Communicating Coastal Hazards and Oceanic Conditions in San Juan, Puerto Rico

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Executive Summary

As an island on the edge of two tectonic plates and in a hurricane prone region, Puerto Rico is in danger of experiencing coastal hazards. Unfortunately, Puerto Rico does not have a well-organized system for communicating information about these coastal hazards and oceanic conditions. There are many factors to consider when creating a communication system, taking into account the opinions of local communities and stakeholders on their preferred method for receiving coastal information. The Caribbean Coastal Observing System (CariCOOS) is one resource used in Puerto Rico to provide coastal information; however, CariCOOS needs a comprehensive and accessible warning system for communicating coastal hazards and oceanic conditions.

The goal of this project was to propose recommendations to CariCOOS for an efficient and effective warning system for communicating coastal and oceanic hazards in San Juan, Puerto Rico. To achieve this goal, we developed three project objectives. Our first objective was to identify the impacts of coastal hazards and adverse oceanic conditions in Puerto Rico. We accomplished this objective by surveying people who frequent the coast, including fishermen, surfers, beach goers, boaters, tourists and residents who live and work along the coast. Our second objective was to identify the advantages and disadvantages of current coastal communication systems in San Juan and to identify improvements to these systems. To pursue this objective, we interviewed experts at Sea Grant, the National Weather Service, and the Puerto Rico Seismic Network. We also used the survey mentioned above to gather the general population’s perspective on the current warning systems. The third and final objective of our project was to define an improved method for the communication of coastal hazards in Puerto Rico. A major component of this task was to identify effective and time efficient communication

channels to report the coastal hazard information. The survey helped us determine which communication techniques would reach the largest number of affected residents in a timely manner.

From speaking to experts and surveying the general public, we concluded that there are many problems hindering the current coastal hazard communication system from being effective. There is a lack of interconnectivity and communication between agencies, specifically the present system lacks a cohesive method for informing the public. Furthermore, people located in the coastal zone do not know where to obtain vital information, nor are they familiar with the already existing products that are available to them.

Perhaps most importantly, our research concluded that there is a large gap between the knowledge of and the preparedness for coastal hazards and oceanic conditions in Puerto Rico. The preferred method for receiving coastal information of both the general population and businesses would be a warning siren followed by an announcement. However, based on the survey, other methods such as using cell phones or the Internet would also be effective for informing large amounts of people.

Our research determined that CariCOOS should use local media broadcasts to increase public awareness of the organization's products. Specifically, it should better utilize Facebook to increase its visibility among the general population, develop a smartphone application for people to check and receive daily coastal information, and use mailing list serves and text messaging signups to allow people to constantly receive coastal information. These measures would significantly enhance the education of the general population, particularly the younger population. We have also determined that in order to improve CariCOOS's warning system, CariCOOS should distribute more effective signs along the beach and implement a regularly updated beach flag system to warn beach goers against dangerous oceanic conditions, as well as promote the use of thirteen 15V2T warning sirens along the San Juan coastline for the occurrence of tsunamis.

Abstract

The coastal regions of Puerto Rico do not have sufficient communication systems in place to warn the public about potential coastal hazards or threatening oceanic conditions. There present systems provide information to the public; however, they have proven to be coarse and unhelpful. The goal of our project is to provide recommendations to the Caribbean Coastal Observing System (CariCOOS) for an efficient and effective warning system that can be deployed to inform the Metropolitan San Juan area.

Authorship Page

Ruth McNab, Daniel Mullen, Mohamed Yatim, and Kristine Zeeb all contributed to the research of writing of this report. The following is a breakdown of how the report was written for this project.

Ruth McNab contributed to the background section entitled 'Coastal Hazards of Puerto Rico', both results and analysis sections entitled 'Survey of Business Owners', and the recommendations chapter. Ms. McNab also collaborated on the executive summary with Mr. Mullen and Mr. Yatim.

Daniel Mullen collaborated with Ms. McNab and Mr. Yatim on the executive summary and methodology chapter and Mr. Zeeb on the results and analysis section entitled 'Analysis of the Most Effective Form of Media'. Mr. Mullen also contributed to the background sections entitled 'Disaster Management Strategies' and 'Coastal Management Agencies of Puerto Rico'.

Mohamed Yatim contributed to the background sections entitled 'Coastal Warning Systems' and 'Current Coastal Warning System in Puerto Rico' and collaborated with Ms. McNab and Mr. Mullen on the executive summary and methodology chapter and Ms. McNab on the results and analysis section entitled 'Analysis of Strengths and Weaknesses within the Current Communication System'.

Kristine Zeeb contributed to the introduction, the background sections entitled 'Coastal Hazards' and 'Disaster Management Strategies', the objective, and the results and analysis section entitled 'Impacts of Coastal Hazards and Oceanic Conditions in Puerto Rico'. Ms. Zeeb also collaborated with Mr. Mullen on the results and analysis section entitled 'Analysis of the Most Effective Form of Media' and contributed to the conclusion chapter.

In addition to writing individual sections of this report, as a group Ruth McNab, Daniel Mullen, Mohamed Yatim, and Kristine Zeeb established the project goal and objectives, determined conclusions and recommendations, and edited the report.

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1. Introduction

Coastal hazards and ocean conditions affect millions of people each year. The U.S. Department of Commerce and National Oceanic and Atmospheric Administration estimated that in 2003, up to 153 million people lived in a coastal region in the United States, and that by 2015 this number should increase by 12 million (Crossett, Culliton, Wiley & Goodspeed, 2004). Worldwide, 40 percent of the population lives in a coastal zone, which places a large number of people at a high risk for coastal hazards (Levy, 2011). Coastal hazards vary in severity and can include coastal storms, tsunamis, flooding, and coastal erosion. Coastal storms encompass tropical storms and hurricanes as well as northeasters (NOAA, 2010). These storms cause beach erosion, flooding, and storm surges (FEMA, 2010b). Tsunamis are tidal waves caused by a shift in the Earth's tectonic plates that cause extensive damage to coastal infrastructure (NOAA, 2010). Coastal flooding usually occurs as a result of coastal storms and tsunamis, and the flooding can cause damage to homes, businesses, and beaches. Coastal erosion is the process by which coastlines are eroded away, which then places property on the coast at an even greater risk to hurricanes and tsunamis.

Since so many people are susceptible to coastal hazards, it is important to rapidly communicate warnings and other important safety information about these hazards to them. In Puerto Rico, the challenges of being an island community have brought about the need for changes in the communication strategies for coastal information. The island of Puerto Rico is extremely susceptible to coastal hazards such as hurricanes, coastal flooding, tsunamis and winter swells, and also to hazards that threaten the shore such as undertows, storm surges, floods, and water pollution. Unfortunately, in Puerto Rico there is not a well-organized system for communicating information about these coastal conditions. To improve this situation, there are many factors to consider, including the opinions of local community members, resource users, and other stakeholders on what information they need to receive. Today, Puerto Rico has the ability to provide coastal news using the Caribbean Coastal Observing System (CariCOOS) website, but CariCOOS needs a comprehensive warning system for all coastal hazards and oceanic conditions.

According to Basher (2006), coastal warning systems should be composed of four different phases: i) monitoring of precursors, ii) forecasting of a probable event, iii) the notification of an alert, and iv) an onset of emergency response activities once the warning has been issued. The system should be reliable and understandable to the community. Puerto Rico currently has systems in place to detect hurricanes and tsunamis. The system Sea, Land, and Overland Surges from Hurricanes (SLOSH) was developed for real-time forecasting of hurricane storm surges (Mercado, 1994), and it provides information in regards to evacuation procedures and the projected impacts (Allen, Sanchagrin, & Lee, 2010). Additionally, Simulating Waves Nearshore (SWAN) is the most widely used computer model to compute irregular waves on the coast and is being implemented in Puerto Rico (Digital Hydraulics, 2011b). The Puerto Rico Seismic Network (PRSN) and Puerto Rico Strong Motion Program (PRSMP) are joint programs monitored by the University of Puerto Rico at Mayagüez that provide information about earthquakes in the Caribbean region (Clinton, 2006).

There has been previous research conducted about warning systems for coastal hazards in other coastal regions (Mercado, 1994; Tatehata, 1997; Crawford, 2005; Basher, 2006; Clinton, 2006; de León et al., 2006; Becker, 2008; Hirschfield, 2010; Sorensen, 2000), but it appears no one has investigated a warning system that communicates both coastal hazards and oceanic conditions. It is important to understand the different coastal hazards and oceanic conditions of

Puerto Rico and how to best communicate information regarding imminent threats to the public. If these conditions are not transmitted effectively, there could be loss of life and property damage.

2. Background

Due to the often unpredictable nature of coastal hazards and oceanic conditions, there are certain challenges that exist in communicating these hazards to the public, most notably to local communities, resource users, and other stakeholders. This chapter will identify coastal hazards throughout the world, the most common types of coastal hazards in Puerto Rico, the agencies that deal with coastal hazards, the current hazard warning communication strategies in coastal areas around the world and in Puerto Rico, and the gaps in existing communication strategies that need to be addressed.

2.1 Coastal Hazards

With an increasing number of people moving to coastal regions, more and more individuals are making themselves susceptible to coastal hazards (NOAA, 2010). In 2003, it was estimated that 153 million people or 53 percent of the population of the United States lived in a coastal region (Crossett, Culliton, Wiley & Goodspeed, 2004). By 2015, this number is expected to increase by 12 million. Worldwide, 40 percent of the population lives in a coastal zone. Of this 40 percent, the majority live in a low elevation coastal zone of less than 10 meters above sea level, placing them at even greater vulnerability to coastal hazards (Levy, 2011). This section explains the different types of coastal hazards and their effects on the coastal zone.

2.1.1 Coastal Storms

Coastal storms encompass a wide variety of natural disasters including tropical storms, hurricanes, and northeasters (NOAA, 2010). Tropical storms and hurricanes are caused by changes in atmospheric pressure, wind, and warm water (Delaware Department of Natural Resources and Environmental Control, 2011). The ocean provides the storm with energy, causing the air in the center to rise and condense, resulting in a tropical depression. The tropical depression can then become a tropical storm, even a hurricane, if the right hydrodynamic conditions are met. When hurricanes reach land, they bring storm surges, tornadoes, high wind, rain, and flooding (FEMA, 2010b). In the Atlantic Ocean and Caribbean Sea, an average of ten tropical storms develops every year. On average, six of these storms become hurricanes; fortunately, most of the storms do not impact the United States. However, every three years approximately five hurricanes damage the United States coastline, causing millions of dollars of damage to homes, public buildings, and infrastructure. A northeaster is a storm caused by extremely high winds that occurs along the northeast coast of the United States (Delaware Department of Natural Resources and Environmental Control, 2011). Northeasters are extremely destructive and cause beach erosion and flooding due to the large water waves caused by the wind.

2.1.2 Occurrence of Tsunamis

Tsunamis are a series of tidal waves caused by the displacement of large amounts of water (NOAA, 2010). They are most commonly caused by earthquakes due to shifting of the tectonic plates, underwater landslides, or volcanic eruptions (NOAA, 2011d). These disruptions on the ocean floor create changes on the surface of the ocean, resulting in the propagation of elastic waves of varying amplitudes and directions. There is neither a tsunami season nor the occurrence of any regular propagation patterns. Tsunamis are capable of traveling across entire oceans. They are extremely dangerous and cause extensive damage to coastal areas (NOAA, 2010). The true danger of tsunamis was made apparent after an earthquake in the Indian Ocean caused multiple tsunamis on December 26, 2004. The tsunamis killed about 230,000 people and caused billions of dollars in property damage.

Most recently, a massive earthquake hit the northern part of Japan on March 11, 2011, showing just how timely the issue of communicating coastal hazards can be. The earthquake was eventually measured to be of magnitude 9.0 on the Richter scale, the largest earthquake Japan has ever experienced in its history (Plain 2011). Although the country was highly prepared for the earthquake, as they receive many earthquakes each year, they were not prepared for a tsunami of such a scale. Coastline villages were protected by seven meter high tsunami walls; however, these barriers proved insufficient to stop a 10 meter high tidal wave that reached the coast 30 minutes after the earthquake.

A study by Plain (2011) right after the earthquake made the following interesting observation:

> [The residents] were well prepared within 10 minutes of the earthquake it had been calculated that a tsunami had been formed and warnings were sent out. Text messages were sent to phones, alerts appeared on all TV channels, sirens went off and police alerted residents to the danger. However, people had become desensitized by so many false alarms and assumed tsunami walls could handle it, which meant that many did not evacuate.

2.1.3 Coastal Flooding

Flooding is a natural disaster that can be caused by coastal storms, tsunamis or heavy rainfall (NOAA, 2010). Floods either develop over a long period of time or in a few minutes, as is the case with flash flooding (FEMA, 2010a). Coastal flooding occurs when a low-pressure system off the shore drives water inland (New York City Office of Emergency Management, 2011). Coastal flooding is typically categorized into three levels – minor, moderate, or major – depending on the amount of water that rises above the normal tide level. A minor coastal flood will cause a small amount of beach erosion but should not produce any major structural damage, while a moderate coastal flood may cause damage to homes and businesses along the coast. A major coastal flood is a large threat to safety due to the extensive beach erosion and infrastructure damage. In the United States, flooding causes more damage than any other weather related disaster. Every year, over six billion dollars are spent on flood related damages despite the fact that millions are invested in infrastructure to protect against flooding (NOAA, 2010).

2.1.4 Coastal Erosion

Coastal erosion, the process by which beaches and coastlines are worn away, is caused by many natural factors and human activities (National Research Council (U.S.) Committee on Coastal Erosion Zone Management, 1990). The natural factors include the size and density of the sand, the direction and currents of the wind and ocean waves, and the rise and fall of sea levels. Human activities also accelerate the process of coastal erosion by creating harbors, jetties and dams. Coastal erosion causes both infrastructure and economic damage (NOAA, 2010). It is estimated that in the United States each year, 500 million dollars are lost in coastal property damage. Moreover, the United States government spends an average of 150 million dollars to control shoreline erosion. The main long-term concern with continued coastal erosion is that it places coastal infrastructure and property at even greater risk to hurricanes and tsunamis.

2.2 Coastal Warning Systems

According to Hirschfeld (2010), coastal communities throughout the United States have dealt with the devastating effects of coastal hazards for centuries; however, the threats presented today are greater due to three main factors. First, the population along the coastline is projected to continue to increase. Second, the possibility of a natural disaster was not taken into consideration in prior land use management decisions. Lastly, climate change will affect coastal areas even more as the severity of storms continues to increase. These factors, put together, have resulted in coastal communities facing a very dangerous situation.

Over the last decade nearly a million people have been killed by natural coastal disasters worldwide (de León, Bogardi, Dannenmann, & Basher, 2006). In many cases the loss of human lives could have been avoided if the proper precautions had been in place. For example, the Indian Ocean Tsunami of 2004 caused the death of over a quarter of a million people and resulted in 15 billion dollars worth of damage. These numbers could have been lower if proper precautions and measures had been in place. In Sri Lanka, thousands of people have lost their lives due to the lack of an efficient and effective tsunami early warning system. In retrospect, it was determined that there was sufficient time to warn these coastal populations. However, the lack of an early warning system and the lack of awareness to a warning inhibited the execution of proper measures. Many lives would have been saved if a proper coastal warning system had been in place.

The traditional framework of early warning systems (EWSs) is composed of four phases: monitoring of precursors, forecasting of an event, notification of an alert, and operation of emergency response activities once the warning is issued (Basher, 2006). An effective EWS requires practical foundations and good knowledge of the risks (de León et al., 2006; Wenzel, 1999). The EWS must also be strongly people centered, have clear messages, use broadcasting systems that reach those at risk, and provide knowledgeable responses from risk managers to the public. Public awareness and education are important; therefore, many sectors have to get involved. Effective EWS must be understandable and relevant to the communities which they serve.

2.2.1 United States Warning Systems

According to Sorensen (2000), the United States does not have a complete national warning strategy that covers all hazards in all parts of the country. The Emergency Alert System (EAS) is the main warning system used in the United States (Partnership for Public Warning, 2004). It allows the President to send messages during a national emergency, and it allows state and local officials to communicate pending hazards. All radio and television stations are required to install and maintain EAS equipment. National EAS alerts are issued through the Primary Entry Point (PEP) system to 34 locations that cover approximately 90% of the continental United States, Hawaii, Alaska and Puerto Rico. Financial support for developing state and local EAS plans has decreased over the years. There are three main obstacles that hinder the EAS from being a unified warning system. The PEP system cannot be monitored by all of the state EAS networks and national cable programs are not part of the national EAS network. Government support has dwindled since no government agency is in charge of the system. There also is not a government or industry effort that combines EAS and other alert strategies with new technologies, such as cell phones and the Internet.

Over the past 20 years, major advances have been made in warning system technology (Sorensen, 2000). The most common technologies used for public warnings are outdoor sirens, electronic media, and the alert system of officials with loudspeakers. The problems of outdoor sirens were that people either ignored them or did not understand the meaning of the different sounding signals. To solve this limitation, electronic sirens are now made with voice capabilities; they provide both an alert mechanism and a voice message. The major limitation of the electronic media in reaching the public with a warning message is that their effectiveness is highly variable depending on the time of day and who has access to such media. The alert system of officials with loudspeakers is constrained by the number of emergency personnel available to disseminate the warning in correlation to the size of the area to be warned.

Tone alert radio (TAR) is a common technology being used across the U.S. to provide a highly modified warning mechanism (Sorensen, 2000). This technology has been used by The National Weather Service for some time. Recent advances in battery design, self-diagnostic circuitry, and engineering make TAR technology a very reliable method of broadcasting warnings.

Evacuation is the most common recommendation for a protective action (Sorensen, 2000). However, research continues to document cases where evacuation is not the best action. For example, attempting to evacuate in a vehicle is a major cause of fatalities in flash floods. As a result, planning should consider an extended range of alternatives to evacuation. Alternatives to vehicle evacuation that are used in the U.S. include a vertical evacuation for floods and hurricanes and in-place sheltering for tornadoes and earthquakes; however, minimal research has been conducted on the responses to warnings to seek shelter.

2.2.2 StormSmart Coasts

StormSmart Coasts Education and Outreach (2011), implements general hazard awareness, hazard training for local officials, and sources for outreach materials. This program was designed to help local officials address the impacts of erosion, storms, floods, and sea level rise (Hirschfield, 2010). Since 2008, the Massachusetts StormSmart Coasts program has been working on five projects and two of these projects have shown great success.

One StormSmart project looks at the town of Hull, a highly developed community that extends to the Boston Harbor (Hirschfield, 2010). Over half the town is in a FEMA designated flood zone; therefore, a tool was developed to visualize the impacts of sea level rise. Applied Science Associates, a global science and technology solutions company, helped create these images in order to compare flooding under different sea level rise scenarios. This tool has aided the communication between the town's conservation agent, local officials, and the facility's managers about the variety of risks that the town may face in the near future. Over time, this innovation could lead to more homes being built outside the flood zone and with the competence to withstand rising seas. The town of Hull plans to improve this imaging technology in order to adapt to these fluctuations in sea levels.

The second project looks at the community of Oak Bluffs, located on the island of Martha's Vineyard, where regulatory update of coastal flooding was the focus (Hirschfield, 2010). Although the town currently experiences minor flooding during coastal storms, the town had not fully updated its floodplain overlay district since 1976. Updating the floodplain overlay would help to address the issue of flooding. Regulatory changes have been introduced and the town of Oak Bluffs will begin to limit the amount of development in the floodplain. By preventing development on these areas, this community will protect itself from rising seas as these uninhabited areas will act as receiving areas for flood waters.

In looking at these two projects, one can see that each has been a success in its own right (Hirschfield, 2010). In the case of Hull, the images are an improved method for understanding and visualizing coastal flooding in the area. This improvement led to a creation of a program that will educate the citizens about this coastal hazard and possibly create more flood proof homes. Oak Bluff's success has resulted in the amended regulatory language, which is an enhancement of the outdated language, and will start to limit development in areas known to be hazardous to the town's citizens.

2.2.3 All Hazard Alert Broadcasting

The state of Washington is situated in the northwestern corner of the United States in the region known as the Pacific Northwest (Becker, 2008). Due to its geographic location, this state is vulnerable to earthquakes, up to level 9 on the Richter scale, resulting from shifts in tectonic plates. The dangers of tsunamis are also present due to the risk of earthquakes. Deaths from future tsunamis could be minimized if people understood the consequences of the ground shaking, and if they responded immediately after the earthquake by moving inland or to higher ground.

NOAA Weather Radio "All-Hazards" Warning System was implemented in Washington to warn about tsunamis and other natural disasters (Crawford, 2005; Titov, 2009). To communicate these warnings, the All Hazard Alert Broadcasting (AHAB) radio was developed and installed in Ocean Shores, Washington. This radio is economical, reliable, sturdy, and can broadcast messages in remote coastal communities. If data indicate a tsunami or natural disaster, a warning is issued to the National Weather Service, and local officials will then relay the message to the AHAB radio. Public education programs were also developed to improve the understanding of what actions should be taken if a natural disaster should occur.

The state of Washington developed the NOAA Weather Radio Emergency Information Network to provide state and local officials with the means to effectively address any hazardous situation (Crawford, 2005; Titov, 2009). NOAA Weather Radio is located in facilities, hotels, motels, businesses, and homes that are more prone to these situations. The Washington State Emergency Management Division (EMD) and Federal Signal wanted to increase the effectiveness of this communication network, so they designed and developed a system that provides both tone and voice alert capabilities for state and local emergency management authorities to use in any hazardous situation. The AHAB Radio System can be activated via NOAA Weather Radio (NWR), local emergency management activation of the Emergency Alert System, or other communication protocols, such as a public safety response vehicle. It also can be placed in high traffic areas where no electrical power is available. The system uses voice and tone alerting and has a distinct blue strobe light, which provides a visual warning for areas of high ambient noise and for the hearing-impaired. This radio system minimizes any incorrect delivery of alerts to the public by broadcasting watch and warning information directly from the source. Notifications of an approaching tsunami are quickly sent to residents and visitors, warning them to take immediate action such as heading inland or to higher ground. Since 2002, an AHAB Radio System has been installed by the State Earthquake Program in communities that are prone to tsunami, volcanoes and other hazards. This joint effort between EMD and Federal Signal is a classic example of the power of public and private partnerships (PPPs) to meet the alert and notification requirements for any hazard.

The key component of the Washington State Tsunami Program is the diversified State and Local Tsunami Work Group, which composed of representatives from coastal communities and state and federal agencies (Crawford, 2005; Titov, 2009). This unique group meets quarterly and invites people from various authorities to discuss tsunami issues and possible plans. The process of all these programs working together resulted in the communities gaining trust in the program and has led to rapid implementation of mitigation and preparedness tools.

2.2.4 Japanese Meteorological Agency

Japan is situated in a region where the Pacific and Philippine Sea plates are in tension with the Eurasian plate (Doi, 2002). This causes stress and strain on the earth's crust, resulting in many earthquakes and tsunamis. The Japanese Meteorological Agency (JMA) has been involved in tsunami forecasting for Japan since 1941 (Tatehata, 1997). The tsunamis that occurred in 1983 and 1993 resulted in the loss of many lives. This increased the desire for a more rapid and accurate forecasting system. The new tsunami warning system is composed of three components: a new seismographic network containing P-wave magnitudes, rapid numerical tsunami modeling, and a satellite-based dissemination system.

P-wave stands either for primary wave, as it is the wave with the highest phase velocity, or pressure waves, as it is formed from compressions and refractions (Dahlen 1974). This is a type of elastic wave, also called seismic wave, which has the ability to travel through solids, liquids, and gases. P-waves are generated by earthquakes and recorded by seismographs. Seismologists can then analyze the data in terms of arrival time and severity of the wavefronts. Since the P-wave is the fastest traveling seismic wave and rarely causes major damage, it often permits an early warning before the slower travelling and more destructive shear wave arrives (Ventura, 2010).

To minimize the dangers from these tsunami disasters, JMA has continued to improve this forecasting system. For rapid broadcasting, a Satellite-Based Emergency Information Multi-Destination Dissemination System has been installed. This system is expected to be upgraded as technology advances.

2.2.5 Pacific Risk Management ‘Ohana

The Pacific Risk Management ‘Ohana (PRiMO) is a group of local and national agencies whose goal is to increase community resilience in the Pacific through risk management education and services (NOAA Pacific Services Center, 2011). PRiMO was created due to the Federal Hazard Mitigation Partners in the Pacific Islands (FHMPPI) Roundtables that created hazard specific organization frameworks for seismic, volcanic and tsunami hazards, climate and weather hazards, and human induced hazard risks. The Roundtables confirmed the need for a partnership among coastal management agencies, thus PRiMO held its first meeting on March 15- 17, 2005. PRiMO is made up of *huis*, working groups, that relay information to stakeholders and policy makers and is governed by a Council of Navigators. Currently, PRiMO has seven focus areas: Risk Reduction and Post Disaster Evaluation, Communications, Education and Outreach, Traditional Knowledge and Practices, Data Analysis and Decision Support Tools, Data Management and Observations, and Training. Every year, PRiMO holds a meeting to discuss coastal hazards, coastal management, and gaps in existing resilience programs. Since 2005, there has been an increase in participation from jurisdictions around the Pacific.

2.3 Disaster Management Strategies

In order to have an effective warning system, there needs to be effective communication between the agency issuing the warning and the residents receiving the warning. This section looks at what aspects make disaster communication strategies both effective and ineffective in general and the factors that affect a person's response to the communication strategy.

2.3.1 Effective Disaster Management Strategies

The purpose of communicating hazard warnings is to enable people and communities to appropriately respond to disasters in order to reduce the amount of damage to property and loss of life (Convenors of the International Expert Groups on Early Warnings of the Secretariat of the International Decade for Natural Disaster Reduction, 1997). For clear communication of hazard warnings to occur, several groups need to be involved and held responsible. Members of communities that are at risk to natural disasters should be informed and aware of the potential threats, as well as the steps that should be taken should a hazard occur. Governments should issue warnings in a timely manner and confirm that the warnings reach the most vulnerable communities. Regional organizations should provide assistance to national risk efforts as well as aid in transmitting early warnings to nearby countries, while international agencies should share knowledge among themselves in order to transfer advisory information.

In New Zealand, regional and territorial authorities are involved in avoiding and mitigating coastal hazards through the Local Government Act 2002 and the Resource Management Act (Ministry for the Environment, 2011). Effective coastal hazard management involves recognizing changes in the environment, having clear roles for regional authorities, and educating the community in regards to hazard avoidance. This can be done through risk reduction measures and emergency management measures.

2.3.2 Ineffective Disaster Management Strategies

For a hazard communication system to be effective, there are many procedures that need to work harmoniously. Therefore, a system can become ineffective if any of these steps are unsuccessful (Basher, 2006). It can also be noted that people generally do not respond to early warning systems until some event occurs that is personally threatening. One of the shortcomings that exist in today's current communication strategies is that the main focus is still on the hazard; consequently there is less emphasis on the vulnerabilities, risks, and response capacities. Another common problem is that different hazards are dealt with by different independent agencies with little synergy among them. Finally, a warning system that is too complex can result in uncertainty and can lose the meaning of the warning. The response to Hurricane Katrina is an example of ineffective hazard communication. The meteorological warnings of wind speed, storm surge, and rainfall were accurate and well communicated to the public; however, their response to the warnings was inadequate.

2.3.3 Factors Affecting Response to Disaster Management Strategies

Despite the best disaster communication strategies, there still may be citizens who do not follow by the strategy (Charveriat, 2000). There are multiple factors that could influence this decision. Many people that live in homes located in high-risk areas for natural disasters have a low income and do not have an alternative location to move to when there is a disaster. Moving could also be detrimental to an individual's income if, for example, the land is fertile or has easy access to water and other natural resources. There may also be cultural reasons that influence a person's desire to stay in a hazardous location, if they were born in that area or have extended family there.

Palm and Hodgson believe that there are five factors that affect an individual's decision to take action (1993). First, people will only respond to hazards that seem more important to them than the other problems in their daily life. Secondly, some individuals believe that they do not have control over their destiny and will remain passive in the face of disaster. Third, a person's response is also dependent on their knowledge about the risk and its potential dangers. Fourth, people will also calculate the probability of a hazard themselves and not rely on expert opinions. And lastly, an individual that has a connection to the area he or she is living is much less likely to respond to a hazard.

2.4 Coastal Hazards of Puerto Rico

The island of Puerto Rico, located in the northeastern Caribbean Sea region, is vulnerable to many natural coastal hazards. Therefore, in order to propose hazard communication strategies, it is important to understand these natural coastal hazards. Puerto Rico in general is susceptible to seasonal hurricanes, coastal flooding, earthquakes and tsunamis. While these are the major spontaneous hazards, there are other, more common hazards that threaten the shore and those who utilize it. These common hazards include but are not limited to undertows, storm surges, floods, and pollution that threaten the water quality. This section will focus on the more common hazards.

2.4.1 Coastal Flooding and Oceanic Conditions

Caused by a rise in sea level, coastal flooding in Puerto Rico occurs as a result of prolonged strong onshore flow of wind and/or high astronomical tides (Bush et al., 1995). As a result of the change in ecological conditions around the earth, storm surges and storm tides have become more prominent, thus increasing the threat of coastal flooding.

Storm surges, storm tides, and undertows pose a regular threat to fishermen, tourists, surfers and others who utilize the shore in Puerto Rico (Bush et al., 1995). An undertow is a strong undercurrent flowing in a different direction from the surface current. Dangerous undercurrents pose a threat to average beach goers and especially to tourists in Puerto Rico who are not familiar with the currents.

Usually associated with tropical storms and hurricanes, a storm surge is a rise above the normal water level along a shore caused by strong onshore winds and/or reduced atmospheric pressure (NOAA, 2011b). The surge height is the difference between the observed water level and the predicted tide. Hurricanes often produce high storm surges that can cause fatalities as seen in the case of Tropical Storm Claudette of 1979 and Hurricane Hugo 1989, which caused the death of one person and five people, respectively.

A storm surge should not be confused with storm tide. A storm tide occurs when the water level rises due to the combination of storm surge and the astronomical tide (NOAA, 2011c). This rise in water level can cause extreme flooding in coastal areas particularly when storm surge coincides with normal high tide, resulting in storm tides reaching up to 20 feet or more in some cases. Figure 1 is a pictorial representation of a storm surge and a storm tide, compared to a normal tide.

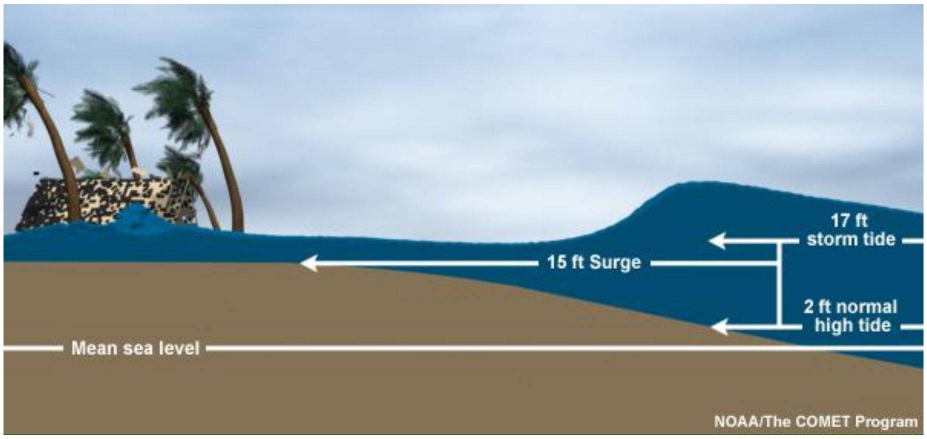

Figure 1: Storm surge versus storm tide (NOAA, 2011c, Storm Surge vs. Storm Tide section).

Aside from storm surges and storm tides, Puerto Rico has a seasonal cycle for ocean wave heights, but the winter season, which lasts from November to April, provides the most consistent waves (Canals, personal communication, 3/18/11). There are three typical swells in Puerto Rico; trade wind swells, cold front swells, and North Atlantic storm swell (Ibid). These swells cause coastal erosion, coastal flooding, and concerns of safety for those who live in coastal communities (Vitousek & Fletcher, 2008). A trade wind swell is caused by eastern trade winds and range from two to six feet in height (Canals, personal communication, 3/18/11). As its name implies, a cold front swell is generated by cold fronts from the East Coast of the United States. These swells are six to twelve feet and can often be accompanied by strong winds. North Atlantic storm swells are due to northeasters that occur about a thousand miles of the Puerto Rican shore and are often accompanied by moderate winds.

2.4.2 Water Quality

Another coastal threat that affects oceanic conditions is poor water quality. It is very common for beaches to be exposed to bacteriological threats in the form of fecal coliforms and enterococci (JCA, 2011). When the maximum acceptable values of these indicators are exceeded, there is fecal contamination. These conditions may expose swimmers to diseases such as infections of the skin, eyes, nose, throat and gastrointestinal diseases.

It is common practice around the world to test water at beaches for high concentrations of fecal coliform and enterococcus, both of which are bacteriological indicators of possible fecal contamination (JCA, 2011). Beach water is considered safe for swimming if the analysis shows that the concentration of fecal coliform is less than 200 colonies per 100 ml and the concentration of enterococcus is less than 35 colonies per 100 ml. In Puerto Rico, the Environmental Quality Board has the responsibility of performing bacteriological sampling and analysis at beaches frequently visited by swimmers. They then provide public notification about the safety of the water at each of the tested beaches. If the results for a beach are not safe, those results should remain in effect until the next round of water testing. The results of the March 11, 2011 Beach Water Quality results can be found in Figure 2, which is a computer generated display of the tested beaches. All of the beaches tested met the water quality standard, as indicated by the green triangle on the map. Had they not met the requirements, there would have been a yellow triangle at that location.

Figure 2: Puerto Rican beach monitoring and public notification program (JCA, 2011, Beach Monitoring Program section).

2.5 Coastal Management Agencies of Puerto Rico

The Puerto Rican coast is susceptible to a variety of natural hazards including tsunamis coastal storms, flooding, erosion and a change in water quality. There are many agencies that work collaboratively to oversee these hazards in Puerto Rico. These agencies include the National Oceanic and Atmospheric Administration (NOAA), the Department of Natural and Environmental Resources (DNER), the Puerto Rico Coastal Zone Management Program (PRCZMP), the Caribbean Coastal Ocean Observing System (CariCOOS) and Sea Grant. The following sections will go into detail about each of the organizations and how they work together.

2.5.1 National Oceanic and Atmospheric Administration

The National Oceanic and Atmospheric Administration (NOAA, 2011) is a scientific agency of the U.S. Department of Commerce concentrated on "keeping citizens informed of the changing environment around them" (Para. 1). Dating back to 1807 the NOAA follows the mission: "To understand and predict changes in Earth's environment and conserve and manage coastal and marine resources to meet our Nation's economic, social, and environmental needs" (Mission Section). Having a presence in every state and United States territory, the NOAA's activity influences "daily weather forecasts, severe storm warnings and climate monitoring to fisheries management, coastal restoration and supporting marine commerce" (Para. 2). The NOAA works towards its mission through six Line Offices: the National Environmental Satellite, Data, and Information Service, the National Marine Fisheries Service, the National Ocean Service, the Office of Oceanic and Atmospheric Research, the National Weather Service, and the Office of Program Planning and Integration.

The NOAA sponsors many environmental programs encompassing the different regions of Puerto Rico (NOAA National Weather Service, 2010). Specifically related to coastal hazards, the NOAA has a program through the National Weather Service called the NOAA Weather Radio All Hazards (NWR), which is a network of radio stations that continuously broadcasts weather warnings, watches, forecasts, and other hazard information. The NWR is the single source for complete weather and emergency information. Under the Office of Oceanic and Atmospheric Research, the NOAA sponsors the National Sea Grant College Program, which is "devoted to the conservation and sustainable use of coastal and marine resources in Puerto Rico" (Sea Grant Section). The Sea Grant Program will be discussed more in detail in section 2.5.5.

2.5.2 Department of Natural and Environmental Resources

The Department of Natural and Environmental Resources (DNER) (2006a) is a non-profit, government agency consisting of 54 divisions. The DNER's mission is to "protect, conserve and manage natural resources and environmental aspects of the country in a balanced form, to ensure future generations their enjoyment and foster a better quality of life" (Navigating the DNER section). Formed in 1972 and reorganized in 1993 the DNER is in charge of environmental protection and natural resource conservation. In addition, its vision is "to encourage a healthy environment through the promotion of sustainable use of natural resources, environmental management and the transformation of an environmental culture of Puerto Ricans with the participation of all sectors of society to improve the quality of life" (How did the DNER section). In Puerto Rico's Coastal Program, the DNER is the lead agency responsible for managing coastal waters.

2.5.3 Puerto Rico Coastal Zone Management Program

The Puerto Rico Coastal Zone Management Program (PRCZMP) (DNER, 2006b) works in partnership with the DNER to achieve its mission of, "[promoting] the protection, conservation, sustainable use and socioeconomic development of Puerto Rico's coastal zone and natural resources" (Mission section). In order to accomplish this mission the PRCZMP focuses on four primary goals: guidance of coastal development, conduct management of coastal resources, foster scientific research, and educate for sustainable coastal development.

2.5.4 CARA and Caribbean Coastal Ocean Observing System

The Caribbean Coastal Ocean Observing System (CariCOOS) (2011c) provides oceanic observation for the Caribbean Regional Association (CARA). Along with other federal agencies, CARA is one of eleven coastal observing associations that comprise the NOAA's Integrated Ocean Observing System.

CariCOOS (2011c) provides coastal news of current and future coastal hazards for Puerto Rico and the Virgin Islands. The website focuses mainly on presenting wind conditions, wave conditions, tides, currents, and ocean color. Under each category there are maps of Puerto Rico indicating live hazard data in specific locations around the Puerto Rican coast. CariCOOS also offers a Twitter account which broadcasts updates to current coastal conditions.

2.5.5 University of Puerto Rico Sea Grant College Program

The University of Puerto Rico Sea Grant College Program has a twofold mission (Sea Grant, 2011):

1. To conduct scientific research of excellence in the thematic areas of: water quality, fisheries and mariculture, coastal community economic development, and coastal hazards and safety.
2. To apply our scientific knowledge to a variety of marine and coastal problems and issues that our community of users face every day (About Us Section).

Through this mission the Sea Grant program is devoted to the "conservation and sustainable use of the ocean and coastal resources of Puerto Rico, the U.S. Virgin Islands and the wider Caribbean area" (About Us Section). Performing research, education, and outreach, Sea Grant has functioned through the University of Puerto Rico (UPR) since the early 1980's.

Sea Grant (2011) sponsors the UPR Marine Outreach Program (MOP), which is a method of communicating coastal information and technology to resource users, managers, and the general public in order to promote more sustainable coastal and marine resources. The MOP thematic areas are water quality, coastal community development, fisheries, tourism and recreation, seafood safety, and coastal hazards. In order to provide information on each of these topics, Sea Grant completes many research projects each year.

2.6 Current Coastal Warning Systems in Puerto Rico

Puerto Rico currently has different methods of communicating coastal hazards and oceanic conditions. Past tsunamis in Puerto Rico have raised awareness of coastal hazards in general (Mercado, Hillebrandt, & Huerfano, 2006). The following section highlights two methods that Puerto Rico currently employs to warn about hurricanes and seismic activity.

2.6.1 Sea, Land, and Overland Surges from Hurricanes

Sea, Land, and Overland Surges from Hurricanes (SLOSH) was developed by FEMA, United States Army Corps of Engineers, and the National Weather Service (Mercado, 1994). It is used by the NOAA National Hurricane Center (NHC) for real-time forecasting of hurricane storm surges across inland water bodies and along coastlines. This tropical storm surge model is two-dimensional, covering both water bodies and terrain. The present version of SLOSH at the University of Puerto Rico does not consider wind generated waves, rainfall flooding, tidal effects, nor river flooding effects; however, this model has been proven to be accurate within 20 percent of observed water levels. For example, if a forecast predicts the peak of a storm surge to be 10 feet then the actual peak may range between 8 and 12 feet.

Emergency managers use the data presented by this version to determine which areas need to be evacuated (Allen, Sanchagrin, & Lee, 2010). It provides evacuation decision-making, as well as areas of widespread flood impacts and timely disaster response. The SLOSH model requires a selection of meteorological parameters in order to obtain data on surge levels. The calculations utilize the latitude and longitude of the storm's eye, atmospheric pressure, the radius of the maximum winds (RMW), as well as storm track and speed in time intervals. The input parameter is water levels and is forced by an idealized wind field that depends upon the pressure deficit and the RMW from the storm center. The SLOSH model solves a complex set of equations and outputs data which are shown as color-coded storm surge on the SLOSH display. The SLOSH model is best used for defining the potential maximum surge for a location; however, the model's output is particularly coarse and provides little assistance in hurricane mitigation.

2.6.2 Seismic Monitoring

The seismicity of Puerto Rico is monitored by the Puerto Rico Seismic Network (PRSN) and the Puerto Rico Strong Motion Program (PRSMP), both operating within the University of Puerto Rico at Mayagüez (Clinton, 2006). From various stations in Puerto Rico, these agencies acquire, analyze and document broadband, seismic data in continuous real-time format for Puerto Rico as well as parts of the Caribbean Region.

The PRSN is mainly responsible for identifying and providing information on local, regional, and teleseismic earthquakes. They are also the host of the Emergent Tsunami Warning System for Puerto Rico and the Virgin Islands (Clinton, 2006). The PRSN is the reporting authority for dangerous locations and magnitudes. The main objective of the PRSN is to conduct research on local and regional earthquakes, and provide high quality information to be able to respond to the needs of the general public. The PRSN operates 13 broadband stations and 10 short-period stations throughout Puerto Rico and the US and British Virgin Islands.

The PRSN has been working towards establishing a local Tsunami Warning Center for the region since 2000 (Clinton, 2006). The original goal was to provide a base for tsunami warnings to Puerto Rico, but this has now progressed into an initiative to create a Caribbean Tsunami Warning Center, which would be a fundamental component of Coastal Hazards Warning Systems for this region. In 2003, the installation of the Early Bird System (EBS) at PRSN for the detection and coverage of tsunamigenic earthquakes has laid the foundation for this center. This system monitors the seismic stations of the PRSN and 35 other stations in and around the Caribbean that are available through the Global Seismographic Network (GSN).

The EBS locates earthquakes, projects different magnitudes for the events, and informs personnel of the PRSN once the thresholds have been exceeded (Clinton 2006). In 2006, the PRSN installed six tsunami-ready tide gauge stations in Puerto Rico and Geostationary Operational Environmental Satellite (GOES) receivers at Mayagüez which are used to gather data from these and other regional tide gauges as shown in Figure 3 (Gonzalez, Milburn, Bernard, & Newman, 1998). Water level observations from these tide gauges are recorded onto the data collection platforms. The GOES then transmits all the data from the stations, not only to the PRSN, but also San Juan Forecast Office of the National Weather Service (NWS) for analysis. GOES imagery provides continuous monitoring which is necessary for data analysis. These tidal stations have become an integral part of the Pacific tsunami detection and warning network. Tidal data, matched with data from the NOAA Deep-Ocean Assessment and Reporting of Tsunamis (DART) buoys, will allow the NWS tsunami warning centers to confirm a tsunami and forecast the properties of the waves more accurately. DART is part of the larger U.S.

National Tsunami Hazard Mitigation Program (NTHMP). The NTHMP is a joint Federal and State effort to reduce the loss of life and property damage due to tsunami inundation of U.S. coastlines.

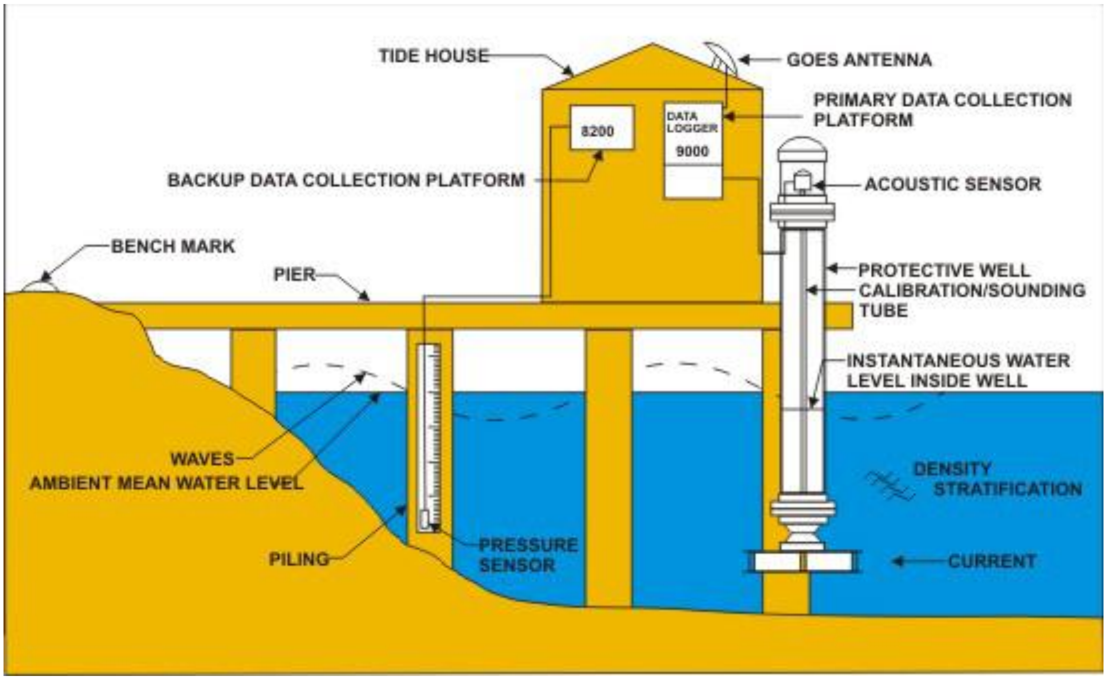

Figure 3: Schematic depicting the components of a typical tide station (NOAA, 2011e).

The EBS has been providing faster solutions than those available from the National Earthquake Information Center, the Pacific Tsunami Warning Center and the West Coast and Alaska Tsunami Warning Center (Von Hillenbrandt-Andrade & Moreno, 2006). The information disseminated by the EBS regarding location and magnitude for tsunami warning purposes has also been proven accurate. As soon as the EBS detects an event the information is automatically dispersed over the Internet. The personnel of the PRSN receive the information on their cell phones and pagers. The PRSN presently only distributes earthquake information that has been reviewed by an analyst.

To achieve an ideal Tsunami Warning System, the PRSN balances improved monitoring capabilities with research, education, and outreach programs (Clinton, 2006). The improved monitoring capabilities include tsunami flood modeling, protocol development, improved dissemination techniques, and the production of audiovisual materials, workshops, talks, and activities. In May 2006, NOAA declared Mayagüez as the first Tsunami Ready community in the Caribbean. The Tsunami Ready program has been widely accepted by most of the inhabitants in Puerto Rico, as it promotes and validates tsunami readiness.

2.6.3 Simulating Waves Nearshore Model

The Stimulating Waves Nearshore (SWAN) model is a computerized wave spectral numerical model that provides the translation of wave height, duration, and direction into graphical displays (Digital Hydraulics, 2011a). It was created by the Delft University of Technology in Delft, The Netherlands (Deltares, 2006). SWAN determines all the parameters that affect the waves entering the coast from the deep ocean. Some parameters that are taken into account include currents, tides, bottom topography, and the sun's reflection and diffraction (Digital Hydraulics, 2011a).

SWAN is the most widely used computer model to predict irregular waves on the coast (Digital Hydraulics, 2011b). This system is free for the public to use and is used by government authorities and research institutes around the world (Ekphisutsuntorn, Wongwises, Chinnarasri, Vongvisessomjai, & Zhu, 2010).

The SWAN model by Digital Hydraulics of Holland (DHH) offers a number of graphical output facilities and it is called SWAN-DHH (Digital Hydraulics, 2011b). SWAN-DHH provides the option to produce color-coded pictures of the wave parameters. DHH is continuously trying to enhance the effectiveness of this model through implementing different graphic extensions, software packages, and graphic interfaces (Digital Hydraulics, 2011a). A current limitation of SWAN is that it depends on the hydrodynamic properties of the sea bottom, which has shown variances from experimental and actual estimates. There are physical processes SWAN does not take into consideration, such as wave-induced currents and the variation of tides as the water level changes greatly between low tide and high tide.

Puerto Rico has implemented this method of communicating irregular waves on the coast. During March 2010, CariCOOS researchers carried out a field experiment in Rincón, Puerto Rico, to validate the SWAN model (NFRA Newsletter, 2010). For this experiment, two pressure sensors and an acoustic current meter were deployed in the ocean. These instruments are used to measure the velocity and direction of ocean currents, vertical current profiles, as well as obtain field measurements of wave height to characterize wave distortion or refraction

The CariCOOS website contains the experimental SWAN forecast through graphical displays. This model depicts that waves change height, shape and direction as a result of wind, wave breaking, energy transfer between waves, and variations in the ocean floor and currents (CariCOOS, 2011b). Initial conditions, including wave height, direction, and period, are entered into the model, and the model computes changes to the input parameters as the waves move toward shore. Model results are computed on a grid for analysis and then output information of wave height, direction, and velocity for each cell in the model grid is displayed. As shown in Figure 3, this information can be depicted in a map view to simplify visualization of changes in waves over the study area. This graph illustrates the significant wave amplitudes ranging from 0-12 feet and peak direction in arrows for the whole island of Puerto Rico. Other information that is presented on this page includes period and wave direction and wind forcing. Although it is widely used, there is still need for improvement and effectiveness within this model. The graph on this page is solely used for informational purposes. The National Service Forecast Service provides information on emergency situations.

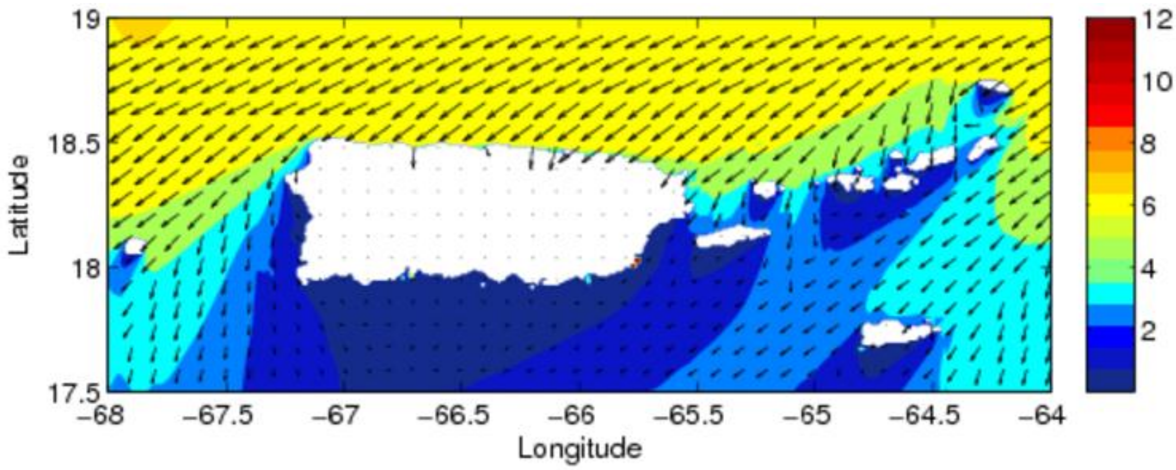

Figure 4: Significant Wave Height (feet) and Peak Direction (arrows) on April, 20, 2011 at 5:00 a.m. Local Time (NOAA, 2011b)

2.7 Summary

As an island on the edge of two tectonic plates and in a hurricane prone region, Puerto Rico is in critical danger of many coastal hazards including coastal flooding, undertow, water pollution, and storm tides and surges. Puerto Rico currently employs three systems for communicating warnings of hurricanes and seismic activity – Sea, Land, and Overland Surges from Hurricanes (SLOSH), Early Bird System (EBS), and Stimulating Waves Nearshore (SWAN). While oceanic conditions are communicated through the Caribbean Coastal Ocean Observing System (CariCOOS) website, much of the public is unaware of this service. CariCOOS works in conjunction with the National Oceanic and Atmospheric Administration, Department of Natural and Environmental Resources, Puerto Rico Coastal Zone Management

Program, and University of Puerto Rico Sea Grant College Program. Because of potential natural disaster risks, CariCOOS would like to implement a system that more effectively communicates these coastal hazards and oceanic conditions.

3. Objectives

The overall goal of our project is to provide recommendations to CariCOOS for an efficient and effective warning system for communicating coastal hazards and oceanic conditions to the residents of Puerto Rico. This goal will be pursued through surveys of people who frequent the coast, interviews of government officials and experts, and data analysis.

In order to accomplish our goal, we have developed in conjunction with our sponsor the following three objectives:

- Identify the impacts of coastal hazards and oceanic conditions in Puerto Rico.
- Identify strengths and weaknesses within the current communication system.
- Determine what forms of media would be most effective for informing the largest number of people in Puerto Rico.

Our evaluation will provide CariCOOS with suggestions and recommendations to strengthen their communication strategies in an effort to reduce the loss of life and property damage caused by coastal hazards and oceanic conditions. Our detailed plan is described in the following chapter.

4. Methodology

The goal of this project was to propose recommendations to the Caribbean Coastal Observing System (CariCOOS) for an efficient and effective warning system for communicating coastal hazards and oceanic conditions in San Juan, Puerto Rico. In order to accomplish this goal we identified the public's perceptions of the system that is currently in place. Furthermore, we determined the best methods for educating stakeholders in the use of this system. Stakeholders included general users of the coast such as beach goers, surfers and tourists, as well as fishermen and people who live and work along the coast. We have developed a methodology that will help identify the current inefficiencies and shed light on possible solutions. The following sections will explain how we will achieve each of our objectives.

4.1 Impacts of Coastal Hazards and Oceanic Conditions in Puerto Rico

In the first phase of our project, we determined how to enhance awareness of coastal hazards. Before we could help to increase awareness, we needed to know the impacts of coastal hazards and adverse oceanic conditions such as storm surges, rip tides, coastal flooding and water pollution on the island. This was accomplished by having direct contact with residents. We interacted with citizens by approaching them with a questionnaire. We reached people through convenience sampling by stopping them at local malls, plazas, surf shops, water sport and dive shops, and along the coast to obtain responses from 300 people. We chose a quota of 300 people in order to have a 95% confidence level and a 5.66% margin of error. This was based on the approximation that San Juan has a population of one million residents. We targeted people who frequent the coast, such as fishermen, surfers, beach goers, boaters, and tourists. We also surveyed 30 business owners in order to obtain 10% of our sample size. We felt it was important to separate business owners from the general population because they provide a different viewpoint. Business owners carry a special responsibility since they frequently have to deal with a large number of people; for instance, a restaurant owner may have 50 or more guests on his/her premise. We concentrated our data accumulation in Metropolitan San Juan which included Condado Beaches, Old San Juan, Luquillo Beach, Ocean Park, Piñones San Juan Bay Marina, Club Náutico de La Parguera, and Plazas Las Americas. The preamble and questionnaires can be found in Appendices B, C, and D.

4.2 Identification of Advantages and Disadvantages of Current Communication Systems

In order to fully understand the existing communication, we thoroughly analyzed the system from an administrative and an average citizen viewpoint. We took into consideration the opinions from interviews with experts from personnel at various coastal management agencies including Sea Grant, the National Weather Service (NWS), and the Puerto Rico Seismic Network (PRSN). With the help of our project liaison NOAA Coastal Management Fellow Kasey Jacobs, we identified the agencies and appropriate personnel in order to start the interview process. In gathering this information, it was our aim to target between two to three people from the relevant agencies, which yielded six interviews. During these interviews, we asked the experts what they believed the current flaws in the system were and the effectiveness of the system.

The opinions of average citizens' regarding the current coastal hazard communication system were obtained through the survey described in section 4.1. Direct contact with coastal inhabitants was imperative for this part of our research, and our methods helped us to better understand the public's perception of the current warning systems. With this information, we created a weighted list of advantages and disadvantages of the major coastal hazard communication systems in Puerto Rico.

4.3 Effective Methods of Communication

The last phase of our project consisted of defining an improved method for the communication of coastal hazards in Puerto Rico. A major component of this task was identifying effective and time efficient media to report the coastal hazard information. For the proposed system to be effective, it reached the greatest number of people in danger. A time efficient method of communication reached the targeted people in a timely manner.

We used the same surveys as described in section 4.1 to determine how average citizens would change the current system. The questionnaire contained questions that specifically asked which method the person uses to determine if there is a coastal hazard and what would be their preferred method for receiving coastal information. While the questionnaire was being administered, the person was also informally asked whether they were familiar with the products that CariCOOS offered to see if the website is an effective method for communicating coastal hazards and oceanic conditions.

4.4 Summary

Determining how the government communicates with its emergency management services and how they in turn communicate the warnings about coastal hazards and oceanic conditions to the public are key factors in our recommendation for an improved system. Our primary means of collecting data was through surveys and interviews with the various experts, and users of the coast. These methods allowed us to analyze the problem and enabled us to see where there is a breakdown in communication and how the system can be enhanced.

5. Results and Analysis

5.1 Analysis of the Impacts of Coastal Hazards and Oceanic Conditions

To understand the impacts of coastal hazards in the San Juan metro area, we asked both the general population and business owners whether they had been affected by a coastal hazard or oceanic condition. As mentioned in the Methodology chapter, due to time constraints we used a sample size of 300 people in order to obtain a 95% confidence interval and a 5.66% margin of error for the population of San Juan. Figure 4 shows that the most prevalent hazard among those respondents affected by coastal hazards and oceanic conditions is coastal flooding. When asked to describe the coastal flooding, the majority of people stated it was oceanic flooding rather than flooding caused naturally, such as heavy rainfall.

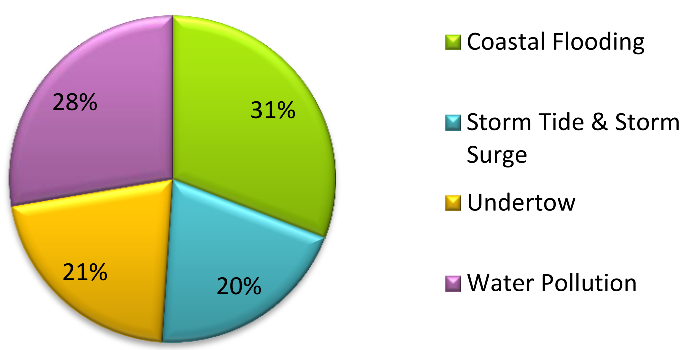

Figure 5: Percent of the affected general population impacted by different coastal hazards and oceanic conditions

We also compared the types of coastal hazards experienced by different business located along the coast. Figure 5 shows that businesses are also most affected by coastal flooding. This was determined because every type of business experienced coastal flooding, whereas restaurants were not affected by either storm tide and storm surges or water pollution.

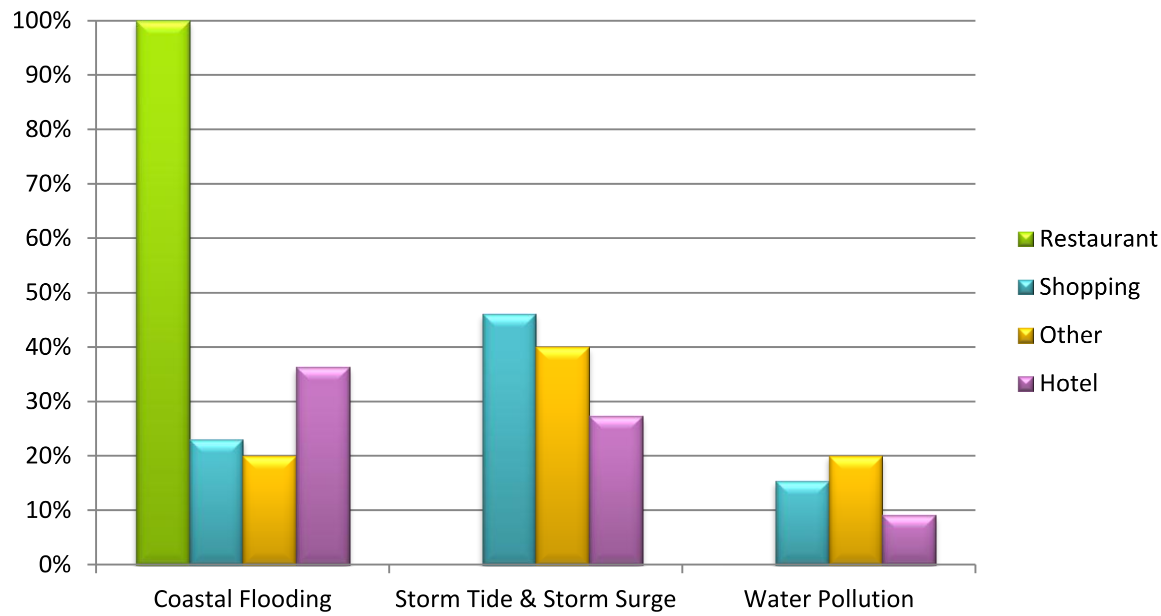

Figure 6: Percent of the businesses affected by different coastal hazards and oceanic conditions

5.2 Analysis of Strengths and Weaknesses within the Current Communication System

In order to analyze the strengths and weaknesses of the current communication system, we examined the interviews with different experts as well as specific questions from the survey. This allowed us to determine the advantages and disadvantages from both an administrative viewpoint and from the perspective of an average citizen.

5.2.1 Interviews with Experts

During the course of our research, we spoke with experts at Sea Grant, the National Weather Service (NWS), and the Puerto Rico Seismic Network (PRSN). The interview transcripts can be found in Appendix E. Although the interview protocols varied for the different agencies, the questions focused around three similar points. Each person was asked in some form how their agency disseminates information to various personnel, what is the chain of communication among agencies involved in coastal zone management, and whether they personally believed the current communication system is effective and how it could be improved. From these questions, we determined both the advantages and disadvantages of the current communication system.

Through these interviews, there were only a few strengths found within the current communication system. Both the experts at the NWS and PRSN stated that their products can be found in both English and Spanish. Since both of these agencies serve Puerto Rico as well as the U.S. Virgin Islands, this bilingualism is a strength allowing communication with the majority of people among the islands. An additional strength of the current communication system is that the scientific information about coastal hazards and oceanic conditions is reliable and offered at all times. The products that the NWS and PRSN provide are always available on their respective websites, the radio, and through free subscriptions that allow people to receive information through their phone. On March 23, 2011, Puerto Rico issued a tsunami warning to test their communication systems. Although María Font, the Information Specialist of Marine Education at Sea Grant, believed the drill failed because a majority of the public was uninformed, experts at the NWS and PRSN confirmed that their scientific data was disseminated, but there were problems within municipal agencies that were in charge of providing this information to the public.

Despite these advantages, every expert whom we interviewed stated that the current communication system is either flawed or ineffective. This is a clear indication that the current system is extremely weak and not functional. Experts stated that there were flaws with both the dissemination of information and the communication among agencies, as well as specific problems regarding their agency's role in communicating coastal hazards.

Experts at Sea Grant, the NWS, and the PRSN stated that information is given to people who request it. Therefore, the primary responsibility is on the citizen rather than the agency to initiate this contact. This is a disadvantage because if a person is unsure how to access these agencies, they may never receive the information.

Another disadvantage is that although experts stated that there is a certain degree of collaboration among the different coastal zone management agencies, this communication is fragmented and usually occurs only when information is required. Thus, there is a lack of interconnectivity among the agencies even though many have the same goal of providing the public with coastal information. Therefore, communication between the government agencies and Sea Grant, which is operated through the University of Puerto Rico, is disjointed. The experts we interviewed at Sea Grant all felt that the government was lacking concern for coastal hazards. Likewise, many experts stated that building permits are being granted in tsunami prone areas or coastlines that have already been affected by oceanic conditions. This lack in cohesiveness is addressed in our recommendations discussed in Chapter 7.

5.2.2 Survey of General Population

To determine the advantages and disadvantages of the current communication system, we looked at what resources the general population currently uses to obtain coastal information. As shown in Figure 6, the main resource relied on was television. This was followed by the Internet and radio, while cell phones and word-of-mouth had the same percentage of use, and newspapers were the least popular resource.

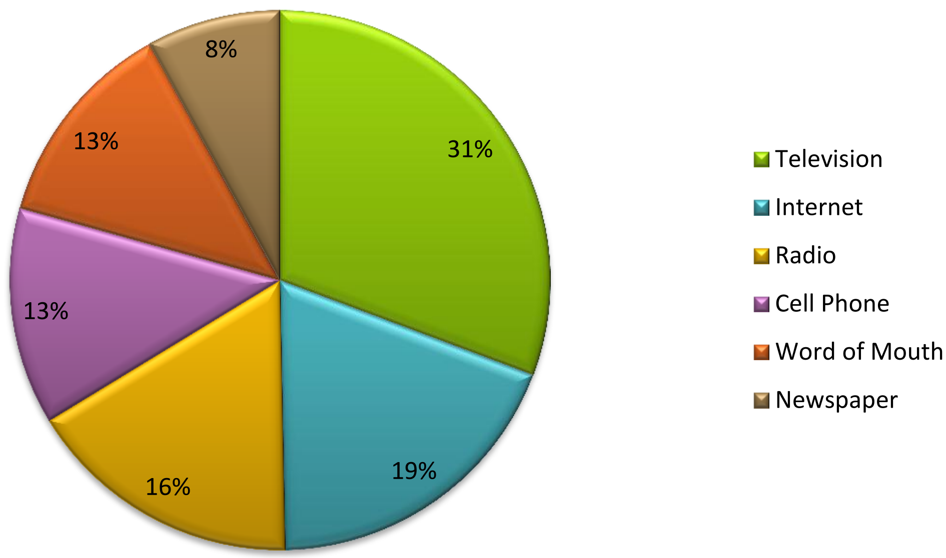

Figure 7: Resources used by the general population to obtain coastal information

This data gave us a starting point to then explore the advantages and potential disadvantages of these resources. Based on the resources used to receive coastal information, the public felt that not only was the resource easy to access but the resource's message was also easy to understand. Of the 300 people surveyed, 89% said it was easy to access and 90% said it was easy to understand.

Despite these advantages, when informally asked if a person was familiar with the products that CariCOOS offered, all respondents replied they did not know they could receive coastal information through CariCOOS's website, Twitter, or Facebook group. The majority of people also stated that a warning did not take place during a coastal hazard they experienced. Even if people can easily obtain some coastal information, there needs to be warnings for dangerous oceanic conditions and coastal hazards. Of the 300 people surveyed, 31% have been affected by a coastal hazard. As shown in Figure 8, for every coastal hazard and oceanic condition, over 60% of people stated that a warning was not issued.

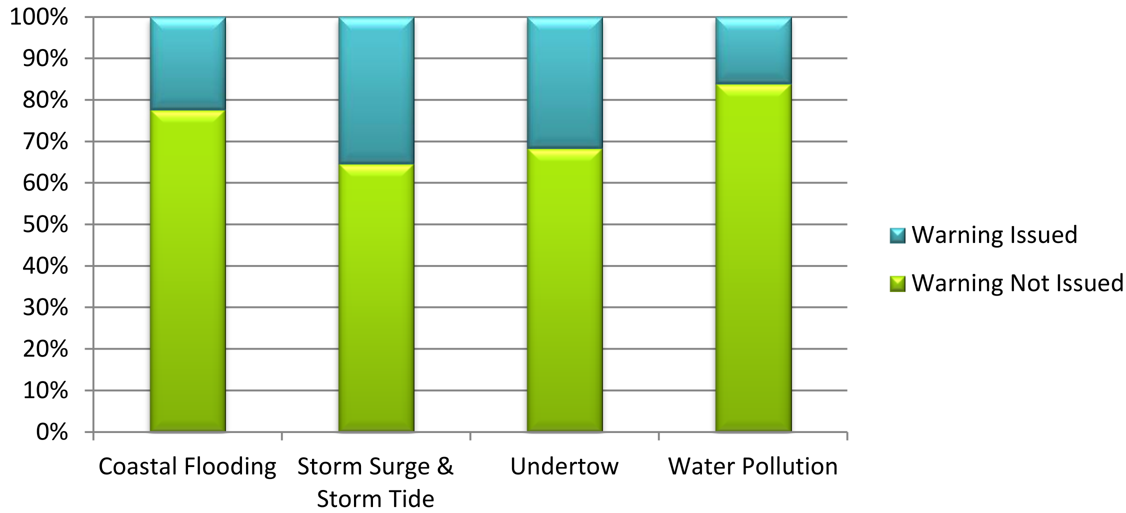

Figure 8: Percent of warnings issued for different coastal hazards and oceanic conditions

Another disadvantage in the eyes of the public is that the system shows many flaws and is in need of improvement. Although the resources are accessible and understandable, the general public still feels vulnerable to coastal hazards. We asked the general public if they knew what to do if there was a coastal hazard, as reported in Figure 9, over 50% responded either strongly disagree or disagree. In discussion with the 27% of the population that said they agreed or strongly agreed, the majority claimed they would run or drive to high ground.

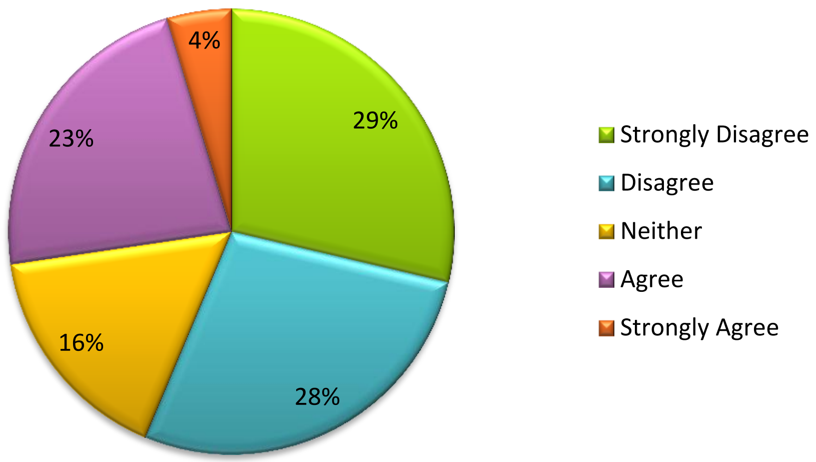

Figure 9: Percent of people who know what to do if there is a coastal hazard

We also asked the public if they felt well prepared for a coastal hazard. As depicted in Figure 10, an even greater percentage of people strongly disagreed or disagreed. Less than a quarter of the population surveyed agreed or strongly agreed that they were well prepared for a coastal hazard. Specifically, only 4% felt they were well prepared for a hazard.

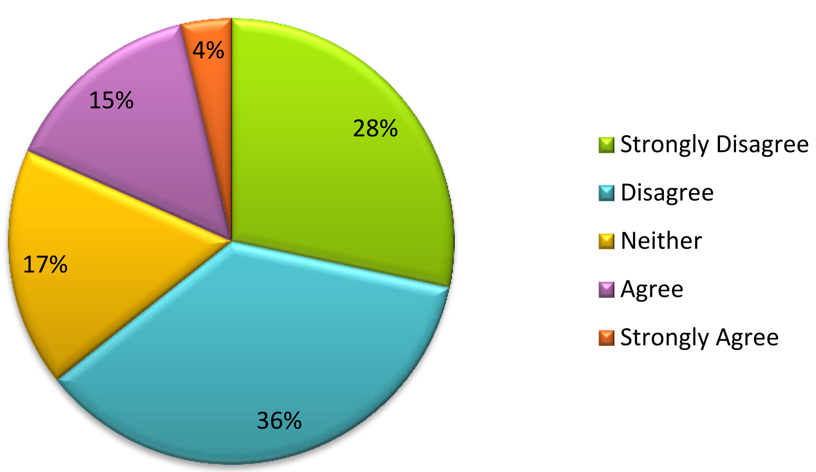

Figure 10: Percent of people who feel well prepared for a coastal hazard

5.2.3 Survey of Business Owners

To discover if there are other advantages and disadvantages within the current communication system, we analyzed the surveys of the business owners. Figure 11 highlights an advantage of the current system. In 90% of all cases of coastal hazards that affected businesses, warnings were issued. For restaurants, shops, and service orientated business, as indicated by the column ‘other’, warnings were reported 100% of the time.

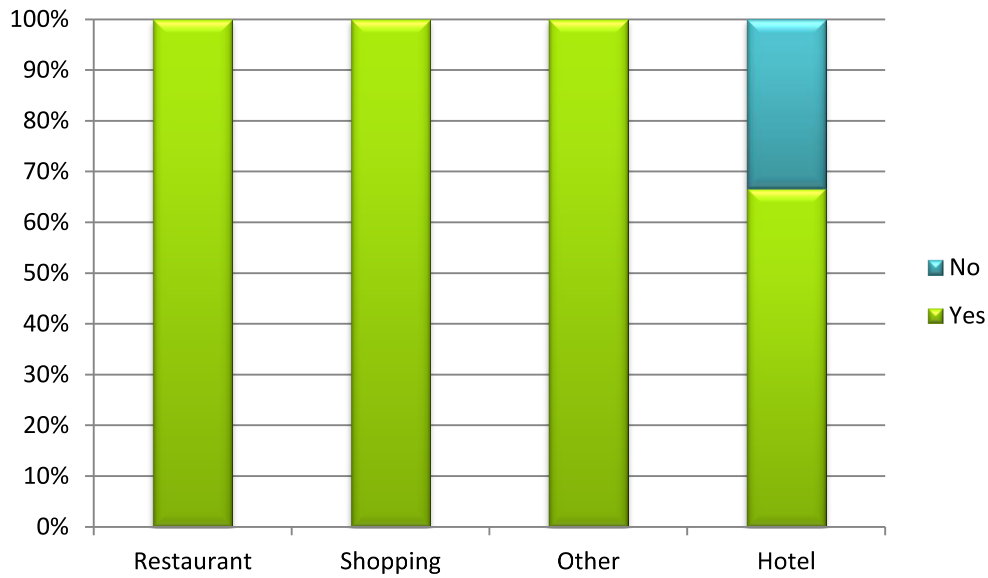

Figure 11: Percent of warnings that were issued for coastal hazards that affected different types of businesses

To determine the weaknesses, we asked business owners if they knew what to do in the event of a coastal hazard. Shown in Figure 12, 42% of all respondents said they felt they knew what to do in case of a coastal hazard while 18% were indifferent, and 39% disagreed completely. The type of business that most strongly agreed was shopping businesses. This could be due to the fact that shopping businesses are owned by corporations which place a stronger emphasis on limiting liability exposure than independently owned businesses. While this can be seen as an advantage, the difference between agreeing and disagreeing is approximately 3%.

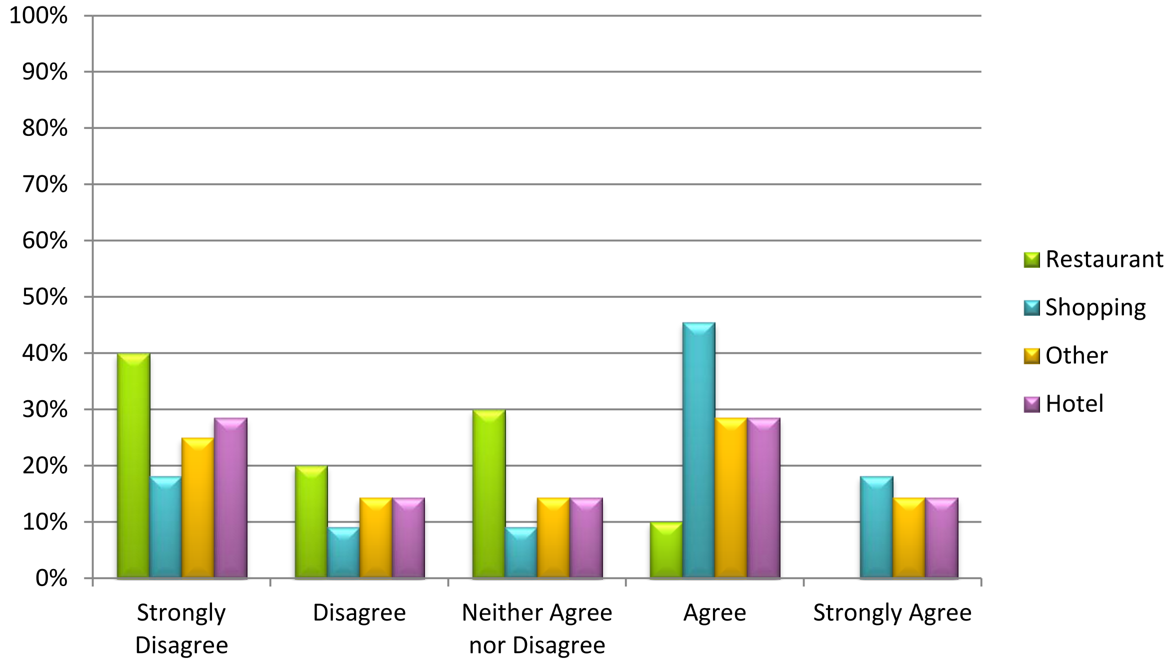

Figure 12: Percent of business owners who know what to do in the event of a coastal hazard

Additionally, we asked business owners if they felt prepared in the event of a coastal hazard. Here the data does change; as shown in Figure 13 an overwhelming 66% said that they disagreed with that statement, while 25% were indifferent. Only 9% of business owners agreed that they felt prepared. It should also be noted that none of the respondents claimed that they strongly agreed with the statement of preparedness. Furthermore, when we investigated the *Other* category, which is comprised of service-oriented businesses such as FedEx, Rent-A-Car, etc., these establishments were split 50-50 between 'Strongly Disagree' and 'Disagree.'

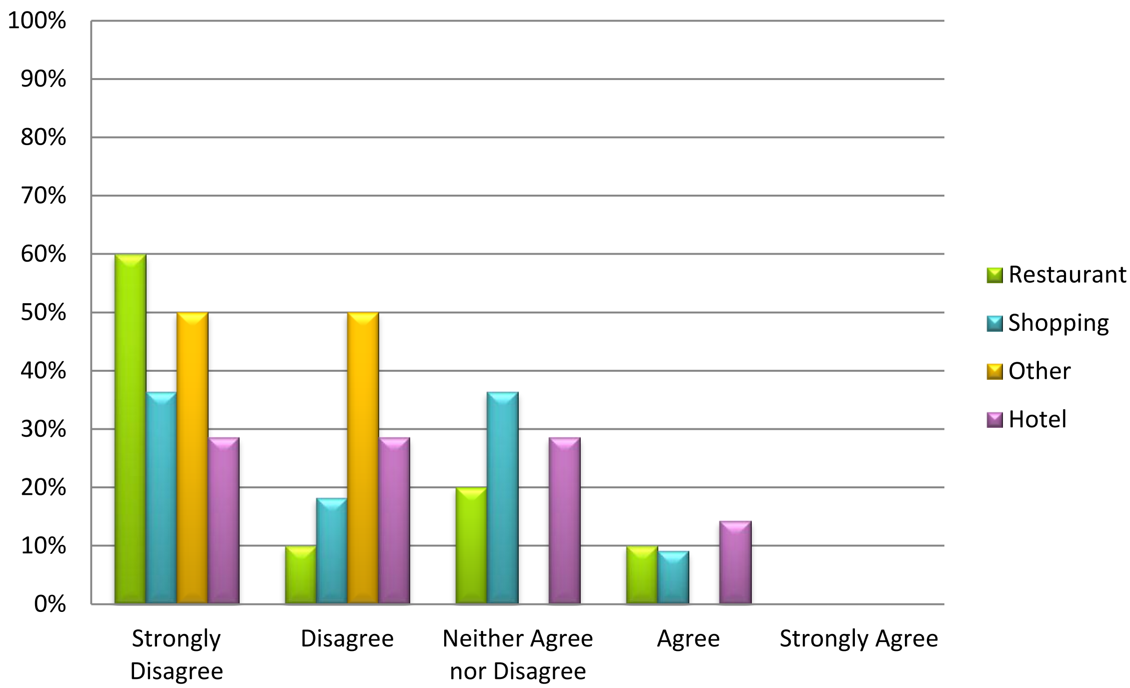

Figure 13: Percent of business owners who feel well prepared in the event of a coastal hazard

5.3 Analysis of the Most Effective Form of Media

In order to determine an improved method for communicating coastal hazards and oceanic conditions we studied the survey of both the general population and of business owners. This allowed us to evaluate what methods would reach the greatest number of people in the most time efficient manner.

5.3.1 Survey of General Population

From the survey of the general population, we discovered the most effective form of media for informing the general population. Question 13 on the survey was asked in order to gain the public's opinion of the preferred/ideal method of receiving information about coastal hazard and oceanic conditions. Figure 14 depicts the methods that people would prefer to receive coastal hazard information. The graph shows that 43% of the general population preferred a warning siren and announcement, followed by phone, radio, and the Internet.

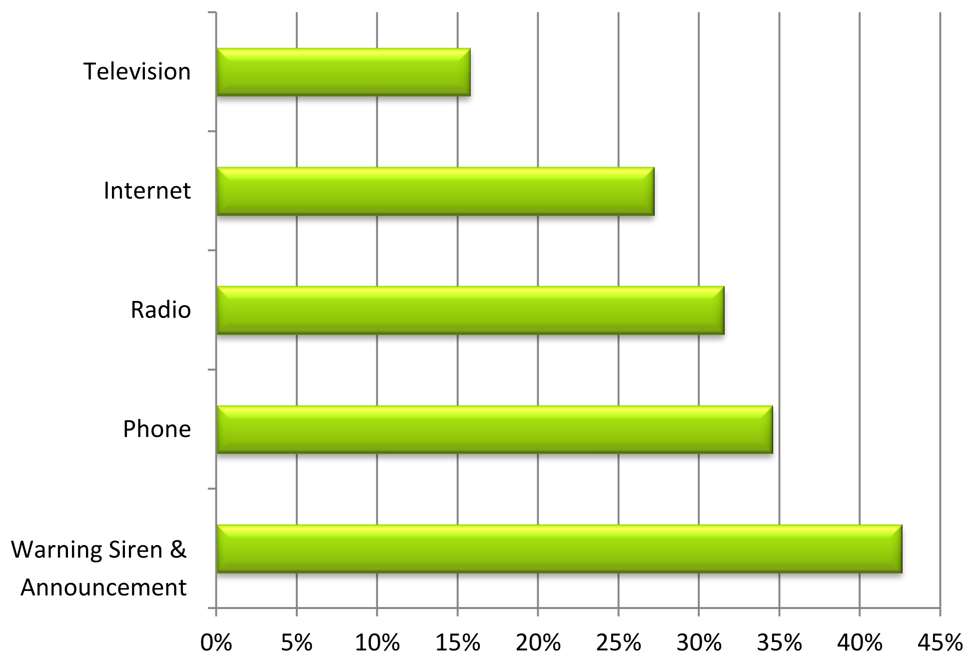

Figure 14: Resources the general population would prefer to obtain coastal information

Our research into various siren systems uncovered a number of technical and financial details that should be evaluated. One large siren vendor, the American Signal Corporation (ASC, 2011) states that "sirens are still the most effective method to warn the population at large in the shortest amount of time" (Para. 4). ASC offers a broad range of electronic and mechanical sirens that can meet many different requirements. Although they are highly effective, there are precautions that need to be considered when installing sirens (Federal Signal Corporation, 2007). The siren may not produce the intended optimum audible warning if: i) the proper warning equipment is not purchased, ii) the most ideal location for the installation is not chosen, iii) the siren is improperly installed, or iv) the sirens are not activated in a timely manner when an emergency condition exists. It is imperative that experts are available to authorize the activation of the sirens at any given time. People indoors may not be able to hear the warning siren; therefore, separate warnings are needed to effectively alert indoor residents. The sound output of sirens is capable of causing permanent hearing damage; consequently, it is highly important to carefully plan siren placement, post warning signs, and restrict access to areas near sirens. Any sound greater than 85 dB can cause hearing loss (Audiotech Outdoor Warning Sirens and Siren Controllers, 2011c). The decibel, abbreviated dB, is the standard unit used in engineering to measure the intensity of sound. Both the intensity and length of the sound exposure are factors that can lead to hearing loss. Activating the sirens may not result in people taking proper actions; thus, siren users need to be educated and should follow proper mitigation techniques (Federal Signal Corporation, 2007).

The effective range of any siren is the maximum distance at which it can be heard at a level of 70 dB or louder (Audiotech Outdoor Warning Sirens and Siren Controllers, 2011c). Environmental factors may alter the range of any siren in real-world applications; however, in order to simplify our analysis of selecting the most suitable siren for San Juan we ignored these factors. It is our opinion that these factors will not adversely affect our subsequent analysis.

It is imperative to take the additional field equipment costs into consideration when installing a siren. This equipment is sold separately and the prices vary depending on the models (Audiotech Outdoor Warning Sirens and Siren Controllers, 2011b). In general, installation prices range from $3,500-$8,500 depending on the mounting pole type and its location. Table 1 lists the sirens that are currently on the market and could be deployed along the San Juan coastline. In our analysis of choosing the best siren, we removed any unit that did not have battery backup or were not omni-directional in terms of their sound radiation pattern. Based on these criteria, we narrowed down our search to the Model 7V8, 2001 DC, Modulator, and the 15V2T.

Table 1: Available warning sirens currently on the market (Audiotech Outdoor Warning Sirens and Siren Controllers, 2011b)

Siren Model	Power Requirements	Effective Range (ft.)	Battery Backup	Siren Weight (lbs)	Siren Cost ($)
STH10	3-phase AC	2,400	No	400	5,075
Model 7V8*	AC or DC[2]	2,500	Yes	350	3,275
2001AC	240 VAC[3]	5,600	No	410	8,650
2001DC	120VAC[3]	5,600	Yes	410	10,250
Modulator	120VAC[3]	1,200-4,500	Yes	181-760	Up to 17,270
10V*	240 VAC[2]	3,000	No	325	3,475
10V2T*	208-460VAC	4,000	No	600	6,500
15V2T*	AC or DC[2]	4,700	Yes	750	7,250

***Siren is available in stainless steel**

[2] siren is available in single or 3-phase- prices shown are 3 phase

[3] siren is available in single phase AC only

The Model 7V8 shown in Figure 15 is an omni-directional warning siren capable of a tone warning of up to 112 dBC at 100 feet (Audiotech Outdoor Warning Sirens and Siren Controllers, 2011c). The C after the decibel label dB refers to decibels relative to the carrier, which is the power level recorded at a single frequency. In telecommunications, a carrier is a wave form that can be modified with an input signal for the purpose of conveying information (Scribd, 2011). The 100 feet signifies the distance at which the sound measurement is taken (Audiotech Outdoor Warning Sirens and Siren Controllers, 2011b). This siren is popular for departments that need to cover a large area on a small budget. It has a non-corrosive cast aluminum fan and powder coated finish. Installation may be done on any flat surface or on a pole mount bracket. It is available in single or 3-phase AC, or it can be operated from batteries. In addition, a motor starter and a Vendette siren controller are needed for this model. The Vedette is a solid state controller that has no moving parts (Audiotech Outdoor Warning Sirens and Siren Controllers, 2011a). The number of cycles the siren sounds when an alarm is initiated as well as the length of each siren cycles is adjusted. The Vedette will work with any existing electromechanical warning siren and can readily be installed by an electrician. The cost of this controller is $1,695.

Figure 15: Model 7V8 Siren (Image Courtesy of Audiotech Outdoor Warning Sirens and Siren Controllers).

The 2001DC model, shown in Figure 16, is a rotating mechanical siren that can operate on batteries (Audiotech Outdoor Warning Sirens and Siren Controllers, 2011c). It has a sound output of 128 dBC at 100 feet and an effective range of 5,600 feet, making it one of the loudest sirens available. In the event of power loss, the 2001 DC siren can operate from its back-up batteries for only 15 minutes.

Figure 16: 2001DC Siren (Image Courtesy of Audiotech Outdoor Warning Sirens and Siren Controllers)

The Modulator Series Siren shown in Figure 17 is an electronic siren (Audiotech Outdoor Warning Sirens and Siren Controllers, 2011b). Here, the Modulator is composed of one to six speaker cells. Modulators have an inactive speaker cell on the bottom of the stack that is used to help project sound in all directions. Without the inactive cell there would be unbalanced sound distribution. There are many advantages of the Modulator over a traditional electromechanical siren, including the ability to produce various warning sounds, completely solid-state technology, battery backup operation, low power consumption, and voice broadcasting capability. The Modulator comes in six different configurations from 106 dBC to 121 dBC at 100 feet depending on the required sound output. Pricing starts at $8300 and includes the controller, but not the batteries.

Figure 17: Modulator Siren (Image Courtesy of Audiotech Outdoor Warning Sirens and Siren Controllers)

The 15V2T model, shown in Figure 18, is an electro-mechanical warning siren and is considered the best-selling dual tone siren available today (Sentry Siren, 2011).   Highly durable, the Nuclear Regulatory Commission (NRC) has given the siren an expected usable life of 53 years. This siren is also FEMA and USDA grant compliant. It is capable of producing a warning tone of 122 dBC at 100 ft. It is also available in a 460 Hz tone model, the lowest pitch in the market; meaning its sound will fade at a lower rate than its competitors, giving the user more distance per decibel.

Figure 18: Image of 15V2T Siren (Photo Courtesy of Sentry Siren)

In addition to warning sirens and announcements, we furthermore attempted to determine if warnings through cell phones would reach the majority of the population of Metropolitan San Juan. In order to accomplish this, we first asked if the respondent had a cell phone. Figure 19 compares the percentage of people who own a cell phone versus those who do not own a cell phone broken down by age groups. As shown, 90% of the population older than 17 years old has a cell phone. Although the percentage of those less than 17 years of age that owned a cell phone was not above 90%, the majority of the age group does have a cell phone.

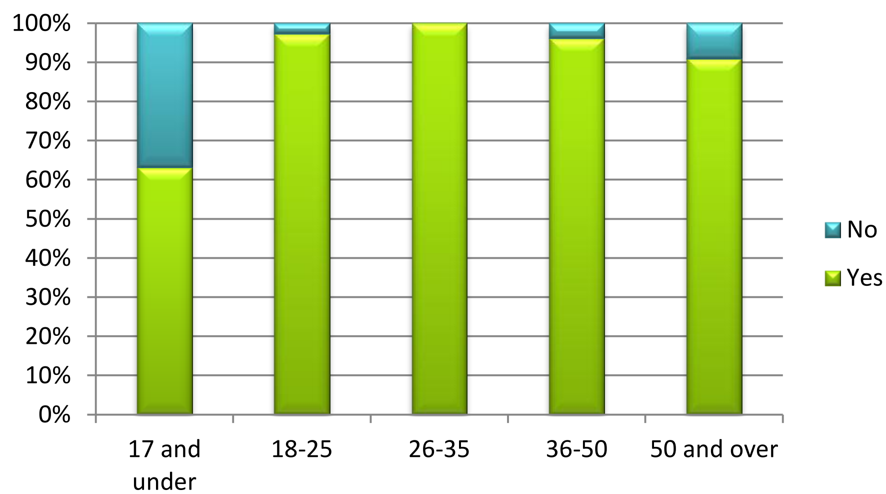

Figure 19: Percent of the general population broken down by age that has a cell phone

In order to determine if warnings could be issued through text messages or through a smartphone application, we asked if the respondent had a text messaging plan or a data plan. Figure 20 compares the percentage of cell phone users who have a text messaging plan with those who do not. Over 80% of cell phone users have a text messaging plan, and this number increases to 90% of the cell phone users surveyed between the ages of 18 and 50.

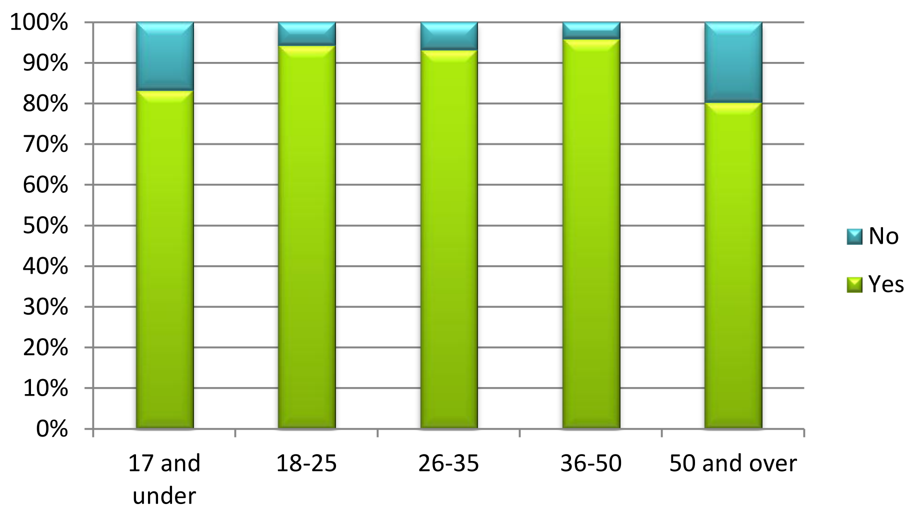

Figure 20: Percent of cell phone users broken down by age that have a text messaging plan

To further study cell phone users, Figure 21 depicts the percentage of cell phone users who have a data plan broken down by age groups. Over 60% of all cell phone users have a data plan, including 40% of cell phone users less than 17 years of age and over 50 years of age.

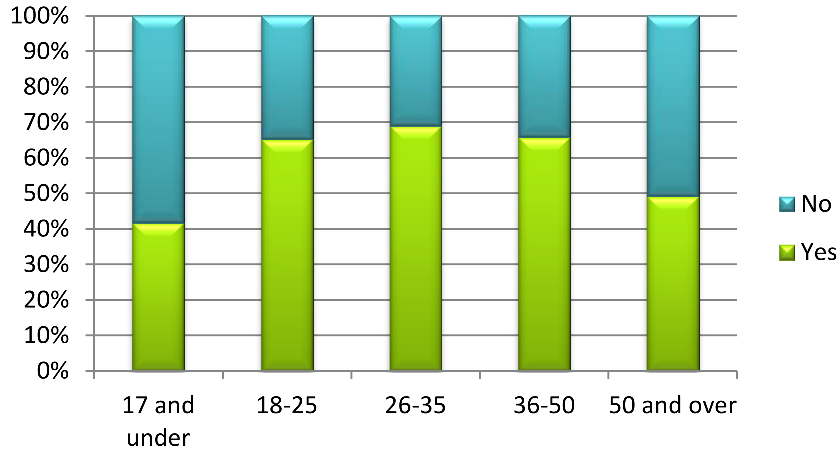

Figure 21: Percent of cell phone users broken down by age that have a data plan

In order to determine if warnings could be issued over the internet, we asked if the respondents had access to the internet. Figure 22 depicts the responses based on the age groups. Over 70% of the public surveyed have access to the internet and over 90% of the respondents between the ages of 18 and 50 have access to the internet. Moreover, 84% of the public that responded yes to having internet said that they used the internet daily. Because such a high percentage of the general public uses the internet, this suggests that if the public knew where on the internet to look for coastal warnings, they could be very effective.

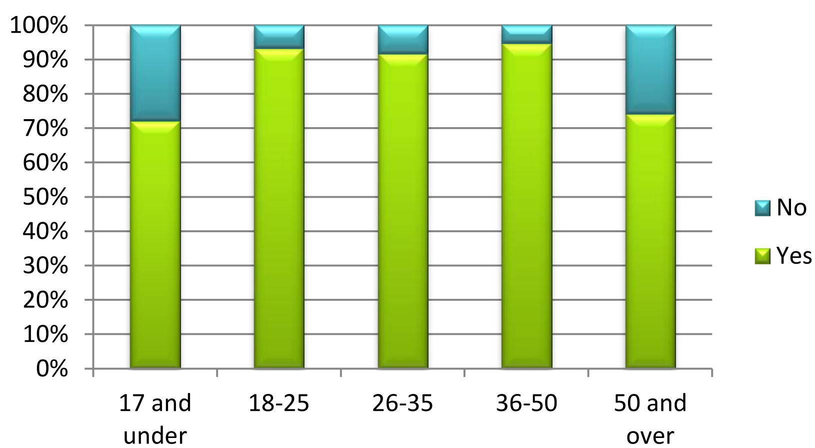

Figure 22: Percent of the general population broken down by age that have access to the Internet

To determine if social networking sites such as Facebook and Twitter would be an effective method of distributing coastal hazard warnings, we asked whether or not the respondent used social networking sites. Figure 23 reports the percentage of the responses from the survey that use social networking based on different age groups. It is shown that over 70% of the public under 50 years old use social networking sites, mainly Facebook and Twitter. This high percentage indicates that warnings through social networking sites could reach a high percentage of the public, especially people under the age of 50.

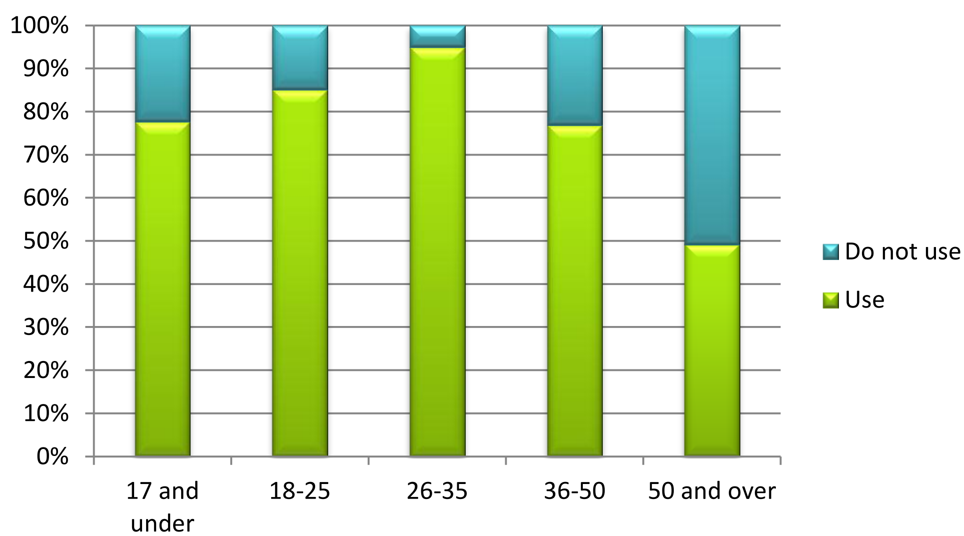

Figure 23: Percent of the general population broken down by age that use social networking sites

As stated in section 2.5.4, CariCOOS has a Twitter account in which they submit Tweets with warnings of coastal hazard and oceanic conditions in Puerto Rico. Figure 24represents a graphic of the percentages of people who use each of the social networking sites broken down by age. The figure illustrates that Facebook is the predominant social networking site used by the public. For each age group over 90% of the public who responded positively to using social networking sites use Facebook. Unfortunately, only 10-30% of each age group who responded positively to using social networking sites rely on Twitter. Also, 15% of the public who responded positively to using social networking sites mentioned that they used both Facebook and Twitter.

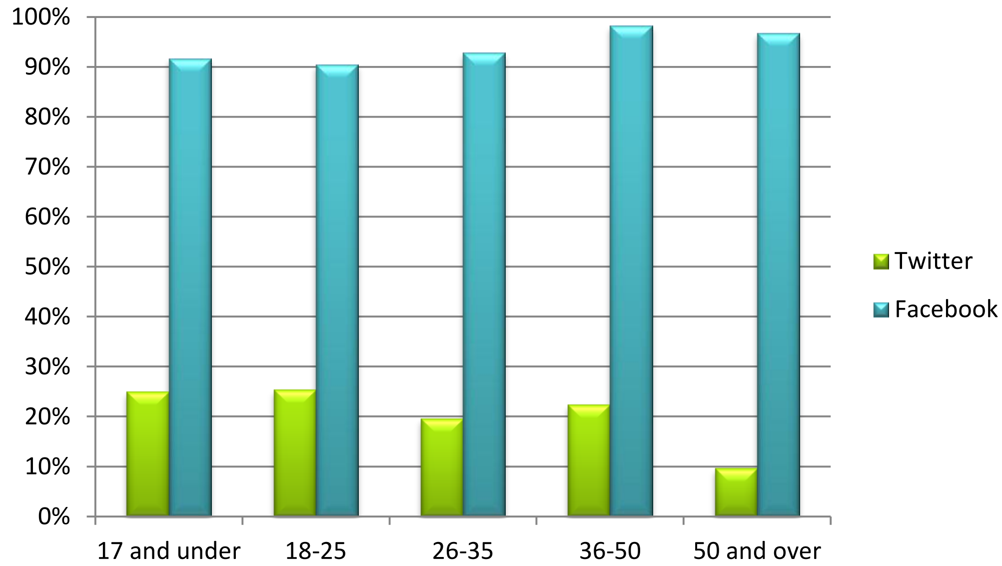

Figure 24: Percent of the general population broken down by age that use Twitter and Facebook

However, it should be noted that communicating such lifesaving information over third party sites can imply legal risks. For example, Facebook has a policy that attempts to free itself from any liability that would result from miscommunication. Its policy states:

> *We try to keep Facebook up, bug-free, and safe, but you use it at your own risk. We are providing Facebook "as is" without any express or implied warranties including, but not limited to, implied warranties of merchantability, fitness of a particular purpose, and non-infringement. We do not guarantee that Facebook will be safe or secure. Facebook is not responsible for the actions, content, information, or data of third parties, and you release us, our Directors, Officers, Employees, and Agents from any claims and damages, known and unknown, arising of or in any connected with any claim you have against any such third parties (Facebook, 2011).*

If CariCOOS were to use Facebook to communicate warnings and the site was down, Facebook would be free from all liability. Therefore, CariCOOS must carefully consider the legal ramifications when establishing channels that communicate coastal hazards over private networks.

With all of these possible ways to inform people of coastal conditions, we attempted to explore if there is a correlation between a preferred resource and the way a person uses the coast. Figure 54 compares these two variables. Fishermen and boaters would like to be able to rely on radios, while people who work or live along the coast would like a warning siren and announcement. People using the beach have varying opinions on what resource they would like for receiving coastal information, although television is the least popular option.

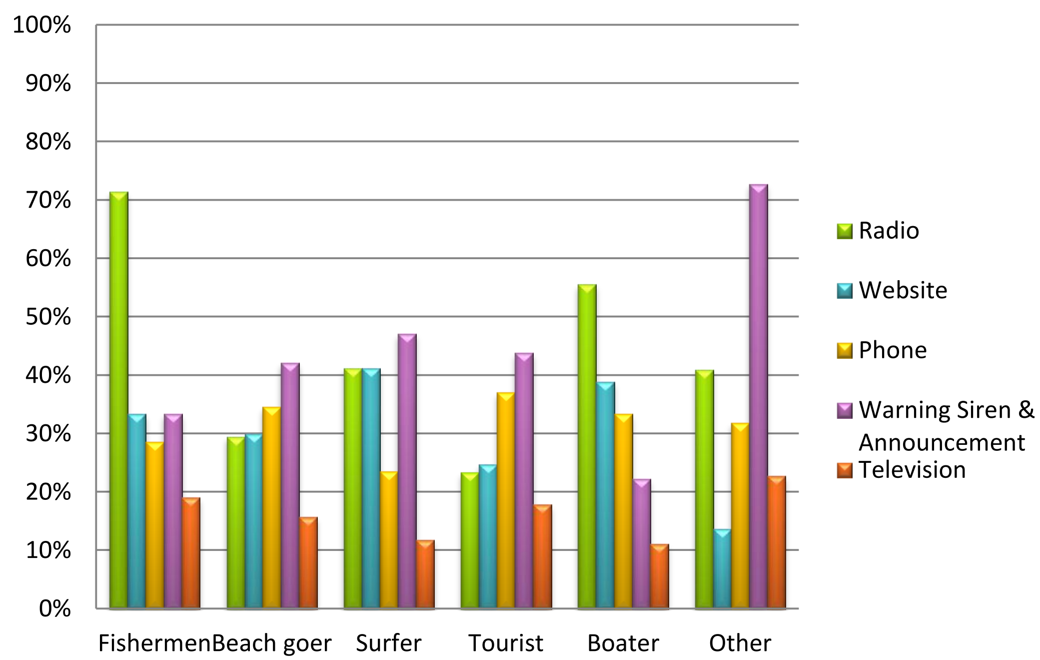

Figure 25: Preferred methods of the general population for receiving coastal information

5.3.2 Survey of Business Owners

To determine the most effective form of media for communicating coastal hazards to business owners, we asked respondents to indicate how they presently receive coastal information. This information is depicted in Figure 26. From this we can see that almost half of respondents use media broadcast, followed by the Internet, thus indicating that these two methods are the most popular.

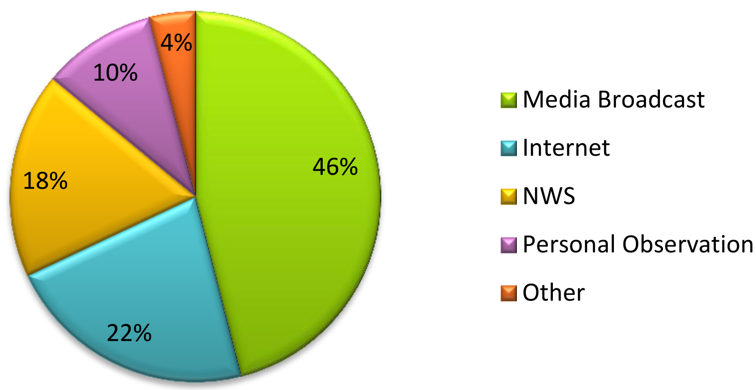

Figure 26: Resources used by businesses to obtain coastal information

Upon closer inspection, we see that the trend is the same when looking at the different categories of businesses individually. As shown in Figure 27, media broadcast is clearly the preferred method with the Internet just surpassing the National Weather Service.

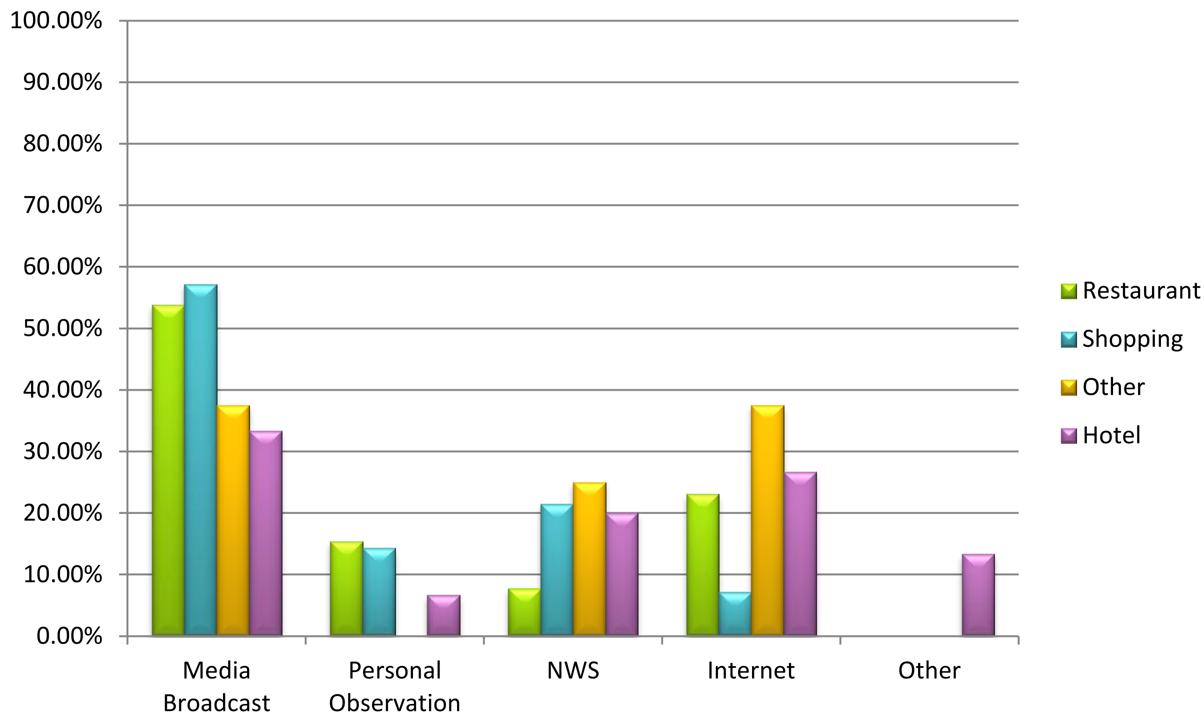

Figure 27: Resources used by different businesses to obtain coastal information

Concerning preferences, all types of businesses would prefer to have warning sirens and announcements implemented as shown in Figure 28. However, the categories of *Radio* and *Other* were the second most preferred method. The *Other* category 89% of the time referred to either television broadcast or newspaper print; therefore, in general a local media broadcast would be the second most effective form of disseminating coastal information to businesses.

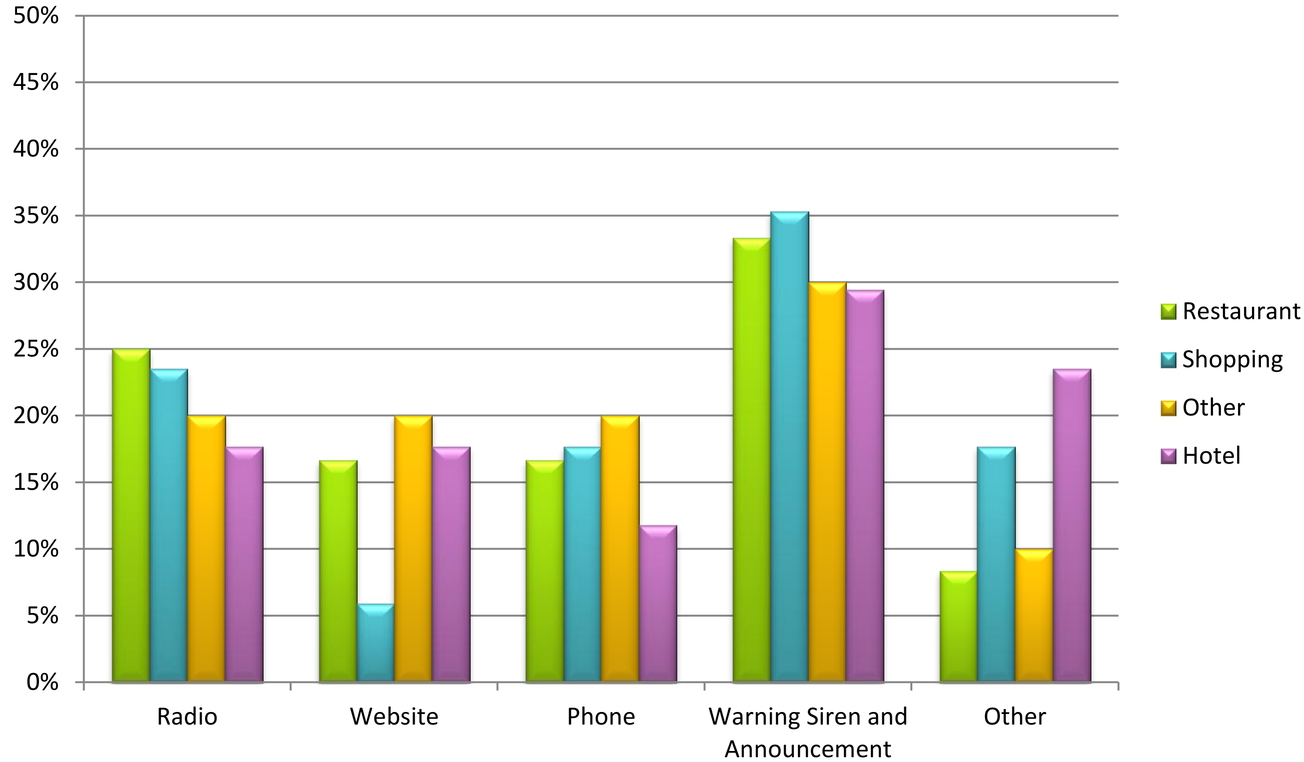

Figure 28: Resources preferred by different businesses to obtain coastal information

6. Conclusions

By sampling experts, we concluded that one of the largest problems within the current communication system is a lack of interdepartmental communication. We found that although there are a variety of agencies with vital information regarding coastal hazards and oceanic conditions, there is little communication between these agencies. The present warning system does not provide a clear method of informing the public. Our research showed that people generally do not know where to turn for information nor do they know all the resources that are made available to them. Of those surveyed, approximately 50% did not know what to do in the event of a coastal hazard and over 50% did not feel well prepared for a coastal hazard

In addition, our research concluded that there is a large gap between the knowledge and preparedness for coastal hazards and oceanic conditions in San Juan. In our opinion, this shows that the disadvantages of the present communication system greatly outweigh the few advantages.

Furthermore, our research showed that the preferred method of both the general population and businesses is a warning siren and announcement, but other methods would also be effective. A warning system through cell phones or the Internet would be a viable option for informing large number of people. Based on our survey, 90% of those older than 17 years use cell phones and 90% of people between the ages of 18-50 have a text messaging plan. This same demographic also has access to the Internet, and 60% of all surveyed have a data plan on their cell phone. Regarding the Internet, 90% of those who use social networking sites have a Facebook account. A social network site like Facebook would be a good approach to reach a large number of residents of varying ages.

After investigating the current views of hazards, the advantages and disadvantages of the systems currently in place, and the most time efficient form of media for informing the public, we concluded that the present communication systems have not been effective in educating the public about the dangers of coastal hazards and oceanic conditions. These systems have also been unable to warn the larger population in the event of such threats. Since the majority of the population is unaware of the efforts put forth by CariCOOS, we have developed several recommendations (see Chapter 7) for CariCOOS in order to more effectively and efficiently communicate these coastal hazards and oceanic conditions.

7. Recommendations

As a result of our data collection, analysis, and conclusions, we have developed a set of recommendations for CariCOOS to improve its communication with the public in regards to coastal hazards and oceanic conditions. Our recommendations fall into two broad categories:

- Inform residents and visitors of coastal hazards, but also educate them about the resources they can use to obtain coastal information.
- Propose a physical warning systems that residents and visitors can rely on in case of dangerous oceanic condition.

While the first category is educational in nature, the second category explores the technical aspects of reaching out to the population at risk.

7.1 Education and Public Awareness

One of CariCOOS's goals is to work in close collaboration with various agencies, private companies, and rely on a number of programs. In doing so CariCOOS develops products that provide "*data visualization of waves, winds, currents, water quality and coastal flooding in real time to the various users of coastal waters such as recreational and commercial fishermen, surfers, swimmers, sailors, students, researchers, government regulatory agencies, and emergency management agencies, among others*". (CariCOOS, 2011a, Education section). However, our research has shown that most people are largely unaware of the products put forth by CariCOOS; therefore, we have the following recommendations.

We recommend that CariCOOS uses local media broadcasts to increase public awareness of the organization's products.

A majority of the general population, including business owners, utilizes local media broadcasts to access coastal information. It would therefore be advantageous to use these resources to educate the public of the CariCOOS products that can be made available to them. The awareness could be raised in the form of CariCOOS sponsored-television commercials and radio advertisements; they could highlight and display the various methods of accessing information, whether it is radio broadcast, social networking, or through one's cell phone.

We recommend that CariCOOS utilize Facebook better to increase its visibility among the general population.

CariCOOS presently utilizes Twitter and Facebook; unfortunately, there are only 16 members of the CariCOOS Facebook group. Our study shows that the majority of the respondents used either Facebook exclusively, or relied on both Facebook and Twitter. Therefore, it would be prudent to extend CariCOOS's use of social networking sites by placing a greater emphasis on its Facebook page. This would enable people to obtain vital safety information that is posted onto the Facebook page as an automatic notification.

We recommend that CariCOOS develop a smartphone application for people to receive daily coastal information.

With the increasing prevalence of smartphones, it would be advantageous for CariCOOS to create an application that is can be universally used across Droids, Blackberry's and iPhones. This application can utilize push notification technology to give users who download this application alerts relative to coastal conditions and new products offered by the organization.

We recommend that CariCOOS use mailing list serves and text message signups to allow people to constantly receive information about coastal conditions.

Another way to target people who desire to get coastal information and utilize CariCOOS products would be to create a space on its website where interested people can input their cell phone number and relevant e-mail address. This list would then serve to alert the general population of new products put forth by CariCOOS as well as provide updates of the present systems. Furthermore, educational information such as evacuation plans and hazard preparedness guides can easily be sent through such e-mail channels.

7.2 Warning Systems

Another goal of CariCOOS is to use the acquired data to provide Caribbean coastal users with information on ocean conditions that support trade and recreation while ensuring the safety of the population and marine environment (CariCOOS, 2011a). However, if the information is not processed in a timely manner, or people do not know where to access it, then CariCOOS fails in its mission to warn the public. Therefore, we have made the following recommendations on improving CariCOOS's warning system.

We recommend that CariCOOS redistribute signs along beaches to inform beach goers and others who utilize the coast.

In travelling to various beaches in the Metropolitan San Juan area, we noticed warning signs in various states of disrepair - whether they were rusting, covered in bushes or simply illegible. A simple way to keep the public alert to dangers is to have scheduled beach sign inspections; these apply especially to those signs that have had suffered from coastal hazards in the past. It is also advisable that these signs display the radio frequency where coastal users can get up-to-date information on coastal conditions and CariCOOS's web address.

We recommend that CariCOOS implement a beach flag system to warn against dangerous oceanic conditions.

Implementing a flag warning system on beaches that are frequently patrolled by police officers or other emergency personnel is one way to alert coastal users in a real time fashion. The flag system would simply employ the colors of red for '*Extremely hazardous conditions. Stay out'*, yellow for *'Caution! Swim at your own risk'* and green for *'Safe waters. Enjoy!'* This is one direct way of providing important information to the public without them having to seek it.

We recommend that CariCOOS promotes the use of sirens and announcements that warn people of the occurrence of tsunamis.

The use of warning siren and announcements along the beach would allow all of Metropolitan San Juan to be alerted in the case of a tsunami. The 15V2T model should be implemented along the coastline from the tip of San Juan to Piñones. This distance was approximated using Google Earth Map Technology; it is 16.3 miles, or 86,064 feet long. As shown in Figure 29, the effective range of the siren is 4,700 feet. Therefore, 13 sirens would need to be placed to maximize each siren's effective range of sound. To determine this number of 13, an isosceles right triangle is used to maximize the hypotenuse. The maximum radius of the sirens' effective range is represented by the hypotenuse of the triangles or the distances from the red dots to the white dots. The maximum distance of each leg is then calculated to be 3,323.4

feet. Thus, the maximum distance the sirens can be placed from the coastline is 3,323.4 feet, and the sirens can be a maximum distance of 6,626.8 feet from each other.

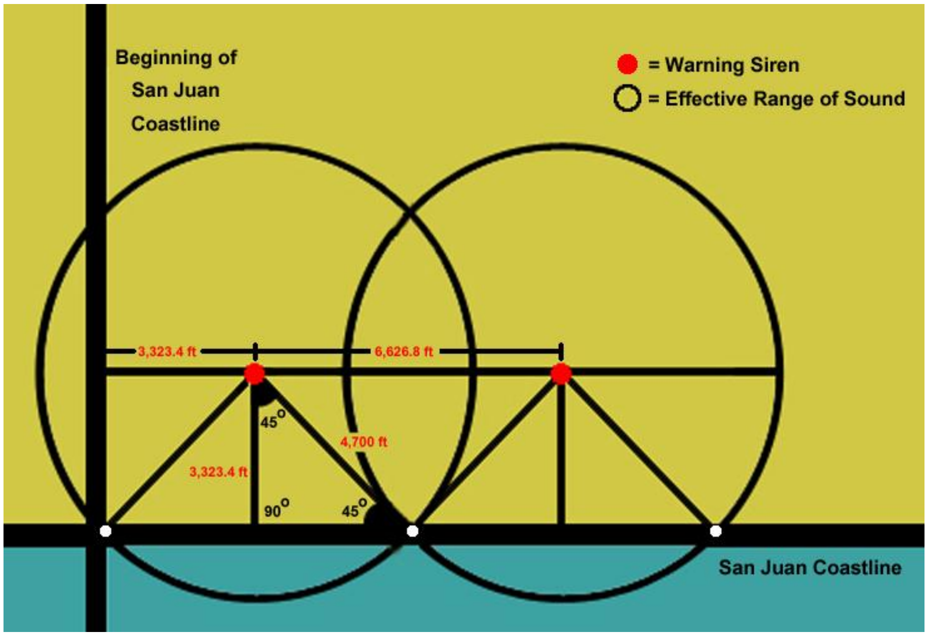

Figure 29: Calculations of optimal placement of 15V2T sirens along the San Juan Metropolitan coastline

However, since the coastline is 86,064 feet in length and cannot be evenly divided by the maximum distance, we recommend that the siren be 3,073.7 feet from the beginning and the end of coastline, i.e., 3,323.4 feet away from the coastline, and 6,147.4 feet apart from each other. A diagram of how the sirens may be placed along the coastline is seen in Figure 30. The minimum cost of these 13 sirens would total $94,250.

Figure 30: Possible placement of the thirteen 15V2T sirens along the San Juan Metropolitan coastline

CariCOOS could propose to the government that businesses that affix such systems to their establishments receive a business tax reduction or rebate since they would actively assist in enhancing public safety. These businesses may also benefit from a special insurance discount; people who are sufficiently warned of a coastal hazard will not likely sue the establishment for negligence.

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Appendix A: Interview Protocol for Experts

Sea Grant

1. What is your role in the dissemination of information when there is a coastal hazard?
2. What is the chain of communication among agencies that deal with coastal zone management?
    a. What is the time frame for information to reach each agency and the public?
3. How effective do you think the present system for communicating coastal hazards works? Do you believe there are any flaws with the system?
4. How could the system be improved?

National Weather Service - NOAA

1. How do you communicate coastal conditions to local emergency management offices?
    a. What is the time frame for information to reach each agency and the public?
2. Do you distribute warnings for storm tides, storm surges, tsunamis, and water pollution? If so, how?
3. What is the chain of communication when a hazard occurs among agencies that deal with coastal zone management?
    a. What is the time frame for information to reach each agency and the public?
4. How effective do you think the present system for communicating coastal hazards works? Do you believe there are any flaws with the system?
5. How could the system be improved?

Puerto Rico Seismic Network – PRSN

1. What information is distributed among the 13 broadband stations and 10 short period stations throughout PR and the U.S. Virgin Islands?
    a. How is the information distributed?
    b. Is it efficient?
2. How does the Early Bird Warning System (EBS) monitor the PRSN and the 35 other stations around the Caribbean?
    a. How accurate is your dissemination system?
    b. Once an event is detected, how and where is it automatically dispersed through the internet?
    c. Is the information dispersed to PRSN personnel through cell phone or pagers?
    d. What are the flaws of the system?
    e. How can it be improved?

Appendix B: Questionnaire

Survey Preamble

Hello! We are students from Worcester Polytechnic Institute in Massachusetts conducting a survey as part of a university project. This questionnaire asks about your use of the coast and how you would like to receive information about coastal hazards and oceanic conditions. The purpose of this survey is to collect valuable information from coastal inhabitants and users in order to enhance communication. Our project is being sponsored by the DNER. Our project team wants you to feel comfortable, so all responses are confidential. No names or identifying information will appear on the questionnaires or in any of the project reports, presentations or publications. While your participation is greatly appreciated, please note this survey is completely voluntary and you may withdraw at any time. We hope you will join us in improving Puerto Rico's coastal management by taking this brief questionnaire.

Questionnaire

Please indicate which best describes you.

Sex: □ Male □ Female

Age: □ 17 and under □ 18 – 25 □ 25 – 35 □ 35 – 50 □ 50 and over

Language (Check all that apply): □ English □ Spanish □ Other Specify ___________

1. **What is the primary way you use the coast?**
   a. Fisherman b. Beach goer c. Surfer d. Tourist e. Boater

   f. Other ____

2. **How often do you use the shore?**
   a. More than once a day b. Daily c. Every couple of days

   d. Weekly e. Bi-weekly f. Not Often. Specify________

3. **Have you ever been affected by any one or more of the following:**
   a. coastal flooding b. storm tide c. undertow d. water pollution

   e. storm surge f. Other ____

4. **If so, please describe your experience.**

   ____

   ____

5. **Were there warnings issued while this was taking place?**

   Yes No

   Explain: ____

6. **What resources have you used to obtain information about daily coastal conditions?**
   a. Radio b. Television c. Newspaper d. Cell Phone

   e. Internet f. Word of Mouth g. Other ________________________

7. **Was the resource easy to access?**

   Yes No

   Explain: ____

8. Was the resource's message easy to understand?

Yes No

Explain: ____

9. Do you have a cell phone?

Yes No

a. **Do you have a text messaging plan?**
   Yes No
b. **Do you have a data plan?**
   Yes No

10. Do you have access to the internet?

Yes No

11. If yes, how often do you access it?

a. More than once a day b. Daily c. Every couple of days

d. Weekly e. Bi-weekly f. Not Often. Specify________

12. Do you use social networking sites? E.g. Twitter, Facebook, MySpace

Yes No

a. **If so, which one? ________________________________**

13. What would be your preferred/ideal method for receiving coastal warnings?

a.
b. Radio b. Website c. Phone d. Warning Siren and Announcement
e. Other ___________________________

14. Please rate the following statements:

I feel well prepared for a coastal hazard.

Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
☐	☐	☐	☐	☐

I know what to do if there is a coastal hazard.

Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
☐	☐	☐	☐	☐

Apéndice C: Cuestionario

Encuesta Preámbulo

¡Hola! Somos estudiantes del Instituto Politécnico de Worcester en Massachusetts y estamos haciendo una cuesta como parte de un proyecto de la Universidad. Este cuestionario le pregunta sobre su uso de la costa y cómo le gustaría recibir información acerca de los peligros y las condiciones oceánicas. El propósito de esta encuesta es recoger información valiosa de los la costa y los usuarios para mejorar la comunicación. Nuestro proyecto está siendo patrocinado por el DRNA. Nuestro equipo del proyecto quiere que se sienta cómoda (o), así que todas las respuestas son confidenciales. Los cuestionarios son totalmente confidenciales y su nombre no será utilizado en los informes de proyectos, las presentaciones o publicaciones. Su participación es muy apreciada, y tenga en cuenta de que esta encuesta es completamente voluntaria, por lo que puede retirarse de la misma en cualquier momento. Esperamos que nos ayude para mejorar la gestión costera de Puerto Rico mediante su participación en este breve cuestionario.

Cuestionario

Por favor, indique que mejor lo describe.

Sexo: □ Hombre □ Mujer

Edad: □ Menores de 17 años □ 18 – 25 □ 25 – 35 □ 35 – 50 □ Mayores de 50 años

1. **¿Para qué mayormente utiliza la costa?**
   a. Pescar b. Recreación c. Surfist d. Turista e. Pasear en barco

   f. Otra ____

2. **¿Con qué frecuencia utiliza usted la costa?**
   a. Más de una vez por día b. Diariamente

   b. Cada par de días d. Semanalmente e. cada dos días

   e. Muchas veces no. Especificar____________________

3. **¿Ha sido afectado usted por cualquiera de las siguientes alternativas?**
   a. Inundación costera b. oleaje debido a tormenta c. resaca
   d. polución del agua e. rompimiento de olas debido a una tormenta
   f. Otro ________________________________
4. **En caso afirmativo, por favor describa la experiencia.**

   ____

   ____

5. **¿Fueron advertidos cuando esto sucedió?**

   Sí No

   Explique, por favor ____

6. **¿Qué recurso utiliza para obtener información sobre condiciones costeras a diario?**
   a. Radio b. Televisión c. Periódico d. Teléfono celular

   e. La red f. se entera por otra persona g. Otro _________________

7. **¿Es fácil tener acceso a información sobre las condiciones costeras?**

   Sí No

   Explique, por favor
   ____

8. ¿Es fácil comprender esta información?

Sí No

Explique por favor ____

9. ¿Posee un teléfono celular?

Sí No

a. ¿Tiene un plan de mensajes de texto?
Sí No

b. ¿Tiene un plan de data?
Sí No

10. ¿Tiene acceso al Internet?
Sí No

11. Si contesta afirmativamente, ¿Con qué frecuencia le hace lo utiliza?

a. Más de una vez por día b. Diariamente
c. Cada par de días d. Semanalmente e. Cada dos días
f. Muchas veces no. Especificar____________________

12. ¿Utiliza sitios sociales en la red? Por ejemplo, Twitter, Facebook, MySpace
Sí No

a. ¿Cuál (es)? _____________________________________

13. ¿Cuál es su manera preferida, o ideal, para recibir sus advertencias costeras?

a. Radio b. Sitio Web c. Teléfono
b. d. la sirena de advertencia y el anuncio e. Otra __________________________

14. Por favor califique las siguientes afirmaciones:

Me siento bien preparado para un peligro costeras.

Totalmente en Desacuerdo	Desacuerdo	Ni Acuerdo ni Desacuerdo	Acuerdo	Totalmente de Acuerdo
☐	☐	☐	☐	☐

Yo sé qué hacer si hay un peligro en la costa.

Totalmente en Desacuerdo	Desacuerdo	Ni Acuerdo ni Desacuerdo	Acuerdo	Totalmente de Acuerdo
☐	☐	☐	☐	☐

Appendix D: Questionnaire for Business Owners

Survey Preamble

Hello! We are students from Worcester Polytechnic Institute in Massachusetts conducting a survey as part of a university project. This questionnaire asks about your use of the coast and how you would like to receive information about coastal hazards and oceanic conditions. The purpose of this survey is to collect valuable information from coastal inhabitants and users in order to enhance communication. Our project is being sponsored by the DNER. Our project team wants you to feel comfortable, so all responses are confidential. No names or identifying information will appear on the questionnaires or in any of the project reports, presentations or publications. While your participation is greatly appreciated, please note this survey is completely voluntary and you may withdraw at any time. We hope you will join us in improving Puerto Rico's coastal management by taking this brief questionnaire.

Questionnaire

Please indicate which best describes you.

Type of business

□ Restaurant/Bar □ Shopping □ Hotel □ Other ____________________

1. **How do you receive coastal warning information?**
   □ Local Media Broadcast (i.e. radio, television, etc.) □ Personal Observation

   □ National Weather Service or other warning service □ Internet

   □ Other. Specify______________________________

2. **Has your business ever been affected by any one or more of the following:**
   a. coastal flooding b. storm tide c. undertow d. water pollution

   e. storm surge f. Other ____

3. **If so, please describe your experience.**

   ____

   ____

4. **Were there warnings issued while this was taking place?**

   Yes No

   Explain: ____

5. **What would be your preferred/ideal method for receiving coastal warnings?**

   b. Radio b. Website c. Phone d. Warning Siren and Announcement
   e. Other ______________________________

6. **Please rate the following statements:**

I feel well prepared for a coastal hazard.

Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
☐	☐	☐	☐	☐

I know what to do if there is a coastal hazard.

Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
☐	☐	☐	☐	☐

Appendix E: Interview Transcripts

Interview with Cristina Olán of Sea Grant
March 21, 2011 at 11:30 am

How long have you been working at Sea Grant?

I have been working at Sea Grant for almost four years. I began working part time as a Spanish editor and then in January 2010 I began working full time.

How many years of experience do you have as the Communications Coordinator?

I have been the Communications Coordinator since January 2010 when I began working full time.

1. **What is your role in the dissemination of information when there is a coastal hazard?**

   Sea Grant has three branches - research, outreach, and education - that each plays a different role in coastal management. My position falls under the outreach branch but our information is received from the research branch. Our information is disseminated through various outlets including magazines, videos, scientific illustrations, Facebook, and Twitter. A potential person to contact in regards of coastal hazard information disseminated would be Aurelio Mercado. His email is aurelio.mercado@upr.edu and his phone number is (787) 832 – 4040 ext. 5461.

2. **What is the chain of communication among agencies that deal with coastal zone management?**

   Sea Grant works with numerous agencies involved in coastal zone management including the Caribbean Fisheries and Management Council, Fish and Wildlife Service, Planning Board, Environmental Quality Board, Department of Natural and Environmental Resources, a climate change education program at the University of Puerto Rico, Enlace, Science for Conservation of Puerto Rico, Conservation Trust, and Scubadogs. There is also the Interdisciplinary Center of Coastal Studies, a part of Sea Grant, which works with coastal communities. Two people to contact would be Lilian Ramirez who works with coastal communities in Mayaguez and Dr. Manuel Valdes, whose email address is valdespiccini@gmail.com or manuel.valdes@upr.edu. Between all these organizations, information is shared through email, phone, Facebook, Twitter, meetings and workshops.

a. **What is the time frame for information to reach each agency and the public?**

Information is shared in a timely manner. There are annual workshops to share information, but it can also be done on a case by case basis. Sea Grant also has an Advisory Council that meets twice a year to make a recommendation on what should be accomplished at that time. As far as information published by Sea Grant, our Twitter page is updated at least twice a week and our magazine *Marieja* (Search) is published twice a year. The publication is announced through our YouTube channel, on the television, and over the radio. For information disseminated after coastal disasters, you may want to contact Aurelio Mercado.

3. **How effective do you think the present system for communicating coastal hazards works?**

I believe the present system is effective.

4. **Do you believe there are any flaws with the system?**

Although I believe the system is effective, I also think there are flaws with the system. Unfortunately, I cannot think of an example of a flaw to describe.

5. **How could the system be improved?**

Since I cannot think of a flaw, I also cannot think of a way to improve the system. We have such a diverse audience which includes people who do not use technology, so we want to reach as many people as possible. We are currently looking into having a program on live television instead of just our YouTube channel.

Interview with María E. Font of Sea Grant
March 23, 2011 at 10:00 am

How long have you been working at Sea Grant?

This is my third year working at Sea Grant.

How many years of experience do you have as the Information Specialist Marine Education and Information Resource Center?

I have always held the same position. It encompasses a lot of tasks including translating, editing and reviewing information.

1. **What is your role in the dissemination of information when there is a coastal hazard?**

   I give information to anyone who requests it, for example students or professors at the different universities. I provide different resources, including publications from the 29 coastal states.

2. **What is the chain of communication among agencies that deal with coastal zone management?**

   We collaborate with many agencies including all those under NOAA and we have a link with the Caribbean Fishery Management Council. Between these agencies we communicate through fax, calls, and emails.

   a. **What is the time frame for information to reach each agency and the public?**

      The time frame varies depending on what information they are requesting and what is available.

3. **How effective do you think the present system for communicating coastal hazards works?**

   I believe the current system is effective.

4. **Do you believe there are any flaws with the system?**

   There are flaws with the system that need to be addressed "people are going to do whatever they please" if there is an emergency. For example, the tsunami drill should have been organized better. There weren't any signal lights and there were traffic jams in the parking lot. Mayagüez also lacks a local communication network to meet and collect information, like the one in San Juan.

5. How could the system be improved?

The system could be improved by having communication start with government. For example, a new school was just built near the Mayagüez port even though that's a tsunami prone sector. The government should stop giving permits to construction like this.

Interview with Walter Snell of the National Weather Service
March 25, 2011 at 10:30 am

How long have you been working at the NOAA?

I have been working for the NOAA since March 1988.

How many years of experience do you have as the Senior Forecaster?

I have been in this position since February 2003 when I moved to San Juan, Puerto Rico.

1. **How do you communicate coastal conditions to local emergency management offices?**

   We use products to relay local coastal information. These products are evaluations of all the models, including SLOSH. There is also the Coastal Weather Forecast that can be updated for unusual events. It appears in a graphical form for wave height and in a text form that can be found by clicking on the map. However, this data is general and uses ranges so specific wave heights cannot be determined. There is also the NOAA Weather Radio which covers most of the island.

   a. **What is the time frame for information to reach each agency and the public?**

      Each event has a different time frame. For example, a tsunami would be immediate and the transmission would most likely from West Coast/Alaska Tsunami Center, whereas storm tides and storm surges would be communicated in a coastal flood watch.

2. **Do you distribute warnings for storm tides, storm surges, tsunamis, and water pollution? If so, how?**

   We distribute information for all those conditions except water pollution.

3. **What is the chain of communication when a hazard occurs among agencies that deal with coastal zone management?**

   Warnings are issued from NWS and then picked up by emergency management agencies and anyone else who is interested. We use a "pull" approach as opposed to "push", so if someone wants our information they will have to look for it. The Internet is most effective way to get information from NWS, but people can also sign up for cell phone alerts. However, the NOAA Weather Radio is a "push" method that we offer.

a. **What is the time frame for information to reach each agency and the public?**

   It is the responsibility of each agency to get information from the NWS, so the time frame may differ based on their resources. If people do not have radio or Internet, they may never get the information and the warnings are usually delayed in getting televised.

4. **How effective do you think the present system for communicating coastal hazards works?**

   I believe the present system is effective for people with resources, such as radio, television, and internet.

5. **Do you believe there are any flaws with the system?**

   Yes, I believe the main flaw is that people who live in the projects or poor communities cannot get our resources unless they are in a tsunami or storm ready community that has sirens and other warning methods.

6. **How could the system be improved?**

   I believe that the television and radio warnings could be more immediate. For example, the warning crawlers that appear on the bottom of the television do not appear regularly and some radio stations will not play warnings messages. In the case of the tsunami warning on March 23rs, some test messages did not go out until 12 hours after the initial warning, but everyone who had a radio should have received the warning at some point.

Interview with Ed Tirado of the National Weather Service
March 25, 2011 at 11:00 am

How long have you been working at the NOAA?

I have been working for the NOAA since 1990.

How many years of experience do you have as the Information Technology Officer?

I have been in this position for four years.

1. **How do you communicate coastal conditions to local emergency management offices?**

   We communicate by phone and through products that relay information to local offices. We usually send coastal hazard messages for large swells in the north side of the island since hurricanes most often come from the south side.

   a. **What is the time frame for information to reach each agency and the public?**

      If there is a large event, we can see this days ahead of time and will usually advertise the event 3-5 days in advance. We will also contact emergency management agencies at least 48 hours in advance of a big event. All products are issued at the same time and those on the Internet are instantly available.

2. **How effective do you think the present system for communicating coastal hazards works?**

   I believe the current system is effective, but more so for large events rather than short ones.

3. **Do you believe there are any flaws with the system?**

   Yes, I believe the greatest flaw with the system is in regards to language. We serve both Puerto Rico, whose primary language is Spanish, and the U.S. Virgin Islands, which speaks English. Warnings are issued first in English and then translated to Spanish, so there is a break in time from when the message is issued to when most people actually receive the warning. There is a dilemma in which language the message should be broadcasted in first since English is required but 95% of the population of Puerto Rico speaks Spanish.

4. **How could the system be improved?**

   The system could be improved by making communication more direct. There should be a hotline for emergency managers and others involved in hazard warning and mitigation so everyone can be called at the same time and share information.

Interview with Ruperto Chaparro of Sea Grant
March 28, 2011 at 10:30 am

How long have you been working at Sea Grant?

I have been with Sea Grant for 24 years.

How many years of experience do you have as Director?

I have been the Director for 6 years.

1. **What is your role in the dissemination of information when there is a coastal hazard?**

   Sea Grant is committed to providing education, research, and services on coastal hazards. We also have Aurelio Mercado, a specialist in coastal hazards. I believe we are the leaders for researching and educating about hazards in Puerto Rico.

2. **What is the chain of communication among agencies that deal with coastal zone management?**

   Since Puerto Rico has not been struck with a major hurricane or tsunami in about 100 years, we focus more on educating people about resiliency and promoting sustainable development of resources in coastal areas. If a hazard were to occur, we would be ready to help and contact emergency management agencies, but other organizations are in charge of responding to hazards.

3. **How effective do you think the present system for communicating coastal hazards works?**

   I do not believe the current system is very effective and there is a lot of room for improvement. Most agencies involved in coastal hazards work top-down and there is a gap in communication. We recently spoke to four coastal communities in Mayagüez and found that their evacuations routes went through flood prone areas. We set up an activity with these communities and hazard management agencies so they could communicate and express their concerns.

4. **How could the system be improved?**

   This system could be improved if the Department of Natural and Environmental Resources, Planning Board, and Environmental Quality Board stopped granting permits for construction in coastal areas and maritime zones. Recently, school, condominiums, and roads have been built in vulnerable coastal areas. The government does not recognize the risks of hurricanes, tsunamis, and floods and if a major disaster were to occur, they would be responsible for allowing development in these areas.

Interview with Lillian Soto of the Puerto Rico Seismic Network
April 12, 2011 at 4:00 pm

How long have you been working at the PRSN?

I have been working for the PRSN for three years, but I also worked at the PRSN as a student before I went for my Master's Degree in California.

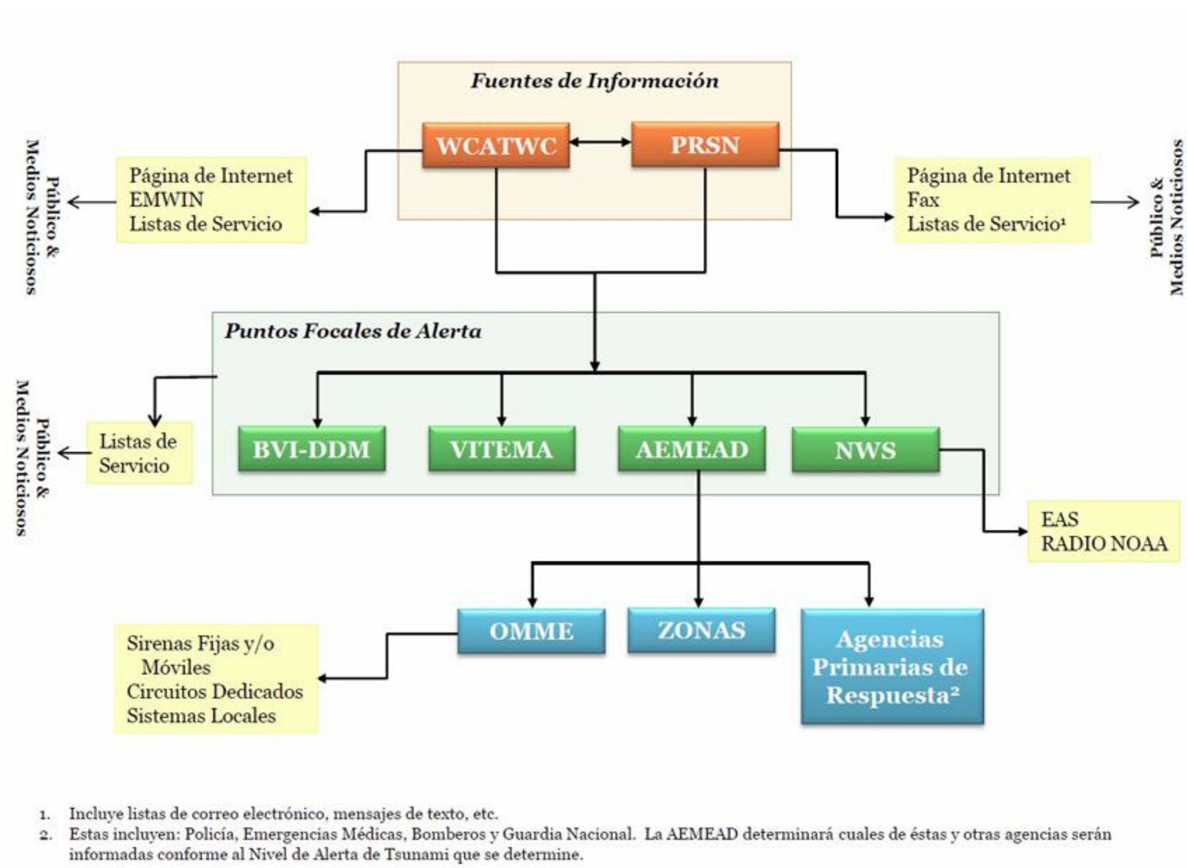
How many years of experience do you have as the Chief Geophysical Data Analyst?

I have been in this position since the PRSN began providing 24 hour service.

1. **What information is distributed among the 13 broadband stations and 10 short period stations throughout PR and the U.S. Virgin Islands?**

   If you look at the following flow chart, which will soon be translated into English, it shows the how information is distributed from the PRSN to the public.

Diagrama de Flujo de Información



http://redsismica.uprm.edu/Spanish/tsunami/media/flujograma.jpg

a. **How is the information distributed?**

The sources of information (orange boxes) are the West Coast Alaska Tsunami Warning Center (WCATWC) and the PRSN. We provide real-time seismic monitoring and can determine a tsunami alert level within five minutes of the initial earthquake reading. We provide information to the Alert Focal Points (green boxes) which include the British Virgin Islands Department of Disaster Management (BVI-DDM), U.S. Virgin Islands Emergency Management Agency (VITEMA), the Puerto Rico State Emergency Management Agency (AEMEAD), and the National Weather Service (NWS) through webpages, fax, email, and texts. These focal points are then responsible for activating internal processes to give information to the public. They provide information to the blue boxes which are the Municipal Office of Emergency Managers (OMME), the different regions of the island (ZONAS), and the Primary Response Agencies (Agencias Primarias de Repuesta) which include police, fire, and medical personnel as well as the National Guard. We have no control of this part of the flow chart, out responsibility is just to provide information to the focal points.

b. **Is it efficient?**

Our system is efficient because we have a partnership with the WCATWC. This provides redundancy if one of us cannot get information out. Our website also provides listings for earthquakes greater than a 3.5 and all tsunamigenic events. People can subscribe to our mailing list for free or sign up to receive texts for tsunamigenic events. All these products are sent out in both English and Spanish instantaneously.

2. **How does the Early Bird Warning System (EBS) monitor the PRSN and the other stations around the Caribbean?**

Between Puerto Rico and the U.S. Virgin Islands there are 25 seismic stations, but we monitor over 100 stations around the Caribbean and the rest of the world. Even if an even occurs outside the Caribbean it can still have an effect on Puerto Rico. There are also 17 tide gage stations operated by the PRSN and NOAA located throughout the Caribbean and Atlantic Ocean.

a. **What are the flaws of the system?**

A flaw within the system is that it can take longer for information to disseminate than for a tsunami to hit the island. For example, in 1989 a tsunami hit Puerto Rico within five minutes of the earthquake. If people are on the coast and see an earthquake, they immediately need to evacuate.

b. **How can it be improved?**

We are constantly improving our system. For example, during an earthquake last year our webpage went down because our server couldn't handle the amount of hits. We now have three servers in order to manage the amount of people that use the webpage. However, although this was a problem it also means that people are familiar with our products.

3. **How efficient was the tsunami drill that occurred on March 23rd?**

The information for the tsunami drill was properly disseminated to the focal points but the communication after that is where there were problems. We provided the scientific information, but the focal points need better mechanisms to make this information available to the public. At the PRSN there are two people who are monitoring 24 windows of data at a time. Our focus is to monitor information and then this information must be disseminated by our partners.

People also need to be better informed on how they are going to receive the information and be proactive. People in Puerto Rico are now proactive with hurricanes and this needs to happen with tsunamis. We have improved a great deal in the last ten years, but there is still work to do.

Interview with Aurelio Mercado of Sea Grant
April 13, 2011 at 9:00 am

How long have you been working at Sea Grant?

Aside from being a professor at the University of Puerto Rico, I have been working with Sea Grant for at least 15 years.

How many years of experience do you have as the Coastal Hazards Specialist?

I have always had the same position within Sea Grant.

1. **What is your role in the dissemination of information when there is a coastal hazard?**

   I give talks throughout the island and interviews with the press. I also provide research on tsunamis and storm surges and prepare inundation maps. I advocate for public beaches and give talks about the privatizations of beaches and the maritime zone.

2. **What is the chain of communication among agencies that deal with coastal zone management?**

   Agencies that deal with coastal zone management will only communicate with one another if something is proposed that they are in favor of. If an idea is proposed that is against different agency's wishes then there will be no communication. There is a bias for developers in government administrations. For example, in Isla Verde there is interest to build a hotel on a portion of the shoreline that has been seriously eroded.

   a. **What is the time frame for information to reach each agency and the public?**

      Puerto Rico does not have one agency that deals specifically with coastal hazards so there isn't a time frame. The State Emergency Management Agency (SEMA) is uniformed and doesn't have the slightest idea about climate change and coastal hazards. Most of its employees are friends of current politicians who come and go with new administrations so they are not invested in the problems associated with climate change and coastal hazards.

3. **How effective do you think the present system for communicating coastal hazards works? If not, what are the flaws associated with the current system?**

   I believe the present system is very ineffective. I was at a conference yesterday discussing the Puerto Rico Coastal Zone Management Program (PRCZMP). Part of that program is under the Department of Natural and Environmental Resources (DNER) while the other portion is under the control of the Planning Board. The part under the Planning Board doesn't care about sustainable coastal development while the part under the DNER is composed of well-informed scientists who cannot speak out on these issues. Their statements must come from the Secretary of the DNER who is under the payroll of the developers.

We need a way to bring the issue of climate change and coastal hazards to the politicians. Currently, the government is using FEMA flood insurance maps to estimate flooding due to storm surges from a hurricane. However, these maps are extreme underestimates and are accurate only for a Category 2 hurricane. If a Category 4/5 hurricane were to hit the island, many communities not included in the FEMA maps would be completely underwater. Since a hurricane hasn't hit Puerto Rico since 1928, a sense of complacency has hit the island. I think the only way the government will listen is if a large coastal hazard hits the island.

4. How could the system be improved?

In order to improve the system, the PRCZMP should be given to the University of Puerto Rico Sea Grant. Currently there is a federal law stipulating the current arrangement, but the NOAA is wasting money on the PRCZMP because the program is essentially nonexistent in the current situation. The program needs to come out of governmental hands.