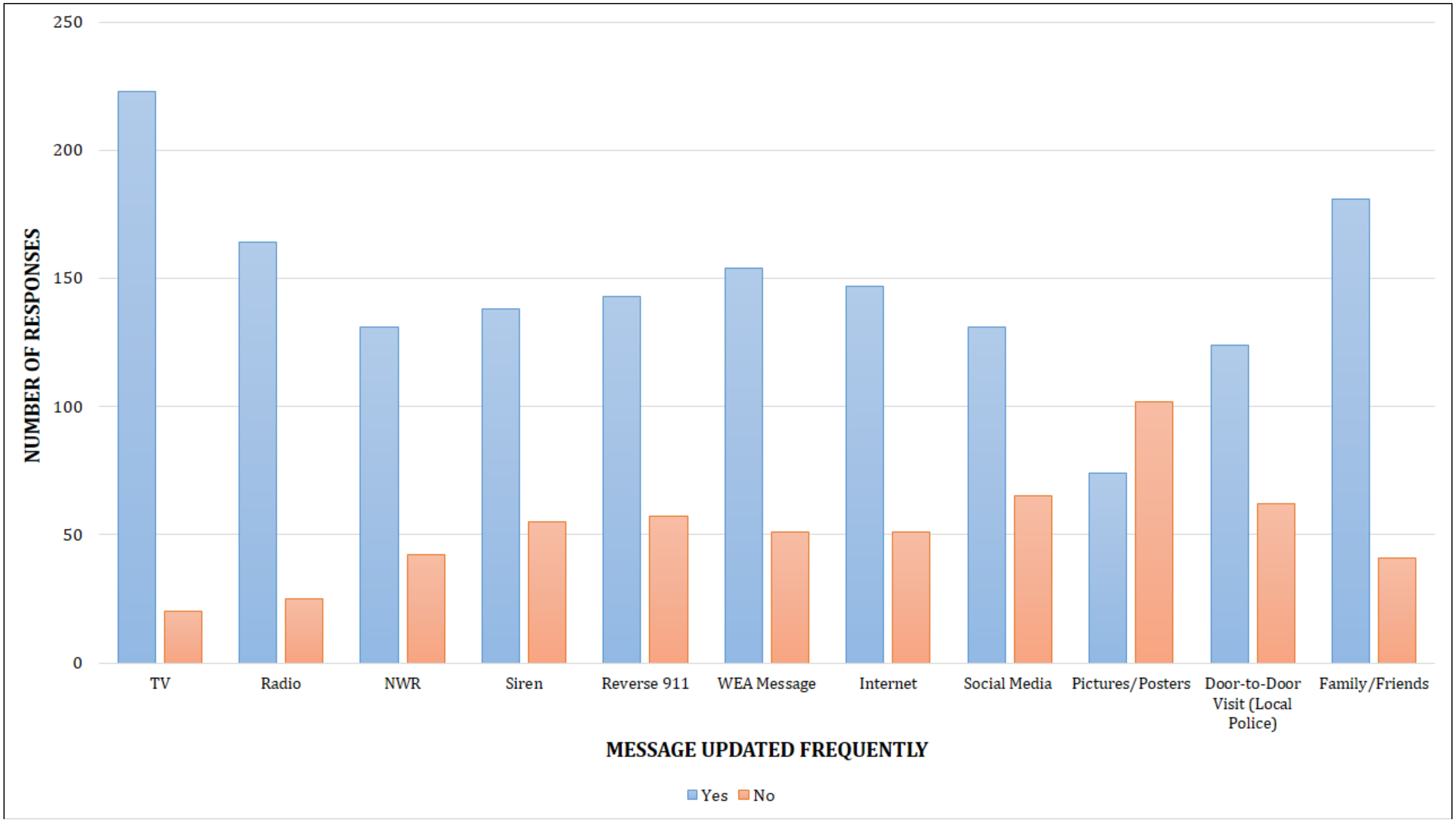

Figure 18: Alert and Warning Devices Updating Messages Frequently

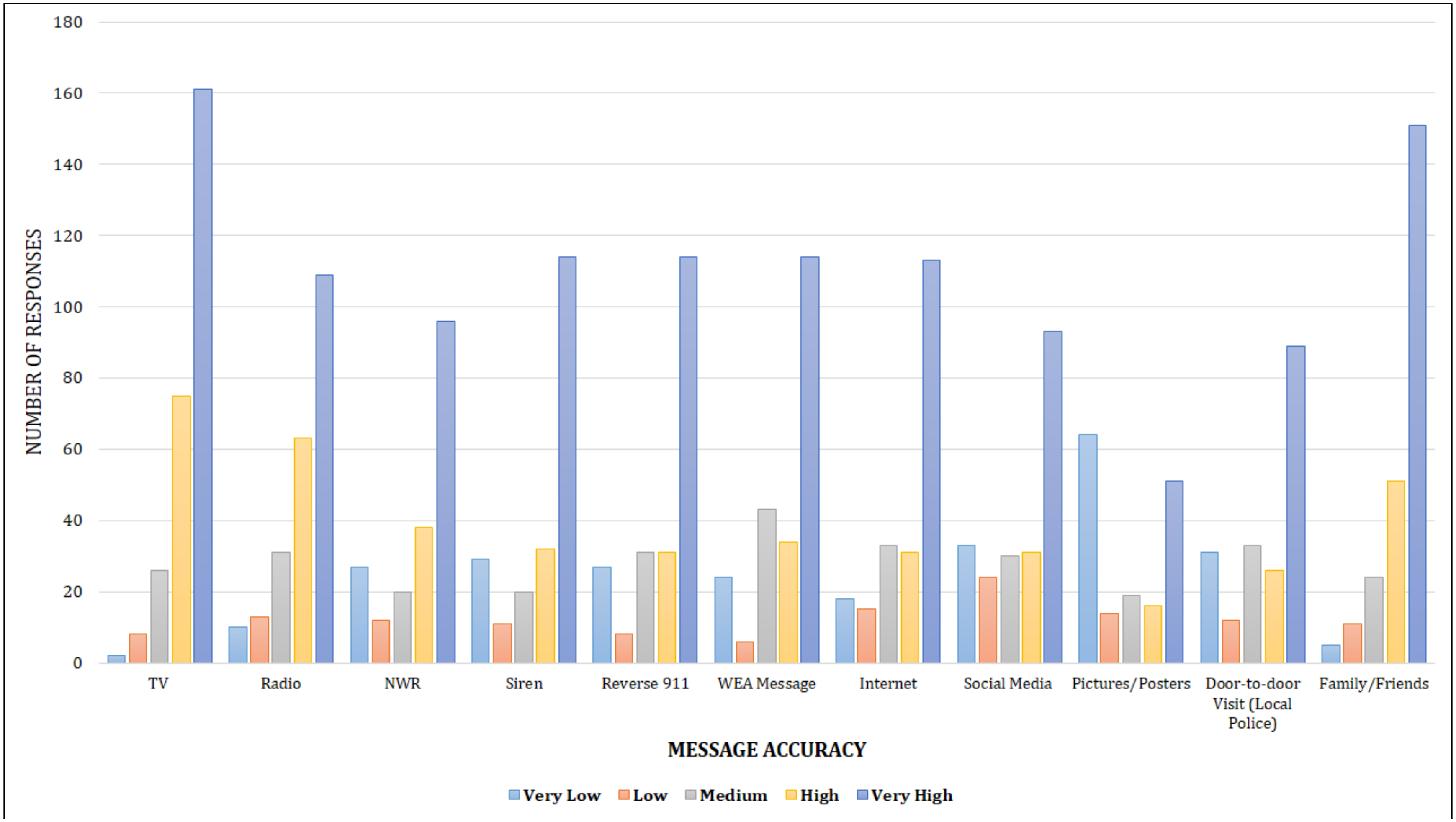

Figure 19: Alert and Warning Devices Providing Accurate Messages

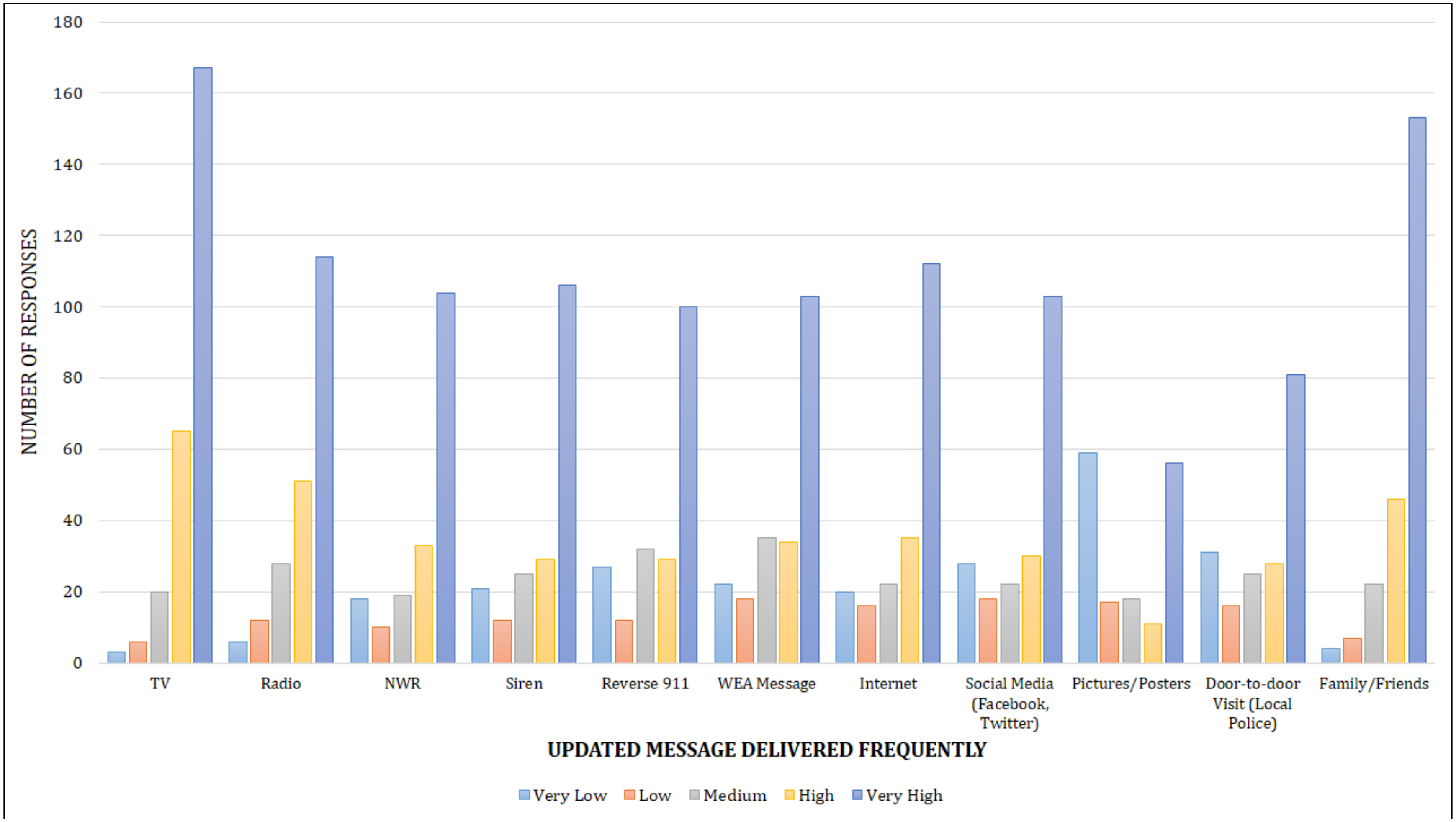

Figure 20: Alert and Warning Devices Frequently Delivering Updated Messages

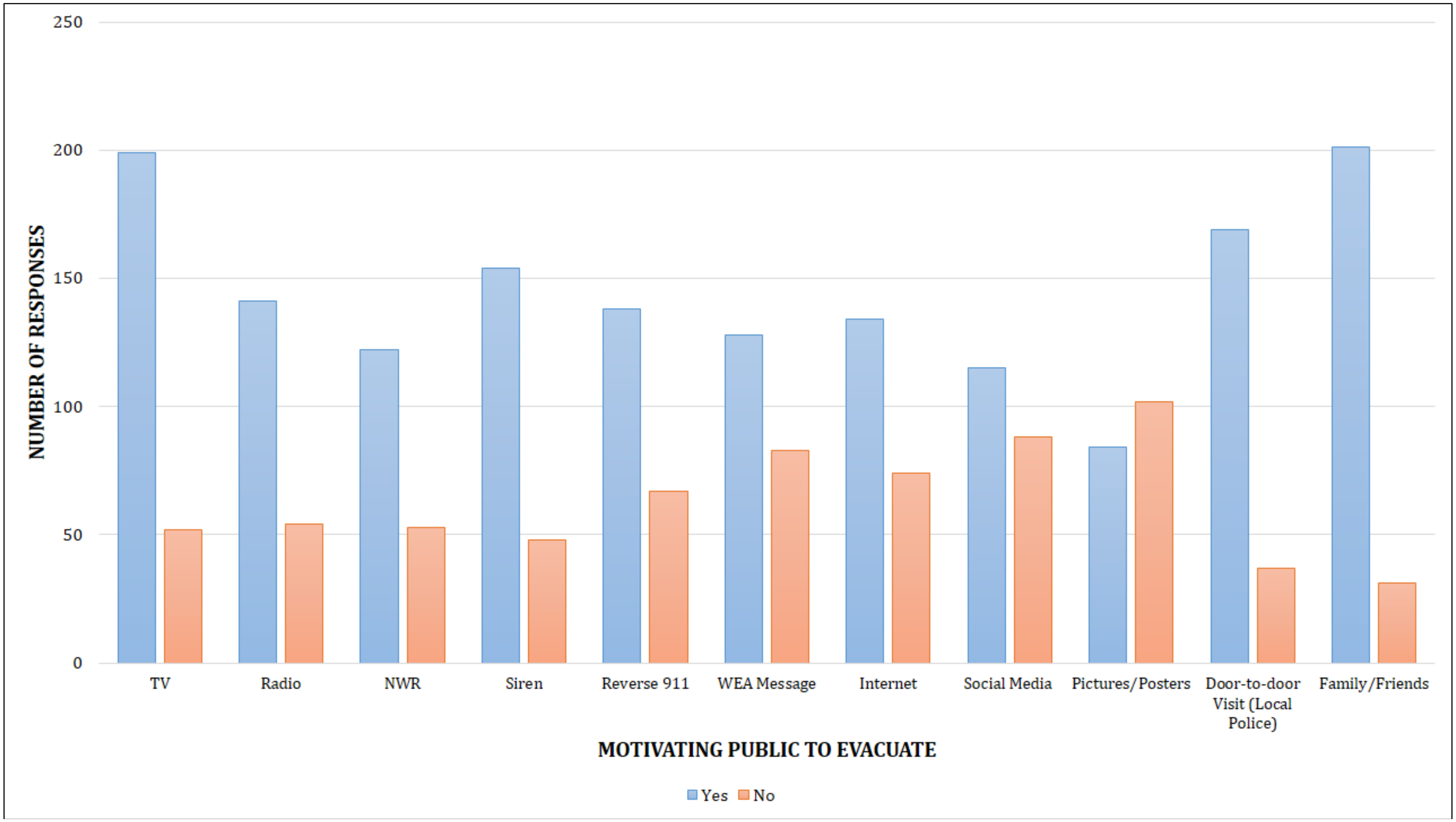

Figure 21: Alert and Warning Devices Effective in Motivating Public to Evacuate

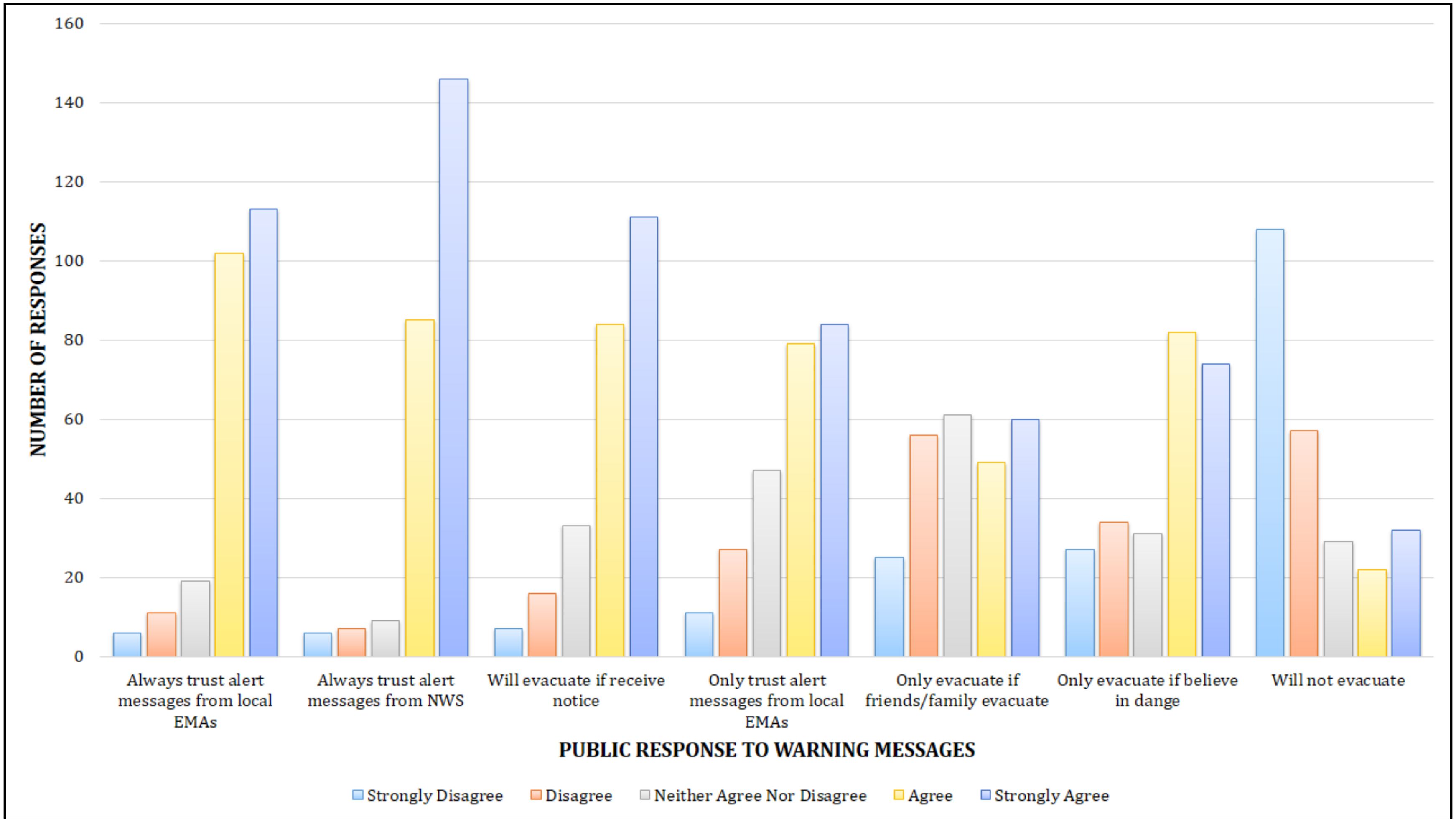

Figure 22: Public Responses to Alert and Warning Messages

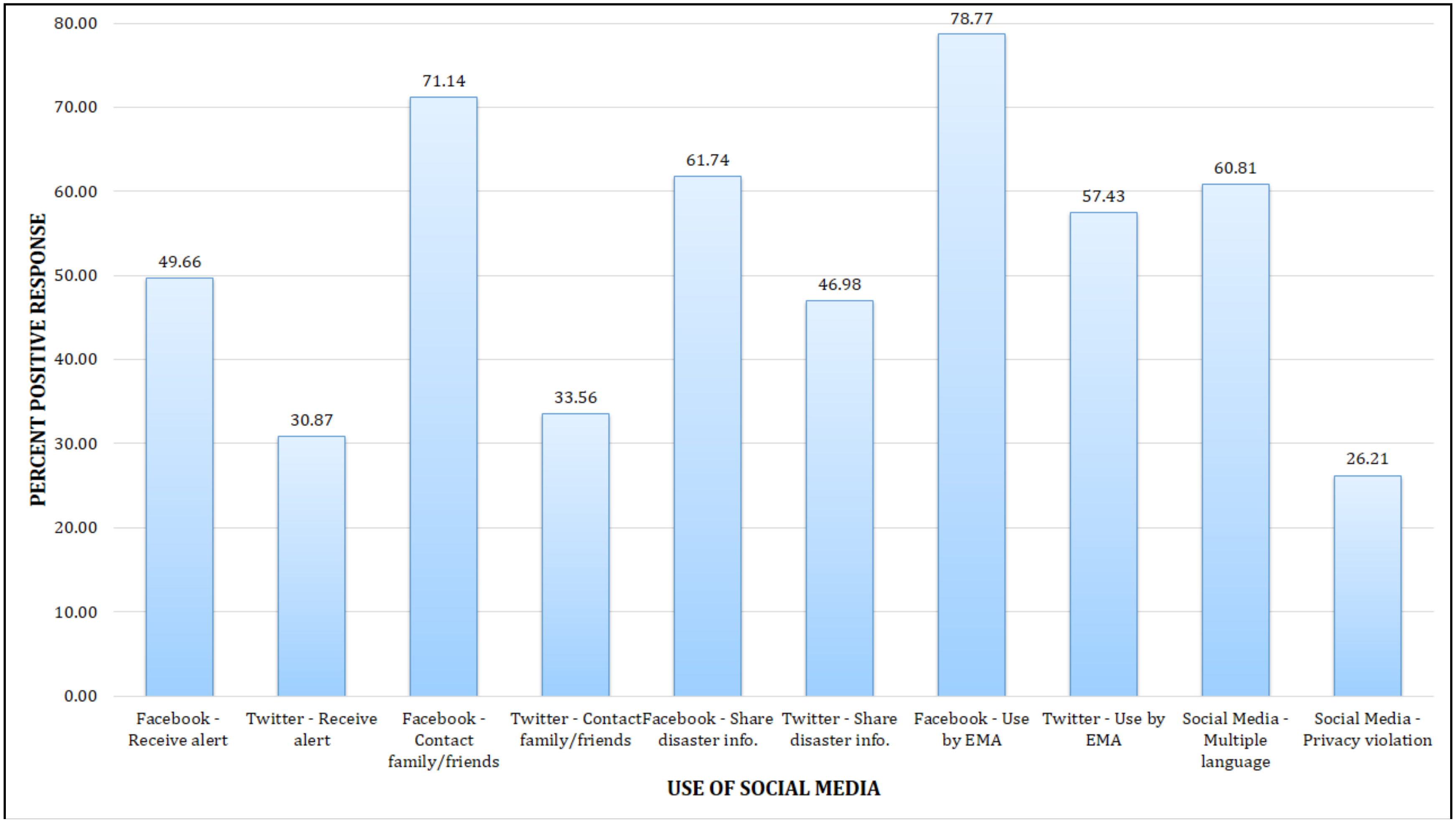

Figure 23: Public Responses About Social Media Usage for Risk Communication

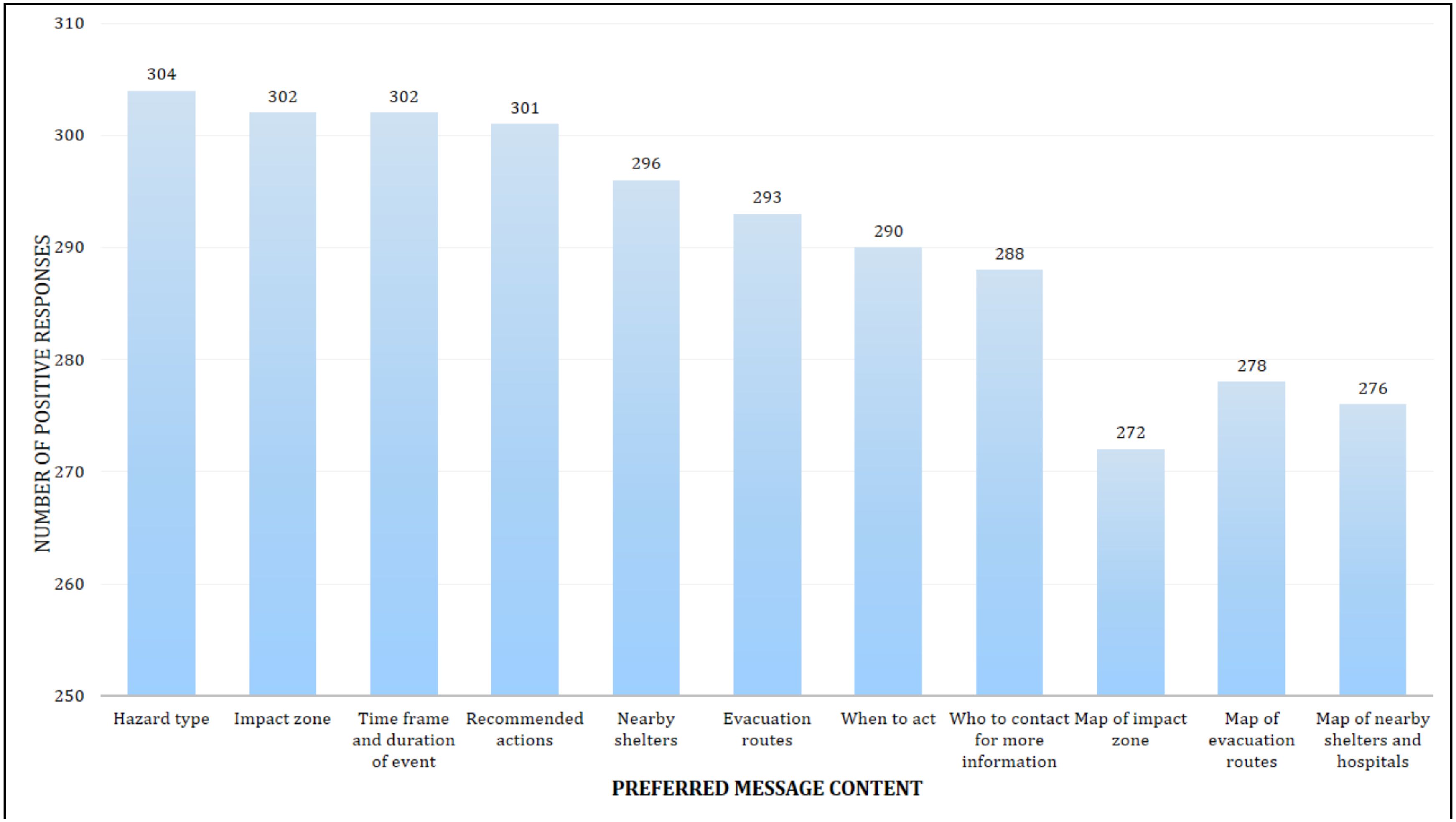

Figure 24: Public Preference of Contents for WEA Message (Ranked by Number of Responses)

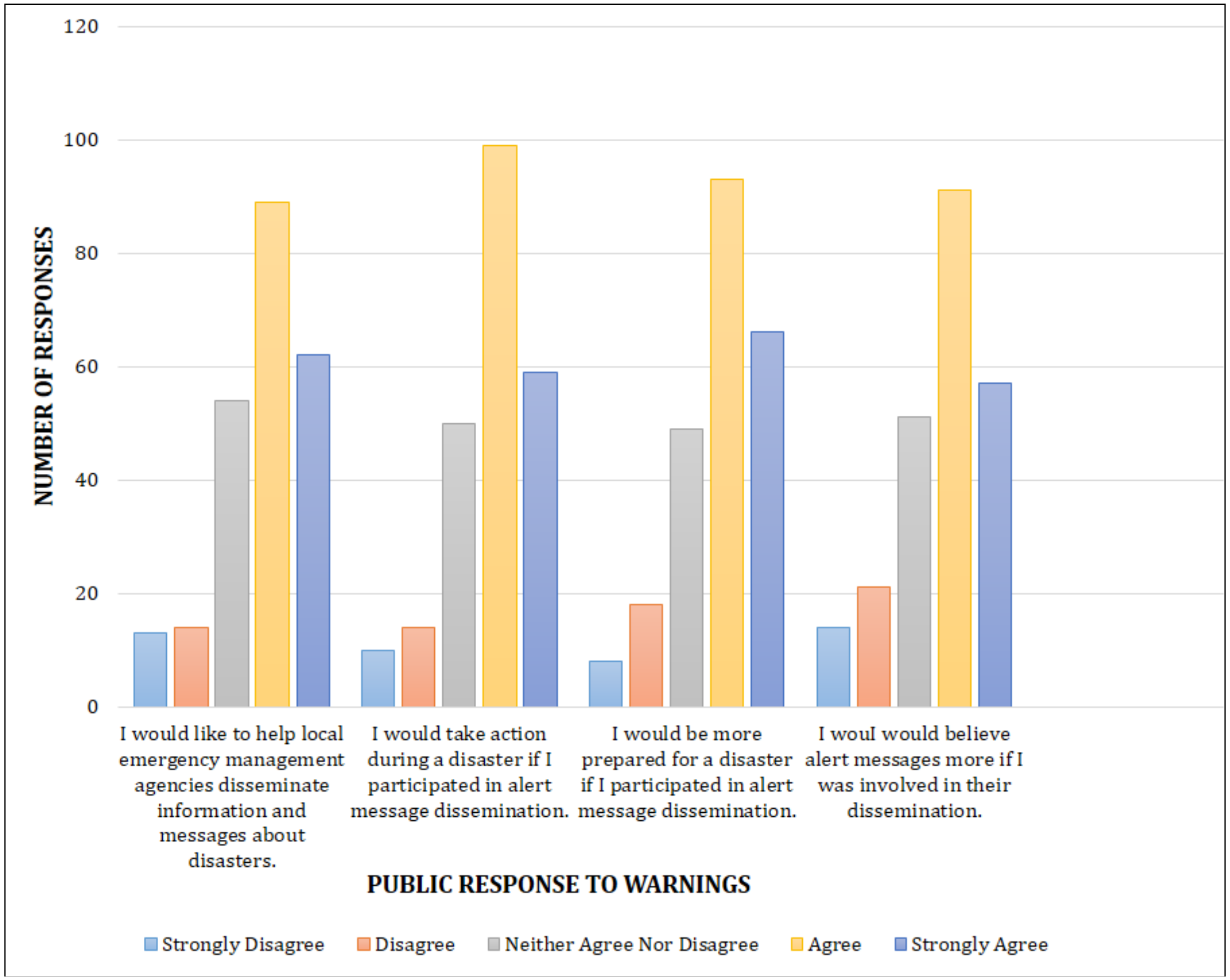

Figure 25: Public Responses to Warnings Based on Participation

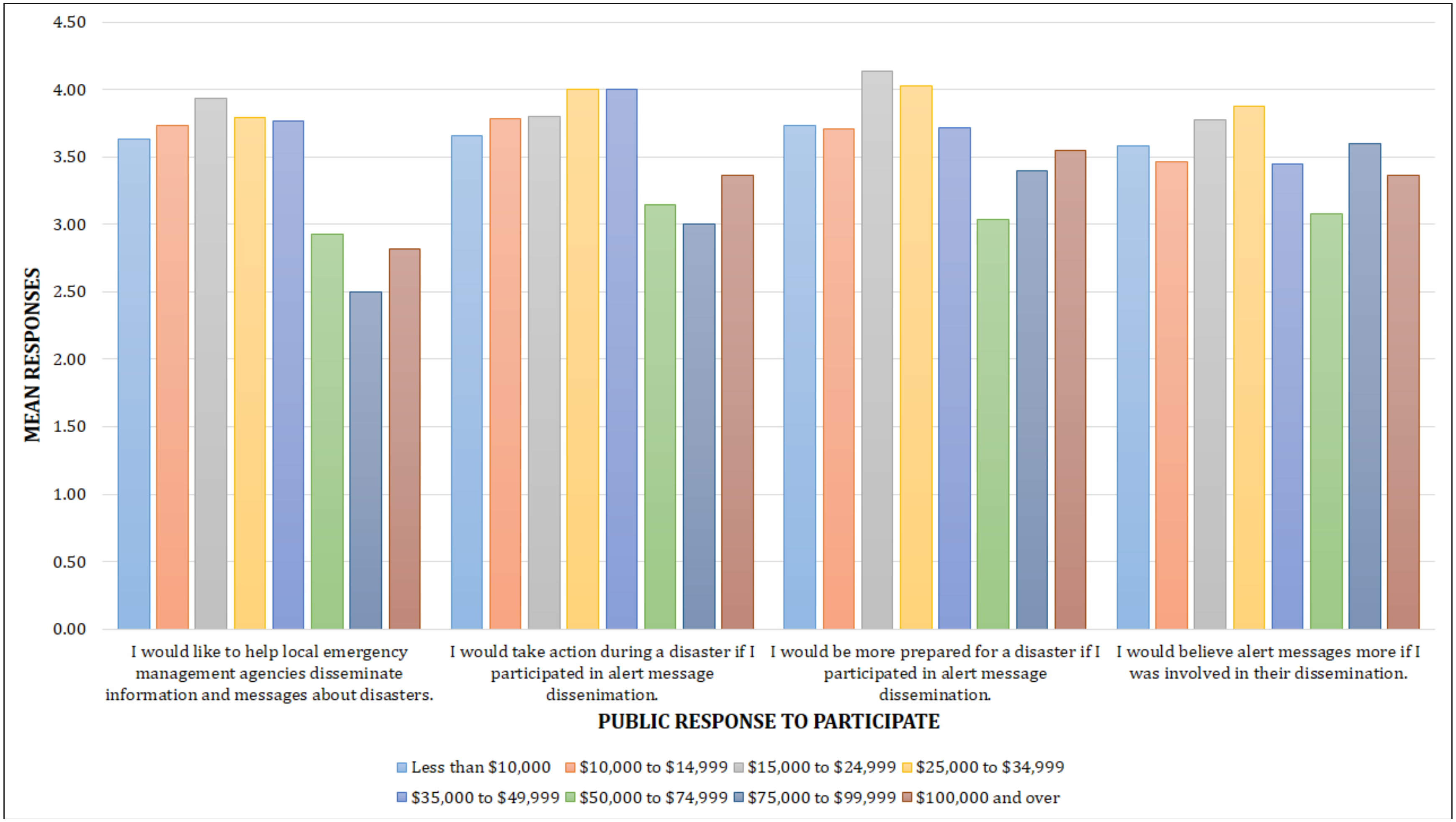

Figure 26: Public Willingness to Participate in Message Preparation and Dissemination Based on Income Categories

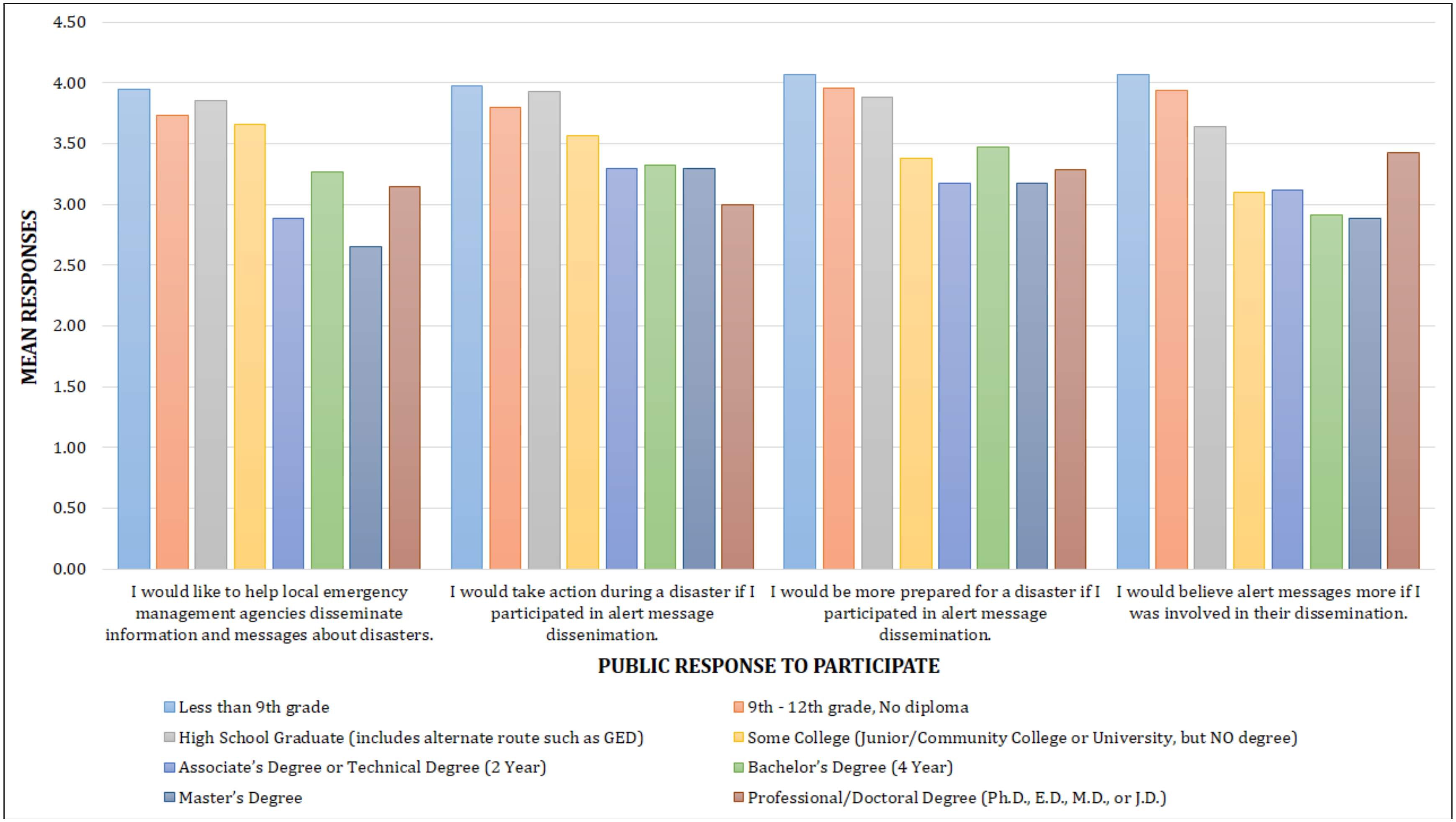

Figure 27: Public Willingness to Participate in Message Preparation and Dissemination Based on Education

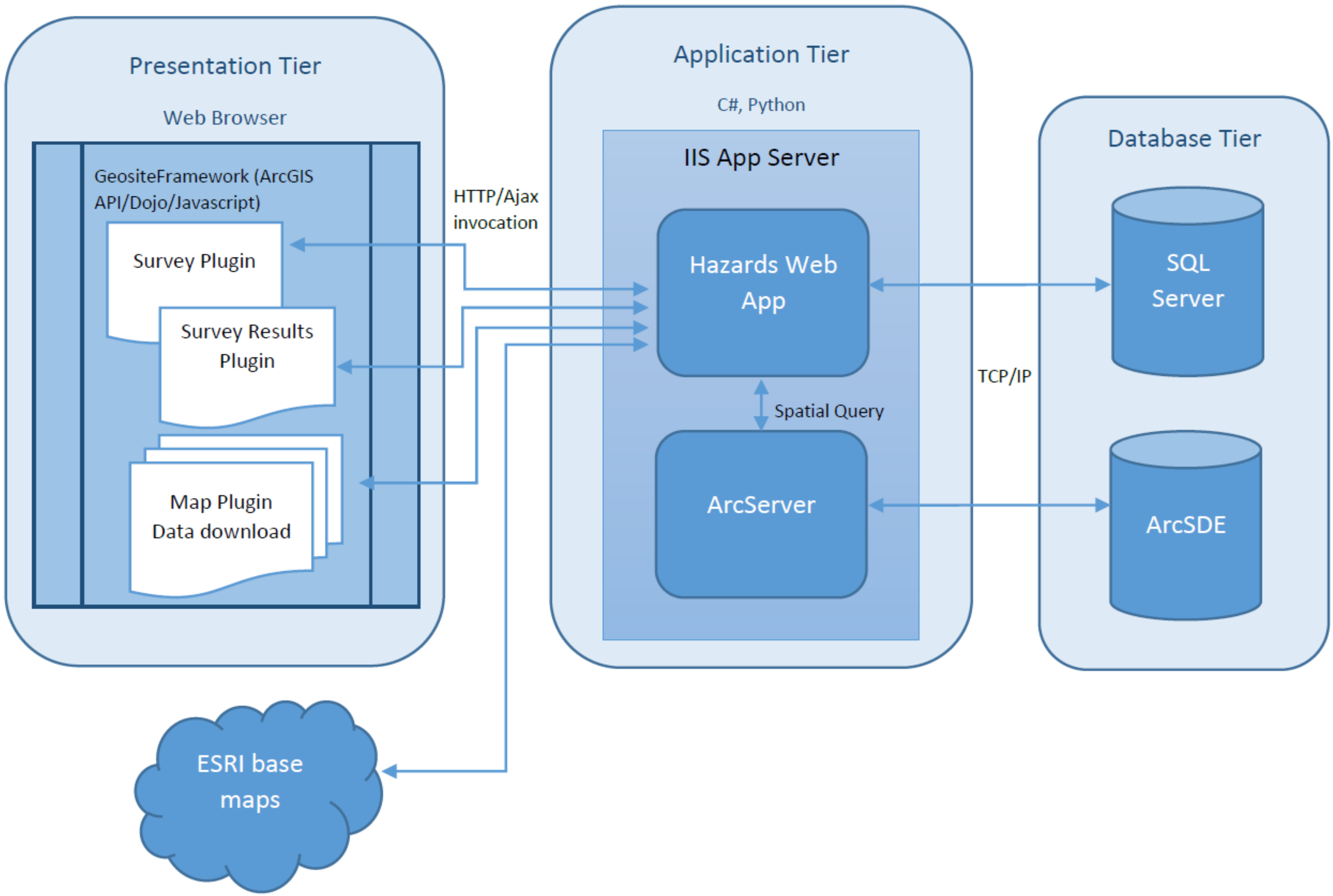

Figure 28: Architecture of the SDSS

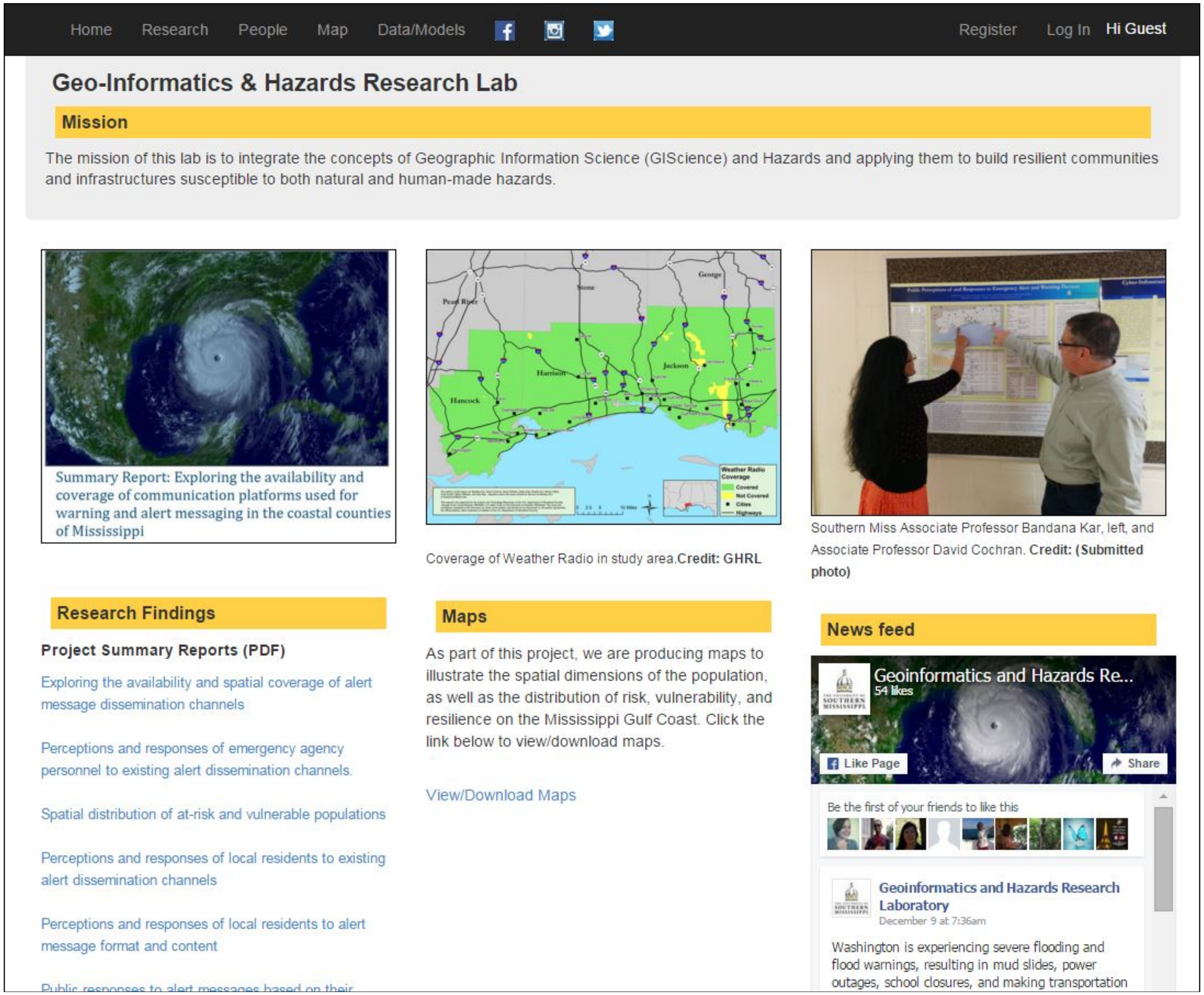

Figure 29: Homepage of the SDSS

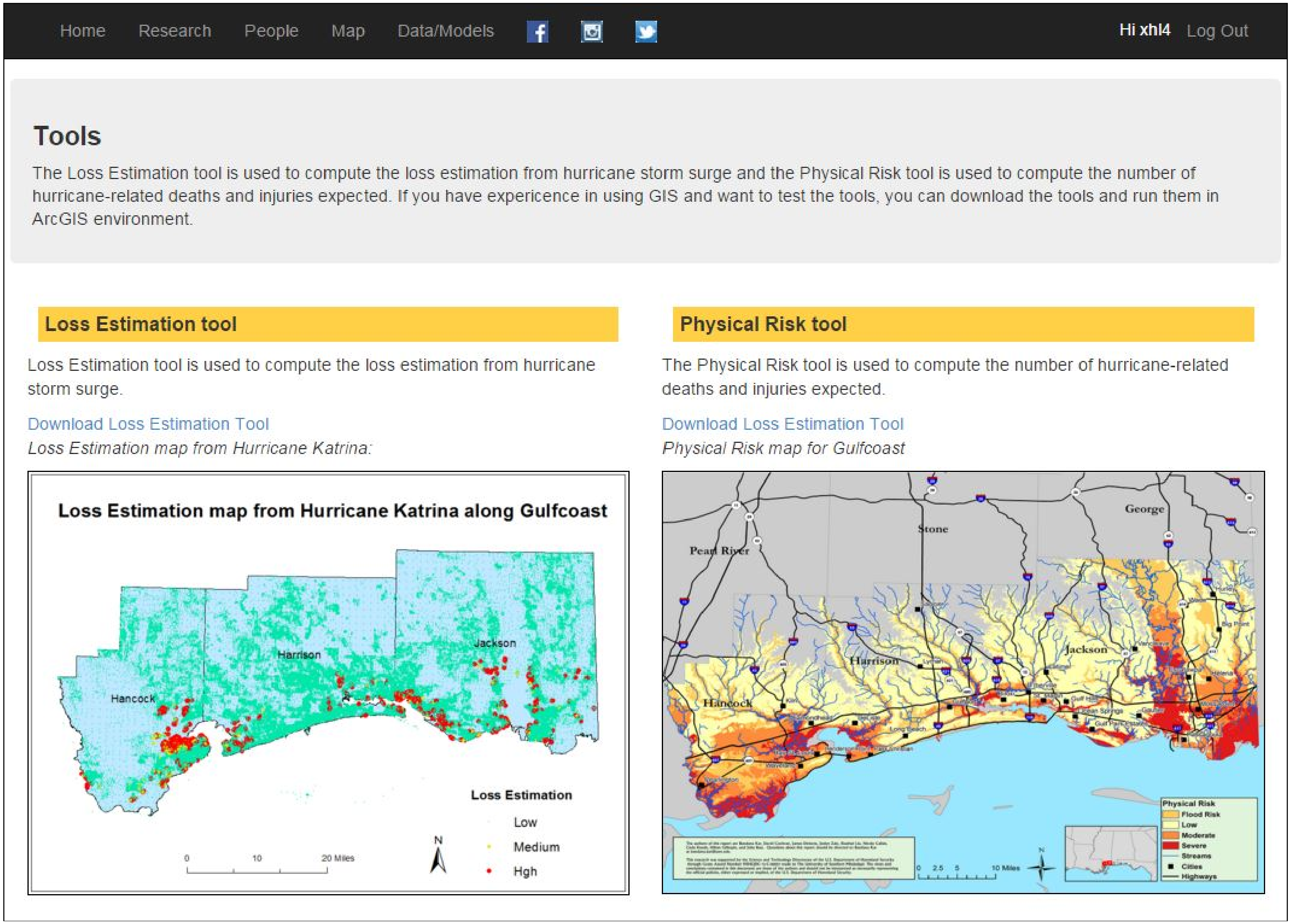

Figure 30: Data and Tools Download Portal

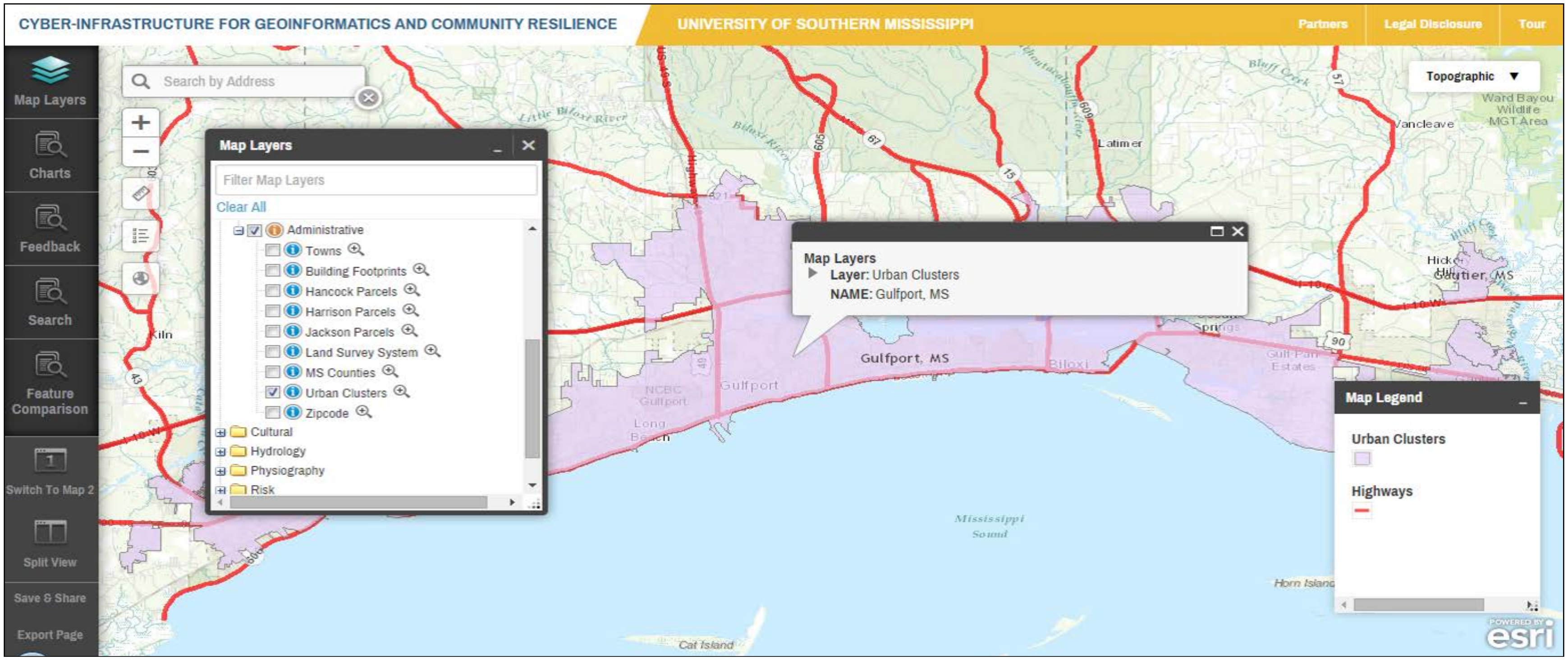

Figure 31: Science Gateway CIGIR – Citizen Participation/Spatial Data Visualization Portal

Appendix 1 – Agency Perceptions of Alert and Warning Devices

Question 1. Name of your government agency or nongovernmental organization:

Question 2. Please provide the office location of your agency/organization:

City _______________________ State _________________________ Zip-code ____________________________

Question 3. Identify how often the following alert and warning devices/channels are used by your agency/organization during a tropical cyclone:

Alert and Warning Device/Channel	Frequency of Use by your Agency/Organization					
	Not Used	Never	Rarely	Sometimes	Often	Always
TV (Weather Channel)	❍	❍	❍	❍	❍	❍
Radio/Weather Radio	❍	❍	❍	❍	❍	❍
Siren	❍	❍	❍	❍	❍	❍
Cell Phone/WEA Messages	❍	❍	❍	❍	❍	❍
Reverse 911	❍	❍	❍	❍	❍	❍
Social Media (Facebook, Twitter)	❍	❍	❍	❍	❍	❍
Pictures/Posters	❍	❍	❍	❍	❍	❍
Face-To-Face Visit (Local Police, County Sheriff's Office)	❍	❍	❍	❍	❍	❍

Question 4. Use your opinion and experience to rate each of the following warning devices/channels that your agency/organization uses in terms of frequency of message delivery and message update.

Alert and Warning Device/Channel	How frequently is the message content updated?							How frequently is the same message delivered?					
	Not Used	**Not Frequent**	**Somewhat Not Frequent**	**Moderately Frequent**	**Somewhat Frequent**	**Very Frequent**		**Not Used**	**Not Frequent**	**Somewhat Not Frequent**	**Moderately Frequent**	**Somewhat Frequent**	**Very Frequent**
TV (Weather Channel)	❍	❍	❍	❍	❍	❍		❍	❍	❍	❍	❍	❍
Radio/Weather Radio	❍	❍	❍	❍	❍	❍		❍	❍	❍	❍	❍	❍
Siren	❍	❍	❍	❍	❍	❍		❍	❍	❍	❍	❍	❍
Cell Phone/ WEA Message	❍	❍	❍	❍	❍	❍		❍	❍	❍	❍	❍	❍
Social Media (Facebook, Twitter)	❍	❍	❍	❍	❍	❍		❍	❍	❍	❍	❍	❍
Pictures/Posters	❍	❍	❍	❍	❍	❍		❍	❍	❍	❍	❍	❍
Face-To-Face Visit (Local Police, County Sheriff's Office)	❍	❍	❍	❍	❍	❍		❍	❍	❍	❍	❍	❍

Question 5. We use the following languages to send alert and warning messages to the public (select all that apply):

- ❑ English
- ❑ Spanish
- ❑ French
- ❑ Vietnamese
- ❑ Portuguese
- ❑ Chinese
- ❑ Korean
- ❑ Others - Please Specify:

Question 6. Use your opinion and experience to rate each alert and warning device/channel in terms of message accuracy and ease/difficulty of its use:

Type of Alert and Warning Device	How accurate is the message disseminated?						How easy is the device/channel to use?					
	Not Used	**Very Low**	**Low**	**Neither High Nor Low**	**High**	**Very High**	**Not Used**	**Very Difficult**	**Difficult**	**Neither Easy Nor Difficult**	**Easy**	**Very Easy**
TV (Weather Channel)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Radio/Weather Radio	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Siren	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Cell Phone/WEA Message	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Reverse 911	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Social Media (Facebook, Twitter)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Pictures/Posters	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍
Face-To-Face Visit (Local Police, County Sheriff's Office)	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍	❍

Question 7. Which of the following social media sites do you use?

- ○ Facebook
- ○ Twitter
- ○ MySpace
- ○ LinkedIn
- ○ Instagram
- ○ Others (Please Specify): ______________________________

Question 8. Use your opinion and experience to rate each alert and warning device in terms of its effectiveness during power outage, and in motivating public to take action in response to alert and warning messages situations (NA = Device is not used; 1 = Very Ineffective; 2 = Ineffective; 3 Neither Effective Nor Ineffective; 4 = Effective; 5 = Very Effective).

Alert and Warning Device/Channel	How effective is each device/channel during power outages?							How effective is each device/channel in motivating people to take action?					
	NA	**1**	**2**	**3**	**4**	**5**		**NA**	**1**	**2**	**3**	**4**	**5**
TV (Weather Channel)	❍	❍	❍	❍	❍	❍		❍	❍	❍	❍	❍	❍
Radio/Weather Radio	❍	❍	❍	❍	❍	❍		❍	❍	❍	❍	❍	❍
Siren	❍	❍	❍	❍	❍	❍		❍	❍	❍	❍	❍	❍
Cell Phone/WEA Message	❍	❍	❍	❍	❍	❍		❍	❍	❍	❍	❍	❍
Reverse 911	❍	❍	❍	❍	❍	❍		❍	❍	❍	❍	❍	❍
Social Media (Facebook, Twitter)	❍	❍	❍	❍	❍	❍		❍	❍	❍	❍	❍	❍
Pictures/Posters	❍	❍	❍	❍	❍	❍		❍	❍	❍	❍	❍	❍
Face-To-Face Visit (Local Police, County Sheriff's Office)	❍	❍	❍	❍	❍	❍		❍	❍	❍	❍	❍	❍

Question 9. In your opinion, how frequently do residents in your community use the following alert and warning devices/channels during tropical cyclones?

Alert and Warning Device/Channel	Not Used	Never	Rarely	Sometimes	Often	Always
TV (Weather Channel)	❍	❍	❍	❍	❍	❍
Radio/Weather Radio	❍	❍	❍	❍	❍	❍
Siren	❍	❍	❍	❍	❍	❍
Cell Phone/WEA Message	❍	❍	❍	❍	❍	❍
Reverse 911	❍	❍	❍	❍	❍	❍
Social Media (Facebook, Twitter)	❍	❍	❍	❍	❍	❍
Pictures/Posters	❍	❍	❍	❍	❍	❍
Face-To-Face Visit (Local Police, County Sheriff's Office)	❍	❍	❍	❍	❍	❍

Question 10. In your opinion, how much trust do local residents have in the following alert and warning devices/channels?

Type of Alert and Warning Device	Not Applicable	Very Low	Low	Neither High Nor Low	High	Very High
TV (Weather Channel)	❍	❍	❍	❍	❍	❍
Radio/Weather Radio	❍	❍	❍	❍	❍	❍
Siren	❍	❍	❍	❍	❍	❍
Cell Phone/WEA Message	❍	❍	❍	❍	❍	❍
Reverse 911	❍	❍	❍	❍	❍	❍
Social Media (Facebook, Twitter)	❍	❍	❍	❍	❍	❍
Pictures/Posters	❍	❍	❍	❍	❍	❍
Face-To-Face Visit (Local Police, County Sheriff's Office)	❍	❍	❍	❍	❍	❍

Question 11. In your opinion, how do you rate the following alert and warning devices based on their overall performance (trust, accuracy and timeliness of message content and frequency of message delivery)?

Type of Alert and Warning Device	Not Used	Very Low	Low	Neither High Nor Low	High	Very High
TV (Weather Channel)	❍	❍	❍	❍	❍	❍
Radio/Weather Radio	❍	❍	❍	❍	❍	❍
Siren	❍	❍	❍	❍	❍	❍
Cell Phone/WEA Message	❍	❍	❍	❍	❍	❍
Reverse 911	❍	❍	❍	❍	❍	❍
Social Media (Facebook, Twitter)	❍	❍	❍	❍	❍	❍
Pictures/Posters	❍	❍	❍	❍	❍	❍
Face-To-Face Visit (Local Police, County Sheriff's Office)	❍	❍	❍	❍	❍	❍

Appendix 2 – Household Perceptions of Alert and Warning Devices

Question 1. Please provide the following information about your place of residence:

City ________________________ State _________________________ Zip-code (e.g., 39503) ____________________________

Question 2. Please specify your age group, gender, and ethnicity.

Your age group in years is:						Your gender is:		Your ethnicity is:						
18-25	26-35	36-45	46-55	56-65	66+	Male	Female	Caucasian/White	African-American	Native-American	Pacific Islander	Hispanic	Asian	Others
O	O	O	O	O	O	O	O	O	O	O	O	O	O	O

Question 3. Please identify the language(s) in which you would like to receive alert and warning messages:

- O English
- O Spanish
- O French
- O Vietnamese
- O Portuguese
- O Korean
- O Other (Please specify):________________________

Question 4. What is the highest level of education that you have achieved?

Less than 9th Grade	9th – 12th Grade, NO diploma	High School Graduate (includes alternate route such as GED)	Some College (Junior/Community College or University, but NO degree)	Associate's Degree or Technical Degree (2 Year)	Bachelor's Degree (4 Year)	Master's Degree	Professional/ Doctoral Degree (Ph.D., E.D., M.D. or J.D.)
O	O	O	O	O	O	O	O

Question 5. You are:

- Student
- Employed (Full Time)
- Employed (Part Time)
- Unemployed (Out of Work and Looking for Work)
- Homemaker
- Retired (and do not work)
- Retired but still work (either full or part time)
- Other (Please specify):___________________________________

Question 6. What is your household income?

- Less than $10,000
- $10,000 to $14,999
- $15,000 to $24,999
- $25,000 to $34,999
- $35,000 to $49,999
- $50,000 to $74,999
- $75,000 to $99,999
- $100,000 and Over

Emergency management agencies (EMA) disseminate WEA (Wireless Emergency Alerts) messages to residents on their smart phones about impending disasters (tropical cyclones, tornados, oil spills, etc.). WEA messages appear in a format similar to text messages. Reverse 911 is a service used by EMA to send alert messages to residents on their home phones and cell phones.

Question 7. Have you registered your phone number(s) (cell phone and/or land line) for Reverse 911?

- Yes
- No

Question 8. Which of the following social media sites do you use?

- I don't use social media
- Facebook
- Twitter
- MySpace
- LinkedIn
- Instagram
- Others (Please Specify): ____

Question 9. Please respond to the following statements based on your past experience with tropical cyclones and your current knowledge of public alert and warning messages.	Yes	No
I have experienced a tropical cyclone before.	O	O
I am at risk from future tropical cyclones.	O	O
I think I am well prepared to deal with future tropical cyclones.	O	O
I think we have a good warning system to alert us in case of a tropical cyclone.	O	O
During a tropical cyclone, I will use social media to warn my friends and family.	O	O
During a tropical cyclone, I would like to receive messages via social media from emergency management agencies.	O	O

Question 10. To the best of your ability, please rate the following devices that are used by your county emergency management agency to deliver alert and warning messages in the event of a tropical cyclone.

Alert and Warning Devices/Channels	How accurate is the message provided by the device?							How much do you trust the warning message received from the device?					
	Not Used	**Very Low**	**Low**	**Neither High Nor Low**	**High**	**Very High**		**Not Used**	**Very Low**	**Low**	**Neither High Nor Low**	**High**	**Very High**
TV (Weather Channel)													
Radio/Weather Radio													
Siren													
Cell Phones/WEA Message													
Reverse 911													
Social Media (Facebook, Twitter)													
Pictures/Posters													
Face-To-Face Visit (Local Police, County Sheriff's Office)													
Family/Friends													

Question 11. To the best of your ability, please respond to the following statements about the following devices that are used by your county emergency management agency to deliver alert and warning messages in the event of a tropical cyclone.

Alert and Warning Devices/Channels	I always receive warning messages from this device.						I will evacuate if I receive an evacuation message from this device.					
	Not Used	**Never**	**Rarely**	**Sometimes**	**Often**	**Always**	**Not Used**	**Very Ineffective**	**Ineffective**	**Neither Effective Nor Ineffective**	**Effective**	**Very Effective**
TV (Weather Channel)												
Radio/Weather Radio												
Siren												
Cell Phones/WEA Message												
Reverse 911												
Social Media (Facebook, Twitter)												
Pictures/Posters												
Face-To-Face Visit (Local Police, County Sheriff's Office)												
Family/Friends												

Question 12. To the best of your ability, please rate each device in terms of how frequently is the same message received.

Alert and Warning Devices/Channels	Not Used	Not Frequent	Somewhat Not Frequent	Moderately Frequent	Somewhat Frequent	Very Frequent
TV (Weather Channel)						
Radio/Weather Radio						
Siren						
Cell Phones/WEA Message						
Reverse 911						
Social Media (Facebook, Twitter)						
Pictures/Posters						
Face-To-Face Visit (Local Police, County Sheriff's Office)						
Family/Friends						

Question 13. To the best of your ability, please rate each device in terms of its effectiveness during power outage and based on its overall performance (trust, accuracy of message and in motivating to evacuate):

Alert and Warning Devices/Channels	How effective is each device during power outages?							What is the overall performance of each device?					
	Not Used	**Very Ineffective**	**Ineffective**	**Neither Effective Nor Ineffective**	**Effective**	**Very Effective**		**Not Used**	**Very Low**	**Low**	**Neither High Nor Low**	**High**	**Very High**
TV (Weather Channel)													
Radio/Weather Radio													
Siren													
Cell Phones/WEA Message													
Reverse 911													
Social Media (Facebook, Twitter)													
Pictures/Posters													
Face-To-Face Visit (Local Police, County Sheriff's Office)													
Family/Friends													

Question 14. In your opinion, which factors influence people's decisions to ignore official recommendations to evacuate during tropical cyclones? Select all that apply:

❑ Age ❑ Gender ❑ Ethnicity/Race ❑ Language ❑ Income ❑ Having Dependents (for example, children or elderly relatives)	❑ Chronic Illness ❑ Home Ownership ❑ Not Owning an Automobile ❑ Pets ❑ Prior Experience with Disasters ❑ Other (please specify):_______________________________

Appendix 3 – Household Perceptions of Alert and Warning Messages

1. Please answer the following questions about where you live:

County: _______ Hancock _______ Harrison _______ Jackson

City: _______________________ **Zip-code (e.g., 39503):** _______________________

2. What is your ethnicity?						
White (Not Hispanic)	African-American	Native-American	Pacific Islander	Hispanic	Asian	Other (Specify):
○	○	○	○	○	○	

3. What is your gender? _______ Male _______ Female

4. What is your age? _______ Years Old

5. What is your marital status?					
Single, Never Married	Married	Cohabitating	Divorced	Separated	Widowed
○	○	○	○	○	○

	6. You are fluent in the following language(s) [Check All That Apply]:
English	○
Spanish	○
Vietnamese	○
Chinese	○
Other (Specify):	

7. What is the highest level of education that you have achieved?

Less than 9th							
○	○	○	○	○	○	○	○

8. What is your employment status (check all that apply)?

________ Student
________ Employed (Full Time)
________ Employed (Part Time)
________ Unemployed (Out of Work and Looking for Work)
________ Homemaker
________ Retired (And Do Not Work)
________ Retired but still work (Either Full or Part Time)
________ Other (Please Specify):________________________________

9. What is your household income?

________ Less than $10,000

________ $10,000 to $14,999
________ $15,000 to $24,999
________ $25,000 to $34,999
________ $35,000 to $49,999
________ $50,000 to $74,999
________ $75,000 to $99,999
________ $100,000 and over

10. Do you own a smart phone (for example, iPhone, Android or Blackberry)?

________ Yes ________ No

Emergency management agencies (EMA) disseminate WEA (Wireless Emergency Alerts) messages to residents on their smart phones about impending disasters (tropical cyclones, tornados, oil spills, etc.). WEA messages appear in a format similar to text messages.

11. Please respond to the following questions about WEA messaging and Reverse 911.

Did you know about WEA messages prior to this survey?	O	O
Have you received a WEA message on your smart phone?	O	O

12. By law, WEA messages can't be more than 90 characters in length. What is your opinion on this maximum length requirement for WEA messages? [Note: 90 characters is approximately one line of text]

________ 90 characters is too short for a warning message

________ 90 characters is just right for a warning message

________ 90 characters is too long for a warning message

13. In your opinion, which of the following should be included in a WEA message? Please rank your choices in the order you think the information should appear in the message (1 = Most Important, 8 = Least Important).

________ Nature of the disaster

________ Impact zone of the disaster

________ Time frame and duration of the disaster

________ Recommended actions (for example: evacuate or take shelter in place)

________ Nearby shelter locations

________ Evacuation routes

________ When to take action

________ Who to contact for further information

14. Please answer the following questions about WEA message content:	**YES**	**NO**
Should WEA messages include maps showing the impact zone of the disaster?	○	○
Should WEA messages include maps showing evacuation routes?	○	○
Should WEA messages include maps showing the locations of nearby shelters and hospitals?	○	○
Do you receive WEA messages in a language other than English?	○	○
Would you like to receive WEA messages in a language other than English?	○	○

15. Do you use Facebook or Twitter?

________ Yes ________ No [If you answer "No" to this question, go to Question 17]

16. If you chose "Yes" for Question 15, please answer the following		
Do you use Facebook to receive alert messages during a disaster?	○	○
Do you use Twitter to receive alert messages during a disaster?	○	○
Do you use Facebook to contact family and friends about disasters?	○	○
Do you use Twitter to contact family and friends about disasters?	○	○
Do you use Facebook as a platform to share disaster-related information (for example, images and address information about impacted areas)?	○	○

Do you use Twitter as a platform to share disaster-related information (for example, images and address information about impacted areas)?	O	O
Would you like your local emergency management agency to use Facebook to deliver alert messages during disasters?	O	O
Would you like your local emergency management agency to use Twitter to deliver alert messages during disasters?	O	O

17. Please indicate your opinion of the following					
I always trust alert messages I receive from local emergency management agencies (city or county).	O	O	O	O	O
I always trust alert messages about severe weather events (such as tropical cyclones or tornados) if I receive them from the National Weather Service.	O	O	O	O	O
If I receive an evacuation notice, I will follow it.	O	O	O	O	O
I will follow an evacuation notice only if I receive it from my local emergency management agency (city or county).	O	O	O	O	O
I will follow an evacuation notice only if my family and friends are evacuating as well.	O	O	O	O	O
I will follow an evacuation notice only if I believe that I am in danger.	O	O	O	O	O
I would like to help local emergency management agencies disseminate information and messages about disasters.	O	O	O	O	O
I would take action during a disaster if I participated in alert message dissemination.	O	O	O	O	O
I would be more prepared for a disaster if I participated in alert message dissemination.	O	O	O	O	O

I would believe alert messages more if I was involved in their dissemination.	o	o	o	o	o

18. I have helped local emergency management agencies disseminate information about disasters.

________ Yes ________ No

19. Have you ever disregarded the instructions of an alert message during a disaster?

________ Yes ________ No

20. If you answered YES to Question 19, what was your reason for disregarding the message? Select all that apply:

________ Message content or instructions were unclear

________ Message content was too short or incomplete

________ Message content was inaccurate

________ Message content was not up-to-date

________ Message content was not delivered in time for me to take action

________ Message content contradicted information from local media