

Public Risk Interpretation and Community Resilience Planning: A Case Study in

Aberdeen, Washington

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Abstract

There has been little empirical study of how emergency planners, the public at large or even scientists from different disciplines understand and use various representations of hazards to communicate risk for disaster preparedness. Yet effective communication is the critical component that helps communities understand, prepare for, respond to, and recover from emergencies. One example of this is preparing for an earthquake and tsunami event. The most common way of talking about earthquake safety to the public has been through universal deterministic models that use crisp, clear lines to designate regions at differing degrees of risk. A community outreach workshop was conducted in the coastal city of Aberdeen to understand how individuals interpret and use hazard information for short and long term planning, using a new interactive mapping technology referred to as WeTable. Twelve residents attended and separated into groups that differed in the hazard map content they received (deterministic or probabilistic) and the planning context for their task (asset-based or hazard-based) with responses recorded to observe patterns. No significant differences in the deliberations of groups associated with the hazard map content they received but context influenced group deliberations, with asset-based planning groups able to look past the initial realization of all their services being within the inundation zone to consider what their new normal might look like. Whether that be completely rebuilding or establishing a new community on underused land, bordering other cities in the region. The notes from round three in each of the vulnerability-focused groups saw that the only mentioning of the long term was in contemplations of whether or not the city could, or should rebuild. Although this study can only provide limited qualitative insights, findings

suggest that contrary to some fears, providing probabilistic information may not adversely affect planning. Findings also imply that future hazard mitigation and community planning efforts could be improved by using an asset-based approach to planning, in order to create risk-prepared, resilient communities. As well as incorporating interactive technology, such as the WeTable, to help community participants be more a part of the planning efforts in their cities.

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Chapter 1: Introduction

Community emergency preparedness planning is a process through which societies acquire hazard information in the pursuit of building capacity to mitigate the economic, social and environmental consequences that hazards can cause. On average coastal communities are confronted with a higher prevalence of natural hazards, which often includes earthquake tsunami events. Most of the time educating communities for preparedness, response and recovery is conveyed through deterministic Tsunami Hazard Maps (THM) that display zones of inundation through crisp, clear lines. Complex modeling that assesses spatial and temporal details of the tsunami source, tidal stage, vulnerable bathymetry, topography, underground landslides and seismic uplift (Goda & Song 2012) are crucial to creating these maps but scientific uncertainties are inherent in modeling each of these. Yet such uncertainties are not often represented in tsunami hazard maps. Decisions that are made based on information portrayed in visual representations of risk hold real world significance economically and socially. Further, due to the impossibility of creating visuals with complete confidence, it could be argued that uncertainties should be conveyed at each stage in the risk management process (Roth 2009).

Along with this, the conventional use of hazard maps in community education follows a very direct protocol of presenting a hazard scenario and associated community vulnerabilities, followed by a discussion of mitigation and response strategies, in hopes of coming up with disaster planning solutions (see Appendix A for Tsunami Hazard Mapping 2015 write up). The National Mitigation Framework, created by FEMA in 2013, [pg 3] describes effective mitigation against risk as identifying the

threats and hazards a community faces and determining the associated vulnerability and consequences (FEMA 2013). The framework applies the concept of risk to a broad range of threats including natural hazards, biological hazards, technical hazards and terrorism. Applied to a natural hazard like an earthquake tsunami event, vulnerabilities and consequence refers to the social, natural and built aspects of a community that are threatened by the event. However, there is an interest by agencies, such as FEMA, to alter the traditional approach to emergency and disaster preparedness planning in order to create a more risk minded culture. For example, contrary to identifying the vulnerabilities and then creating a response plan, an asset-based approach begins with taking an inventory of built, social and natural assets, and, after analyzing the hazard scenario, identifying the assets that could facilitate adaptive community planning (Freitag et al. 2015).

This thesis centers around ongoing efforts by an interdisciplinary team associated with the University of Washington researching the risks of earthquake and tsunami events, and related planning and risk mitigation, in this case Cascadia Subduction Zone earthquake events, for coastal communities of Washington. An advance design studio was organized for the winter quarter 2016, recruiting the assistance of urban design and planning students to carry out research endeavors through a community workshop in the city of Aberdeen WA. During the months of January and February, I reviewed literature on key concepts of emergency preparedness, hazard mitigation, adaptive planning, resilience, risk and uncertainty in hazard information in preparation for the workshop. The workshop was conducted on

February 11 in Aberdeen. The data collected were used in the subsequent weeks to inform students design work. I transcribed notes, organized the data into tables, and presented an overview of the workshop and studio in the month of March to reviewers at the University of Washington. I wrote up the literature review and overview through the months of April and May with conclusions I arrived at, organized and written in June.

International efforts to mitigate and educate coastal communities of the impacts of earthquake tsunami events gained momentum after a series of tsunamis struck the coast of Alaska and Chile in the 1960's (Bernard et al. 2005). This led to the establishment of The Pacific Tsunami Warning Center (PTWC) in Hawaii as a tool to disseminate data and warnings to coastal communities. Tsunami researchers faced significant obstacles in trying to assess and inform the mitigation of associated damage and loss. For one, the occurrence and behavior of tsunamis was still largely unknown by the public and seismic scientists.

A string of occurrences in the 1990's elevated awareness of tsunamis as over 4800 people died from 11 destructive events (Bernard et al 2006). Before this, the United Nations had declared 1990-2000 the International Decade of Natural Disaster Reduction recognizing the importance of reducing the impact of natural disasters for all people.¹ The destruction of the built environment and loss of people raised concerns about U.S. tsunami preparedness in particular. According to an academic paper written by E.N. Bernard (2004) The U.S. Appropriations Committee, in reaction to two, recent tsunamis, directed NOAA to form and lead a Federal/State working group to develop an

¹ UNISDR--History. <https://www.unisdr.org/who-we-are/history>

action plan to address tsunami mitigation based on twelve recommendations from three tsunami workshops hosted by NOAA that discussed hazard assessment, warnings and education. The National Tsunami Hazard Mitigation Program was established as a result (Bernard et al. 2006).

Around this time, an interdisciplinary effort was launched to help the entire Cascadia Region plan for earthquakes and become more resilient to risks from the Cascadia Subduction Zone related hazards. This non-profit coalition is known as the Cascadia Region Earthquake Workgroup (CREW) and, continues to host meetings and workshops to produce resources for communities in the form of information and expertise.

Since, many efforts have been made that are similar in nature to the goals of the CREW. In 2009, increasing awareness of the vulnerability of Washington coastal communities to a magnitude 9+ Cascadia earthquake and tsunami by seismic scientists spurred interest from county and state emergency management officials. Recognizing that large coastal communities were at high risk, a community driven process for identifying potential evacuation solutions was organized. Specifically, state and county emergency managers were interested to know how local communities could use new models with earthquake and tsunami hazard information for immediate life safety as well as long-term land use planning. Project Safe Haven was the first of its kind that focused on developing strategies for vertical evacuation. Four coastal communities in Pacific county, WA were approached and asked to discuss strengths and weaknesses of different vertical evacuation options and, using interactive hazard maps, identify locations for them. The public process was transparent and inclusive from beginning to

end; comprising multiple community meetings and charrettes to ensure the structures would fit in with the context of each community.

Project Safe Haven used grassroots public processes in coastal communities but up to that point, few ventures explored alternate research approach for talking about and preparing for a possible earthquake tsunami risk. In 2013-2014 students and staff from the University of Washington undertook further community-based research to demonstrate how both mitigation and recovery planning can benefit from incorporating general land use and community planning goals for everyday betterment (Freitag et al. 2015). The city of Redmond focused on the Seattle Fault Line, Everett considered an earthquake along the Whidbey Fault and Neah Bay discussed a Cascadia Subduction zone earthquake. Alternative research approaches to the conventional hazard mitigation and pre-disaster recovery planning process were explored to see if they steered participants towards more adaptive strategies that promoted human wellbeing (HWB). Discussion de-emphasized the specifics of the risk scenario itself and, instead, compared the goals of the comprehensive plan with mitigation and recovery strategies to not just, come up with solutions to address one disaster, but long-term planning. Funding was provided by Federal Emergency Management Agency (FEMA) in hopes that this research could increase community participation and better integrate a program known as RiskMAP into communities ongoing land use planning. This work added a layer to hazard mitigation and planning that had previously, not been explored. Findings suggested FEMA'S Risk Map process would benefit from using human wellbeing to drive future discussion.

Yet, scholarship on how scientists, emergency managers, planners and the public understand and use different visual and textual representations of hazard information for community planning is still sparse. The University of Washington M9 project funded by the National Science Foundation (NSF) currently is addressing this gap in research, as part of a larger interdisciplinary effort to help reduce associated risks of a Cascadia earthquake event to coastal and Puget Sound area communities by improving estimation of their effects (see Appendix A for write up on Tsunami Hazard Mapping). One challenge is understanding the ways current science, given its uncertainty aspect, can be conveyed on maps in a public forum in ways that generate creative resilient planning solutions. The effectiveness of different visual symbols to convey uncertainty have been explored previously, but research on how communities planning for resilience interpret and make use of new probabilistic hazard information remains inadequate.

The mechanism used to explore this, a community workshop, comprised small-group interactions, and was designed to inform on-going planning efforts in partner communities and observe collective human response to different types of hazard information. The workshop, conducted in the coastal city of Aberdeen Washington, was led by students participating in an Advanced Design Studio course at the University of Washington and was the culmination of previous research efforts. The goals of the studio were to observe the role of probabilistic or uncertainty in tsunami hazard maps in the decision making process, and, if beginning community discussion with assets rather than vulnerabilities influenced adaptive planning strategies. The 2016 Advanced Design Studio combined the alternative method for talking about and preparing for an

earthquake tsunami event from Project Safe Haven, the public process that focused on alternative research approach for discussing hazard information from the UW FEMA RiskMAP project, and the M9 project's exploration of ways current science can be conveyed in a public forum.

A high percentage of the world's population lives at risk of experiencing devastation caused by an earthquake tsunami event. Of all tsunami-prone areas in the United States, CSZ-related tsunamis represent one of the greatest threats to human safety based on the regional extent of the source (~1,000 km from northern California to Washington), the limited amount of time available for evacuations (15--30 min for many communities), and the thousands of people that would need to self-evacuate (Wood et al. 2015). Community outreach and education is the most effective way of ensuring the least amount of loss to the built and social environment. Observing how individuals understand and interpret natural hazard information is an important step to designing outreach materials and protocols. The purpose of this thesis was to not only observe how the use of different content and context in the dissemination of natural hazard information to communities influences the community planning process but also to try and understand if perceptions are shaped by these different approaches.

Research Questions

- 'How do different approaches to talking about, and displaying risk and uncertainty shape perception of stakeholders and influence planning efforts to cope with risk?'

- 'Does including uncertainty when communicating risk in community planning make a difference in adaptive community planning?'

Hypothesis

The literature review and knowledge of previous research on the topic of risk communication and tsunami hazard mapping with uncertainties contributed to the following hypotheses for the workshop:

- In community discussions about how to plan for recovery from natural hazards, using hazard maps that include representations of uncertainty will lead to more creative ideas than using maps that represent the hazard deterministically.
- Beginning discussion with an assessment of community assets will influence stakeholders and citizens to consider more resilient planning solutions for mitigation and long-term recovery than would beginning the discussion with community vulnerabilities.
- When put into two different groups, one that viewed displays of a deterministic map and one that viewed displays of a probabilistic map, stakeholders in the deterministic group are more likely to divide themselves with respect to the single scenario of hazard (e.g. on one side or the other of the crisp line), whereas stakeholders in the second group are more likely to seek consensus and/or develop strategies that work for multiple sets of interests.

The thesis follows with a subsequent research approach chapter summarizing the overall report including the literature review, research approach, research design, data

collection, how the participants were selected and, coding and analysis of the data. Chapter 3 defines the key concepts of emergency preparedness, hazard mitigation, adaptive planning, and the literature on risk communication, visualizing uncertainty and asset-based planning. Chapter 4 presents a community profile of Aberdeen outlining its location, demographics, hazards, and summary description of the studio and community workshop. The students' design work and how it is incorporated into ongoing mitigation projects underway in Aberdeen is presented in Chapter 5, which provides a detailed description of the community workshop. Chapter 6 provides conclusions of the collected data, reflections on the hypothesis and the lessons learned. Implications for future research approaches and focuses conclude.

Chapter 2: Research Approach

Motivation for Research and Design

The motivation for the design and research is outlined best in the studio Tsunami hazard mapping write up (see Appendix A for full Tsunami Hazard Mapping write up). As stated there is little empirical study of how emergency managers, planners, the public or even scientists from different disciplines, might understand and use representations of probabilities and/or uncertainty in various kinds of hazard maps, especially for rare events such as tsunamis. Some research suggests that visual uncertainty information can reduce the quality of decisions in frequent events such as icing. However, this same research also demonstrates that uncertainty information presented in other formats can actually improve decision-making (Savelli and Joslyn, 2013). Previously conducted literature research by the M9 team directed a few assumptions:

- 1) Discussions of hazard response that invoke a greater diversity and number of different community assets and values as sources of resilience are likely to favor more precautionary courses of action, but also more creative strategies in contrast to conventional mitigation. Strategies include policies, investments, and initiatives that meet a wide range of community development goals beyond the avoidance of damage to existing assets (Freitag et al 2015).

- 2) A focus on a catastrophic, high-consequence, low-probability hazard (such as a large tsunami) will prompt discussion of more precautionary courses of action than a representation that includes higher probability of less extreme outcomes, according to

Prospect Theory (Kahneman & Tversky 2001; Sunstein 2015; Tversky & Kahneman 2001).

3) Fuzzier information will also prompt discussion of more precautionary action. In other words, representations of uncertainty associated with probabilistic hazard assessments may evoke different risk attitudes than do deterministic representations of expected inundation (i.e., sharp lines). In past studies, showing confidence bounds on point estimates, some portion of message recipient's focus on the riskiest estimates rather than the expected values (see discussion in Bostrom, et al. 2015). In contrast, a gradient representation of predictive interval temperature forecast (i.e., an interval based on the probabilistic distribution of forecast temperatures) was tested in Savelli and Joslyn (2013) and bears some visual resemblance to the type of fuzzy line that are also proposed in their study. The probabilistic distribution of forecast temperatures was then compared experimentally to a deterministic temperature forecast (i.e., a single estimated temperature), and it was found that the gradient predictive interval improves risk decision-making over the deterministic forecast, although the gradient does not alleviate some known interpretation errors (e.g., the deterministic construal error). Also, recent research on probabilistic volcanic hazard maps finds that data classification, color scheme, content and how the map key is expressed all influence how users engage with and interpret these maps (Thompson et al. 2015), for which reason these elements would likely be kept as similar as possible across maps to be assessed.

Literature Review Research Approach

A write-up that rationalized proceeding with the workshop (see Appendix A) and an M9 write-up (see Appendix B) provided a baseline for students of the studio and I to understand the motivation for the work. The write-ups delineated publications that focused on risk communication, and visualizing uncertainty in natural hazards information. A collection including these and other authors works was collected and organized by M9 researchers before the winter studio. I was able to access these texts and begin my literature review for the thesis through the months of January and February.

To facilitate a workshop with stakeholders that centered on making resilient planning solutions using geographical information to convey a hazard, background information of risk communication, risk perceptions, resilience planning, and uncertainty in geographical information was used. Research investigating earthquake tsunami hazard mapping, risk perceptions and visualizing uncertainty information exists (Eiser et al. 2012 MacEachren et al. 2006, Svrtson & Burt 2012 , Teigen & Brun 2003).

The outcome from the workshop was to observe if participants could generate better planning solutions in the form of whole community resilience. The key concept of adaptive planning and resilience was acquired through previous coursework taken through the urban design and planning department at the university of Washington. An ecologist by the name of C.S. Holling is credited as applying the important concepts of systems resilience and adaptive management to ecology and other social sciences. Publications (Holling 1973; 1996; 1998) accredited to him were important for defining

key concepts of resilience and adaptive management. Other authors such as Peterson et al. (2003), Walker et al. (2002), Davoudi (2012) and Liu et al. (2007) discussed complexity of coupled natural and human systems and uncertainty, justifying the use of scenario planning and resilience in planning.

In order to participate in a community outreach and planning workshop it was important to understand the current research approach used in hazard mitigation and preparedness planning. An informational meeting was arranged with an emergency management representative from Seattle City Light where I was directed to the FEMA National Mitigation Framework (2013) and FEMA 428 (2003). These reports helped establish a starting point for current hazard mitigation strategies as well as the introduction of asset-based planning. Further discussion of using an asset-based approach in planning was taken from a JAPA article entitled Whole Community Resilience (Freitag et al. 2015). Not only did this text detail the application of this approach but it also provided other useful references to explore. Other resources that were necessary to acquire a basic background of the coast of Washington, Grays Harbor and Aberdeen were provided through the studio or found during online research.

Research Design

The primary research was collected through a community workshop format that was organized through an Advance Design Studio at the University of Washington. The design of the workshop followed closely the model that was used in the workshop conducted in Redmond, Everett, and Neah Bay in 2015. Participants were split up and organized around different tables but the difference was that the workshop in Aberdeen

wanted to observe content as well as context and thus none of the tables worked with the exact same material or discussion. The workshop protocol is discussed in detail in the next section.

Variables

The content (deterministic or probabilistic map) and context (asset-based or hazard-based) served as the independent variables in the research. Dependent variables of particular interest were the extent to which these different combinations of discussion conditions prompted participants to: (1) list more or fewer types of assets and values as important to community resilience; (2) imagine strategies that are either more risk-taking or more precautionary (i.e. involving multiple backup plans, redundancy in the systems they would put in place, etc.); and (3) take positions that either reflect particular individual interests with respect to the hazard, or reflect a desire for consensus among all community members. The participants were volunteers not previously identified before the workshop.

Coding Scheme

A focus group is a method of research that uses group discussion to solicit ideas and feedback about a concept or product (Moran 1998)(Roth 2009) where the focus is not so much on the outcome that is reached but how and why people respond to and reach that outcome. The process of, capturing dialogue along different themes through recordings and note taking, providing descriptive summaries for each codes and using direct quotes that exemplify important issues or opinions was a tactic used by Roth

(2009) in assessing the effectiveness and perception of uncertainty in flood plain maps. A similar approach to understanding how different approaches influence decision-making was used in the workshop in Aberdeen.

The discussions at each table were recorded and transcribed in an attempt to make sense of the participant's perception of risk and process for planning solutions contingent on the type of content they received and in what context it was presented. The literature review discusses how the role of personal belief, background and education plays out in risk interpretation but in order to protect the participant's identities their backgrounds were documented but responses are only identified through numbers given to each member. Their responses cannot be tracked back to them but the students were still able to factor in if their backgrounds may have some influence on their responses to the prompts. Along with participants' responses, body language, interaction with the map and engagement with their fellow tablemates was noted to provide context to the statements.

Responses were ordered conferring to Roth's (2009) summary of grouping responses according to frequency and extensiveness of statements. This also follows MacEachren's (2005) typologies, seen in Figure 1 below. The components of information and types of uncertainties are centered on three components of geographic information: 1) space 2) time and 3) attribute, inductively. This seems appropriate for organizing how participants responded to the data as it helps answer the question of 'How do different approaches to talking about, and displaying risk and uncertainty shape stakeholder's perception and influence planning efforts to cope with risk?' If groups showed no difference in planning solutions then measuring their responses with these

typologies might inform us as to if the problem was in the map display they worked with or the context with which they discussed the hazard. If a category of uncertainty is perceived as influential, its communication to decision-makers has the potential to significantly, alter both the way that the information representations are used during decision-making and the decision outcomes (Roth 2009).

Category	Attribute Examples	Location Examples	Time Examples
Accuracy/error	counts, magnitudes	coordinates, buildings	+/- 1 day
Precision	nearest 1000	1 degree	once per day
Completeness	75% of people reporting	20% of photos flown	2004 daily/12 missing
Consistency	multiple classifiers	from / for a place	5 say Mon; 2 say Tues
Lineage	transformations	#/quality of input sources	# of steps
Currency	census data	age of maps	$C = T_{\text{present}} - T_{\text{info}}$
Credibility	U.S. analyst interpretation of financial records <...> informant report of financial transaction	direct observation of training camp <...> e-mail interception with reference to training camp	time series air photos indicating event time <...> anonymous call predicting event time
Subjectivity	fact <...> guess	local <...> outsider	expert <...> trainee
Interrelatedness	all info from same author	source proximity	time proximity

Table 2. Typology of uncertainty of geospatial information, (Adapted from (Thomson et al., 2004).

The table (see Appendix D for Themes) of 11 themes was created by me and provided to the student note takers. The themes are risk/disaster, uncertainty, probability, recovery, resilience, asset/values, preparation, precaution, trust and vulnerability. A publication by MacEachren et al (2012) focused on two empirical studies of uncertainty visualization, utilizing a wide variety of research and helped to inform process for the purposes of this thesis in the workshop. Surveys were used in the experiments assess which map participants preferenced and why. In the workshop, not only were we looking at if each group came up with similar or different planning solutions but, also, attempting to discern how the participants reflected on the map they were provided. Surveys were dispersed to all participants following the completion of the small group discussion. A

Likert scale approach was used to understand how much participants thought about a CSZ event before viewing the maps, after viewing them and why, using a scale of 1 to 7 with 1 being least/not at all and 7 most/ a lot. An aggregate table of these responses can be found in Appendix C.

The transcribed responses were separated along themes, by specific groups, rounds, and then displayed in a table (Appendix D). The reasoning for this was to observe if the different discussion emphases brought up different topics or if the same subjects were discussed regardless of how the conversation began. I assumed that groups that began their discussion with assets rather than just discussing the hazard would have different planning outcomes. The outcomes are looked at but I was more interested in the types of themes that were used in leading up to those outcomes. For example, it is assumed that the hazard-based groups would talk more about vulnerabilities and risk, and less about assets and resilience.

Who Was Involved and How: M9 Project and University of Washington

Analysis of the effects of a Cascadia Subduction Zone event by researchers at the University of Washington (UW) is a relatively recent focus. It was not until the early 1980s that researchers began to recognize the zones potential to produce great earthquakes (CREW 2013). A group known as the Cascadia Region Earthquake Workgroup (CREW) is non-profit coalition comprised of business people, emergency managers, scientist, engineers, civic leaders and government officials. Their goal is to reduce the effects of earthquakes in the Pacific Northwest first publishing on the topic of CSZ earthquakes in 2005. Work such as this, and interest from emergency

management and scientific agencies in the PNW, has led to interdisciplinary efforts to reduce the risk of loss caused by an earthquake. One such UW affiliated project, funded by a grant from the National Science Foundation, is known as the M9 Project.

The project is made up of a team of experts in fields of Earth and Space Sciences, Urban Planning, Civil Engineering, Applied Mathematics and Public policy whom are working together to address scientific and engineering challenges in reducing risk. A piece of the project involves employing a suite of 3D state-of-the-art simulations of fault rupture and ground motions of Cascadia megathrust earthquakes. M9 research aims to advance hazard sciences by moving away from generalized scenarios toward probabilistic predictions of M9 seismic events and the subsequent hazards, with the objective of integrating these into community resilience planning and advancing the state of earthquake early warning systems (see Appendix A for write up of the M9 proposal).

Along with reducing risk to citizens, the project hopes to acquire deeper insight into the phenomena of earthquakes and tsunami and improve estimation of their effects by considering factors that have previously not been addressed such as: distribution and timing of energy release on the fault, the coherent variation of frequency content of fault motion and depth, the 3D effects of the deep basins along Puget Sound, more realistic scenarios of seafloor deformation, and estimating battering power of entrained debris. The researchers have been confronted with a wide range of challenges including understanding the ways current science can be conveyed in a public forum to a degree that generates creative, resilient planning solutions.

The interdisciplinary project is pulling expertise from a variety of specializations including geology, engineering, urban design and planning, earth and space sciences, statistics and applied mathematics. The tsunami hazard maps were produced by Peter Dunn, Mike Greenfield and Alex Grant. The underlying modeling (four GeoClaw runs, based on a single subduction zone event) was done with support from Randy LeVeque, Loyce Adams and Frank Gonzalez (Gonzalez et al. 2013).

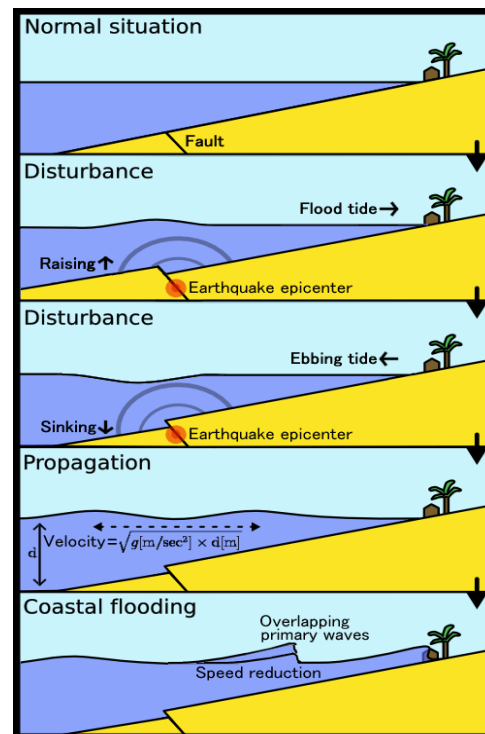
To prepare for the Urban Planning and Design Studio Winter of 2016, M9 organized a Student Workshop specifically focused on Mapping Hazard Information with uncertainties (see Appendix B for M9 Mapping Workshop). Attendees included University of Washington graduate students working on the M9 project or with M9 faculty, from a variety of disciplines. The purpose of this workshop was to engage M9 graduate students in interdisciplinary research relevant for the development of maps for community planning that convey probabilistic hazard information. The workshop in the Fall of 2015 as well as the studio in Winter 2016 contributed to the small body of research on the effects of representing probability and uncertainty information in maps, especially for tsunami hazards. The involvement of so many specializations achieves a holistic analysis that looks at the phenomena of earthquake tsunamis from as many angles as possible to find varied solutions. Ultimately, the goal is to derive deeper insight on how to communicate the best scientific knowledge (including probability and uncertainty information) so that communities can better plan for hazardous events while also enhancing public understanding of the evolutionary nature of hazards science to foster a higher level of trust in scientific knowledge that will improve decision-making.

The following section discusses the wide variety of scholarship on earthquake tsunami hazard mapping, visualizing uncertainty, resilience and emergency management.

Chapter 3: Literature Review

History of Tsunami Warnings and Education

When it comes to loss of life and property tsunamis rank high on the scale of natural disasters. Since the year of 1850, more than 420,000 lives and billions of dollars in damage of coastal structures (Bernard et al. 2006) can be attributed to this powerful natural phenomenon. Seismic science and modelling have advanced in the second half of the twentieth century but forecasting when and where a tsunami will strike is still currently impossible until after an underwater earthquake has been generated. Upon detection, the arrival and impact of a tsunami is measurable with modelling technologies. Insight into the difficulty of predicting and modelling tsunamis will help to enlighten why uncertainty in tsunami risk management is unavoidable and necessary to convey in planning efforts for response and recovery.



Not all earthquakes on the ocean floor generate tsunamis. An earthquake needs to measure at least a 7 on the Richter scale with a source of 30 km or less below the surface. When a powerful earthquake struck the coastal region of Indonesia in 2004, the movement of the seafloor produced a tsunami with an amplitude in excess of 30km (100ft) along the coastline (Red Cross 2005) eventually killing more than 200,000

people. All tsunami waves have basic characteristics defined by a travel speed proportional to the square root of the water depth (Figure 5). As the waves approach land their heights increase while their lengths decrease. Thus, in the open ocean, these waves propagate at the speed of a jet airplane but slow to the speed of an automobile as they flood the land (Bernard et al. 2006).

It is knowledge of the mathematical rules governing this behavior that has allowed scientists to better predict the arrival time of a tsunami as long as source and variation of water depth is known. One very important fact about tsunami waves that is often not known is that they are usually composed of anywhere from 6 to 12 large waves that can attack the shore at intervals of 30 to 90 minutes (Titov et al 2005). The first wave is not usually the most damaging but is known to weaken infrastructure and has the capability to pick up large debris (boats, cars etc) and turn them into battering rams, subservient to the force of the waves. Advances in technology have created tools that allow for numerical models of inundation that simulate flooding potential of tsunamis and, are presently used to plan evacuation procedures for threatened coastal communities (Gonzalez et al. 2005).

The ability to understand the complex dynamics that give rise to tsunamis is closely tied to accurately characterizing the source and observed generation, propagation, inundation and interactions with structures (Bernard et al. 2006). Source observations can be especially tricky as determining it is affected by intense solid earth shaking, underwater landslides, and deformation of the crust and activation of splay faults. Not to mention that coastlines are under constant physical development. The position of the coastline, bathymetry (study of underwater depth) and topography can all

be altered in this process affecting the accuracy of inundation models and complicating efforts to educate coastal communities about their options for preparedness and evacuation.

The international effort to mitigate and educate coastal communities of the impacts of tsunamis began over 40 years ago after a series of tsunamis in Alaska and Chile killed hundreds of people from several different countries. The Pacific Tsunami Warning Center (PTWC) in Hawaii was established to efficiently organize and disseminate tsunami data and warnings to all nations in the Pacific as well as encourage localized warning systems for coastal communities. Unfortunately the uncertainty of when earthquake faults induce tsunamis created an issue of over-warnings i.e. warnings that are unnecessary because the observed wave is non-destructive. From 1949-2000 about 75% of tsunami warnings turned out to be unnecessary (Bernard et al. 2005) causing credibility issues among the populations being served as false alarms not only disrupts life but causes major economic losses. The powerful devastation of tsunamis made its way to the forefront of global issues in the 1990's after a string of occurrences all over the Pacific, which encouraged The United Nations to establish International Decade of Natural Disaster Reduction (1990-2000). This directly led to the use of tsunami science technology in the production of many community-level inundation maps. The impact was overwhelmingly positive and provided communities with the information to plan for tsunamis with evacuation procedures and recovery plans such as the one below that was created for the cities of Aberdeen and Hoquiam (Figure 6).



In 1992, a tsunami was felt along the fault lines that form the Cascadia Subduction Zone off the shore of California. In response, The National Tsunami Hazard Mitigation Program was created to address two concerns: 1) the possibility of a huge CSZ earthquake/tsunami and 2) over-warnings. As technology progressed scientists improved their ability to detect tsunamis in the deep ocean. This led to the reduction of over-warning, production of over 130 inundation maps for coastal communities and introduction of the concept of tsunami-resilient communities. (Bernard 2005).

Yet tsunami researchers still face a significant obstacle in their efforts to mitigate associated damage and loss; figuring out how to change the public perception that tsunamis are rare events. According to the National Oceanic Atmospheric Administration (NOAA) at least one tsunami is created causing damage to coastal communities every year (NOAA – The Tsunami Story). Populations that are aware of tsunamis hazards and physical indicators of their presence can significantly reduce fatalities. For example in the 2004 Indian Ocean tsunami the indigenous people responded quicker and much more appropriately (seeking higher ground) than tourist (remained on the beach). When comparing survival rates between a tsunami in Japan in

1996 and one in Papua New Guinea in 1998, the former had significantly less fatalities, which is attributed to public education efforts and more frequent exposure. The challenge is effectively communicating risk to a wide range of communities varying from subsistence villages to major metropolitan ports.

However little research has been done on the human response to tsunamis and how education could enhance capabilities. Surveys conducted in 2006 of Washington state residents living along the coast revealed that residents were aware of tsunamis but still not taking any concrete action to prepare for them (Johnston et al. 2005) indicating that researchers are missing a social element in existing educational approaches to motivate change. One way to alleviate this may be to analyze social behavior of recent disasters to determine how human response can be simulated.

Understanding how individuals perceive risk and hazard information is difficult however, in part because of the values they attach to different kinds of outcomes (Eiser et al 2015) and also due to the fact that construction of risk in the mind of the perceiver depends on the representation of the underlying hazard. Everything from the type of information conveyed and the design of the user interface will influence risk perceptions and decisions-making processes (Bostrum et al 2008). The next section addresses the current hazard mitigation strategies at the federal, state (Washington) and local level (Grays Harbor).

Hazard Mitigation Strategies

To the Federal Emergency Management Agency (FEMA) and other civil agencies, the term hazard can be applied in several different contexts (FEMA 428,

2003). For the purpose of this thesis, the definition I will be working with is that of a *natural hazard* defined as a natural event such as an earthquake, a flood, or a wind disaster with the potential to cause harm to humans and/or the stuff they value (National Mitigation Framework 2013).

State

FEMA is a federal agency that falls under the Department of Homeland Security (DHS), a sector of the federal government responsible for a wide range of services that can be categorized under strategies of security, resilience and customs, and exchange (dhs.gov). The main objective of FEMA is to support citizens and first responders to improve capability to prepare for, protect against, respond to, recover from, and mitigate all hazards (DHS). Financial and physical assistance, systematic disaster aid, and insurance policies are initiated through FEMA. During a Cascadia Subduction zone event the State Emergency Management Division in Washington State will receive alerts from USGS and notify state agencies and local governments of an earthquake and possible tsunami.

The state division operates the State Emergency Operation Center located at Camp Murray near Tacoma which helps to decide how best to coordinate response quickly and effectively by gathering, analyzing and disseminating information to prioritize use of state resources. The Division of Emergency Management (DEM) in Grays Harbor develops and maintains local infrastructure for emergency and disaster preparedness, response, mitigation and recovery. This cannot be done effectively without up-to-date information about localized natural disasters. The county operates out of their own EOC performing the same duties as the state level and coordinating

with law enforcement, fire services, public health, and environmental health agencies to deliver timely and effective response in the case of an emergency. During an event, the city workers in departments of safety, security, and public works are tasked with assessing the extent of the damage and reporting to the county EOC so that resources can be allocated accordingly.

Local

Due to a high prevalence of natural hazards within this particular region, Grays Harbor and Aberdeen have been the focus of many risk assessment efforts and mitigation campaigns. In 2009, the Washington State Emergency Management Department was chosen for a pilot project to put together and circulate an *All Hazards Guide*, an informative guidebook that outlines all the disasters within Grays Harbor and recommends the best ways for citizens to prepare for and respond to them. The guide included actionable responses to different kinds of hazards including a tsunami evacuation map (Figure 6) that highlights routes out of the danger zone in red and the tsunami inundation zone in yellow. The Hazard guide hopes to inform citizens of potential risks to encourage a response plan that could save lives but lacks any mention of long-term planning, resilience, and/or recovery information for citizens.

A more comprehensive project known as The Grays Harbor Coastal RiskMAP began in 2012 to analyze coastal flood risk; earthquake and tsunami risk (FEMA-Risk Report 2014). FEMA completed a detailed risk assessment for Grays Harbor County including evaluating the stability of every building and determining losses that are possible from an earthquake, landslide, and/or tsunami using a loss estimation software known as HAZUS, created through FEMA and utilizing local data from the assessor's

office. The report, created in conjunction with State Department of Ecology (DOE), the Department of Natural Resources (DNR) and each of the communities of Grays Harbor, also highlighted potential and current mitigation projects in each jurisdiction. The main goals of the report is to educate citizens about regional specific risks related to natural hazards and provide citizens with suggestions to help reduce their risk. Local officials will be able to use the report to update plans, revise emergency operations and response plans, and communicate risk.

Upon completion of a draft, representatives from FEMA coordinated a meeting to facilitate a detailed conversation with the community on mitigation and resiliency in the city of Aberdeen. Invitation for the meeting was extended to local elected officials, community planners, emergency managers, and public works officials. The report includes many visuals such as tables and figures that estimate damage from a magnitude 9.0 Cascadia Subduction Zone Earthquake with corresponding maps illustrating the destruction and potential tsunami flood depths using primary colors and abstract symbols. The information is available on FEMA's website (FEMA.gov) and Grays Harbor Emergency Management Division website and therefore accessible to all citizens but is likely going to be used as an educational tool to guide county and community officials when communicating preparedness and response to citizens at risk.

Grays Harbor Risk Report

Planning for preparedness includes not only complex administrative arrangements, but also the inclusion of those at risk (e.g. residents, business owners) who are being gradually transformed into active risk managers. (Scott, 2013). A paper written by Kuhlicke and Steinfuhrer's (2011) addresses issues surrounding flood risk

governance and the “governance of preparedness”, which are becoming increasingly complex in the context of the shift from purely engineering solutions towards a more holistic risk management approach. (Kuhlicke et al 2011). The need to build social capacity is becoming increasingly difficult in the face of social, environmental, and economic consequences of natural hazards.

FEMA, utilizing a loss estimation software known as HAZUS, approximated that Aberdeen stands to suffer a loss of \$277 million of their \$800 million building inventory. This is a 32% loss ratio in the event of a 9.0 Cascadia Subduction Zone Earthquake (Risk Report 2013). The total loss for Grays Harbor is estimated at over \$1.5 billion, 57% of the total building infrastructure. The percentage of the population that is expected to be affected ranges anywhere from 28% to 54% but the exact number will depend on the time of the day. According to the American Census Survey, about 55% of the citizens living in Aberdeen also work there whereas 45% of those employed commute from elsewhere. Not only does this have implications for if the event happens during the work day (more hazard refuges present), but if an earthquake happens outside of workday hours those employed in jobs of security, protection and emergency management will most likely not be present as many of them live outside of Aberdeen.

Federal

At the federal level, FEMA completed their National Mitigation Framework in 2013 to establish a platform on which communities can work to manage risk by providing mitigation capabilities to improve preparedness, response, and recovery. FEMA seeks to reduce the loss of life, property, and disruption of daily life through the utilization of community experience as well as objective and evidence-based

knowledge. The framework emphasizes resilience through increasing risk awareness among whole communities denominated as—individuals, families, and households; communities; NGOs; private sector entities; local governments; state, tribal, territorial, insular area Governments; and the Federal Government (National Mitigation Framework 2013)—as a way to help residents feel safer through creating resilient communities.

Resilient communities are defined as communities that proactively protect themselves against hazards, build self-sufficiency, and become more sustainable through technical, organizational, social, and economic dimensions (Godshalck et al. 2009). Further discussions of resilient communities are explored later in the text. To understand the role of risk communication in planning the following section outlines the current strategies being used for hazard mitigation and the way FEMA communicates risk to state and local government.

The framework identifies that effective mitigation begins with assessing the threats and hazards a community faces then, determine the associated vulnerabilities and consequences through credible science, technology and intelligence. Mitigation strategies are developed and decisions of whether to accept, avoid, reduce, or transfer those risks are enacted. This is a shift from incidence-based, looking at isolated occurrences, to risk-based, considering all possibilities of risk in a hazard (National Mitigation Framework 2013). FEMA aspires to incorporate risk management into every aspect of planning to create a well informed and risk minded culture. As a way of achieving this the National Mitigation Framework presents seven core capabilities required for mitigation: threat and hazard identification, risk and disaster resilience assessment, planning, community resilience, public information and warning, long-term

vulnerability reduction, and operational coordination. All of which are mentioned throughout this thesis

At the local level, FEMA has organized local Citizen Corps Councils to assist with bringing government and civic leader organizations together. These local councils engage broad participation in assessing and reviewing community risks and are in position to integrate resources from the community by bringing relevant leaders from all sectors to the table to participate in decision-making. The state of Washington has a state council in each county. Grays Harbor has four citizen corps partner programs that use volunteer police efforts as well as medical, fire and community emergency response teams engaged within the community.

Another tool used to simplify emergency planning has only begun to garner use in hazard mitigation planning. The costs of risk reduction measures are very high and therefore planning entities use many different decision making tools before making investments. The International Federation of Red Cross/Red Crescent Society has been attempting to integrate a cost-benefit tool into existing community-level vulnerability and capacity assessments, as it can help communities to identify the intervention that may be the most cost-effective. The use of this tool analyzes the cost of community-based disaster risk reduction and climate change adaptation before a program is implemented to decide if it is appropriate or after a program has been implemented to assess its effectiveness (Venton et al. 2013).

The combination of these efforts seeks to create a risk minded culture, incorporating all levels of individuals but does little to integrate science, policy and mitigation as displaying the uncertainty with which tsunami hazard information is

created is not a priority. The tsunami evacuation map created for Hoquiam and Aberdeen is the only tsunami information most residents will ever view, and yet it gives little background information about the behavior or unknowns of a CSZ event. Similarly, hazard planning continues to focus on vulnerabilities, which narrows the scope of community planning. The next section describes an alternative planning approach and the role it could fulfill in community resilience planning.

Asset-based planning

Vulnerability assessment evaluates the vulnerabilities of a community at risk to determine mitigation efforts to undertake. Every aspect from the built, social, and natural environment is considered so that mitigation efforts can be comprehensive and robust. In contrast, utilizing an asset-based approach in public outreach asks that stakeholders take an inventory of the built, social, and natural community assets and, after examining a hazard scenario, identify the assets that could facilitate adaptive community planning to enhance mitigation of the hazard and ensure long-term recovery from the disaster. (Freitag et al., 2015).

An asset is a resource of value requiring protection (FEMA 428, 2003) and placing more attention on them or a resource of value requiring protection can encourage solutions that are more resilient to protect against natural hazards. Assets can be tangible such as people, infrastructure, and goods or intangible like community closeness and social identity. Three categories of assets were explored during the workshop, drawn from the Millennium Ecosystem Assessment (2005), and are defined as follows:

1. *Built Capital*: things built by humans for specialized purposes, and with significant ecological footprints such as bridges, buildings, dams, machinery.
2. *Natural Capital*: environmental features that yield a flow of ecosystem services and tangible natural resources—forests, wetlands, trees, soil, fossil fuel.
3. *Social Capital*: networks and associations of human relationships based on mutual trust, common interests or particular skills such as service providers, social and cultural gatherings, festivals, faith-based organizations, volunteer work.

It is important to note that these categories are not mutually exclusive as different things can belong to more than one designation. For example, a building or park are both built but also contribute to social and natural capital as well. Specifically this approach applies principles of asset-based community development to disaster planning (Green & Haines, 2012), especially the idea that creative thinking leads from strength-based positive approaches to inquiry and actions, as expressed in the Appreciative Inquiry (AI) model (Emery & Flora, 2012).

Current hazard mitigation and risk management strategies typically begin with taking a vulnerability assessment and identifying steps that will alleviate the exposure. In 2003 FEMA created FEMA 428, a *Primer for Design Safe Schools Projects in Case of Terrorist Attacks* as a mitigation tool for school administrators to design schools safe from terrorism threats. This report analyzes assets before identifying vulnerabilities, recognizing this as a critical step to reduce risk at the least cost. The report emphasized

that the first step towards mitigating hazards is recognizing what is in need of protection and then taking an inventory of vulnerabilities.

The “Asset-based” approach used in the workshop, aims to coax the stakeholders into creating an inventory of built, natural, and social community assets, then examine the hazard scenarios and associated vulnerabilities and, finally, identify those assets that could facilitate planning that is adaptive i.e., assets that could help achieve comprehensive community planning goals, enhance mitigation of the hazard, and recover from the disaster (Freitag, et al., 2015). The “Hazard-based” approach emphasizes vulnerabilities of the city and is the most common approach taken in hazard mitigation and community collaboration efforts.

There has been much research on the topic of risk communication and the inclusion of uncertainty in natural hazard information. The next sections will discuss this research and explore how different approaches to displaying and talking about rare natural hazard information can help with whole community resilience planning.

Defining Risk

The Purpose of risk communication is to assist people in obtaining the information they need to make informed choices about preparing for and mitigating against a specific risk. The use of maps to reach individuals facing risk is rapidly expanding in hazard mitigation. How the public perceives and understands this information is crucial to if individuals and communities take on risk-averse behavior to reduce damage and loss during an earthquake tsunami event.

The use of risk communication to convey hazard information possesses many intersecting themes of public perception, visual uncertainty, hazard mitigation, and community resilience. The role of personal belief, background, and education plays a key role in how creators of visual hazard information is defined and conveyed which in turn influences how users of the same information understand and apply it. (Eiser et al. 2012). Often in disaster management, the concepts of Risk and Hazard are used interchangeably and clarifying the difference is important, as this is a central issue in policy, security, hazard mitigation, technology, environment, and economy. As previously stated a hazard is an act or phenomenon that has the potential to cause harm to humans and/or what they value (Svertson and Burt 2012). Risk can be defined in terms of risky events or activities, but this generalizes risk and makes it harder to govern whereas if risk were to be defined in terms of processes it can be seen as a function of 1) likelihood and 2) value of some possible future event or events (Eiser et al) or, in a more formal analysis as perceived magnitude and perceived loss (Bostrom et al. 2008). The discipline of scientific risk recognizes that defining risk within constraints of expected values disregards that certainty is unrealistic. Therefore, risk is best described as the combination of probability and consequences (Aven 2006) with consequences defined in aspects of the social, economic, and environmental losses.

Defining Uncertainty

Uncertainty is a complex and multifaceted concept. The academic literature on the topic of uncertainty alone covers a broad range depending on the context in which it is being applied. To understand the phenomenon of uncertainty in risk communication it

will be helpful to start with defining and understanding the two forms of uncertainty in seismic hazard studies; aleatory and epistemic (Abrahamson and Bommer 2005).

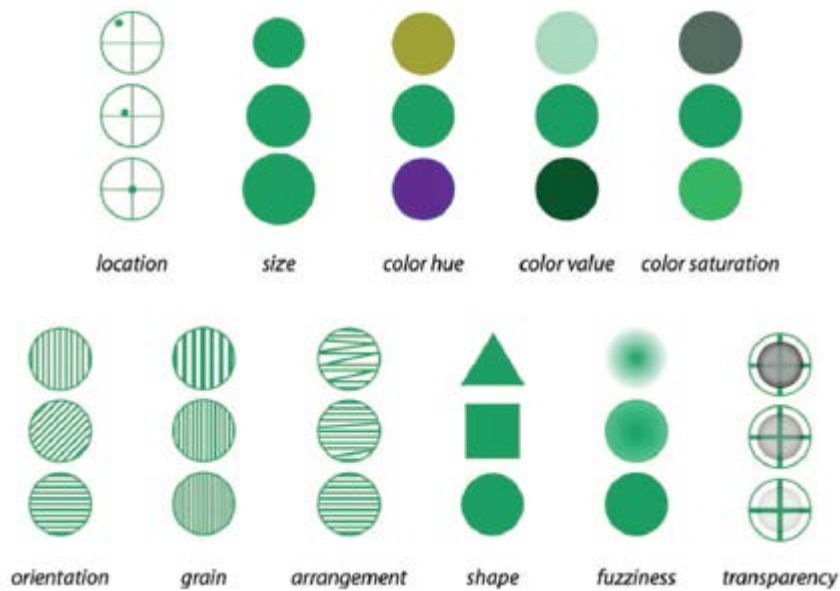
Aleatory uncertainty refers to the kind of uncertainty we all experience when we have incomplete knowledge about earthquake processes (Aven 2006). This type of uncertainty can be alleviated through the collection of more knowledge. Epistemic uncertainty is inherent due to the unpredictable nature of natural disasters (Spiegelhalter and Riesch 2011). This refers to the unique details of source, path, ground motion and site specifics that cannot be known before an earthquake happens. Epistemic also refers to that which we do not even know we do not know.

There is a wide variety of uncertainty that decision makers must face, and, to be useful, representations of uncertainty, visual or other, must address this variety (MacEachren et al 2006). One of the earliest conceptual frameworks for geospatial uncertainty that recognized the separate error components of value, space, time, consistency, and completeness was proposed by Sinton (1978) and elaborated on later by Chrisman (1991). Intermittently uncertainty in geographic data has been described in a variety of alternative ways but always with at least one common aspect; the observation that uncertainty itself occurs at different levels of abstraction (MacEachren et al 2006). In order to be understandable and useable a map must abstract reality, and only accentuate features of interest for, without it, a map carries little semiotic advantage (Roth 2009). In doing this, however, information is removed that may be important for a clear and comprehensive understanding of geographic phenomenon or processes.

Upon running the models, the researchers of M9 grappled with how to communicate the different scenarios and the uncertainty of seismic science to the public with visual representations. Originally outlined in 1967 by a French cartographer named Jacques Bertin, the seven variables on which any information graphic can be built is 1) location 2) size 3) color hue 4) color value 5) grain 6) orientation and 7) shape. Believed by Bertin, and still accepted at this time, that there are a set of fundamental visual variables from which any information graphic is created. This was the development of grammatical rules or syntactic of a sign system which detailed how and when the elements of a sign-system should be used (MacEachren et al 2012). Three additional variables; clarity, resolution and transparency, were later added by MacEachren (2009). Pre attentive processing is the subconscious accumulation of information from the environment, which happens before the brain filters and processes what is important and what can be disregarded. Ideal symbols, then, are ones that can be easily understood while also being effective for map reading tasks requiring visual aggregation (MaEachren et al 2012) thus highly abstract symbols that vary only a single visual

variable are most effective seen below (Figure 7).

THE VISUAL VARIABLES



MacEachren et al 2012 visual variables applied to point symbol sets.

Alternatively, iconicity employs pictures rather than geometric associations to prompt metaphors to match correctly with qualitatively different aspects of information. Alas, iconic sign vehicles only work well if users understand both the aspect of uncertainty being signified and the metaphor upon which the sign-vehicles are based. To convey an earthquake and tsunami hazard, information that was simple to understand by participants unfamiliar with hazard maps and appealed more to pre-attentive processes was employed for this particular workshop. Specifically color value and the use of fuzzy boundaries were used to create the different events displayed in the probabilistic map.

Why Uncertainty?

In the efforts to quantify the different effects of hazards there is much that is unknown. Uncertainty refers to the likelihood of an event and the value of the consequences in an event with value denoting anything that falls within the social, built, natural environment. Scientists and researchers often grapple with the question of, to what extent uncertainty should be depicted in community outreach efforts that require planning interventions for safety and security. Preparing for what is perceived to be the worst-case scenario can be deceiving for users of hazard information and comes with many issues, which recently has been exemplified in predictions of the effects of climate change.

The inclusion of climate change into the public consciousness introduces issues of working with probabilities that are less able to calculate effects with a high degree of certainty (Eiser et al. 2012). The 1950's was a decade that saw the advancement of climate science so that the effects of human activity on ecological processes and human health could be measure for the first time. Tools that could measure greenhouse gases soon became available and, with this knowledge and available data on global temperature, anthropomorphic influences on the changing climate started to be realized (Revelle et al. 1965; Haasnoot and Middlekoop 2012) (Bennis et al. 2016b). One aspect of this is the high influence of urbanization on altering the effects of floods. The general increase in urbanization within a catchment increases surface water runoff in ways that challenge accurate quantification (White & Howe, 2004) and therefore is hard to convey with absolute certainty.

Sea level rise threatens numerous coastal areas but in the case of the Pacific Northwest, it is experiencing it in a different way. The activity of the tectonic plates is

causing the earth to bulge upwards. When a Cascadia earthquake disturbs the land and the ground subsides, mean high water level will completely cover once exposed land. It is very possible that the Washington coast will experience decades of sea level rise all at once with no way of really knowing what that might look like.

Risk management and Uncertainty

Displaying uncertainty can be tricky depending on the arena (science or policy) within which it was generated and applied, and the level of trust in the source of the information. If citizens do not trust the source of natural hazard information, not only is the information disregarded but also uncertainty is in danger of being equated with inadequacy. Scientists are often privy to reliable uncertainty estimates in many domains, which have important implications for public safety and well-being. However, they are often reluctant to share this information for fear it will be confusing to the public or reduce credibility (Frewer et al., 2003; Shackley et al., 1999) (Joslyn & LeClerc 2015).

Geographic information is commonly used in decision-making processes about planning against rare hazards like tsunamis. Uncertainty is inherent and research in GIScience should focus on better ways to manage and use uncertainty during decision-making rather than attempting to purge it from all geographic information (Coucleis 2003; Deitrick and Edsall 2008). It was initially believed that uncertainty information acted much like any other type of geographic information during multivariate representation in that it's inclusion only made the map more difficult to use during decision-making (Roth 2009). In order to avoid the possibility that primary information

does not become unusable researchers Beard and Mackaness (1993) and McGranaghan (1993) cautioned against representing uncertainty. Yet others dissented this belief, such as Leitner and Buttenfield (2000), indicating that the inclusion of uncertainty representations actually decreases the time taken in decision making processes by clarifying the underlying geographic information and also increasing the confidence of the decision-maker in their decisions (Roth 2009).

As one can see, the consensus on whether or not to include uncertainty can often be in contention. Nowhere is this more apparent than in the arenas of science and policy as these entities differ so dramatically between the approaches they employ to characterize uncertainty and strategies for coping with it. Policy is a tool that addresses societal ill[s] with timeliness being of the utmost importance and therefore policies, at times, proceeds knowledge. Science is a discipline that builds on previous acquired knowledge, and, any inaccuracies can lead to subsequent acquired knowledge being incorrect requiring a longer timeline for development (Kinzig and Starrett 2003). Equally, where planning and policy interventions occur they may serve to drive risk. This is seen in the management of flood defenses where protection of a region can increase exposure via the “escalator effect” (Parker, 1995) or “safe development paradox” (Burby 2006), whereby defenses subsequently make the land behind them appear “safe” and attractive for development (White 2013). The equivalent of this in planning for a hazard like tsunamis is the illusion created by the deterministic map that gives the impression that it is explicitly known which regions are “unsafe” and which are “safe.” Employing communities with the knowledge of the unpredictability of these events can provide them with more options than depending one ultimate plan can.

The inability of science to accurately predict the behavior of tsunamis is a major rationale behind including uncertainty in probabilistic terms within hazard information. The science of earthquake predictions has become more accurate in recent decades with models that can determine relative damage and losses to critical infrastructure but no matter how precise models become it is impossible to determine which models will play out in real life. According to Roth (2009) there are at least three challenges to coping with geographic information uncertainty: 1) determining the current involvement of uncertainty at different stages in the geographic lifecycle (what was the intended purpose of the information collected?) 2) identifying the many forms that uncertainty can take and do the decision-makers need to consider these different categories of uncertainty? 3) understanding the influence these forms have on the use of geographic information (are all uncertainties considered equal?). Addressing the first challenge GIScience literature has a strong emphasis on coming up with new research approach for collecting and representing uncertainty information but rarely is there a follow-up component that investigates how the techniques that are suggested are applied in practice. There are numerous attempts at defining the components of uncertainty but there is little agreement among scholars. This motivated the creation of a nine-category typology of uncertainty initially presented by Thomson et al. (2005) that was elaborated on by MacEachren et al. (2005) (Roth 2009). This typology is specific to uncertainties that influence information analysts. There has been a wide variety of writings on the uncertainty typologies but the authors of these have only speculated on the relative influence of these categories on the decision-making process while the focus has typically focused on decision-making influence with a broad definition of uncertainty.

In order to effectively, communicate risk, approaches need to adhere to basic standards: messages should be crisp and easily understandable and include actionable recommendations that are empathetic, and complement messages that describe the scope of the problem, explain the risk to residents, and tell the intended audience what action can/should be taken (Meredith et al. 2012). Not only that but peoples' past experiences, the opinions of their social networks, their level of control over the risk and many other factors contribute to how people perceive the risk (ITIC 2016). This can often be disregarded or ignored by risk managers instead feeling that increasing community knowledge will influence behavior.

Construction of risk in the mind of the perceiver also depends on, at least in part, the representation of the underlying hazard. This means that the user interface for natural hazard mitigation software will inevitably influence risk perceptions and decision-making processes. (Bostrom et al 2008). Uncertainty must first be acknowledged as an important characteristic in order to capture and map it and therefore the attitudes and opinions of those creating the visual representations are just as crucial as the interpretation of the public and planners (Roth 2009). Deterministic maps that display hazard information in a concrete, simplistic way gives the impression that seismic behavior can be predicted with a confidence that, in reality, does not exist. The point of including a display of information geographically is not precisely to convey exact information to provide ideal decision making conditions but used to help planners and the public feels fully informed as well as minimize uncertainty that can be added during information creation. (Roth 2009).

Uncertainty is represented in the maps as the probabilities inundation, which are shown associated with 3 different CSZ scenarios used to model the inundation risk for the probabilistic map. The M9 team modeled three distinct CSZ events representing the current scientific understanding of possible fault rupture scenarios labeled L1, M1, and SM1 (for “large”, “medium,” and “small/medium”). The team ran through 15 different models looking at both the likelihood of some level of subsidence and inundation providing the students with three models to use in the workshop. For a given area, inundation/ subsidence at the defined threshold is caused by a L1 scenario which has a 25% probability of being experienced, a L1 and M1 scenario at a 80% probability and a L1, M1 and S1 scenario at a 99% probability. The different levels cause different extents of damage, impacting regions within Aberdeen and Hoquiam differently.

Probability itself, can be defined differently depending on if the underlying probability is unknown and estimated in risk analysis; the relative fraction of the times events occur if repeated an infinite amount of times, or, if the probability is a subjective measure related to the occurrence of an event; a measure of what the outcomes (consequences) will be as seen through the eyes of the assessor based on the collected background information (Aven 2006). In the case of a low probability and high consequence disaster uncertainty plays more of a role as specialist cannot rely on an antecedent collective knowledge of events that can be applied to future preparedness and planning actions. A Cascadia Subduction Zone event occurs at intervals of about 300-500 years with the last recorded CSZ megathrust earthquake in the Pacific Northwest estimated to have happened on January 26, 1700. Radiocarbon dating, tree ring science (Ludwin et al. 2011) and oral history passed down through tribes that have

resided on the coast for thousands of years helped seismic scientist to narrow down this event to the exact day. However, even with this knowledge, scientists have no way of knowing exactly when the next one will strike and how big it will be.

Cartographic Interaction

Cartography emerged as a legitimate scientific discipline post World War II as interest of empirical map design and research was becoming more prevalent. Research in this field can focus primarily on cartographic representation, on cartographic interaction or on how each of them can influence the other. Cartographic interaction is defined as the dialogue between a human and a map mediated through a computing device—each holding the ability to affect change to the other. The intent was to use the map as a conduit through which a message can be passed from the mapmaker to the map user (Roth 2006). The process of visual externalizations allow individuals to offload thinking onto information graphics, using perceptual (seeing-that), cognitive (reasoning-why), and motor (Interaction-with) processes to reintegrate the external knowledge into existing internal schema (MacEachren; Ganter, 1990).

Using Cartography interaction was a focal point in the studio adding another faucet to our research endeavors. Researchers from the M9 Team provided the models that were displayed on new technology never before used in Washington. Known as WeTable, this interactive GIS mapping technology used a projector, a light pen, and a Wii remote to create a useable interface on any tabletop allowing community participants to interact with the hazard information. The process involved very little instruction but was instrumental in helping the participants to share with the students what mattered most to them about their city. Collecting background data about the city

and the proposed levee project (discussed later in the paper) and facilitating the workshop, were the main influence for the students creative urban design solutions. The goal was not to reinvent the wheel but to come up with designs that complimented what was already there.

The levee project represents an interesting challenge for good urban design and ecologically sensitive hazard mitigation in the cities of Hoquiam and Aberdeen. The students, playing off this, felt that there could be another layer added on to the levee project that incorporated the long-range vision for Aberdeen and protect areas of the city from frequent storm flooding, and the rarer but highly consequential Cascadia earthquake subsidence and tsunami hazards. The digital environment allows visual thinking/map interaction to proceed in real time with cartographic displays presented as quickly as an analyst can think of the need for them, revealing anomalies, patterns, and trends in the data that were previously unknown. This can lead to new geographic insights and understanding about the true nature of the studied geographic phenomenon (MacEachren; Monmonier, 1992). The spatial cognizance of the participants in the workshop was both surprising and enlightening as far as the many benefits that can come from using this technology in community outreach.

Concerning conveying hazard information through cartography, it is important to note that not all visual representations work for all types of hazards and across general groups of map users. A humanistic viewpoint considers the unique conditions that contextualize mapmaking and map use, as well as cartographic representation and interaction. This emphasizes the application of user-centered design, which focuses on the development of a single cartographic interface to meet a single map use scenario

and user group, rather than generating insights that are generalizable across all map uses and map users (Roth 2013). The weight of which is explored further in the next section.

Modeling Earthquakes/Tsunamis

All natural hazards are place-specific but particular characteristics of different hazards result in different scales of spatial variation. No more is this truer than in the case of an earthquake and tsunami where susceptibility is locally focused based on measurable local properties dependent on site elevation and distance from the shore. In the city of Aberdeen, a whole host of possibilities could happen if an earthquake along the Cascadia Subduction Zone hit ranging from landslides, liquefaction, subsidence, and inundation, all before a tsunami even reaches the shore. Due to the inescapable fact that a megathrust earthquake along the CSZ will happen, there are many efforts to map and model the possible extent of damage. To do this previous knowledge from events such as what happened in Japan in 2011, the Indian Ocean in 2004 and even the previous CSZ event in 1700 are being used.

Emergency managers in Grays Harbor can estimate how much of the population, infrastructure and land will be affected but the extent of the damage is epistemic and will not be fully grasped until an event occurs. For a CSZ, the known is that there will be some level of subsidence (lowering of the ground below mean high water level because of the slipping of tectonic plates), some level of inundation, a result of the subsidence, and flooding caused by tsunami waves. The size of a megathrust earthquake is an uncertainty that specialist will not be able to attenuate through the collection of more

knowledge. As stated previously the M9 researchers modeled three distinct CSZ events that represent the current scientific understanding of possible fault rupture scenarios. The L1 areas included all of the M1 areas and the M1 areas included all of the SM1 areas so there is no case where an area is affected by an SM1 but not a M1 or a L1. Given the current state of CSZ science, the hazard researchers are quite uncertain about these probabilities. They also caution that these three events are only a sample of some 15 possible rupture scenarios, each of which would generate its own exposure map with its own probability of occurrence. These three events and their relative probabilities are rough estimates of this greater set of possible hazards.

Regardless of the unknowns, data representing estimated susceptibility to natural hazards at the neighborhood or parcel scale is extremely useful for the site-specific land use and development decisions for short and long term planning. Additionally, hazard information within a local context is found to be more effective than ones that are global represented. For instance, most climate projections describe global averages, abstractions that might seem irrelevant to most people and fail to generate an effective response (Weber, 2006). If so, local projections (e.g., sea level rise in one's own region) might generate more concern (Leiserowitz, 2006) because they may be more personally relevant. (Joslyn and LeClerc 2014). Nevertheless, planning entities in Grays Harbor are working under the assumption that a megathrust earthquake will fall under a measurement of a 9.0 magnitude, or the 'worst case scenario' with the extent of the damage displayed in a deterministic representation.

Given the uncertainty of both the extent of and scientific understanding of a CSZ earthquake event, using simplistic deterministic models can be misleading and less

helpful for local decision-makers than risk information displayed in relative and probabilistic terms. Due to unknowable futures and difficulty of conveying these uncertainties to populations, probabilistic forms of hazard information is commonly avoided. Yet a probabilistic understanding of how an event can likely affect local vulnerability can help local planners to decide where to locate essential support services, evacuation routes and, if development in a particular region is the best option. An experiment conducted in the Department of Psychology at the University of Washington found that, as with weather forecasts, people have greater trust in climate projections that include an uncertainty estimate. (Joslyn and LeClerc 2014). This could be because, as with weather forecasts, people had intuitions about the uncertainty involved and feel more trust in projections that acknowledge this rather than deterministic models that disregard it.

Public Perception

Presenting hazard information is not as simple as figuring out the format and medium with which to present to the public, stakeholders, and planners but also incorporates delving into the cultural influences that lead to planning ventures.

Local government and planning professionals can benefit from taking time to first, understand the cultural context. The west coast of Washington is the location of an impressive Native American population organized into different tribes. As with the entire west coast, these tribes will also have to consider how to prepare for changes associated with climate change and a Cascadia Subduction Zone event. In the city of Queets, located in the Quinault Reservation, is already contemplating planning solutions

in the form of relocating critical infrastructure out of flooding regions to an uphill location. The success of this, in part, is attributed to the level of trust in the political and social organization that exists within the tribes. As was expressed in the FEMA National Mitigation Framework (2013) local planning agencies used the trust of cultural leaders within the tribes when proposing hazard mitigation strategies.

After Katrina devastated the city of New Orleans advisors from the Netherlands almost immediately reached out to leaders in New Orleans to lend their knowledge and expertise about water management and flood control in a series of workshops known as Dutch Dialogues. The Urban Water Plan that was presented September 2014 proposes a new strategy that does not rely on levees and pumps to keep the water out, rather retain the water through series of canals, urban wetlands, and retention ponds. John Klingman, a New Orleans architect involved in the process from the beginning was confronted with questions such as “How can you be a water city with no visible water?” from the Dutch water managers who could not understand the cities disjointed water relationship. In the Netherlands, citizens have been living in one way or another with the water for centuries so the idea that the citizens of New Orleans had no desire to incorporate water into their planning designs was confounding.

The new trend unveiling itself in the Netherlands is a program known as *Planologische Kernbeslissing Ruimte voor de Rivier*, (Room for the River) and it recognizes the inevitable limitations of protecting cities with levees, pumps and dike projects and suggests allowing rivers to recapture land and revert it back to the wild. In some ways the idea itself was pushed for by the citizens in light of devastating floods in 1993 and 1995 that called for the evacuation of over 250,000 citizens in a time when

flooding was seen as a nuisance of the past. Room for the River comprises of pushing dikes inland and creating more channels allowing the river room to meander naturally as it is intended to do. The major theme asks for citizens to accommodate the water and give land back to it so that they can avoid devastating future floods caused by bottlenecks and funneling that increases height and velocity of the water (Ruimet voor de Rivier). Through the implementation, the Dutch succeeded in creating more resilient systems that incorporated the uncertain possibility of high water levels caused by increased precipitation, mountain snowmelt and sea level rise. The long struggle of the Netherlands where 24% of the land and 60% of the citizens reside below sea level has influenced citizen initiative and cooperation with changing water management regimes.

In the case of the New Orleans, the different demographic and cultural background resulted in a different view of water management. In the United States, the Urban Water Plan endeavors to make water more visible and a part of daily life in NOLA where it has previously not been. The reception of citizens has not been as accommodating as what is typically experienced in the Netherlands. The citizens in New Orleans are, simply put, uncomfortable with water. This uneasy feeling has proliferated throughout the city's history and was exacerbated when levees breached during Hurricane Katrina. People associate negative conditions with water and, in a city with the highest rate of people that do not know how to swim, a result of the cities demographic and a long and complicated racial history (Martin 2013), the plan's components that call for floating streets, wetland reclamation and extended canals are met with mixed emotions.

How well local government and planning agencies communicates and present hazard information is a key component of community outreach and risk communication but understanding how the social and urban history also ties in with decision making is as equally, if not more, important. Stakeholder (inhabitants and entrepreneurs) knowledge is steeped in local experiences and knowledge. Their acceptance of an idea is processed directly through how this will affect their day-to-day lives. Technical experts strive for a universal understanding and adoption. Important but lost if the plan does not consider local needs and way of life (Eiser et al. 2015). Employing an asset based approach can help by assessing what citizens and stakeholders value within their city giving planners and researchers a baseline to build off of while still acknowledging the needs of the community.

Planning for Whole Community Resilience

Defining Resilience

Resilience was adopted from the physical science discipline and applied to describe different phenomena in psychology and ecology in the 1970's. Holling (1973) is credited with his application of resilience in ecology as a measure of the ability of systems to absorb changes of state variables caused by driving variables and persist. Yet, in Holling's 1973 article, he also distinguishes engineering resilience, which is the ability of the system to return to an equilibrium steady state after a disturbance, such as a natural disaster. The faster the system bounces back, the more resilient it is seen to be.

In the 1980's resilience as applied to describe disasters and a community's ability to absorb and recover from a natural hazardous event (CRRRI Report 2013) was gaining more recognition in disaster management and planning. In this discipline urban resilience is often defined as "the capacity of a city to rebound from destruction" (Vale & Campanella, 2005) with the focus being on whether the city has quantitatively recovered economically, population wise and its built form. Since that time resilience has taken on many adaptive definitions in a wide range of disciplines including engineering and planning, focusing on how an individual, community or system responds to and recovers from some kind of event. No agreed upon definition that applies across all disciplines was established though. The basis of the research conducted during the workshop in Aberdeen was to assess how stakeholders viewed different hazard information in the pursuit of achieving whole community resilience. For the purposes of this research paper, it was important to establish one definition. When resilience is referenced, it is meant as the ability of social units to mitigate hazards, contain the effects of disasters when they occur, and carry out recovery activities in ways that minimize social disruption and mitigate the effects of future earthquakes (Bruneau 2003).

When a change does occur, it is said to have experienced a regime shift, defined by a shift from a state of equilibrium in an ecosystem to an irreversible alternative state (Biggs 2012). An ecosystem falls victim to a regime shift when it has been pushed passed a critical threshold and has experienced an alteration in structure and dynamics. For an urban landscape, this comes in the form of environmental, social and economic shocks. The vulnerability of communities to irreversible shifts is exemplified all over the globe with coastal communities facing the highest risk. The occurrence of a CSZ in the

Pacific Northwest is a prime example of a possible regime shift. The disruption of an earthquake tsunami event would cause an insurmountable amount of damage to all aspects of urban life, irreparably changing the landscape and forcing much of the city of Aberdeen's population to relocate. The CSZ event in 1700 led to a drop in elevation, driving an entire forest below the mean high water level, killing all the trees exposed to the salt water (Spitz 2015). The subsidence of the earth below the mean high water level would create a new shoreline and, among other things, prevent most rebuilding operations.

To understand the mechanisms that make up a resilient system the interaction between humans and the natural environment must be reviewed together. Ecosystems are dynamic, inherently uncertain, with potential multiple futures. Moreover, managed ecosystems are transformed into new entities in order to create economic or social opportunity, and the success of that endeavor itself generates new classes of surprise and uncertainty (Holling 1996). Development and land use conversion is one of the major factors that delineate coupled ecosystems because it changes everything about the system's natural processes and coping ability. In the urban landscape factors like the urban form, built infrastructure, location and consumption preferences of households (Liu et al. 2007:1514) determine how a region will cope when confronted with a possible regime shift.

Adaptive Capacity

Adaptive capacity is an aspect of resilience that reflects learning, flexibility to experiment and adopt novel solutions and development of generalized responses to

broad classes of challenges (Walke et al. 2002). A definition of community resilience was first written about by Timmerman (1981), as a system's capacity to absorb and recover from the occurrence of a hazardous event; reflective of a society's ability to cope and to continue to cope in the future. (Timmerman 1981). Many similar definitions of community resilience since then emphasizes the system's ability to 'bounce back', 'capacity to cope' and a measure of "adaptation and flexibility'. While conservative interpretations of resilience emphasize self-reliance and the ability of a place to "bounce back" in the aftermath of a major shock, as Davoudi et al. (2012) highlighted in a recent *Planning Theory & Practice Interface*, a more progressive view is to consider resilience in terms of adaptability and transformability; to not only bounce back but also to reduce exposure to future risks. Therefore, an "evolutionary perspective" of resilience places significance on transformation, whereby social systems (through individual or collective agency) can adapt or search for and develop alternative development trajectories (Davidson, 2010). Similarly, Hudson (2010) argues that a resilient system is an adaptive system: Creating resilience is therefore most appropriately thought of as a process of social learning, using human capacities and knowledge to reduce vulnerability and risk in the face of the unknown and unexpected (Scott, 2013. 104).

Scenario Planning

Employing scenario planning can present an opportunity that enables people with different backgrounds and education levels to not only meet and exchange ideas but also consider all possible variables acting on ecological systems at any given time. The central idea of scenario planning is to consider a variety of possible futures that include

many of the important uncertainties in the system rather than to focus on the accurate prediction of a single outcome (Peterson, Carpenter and Cumming 2003, 359). In order to ensure that we are considering a variety of prospects planning officials can benefit from formulating three plausible scenarios. The reason for creating three possible trajectories is that two presents an ultimatum situation and does not expand thinking enough while four or more will limit ability for all the variables of uncertainty to be explored. These scenarios can act as brief narratives that connect historical events and current trends in order to consider hypothetical futures. They require a relevant period, singular location and actors that are associated with the issue. Scenarios do not indicate what the future will look like and can be snapshots of different possibilities based off current trends or new theories.

Not only can scenarios be used as a tool for co-adaptive management that enables a community to respond to changes but also help them to anticipate them. The purpose of scenarios are not to indicate what the future will be but what it *could* be using what is known from history, current models and considerations of what the effect of driving forces will have on these paradigms. Scenarios help stakeholders to cope with uncertainty, not by eliminating it, but rather by framing it and understanding the range of associated implications (Wallenburg, Buck and Edmunds 1999, 70). The uncertainty of the future plays out in many different manifestations creating a wider comprehension of what it means to plan for resilience.

Why not Sustainability

Sustainable development is defined as “development which meets the needs of current generation without compromising the ability of future generations to meet their own needs (Brundtland Commission’s report 1987). Resilience is seen as the ability of the system to avoid shifting into a new state, return back to the state it was before the perturbation or, capacity to function post-disturbance. (Walker et al. 2004). The concept of sustainability has garnered much support through the past three past decade, making its way into the planning lexicon. The term sustainable development was popularized in a report by the World Commission on Environment and Development in 1987 known as the Bundtland report (IISD 2010). In the state of Washington, sustainability was employed in community’s visions for the future, exemplified in *Seattle’s Comprehensive Plan: Toward a Sustainable Seattle* written back in 1994. However, in employing this concept planning entities need to reflect on the question, sustainability of what to what?

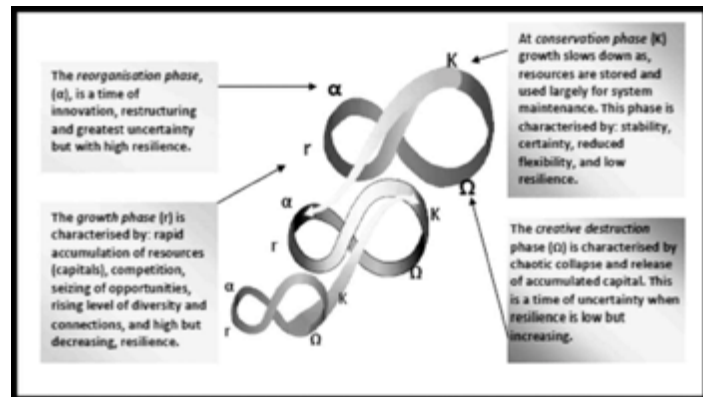
Sustainability aims to ensure that systems do not deviate from their current state but what if the current state is not the desirable state? The goal is not to maintain a system that is not sustainable in the greater context but to help the system reach a state where its processes and needs are met even through a shock (Walker et al. 2002). For this reason, it appears that resilience is replacing sustainability in everyday discourses in much the same way as the environment has been subsumed in the hegemonic imperatives of climate change (Davoudi, 2012). Yet resilience is itself, not necessarily desirable, as building resilience of a desired system requires enhancing the structures and processes that enable it to reorganize following a disturbance. It also requires reducing those that tend to undermine it. (Walker et al. 2002). In addition, as stated above, it is not always clear across disciplines what resilience means.

The emphasis in resilience is on the return to “normal” without questioning what normality entails (Pendall et al. 2010). One example of the potential undesirability of the “normal” is the 2005 Hurricane Katrina. The hurricane did not only destroy the physical fabric of New Orleans, but also revealed social processes which many people did not find acceptable enough to want to return to the pre-disaster normal (Davoudi 2012). On the contrary, what was aspired to be a “new normal” in social, economic, and political terms (Pendall et al. 2010) was not a desirable state to return to for everyone.

Another justification for seeking a “new normal” is that everything we knew about previous patterns will be completely ineffective. Instead, we will have to think more creatively and break out of established patterns of assessing situations and planning actions, so that we can better adapt to the future. Uncertainties are large and difficult to characterize due to the nonlinearity of key drivers such as climate and technology but it is for this reason that communities need to be educated on and prepared for numerous possibilities. For Aberdeen, a city that is strategically located in a region at high risk for both an earthquake and tsunami, the probability of the event is not the most important factor. Rather the more crucial consideration is what the extent of the damage to property and people will be and what this might mean for preparedness and long range planning.

According to a model by Holling and Gunderson (2002) there are four distinct phases of change in the structures and function of a system: growth, conservation,

release and reorganization (Figure 12). This is important for the purposes of this thesis because the model implies that as a system matures, its resilience reduces and becomes “an accident waiting to



happen” (Holling 1996), and when the system collapse (such as when an earthquake alters the physical appearance, “a window of opportunity” (Olsson et al. 2006) opens up for alternative systems configuration (Davoudi 2012). Examples of participants employing this kind of thought process is discussed further in the findings section in Chapter 5.

Notwithstanding the above model, there is a lot of difficulty in translating resilience thinking from the natural world to the social world. Interventions by humans in processes through ingenuity and technology can indeed diminish, sustain, or enhance resilience (Davoudi 2012). Intervention can raise a whole set of its own normative and political issues but the one I am most focused on in regards to this research is the idea of self-organization. Translated into the social context this concept is charged with ideological overtones as it relates to self-reliance, a quintessentially American idea (Swanstorm, 2008). The issue comes into play when considering if self-organization urges communities to become more self-reliant and the overarching government retreat from its responsibilities. This is currently the favorable conclusion in the neoliberal

climate in the UK. While the existence of engaged social networks help foster adaptive capacity and enhance transformative resilience, it is not a substitute for responsive and accountable governance (Davoudi 2012). As resilience is being applied more and more to social systems it will be important for planners to act as a guide and provide clear definitions for what the desired outcome of whole community resilience looks like.

A goal of the studio project in Aberdeen was to explore how different approaches of communication can help a community to consider its own resilience. To achieve this it is essential to first develop a historical profile covering local, regional and multiregional aspects as a way to deduce what changes have occurred at what scale and how the system might respond to future shocks. What factors are controllable and which are not? What are the uncertainties that can neither be controlled nor quantified? What are the current institutional arrangements that will affect planning processes? The next section encompasses the regional profile of Aberdeen and the contributions that the workshop made to the student's personal design projects before discussion the interpretations from the community workshop.

Chapter 4: The Aberdeen, WA Case

The city of Aberdeen is situated 35 miles past the capital city of Olympia, along I-5 as it branches to the west and becomes Highway 101, nestled between the Pacific Ocean to the west and lush forest to the north east (Figure 13, 14, 15).



The Wishkah and the Chehalis rivers converge at this point contributing to the topography characteristics of the land, a result from centuries of sediment deposits. Incorporated in 1888, Aberdeen fulfills the role of the residential and commercial core in Grays Harbor.² Because of the location, the city maintains the only deep-water port on the west coast of

² History of Aberdeen. <http://www.aberdeenwa.gov/history-of-aberdeen/>

Washington with the port of Grays Harbor being the largest coastal shipping port north of California. Settlement in the region grew from successful ventures in timber and fishing due to the burgeoning natural resources and proximity to the ocean and rivers as avenues for transporting goods. The success soon furnished businesses such as mills, canneries, and shipbuilding that continued to contribute prosperity to the region well into the twentieth century. By 1970, the timber industry began to slow due to over logging and by the 1990s most of the mills closed down culminating in an economic downturn for the region and a general shift away from natural resource industries to be replaced by education, health care services and retail industries.³ It has maintained a modest increase in population since the 1990's but has yet to recoup the 15.1 percent loss of population from 1950 to 1990. Tourists from all over Washington are drawn to the region for the opportunity to pass through the gateway to the pacific coast, the Olympic National Park, and the gorgeous beaches along the coast. Calling South Aberdeen home, the Grays Harbor Historical Seaport provides many opportunities for tourist attraction through their procurement of the vessels the Lady Washington and Hawaiian Chieftain. This nonprofit organization engages tourist with educational programs, public sailing excursions, public walk-on tours, as well as battle sails that provide a taste of 18th century maritime life. The national popularity of the band Nirvana also continues to contribute to the tourist traffic through the region with the Kurt Cobain Memorial Park and welcome sign emblazoned with their most infamous lyrics as well as a multitude of recreational options that allows individuals to be immersed in nature.

³ Aberdeen—Thumbnail History.
http://www.historylink.org/index.cfm?DisplayPage=output.cfm&file_id=7390

Demographics

The city harbors a population of over 16,000 at a density of 1,586 per square mile, making it the biggest city on the west coast.⁴ When combined with Hoquiam and Cosmopolis, the three cities are the basis of the economic hub and location of half the population for the county of Grays Harbor. The population alters throughout the day as only 3,185 or 55% of citizens who work in Aberdeen live within the city limits. The other 2,499 or 45% of workers commute from all over the region. This is an important aspect to consider when it comes to having the knowledge during times of crisis. In particular, many of the representatives from emergency management, safety and security, do not live within the city.

The City of Aberdeen has a slightly higher percentage of single-family residences and a significantly smaller percentage of mobile homes than the statewide averages. Aberdeen has the lowest percentage of family households, at 60.7 percent, and persons per household, at 2.34 percent, of the Harbor cities. Approximately one-quarter of the housing stock in Aberdeen is multi-family housing. Between 1990 and 1997, the number of multi and single family housing units declined in Aberdeen. Of the 6,074 residential units in Aberdeen 3,281 are owner occupied and 2,793 are renter-occupied. According to the American census data over 1,000 residence are vacant with an estimated 133 of these designated as homeowner vacant, most likely second homes. Around 50% of the 16,371 population is female and at a median age of 35 years. The 2011 comprehensive

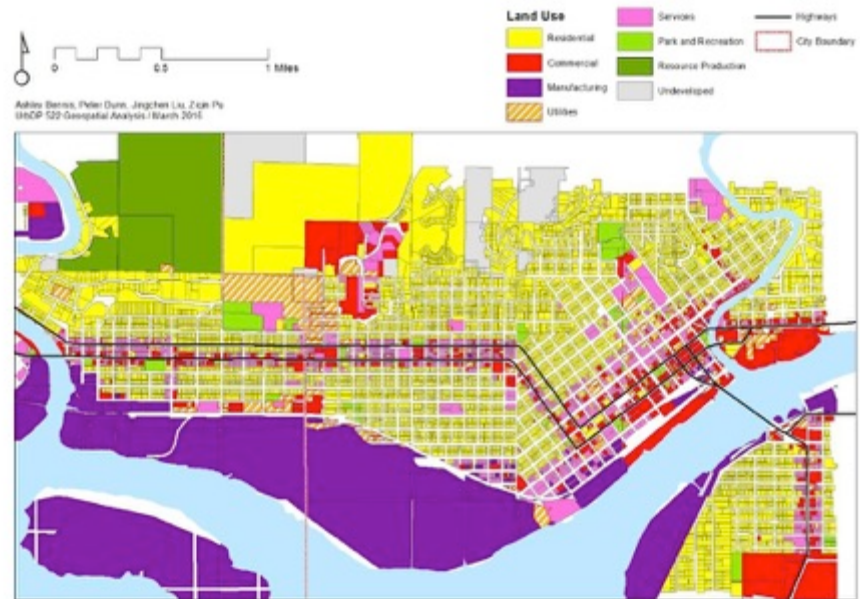
U.S. Census Bureau—Aberdeen, Washington.
<http://www.census.gov/quickfacts/table/RHI805210/5300100>

plan notes that in age groups six through 64 Aberdeen experiences a drop in population of about three to five percent that is contributed to the large migration of younger city residents during the economic downturn of the 1980's. About 18 percent of Aberdeen's population are located below the poverty level with is much greater than the state's average of 10.9%.

Land Use

The land use map to the right (Figure 8) shows how much of the industrial uses in Aberdeen are located on the waterfront that is shared by larger commercial uses located near the

Land Use in Aberdeen and Hoquiam Study Area



Wishkah River. The historic downtown core is located at the southeast region of city along Highway 101. Around 80% of the land is zone as some level of residential and covers a wide range of economic roles.

Assets

Aside from natural amenities, Aberdeen boasts a wide range of built and social capital providing a quality of life for all stages of life. A robust education system

complete with four elementary schools, two high schools, two colleges and a much-anticipated STEM school provide opportunities to the younger residents of the town. Aberdeen is the medical hub for the coastal region with the newly built Grays Harbor Community College and wide array of specialized clinics that can address most medical ailments. A strong Public Utilities network has provided unobstructed power to the residents and businesses of Aberdeen throughout countless natural disruptions. Not to mention a thriving international port, home to a wide variety of businesses that provide jobs and economic opportunities to both Aberdeen and Hoquiam. Though a small town by Seattle standards, Aberdeen provides an exorbitant amount of amenities for its citizens to grow up, learn, recreate, work and retire while still maintaining a small town feel that contributes to the strong social ties that characterize the town.

The passion of the citizens of Grays Harbor and proximity to such a variety of natural resources has also inspired a number of collaborative efforts in the region, including;

Forterra- Citizens in the city of Aberdeen are passionate about their past in seafaring and have been collaborating on their Coastal Resilience and Shoreline Master Plan to reconnect the city with the waterfront. Forterra is one of the largest conservation and community building groups in the Northwest, was hired by the Grays Harbor Historical Seaport Authority to assist with grant writing and fundraising from public and private corporations, and government. This work is a part of Forterra's Olympic Agenda, an organization that focuses on developing economies in rural communities in ways that are sensitive to the environment. Forterra has also helped facilitate community listening

sessions to engage residents in planning efforts to redevelop the historic downtown area.⁵

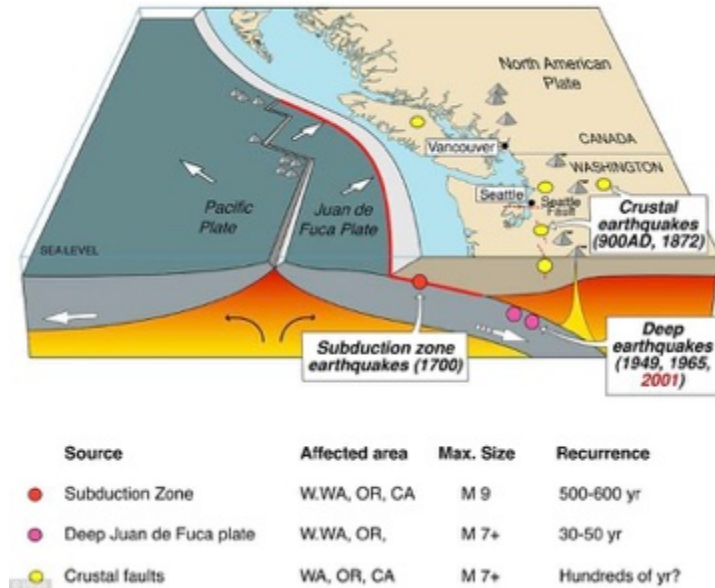
Washington Sea Grant—the Washington Sea Grant is part of a national network of 33 Sea Grant Programs that is administered by the National Oceanic and Atmospheric Administration. Building off the University of Washington’s academic strengths in marine science, engineering, and policy the WSG supports marine research, education and works with communities to strengthen understanding and sustainable use of ocean and coastal resources. WSG is currently a part of the state team commissioned by the Washington Legislature to develop a Marine Spatial Plan for Washington’s Pacific Coast. The WSG is trying to find a balance between the variety of uses (shipping, recreational, fishing, habitat conservation) by creating a spatial plan grounded in public participation and science-based decision-making. WSG is working with Aberdeen and other coastal communities to help them understand these implications and facilitate information sharing between state planners, federal partners, tribes, and other stakeholders (WSG). As Aberdeen is located within the Marine Spatial Planning study area boundary WSG is looking at a variety of factors from energy suitability, possibility for recreational activities, habitat conservation, water quality, infrastructure and human uses.⁶

A Region of Many Hazards

The Daily World—Squint and you can see more than Seaport Landing. <http://thedailyworld.com/sections/news/local/squint-and-you-can-see-more-seaport-landing.html>

Marine Spatial Planning for Washington’s Pacific Coast—WSG. <https://wsg.washington.edu/marine-spatial-planning-for-washingtons-pacific-coast/>

Cascadia Subduction Zone



Not only is Aberdeen located in the geological hot spot known as the 'Ring of Fire', a region where tectonic activity produces frequent earthquakes and occasional tsunamis, the sediment buildup of the Wishkah and Chehalis Rivers over centuries has created a landscape highly susceptible to

landslides and liquefaction. As can be seen in the image (Figure 2) created by the United States Geological Survey (USGS), the county of Grays Harbor is located at the convergence of the Pacific plate, the Juan de Fuca Plate and the North American Plate.⁷The fault line created from these plates is known as the Cascadia Subduction Zone named for the volcanic mountain range that runs parallel 100 miles inland, and can potentially cause a substantial amount of damage to the built, social, and natural environment. Any amount of ground shaking endangers the entire region to liquefaction of the soil; a phenomenon in which water saturated layers of soil take on properties of a liquid due to the pressure created by the earthquake.

The Juan de Fuca Plate is currently sliding underneath the North American Plate causing the land plate to bulge upwards at a rate of about 3 to 4 millimeters a year and compress eastward at a rate of 30 to 40 millimeters. If the tension, which has been

⁷ Cascadia Subduction Zone—USGS. <http://earthquake.usgs.gov/data/crust/cascadia.php>

building up for the past 300 years, is released, an earthquake at a magnitude of 8.7 to 9.2 could be felt all along the western coast from Cape Mendocino California, through Oregon and Washington up to Vancouver Island in Canada. An event of this magnitude would create enough destruction alone but as the fault is located offshore, the implications for subsequent, damaging tsunami waves are great. Various models implicate that millions of citizens will be affected by such an event with exact numbers impossible to predict.

Flooding

According to a Sea Level Rise in the Coastal Waters of Washington State report by the University of Washington Climates Impact Group and the Washington Department of Ecology the sea level rise on the west coast of Washington is less than the global average due to the amount of tectonic uplift. The International Panel on Climate Change estimates that the Olympic Peninsula can stand to see 35 cm of sea level rise by 2050 and 88 cm by 2100. It is Aberdeen's strategic location at the convergence of the Wishkah and Chehalis River that creates substantial flooding issues, especially in the historic downtown core. During the winter and spring time, when snowpack melt is high, the city can experience devastating floods. It is estimated that Aberdeen residents pay some of the highest premiums for flood insurance in the state.⁸

Landslides

⁸ Sea Level Rise in the Coastal Waters of Washington State.
<http://www.cses.washington.edu/db/pdf/moteetalslr579.pdf>

Aberdeen has always enjoyed a milder climate with a high prevalence of rain, which can cause the soil to liquefy and flow. As a result, Aberdeen has a high prevalence of landslides along the bluffs that designate upper and lower Aberdeen.

Storms and Strong Winds

The coast of the Pacific Northwest experiences several low-pressure systems, which can produce winds as strong as 60 mph from the months of October to March. Winds have been known to cause downed power lines, tree branches, and external damage to houses.

Fires

The Olympic National Park is one of the wettest places on earth but an unusually dry winter prevented the formation of snowpack in 2015 causing a devastating fire to overtake the forest. The fire lasted for more than 3 months and burned through over 1,600 acres of forest before it was distinguished. Changing climate conditions will continue to trigger unusual events that are not often seen such as the Paradise Fire in Washington. Along with that, the older median house age in Aberdeen means homes are constructed from wood and have older electrical systems that have caused many fires for a city of its size in the past.⁹

FEMA National Flood Insurance Program and Flood Insurance Rate Maps

Flooding is an expensive issue that affects many communities all over the United States. As a way to keep damage associated costs at a reasonable level, the United

Grays Harbor County—All Hazards Guide. <http://nws.weather.gov/nthmp/documents/FINAL-GHCAIHHazardsGuide.pdf>

States Congress implemented the National Flood Insurance Program in 1968. The basic role of the NFIP is to help FEMA to identify flood hazards, assesses flood risks and partner with states and communities to provide accurate flood hazard and risk data to guide them to mitigation actions. The Floodplain maps are the basis for the NFIP regulations and flood insurance requirements displayed in the Flood Insurance Rate Maps (FIRMs). FIRMs include statistical information about data such as river flow, storm tides, hydrologic/hydraulic analyses and rainfall and topographic surveys using best available technical data.¹⁰

North Shore Levee Project

The susceptibility of the Hoquiam and Wishkah River to flooding has created extensive issues for the citizens of Aberdeen that are both disruptive and costly. Currently flood insurance rates in Aberdeen are egregiously expensive due to a lack of flood protection measures in the city. In an effort to protect the cities of Aberdeen and Hoquiam the North Shore Levee project has been proposed to decrease the risk of annual flooding and insurance rates for citizens and business owners. Generating business growth has proven to be difficult not only because of the high insurance rates but because both downtown cores in each city are located in the worst flooded regions of the city.

The Levee project is the combination of many previous projects aimed at flood mitigation and has narrowed down to two major implementations; a dike along Market

FEMA—The National Flood Insurance Program. <https://www.fema.gov/national-flood-insurance-program>

Street and a South Side Dike/Levee Certification. Acquiring a Conditional Letter of Map Revision, a letter received by FEMA that indicates whether a project, if built, would be recognized by FEMA, is the first step towards a letter of map revision (LOMR). A LOMR “is a legally-binding document guaranteeing that if a levee system is built as submitted to FEMA, and is in agreement with effective FEMA models and maps at the time of construction.” The completion of the Letter of Map Revision (LOMR) can lead to “eliminating mandatory flood insurance through the National Flood Insurance Program for mortgages while also providing comprehensive protection to frequently flooded areas” (Aberdeen-North Shore Levee Project). The project is scheduled, funded by the Chehalis River Basin Authority, and underway. The following projects are proposed and funded through the North Shore Levee Project:

- 1) Market Street Dike Status: Project is getting prepped to hire design/engineering consultant

Purpose: This project will protect Aberdeen and Hoquiam from coastal flooding. It is aimed at removing Aberdeen and Hoquiam from the floodplain and placing them in a mapped zone x, eliminating mandatory flood insurance through the NFIP for mortgages while also providing comprehensive protection to frequently flooded areas. Projected to protect 2,700+ homes/properties and provides projected annual flood insurance savings (\$1M-\$1.5M).

- 2) Southside Dike/Levee Certification Status: Certification is about 60% complete

Purpose: This levee was designed by the Army Corps of Engineers and built to protect south Aberdeen. This project currently needs a complete certification process.

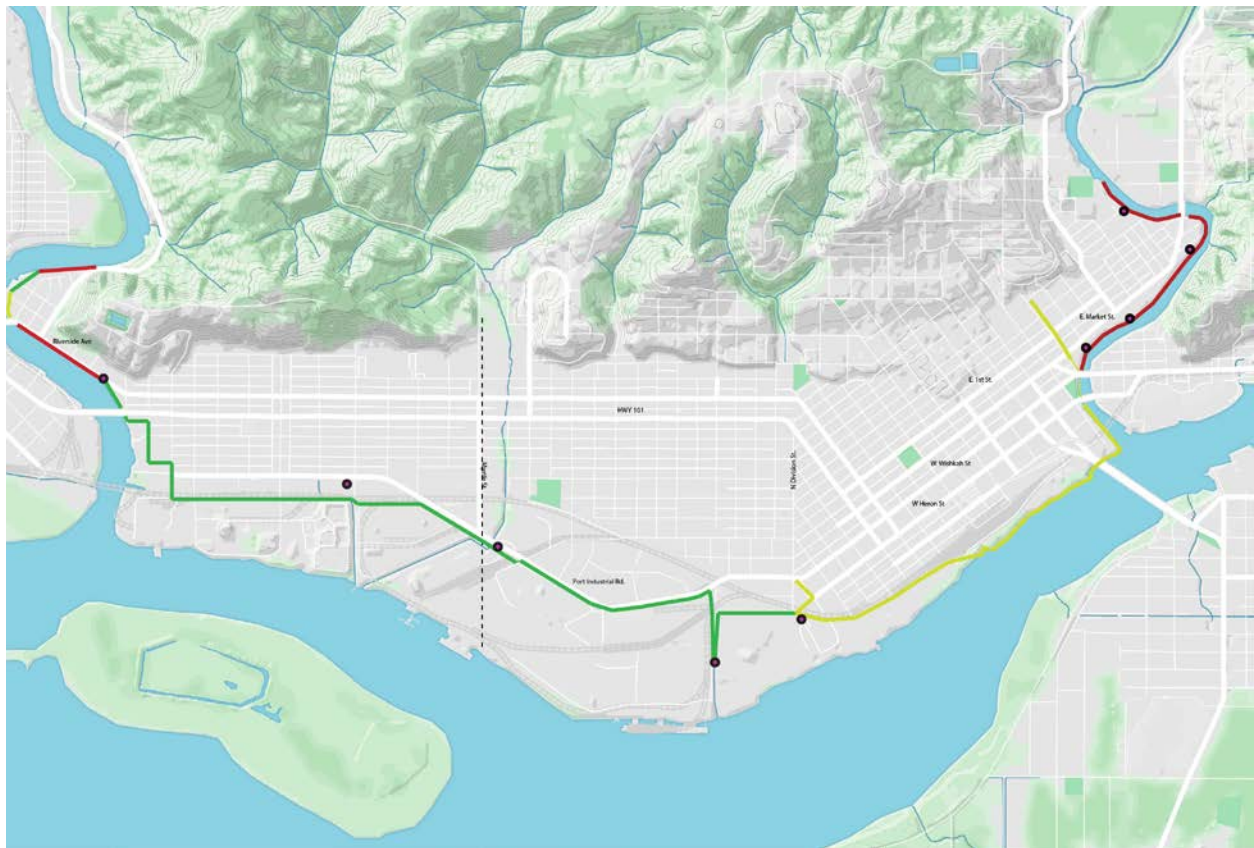
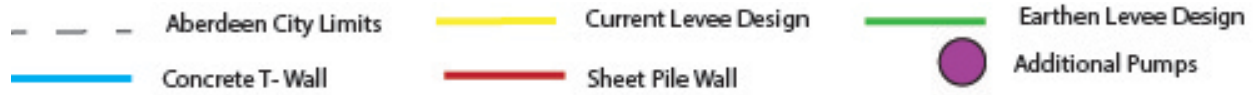
Certifying the South side, Dike will ensure the compliance with USACE standards and the effectiveness of the Dike to protect South Aberdeen. It will protect a residential population (approx. 4000 people) an elementary school, junior high school, major shopping centers and various commercial businesses.

Project Schedule:

- July 2016 -- Alignment Analysis & Concept Design
- October 2016 -- 60% of plans complete
- February 2017 – CLOMR submittal & FEMA Review¹¹

A map of the extent of the levee is provided in the Figure 16.

¹¹ Aberdeen- North Shore Levee Project. <https://www.ezview.wa.gov/?alias=1775&pageid=34768>



Advanced Design Studio

The 2016 Master of Urban Planning class is an Urban Design studio project working in conjunction with the “M9” project to study how communities planning for resilience might make use of new probabilistic information about tsunami hazards associated with a Magnitude 9 (M9) Cascadia Subduction Zone (CSZ) earthquake. However, the studio focused mainly on design-centered solutions the three-month course involved much more than that.

Goal

Through a short but intensive community collaboration, the studio explored how framing an issue can contribute to planning in a creative and resilient way. Students created nine design-based planning solutions and though there are varying levels of feasibility, the students recognized the importance of trying out a variety of approaches to find a solution that fits.

Studio Process

The 11-week studio centered on a workshop with local staff and residents that combine asset-based community mapping techniques with hazard mapping using the latest scientific models and interactive participatory GIS technology. The workshop as part of a larger visioning exercise for new settlement siting and forms based on local values and assets, to explore how planning for long-term adaptation in the face of an infrequent, unpredictable but consequential change can help a community realize its short- and medium-term developmental and environmental goal (see appendix A for full syllabus). Each of the students design work is presented in Appendix A section along with a map that displays the spatial reference of each project. The following section discusses the multi-faceted layers of that design work and how they reinforce or contrast one another.

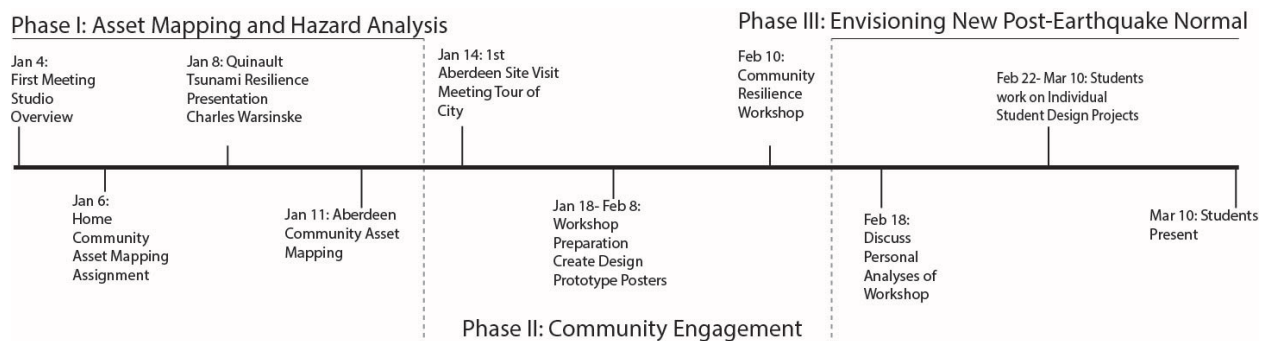
Retreat, Accommodate, Protect

One general concept of the studio is to illustrate how different responses to frequent flooding from storms, as well as rarer more severe flooding from earthquake-

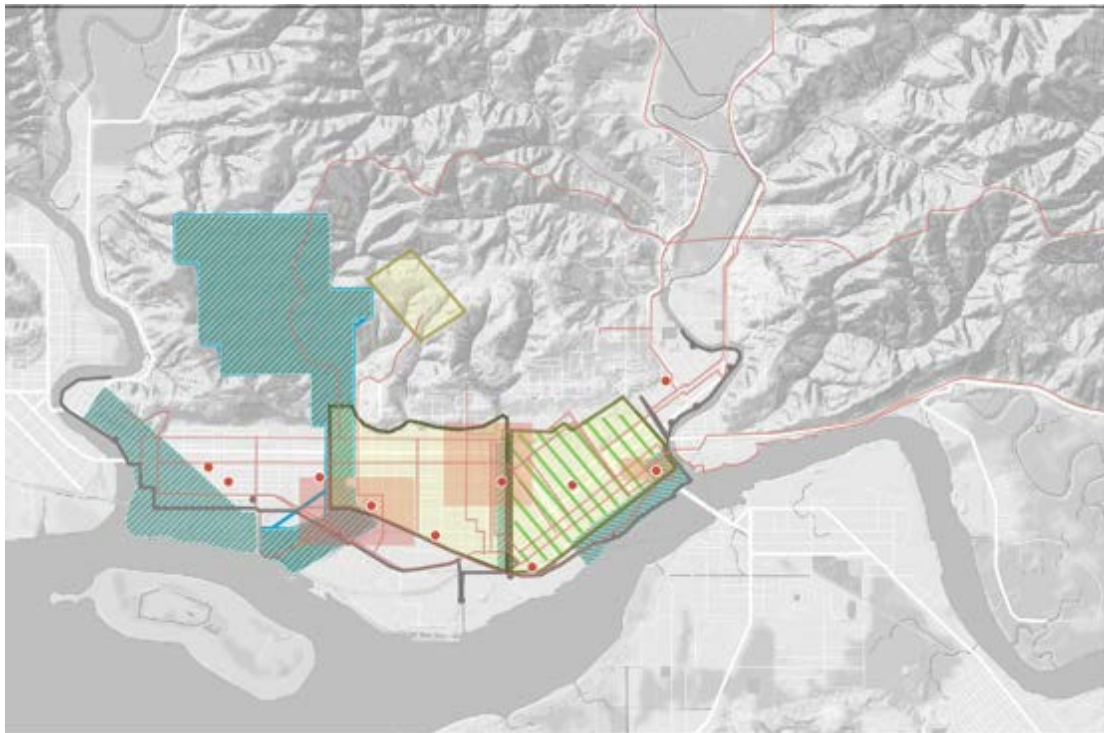
related subsidence and tsunamis, could either work together or separately. The students of the studio employed a variety of design solutions; in some cases designing for robust protection of important assets like the historic downtown from all these hazards, in other cases, the students designed for the surrendering of developed land to more biologically functioning streams, wetlands, and shorelines while also considering designs for the coexistence of development and wetland. The variety of students work illustrates how resilience can be achieved through designs and programs that meet short-term developmental goals while providing for a more secure future in the face of long-term threats. Complicated issues require complex solutions, for example, Aberdeen has shrunk economically and demographically in recent decades; perhaps some of it could be given back to nature, while parts of it becomes denser yet intensely protected, more lively but with a smaller footprint.

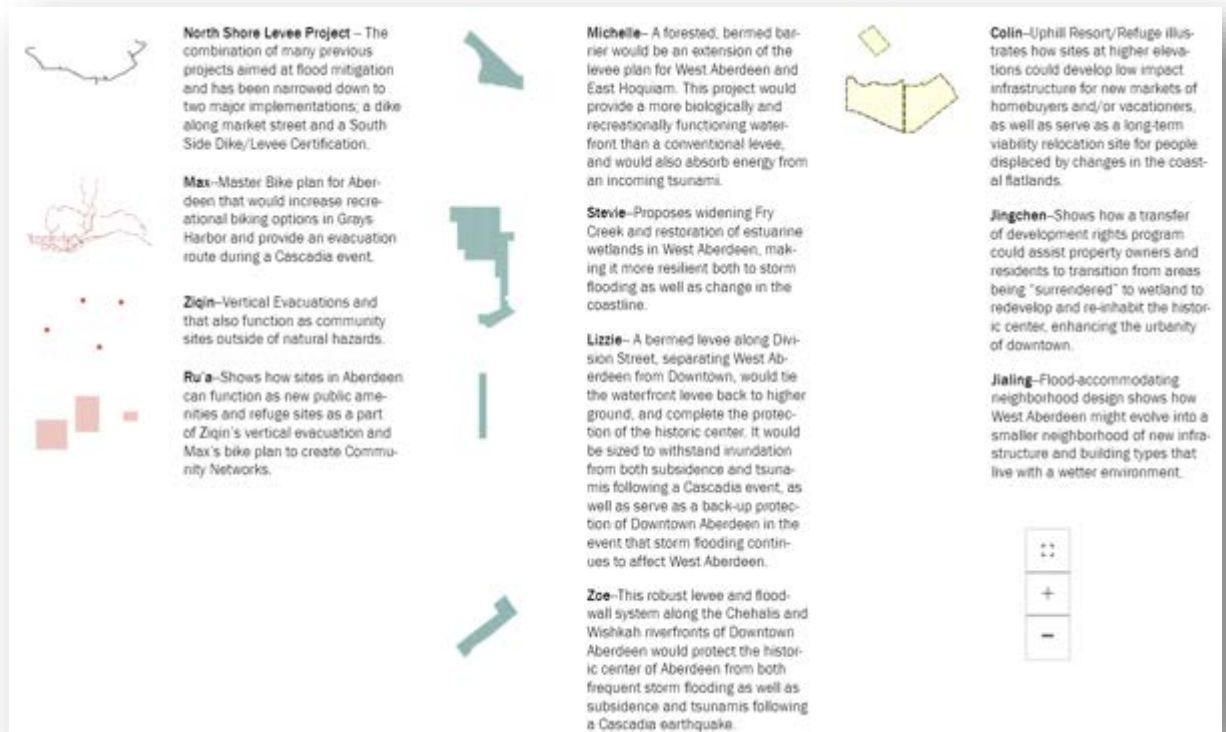
Workshop Contributions

The timeline is of the studio over the three months of the studio beginning in January up until the final presentation in March (Figure 17).



The first was a part of the studio (January) involved collecting background information on Aberdeen to map their assets and analyze the hazard. The second phase of the studio (January-February) involved the community engagement part of the studio during which students visited Aberdeen on two separate occasions. The first visit was part of a ground truthing (fact checking) exercise to scrutinize the background research students conducted earlier in the process. On both occasions, the students were able to meet with citizens of Aberdeen, ask questions, and hear them reflect on their city. Apart from the opportunity to give the studio a third, cultural dimension, students were also able to combine their knowledge of design solutions with the desire of the citizens to produce thoughtful solutions, which made up the third phase of the studio (February-March). The map and associated legend displaying the location of all the student's projects is provided below (Figure18) created by myself in collaboration with another student in the studio, Jialing Liu.





Many things were abundantly clear to the students; for one those employed by the City of Aberdeen and Grays Harbor are fiercely passionate about the fate of their community and the citizens they serve, and the residents that participated valued the wellbeing of their neighbors as highly as they value their own. The city experienced a severe flood event in 2015 but the community spirit could not be deterred as the citizens of Aberdeen felt a commitment to their neighbors, which will be, above all, the most important asset in the event of a CSZ earthquake-tsunami event. By visiting the city and sitting down with the community at the workshop, the students were able to gauge what was truly important to them rather than what the students felt was important from their background research.

The twelve individuals who participated in the community workshop at the Log Pavilion in Aberdeen on February 11 2016 provided a wide variety of information to the students including assets, vulnerabilities, goods, services, and the providers of goods and services. The goods, services, and providers were mapped using the WeTable technology as shown in (Figure 10). There were notable differences between the four groups but there were also universal similarities that the students detected. The value with which the natural resources and recreational amenities offered was indispensable to the residents. Not only is the city close to the Olympic National Park with a multitude of hiking and camping opportunities, Aberdeen has over 20 parks spread out over 273 acres (Aberdeen Parks and Recreation Dept.). The city grew because of the natural prosperity of the region and, even though the city no longer relies on these resources for economic purposes as much, it continues to define the character. Thus a bike plan (see image 18), proposed by one student endeavors to bring the residents and tourist closer to nature by utilizing a network of roads and trails that existed from the height of the logging industry but have since been decommissioned. The Olympic Peninsula already possesses a vast bike network and the bike plan would not only add to this but also provide citizens with alternative escape routes to the upper regions of the city if disaster struck. The network would include a lit portion along Division Street in Aberdeen, which would provide a beacon to residence in the lower region in the case of a total blackout.

Participants also expressed pride in their thriving port and extensive waterfront. A waterfront park and bike path already exists along the northern banks for the Chehalis River but for the most part the waterfront has been largely used for commercial and

industrial purposes. The following descriptions of the student's projects refer to Figure 18 and associated levee.

The first visit as well as the workshop gave the impression of a strong desire to be reconnected with the waterfront, a feat that could be met with one student's natural berm design and another's robust levee and floodwall system. Flooding creates issues from both eastern and western directions in Aberdeen and Hoquiam. The natural berm would provide protection for the residents and commercial core of Hoquiam, activate underused land and provide an opportunity for tourist and residents to reconnect with the water while enjoying a forested, natural environment. The levee and seawall would protect the commercial core of Aberdeen from flooding caused by the Wishkah and Chehalis but also be constructed in a way that would reconnect the downtown with the rivers. Both are an extension of the existing plans for the North Shore Levee but would provide another social, communal and recreational layer. The North Shore Levee project and the Aberdeen Revitalization Movement are both consistent in their desire to protect and enhance a historic gem of the city, downtown Aberdeen. The levee and seawall as well as one student's Division street berm would secure this area from future flooding and inundation caused by a tsunami.

With this extra protection, insurance rates would potentially lower and developers could invest more into development in the downtown. One student's design project looks at the feasibility of increasing density and the urbanity of the downtown region. An aspect of this will show how a transfer of development rights program could assist property owners and residents in areas being "surrendered" to wetland as proposed in one student's Fry Creek design to redevelop and re-inhabit the historic center. The

construction of the North Shore Levee, implementation of the division street berm and erection of the sea wall would ensure that the downtown is the best-protected region in Aberdeen. Visiting Aberdeen, a student could not help but notice the amount of standing water still lingering on the streets near and around Fry Creek. Relinquishing this region back to the wetlands they once were, would add extra storage for floodwaters as well as lessen the impact of tsunamis waves but would also result in numerous displaced citizens. The downtown design project provides an alternative, better protected location for those residents to go. One of the students looked up to the bluffs to create a resort and refuge design, which also provides options for these residents, inspired by plans for pre-tsunami relocation in the nearby Quinault Indian Nation, which studio members also studied and visited. ¹²

The uphill region in Aberdeen currently accommodates a small number of residents and the Grays Harbor County hospital. The uphill design postulates the possibility of creating a low-impact neighborhood that creates new opportunities for homebuyers, those displaced by the wetland design and vacationers. This resort/refuge also designed for basic amenities that could provide much needed refuge in the event of an earthquake that can be easily accessed using the proposed bike network. If subsidence renders a portion of Aberdeen uninhabitable, the resort/refuge could provide people with temporary and long-term residence options. While the downtown flood-accommodating neighborhood design can serve as an alternative for citizens not wanting to relocate from the wetland proposed region as well as be an addition to the housing opportunities created by the downtown and uphill projects. Water is a major

¹² Colin Poff. (2015) "Relocation and Resilience: Exploring Co-Benefits in Aberdeen, WA"

part of the identity of Aberdeen and Hoquiam and along with accommodating it through natural solutions; the city could consider the options for creating flood tolerant buildings as is being proposed in The Netherlands, a country with 24% of land below sea level.

The residents will need many options to help protect them in the event of a CSZ, one student contended with how to create vertical evacuation structures (symbolized as octagons on the map) that also serve vital community functions when they are not being used for protection. The residents and city employees expressed aspirations for more community gathering spaces. This void could be filled with one student's proposed network of refuge and community sites that will connect with the bike routes and vertical evacuation structures. These sites will serve multiple purposes that address current and future community needs.

The goal of the studio was to demonstrate a variety of design solutions to help Aberdeen mitigate the risk of an earthquake and tsunami caused by a Cascadia Subduction Zone. Not all of the design projects reinforce each other and not all of them are economically feasible. If both of the natural berm systems that are largely constructed from soft material could be implemented in congruence with the North Shore Levee project, the downtown region would be protected and the seawall design would be less feasible to implement. Each of the three residence relocation designs offer a different approach to address, essentially, the same need. The downtown project offers the lowest development cost, highest density and could be the most feasible for the city to implement first. The resort/refuge and flood-accommodating neighborhood design have higher costs and require more planning coordination. The proposed numerous vertical evacuation locations might not be necessary if either of the natural

berm systems are implemented. The benefit of having so many options allows the residents and planning team in Aberdeen the opportunity to implement the projects that make the most sense.

Chapter 5: Community Workshop

The studio centered on a workshop with local staff and residents that combined asset-based community mapping techniques with hazard mapping using the latest scientific models and interactive participatory GIS technology. The workshop included a research component to compare how some participants use deterministic representations of the hazard with how other participants use representations that make uncertainty about the hazard more explicit (see Appendix A for Studio Syllabus). For the purposes of this thesis, I collected data that pertained to those research components but also, how perception and interpretations of the hazard information can influence adaptive management planning in communities. The workshop was held in phase two of the studio, on Thursday February 11 2016 in the coastal city of Aberdeen Washington. The staff and students of URBDP 508 B (Advanced Planning Studio) taught by Associate Professor Daniel Abramson facilitated the 3-hour community outreach meeting with stakeholders, local officials and residents of Aberdeen and Grays Harbor.

Workshop Protocol

The following is the exact protocol followed by the students in the Aberdeen workshop (see Appendix B for Workshop Protocol). The main purposes of the meeting were: (a) to discuss and map community assets and values, in the context of Cascadia Subduction Zone (CSZ) earthquake and tsunami hazard scenarios; (b) to inform Aberdeen's planning for resilience; and (c) to conduct research on new research approach of informing such planning. Upon completion, the students used the information generated in the meeting to inform their own attempts at resilient design and

policy strategies with the intent of presenting to community leaders at the end of the quarter. Nine design strategies were created from this effort as discussed in the previous section. I used the collected data to organize responses along themes and make inferences about the participant's interpretations and perceptions.

The workshop was devised using three assumptions; 1) Including representations of uncertainty in hazards maps will lead to more creative ideas about how to plan for recovery from natural hazards than just displaying a deterministic representation, 2) Beginning discussion with an assessment of community assets will influence stakeholders and citizens to consider resilient planning solutions for mitigation and long term recovery than would beginning the discussion with community vulnerabilities and, 3) When put into two different groups, one that displays a deterministic model and one that displays a probabilistic model, stakeholders in the deterministic group are more likely to divide themselves with respect to the single scenario of hazard (e.g. on one side or the other of the crisp line), whereas stakeholders in the second group are more likely to seek consensus and/or develop strategies that work for multiple sets of interests.

Sampling Approach

In order to generate a diverse and robust discussion the organizers tried to find as wide a range of representative participants from the community as possible. Dan Abramson, the instructor of the studio, established a point of contact with the Community Development staff of the City of Aberdeen. Through collaboration with the

studio, the staff reached out to city council members, local government officials, city employees and community members through email word of mouth and flyers to recruit participants. Twelve participants were recruited representing elected positions in local government, representatives from the police and fire department, Port of Grays Harbor and Emergency Management Division in Grays Harbor. The participants, who volunteered and attended the workshop, comprised a diverse group of stakeholders representing different perspectives in the community. Some of the participants hold elected positions in local government, work as staff from the police and fire departments, and municipal water and sewage; or are business and community leaders including representatives of the Aberdeen Revitalization Movement, the Port of Grays Harbor, and the Aberdeen Historical Seaport Society.

Organization

The organization of the 3-hour community meeting is as follows. Following a brief introduction, participants are split up into four small-groups for discussions that are randomly assigned to one of the four conditions (Figure 9) where they then engage in three rounds of discussion. After the third round, the entire group convenes, shares their results and conclusions, and reflects on what was learned. After this I gave each participant a survey to fill out.

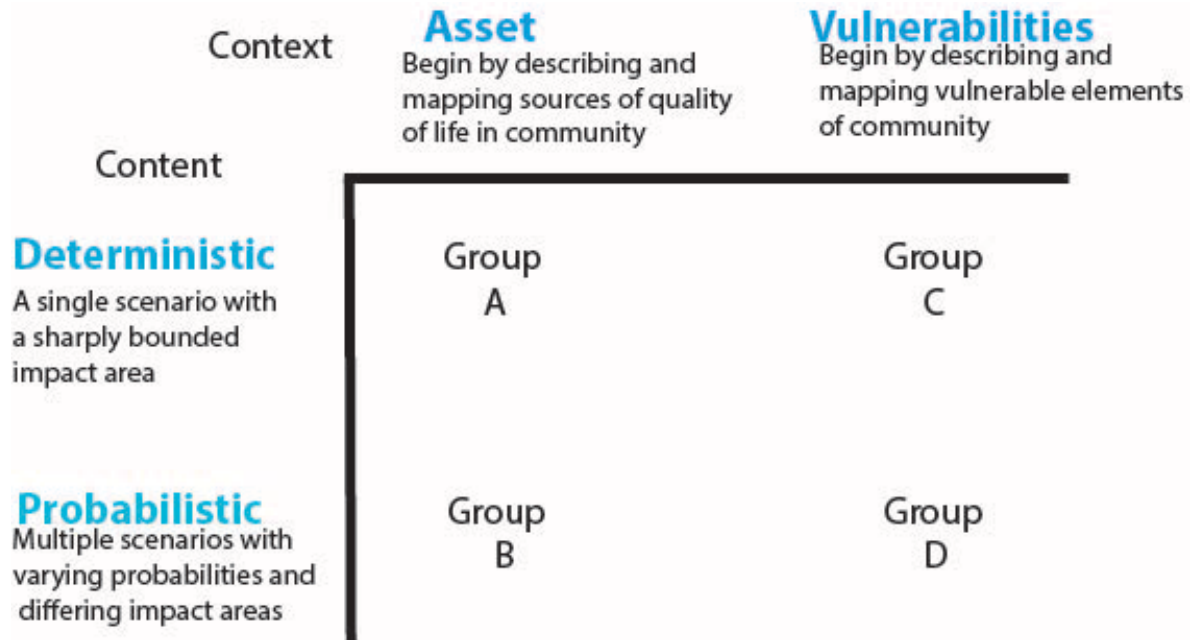


Table setup for the workshop

Each of the four groups sat at a separate small table, so that each table had three community participants, one interactive (Wii) map, and three students. Each group differed in the content and context with which they were working: A) began the discussion with assets, mapping sources of quality of life on a deterministic map, B) also began their discussion with assets but mapped sources of quality of life on a probabilistic map, C) began by discussing the risk and mapped vulnerabilities on a deterministic map while D) began by discussing the risk and mapped vulnerabilities on a probabilistic map.

Each group sat at its own table, surrounding a map, and was assisted by three UW students, one group had an extra note taker included around the table: one group dynamics facilitator; one mapping facilitator; and one-observer note-takers. Group dynamics facilitators were responsible primarily for keeping conversation flowing, within

time, and on topic, and ensuring that all participants in each group have opportunities to speak. Mapping facilitators ensured that as many items mentioned by participants that have spatial/locational properties were mapped. To assess the hypothesized differences in group behaviors and discussions, student observers took notes with quotes from participants and observations regarding how often and in what capacity they talked about assets and values, risk, precaution and hazard, consensus or agreement versus their own differing or independent position, and expressions of uncertainty. Student observers also noted participants' facial expressions, focus, and affect/emotion. The variables and note takers protocol is outlined in the following sections.

Design

As stated previously the workshop focused on small-group interactions, designed to inform on-going planning efforts in coastal communities and address broader questions of collective human responses to different types of visual hazard information. For example, before the workshop was organized Aberdeen already had an ongoing North Shore Levee project in the initial steps of planning. The students of the workshop were familiar with and discussed these planning efforts with the participants in efforts to ground the discussion in local context.

The set-up of the workshop was very similar to the FEMA-funded project conducted in Redmond, Everett and Neah Bay. Participants were separated into four different groups and characterized their community in terms of the goods and services that contributed to a good quality of life in Aberdeen as well as the contributors of those

goods and services. Goods and services included material things and activities such as “food,” “water,” “health care,” “recreation” as well as non-material things like “cultural cohesion,” and “self-sufficiency.” The sources and providers of the goods and services can be spatially located on a map within the community. Of the four different groups, two of the groups began their conversations identifying the goods and services, not discussing the hazard while two of the groups began by discussing the vulnerabilities in the event of a natural hazard.

Assets & Vulnerabilities

Does a conversation beginning with assets rather than vulnerabilities help us understand what actions a community might take to enhance its resilience? To assess the planning implications of starting a conversation with assets rather than hazards participants were separated into four different groups in which the context of two groups was hazard based while the others were asset based. The asset-based groups spent the first round considering the following questions: (1) what made Aberdeen a good place to live and, if a hazard disrupted daily life, (2) what assets are required to ensure that quality of life was not disrupted? Alternately, the hazard-based groups were introduced to hazard right away and asked: 1) what would happen in Aberdeen during and after a CSZ earthquake tsunami? In addition 2), what/who would be at risk during a CSZ earthquake tsunami?

The small-group discussions not only compared how stakeholders approach hazard mitigation and resilience in community planning but also if introducing communities to a discussion on community assets will lead to adaptive planning and

resiliency. The asset approach wanted participants to describe the city of Aberdeen in terms of what makes it a good city in which to live and to what extent do certain goods and services contribute to that. Groups that began with a hazard were asked to assess the extent that a hazard could negatively affect their city then contemplate the providers of goods and services at risk.

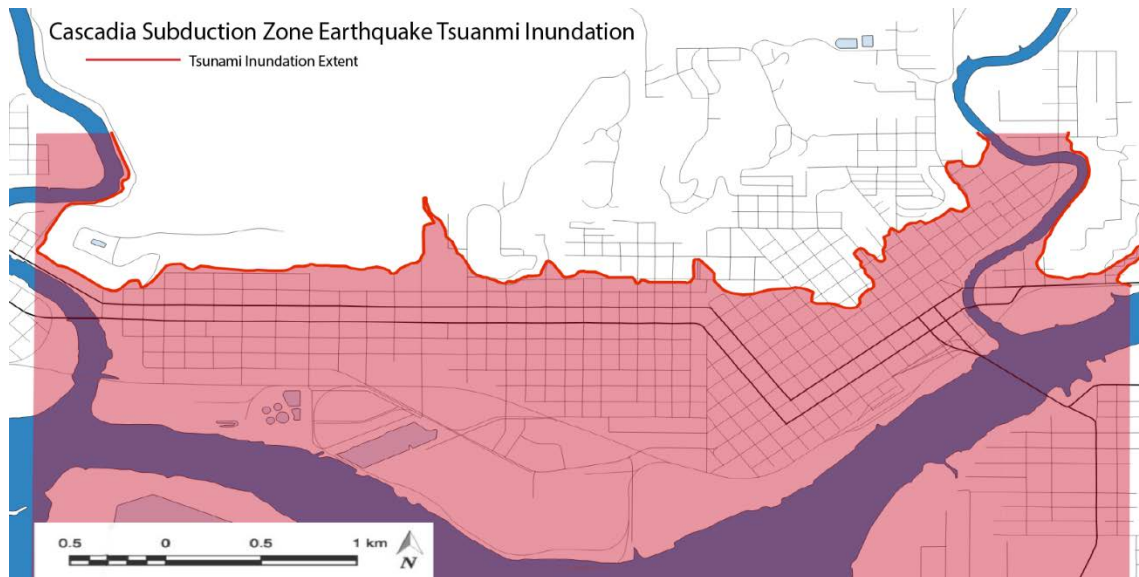
As discussed in the literature review section, the “Asset-based” approach aims to coax the stakeholders into creating an inventory of built, natural, and social community assets, then, examine the hazard scenarios and associated vulnerabilities and, finally, identify those assets that could facilitate planning that is adaptive i.e., assets that could help achieve comprehensive community planning goals, enhance mitigation of the hazard, and recover from the disaster (Freitag, et al., 2015). The “Hazard-based” approach emphasizes vulnerabilities of the city and is the most common approach taken in hazard mitigation and community collaboration efforts.

Probabilistic and Deterministic

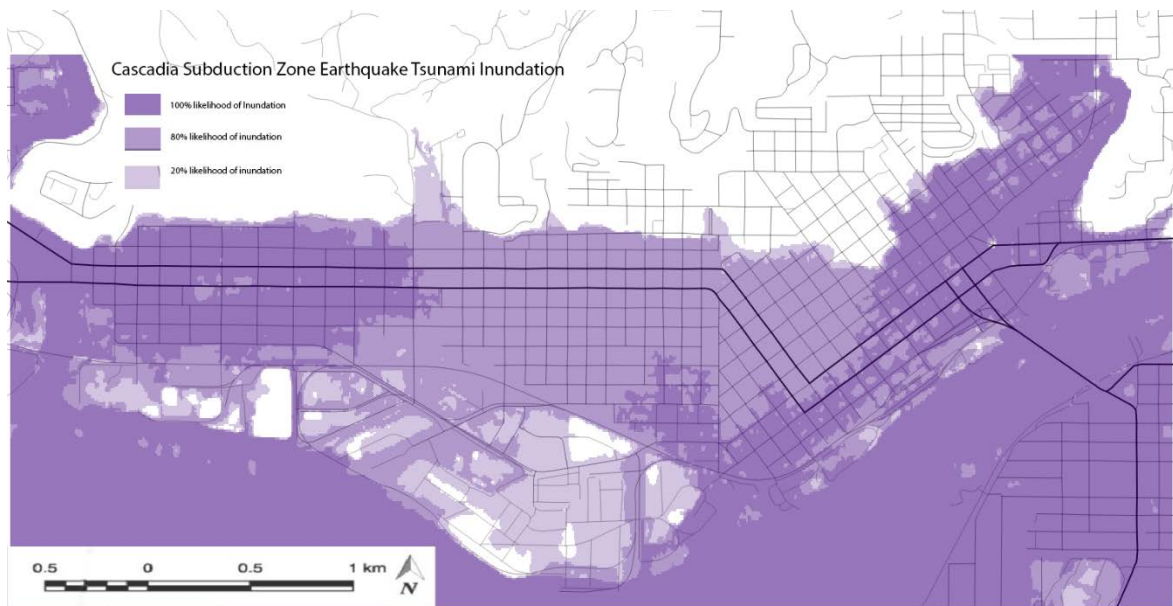
The studio also explored how different visual representations of hazard information can inspire different understanding and solutions in resiliency community planning. Maps that represent earthquake tsunami hazard information are commonly displayed with the inundation area encompassed by a single crisp line (Figure 3). Such maps lack any representation of the uncertainty in the science that underlies these maps including complex modeling of multiple factors of spatial and temporal details of the tsunami source, tidal stage, variable bathymetry and topography, seismic uplift or subsidence of coastal land, etc. (Goda & Song 2015). In contrast, the use of

probabilities (Figure 4) gives the map user a wider range of possibilities offering a better idea of the critical multi-hazard component seen as three different shades of purple. The lightest shade displaying a 20% likelihood of an earthquake event resulting in that level of inundation while the darkest color displays a 100% likelihood of an event causing that level of inundation. The studio hoped to discern if breaking away from the conventional procedure of presenting hazard maps to a community (first using the hazard map scenario, presenting associated community vulnerabilities then developing and discussing possible responses to the hazard) could spur solutions that are more resilient.

[Figure 3: Deterministic Map]



[Figure 4: Probabilistic Map]



The deterministic map (Figure 3) displayed danger as the level of inundation caused by a tsunami generated by a magnitude 9+ Cascadia earthquake with no further information given within the inundation zone whereas there are numerous scenarios for the magnitude of an earthquake that are possible. The look of the deterministic map is very similar to the tsunami evacuation route map (Figure 6) created for the cities of Aberdeen and Hoquiam. A crisp (in this case red) line was drawn separating the city into a region that was safe from tsunami inundation and a region that was not.

The probabilistic map (Figure 4) was created using uncertainties associated with tsunami hazard mapping categorized as Source Specification, Model Physics and Digital Elevation Model (DEM) quality issues. The map shows three varying levels, SM1, M1 and L1, each with a different percentage of likelihood. The inclusion of fuzzy

edges and different shading tones speak to researchers' uncertainty of knowing exactly how an earthquake tsunami will behave while also conveying the prospects of some areas being affected by all scenarios. The creators of these maps are researchers funded through the M9 project. The tsunami hazard maps were produced by Peter Dunn, Mike Greenfield and Alex Grant. The underlying modeling (four GeoClaw runs, based on a single subduction zone event) was done with support from Randy LeVeque, Loyce Adams and Frank Gonzalez.

The maps were displayed using an interactive GIS technology known as WeTable, developed for coastal hazards in Texas by Texas A&M University, and used for the first time in the state of Washington. This technology used a projector, light pen and a Wii remote at each table to encourage participants to not only respond to prompts but also interact with a map of their city. Students were trained before the workshop and were able to provide a short presentation of using the pen before handing it over to the participants. The importance of visual externalizations technology is that it can add another facet to the community planning process by allowing the use of perceptual cognitive and motor processes to devise new solutions (MacEachren; Monmonier, 1992).

Mapping Facilitators and Geospatial Information Systems (GIS)

Included in each table was a student in control of a computer complete with GIS. For the first time in Washington State an interactive GIS mapping technology, known as WeTable, was used to test the benefits of having participants to interact with the maps. Each table was set up so that participants were organized around a large map,

they could. Notes included the participants' responses to the questions, their body language, facial inflections indicating personal feelings (disagreement, discomfort, and complacency) and whether or not the participants engaged with one another. The reasoning behind capturing body language along with the dialogue was to get a sense of the participant's disposition in regards to the data that, recorded dialogue might not indicate.

The first thing the note takers were expected to do was take note of the group they were assigned during the meeting (A, B, C or D) as well as write down the positions of the participants. Each of the note takers used Table 1 (below) as a guide of what to pay attention to. The phrases and keywords provided as examples in the table below were articulated during this initial meeting. As stated previously the notes were assessed using Roth's (2009) uncertainty analysis research approach. Categorizing uncertainty refers to looking at the unique subcomponents of uncertainty and assessing their designation, articulation and analysis (Roth 2009) so the actual influence of uncertainty could be analyzed rather than just the outcome of the decision making process. Community workshops can move at a fast pace and it was probable that the note takers were going to miss parts of the conversation. A table (see Appendix D for

Themes) was created to clarify for the note takers the themes to focus on.

When did it happen?	What was said? Who said it?	Body Language/Social Interactions
Round 1		
Round 2		
Round 3		

Sequence of Discussion

The full workshop protocol and discussion can be found in Appendix B. The meeting began with a brief introduction discussing the studio, the purposes for this meeting a brief over view of the protocol, and purposes of the meeting led by Dan Abramson. Only after the participants are separated into their groups do the students take over and describe the sequence and qualitative experiences and damage forecast for the earthquake and tsunami as well as the predicted long-term changes. The timeline of the workshop can be seen in the table below.

The meeting consisted of two or three rounds of discussion, depending on the different sequences outlined above, according to the draft agenda below:

<p>6:00-6:30</p>	<p>Introduction by Lisa Scott and UW lead faculty Dan Abramson, outlining the background and objectives of the meeting as described in the first paragraph above. The introduction will be neutral with respect to the different kinds and sequence of information being used by the different groups. Participants grab pizza, and form into the four groups. (They will be pre-assigned, so that each group has a balanced number of elected officials, municipal staff with some expertise in emergency management, and other community stakeholders.)</p>	
<p>6:30-7:00</p>	<p>Round 1 Discussion</p>	
	<p>In the first 5 minutes, student facilitators present to Groups A and B a brief definition of “quality of life” based on the Millennium Ecosystem Assessment, and explain the distinction between the goods and services necessary for quality of life (basic material, health, security, and good social relations), and the local providers of those goods and services.</p> <p>Groups A and B discuss three questions:</p> <ol style="list-style-type: none"> 1. What generally makes Aberdeen a good place to live? 2. “What specific goods and services contribute to quality of life in general?” 3. “What/who specifically in Aberdeen provides those goods and services?” <p>To the extent these providers can be mapped, participants or student notetakers will mark them on maps. Non-mappable providers will just be listed on a chart. Facilitators encourage participants to be broad and inclusive in listing these providers, considering built, natural and socio-economic, but avoid suggesting specific possible answers.</p> <p>For the last five minutes, stakeholders select the 3-5 most important providers.</p>	<p>In the first 5 minutes, student facilitators present to Groups C and D a definition of “hazard”, “vulnerability” and “risk”, and a summary explanation of CSZ hazards facing the community, shown on maps (deterministic for Group C and probabilistic for Group D), and supplemented by analysis using FEMA’s HAZUS software and local data from the existing hazard mitigation plan.</p> <p>Groups C and D discuss three questions:</p> <ol style="list-style-type: none"> 1. “What would happen in Aberdeen during and after a CSZ earthquake and tsunami?” 2. “What/who in Aberdeen would be at risk during a CSZ earthquake and tsunami?” 3. “How would a CSZ earthquake and tsunami affect quality of life (as defined by basic material, health, security and good social relations) in Aberdeen?” <p>To the extent that at-risk items (people and things) in Aberdeen</p>

		<p>can be mapped, participants or student note-takers will mark them on maps. Non-mappable risks will just be listed on a chart. For the last five minutes of the round, stakeholders select the 3-5 most important at-risk items.</p>
<p>7:00-7:30</p>	<p>Round 2 Discussion</p>	
	<p>In the first 5 minutes, student facilitators present to Groups A and B a definition of “hazard”, “vulnerability” and “risk”, and a summary explanation of CSZ hazards facing the community, shown on maps (deterministic for Group C and probabilistic for Group D), and supplemented by analysis using FEMA’s HAZUS software and local data from the existing hazard mitigation plan.</p> <p>Groups A and B discuss “Immediately after a CSZ event, what/who would provide the goods and services you identified in the first round as contributing to quality of life? Which of the providers identified in Round 1 will be able or unable to withstand changes inflicted by the hazard, and which will enable the community to maintain its viability and identity through the changes?”</p> <p>As above, student facilitators list participants’ answers to this question on a chart, and map as many items as can be mapped. Participants are free to add any new goods and services to the initial list.</p>	<p>In the first 5 minutes, student facilitators present to Groups C and D a brief definition of “quality of life” based on the Millennium Ecosystem Assessment, and explain the distinction between the goods and services necessary for quality of life (basic material, health, security, and good social relations), and the local providers of those goods and services.</p> <p>Groups C and D discuss “Immediately after a CSZ event, what/who would provide the goods and services you need for quality of life? In addition to the providers identified in Round 1, what other providers will be able to withstand changes inflicted by the hazard, and which will enable the community to maintain its viability and identity through the changes?”</p> <p>As above, student facilitators list participants’ answers to this question on a chart, and map as many items as can be mapped. Participants are free to add any new goods and services to the initial list.</p>

7:30-8:00	<p>Round 3 Discussion</p> <p>All groups (separately) discuss “In the months and years following a CSZ event, what/who from round 1 (column 2) and round 2 (column 3) provides the goods and services that would do ALL of the following: (1) best help the community adapt to the "new normal" and recover over the long term; (2) put the community in better position should another disruption occur; and (3) provide a better quality of life.”</p>
8:00-8:05	<p>Break</p>
8:05-8:40	<p>Report Back and Full Group Discussion</p> <p>Each group then elects a spokesperson to summarize for the whole gathering the results his/her group’s discussions in each round.</p> <p>The UW faculty explains to the whole gathering the different types of information and sequences of discussion each group worked with, and the rationale for dividing the activities in that way. The whole gathering then reflects on what was learned.</p>
8:40-8:50	<p>Students set up easels with posters of preliminarily researched potential design and policy strategies, while community participants fill out a questionnaire with questions as listed below.</p>
8:50-9:00	<p>Community participants’ give feedback on posters by writing on post-it notes.</p>
9:00-10:00	<p>Community participants adjourn. Students stay to write up field notes on their group discussions, and go through their notes to clarify them.</p>

The survey (see Appendix C) was dispersed to the participants immediately after the big group discussion and promptly collected. All twelve participants were able to complete a survey; the answers were aggregated into a table (see Appendix D).

Findings/Results

To simplify the following discussion of the findings I will be referring to groups in a short hand format. Group A, asset-based deterministic information will be referred to as A-BDet, Group B, asset-based probabilistic information will be A-BProb, Group C, hazard-

based deterministic information will be H-BDet and Group D, hazard-based probabilistic information will be H-BProb. To back up interpretations of the results I will be providing snap shots of the tables, full tables can be found in Appendix D.

Asset-Based Groups

The table displayed below outlines the aggregate responses from participants in the groups that began their discussions with assets (groups A & B). Participants highlighted the inexpensive, small town feel of the city yet there were still good amenities and plenty of recreational activities to do in close proximity. The health care and education system as being excellent for a town of that size making many feel safe and well provided for. The deep-water port provided economic stability in the region and was frequently cited as the reason people would return after a hazard event. One of the most highlighted points made by the asset groups was the social resilience and self-sufficiency that existed in Aberdeen. The region has frequently been tested with devastating natural hazards such as flooding and landslides but the ability of neighbors to care for and help each other will be a defining aspect in the response and recovery after a CSZ event. Though the groups did recognize the bleak-ness of the situation they were able to contemplate solutions that would lead to a new normal in Aberdeen. These solutions are discussed in the section that compares the asset-based and hazard-based groups.

Goods and Services	Providers	Post-Providers	New Normal
Utilities/Infrastructure	PUD. Reservoir upper level. Sewer treatment plant. Electrical Grid	Utility crews but mobilization will be slow. A water replacement could be Lifestraws. But there are not guarantee there will be replacements	Grays Harbor will continue to provide utility services but should consider moving uphill out of inundation zone

Education Institutions	Grays Harbor College, Elementary Schools, High School	Highschool and College would likely withstand earthquake/tsunami	The college and Highschool will continue to function
Healthcare/Social Services	Community Hospitals. Ambulance services. Nonprofits (Mission and Coastal Alliance).	Hospital is located out of inundation zone. St. Joesph's could be an alternative. Ambulance services are in inundation zone	If unaffected by earthquake the hospital will continue to function as the healthcare hub for the region
Security	Police Department	police department is in inundation zone	make a secondary command center uphill? Store emergency vehicles out of inundation zone?
Safety	Fire Station	fire station is in inundation zone	make a secondary command center uphill? Store emergency vehicles out of inundation zone?
Social Relations/Gathering	Community Members	neighbors helping neighbors	Neighbor relations will be key for resilience.
Recreation	GH County extensive trail network. Aberdeen Parks Department	Possible places of gathering: Sam Benn Park, Highlands, Think of Me Hill (has evacuation route), GH College, Highschool	Parks and trails can be used for meeting areas and further reinforced as evacuation routes.
Food	Walmart and Safeway	Both are in inundation zone. People will have to fend for themselves immediately after event.	Survival kits are available through the city.
Transportation	Department of Transportation	Department of Transportation will continue to provide services Grays harbor Transit Authority - buses are available to take people to higher ground.	Access is going to be a huge issue for us. Are they going to take precedence on I-5?

Aggregated results I created of table discussion from groups working with the asset-based formula (Groups A & B).

Hazard-Based Groups

The table below outlines the responses from the hazard-based groups (C & D). One statement that frequently was stressed by these participants and, can be seen in the table, is that there are not many options for during and after the event that does not

exist in the inundation zone. When asked by the discussion facilitator if there was going to be a provider for food during and after an event one participant responded “Is SOL in the dictionary?” Albeit light-heartedly but this sentiment defined the mentality of both hazard-based groups. The H-BProb group comprised of a representative of the emergency management division in Grays Harbor and a public works employee, two factions that are very familiar with what is vulnerable in the event of a Cascadia Subduction Zone earthquake tsunami event. Without prompting, the participant from the emergency management immediately highlighted the vulnerability of the utilities, including electricity, water, and gas. Because of this knowledge, it was also expressed to the students the considerations of the public works department and GH PUD to relocate critical infrastructure and staging equipment to higher ground so that it could be available during and after an event. Both groups highlighted the importance that outside help will be, as many could not fathom who the providers of critical resources would be due to their precarious locations in the inundation zone. Throughout round three discussion it was difficult for facilitators to prompt participants to consider the long term recovery but a few tidbits were offered up including the confidence that the town would not return without the port, a similar sentiment mentioned in the asset based groups, but the difference in the hazard group was their skepticism that residential would return. One other similarity with the assets groups was the mentioning of the resilient and self-sufficient nature of the citizens but a participant from the H-BProb group saw this as a possible negative trait; “the residents might have an issue with believing that they could survive whatever happens because of how they have survived in the past through

flooding and storms.” Further comparisons of the asset and hazard-based groups are explored in the next section.

Vulnerable Goods and Services	Providers	Post-Providers	New Normal
Bridges	Washington State Department of Transportation, GH Public Works Department	Washington State Department of Transportation "There is no alternative that dont exist within that red If we have some sort of catastrophic event the only way we can get to the hospital is over the hill."	"That's the problem, there is not evacuation route" "we are most likely going to lose the bluff. There's a way out if you can get across the bridge."
Safety (Fire and Emergency Services)	Fire Department	Hospital as a safe area, No cops, no fire, no city hall, no roads, no gas, no bridges--you're stuck. might be able to use logging roads as safety routes. Satsop park as a military base and safety location.	Outside resources: Military, Federal Government. If we can get staging equipment out before an event we will have this during/after disaster.
Security (police)	Police Department	Hospital as a safe area, No cops, no fire, no city hall, no roads, no gas, no bridges--you're stuck	Outside resources: Military, Federal Government
Port	Port of Grays Harbor	operations suspended until they can rebuild	The port is one of the main economic drivers for the county--if we lose that "do they turn the lights back on"
Sewer Treatment Facility	Wastewater Treatment Division		Everything would have to be fixed--water, power, PUD, sewers.
Grocery Stores	Walmart and Safeway	Sam Benn park for storage of canvas tents and food? Hospital as storage for food? Everything is within the inundation zone	Supplies are coming from other states The military have plans to drop resources to certain areas but it will not be enough Prepare people for 7-10 days of self-sufficiency
Electricity	Grays Harbor PUD	?? At night time it will be black--this might be a problem for evacuation	There will still be a cable that comes in from the North from the city (seattle) but it will take a long time for it to be hooked up again
Methanol Tanks (explosion hazard)	Port of Grays Harbor		

Drinking Water	City of Aberdeen Water Department Public Works Department	uphill water tanks/reservoir resources from outside the region	Everything would have to be fixed-- water, power, PUD, sewers.
Residential Buildings		Still a deepwater port But why would they ever allow residential again?	"Highlands--housing development-- lots set aside--none of its been developed yet. It is all really nice--really usable property." "Looking at a 3-500 year time frame--maybe rebuild bc you'll never see the next one." (laughter)

Aggregated results I created of table discussion from groups working with the vulnerability-based formula (Groups C & D).

Asset-based v. Hazard-based Approach

One of our hypotheses with which I entered the workshop was that beginning the discussion with an assessment of community assets will influence stakeholders and citizens to consider more resilient planning solutions for mitigation and long term recovery than would beginning the discussion with community vulnerabilities. In line with that hypothesis, the hazard and asset groups did have some differences that manifested themselves through the different rounds. The groups that began their discussion with the vulnerabilities were unable to remove their thought processes from the hazard, spatially or temporally, in order to think of adaptive planning solutions for the long-term recovery. These groups only considered the days and weeks after the event and had a much harder time considering the long-term recovery. They also had difficulty looking beyond the low-lying inundation zone and outside of the City limits to consider other solutions. All groups thought aloud of whether or not rebuilding after such an event would even be worth it but only the asset groups contemplated that the

destruction of the lowlands could lead to a positive rebuild of the entire area (see below).

		Group A- Asset-Deterministic
Recovery	Round 1	
	Round 2	We can restart, build a town square.
	Round 3	"New infrastructure at the port is new and should be seismically sound. Businesses and amenities will be what brings back the citizens." "All existing infrastructure will not cease to exist. We are a deep water shipping port closest to the pacific rim, it will come back for that."



The participants in the Asset-based/Deterministic Information (A-BDet) group informed the students of the lack of public spaces within Aberdeen because of the town's origin as a work-based location. The map they were working with displayed a bleak outlook for the low-lying land, discouraging but having reflected on the assets of the city earlier the group was able to come full circle to consider that maybe an event could be an opportunity to build better. More structurally sound and with more of a focus on community.



	Round 3	<p>"Is it an opportunity to start over [for us]? Build earthquake resistant structures, vertical evacuation center, make everything shiny and new."</p> <p>"You could say it's a rebirth. We have significant fire issues in older houses with shotty electrical work."</p> <p>"Central Park might become the new center in GH. It has room for growth. It is actually one of the sites that we are looking at for the new transfer station...that may be the new Aberdeen."</p> <p>"Not sure how to respond (what is the new normal?) It's a pretty bleak picture. Would we Rebuild? You can't really build on top of the hill. This is timber country. Do you put an elevated road so people can bypass?"</p>

Responses from community participants in the asset-based groups that refer to recovery after an CSZ earthquake event.

The Asset-based, Probabilistic Information (A-BProb) included individuals from the fire department, city council, and GH PUD. It had many similar sentiments of building new, stronger and with earthquakes and tsunamis in mind. The hopeful purpose of the workshop was to test if the inclusion of uncertainty in hazard tsunami maps would generate more adaptive planning solutions. The particular group that worked with this uncertainty information was the only group to suggest that relocating outside of Aberdeen might be the best possible adaptation the residents could do for long-term recovery.

Group C- Hazard-Deterministic

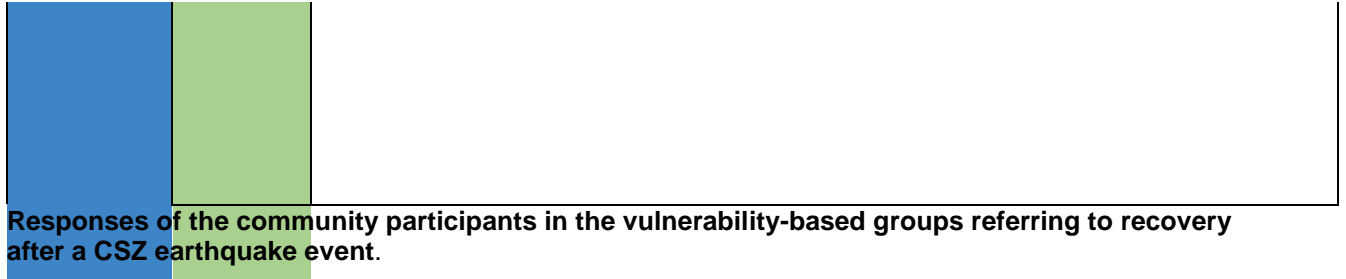
Recovery	Round 1	<p>"Bridges are key to getting out, otherwise isolated" "There is no alternative that don't exist within that red"</p> <p>"[The city is] Unique--aren't many ways in and out" "Unless the hospital starts stockpiling food and water we don't have options"</p>

Round 2	
Round 3	<p>"These are state highways so the state would have to be involved in rebuilding some of the infrastructure." "I could see the port rebuilding" "[the question is] would you rebuild in the same location? If I lost my buildings in an earthquake I'm not sure I'd rebuild them."</p>

The Hazard-based, Deterministic Information (H-BDet) included representatives from the Port of Grays Harbor and a City of Aberdeen employee. The conversation focused on the hazard through the three discussion rounds and at many times stagnated with the participants at a loss for what to say. The tone was light hearted but the gravity of the situation in Aberdeen did seem to sink in which is exemplified in the statement by

one participant; “There is no alternative that does not exist outside of the red [according to this map].”

		Group D- Hazard-Probabilistic
Recovery	Round 1	"The public works area--that will be important in recovery."
	Round 2	<p>"Area north of town is undeveloped. Housing development has lots set aside but none of it has been developed yet bc the economy is horrible here. It is all really nice, really usable property."</p> <p>"But it there is nothing left it falls back on industry and maybe there will be residential for the workers."</p> <p>"They do not have the continuity to rebuild. If we lose part of it, just like in NOLA, and they did not have a plan the government can just come and take it. If Aberdeen has a plan than maybe it will come back."</p> <p>"Dam 20 miles out of town--if you can't restore water--won't have a community. Wenatchee may be a source but it would take decades to make drinkable."</p> <p>"I think they'd still have a community--the port is still viable--industry would be back if they saw it as a viable place."</p>
	Round 3	<p>"I think they need better codes for where and what to build. Buildings should be more structurally sound."</p> <p>"No cops, no fire, no city hall, no roads, no gas, no bridges--you're stuck."</p> <p>"Less than 10% of than work force lives in Aberdeen."</p> <p>"At night time it will be black-- if you can see where to go uphill that will be an issue for survival."</p>



The Hazard-based, Probabilistic Information (H-BProb) group included an individual from the Emergency Management Division, City of Aberdeen employee, and Public Works Department. They began their discussion with hazards and never altered from that, even when trying to think of long-term recovery options. Just as with other groups the participants discussed building more structurally sound buildings but continued to outline all the vulnerabilities and their roles in disrupting long-term recovery.

As seen, almost all of the participants referenced the bleak outlook for Aberdeen after a Cascadia subduction zone event, but there were a variety of tones in which it was discussed from group to group. Many of the participants jokingly declared that Aberdeen was doomed (“is SOL in the dictionary?”) but the asset groups were able to look past the initial realization of all their services being within the inundation zone to consider what their new normal might look like. Whether that be completely rebuilding or establishing a new community in other cities. The notes from round three in each of the vulnerability focused groups saw that the only mentioning of the long term for these participants was in their contemplations of whether or not rebuilding would be possible. With slight exception, the participants from the H-BProb group had backgrounds in emergency management and planning and were privy to knowledge most did not have such as possible alternate water sources and the route of electrical wires. However,

their responses in round three did not reference long-term recovery (figure above, see Appendix D for full table).

One interesting insight seen above in the first table snapshot that displays the A-BDet responses, is that the conversations of the asset groups not only included positive aspects about Aberdeen that contributed to a quality of life, components absent in the hazard-based groups, but also, their discussions about vulnerabilities in the city did not centrally focus on vulnerabilities that pertained to the disaster. The table above references a resolve of a conversation that the A-BDet group had about the city being originally built by and for the workers of the timber industry. The focus was on shelter, provisions, and less on creating a community. A century later the close-knit community is one of the defining aspects of Aberdeen but there exists little to no community gathering spots. In many ways, this reflection on the shortcomings of Aberdeen's contribution to a community lifestyle inspired the participants in the asset-based groups to consider the possibilities that an event could present for the region.

Probabilistic Information v. Deterministic Information

Addressing the first hypothesis, (*Including representations of uncertainty in hazards maps will lead to more creative ideas about how to plan for recovery from natural hazards than just displaying a deterministic representation*) overall, the workshop did not provide much meaningful difference in responses depending on if a group was working with a deterministic map or a probabilistic map. There could be a couple of different reasons for this, for instance, many of the participants were generally very familiar with tsunami hazard maps. A number of the participants worked for the city

or county, had already been exposed to information about a Cascadia Subduction Zone earthquake tsunami event, and were already in the midst of different planning solutions.

Participants from both groups B and D are employed with positions of safety, security, and public works and thus were privy to county plans to relocate utility infrastructure and emergency vehicles out of the inundation zone so that “they will hopefully be available during/after an event.” Both Groups B and D had previously worked with the probabilistic information but a participant from Group D (hazard/probabilistic) mentioned “seeing models that were way worse than the one [they were] being shown” in response to a prompt about whether or not the different levels of risk made a difference in how they regarded the response and recovery. The thought that there were different scenarios and some regions of Aberdeen might not be affected in the same way had never been presented to them. They were surprised to discover that the port area would under most circumstances not succumb to inundation but this made little difference in planning solutions as one survey participant expressed: “I think it will be much worse than your map predicted. Many areas your map shows as minimally impacted are areas of poor soils and low elevations.”

In line with the third hypothesis, (*When put into two different groups, one that displays a deterministic model and one that displays a probabilistic model, stakeholders in the deterministic group are more likely to divide themselves with respect to the single scenario of hazard (e.g. on one side or the other of the crisp line), whereas stakeholders in the second group are more likely to seek consensus and/or develop strategies that work for multiple sets of interests*), the groups working with a deterministic map took inventory of what was safe and what was not safe. This was particularly evident

throughout round two, which asked participants to contemplate response solutions in the hours and days after an event. Group C in particular collaboratively listed any community building they could think of while one would respond with either a “yes” or “no, that’s not safe”. At some points, there were disagreements that could only be resolved by displaying different layers. This was a moment when the use of the WeTable technology came in particular use. For example the HAZUS layer, which depicted the likelihood of a building withstanding the shaking caused by the preliminary earthquake event, was used in most of the groups to resolve participants inquires as to whether a building was safe for refuge or not, an occurrence that would have been impossible with a hard copy map. Nevertheless, if a building was deemed as “unsafe” or not practical for evacuation or safety it was immediately dismissed and the group continued down the list.

On the deterministic map, the entire lower region is portrayed at risk but in reality the port, located on higher ground, will not be as affected as the rest of the city in most scenarios. The port of Grays Harbor is the biggest provider of jobs and economic support and as such, many providers of goods and services are located on this infill land. All of the groups recognized the weight with which the survival of the port has on the viability of the region and, if there was any chance that something survived a CSZ event, the participants in the probabilistic groups noted the benefit of the port being out of the inundation zone. All the groups were certain that the Port would return but less certain as to whether residential or commercial would make a comeback. Yet, the port is comprised of the same soil and susceptibility to liquefaction as the rest of the region so

regardless of its designation as “safe” it is still not a dependable location for refuge or supply storage.

Uncertainties

Does the inclusion of uncertainty make a difference in hazard mitigation planning? Employing the nine typologies of MacEachren (2005) I separated responses about responses pertaining to the information being displayed (See Appendix D). Many inquiries were made about the information displayed in the map; where did it come from? How precise was it? How did we know which buildings would be susceptible to what kind of damage? Some expressed needing a reference point to understand the extent of the subsidence and inundation. These questions could all be answered through manipulation of the map or responses from the knowledgeable students and staff. When organized according to MacEachren (2009) typologies responses fell most into categories of completeness and precision. Exemplifying that participants cared most about how exact the information we were sharing was and had issues with comprehending it as it was displayed. It would be helpful for facilitators to know where the information comes from and, to employ either number percentages or the use of phrases such as, most likely or least likely, to describe what is being displayed. The positive of these inquiries was that participants are less likely to accept the hazard information at face value without, at least, finding out how credible it is. It may have been helpful to describe the process the modelers went through in order to obtain the three levels.

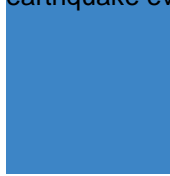
Group C (Hazard-based/deterministic information) had the most questions about the specifics of the event the map was displaying, as seen in the third table snap shot. T One participant asked what magnitude this map was displaying which prompted that inquiry from other participants. The statements from the two groups working with the uncertainties, (the probabilistic maps), Group B (asset-based/probabilistic information) and Group D (Hazard-based/Probabilistic Information) did not express confusion about the information the map was telling them but more so about what might be possibly in the recovery efforts. These groups contained the most informed and experienced collection of people representing public works, security, safety, and emergency management, which could have influenced why they did not have the same detail-specific, inquires as the other groups.

		Group A- Asset-Deterministic
Uncertainty	Round 1	
	Round 2	"What if the town is built on fill--the entire area-- a lot of woodside fill and then timber fill. [showing the shaking map] how do they know that one dot is different from another?" "I dont know that [about electricity]--the BPA lines come from north- not sure about the redundancy."

	Round 3	
Uncertainty		Group B- Asset-Probabilistic
	Round 1	"But there are questions about the landslides and whether the hospital will survive."
	Round 2	"We don't have anything on the hill." [Refers to Japan and relocation of villages on hills.] "Idk if we have that ability but it should be looked at and considered" "I need a reference point to envision where the water will be after an earthquake" "Idk how you plan for it. Doing the best we can until state and federal assets come in. All of our main utilities is in the inundation area." "what happens when they get up? There is nothing up there. It will have to rely on neighbors helping neighbors"

	Round 3	<p>"So the new normal is that underwater at high tide? If I were going to say "I'm going to rebuild, is that possible?"</p> <p>"Access is going to be a huge issue for us. Are they going to take precedence on I-5?</p> <p>Where do we fall in? Would FEMA say we are not going to help you rebuild?"</p> <p>"Looking at Japan--large concrete sea walls- maybe that's a solution for us but if the ground is going to drop is that a feasible solution? That's a question to all of you."</p>
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Responses of the community participants in the asset-based groups referring to uncertainty after a CSZ earthquake event.



Group C- Hazard-Deterministic

Uncertainty	Round 1	
	Round 2	<p>"How big of an event?" "Like a 9.0?"</p> <p>"It's interesting because you can go to a half a dozen different agencies and get a half a dozen different answers"</p>
	Round 3	<p>"Whoever the president is would have to declare a national emergency right?"</p>

		<p>"I want to know the statistics of people who live and/or work in Aberdeen because a lot of people who work here do not live here. How do we deal with those non-residents?"</p> <p>"An event will affect everything from here to Olympia so when you talk about what to do afterwards, that's pretty hard to figure out because it is a regional issue."</p>

Group D- Hazard-Probabilistic

Uncertainty		
	Round 1	
	Round 2	<p>"The port is one of the main economic drivers for the county--if we lose that "do they turn the lights back on?" "why would they?"</p>

	Round 3
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Responses of the community participants in the vulnerability-based groups referring to uncertainty after a CSZ earthquake event.

Survey Results

The survey results were collected and organized into the following table below.

The exact survey can be found in the Appendix C. The participants were asked to answer three questions using a Likert scale from 1 (least likely) to 7 (most likely). I chose to reflect on the participant's responses to question 1 and 2 simultaneously as they are more enlightening together rather than separate.

- 1. How concerned were you before this workshop about the CSZ earthquake and tsunami risk? One representing least concern and seven representing most concern & How concerned about the CSZ earthquake and tsunami are you now? One representing least concern and seven representing most concern.* Of the twelve participants only two, a participant from the H-BDet group and one from the H-BProb group had their level of concern change after the meeting. Both participants were a five (somewhat concerned) before the meeting and changed to a seven (extremely concerned) after they had been exposed to the maps. Aside from this, the participants concerns ranged from two's (not very concerned) to 6-7's (extremely concerned) and were not

altered throughout the meeting. Their personal comments, covered next, provide some insight into this phenomenon but I believe that it is the familiarity with the material behind the reason that many were already concerned going into the meeting. Alternately, I also believe that this familiarity is the reason as to why a few participants were not concerned. For the most part the predictions spell out a bleak outcome for the low-lying lands in Grays Harbor and no matter how much concern a person has, this will not change.

2. *Comments about how concerns changed after viewing the map.* The two participants that did have their concerns altered through the meeting cited very similar reasons as to why; they had not been shown, or told about the major risks involved. Their responses suggest that even though these participants have seen the tsunami evacuation map that displays the inundation line, the specific details of what an earthquake tsunami event could do to their town is not publicly well known. Participant designated as A3 in the table did not have their concern altered but they expressed that their understanding of the scale of infrastructure and number of people in Aberdeen within the hazard zone was improved. Two participants from the same group, the ones that designated their concern as a 2, had a more realist opinion stating that all they could do was “prepare for the worst” and “whatever happens, happens.”
3. *What is your level of confidence in the accuracy of the hazard maps?* 1 designates no confidence and 7 represents high confidence. As can be seen

below the level of confidence ranges from 4's (somewhat confident) to 7's (high confidence). One participant offered further insight as to why they were for the most part confident in the maps: 'I believe the maps are accurate based on the BAS (best available science) and from what we have learned from world disasters.' On the opposite spectrum, a participant that had a 4 level of confidence declared that they think "it will be much worse than your map predicted, many areas your map shows as minimally impacted are areas of poor soils and low elevation." These responses could be representative of the others that also identified with similar levels of confidence; they trusted the maps because they were aware that it is made with best available science or they did not trust the maps because they felt that other factors had not been taken into consideration. To be certain more surveys dispersed to a wider audience would be ideal in order to come to any definitive conclusion.

Group	How concerned were you before this workshop about the CSZ earthquake and tsunami risk?	How concerned about the CSZ earthquake and tsunami risk are you now?	Comments about how concerns changed after viewing the map	What is your level of confidence in the accuracy of the hazard maps?
A1	2	2	Not really. It's very hard to think about massive destruction. All that we can do is prepare for the worst, educate our citizens and be prepared to help.	6- I believe the maps are accurate based on the BAS and from what we have learned from world disasters

A2	2	2	whatever happens, happens. One deals with it as best as one can	6
A3	7	7	Not much. I suppose that my understanding of the scale of infrastructure, no. of people in Aberdeen w/in the hazard zone was improved.	4 (changed from a 5)
B1	6	6	As the fire chief I am aware of the impact a CSZ would/could have on Aberdeen. The exercise was very beneficial due to the probabilistic mapping showing the scientific modeling for subsidence and inundation.	7
B2	6	6	unchanged	5
C1	5	7	It brought home graphically and effectively the stark impact of an earthquake and a tsunami	6
C2	5	5	No	5
C3	5	5	No	5
D1	7	7	I think it will be much worse that your map predicted many areas your map shows as minimally impacted are areas of poor soils and low elevations	4
D2	5	7	The Discussion group high lighted the major risks	6
D3	7	7	I was familiar from my position in EM	5

Aggregate Table of survey responses from the Feb. 11 2016 Aberdeen Community Workshop

Chapter 6: *Implications for the future*

To begin it is important to reflect on the hypothesis and consider whether our assumptions were met.

The hypotheses going into the study were:

- Including representations of uncertainty in hazards maps will lead to more creative ideas about how to plan for recovery from natural hazards than just displaying a deterministic representation.
- Beginning discussion with an assessment of community assets will influence stakeholders and citizens to consider more resilient planning solutions for mitigation and long term recovery than would beginning the discussion with community vulnerabilities.
- When put into two different groups, one that displays a deterministic model and one that displays a probabilistic model, stakeholders in the deterministic group are more likely to divide themselves with respect to the single scenario of hazard (e.g. on one side or the other of the crisp line), whereas stakeholders in the second group are more likely to seek consensus and/or develop strategies that work for multiple sets of interests.

The first hypothesis was not supported in this particular focus group study. Some groups did come up with solutions that are more creative but -this was found among the asset-based groups, according to the asset/ hazard division. The presence of individuals familiar with emergency management plans and possible sources for alternative water may have biased the results. Though the probabilistic map did display different shades of risk, the most important factor to the participants was the largest inundation extent. As previously stated some were surprised to see that the port was safe but knowledge of the soil did not make them feel that it was actually “safe.” Testing different responses to a deterministic map versus a map that shows uncertainty is

important for further research but I think a similar workshop except with more probabilistic map options would be helpful to find out what kinds of visual variables work the best. MacEachren (1990) tested the use of different types of visual variables to see what people understood and responded to more. I suggest having almost the same setup as the above workshop but with more participants, different kinds of maps and maybe a deterministic map as a control. It is my assumption that a map displaying more fuzziness along the edges would read better. A follow up survey such as the one I dispersed in the workshop could help researchers to understand the responses of the participants.

The second hypothesis, as stated previously, was supported, to some degree. The asset-based groups were able to consider other factors outside of the hazard and discussion of what was vulnerable. The biggest difference was seen in their views of an event signaling a new, better, normal for Aberdeen. I believe this assumption to be true but the small sample size makes it difficult to say definitively. I suggest more tests with a larger and more varied crowd would be insightful.

In addition, more time in the beginning to identify specific definitions might be very helpful for the participants, such as; what does whole community resilience entail? The second assumption hinged on if this was a result of an asset-based discussion but at now, point was resilience even defined. As stated in the literature review an exact definition and broad understanding of resilience is lacking and so, just as I did earlier, establishing one definition could clarify the goal.

The third hypothesis was also supported, to a limited degree. Those with a deterministic map were taking inventory of safe and not safe with respects to the red

inundation zone. The probabilistic groups did a similar procedure but, instead, employed the HAZUS layer that displayed the shaking vulnerability of buildings to determine certain buildings in the shaded areas will stand up after the earthquake.

The effectiveness of the technology

Data about a natural hazard is collected, analyzed and constructed in a meaningful way by specialists and then distributed to the local governments and city employees to relay to their citizens. How these individuals understand and convey the information influences how the citizens regard that information. As cited in the literature review this was the approach of FEMA when introducing the Grays Harbor Risk Report and Maps. This workshop introduced brand new technology never before seen in Washington to test how different platforms of presenting the information to the participants can influence the community outreach process.

One of the major issues of displaying uncertainty is the possibility that it will induce mistrust in the information from residents that are unfamiliar with GIS rendered information and geological science. The size and extent of a Cascadia Subduction Zone Earthquake Tsunami is impossible to calculate with precision and so conveying deterministic information is serving an injustice to the community. The same goes for providing uncertainty and probabilities to a community without ensuring that those working with the maps fully comprehend the information.

There were many inquiries about the information displayed in the map made mostly by groups working with the deterministic information but also some from the probabilistic information groups as well. The most pressing questions were; where did it

come from? How precise was it? How did we know which buildings would be susceptible to what kind of damage? Some expressed needing a reference point to understand the extent of the subsidence and inundation (A-BProb). These questions could all be answered through manipulation of the map or responses from the knowledgeable students and staff.

The ability of the facilitators in a workshop to manipulate the map and show different layers was a new and useful tool. Working with probabilistic information would have been less effective and interesting if the workshop had not used the WeTable technology.

Every group engaged multiple layers to help educate participants about what could potentially occur through a CSZ event. Many publications, discussed previously in the literature review, emphasized the importance of localizing hazard information in community outreach planning to give residents a sense of how an event would personally affect them. One of the most surprising results seen in the groups was that the participant's curiosity extended beyond the borders of Aberdeen and Hoquiam but to the entire coast as well as Seattle. Participants were very aware that their precarious location could potentially induce isolation after an event. Their bridges are not up to standards to withstand an earthquake and the bluffs create landslide hazards that have already blocked off access to the upper region for the residents in the past. Many immediate response solutions named outside agencies and other cities as the best chance for help once an event hits but depending on how extensive the earthquake is and the reach of the tsunami will determine where and when that help might materialize. The earthquake that rocked Japan in 2011 and led to one of their most devastating

tsunamis, struck about 373 km or 230 miles from the major city of Tokyo. The residents in the city experienced a great deal of shaking and destruction. Seattle is less than 150 miles from the coast of Washington and, if an earthquake anywhere near the same size hits, the city will experience its own devastation. The extent of that destruction will influence the response and recovery in Aberdeen prompting many to inquire if we had a model that displayed the dispersion of the damage. This was a surprising discover and will be important in future emergency planning efforts.

Each of the group marveled at the WeTable technology considering how it could help them in the future of Emergency Management. Using an interactive map can localize or it can broaden the focus, depending on the needs of the community. Which is a much bigger point. Asset planning is employed to, specifically, focus on the needs of individual communities. The interactive GIS technology can be used where and how it is needed by a particular community. A participant from the A-BDeT group expressed that community support is a county wide not just within Aberdeen. Multiple groups and participants asked if the students had hazard information for the surrounding area. One participant asked if they *"Were we supposed to stay inside one area or if it's on the map its fair game?"* When the map facilitator said that they could zoom out to see more areas a discussion about the potential assistance capacity of other cities followed. Many believed that they would need a lot of outside assistance in order to make it the first weeks and months after an event.

As stated previously, it is widely seen in research and climate predictions that individuals find greater meaning in localized information. One thing to consider moving forward is the wider network of emergency response agencies, location of major cities

and how a county or region works together to solve logistical issues. Saying that individuals are inherently self-centered is disregarding the underlying social processes that tie communities together.

Asset-based Approach

It is difficult to come to definitive conclusions with the small amount of data captured from the workshop but there are a few caveats that should be explored further in future community outreach efforts.

Beginning the conversation with the assets of a city rather than the hazards did generate a different kind of conversation that took people outside of the mindset of that which is vulnerable and that which needs protection. Participants in the asset-based groups (A & B) had fresh in their minds the positive aspects of their town that made it a worthwhile place to live when they were tackling discussion about the hazard and subsequent recovery. It allowed them to consider solutions that were not just reactions to the hazard but would be best for the community as a whole in their long-term recovery efforts. The conversations of the asset groups not only included positive aspects about Aberdeen that contributed to a quality of life, components absent in the hazard-based groups, but also, their discussions about vulnerabilities in the city did not centrally focus on vulnerabilities that pertained to the disaster. The table above references a resolve of a conversation that the A-BDet group had about how the city was built by and for the workers of the timber industry. The focus was on shelter, provisions, and less on creating a community. A century later the close-knit community is one of the defining aspects of Aberdeen but there exists little to no community gathering spots. In many ways, this reflection on the shortcomings of Aberdeen's

contribution to a community lifestyle inspired the participants in the asset-based groups to consider the possibilities that an event could present for the region.

Participants

The workshop intended to capture a wider variety of participants but, rather than being a negative, the narrow audience focus of this particular study can be a valuable contribution to understanding how the Individuals that makes decisions and spearhead efforts within the city, comprehend and interpret the visual hazard information.

The participants disregard for the different possibilities on the probabilistic map could be an indicator of the ineffectiveness of how it was displayed. A larger focus group is needed to know for sure. More experimentation with different displays of probabilistic maps is encouraged for future research in this area. This could be done through a similar experiment that just worked with probabilistic maps that were shown with different numbers of events and in different ways.

Expectations

A few aspects fit our expectations, such as the tendency of those working with a deterministic map to separate themselves along lines of safe and unsafe and the inability of the vulnerable focused groups to separate their thought process from the hazard event. I was initially surprised to discover the lack of regard for the information displayed in the probabilistic map but as stated previously many factors, such as of previous knowledge of Aberdeen's soil properties, and ineffectiveness of the shading display could possible contribute to this.

Another expectation centers on the discussion of the asset and vulnerability groups. Though the sample was small and participant's background knowledge did make a difference, the asset groups did provide some useful information about the city that were not centered on the hazard and absent in the vulnerability-focused groups. An example of this is the discussion on lack of community spaces and resilient nature of their citizens. A good plan and sound infrastructure is imperative in disaster situations but the ties of a community can make a substantial difference when processes alter and resources become scarce.

One major factor that I had not considered was the weight that the facilitator's knowledge and resourcefulness had on the responses generated from the participants. All of the group facilitators were knowledgeable and put forth a valiant effort but some had more experience with facilitating group discussions and were able to maintain a cohesive flow to the conversation, ensuring that each round maintained its intended track. Two of the groups included individuals that made the maps, fulfilling roles as the map facilitators. They were able to answer more of the participants inquiries into the hazard and the information conveyed on the maps. Knowledge alone was not the defining factor, it was more the ability to express complex concepts in a straight forward and easy to understand way that used relatable examples. When prompted to identify the goods, services and providers that contributed to a quality of life in Aberdeen most participants required further explanation. In the end, the facilitators that were able to provide examples and reword their questions in a different way were able to receive useful responses. This will be an important aspect in further community outreach in hazard mitigation.

Limitations

It is imperative to understand how employees of government agencies understand and interpret hazard information. For they are the ones disseminating information to the larger public. Though the workshop was limited in the number of people it was able to capture and is not representative of coastal communities everywhere in the country, however, the data captured does have a credible place in research on perceptions of different tsunami hazard information. A follow up survey similar to the one dispersed in the workshop would have been helpful to understanding motivations and perceptions of risk of a wider audience and is encouraged for future research. Capturing this kind of audience was useful but should be taken with a grain of salt when considered for a different location.

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