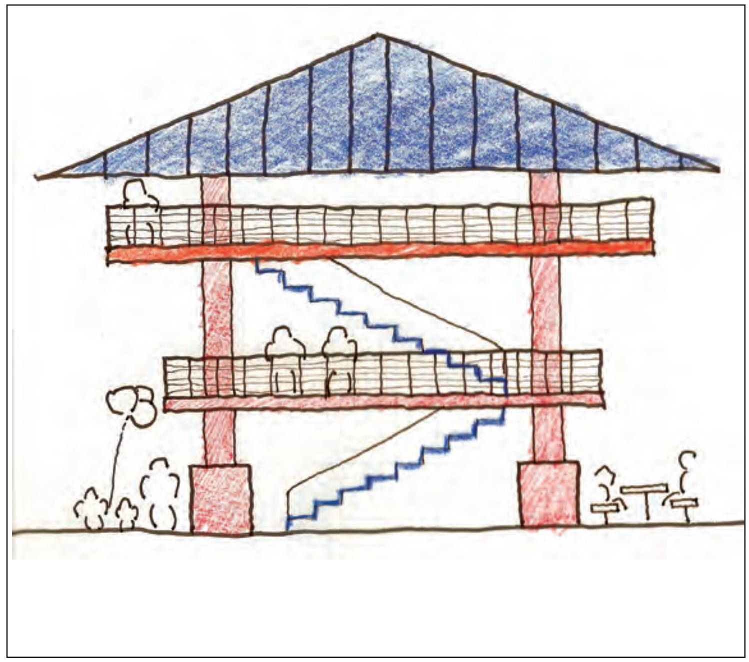
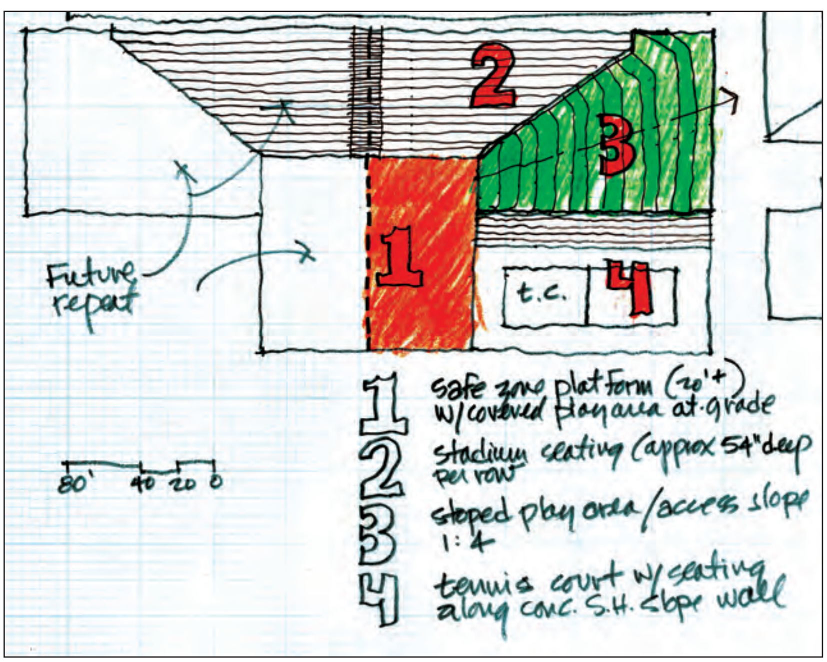
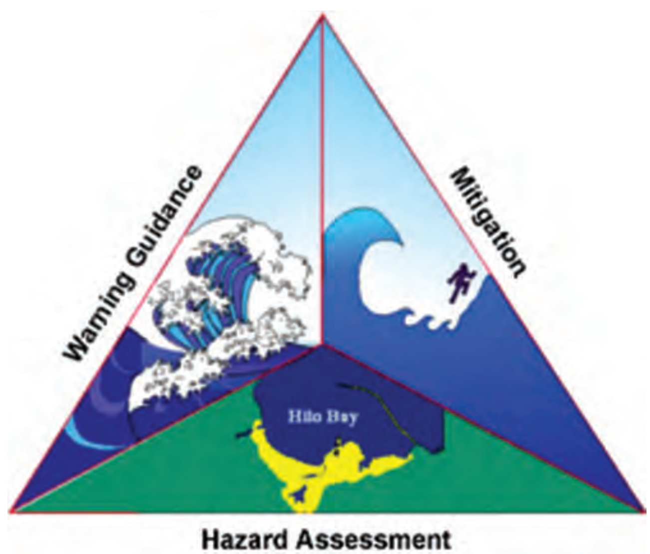
Project Safe Haven:

Tsunami Vertical Evacuation on the Washington Coast





Makah and Quileute Tribes



FUNDING FOR PROJECT SAFE HAVEN PROVIDED BY
THE NATIONAL TSUNAMI HAZARD MITIGATION PROGRAM

Thank you to all the members of the Makah and Quileute Tribes and residents of Clallam County who helped through their comments and participation in meetings.

Acknowledgments

The 2011-2012 Project Safe Haven team for the Makah and Quileute Tribes was led by the University of Washington College of Built Environments and the Washington Emergency Management Division

Research Team

Department Of Urban Design and Planning
Oversight Team: Institute for Hazards Mitigation Planning and Research

Bob Freitag (Principal Investigator)
Meg Olson (Student Lead)
Timothy Lehman
David Smolker

Urban Design Team

Ron Kasprisin (Design Lead)
Dan Abramson, Associate Professor and Neah Bay Studio Instructor
Josh Vitulli (Student Lead)

Department of Construction Management
Cost Estimating Team

Omar El-Anwar (Engineering Lead)
Kirk Hochstatter

Advisory Committee

Washington State Emergency Management Division (EMD)

Dave Nelson (State Lead)
John Schelling (Program Officer)
Noemi LaChapelle

Washington State Department Of Natural Resources (DNR)

Tim Walsh (Geology Lead)

Federal Emergency Management Agency, Region X

Tamra Biasco

United States Geological Survey (USGS)

Nathan Wood

National Oceanic And Atmospheric Association (NOAA)

Frank González

Degenkolb Engineers

Cale Ash, PE, SE (Technical Advisor)

Collaborating Communities

Makah Tribe

Andrew Winck, Emergency Management Coordinator

Quileute Tribe

Larry Burtness, Planner and Grant Writer

Clallam County Emergency Management

Ronald Peregrin, Emergency Manager
Jamie Wisecup, Program Coordinator

Editor

Julie Clark

Table of Contents

List of Figures

List of Tables

1. Executive Summary

The Cascadia subduction zone fault lies off the coast of North America and extends from British Columbia to Northern California. This fault is capable of producing earthquakes in excess of 9.0M (magnitude), and generating a tsunami that will threaten coastal areas along the Pacific Ocean. Geological evidence suggests an earthquake of this magnitude last occurred on the Cascadia fault in 1700, generating the "Orphan Tsunami" in Japan.

Due to the proximity of the Cascadia fault to the coast of western Washington and the lack of effective evacuation options in some communities, a University of Washington Planning Studio created a community-driven method to plan for vertical tsunami evacuation. It implemented the project with the help of Washington State, Tribal, and County officials. The resulting Safe Haven project has already been implemented in communities in Pacific and Grays Harbor Counties.

This report details the Safe Haven planning process in the Clallam County cities of Neah Bay (home of the Makah Tribe) and La Push (home of the Quileute Tribe). It outlines the process, describes the scientific data used, and offers vertical evacuation strategies.

Project Safe Haven emphasizes public participation and local knowledge to create a community-specific, grassroots plan for tsunami evacuation. Vertical evacuation strategies were created and evaluated in three public meetings each in Neah Bay and La Push. A Steering Committee of Tribal, local, and state officials, emergency managers, and scientists paired with the project team from the University of Washington and Washington State Emergency Management Division to identify project sites. Two community meetings were held in the identified cities to generate ideas for placement of vertical evacuation structures and to identify other needs those structures might fulfill in the area. After the project team developed a preferred vertical evacuation strategy with the input from the first two meetings, a third public meeting was held in both locations to evaluate those preferred strategies.

As a part of the process a student studio project team was created to research post-recovery alternatives and pre-event development strategies that would support resilience, not just in the event of a tsunami but also potentially in the event of climate-change-driven sea-level rise. The team supported an approach to relocate community housing and government infrastructure to high ground within the reservation. Tourist-oriented development and marine industries would remain on the coastal floodplain

The preferred strategy for Neah Bay includes a berm designed for interim recreational uses by the school, increased trail connections to higher ground through wooded and wetland areas, and possible integration of vertical evacuation structures in any new development in the area. This strategy could cost almost $900,000.

The preferred strategy for La Push includes an evacuation tower, more effective connections to higher ground, and providing further vertical evacuation, if necessary, in conjunction with new development. This strategy reflects the Quileute Tribe's land swap for higher ground, which was approved in the final weeks of the Safe Haven Project. As a part of this plan, the original site of the preferred vertical evacuation tower will be moved to higher ground as well, causing the team to update the preferred strategy to take this land use change into account. This strategy could cost $518,000.

2. Project Safe Haven: Makah and Quileute Tribes

Neah Bay and La Push are particularly vulnerable to coastal hazards (Figure 1). Neah Bay, home of the Makah Tribe, has beaches on both the Pacific Ocean and the Strait of Juan de Fuca (Figure 2). Makah Tribal government buildings and an emerging tourist development are at risk from waves generated off the Pacific Ocean. Most of the residential, commercial and marine-oriented industry is threatened by waves off the Strait of Juan De Fuca. La Push, home of the Quileute Tribe, is located on the western coast of the county on the Pacific Ocean (Figure 3). Its residential and economic areas are also at risk from ocean waves. Both Tribes are in Clallam County, Washington.

The Makah and Quileute Tribes are vulnerable to earthquake and tsunami hazards triggered by the Cascadia subduction zone fault. Both Tribes are aware of this hazard and have emergency plans for a tsunami event. La Push is actively engaged in long-term tsunami planning. After most of the project described in this paper had been completed, a federal bill approving a land swap for National Park Service land near La Push was approved, allowing the Tribe to make plans to move their school to higher ground (Hotakainen, 2012).

Project Safe Haven identifies potential sites for vertical evacuation structures in areas of tsunami hazard where evacuation to naturally higher ground is not feasible. A community planning process is aided by hazard mitigation, urban design, and engineering experts. The project helps communities identify sites for vertical evacuation

Figure 1: Neah Bay and La Push context map
Both Tribes are in Clallam County, the northwestern tip of Washington state. Map: Josh Vitulli

structures. These structures (multiuse, where possible) are designed to fit in with other community needs and opportunities to give them useful life beyond tsunami evacuation. The Safe Haven Project has been successfully completed in communities further south along the western shore of Washington, including Long Beach, Ilwaco/Seaview, Ocean Park, Tokeland/North Cove, Ocean Shores, Westport, Grayland, and Taholah (Project Safe Haven A and B, 2011).

This document contains the description, methodology, and results of the Safe Haven Project for the Makah and Quileute Tribes. It is designed to be useful in acquiring needed funding for the final design and construction of the vertical evacuation strategies. A description of each project site, a record of public meetings, preliminary strategies and conceptual structure designs, and a selection of preferred strategies for each community are included. In addition, the findings of a University of Washington Urban Design Studio studying long-term tsunami planning in Neah Bay are briefly described.

There is an important limitation for Tribal resilience strategies. Tribal land may be defined by reservation boundaries and the members' cultural identity with their coastal life goes back generations. Residents of non-tribal coastal communities such Ocean Shores, Long Beach and Westport can relocate after a major local earthquake and tsunami. Their homes are insurable through the National Flood Insurance Program, which can support an individual relocating outside of the community if land is submerged. Such relocation is more likely to be acceptable to non-tribal communities than to tribes.

Figure 2: Neah Bay tsunami inundation zone
Much of the area immediately inland of the inundation zone is low-lying, heavily forested wetland. Currently there are no trails that would provide access to high ground following a major local earthquake. Graphic: Josh Vitulli

Figure 3: La Push tsunami inundation zone
The close juxtaposition of low-lying land and steep terrain makes fleeing to safe ground difficult for people in the inundation zone. As with the Makah tribe, the Quileute tribe's adaptive strategy combines improved access to upland areas, new vertical evacuation structures within the inundation zone, and the development of new housing and services at elevations above and outside the inundation zone. Graphic: Josh Vitulli

3. Background

A. Hazard profile

A tsunami is a series of sea waves, caused by landslides, earthquakes, or other geological disturbances in or near the ocean. The severity of a tsunami depends on many factors, including the type of triggering event and the bathymetry of the ocean around the event. A tsunami's effect on people depends greatly on the proximity of the population to the event. Clallam County is located on the Ring of Fire, a particularly volcanically and seismically active area of the earth bordering the Pacific Ocean. It is susceptible to tsunamis caused by both distant and local earthquakes or other seismic events (Atwater and others, 2005).

A *distant* tsunami may be caused by a seismic zones located in other areas of the Ring of Fire, including off the coast of Japan or Alaska. Tsunami waves can travel at the speed of a jet, but a distant tsunami will still take several hours to reach Clallam County (Figure 4). A tsunami warning system operated by NOAA (the National Oceanic & Atmospheric Administration) will provide advance notice of that tsunami event to Clallam County, and residents will have time to evacuate by car or bus, since the distant triggering earthquake will do little or no damage to local transportation infrastructure.

A *local* earthquake could cause extensive damage to local infrastructure even before the tsunami it triggers reaches land. The Cascadia fault (Figure 5), located an average 50 miles off the coast of British Columbia, Washington State, Oregon, and Northern California, is capable of producing an earthquake of 9M (magnitude) or higher,

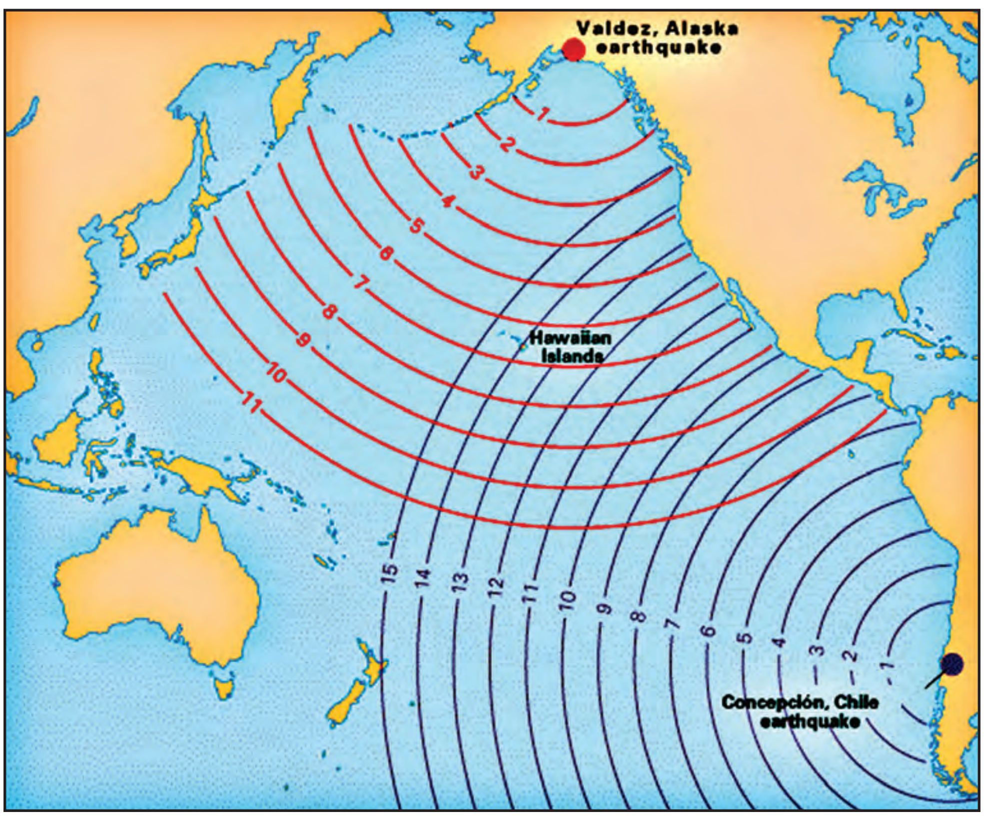


Figure 4: Tsunamis can be generated around the Pacific Ring of Fire
This map shows distant tsunami travel times across the Pacific from earthquakes originating in Alaska and Chile. Map: United States Geologic Survey

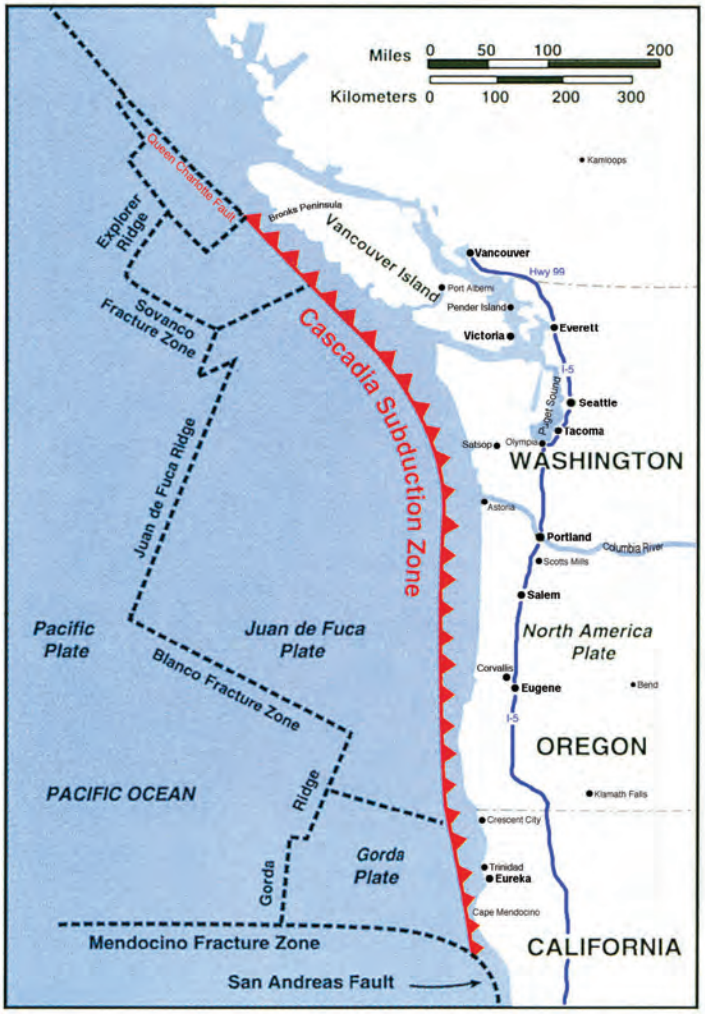


Figure 5: Subduction zone earthquake source
The Cascadia subduction zone produces large earthquakes and tsunamis every 500 years, on average. Map: Oregon Department of Geology and Mineral Industries.

comparable to the March 2011 earthquake and tsunami that devastated northeastern Japan.

Additionally, the tsunami produced by such a close source would leave little time for evacuation; highways and roads would be severely damaged. Much of the coast of Washington lacks high ground that would be accessible in such a short time. Building vertical evacuation structures in these vulnerable coastal areas are vital to keeping people safe in the event of a large local earthquake and tsunami event in Clallam County (Walsh and others, 2000).

B. Modeled Scenario

The Safe Haven Project hazard scenario is based on a plausible worst-case event: a large local earthquake event that generates a tsunami from the Cascadia fault (Figure 5). This is an active subduction zone fault that has had historically large events on the order of 9M, on average every 500 years (Cascadia Region Earthquake Workgroup, 2005). The last large magnitude earthquake on this fault was over 300 years ago, in January 1700. Geological evidence of this earthquake, and other large events before it, has been found on the coast of Washington State. And a historical account of an "Orphan Tsunami" arriving in Japan, one with a date, but no originating location, has also been linked directly to that event (Satake and others, 1996).

This scenario, used for the event assumptions and in the models of the tsunami inundation area, assumes that a 9.1M earthquake occurs on the Cascadia fault (Washington State Department of Natural Resources A and B, 2003). The model indicates coastal land subsidence in Clallam County of six feet, due to the nature of the tectonic movement of the subduction zone earthquake. This land subsidence will place some areas of the coast under sea level before the tsunami arrives. Ground shaking from that earthquake will last about five minutes, during which time the ground will subside and infrastructure, including roads and buildings, will be damaged. Residents of the affected area will become disoriented in the ground shaking. The model shows the tsunami arriving in Clallam County about 30 minutes after the earthquake is felt. But the earthquake will cause moderate to major disorientation, so only about 20 or 25 minutes will be available for evacuation after the shaking stops.

LIDAR data has been acquired for the area and new modeling is expected to be completed in 2013 (personal communication, González). The strategies in this report are not expected to change.

Since roads will be damaged from both cracking and soil liquefaction, evacuation is assumed to proceed solely on foot. In earlier Safe Haven projects, the speed of walking by both healthy adults and slower populations, such as the young and the elderly, were calculated. An average walking-speed individual can walk 3,600 feet in 15 minutes and a slower walking individual can walk 2,700 feet in 15 minutes (Kaeser and Laplante, 2007). For an example in Neah Bay, see Figure 6.

Refuge areas were calculated to provide 10 square feet of space for each evacuee, and will be assumed to be stocked to house the local population of each area on an average summer day in tourist season for two tide cycles (FEMA and NOAA, 2008.).

C. Community profiles

Neah Bay

Neah Bay is located on the 47 sq. mi. Makah Reservation, and is the main town of the Makah Tribe (see http://paddletomakah.org/volunteerinformation.pdf).). While most of their reservation is located on high, heavily forested ground, Neah Bay is only a few feet above sea level. This section of coastal land includes Shi-Shi Beach and Hobuck Beach facing the Pacific Ocean, and a marina area in the Strait of Juan de Fuca at Neah Bay. Neah Bay is especially vulnerable to local earthquake and tsunami events due to its isolated location at the end of Highway 112, which is prone to blockage from landslides.

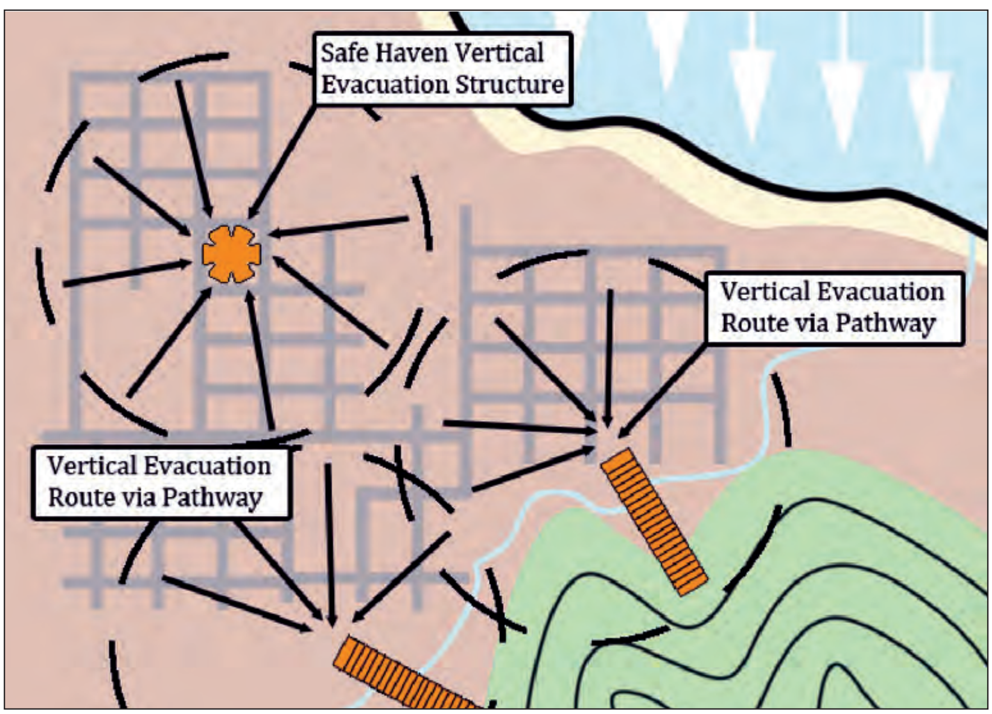


Figure 6: Walking circles show potential evacuation routes at Neah Bay
People must come inland from the water (blue), away from wave direction (white arrows). Once they reach high ground (green), they are safe from the tsunami water. In this conceptual drawing, the circles have a half-mile radius, the time it might take to walk in 15 minutes after a major local earthquake. Each circle has a tower or pathway in its center as a vertical evacuation strategy. This is one possibility, but not the one ultimately decided on by Neah Bay. Drawing: Josh Vitulli

During an earthquake, landslides could prevent outside emergency assistance from arriving in a timely manner.

Table 1: Neah Bay demographics

Neah Bay 2010 Census	
Age Group	Number of people
< 24	352
25 – 44	213
45 – 64	206
65+	94

The majority of the reservation's 1,200 residents live in Neah Bay (Table 1). Essential facilities including a home for the elderly, the school, several businesses, and the Makah Marina are in the inundation zone. A thick rainforest and wetland areas block evacuation routes to higher ground.

Local residents are aware of the tsunami threat, and Emergency Services have conducted tsunami evacuation drills. Tsunami evacuation route signs are posted throughout the city. Fishing and tourism are the main industries in Neah Bay (Figure 7). The town was recently written up in the *New York Times* Travel section as a vacation destination (Yardley, 2012), and tourists are encouraged to fish, hike, and camp on the reservation. The annual Makah Days draw many people to the area (see http://www.makah.com/makahdays.html). For the Makah people, however, the connection to the land is not merely economic. Their ancestors have lived in this area for thousands of years, and depended on the sea for food and materials. The Makah are guaranteed whaling rights by treaty, based on their long whaling tradition. The location of Neah Bay is as important to the Makah for its close connection to the sea as it dangerous because of it. While plans are underway to locate new residential

Figure 7: Fishing is a major industry of Neah Bay
Although there is high ground near the water, it is not always possible to get from the beach or low-lying inland areas to safe high ground.

Figure 8: This 1899 picture shows whaling at La Push.

Figure 9: Fishing on the Pacific
Tribe members shown preparing for fishing at La Push decades ago.

building on higher ground, the Makah must maintain their connection to the low-lying coast (Makah Tribe, 2012).

There are many definitions of recovery from an earthquake and tsunami. For the Makah, the importance is not to rebuild the same buildings in the same place; that will be impossible after a Cascadia subduction zone earthquake and tsunami. The Tribe must provide for safety through the earthquake, safety through the tsunami, including vertical evacuation options, rebuilding options through the use of flood insurance, and planning for the post-event recovery.

The city of Neah Bay will not look the same. It may not recover. But people will. As will the Tribe, as it has for thousands of years.

La Push

La Push is a low-lying coastal town on the Quileute Reservation (Figure 8). The town was the major population center of the Quileute Reservation, but the Tribe has begun to relocate housing and Tribal activities to higher ground due to the risk of a tsunami. In March 2012, the US government approved a land swap deal with the Tribe to allow them former National Park land close to the center of La Push but on safe, higher ground. The Tribal Administration building, marina, school, some homes, and some tourist businesses remain in the low-lying area of La Push, though the tribe has approved funding to move the school to the higher ground (Hotakainen, 2012). These scheduled changes to better adapt the tribe to tsunami risk are reflected in changes to the preferred strategy developed for La Push.

The Tribe has traditionally lived and fished in the area, and maintaining a presence by the ocean is very important to them (Figure 9). Much of the town economy is based on fishing, though tourism is rising, driven in part by the popular novel *Twilight*, which describes a fictionalized version of the Quileute Tribe (http://www.burkemuseum.org/truth_vs_twilight/facts.php, and http://www.quileutenation.org/culture/history).

La Push is a small community, both geographically and in population (Table 2). A large part of its long-term strategy is to relocate. The land swap allows the school to move to higher ground. Over time, the Tribe will begin relocating residential and community infrastructure to high ground. In addition, they plan to restrict coastal land uses to those dependent on a marine waterfront, and construct trails to high ground. Buying flood insurance will provide some working capital in the case of a tsunami.

Table 2: La Push demographics

La Push 2010 Census	
Age Group	Number of people
< 24	178
25 – 44	108
45 – 64	77
65+	8

Though their strategy for resilience is somewhat different than the Makah, the Quileute Tribe and will continue to live by the sea, even if La Push cannot be rebuilt in its current configuration.

D. Vertical Evacuation

Vertical evacuation was proposed for Indonesia after the 2004 tsunami, and was used successfully in Japan during the Tohoku earthquake and tsunami event (Fraser, and others, 2012; Fraser, 2011). Vertical evacuation structures are designed to withstand ground shaking, water flow, and potential debris impacts during a tsunami after a large earthquake. The structures function as refuges, and are designed to hold a certain number of people. Engineering standards for these structures are provided by FEMA in *FEMA P646: Guidelines for Design of Structures for Vertical Evacuation from Tsunamis.* The structures may be stocked with supplies to provide for basic needs during the minimum of two tide cycles that people may need the refuges during a tsunami.

Vertical evacuation refuges provide high ground in areas that do not have easily accessible, natural high ground for evacuation. *FEMA 646*, upon which the project options are based, describes three types of vertical evacuation structure: towers, berms, and buildings. These structures may be used individually or in combination with each other, and designed as stand-alone refuges or built into other types of structures in the community. A detailed description of structure typologies is included in Appendix A.

Tsunami Vertical Evacuation Refuges

It is important to understand that the proposed vertical evacuation structures are *refuges* and not *shelters*. According to FEMA P646, vertical evacuation refuges are not necessarily required to meet ADA requirements when they operate as a refuges. However, for day-to-day uses, vertical evacuation refuges should consider the needs of disabled users to the extent possible and required by law, in the event of an emergency evacuation. During a tsunami evacuation following a near-source earthquake event, disabled evacuees may need additional assistance accessing refuge areas in vertical evacuation structures.

Throughout the planning processes, the communities in Neah Bay and La Push have focused on making vertical evacuation structures as accessible as possible. Compliance with ADA may vary by structure type, function, and whether or not the detailed building plans call for long-term sheltering options as opposed to a short-term safe area for refuge.

The cost of a vertical evacuation structure depends on many factors, including the type of structure, the area of the structure, and the required safe height of the structure. In accordance with the project assumptions, this required safe height includes the wave height projection at the location of the structure, post-earthquake subsidence, and a factor of safety of 10 feet. Based on the standard of 10 square feet per person, the structure area will be 10 times the number of evacuees designated for each structure. Costs also include design, construction and materials, but not the cost of the land the refuges are sited on, which makes publicly owned or otherwise inexpensive land a desirable choice for structure sites. A summary of costs for the selected refuge options for the Makah and Quileute Tribes is provided in Appendix C.

Berms

Berms are an engineered artificial high ground created from soil and other construction materials (Figure 10). They typically have ramps at a 1:4 slope, which provides easier access than stairs for individuals of limited mobility, from the ground to the top of the berm. This ramp gives them a large footprint on the landscape, similar to a hill. Their typically large sizes make them able to hold many evacuees in case of an emergency.

Based on the guidelines of *FEMA P646*, berms also include structural components to dissipate or redirect the impact of a tsunami. This may take the form of a rounded front portion and gabion mound, which is made of containers filled with heavy materials. Additionally, the berm will be reinforced against both water and debris impact and scour by a surrounding wall of metal or concrete. Sheet pilings or internal concrete walls reinforce the entire structure as well as support the top surface of the evacuation refuge.

Advantages

- Ramp provides both a wider access to accommodate more people quickly, and an easier access than stairs for populations with limited mobility.
- Allow people to follow the natural instinct to evacuate to high ground.
- Open design eases fear of entering a structure than may not be safe.
- Multifunctional designs

Towers

A tower may be as simple as an elevated platform or include other features such as a lighthouse. A ramp or stairs leads to the safe platform of this structure. Towers have a smaller footprint than berms, since they stand on legs, and access staircases and ramps tend to be steeper (Figure 11).

Towers will have a driven pile foundation and be stabilized by grade beams. The staircases may be designed to withstand an earthquake, but to then break away from the structure with a tsunami wave. In that event, the structure platforms would be provided with a retractable staircase for exiting the structure after the event.

Advantages

- Tend to cost less than other evacuation structures.
- Since they cost less, could be placed in more locations in the community.
- Smaller footprint on the land.
- Multifunctional.

Figure 10: Constructed berm
Soil berm combined with a community park at Sendai Port, Japan. Concrete lining on the ocean face can deflect incoming waves while sloped sides provide for quick access.

Figure 11: Basic tower for tsunami refuge
This metal tower is used in Japan and this type of structure was important in saving lives in the 2011 Tohoku tsunami.

Buildings

Most vertical evacuation refuges in Japan are reinforced sections of buildings. Those refuges worked very well in the Tohoku event in 2011 (Fraser, 2011). Beyond the reinforced vertical evacuation refuge, the rest of the building may be reinforced to withstand the tsunami wave, or be "transparent", allowing the wave to roll through the rest of the structure while preserving the safe haven. These buildings may be hotels or parking structures, or any other building type (Figure 12).

Advantages:

- Only a portion of a larger structure needs to be reinforced to provide an evacuation refuge.
- The tops of some structures, such as parking decks, could provide a landing pad for helicopters delivering supplies or evacuating people after the events.
- Buildings may be used for other, revenue-generating and community purposes before a tsunami event.

Figure 12: Building for vertical evacuation
Cast-in-place reinforced concrete parking garage in Biloxi, Mississippi after hurricane Katrina. Open structural systems allow water to pass through with minimal resistance, and interior ramps allow for easy ingress and vertical circulation.

E. Recent Tsunami Events

The Makah and Quileute Safe Haven Project took place in the year after the March 11, 2011 earthquake and tsunami in Japan. Along with the February 27, 2010 Chilean earthquake, this event greatly influenced the planning process for the Tribes. Lessons from the experience with vertical evacuation structures in Japan suggested that they saved lives. It is imperative that the event assumptions in these reports are revisited following any significant earthquake and tsunami events, to ensure that they remain valid as planning predictions. Pedestrian travel times, subsidence, wave heights, and engineering assumptions are especially important to revisit. It is important to note that this report is based on existing inundation models done by technical experts, and may need to be revised.

Prior to construction of any proposed vertical evacuation refuge, additional tsunami inundation modeling is required. The approach recommended by this study is to use ensemble modeling, which relies on a combination of inundation models and data sources to determine the impact of a Cascadia event.

Important: While the existing models are useful for traditional evacuation planning, they are not recommended for determining final necessary structure heights of life-safety structures such as these vertical evacuation refuges.

Since Project Safe Haven began in 2009, several large earthquake and tsunami events have brought the risks from these hazards to the attention of the world. The earthquake in Santiago, Chile in February 2010, in Christchurch, New Zealand in September 2010, and February 2011, and the earthquake and tsunami in Japan in March 2011 garnered international attention, and have prompted studies of the structural and social responses to these events. All of these events have illustrated the importance of the Safe Haven Project, but the Japanese experience in planning for and executing a tsunami evacuation has special resonance for this project. The Safe Haven team heard the news of the Japanese tsunami while returning from a series of community meetings in Ocean Shores, Washington.

Lessons learned from the response to the Japanese Tohoku event are directly applicable to the planning for a tsunami event caused by the Cascadia fault. The Washington Emergency Management Department and the New Zealand Ministry of Science commissioned a study of the applicable lessons from that event for tsunami evacuation efforts in New Zealand and Washington State. Lead author Stuart Fraser and his team conducted interviews with emergency planners about the tsunami response. This report is available online (Fraser, 2012), and a video of Stuart Fraser presenting the findings of the report is available on YouTube (Cascadia Earthquake, 2011).

The Tohoku earthquake was larger than the planned-for event in Japan, which caused some pre-arranged plans and safety measures, such as seawalls, to be inadequate against the tsunami (Fraser, 2012, pg 6). About 19,000 people in the tsunami zone died or are still missing. However, the planning and response contributed to a 96% survival rate for people living in the inundation zone. Vertical evacuation refuges saved lives during the Tohoku tsunami, though the higher-than-expected inundation levels overtopped some designated structures (Fraser, 2012, pg vii)

Japan has had building codes for vertical evacuation refuges in place since 2005 (pg 38). Most of the designated refuges conform to post-1981 Japanese seismic building codes, are made of reinforced concrete or steel reinforced concrete composite construction, and are high enough to be safe in projected wave heights (Fraser, 2012, pg 38). In most studied areas, community input was very important in determining which buildings would be designated as refuges, though in one area local government designated the buildings before presenting them to the public (Fraser, 2012, pg 14). Through this community process, some private owners of appropriate buildings were convinced to designate their structures as public vertical evacuation areas. Owners of private structures whose buildings were designated often considered it their social duty to provide emergency evacuation access (Fraser, 2012, pg vii). Signage to vertical evacuation refuges was standardized in Japan in 2004 (Fraser, 2012, pg 55).

The water and debris impact did damage some vertical evacuation structures, with the most common issues consisting of scouring around the foundation (up to 4m deep) and debris impact on steel buildings (Fraser, 2012, pg. 42). Exterior building cladding, including windows, was especially vulnerable (Fraser, 2012, pg. 38). Building contents were destroyed by influxes of tsunami water (Fraser, 2012, pg. 60). Some refuges were damaged by fire caused by accumulated debris, though no one was hurt by them (Fraser, 2012, pg. 42, Cascadia Earthquake, 2011). However, fire suppression equipment should be included in vertical evacuation refuges, to ensure the safety of those staying there (Fraser, 2012). Some vertical evacuation refuges did not have adequate provisions for the people in them to stay for the necessary tidal cycle. Debris blocked the exits of some refuges, which delayed rescues. Provisions in refuges should be increased to plan for this eventuality (Fraser, 2012, pg. 61).

Some concerns with inundation maps and public warnings were expressed. More fatalities occurred in areas close to the border of hazard map inundation zone because people waited longer to evacuate than people living closer to the coast (Fraser, 2012, pg. 31, Cascadia Earthquake, 2011). Washington state is making progress in creating consistent tsunami inundation maps. The report recommends the approach a city in New Zealand takes to publicize inundation zones by painting lines on the roads (Fraser, 2012, pg. 15). The report also recommends making it clear in Washington state that the ground shaking from a local earthquake event be established as the natural warning to evacuate. The Washington State Emergency Management Department publicizes this warning, but the Federal Emergency Management Agency educates residents to wait for an official warning to evacuate over the radio (Fraser, 2012, pg. 27). This discrepancy in messages could lead to confusion during an event.

Some of the material discussed in the report was also discussed as a concern by residents in public meetings in Neah Bay and La Push, including evacuation methods and the concern of parents for their children. The importance of evacuating by foot instead of motor vehicle was discussed, and the report pointed out that traffic jams blocked roads both during the Tohoku event and an evacuation during an aftershock, despite warnings to the contrary (Fraser, 2012, pg. 32-33). The report also noted that many parents tried to pick up their children from school during an evacuation, which led to parents or parents and children being stranded in the inundation zone (pg 34). The evacuation refuge proposed for Neah Bay takes this concern into account, by incorporating additional space for parents. During the community meetings, the project team also discussed how the community could build parent trust in school evacuation plans.

4. Methodology and Results

Initial site visits

Exploratory visits and preliminary meetings with emergency management officials at each site took place in late September 2011. On September 30, Safe Haven project members from the University of Washington met with Emergency Management in Neah Bay and with Emergency Management, the Police, and members of the Tribal Council staff in La Push. In Neah Bay the team gained the permission of the Emergency Management staff to work with the Makah Tribe on the Safe Haven Project. In La Push, the Emergency Management Staff presented the Safe Haven Project to the Quileute Tribal Council. The Safe Haven Project process followed the established procedure of a preliminary Conversation Café Meeting (Figure 13) to determine potential refuge sites and other community needs with resident input, followed by a Design Meeting, or Charrette, to get resident input on design of refuges in specific locations in the community. Final Evaluation Meetings were held in each community to present the refuge alternatives and results of the Design Team's work, and to determine whether the proposed alternatives had community support.

Conversation cafés

The conversation café is a modification of the World Café style of discussion groups that rotate participants among tables to build on previous discussions and generate ideas and consensus

Figure 13: The Neah Bay Conversation Café.
At the meeting, Makah Tribal members discussed a variety of tsunami evacuation strategies.

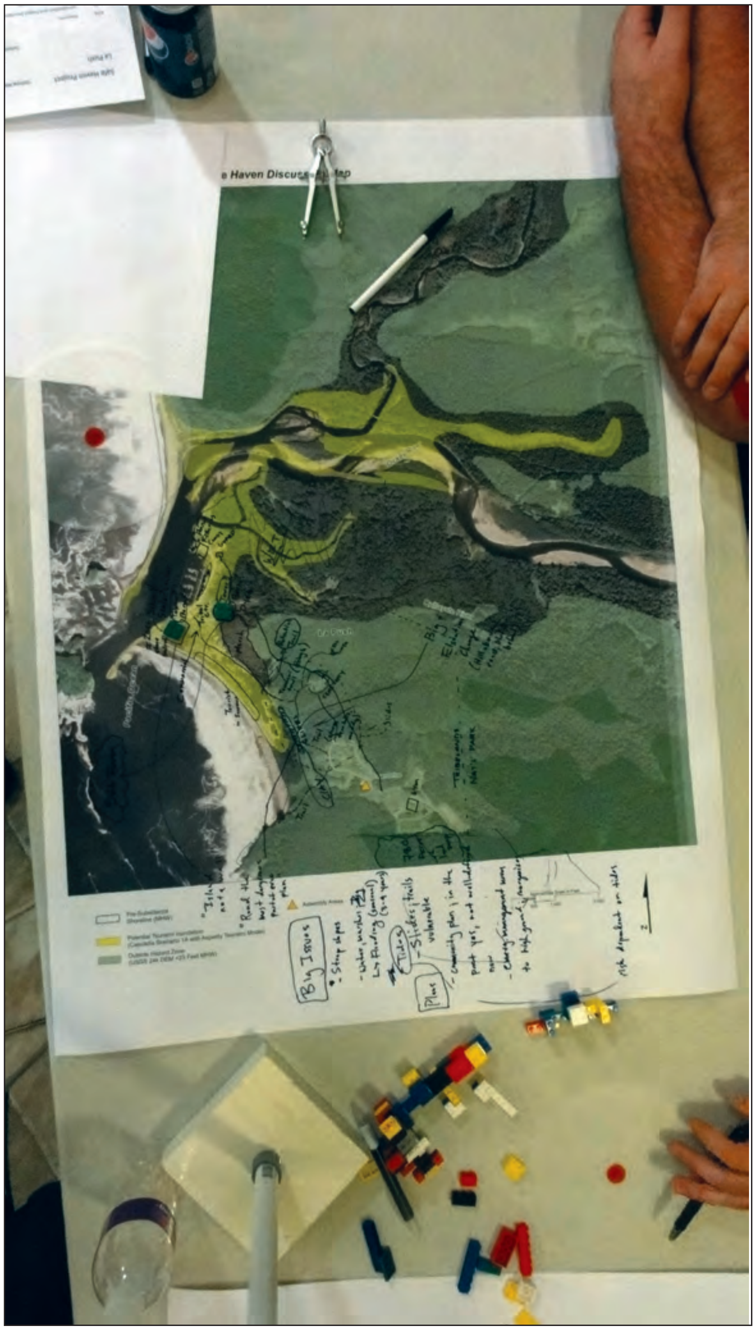


Figure 14: Discussion at the Evaluation Meetings
Tribal members used maps and suggestions from the Project Safe Haven team members and Design Charrette, then added their local knowledge and priorities to come up with preferred strategies for tsunami vertical evacuation and long-term strategies.

in groups. In a relaxed atmosphere, participants begin at one of several stations, and discuss a matter related to the central meeting theme. During this meeting, the project team took notes on the various conversations, but attempted to facilitate, not to lead, the discussion. The participants in the conversation café chose their own discussion leader, who relayed the conversation to the next set of participants as the groups rotated tables after a certain period of time. Each participant got a chance to engage in discussion at each station.

In this event, each table discussion dealt with a specific type of vertical evacuation structure. Participants were given inundation maps of their towns and markers to draw on the maps, as well as foam and Lego pieces to represent vertical evacuation structures.

In this process, the design charrette meeting was held quickly after the conversation café in order to generate momentum for the process.

Evaluation meeting

The project team developed strategies based on the input from the site visits, conversation cafes, and design charrettes. These strategies were then presented to residents in evaluation meetings, along with preliminary cost estimates of the proposed designs, and an analysis of the strengths and weaknesses of the strategy. Residents also were given a chance to comment on the strengths and weaknesses of the overall strategy, as well as the strengths and weaknesses of individual designs (Figure 14). At the end of this meeting a vote was taken, allowing residents to vote for or against a proposed vertical evacuation site, or to vote to give a proposed site less priority in the final strategy. The evaluation meeting was based on the Strengths/Weaknesses/Opportunities/Threats analysis model, which is described in Appendix B, along with the analyses for each Tribes' preferred strategy.

Conceptual cost estimating

The objective of this phase is to estimate the construction cost of each of the proposed vertical evacuation structures. This serves as a starting point for determining the economic feasibility of constructing these tsunami safe haven structures and allows preliminary cost-benefit considerations to be made. This process generally has four main steps. First, a sample of the proposed structures are selected that include representative structures for each typology (e.g. berms, towers, hybrid structures, and buildings); structures geographically distributed throughout the various communities; and structures that have the highest priority for development because of the significance of their locations in their communities (e.g. next to schools). Second, a structural system is selected and preliminarily sized for each structure in compliance with FEMA P646. Third, a conceptual cost estimation is performed for each structure by developing a detailed work breakdown structure (WBS) given the level of detail provided in the conceptual designs; performing quantity takeoffs for each line item under the developed WBS; pricing each line item using quotes from local suppliers and contractors for select items as well as cost estimating reference books (RSMeans 2011a; 2011b; 2011c); and adding other costs to cover design fees, contingencies, general conditions and requirements, and contractor fees. These costs are entered into template formats so that they can be used to provide conceptual estimates for similar structures. In the fourth step, these cost estimating templates are used to provide conceptual estimates for the remaining safe haven structures that are not in the select sample. Most sites were publicly owned, but a few were not. In either case, land cost was not factored into the cost estimates.

For the proposed vertical evacuation structures in Neah Bay and La Push, there was no need to select a sample of projects, because the number of proposed structures was manageable. As such, cost estimates were developed for each of the proposed structures. If the structure design matches one of the pre-developed templates (e.g. a tower), then the appropriate template is used. If the structure incorporate new design concepts (e.g. access trees), then a new template was developed. In both cases, cost adjustments were incorporated to account for cost inflations in 2012 as well as geographical cost differences. Detailed cost estimates are in Appendix C.

Neah Bay

Conversation café

The conversation café to gather community ideas on the location of vertical evacuation refuge sites occurred November 1, 2011, at 6 p.m. Ten residents attended. Three students and a professor from the University of Washington working on a studio about post-tsunami rebuilding of Neah Bay participated in the conversation café event with the project team.

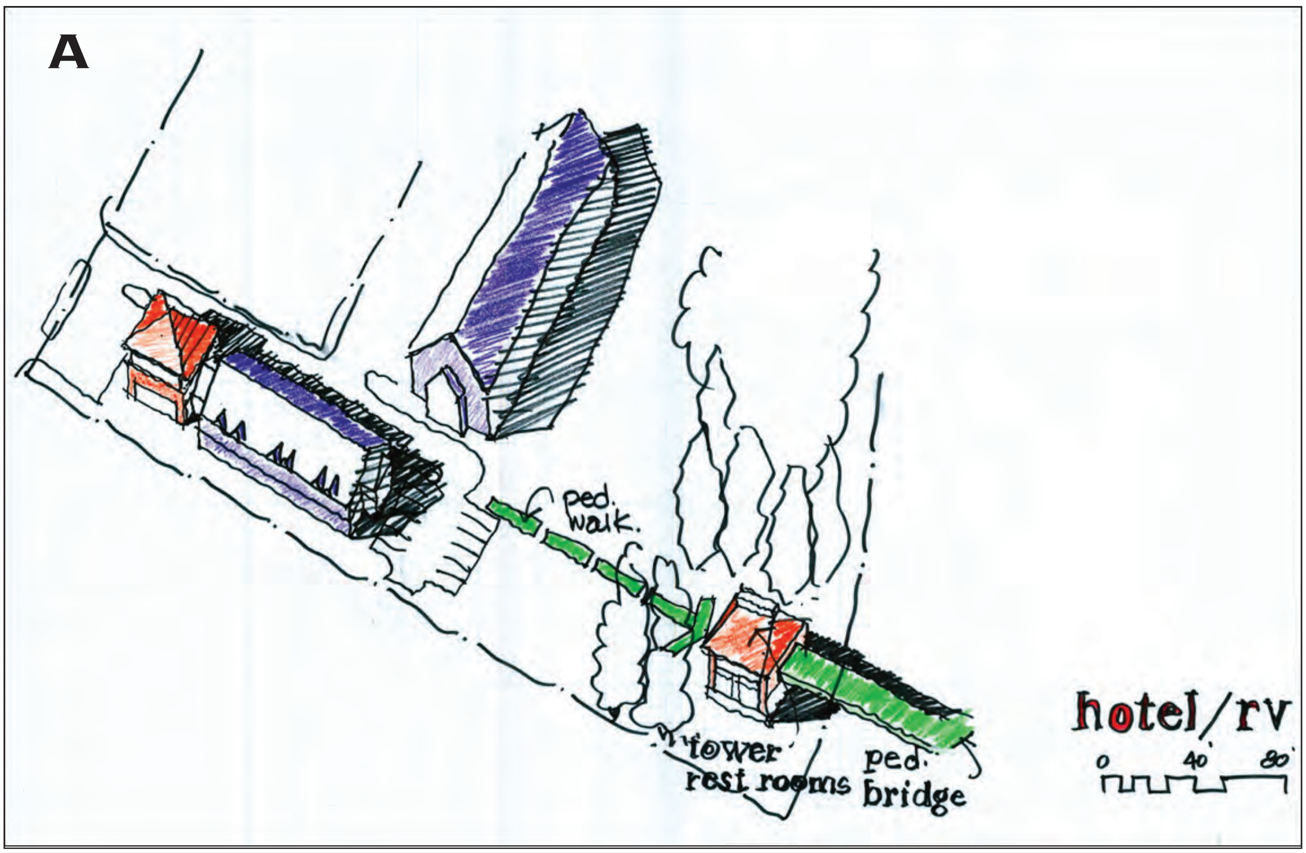
Design charrette

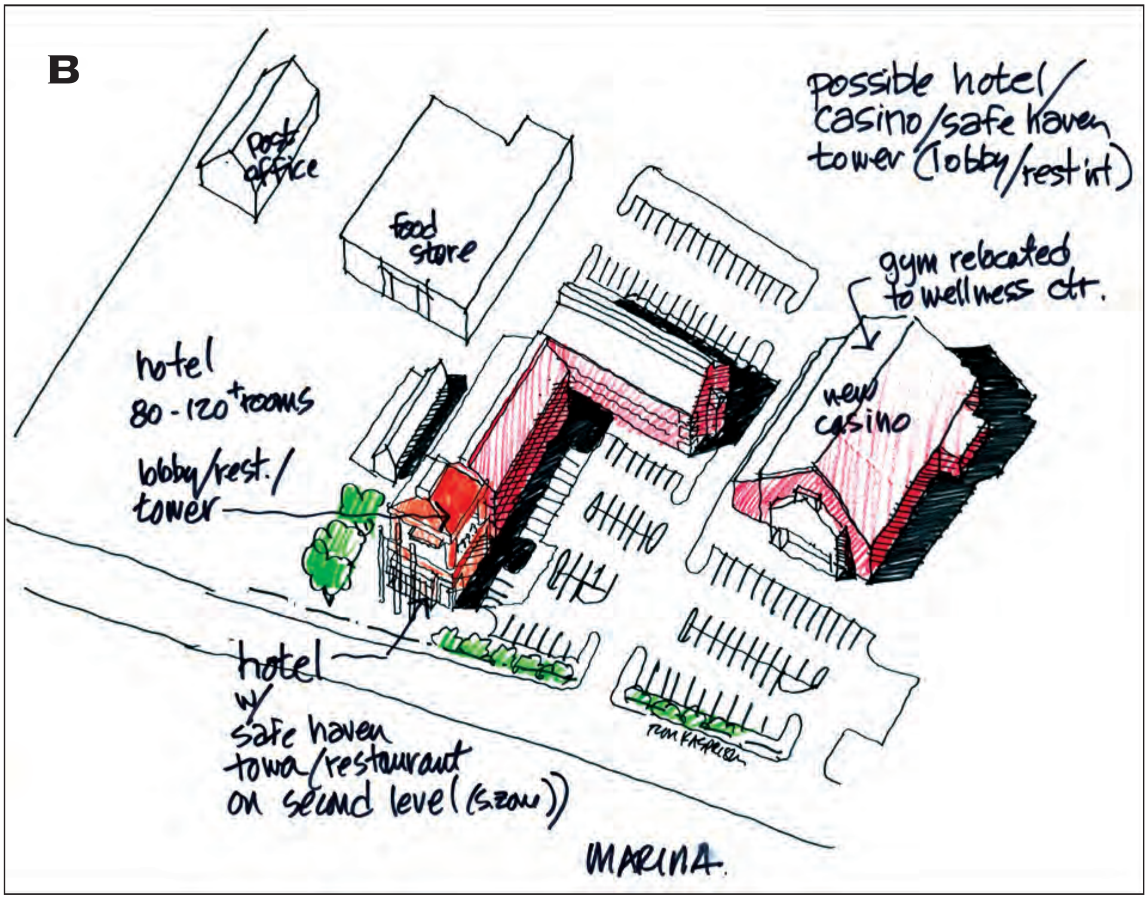
The design meetings were held on November 9 and 10. Seven people attended the event over the two days.

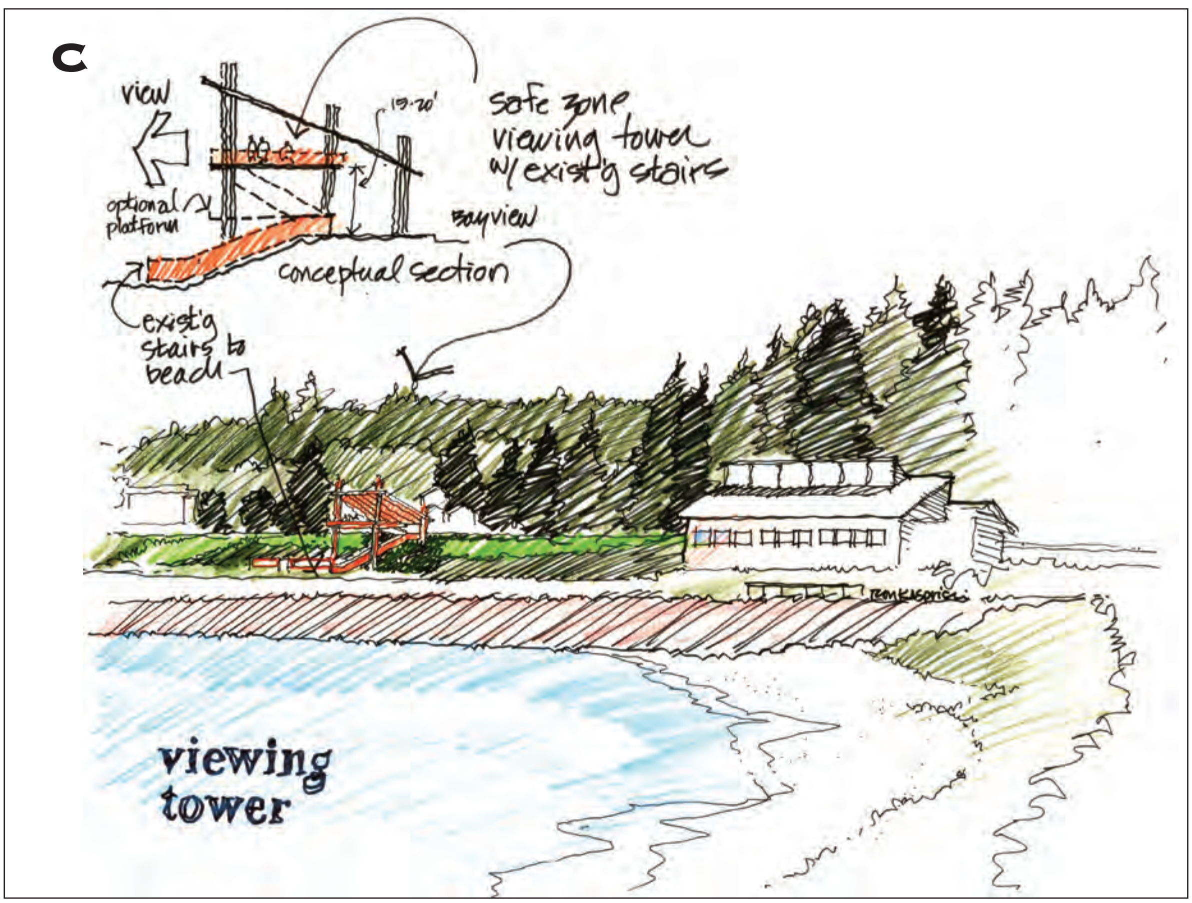
Evaluation meeting

The evaluation meeting was held March 6, 2012, at 6 p.m., with 15 people attending. The strategies on pages 20 and 21 were among those discussed (Figure 15). At the evaluation meeting, the preferred strategy was approved, with most voters approving all three elements. One vote was cast to make the trails a lower priority than the school berm. One vote was cast to not include building vertical evacuation into new development as a part of the strategy.

Figure 15: Several Neah Bay discarded strategies
Each drawing includes safe haven vertical evacuation elements (in orange). The concepts were available to Tribal members for critique throughout the charrette process. These strategies were dismissed during the evaluation meetings in Neah Bay, for a variety of social and economic reasons, in favor of the preferred strategy. A, below, is a hotel/RV complex. B, upper drawing on facing page, is a possible hotel/casino. C, lower drawing on facing page, is a viewing tower. All drawings: Ron Kasprisin




B
possible hotel/casino/safe haven tower (lobby/rest'nt)
post office
food store
gym relocated to wellness ctr.
hotel 80-120+ rooms
new casino
lobby/rest./tower
hotel w/ safe haven tower/restaurant on second level (s.zone)
MARINA.


C
view
safe zone viewing tower w/ exist'g stairs
optional platform
bayview
conceptual section
exist'g stairs to beach
viewing tower

Preferred Strategy

The preferred strategy presented at the evaluation meeting was a berm structure built on land the Tribe owned near the school, including play areas and bleachers (Figures 16 and 17). The project team also suggested a conditional vertical evacuation element be included in any new structures built for the tourism industry in Neah Bay, though none are currently planned. The final section of the proposed strategy was to create a linked trail system in the wetlands and forests around Neah Bay, to make it easier to find evacuation routes to natural higher ground. These trails would also provide an amenity to tourists and residents of the area. This strategy could cost almost $900,000.

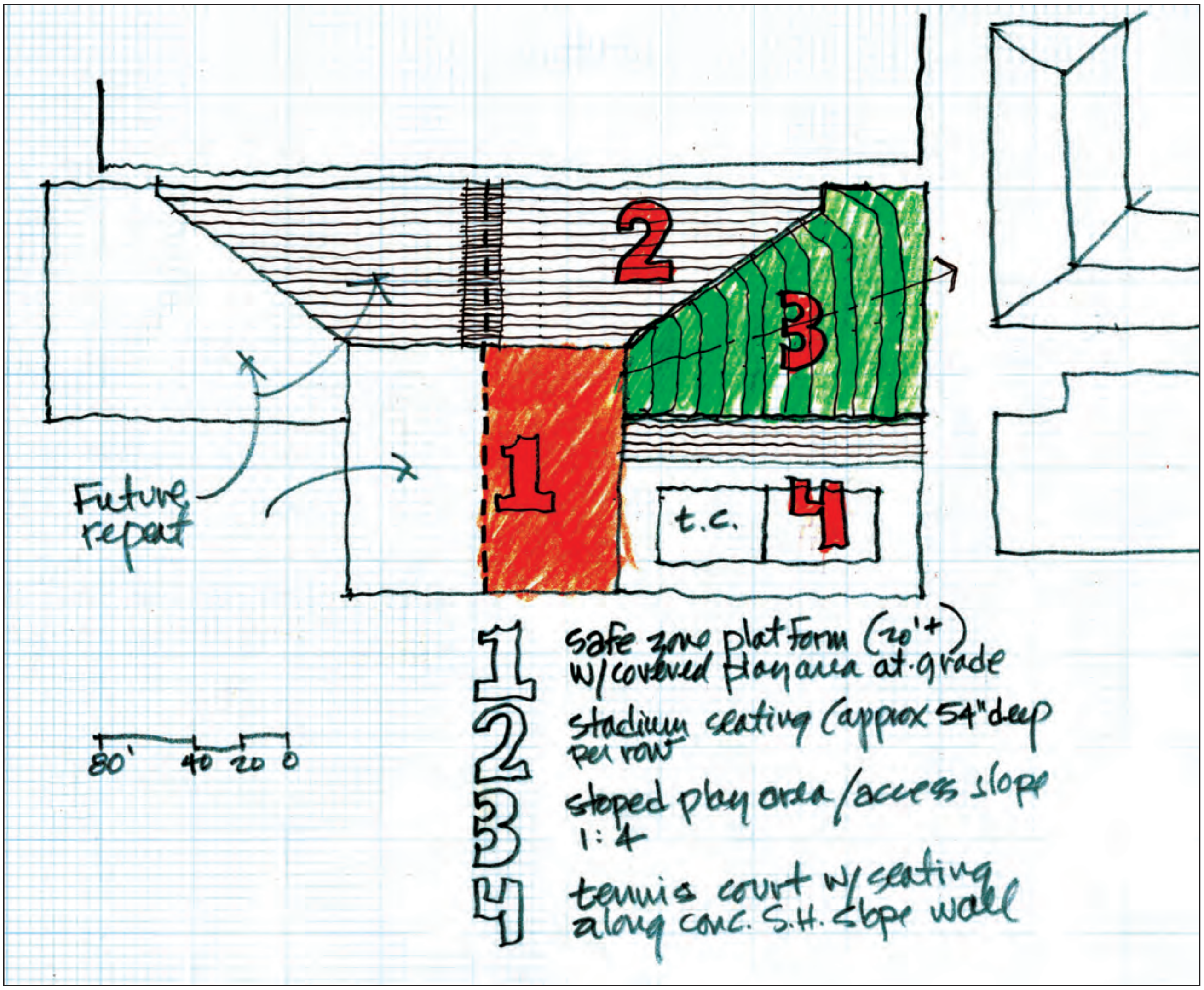


Figure 16: Neah Bay preferred strategy, drawing
The strategy included a berm structure with several components, shown above, along with increased trail connections to higher ground through wooded and wetland areas, and possible integration of vertical evacuation structures in any new development in the area. Drawing: Ron Kasprisin

Figure 17: Neah Bay preferred strategy, map
The map shows walking circles (for average and slower walkers) around some of the preferred strategy options. Much of the population and economic development is in the yellow inundation zone. Graphic: Josh Vitulli

La Push

Conversation café and design charrette

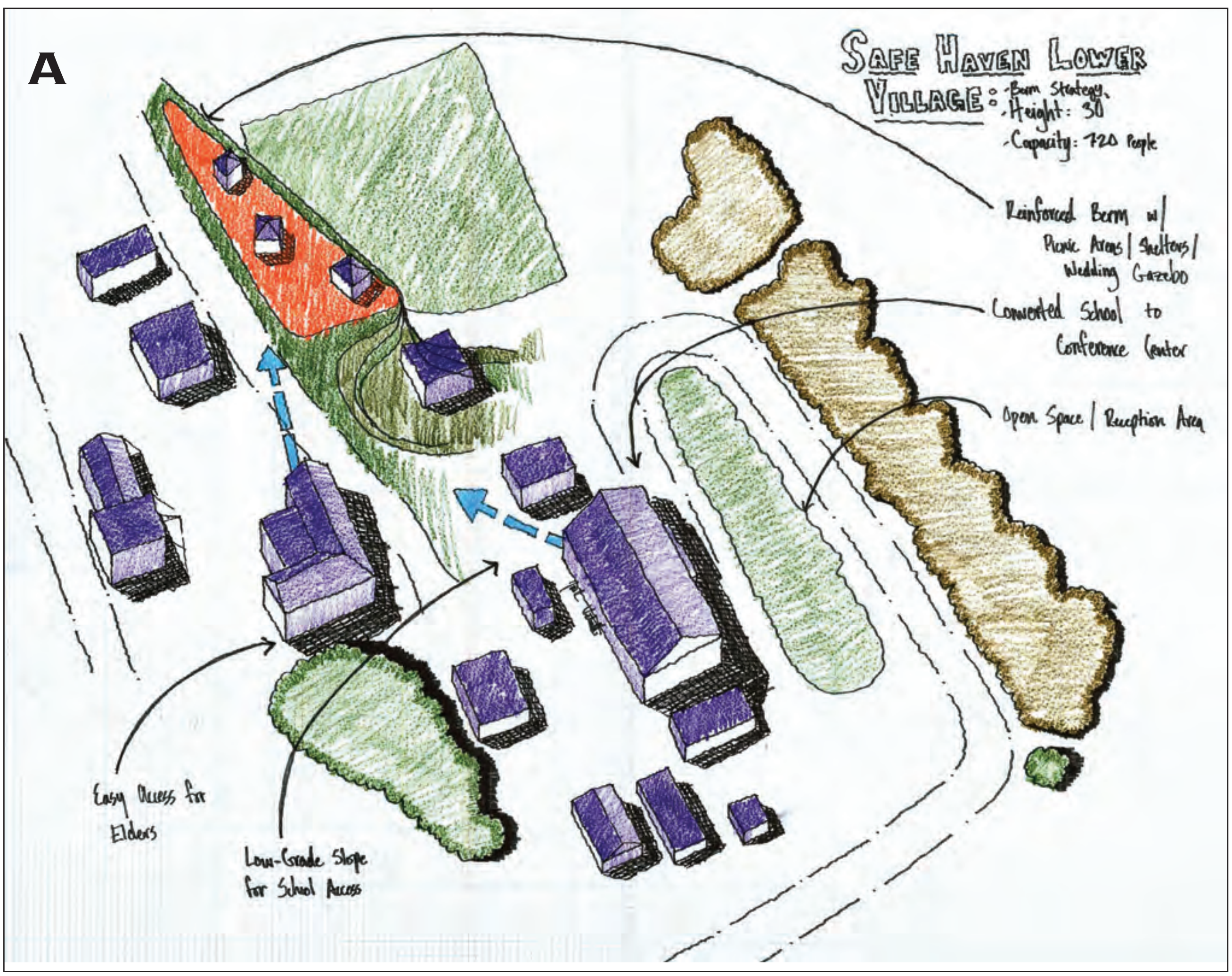
The conversation café was held the same week as the design meetings, from November 29 to December 1, 2011. There were 11 attendants at the conversation café, and 10 people at the design charrette.

Evaluation meeting

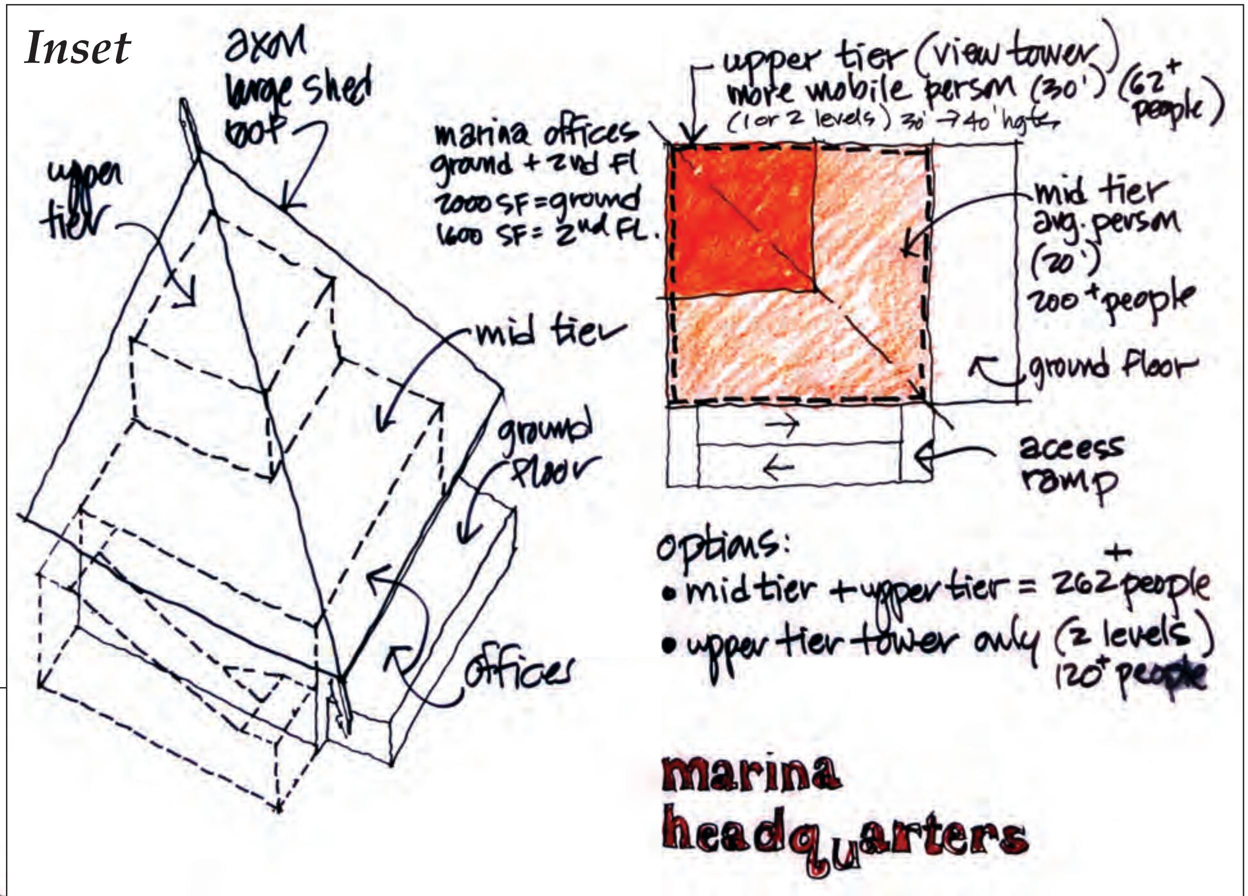
The evaluation meeting was held on February 27, 2012 at 6 p.m. The three options on this and the next page were among those presented and discarded (Figure 18). A recording of the presentation was shown to a meeting of the emergency management staff in La Push afterward. While they approved of the plan in general, they were concerned that subsidence after an earthquake

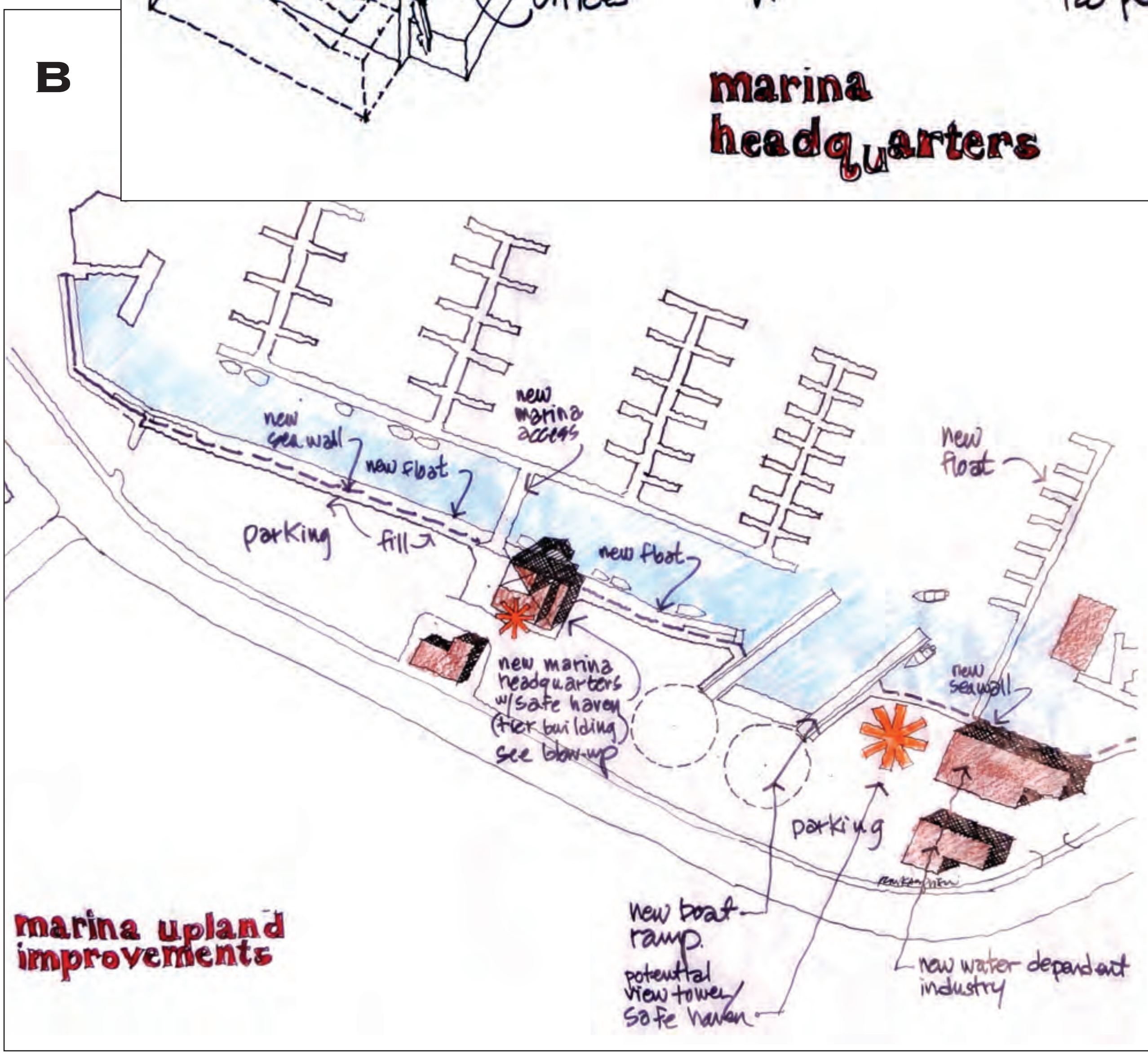
Figure 18: Several La Push discarded strategies
Each drawing includes safe haven vertical evacuation elements (in orange). The concepts were available to Tribal members for critique throughout the charrette process. These strategies were dismissed during the evaluation meetings in La Push, for a variety of social and economic reasons, in favor of the preferred strategy. A, below, is a lower village berm, but there were problems with the site. B, drawing and inset on facing page, included possible improvements to the marina.

Drawing: Josh Vitulli



Drawings: Ron Kasprisin





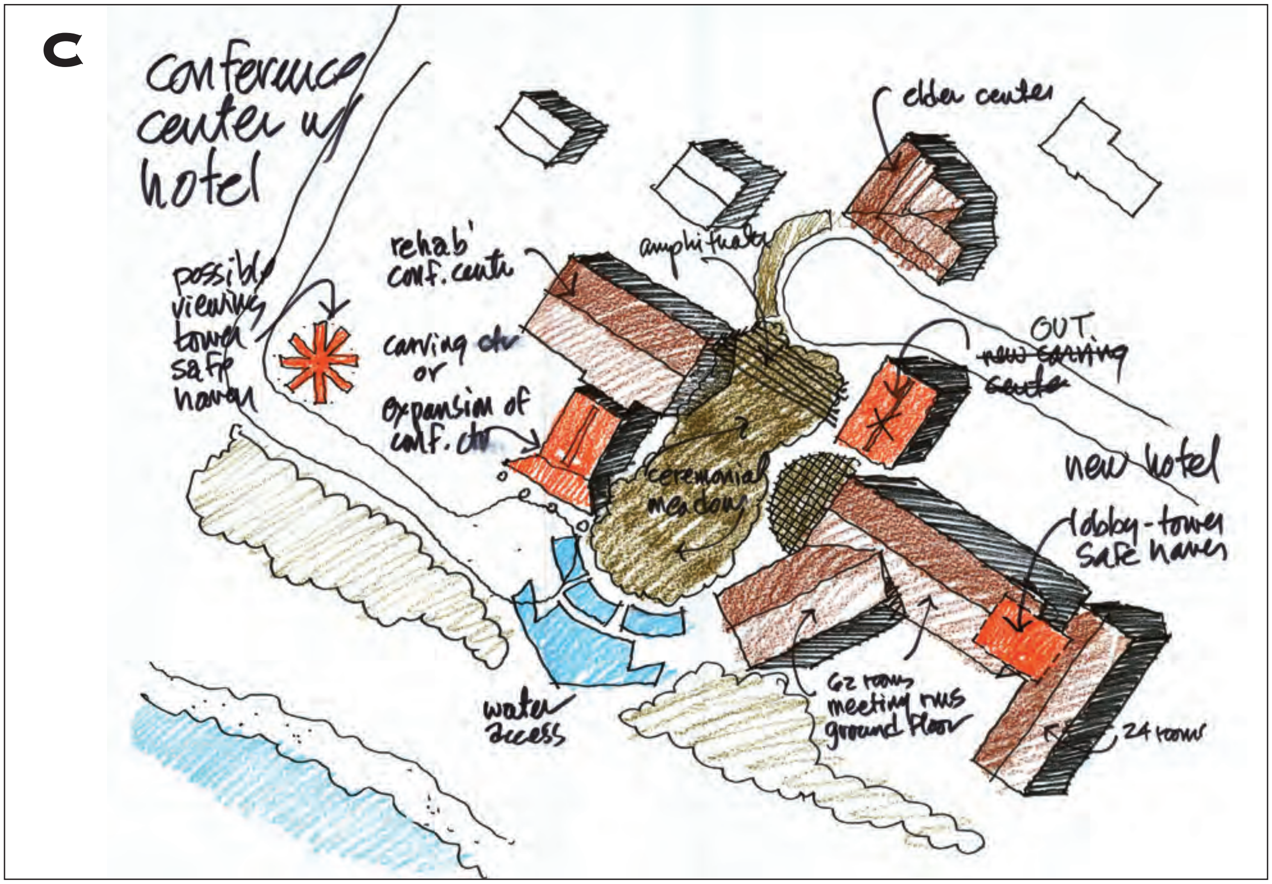


Figure 19: Other discarded options.
C, a conference center hotel, and D, a berm near the school, which was not needed when plans were made for the school to be moved. Drawings: Ron Kasprisin

would submerge a tower site near the school before the tsunami. Special care should be taken to site the tower so it will remain above the water level with the anticipated subsidence after an earthquake.

Preferred Strategy:

Given the approval of the land swap and the money to move the school during the Safe Haven Project in La Push, the project team recommended a tower to be built near the current school, to minimize the necessary investment, provide life safety until the school is moved, and to provide amenities to local tourists and the Coast Guard, who want a tower to view exercises from (Figures 19-23). A second, conditional part of the strategy recommended that future tourist development also contain vertical evacuation refuges. The third section of the strategy presented also included lengthening the existing trail system as an amenity for hikers and ATV riders, as well as more direct route to higher ground through a wetland area surrounding La Push (Figure 24). This strategy could cost $518,000.

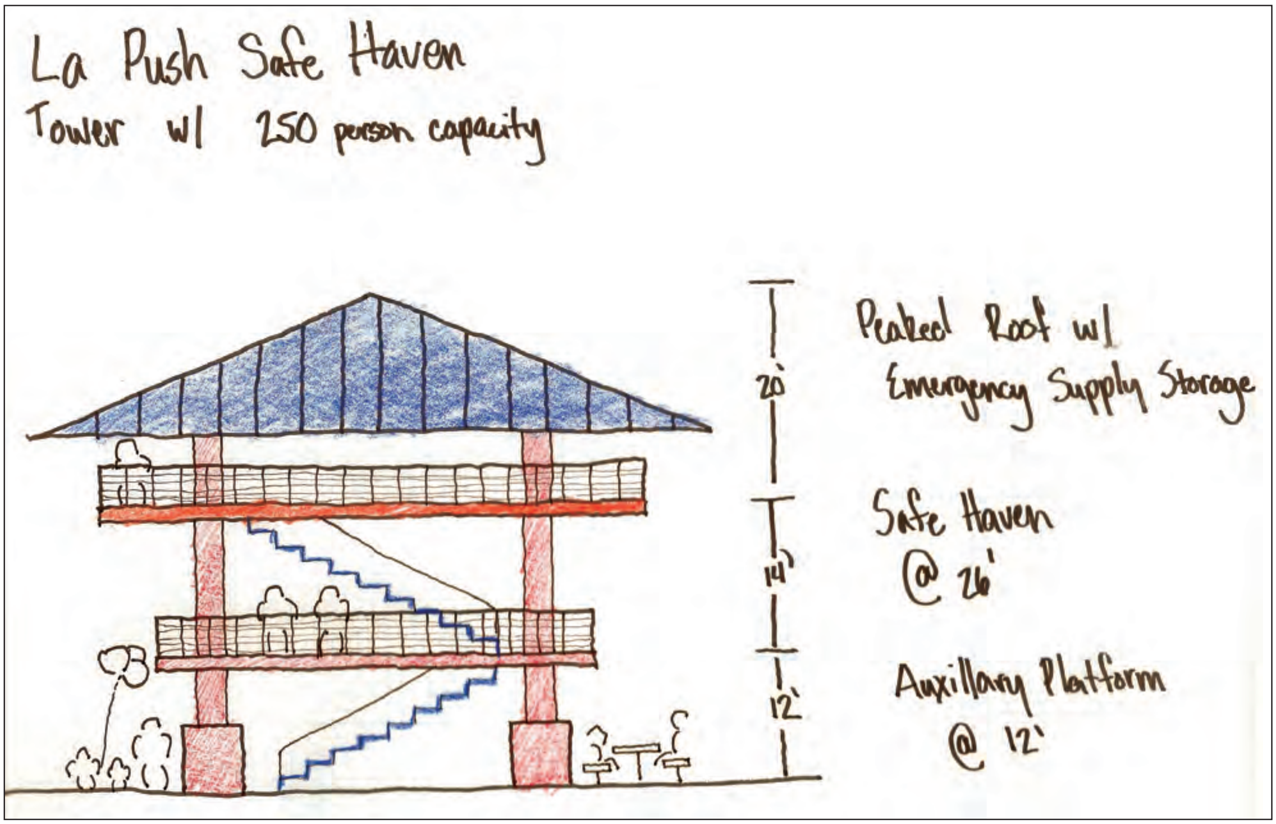


Figure 20: Conceptual designs of La Push tower
This part of the preferred strategy can be built and used at the school's current site, and still used by the Coast Guard and tourists after the school is moved uphill to a safer site. Other parts of the preferred strategy include lengthening the existing trail system for hikers and ATVs, and a more direct route to higher ground through a wetland area. Finally, future tourist development will also contain vertical evacuation facilities. Drawing: Josh Vitulli

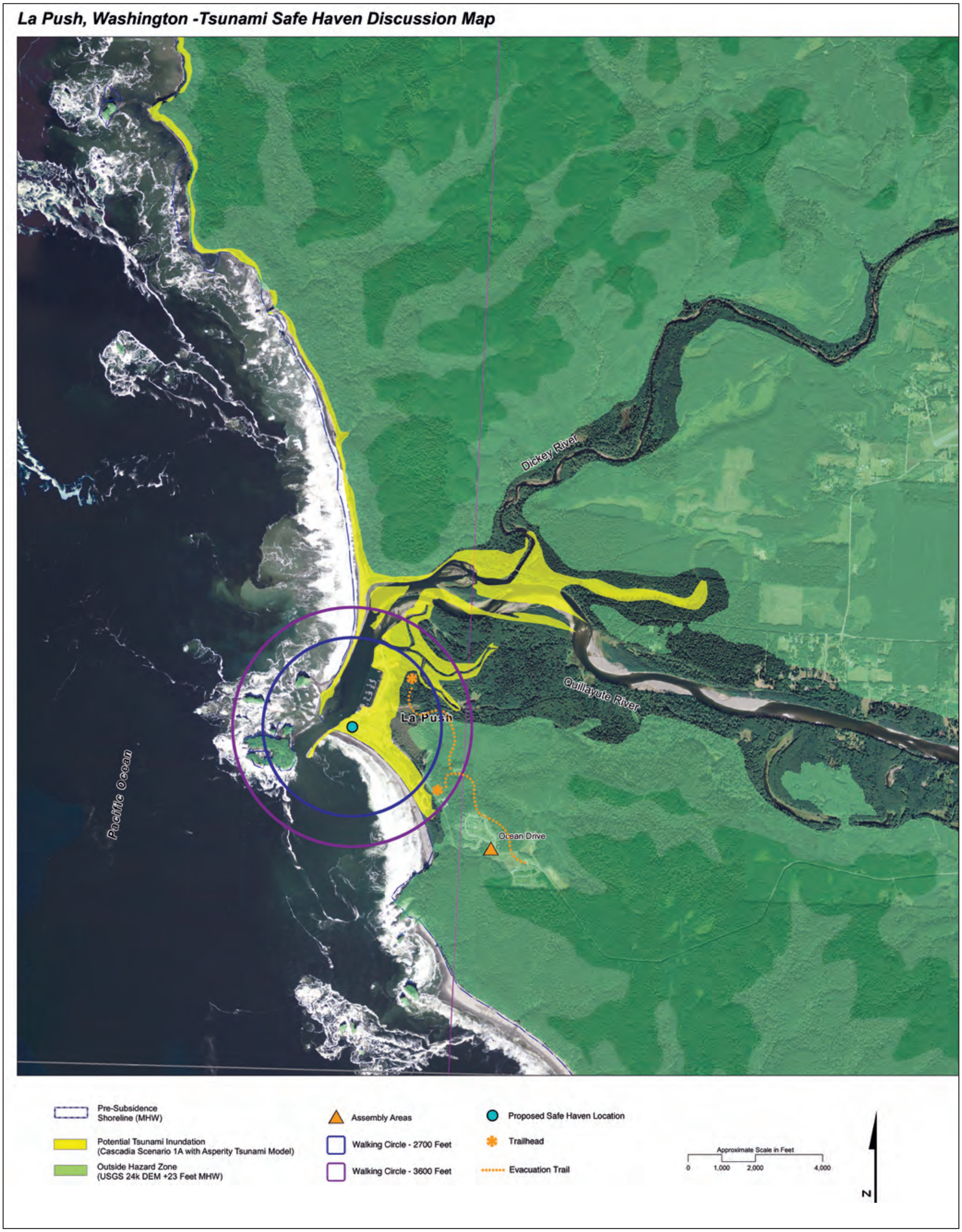
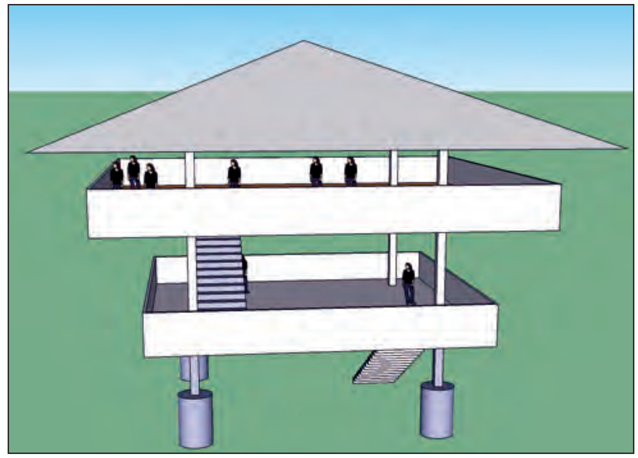
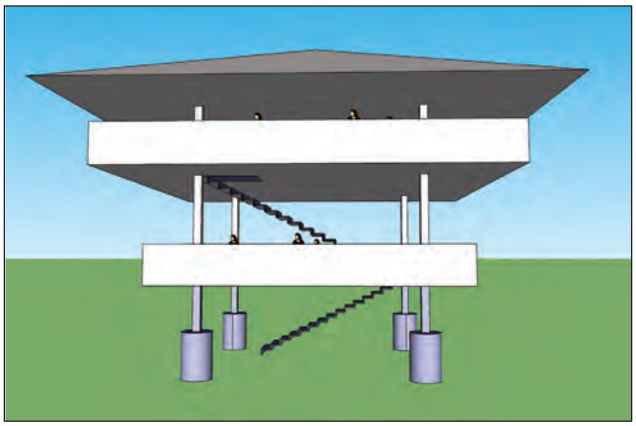


Figure 21: La Push preferred strategy, map
The walking circles (for both average and slower walkers) surround the preferred strategy of a tower at the school. The proposed trail is also marked. Graphic: Josh Vitulli

Figure 22: Views of a tower
These three views of the same tower point out different safety features. The top tier of the tower is safest during the actual inundation of tsunami water and associated forces. Between waves, however, people might be able to spread out on to the lower tier of the tower. If used as a viewing tower between earthquake and tsunami events, two (or more) tiers provides more space for visitor viewing.
The tower is built on resistant footings, to dampen shaking. The lowest level stairs may be built to breakaway in the water All graphics: Josh Vitulli





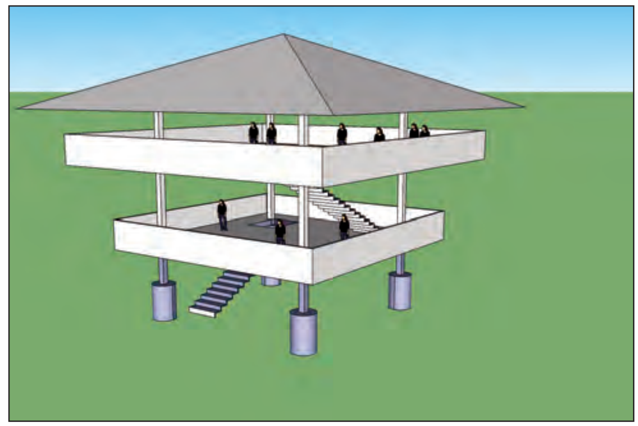


Figure 23: The La Push preferred strategy includes a tower
A conceptual tower is shown here inserted into a photograph of the coast to show potential placement and design of the structure.

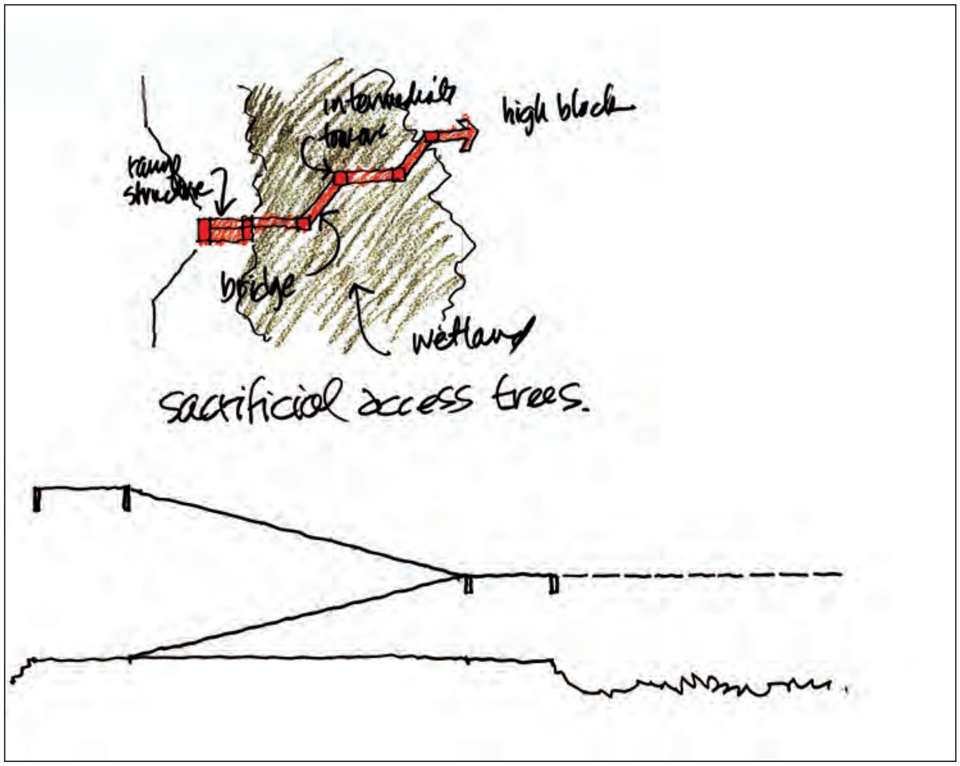
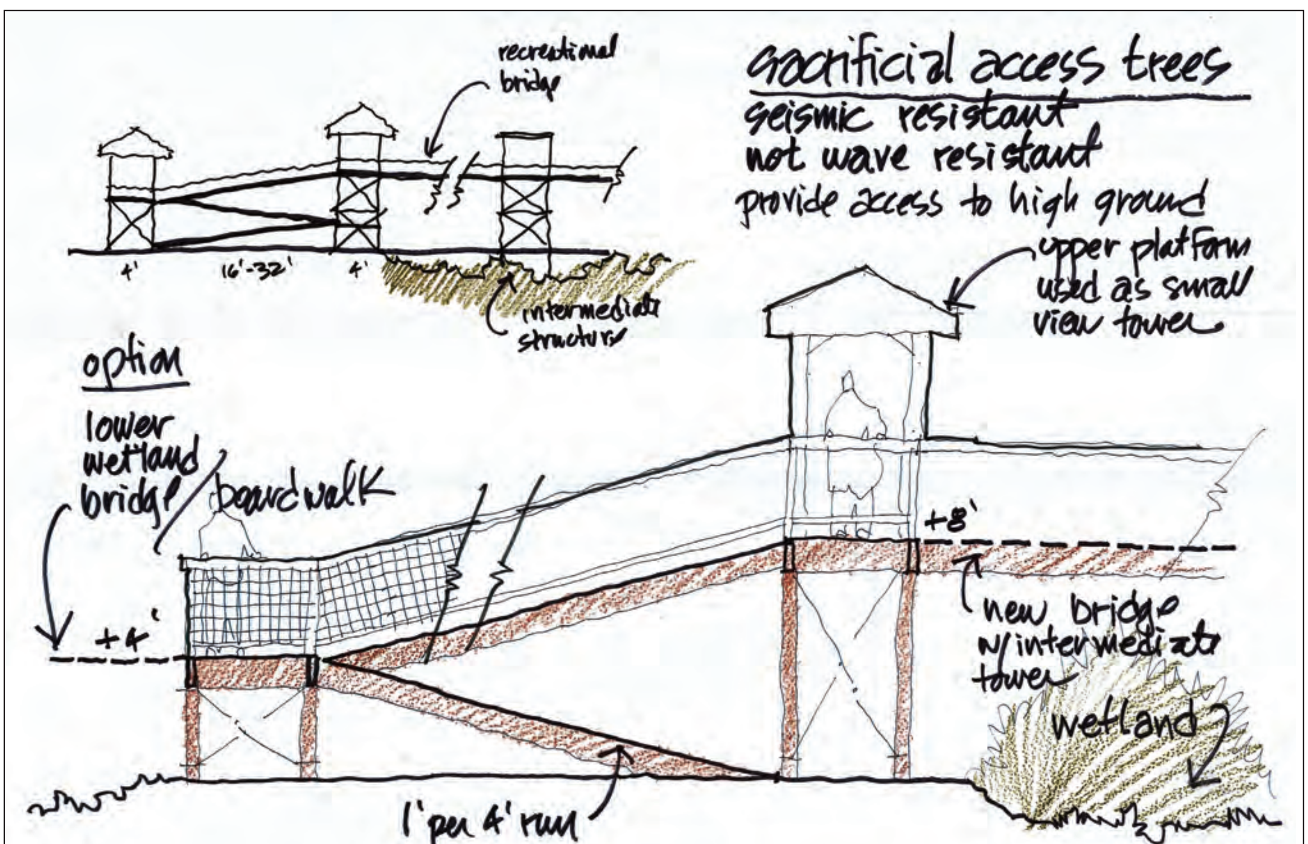


Figure 24: Sacrificial access trees.
An evacuation route through trees would be a new way to get people from the coastal area through the densely forested wetland. The elevated pathway through the trees would have a smaller footprint on the relatively impenetrable land and would encourage ecotourism by allowing people to walk through the trees. The pathway would be earthquake resistant but not resistant to tsunami forces, so it would be a sacrificial feature. Drawings: Ron Kasprisin



5. Post-Event Recovery

Coastal identity

Tribal identity for both the Makah and Quileute Tribes remains centered on coastal access. Coastal land cannot be abandoned. Moreover, the Tribes are culturally, economically and politically bound to their reservations, regardless of what physical changes an earthquake or tsunami may make to their land. Therefore, tsunami preparedness must include an adaptive approach allowing for coastal development, so that even a changed coastline in the event of a tsunami will not prevent the Tribes from re-establishing their communities on the coast. Currently available high ground in Neah Bay and to a lesser extent in La Push, is currently not well-connected with the coast. Resilience under these circumstances requires planning that improves connections between low and high elevations, and balances continued use of the coastline with strategic relocation of certain services and housing to areas that are less vulnerable to tsunami impacts. In the case of the Tribal lands, mitigation measures to protect the coast and coastal access as well as recovery measures to reclaim coastal presence are essential to achieving resilience.

In previous Project Safe Haven reports, the project team recommended preferred strategies to mitigate loss of life through the construction of vertical evacuation structures. The limited intervention required to achieve tsunami-resilience in La Push and Neah Bay allowed the project team to further investigate long-term planning strategies. The team developed a narrative vision for response and recovery that considered the geographic particularities of each community. Both strategies emphasized the eventual transition of residents and essential government services to high ground where local officials can centralize recovery efforts following the event.

Finally, Project Safe Haven partnered with the Urban Design and Planning Department at the University of Washington to create a multiphase plan for Neah Bay. In addition to illustrating how long-term development might adapt to a tsunami-threatened condition, the strategies proposed in this plan had the benefit of also illustrating adaptation to sea-level rise due to climate change. Though the recommendations were unique to Neah Bay, the process and methodology can be applied to other cities vulnerable to earthquakes and tsunamis, and other natural disasters, including the effects of climate change..

Neah Bay: Post-tsunami response vision

Assumptions include:

- Earthquake ground shaking destroys buildings and infrastructure in the lower village. The land subsides and water quickly occupies low places. New buildings were built to earthquake codes and old buildings were retrofitted.
- Residents are not injured and are able to evacuate from the approaching tsunami.
- When the tsunami reaches Neah Bay, most residents evacuate to high ground. They walk over debris and along a network of earthquake-resistant walkways built through wetlands south of Backtrack Road to designated assembly areas
- Those who need help, are weak, or did not react soon enough go to the safe haven built at Neah Bay Elementary and High School. Parents, who rush to the school attempting to rescue their children, find refuge in the safe haven.
- Those injured receive treatment quickly because of a network of trails linking assembly areas with an upper village and Tribal services center. Residents move in with

family outside the area, or Tribal members in the upper village.

- Rescued tourists and seasonal workers return home after several days. Many Tribal members depart to live with friends and families living outside of the damaged area.

Neah Bay: Post-tsunami recovery vision

- The Tribal council convenes in the upper village and begins re-visioning their community (Figure 25).
- Without pressure to respond immediately, Tribal members begin planning for a safer resilient and prosperous community.
- Lands will be reclaimed and redeveloped. Other lands within the lower village, largely due to subsidence, will be abandoned.
- A re-visioned waterfront takes shape with a new marina at its core. A redevelopment plan for a commercial and industrial lower village emerges.
- A plan for an expanded upper village takes shape proving for more homes and business activities.

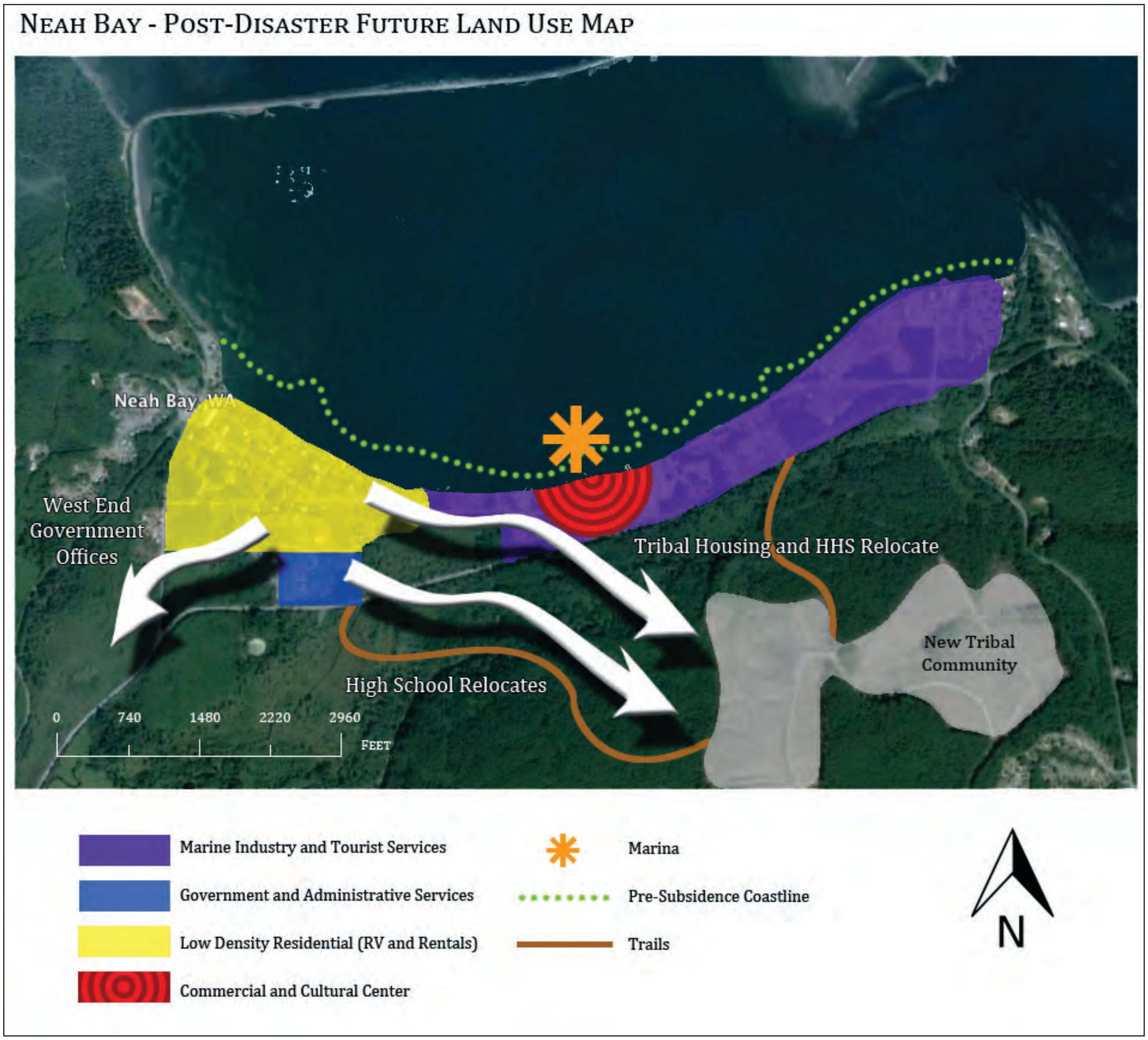


Figure 25: Post-earthquake subsidence at Neah Bay
After a Cascadia subduction earthquake, the land will subside and some of the coastline will be lost. The white arrows show the general route of tsunami evacuation. The map shows post-tsunami development. Graphics: Josh Vitulli

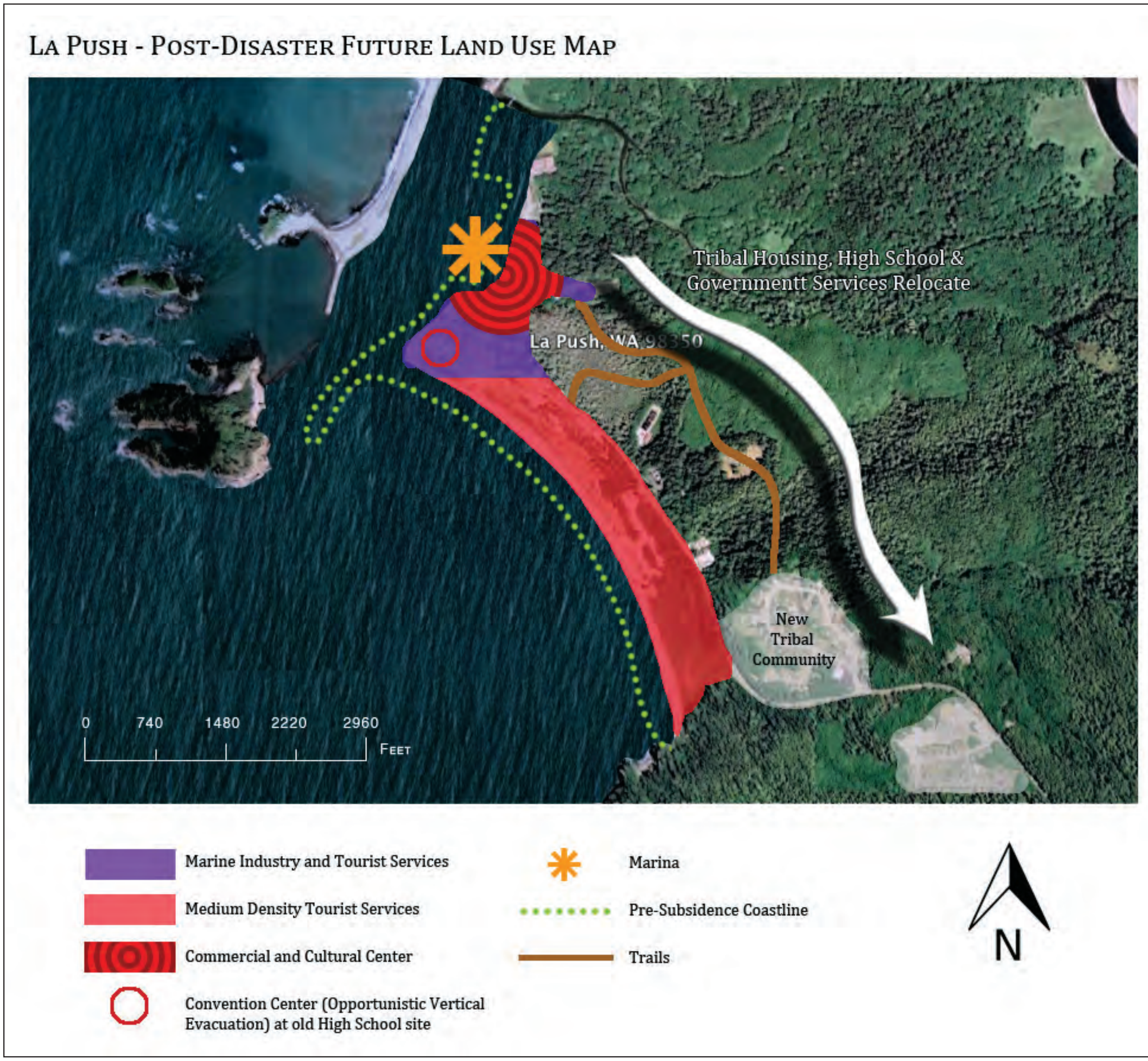


Figure 26: Post-subsidence La Push
After a Cascadia subduction earthquake, the land will subside and some of the coastline will be lost. The white arrow shows the general route of tsunami evacuation. The map shows post-tsunami development. Graphics: Josh Vitulli

- Neah Bay becomes a vibrant community maintaining a strong cultural and economic relationship with the Sea. Together the Tribe triumphs, not without sacrifice, but leaving behind a legacy and viable community for generations to come.

La Push: Post-tsunami response vision

Assumptions include:

- Earthquake ground shaking destroys buildings and infrastructure in the lower village. The land subsides and water quickly occupies low places. New buildings were built to earthquake codes and old buildings were retrofitted.
- Residents are not injured and are able to evacuate from the approaching tsunami.
- When the tsunami reaches La Push, most residents evacuate to high ground. They walk over debris and along a network of earthquake-resistant walkways to

designated assembly areas.

- Those who cannot get to high ground go to the safe haven built at the Quileute Tribal School. Parents, who rush to the school attempting to rescue their children, find refuge in the safe haven.
- Those injured receive treatment quickly because of a network of trails linking assembly areas with an upper village and Tribal services center. Residents move in with family outside the area, or Tribal members in the upper village.
- Rescued tourists and seasonal workers return home after several days. Many Tribal members depart to live with friends and families living outside of the damaged area.

La Push: Post-Tsunami Recovery Vision

- The Tribal council convenes in the upper village and begins re-visioning their community (Figure 26).
- Without pressure to respond immediately, Tribal members begin planning for a safer resilient and prosperous community.
- Lands will be reclaimed and redeveloped. Other lands within the lower village, largely due to subsidence, will be abandoned.
- A re-visioned waterfront takes shape with a new marina at its core. A redevelopment plan for a commercial and industrial lower village emerges.
- A plan for an expanded upper village takes shape proving for more homes and business activities.
- La Push becomes a vibrant community maintaining a strong cultural and economic relationship with the Sea. Together the Tribe triumphs, not without sacrifice, but leaving behind a legacy and viable community for generations to come.

Long-term post-tsunami recovery in Neah Bay

The scope of Project Safe Haven is limited to vertical evacuation strategies. In many coastal communities, long-term post-disaster recovery remains an important consideration. The Urban Design and Planning Department at the University of Washington partnered with Project Safe Haven to address these concerns. In a graduate Urban Design Studio, students participated in community meetings and the design charrette to understand the unique culture and values in Neah Bay (Figure 27). The studio team developed an array of alternatives to prepare for a long-term transition to limit risk exposure and minimize vulnerability. Several critical issues emerged:

- How do communities maintain cultural and historical relationships with the water if housing and commerce are relocated from the waterfront to natural high ground?
- How do decisions about land use and development patterns impact the economic core on the working waterfront?
- How do phasing and development patterns accommodate vulnerable populations within the community?
- How do safe havens and evacuation routes integrate with community and economic development?
- What opportunities are available in relocation to capture value from natural resources, promote sustainable development and minimize impact on the natural systems?
- How is Tribal culture incorporated and considered in a process conducted by an external project team?

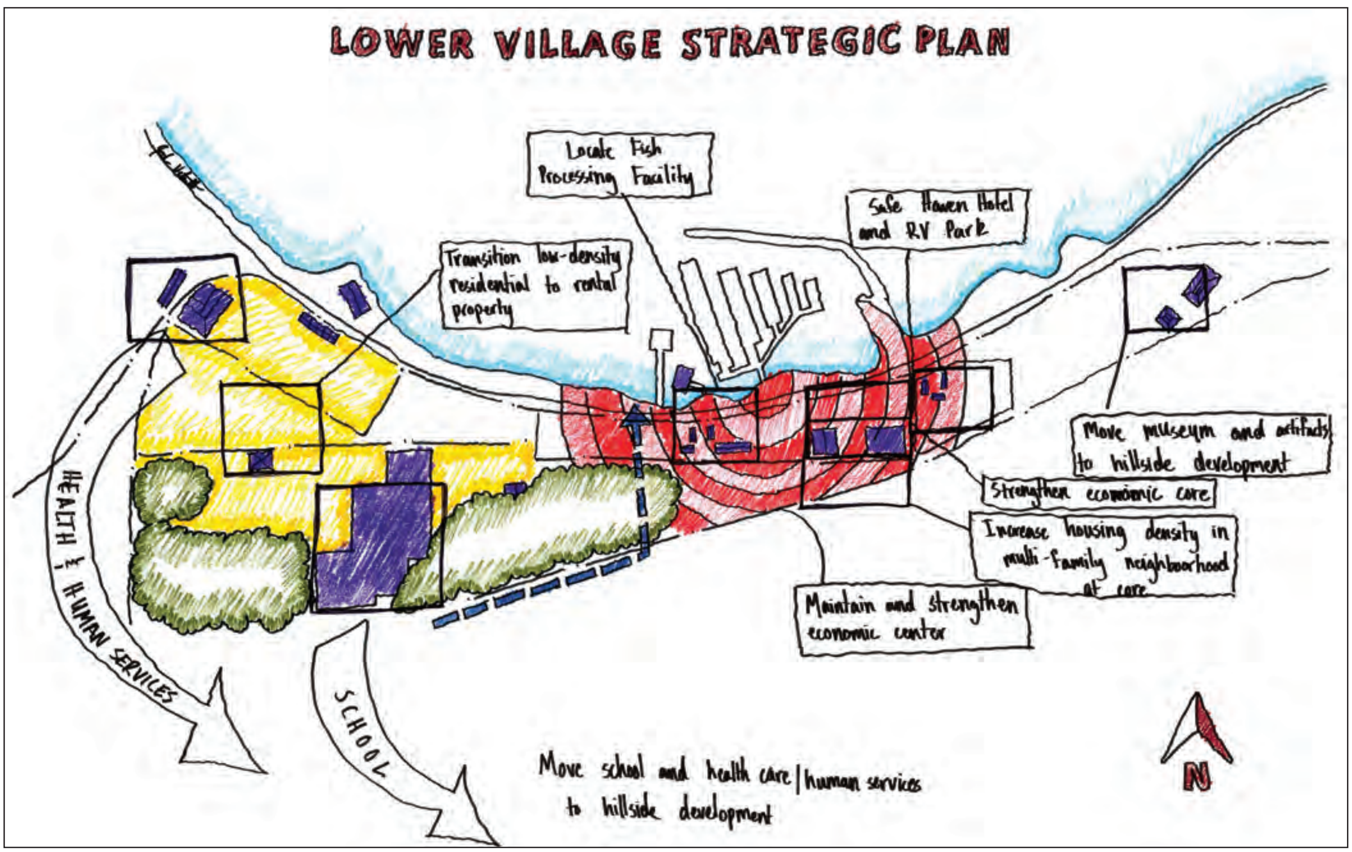


Figure 27: Strategic plan after spatial analysis
The long term plan suggests moving vulnerable populations (children and elders) and high priority institutions uphill to locations safer from tsunamis. Retail and economic activities could remain concentrated in the village center. In the diagram above, the concentric red circles identify the economic core. Health and human services and the school are relocated to the hillside development. Yellow indicates single family residential concentration at the western edge, targeted for eventual phase-out and transition back to a natural landscape. Drawing: Josh Vitulli

A comprehensive, interactive, and participatory research and design process allowed the studio team to develop alternatives that considered both the immediate threat of tsunamis and the function and location of vertical evacuation structures. The team then expanded the scope to integrate life safety strategies with long term planning objectives to limit tsunami risk in Neah Bay and foster sustainable development. The product of that research is presented in this report.

Urban Design Studio process

The Urban Design Studio team integrated multiple methodologies to manage the complexity of the design challenges (Figure 28). The team conducted preliminary research on the Makah Tribe and the history of Neah Bay. The Studio then identified hazard mitigation and disaster response case studies in costal cities in Alaska, Japan, India, Indonesia, and floodplains through the United States. Smaller working groups then identified strategies to facilitate community engagement, encourage community development, promote sustainable ecosystems and economic growth, and foster Tribal culture and values. These methods identified specific populations like youth and Tribal Elders and the Studio team developed community engagement protocols to approximate diverse, multi-generational priorities and values. Officials from the Tribal government provided resources and materials and organized meetings with officials from the planning department, the housing department, the Tribal Council, the elderly center, the school, and emergency management officials.

Research and remote analysis prepared the Studio team for a series of site visits. During the first site visit, the Studio team conducted fieldwork to:

- Analyze the environment and built and natural water systems
- Identify potential sites for vertical evacuation structures and future development outside the tsunami zone

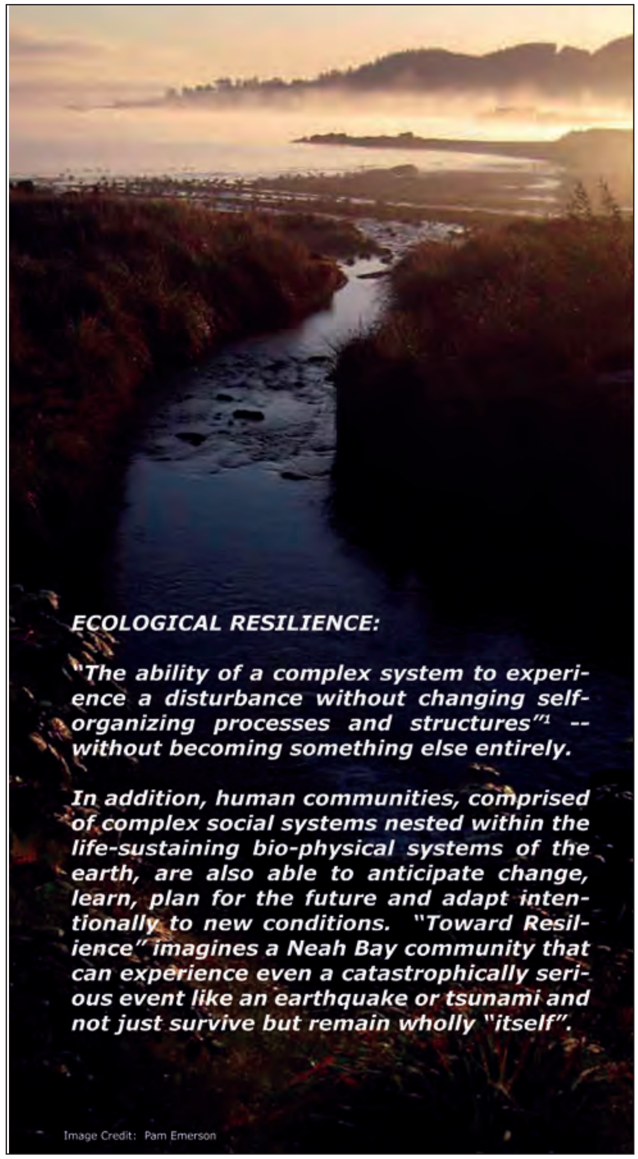


Figure 28: Ecological resilience
The Urban Design Studio team emphasized resilience and adaptability in Neah Bay to prepare the Tribal community for a tsunami, integrating current technology with cultural traditions to save lives. Photo: Pam Emerson

Urban Design Studio

Easton Branam

Ting Chen

Cameron Duncan

Pam Emerson

Timothy Lehman

Joel McMillan

David Smolker

Lisa Sturdivant

Joshua Vitulli

- Characterize housing typologies and spatial relationships
- Evaluate the local economy, business opportunities, tourism infrastructure, and the relationship between the Makah Tribe and the ocean (the traditional source food, culture, and economic growth).

After assimilating field observations with the preliminary research, the Studio organized into teams to address four complimentary topics: Waterfront Development, Uphill Development, Pathways, and Water Systems.

Over the course of three days, the Studio returned to Neah Bay for the design charrette and explored alternatives with community members, proposing design solutions. Community participants and government officials provided instant feedback that allowed the Studio team to redevelop concepts on site. The recursive nature of the community engagement refined designs and concepts to reflect the culture and values of the Makah Tribe.

Initial concepts were limited by topic and thus the preliminary strategy was inconsistent.

Figure 29: Outdoor amphitheater
This structure is an outdoor amphitheater. The seating can lead people to the top of the structure that is 25 feet high, while the hillside to the back can lead less-abled people easily to the top. The top of the structure is 110 x 40 feet, capable of holding up to 450 people. Drawing: Tim Lehman

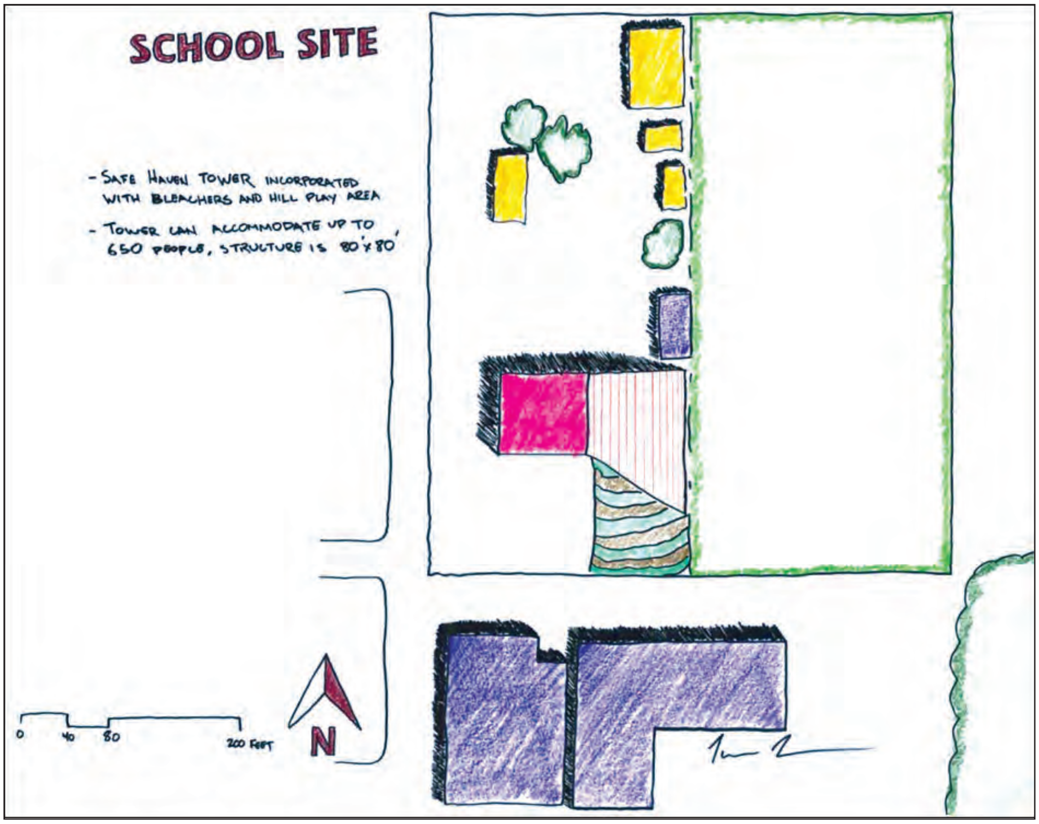


Figure 30: Tower at school
A tower structure can be incorporated with bleachers where people can sit during games. The tower which is 80 x 80 feet and 25 feet high, sits behind the bleachers. Kids can play on a hillside to the left of the bleachers, which also make for easier access to the tower. The tower itself can hold up to 650 people. This tower is a bit bigger than the needs of the school and could be made smaller.
Drawing: Tim Lehman

Economic development strategies differed in programmatic recommendations between waterfront and hillside development; water considerations tempered growth expectations. The Studio team revised the alternatives to eliminate contradictions.

The final Studio product details a robust urban design approach to disaster preparedness and recovery in Neah Bay. It:

- Identifies programmatic alternatives that incorporate hazard mitigation, environmental protection, and economic and community development;
- Recommends spatial restructuring of the town to provide for the safety of residents and tourists, promote tourist development, protect the environment and encourage economic development;
- Identifies strategies for water demand and waste water production and provides guidelines for water systems;
- Details a network of pathways that connect waterfront and hillside developments, increase tourist amenities and provide improved access to evacuation routes and natural high ground;
- Describes the strengths, weaknesses, challenges and priorities of Neah Bay and the Makah Tribe;
- Discusses phasing and decision trees in long-term planning and implementation;

Waterfront Development

For thousands of years the Makah Tribe have lived at the edge of the Olympic Peninsula and derive much of their heritage, culture, values and livelihoods from the abundant resources of the Pacific Ocean. The Makah historically settled in low, flat areas on the waterfront, giving them easy access to the ocean. The population is now mostly concentrated in the shallow crescent of land that borders Neah Bay on the northern side of the peninsula. The lower village, bounded by the Puget Sound to the north and Cougar Hill to the south, also contains the village center, the commercial core, the school, Tribal Elders, the police department, the Makah Cultural and Research Museum and an array of health and human services in a loose complex on the west side of the lower village. In the hills on either side, a handful of Tribal members have formed small residential clusters. A small number of houses stretch along the western edge of the peninsula at Makah Bay. Due to the settlement pattern and close proximity to the Cascadia subduction zone, the Tribe is extremely vulnerable to tsunamis that threaten the traditional living patterns of the Makah Tribe.

The Waterfront Development team attempted to understand the current spatial and cultural relationships in the lower village and reconcile contradictions to maintain a vibrant economic and community core in the lower village and minimize the life safety threats. To begin, the design team catalogued the businesses, housing and housing typologies, and government services located in the inundation zone.

The Uphill and Waterfront development teams then collaborated to identify essential services and vulnerable populations that could relocate to Cougar Hill: the school, elderly housing and the elderly center, and the health clinic.

All of these buildings are on the western edge of the lower village, surrounded by single-family housing. The Waterfront team proposes a phasing strategy: remove essential services from the inundation zone, suggest complimentary reuse of existing buildings, and diminish housing density. The school complex, for example, becomes the site for a vertical-evacuation structure that embellishes the football field and converted school facilities and administrative offices to accommodate Tribal government currently located on the opposite side of the peninsula (Figures 29 and 30). Over time, as residents voluntarily relocate to hillside developments, areas previously used for housing gradually return to a natural state. As residents depart the inundation zone, new opportunities for tourism provide potential revenue sources. In the interim, vacant

Figure 31: Uphill building case study one
Design principles include reflecting historic building features and minimizing energy consumption.

Figure 32: Uphill building case study two
Design principles include connecting indoor and outdoor spaces, minimizing runoff, minimizing construction costs, and maximizing flexibility for future changes.

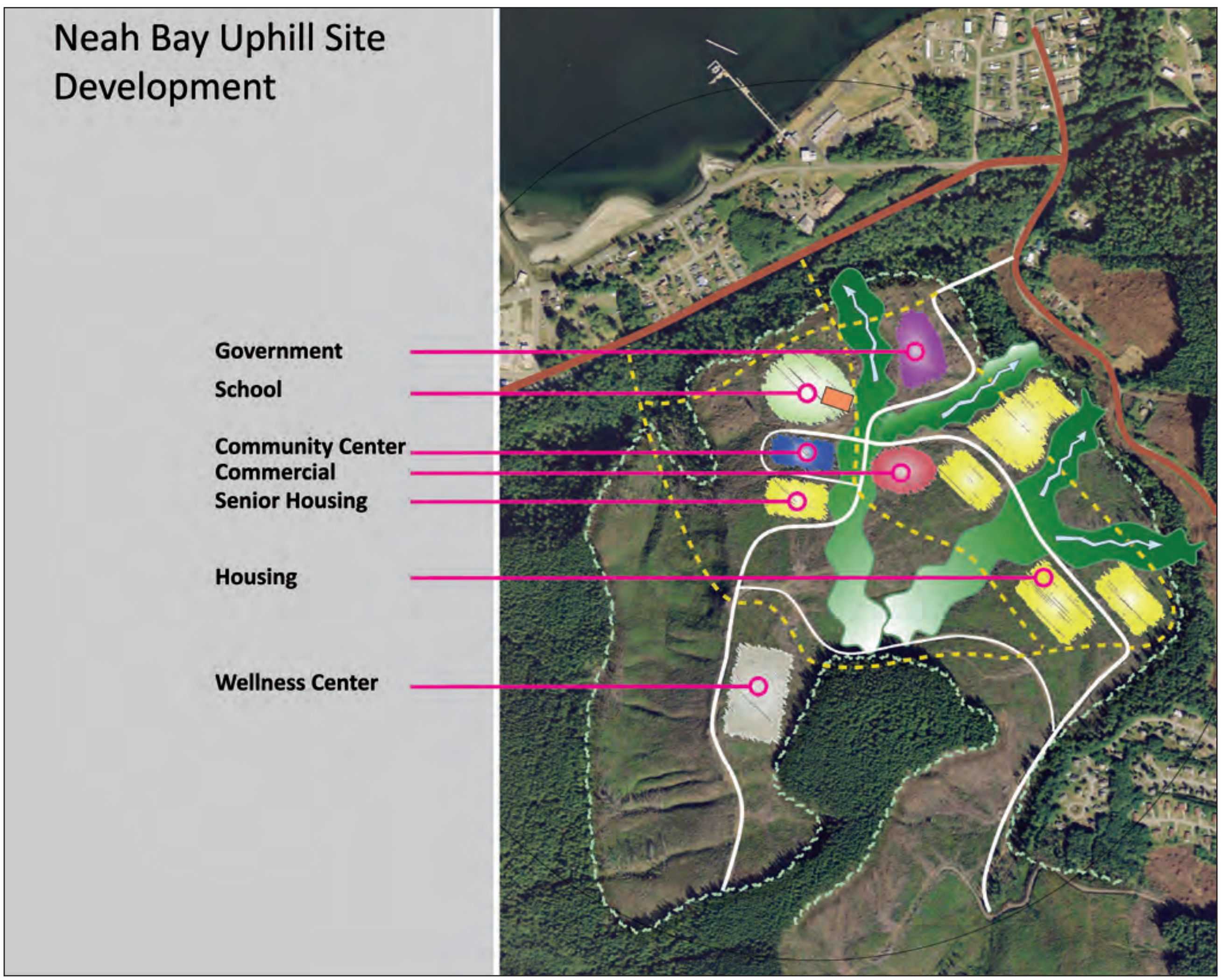


Figure 33: Potential uphill development on Cougar Hill
A phased strategy can be used to move some of the vulnerable population from coastal elevations to uphill developments, safer from tsunamis.

single-family homes can be made available as rental properties or homes for Tribal members that want to return to the Makah Reservation.

The Waterfront Development proposal effectively divides the lower village in half. As the western edge slowly fades and resident use of the area diminishes, the economic core at the waterfront intensifies. This recommendation is not without controversy. New structures in the inundation zone are at risk. However, enrolling in the National Flood Insurance Program allows the Tribe to mitigate the financial risk and maintain an important, traditional relationship between the Makah Tribe and the Pacific Ocean.

The design team conducted an urban design analysis that assumed the eventual development of Cougar Hill and emphasized connectivity between the upper and lower village through a series of walking paths. Field observations also identified an east-west corridor trafficked by pedestrians. These two axes intersect at the current village center, in a public space between the grocery store, the new gymnasium, and the only cluster of multifamily housing in Neah Bay. A combination of proposals strengthen these pedestrian corridors and formalizes a central, public space at the intersection. The current multifamily cluster is intensified, approximately doubling available units, for families, seasonal workers, or Tribal members living off reservation that cannot afford to purchase a new home on the reservation.

Urban design analysis identified a commercial core centered at the marina that radiates outward in decreasing intensity. Updated tourist facilities and RV Parks form an axial spine through the economic core and define the hard edges. A fish processing facility is sited within these boundaries, complimented by cisterns designed to meet increased water demand. A new hotel and casino, an idea proposed by residents and previously discussed by the Tribal Council, is presented as an alternative. The Makah Cultural and Research Museum, which houses an impressive collection of Tribal artifacts, moves to a new location on the hillside to protect the heritage of the Tribe. The existing building is repurposed. Possible uses include partnerships with academic programs, such as the Northwest Indian College, to establish a satellite campus.

The collection of recommendations is a series of options or decisions that are not mutually exclusive. The Waterfront Development proposal intends to provide guidance through the long transition process to build tsunami resilience in Neah Bay without sacrificing culture, community, or economic development. In this proposal, as Neah Bay gradually evolves, life safety risks to residents decrease and a vibrant commercial waterfront core emerges.

Uphill Development

The Uphill Development team identified a phasing strategy to develop a residential village on Cougar Hill and remove vulnerable populations from tsunami inundation zone. In the short to intermediate term, the Cougar Hill Development Plan proposes relocation of essential Tribal government services, seniors, and vulnerable community members to a safer area. Phase one includes a comprehensive health care and disaster relief center and a new school complex. Phase two provides senior housing and a wellness center. The final phase emphasizes residential growth and economic development, in the long term, to create a relatively dense, mixed-use city center (Figures 31-313).

A network of pathways connects the upper and lower village to maintain traditional ties to the ocean. The land use configuration and streetscape design facilitate community development, encourage on-the-street encounters and embody the cultural values of the Makah Tribe. The proposal also minimizes environmental impacts. Land use, siting, and infrastructure avoid and preserve the nesting sites and natural habitat of bald eagles. Strategies to manage

Figure 34: Paths out of inundation zone
The paths (in red), out of the inundation zone (in yellow) to safe areas, also lead to areas of potential uphill development. The entire community must be analyzed to look at the best options for tsunami safe havens and to consider all options for post-tsunami redevelopment. In the present, pathways unite the various parts of the community.

increased wastewater and runoff are prescribed. Cisterns are strategically located to capture rainwater to match increased water demand. In the finished product, the uphill development details the potential future of the Makah Tribe: a robust residential center at Cougar Hill, a complete array of services and amenities, and an economic core.

Pathways

Pathways are the connective tissue that bond dispersed elements of the community. They can also function as evacuation routes to high ground and assembly areas. The wetland between the lower and upper village inhibits rapid access to high ground. The Pathways team explored the possibility of using a series of trails, boardwalks, and floating walkways as evacuation routes. The proposal illustrates innovative solutions that provide access from multiple points in the lower village to high ground. The paths converge at a large assembly area. Residents then choose the closest path to evacuate the inundation area, but reconnect with family and friends at the designated location (Figures 34-36).

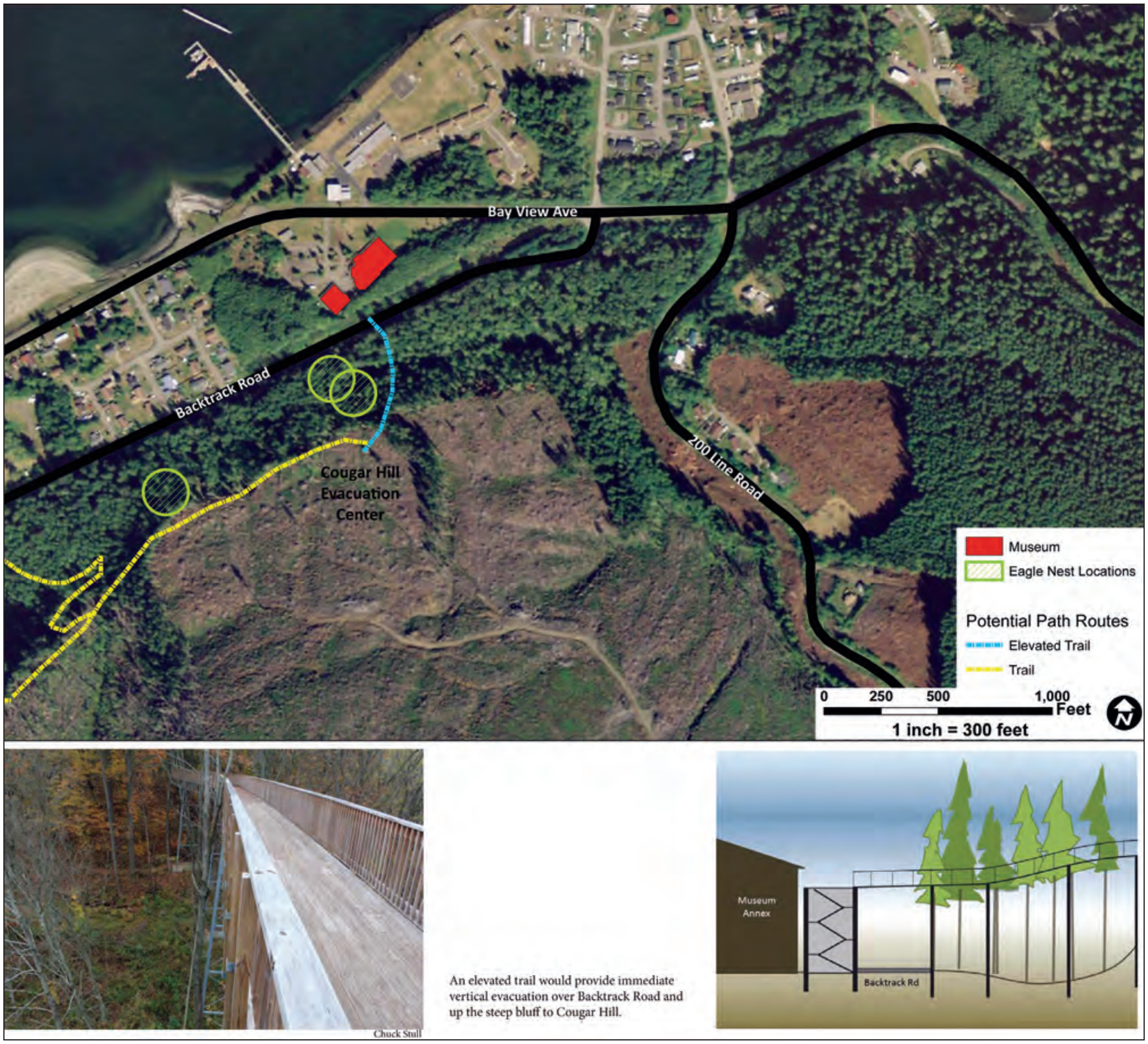


Figure 35: Museum trail
The museum is the final site chosen to provide an exit from the town up to Cougar Hill. The site is a short walking distance (less than 1,000 feet) from the East Nursery Neighborhood, RV sites, and the Coast Guard station, all of which will require evacuation. Also, because the museum itself serves as a stopping point for tourists, access to the trail system will create a natural entry point for recreation, hiking, and wildlife observation for these visitors. A trail through the forest canopy is a relatively new approach to pathways and is important in this area with large wetlands.

The pathways offer secondary benefits to residents and tourists. The paths reinforce connectivity along the two major pedestrian axes. Paths promote healthy lifestyles, providing opportunities for walking and cycling off major roadways. If coordinated with the school curriculum, paths through wetland and forest areas can augment environmental education. The paths also benefit tourists, creating a network for hiking in the local rainforest. With further coordination from the Makah Cultural and Research Center, paths serve as an interpretive trail system.

Water Systems

The Water Systems team sought alternative strategies to maintain the relationship between

Figure 36: Dense woodlands
The dense woodlands in the wetlands is largely impenetrable. The tract lies between the school and safer uphill terrain, leading to creative ideas for floating walkways and other ideas to pass through the wetlands to safe havens.

the Makah Tribe and water while promoting conservation, sustainability and rehabilitating local ecosystems. In the context of tsunami preparedness and planning, the Water Systems team established guiding principles to respond to threats, recognize the inherent value of native-to-place water and the natural environment and reinforce system services to localize and diversify water sources and prevent the degradation of waterways. This framework then allowed the team to recommend a variety of strategies and best practices.

When implemented in concert, the recommendations address environmental and water qualities concerns, and diminish or eliminate dependence on traditional infrastructure and wastewater treatment systems. Collections of rainwater catchment cisterns increase the available water supply and reduce reliance on expensive pumping infrastructure. Composting toilets decrease water demand, reduce wastewater outflow in Puget Sound, and improve soil quality.

A cluster of recommendations emphasizes storm water management. Wider riparian buffers protect natural water systems and habitat. Rain gardens improve water quality and limit impervious areas to minimize contaminated runoff. Green roofs function similarly, detaining and treating storm water to benefit water quality. Storm water is further reduced if permeable pavement replaces traditional impervious surfaces. Bioswales are another alternative: a bioswale functions like a rain garden, but slowly filters polluted runoff through dense vegetation or through soils where microbes process the contamination. Constructed wetlands collect and treat grey water from light uses and complement the local habitat in Neah Bay.

The Water Systems team then analyzed alternatives proposed by the Uphill Development and

Waterfront Development teams within the context of water systems. For example, to evaluate the impact of new construction on Cougar Hill, the team approximated the increase in storm water runoff from new construction to devise treatment strategies and recommend specific measures to minimize contamination. The team also responded to the proposed construction of a fish processing facility discussed in community meetings (Figure 37). The team tested feasibility with regard to supply and demand for water on the peninsula and suggested an appropriately sized facility that considered rainwater catchment, wastewater treatment, and industry seasonality.

When these recommendations are considered as a whole, a robust framework emerges that applies to both current disaster mitigation strategies and the resilience and eventual reconfiguration of Neah Bay while protecting and decontaminating natural ecosystems (Figure 38 and 39).

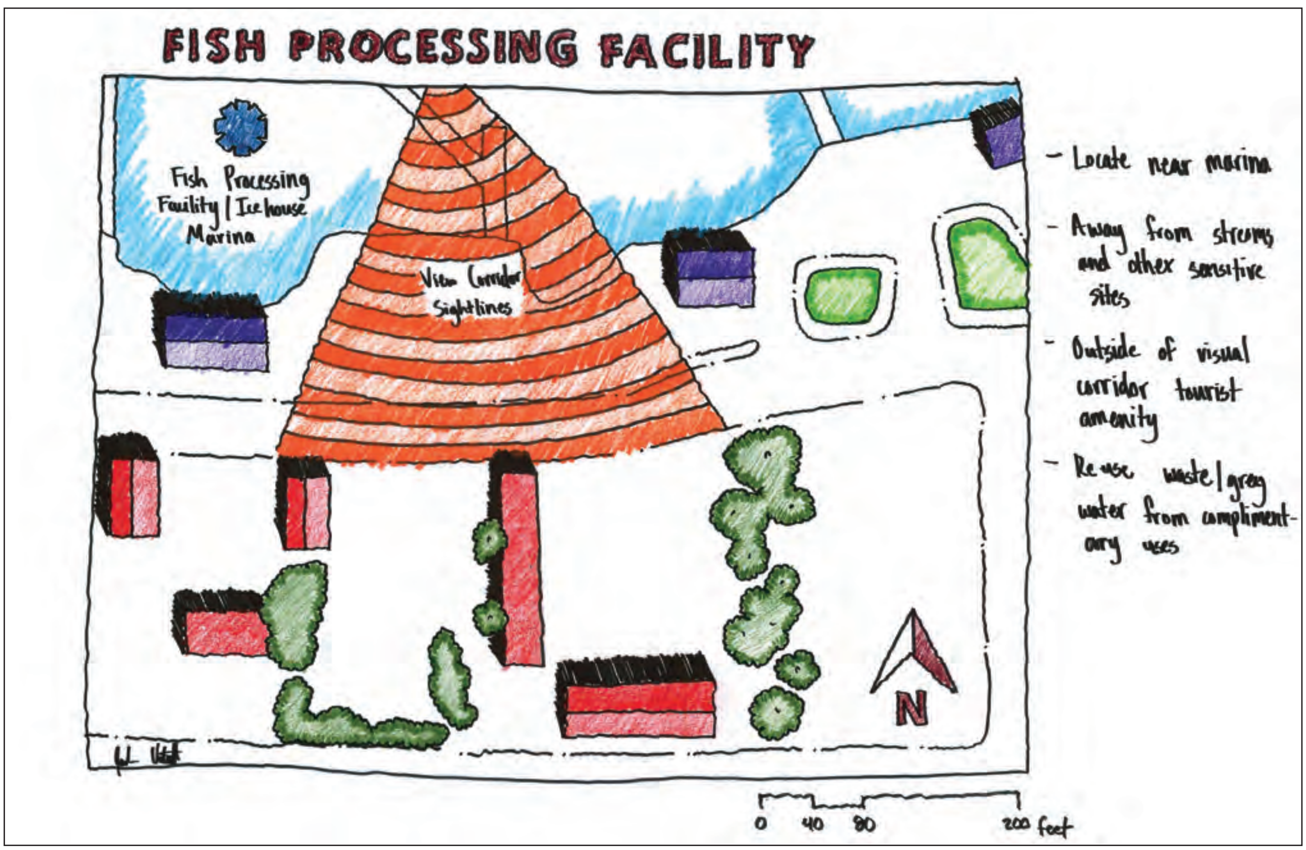


Figure 37: Potential new fish processing plant
A fish processing plant, like the one conceptualized above, would be a viable economic addition to the community but would require careful water management. Drawing: Josh Vitulli

Figure 38: Built water system
The current built water system will need to be rebuilt after a major local earthquake and tsunami. Planning can make this process faster and more cost-effective.

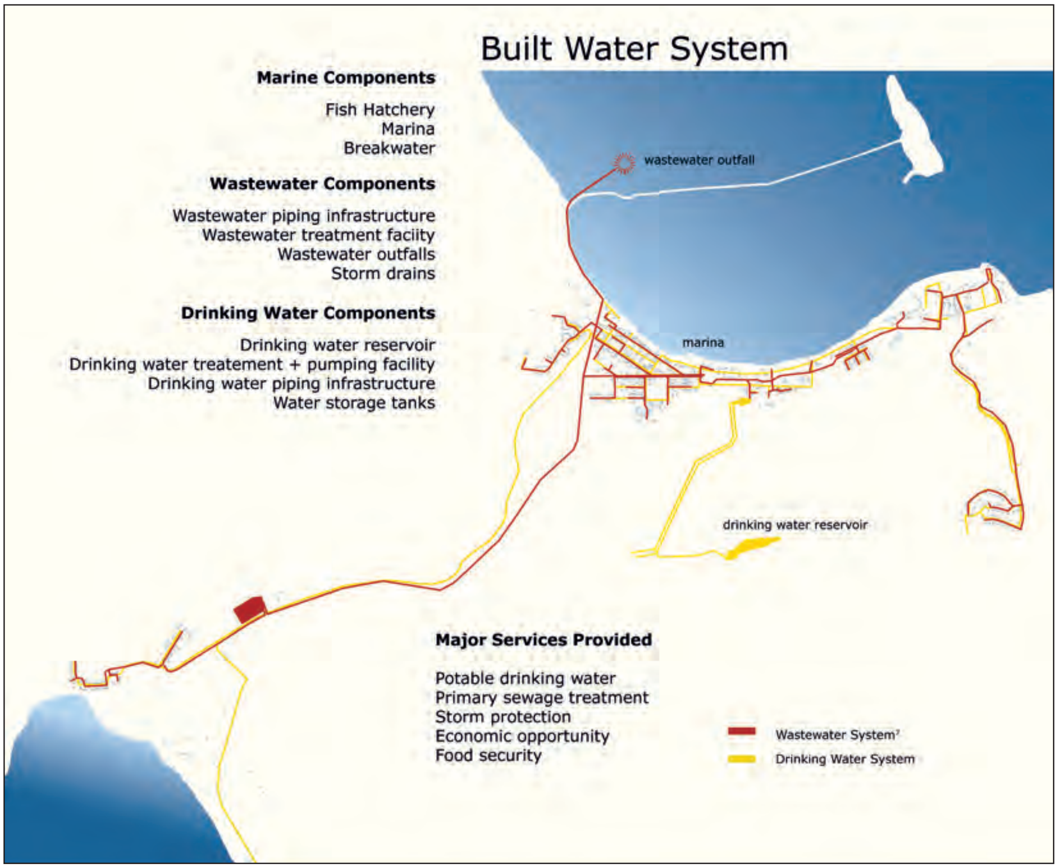


Figure 39: Native water system
The natural water system gives the community many assets which to build on--health, biologic, recreational, economic, and aesthetic. After a tsunami, these assets will still be available.

6. Conclusions and Next Steps

The Makah and Quileute Tribes in Clallam County are susceptible to high-risk, low-frequency tsunami events triggered by subduction zone earthquakes. The last Cascadia earthquake was in 1700. These occur every 500 years on average. The development of vertical evacuation strategies is a timely preventive precaution. The preferred strategies reduce risk by providing refuges accessible to a significant proportion of vulnerable resident and tourist populations. The strategy was created through a process that engaged the community in addressing its strengths and weaknesses. Over time, these strategies may be revisited as desired by members of the involved communities. With the prepared designs, funding opportunities are needed to realize the protection these vertical evacuation refuges will afford the community. Implementation of these projects will take place at a local level with assistance from other funding sources.

Future social science research

Additional research is necessary before this project is implemented. Research should focus on how the proposed vertical evacuation refugees will be phased into an existing evacuation message and plan. A methodology for public education about vertical evacuation refuges needs to be created, along with updated evacuation maps.

Implementation and funding opportunities

Tsunami vertical evacuation refuges have been developed over the course of decades in countries like Japan that have had numerous historic tsunami events. In Indonesia, recent tsunami impacts have led to the development of refuges in outdoor elevated parks. Funding for these projects has come largely from government or private sources. In the United States, no structures have been intentionally designed to serve as tsunami evacuation refuges, and no guidance for development of these projects existed until 2008. Traditional funding sources for structural mitigation activities, such as FEMA's Hazard Mitigation Grant Program and Pre-Disaster Mitigation, do not yet consider tsunami evacuation refuges as eligible projects. It is likely that these projects will require a combination of federal, state, local, private, and/or non-profit sources to be fully implemented. A variety of incentives may be leveraged for privately funded development projects. Funding options currently include, but are not limited to, the following:

Public

- Federal and State financial assistance with grants
- Local Improvement Districts
- Incorporation of safe haven structures or components into new public works projects
- Incorporation of safe haven structures or components into new civic and recreational facilities

Private

- Internal Revenue Service tax credits similar to Historic/Architecturally Significant tax credits
- Business improvement areas
- Local and state tax credits
- Zoning incentives in permitting, site requirements and building program
- Private donations

It is important to remember that Project Safe Haven is merely a starting point. A collective community vision has been facilitated, recorded, and presented. This report may serve as a guide for how tsunami vertical evacuation can be incorporated into the community over a prolonged period of time with continued community support and direction.

Appendix A: The Role of Community Design

The University of Washington Community Design Team explored means and methods to embed the tsunami vertical evacuation structures into the existing and emerging built form; and reduce negative physical impacts on village scale, neighborhoods, schools, commercial districts, parks and open space. The design mission had three key objectives:

- To assess each site and surrounding area for constraints and opportunities regarding the location and secondary use of safe haven structures, including related impacts on natural features, existing and future development patterns;
- To identify alternative community-benefit uses for the safe haven structures;
- To incorporate or embed the safe haven structures into the community built form in a compatible manner, supporting local uses and physical context.

In some situations, safe haven structures are utilitarian safe zone towers or berms with minimal design enhancement. Other structures are designed in ways that visually reduce structure appearance; and integrate or embed them in the landscape through multiple use community forms and facilities. The final design concepts provide guidelines for the community to follow during the implementation stages.

Structure typologies

In preparation for the design charrettes in both Neah Bay and La Push, the design team developed exploratory structure typologies to begin the community dialogue (Table 3). These typologies are examples used to expand the initial community preferences of phase one "preferred strategy" meetings regarding the nature and appearance of typical vertical evacuation structures relative to their communities and neighborhoods.

Berm structures

Berms can be used as viewing areas for athletic fields, as play areas and parks, or as noise barriers near airports and industrial areas. Due to the sloping conditions of all or part of the berms, the actual footprint can be double or triple the size of the safe zone. The footprints for the larger berms can have a significant negative impact on the built form of smaller communities and areas of limited land availability. These are all factors considered in more detail during the design charrette.

Shelters, non-motorized winches, and other climate protection features are optional components and can serve as community amenities for everyday use. Bathroom facilities and storage for basic supplies such as water, medical supplies, and tarps are additional options for more detailed community consideration.

Table 3: Structure typologies

Structure Typologies		
Berm typologies	**Tower typologies**	**Combination typologies**
A. Single berm	A. Single tower	A. Berm-Tower combination
B. Segmented or clustered berm(s)	B. Segmented tower	B. Berm-Building combination
C. Noise berm	C. Clustered towers	C. Tower-Building combination
	D. Tiered tower	
	E. Tower bridge	

Figure 40: Basic berm structure in plan view
The basic single berm structure is a mounded buttress composed of a hardened front façade (rock, steel and/or concrete) and rear sloping access ramp. These basic single berms provide accessible entry and can be integrated as a natural feature in less developed areas with available open space. A modified version of the basic berm is also included to show the many variations that are possible, based on site and cost constraints. Drawing by Ron Kasprisin.

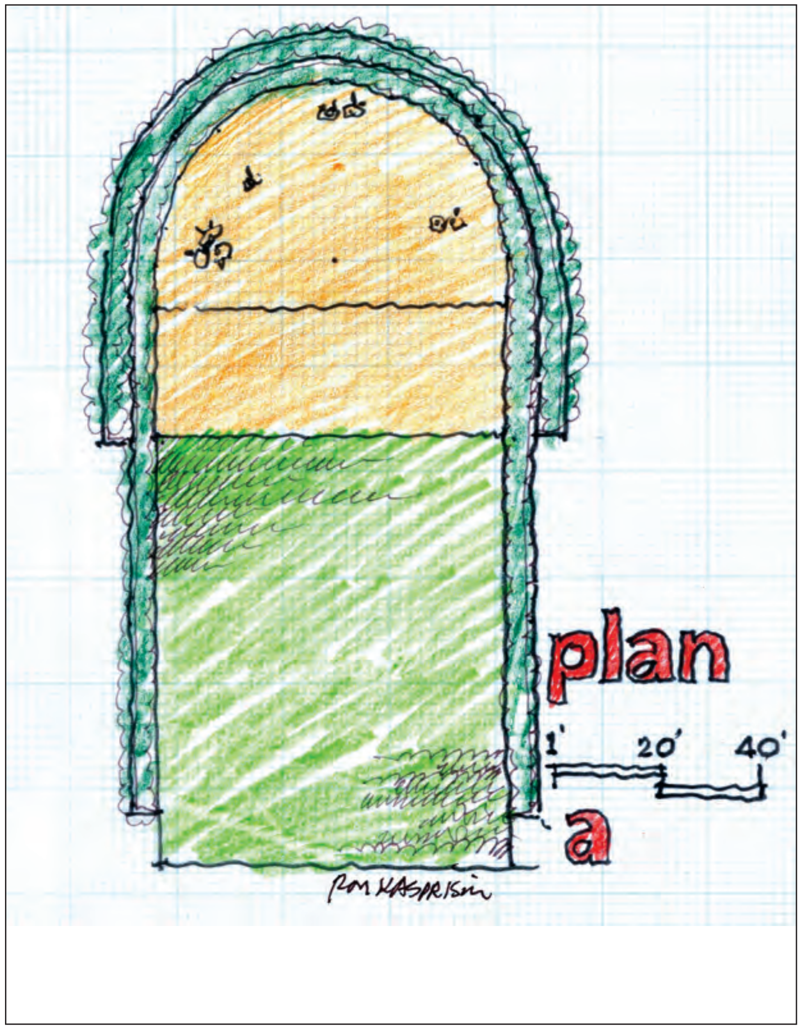
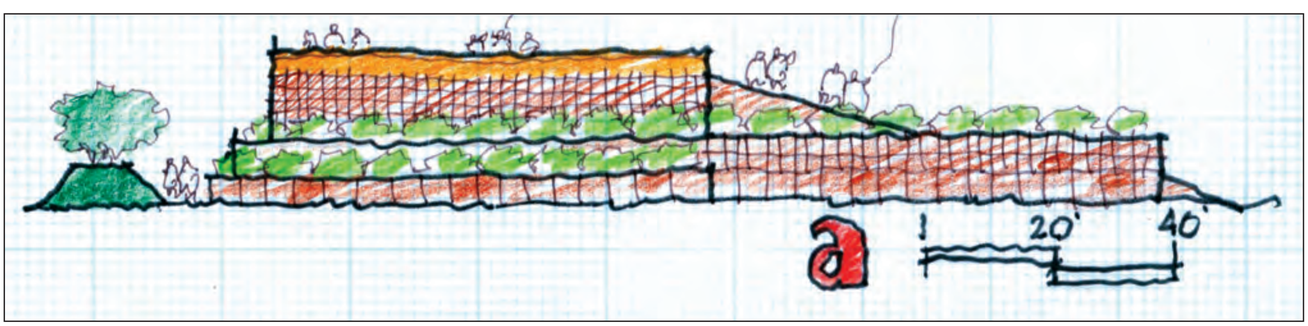


Figure 41: Basic berm structure in profile view
The basic single berm structure can be modified to enhance its visual appearance and utility. There are many variations based on local need and budgets and can include the addition of recreational facilities, landscaping and weather protection. Drawing by Ron Kasprisin.



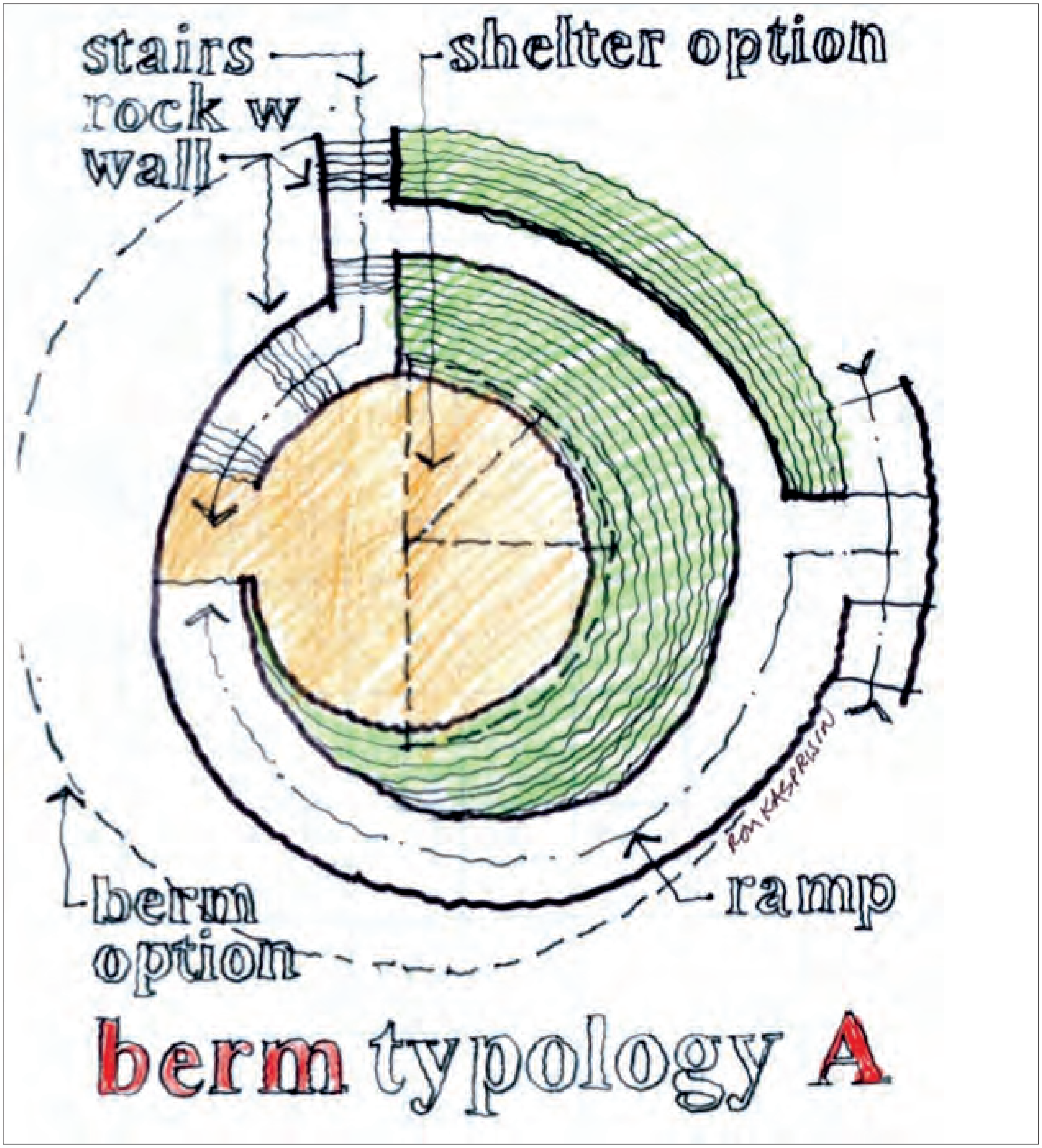


Figure 42: Basic berm structure
The basic berm structure is a mounded buttress with hardened front façade and rear (away from wave direction) sloping access ramp. There are many variations that can improve on the appearance and use of the basic berm, based on local need and budgets. Drawing by Ron Kasprisin.

Berm Typology A: Single Berm

Single berms have one primary safe zone at the top elevation with access provided by ramps, landscaped slopes and/or stairs (Figure 38-40). Alternate uses vary according to location and local context. Single berms are more effective regarding community design impacts when sufficient land area is provided for the base footprint. They are less suited for smaller built-up sites. The design of individual berms can incorporate numerous features to improve compatibility with the surrounding area including landscape

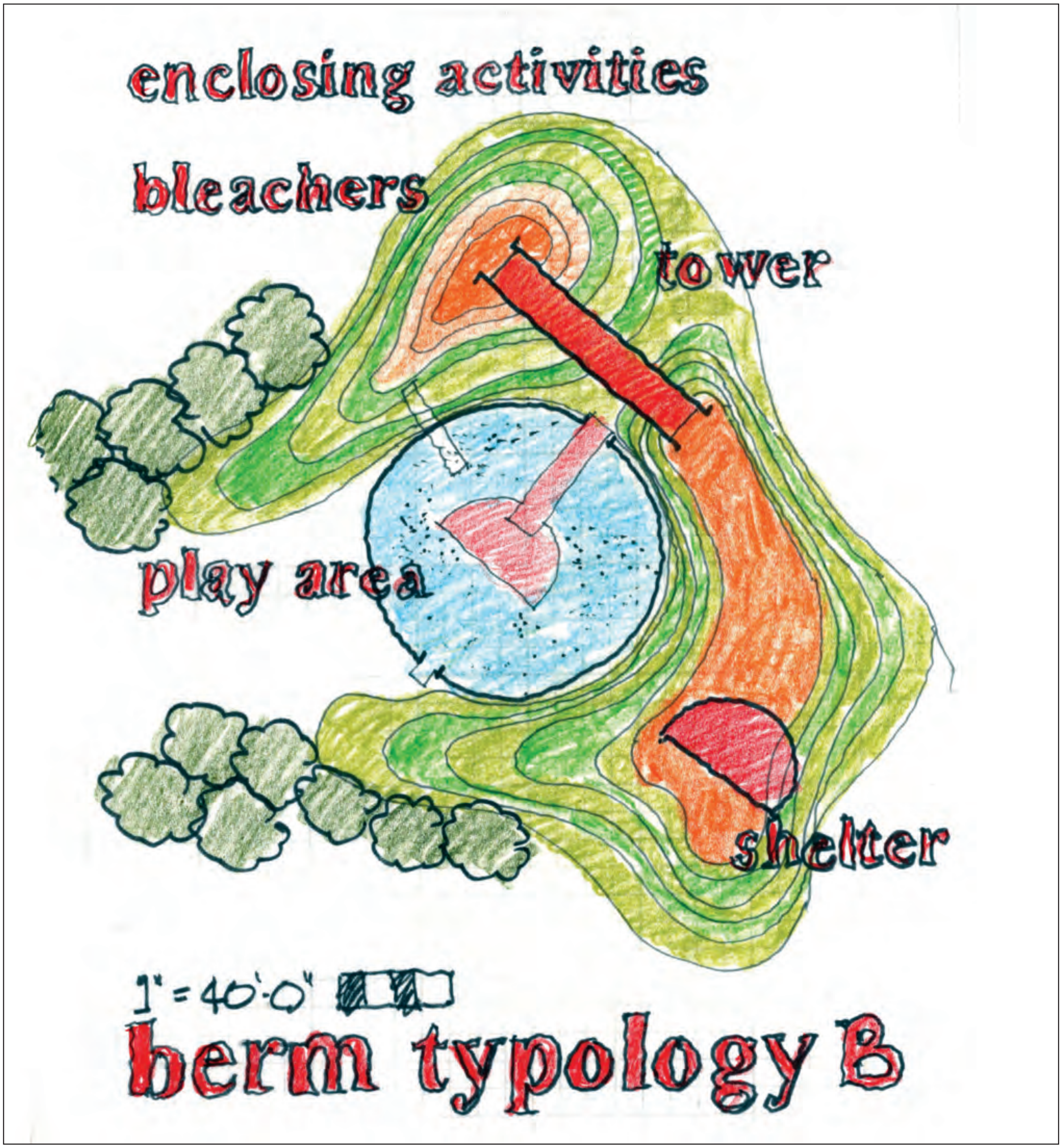


Figure 43: Berm typology B
In this proposed example for Pacific County, a safe zone is embedded into a school berm. Play areas and events facilities can also be incorporated into and surrounding the berm structure. Drawing by Ron Kasprisin.

and natural features such as wetlands, ponds, etc.; and formal forms such as sculpted mounds, pyramids or elevated garden structures (Figures 40-42).

Berm Typology B: Segmented/ Clustered Berm(s)

Segmented berms are separated structures, possibly clustered in close proximity to one another, that disperse safe zones within a given site to reduce the size of the form footprint. Segmented berm safe zones can be connected via pedestrian bridges, ramps, stairs, and safe haven towers. These berms are best suited for larger open space areas such as athletic facilities, farms, golf courses, festival area and undeveloped open space (Figure 43).

Berm Typology C: Noise Berms

Noise berms can be incorporated into transportation improvements for freeways and highways, airports, port facilities and other related infrastructure that generate high noise levels during peak hours of operation. Key locations within the noise berm can be elevated for safe zones.

Tower and Platform Structures

Tower structures are elevated safe zone platforms supported by vertical structural members where the horizontal surface(s) is smaller in proportion to the height of the vertical supports. Platforms are vertical structures where the horizontal surface(s) is greater in proportion to the height of the vertical supports. Both can be freestanding as square, rectangular, circular, and other geometric shapes depending upon local use and context. They generally have open ground level areas to facilitate water and debris flow. Towers can be used for a wide variety of uses including visitor centers, wildlife and scenic observation facilities where at-grade level acts as sacrificial office or display areas, components of fire stations, in conjunction with community water towers, and many private sector uses.

Towers have a smaller footprint than berm structures for the same number of people. Access to tower structures can be restrictive to physically challenged and aged people due to stairs or shortened ramps. The provision of shelters and emergency facilities are optional.

Tower Typology A: Single Tower

Single towers may be the most appropriate structure for less costly safe havens where alternative uses are not feasible and/or land is limited (Figure 44). Alternative uses for the horizontal safe zone and at-grade floor area can be accommodated as fully open space or with sacrificial uses such as shops, information booths, storage areas, etc. Towers can be accessed by stairs, ramps, and mechanical vertical assists in non-emergency situations; and, manual vertical assists (winches, etc.), for emergency events.

Tower Typology B: Segmented Tower

Segmented towers contain multiple safe haven platforms within a given project site in relative close proximity to one another. This tower form reduces the often austere impact of a single tower on local built form. In order to enhance integration into the desired built form the tower platforms can be at varying heights, separate or connected by pedestrian bridges for shared access facilities. Where appropriate they can also be incorporated into or surrounding existing buildings.

Tower Typology C: Clustered Towers

Similar to segmented towers, clustered towers allow for numerous freestanding smaller platforms scattered across a number of sites within a given area. Clustered towers reduce the impact of large safe haven areas on a small-scale urban form. This type of tower may be appropriate where only small pockets of land are available scattered throughout a community or where access within the walking circle is restricted due to barriers.

Tower Typology D: Tiered Towers

Tiered towers can reduce the size of the safe zone horizontal imprint on smaller site areas

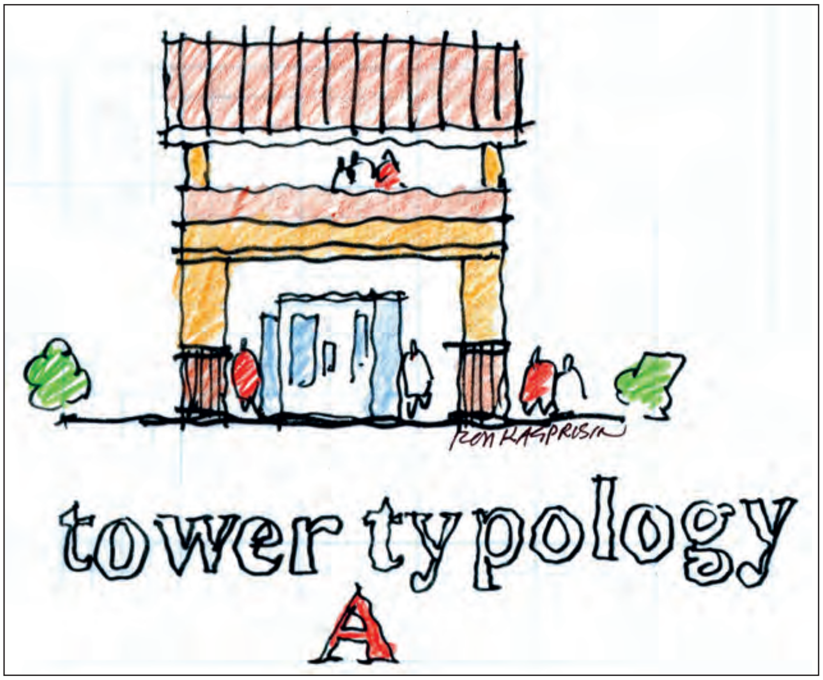


Figure 44: Basic tower structures A basic tower structure consists of an elevated platform on piers with access stair, ramp, or combination. A 'bare-bones' tower, essentially 40 feet square (200 person capacity) is a steel structure with a footprint of approximately 1,600 square feet (sf) minimum (a). Basic design improvements can add temporary activities on the ground level (information booth for example), landscaping, and a roof shelter. Additional adaptations can include a berm-tower combination to improve access for physically challenged persons and reduce the industrial appearance of the tower structure with landscaped berm areas. Drawing by Ron Kasprisin.

by stacking safe zones vertically. The lowest platform level exceeds the minimum inundation elevation. Upper tiers can be available for physically able persons accessed by stairs or ladders.

Tower Typology E: Tower Bridge

A tower bridge structure can connect two or more areas that may or may not be safe zones (such as play berms). These areas can include, for example, two or more safe havens, as in the segmented berm or segmented towers, as a pedestrian overpass in congested areas, as watercourse crossings, or as a connection between freestanding building connections. The tower bridge can either be affixed to two structures designed to withstand earthquake and tsunami forces or have an independent support structure.

Combinations

There are a number of design alternatives that offer hybrid combinations of towers and berms. The combinations offer an opportunity to capitalize on the best components of each structure type within the given physical context. For example, ramp-berms can provide access to tower structures if space permits (Figure 45-47).

Berm-Tower Combinations

Berm-tower combinations present opportunities to reduce the physical and visual impacts of larger tower structures with partial or complete sacrificial berm amendments. They also can reduce the overall footprint for a large berm structure.

Berm-Building Combinations

Berms can be combined with new building structures in certain situations. The berm acts to provide a design element that can soften or reduce building mass and provide sloped access to building roofs and other safe zones. Examples include parking garages, industrial buildings, fire stations, pedestrian overpasses, etc.

Tower-Building Combinations

Tower structures can be incorporated into new building structures to provide safe zones and reduce the construction costs of safe-zone hardening the entire building. Examples include entryways, stair towers, and office components.

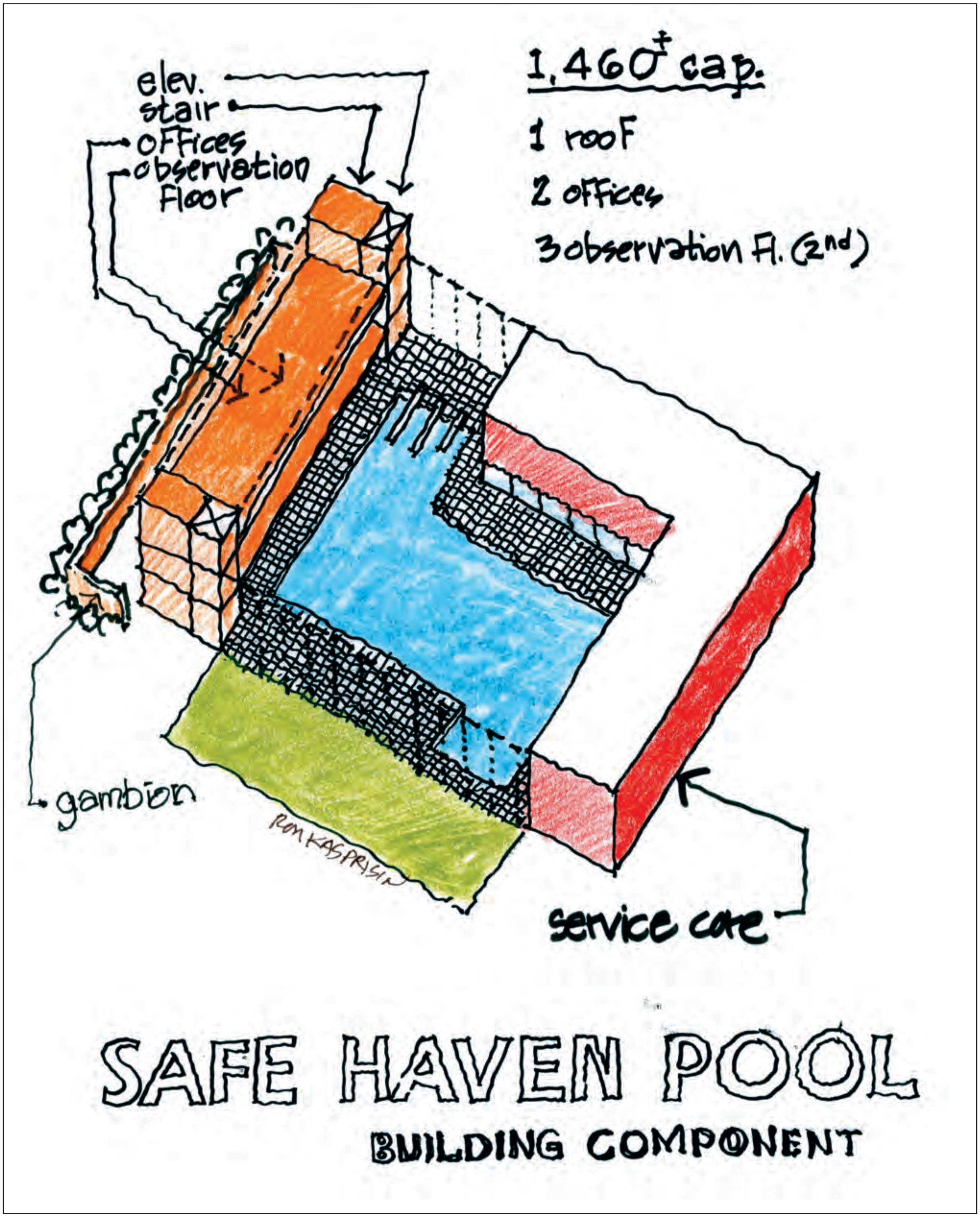


Figure 45: Safe haven building components, swimming pool example
The illustration portrays an enclosed Olympic size swimming pool with related locker room facilities, entry level, office level(s), observation balcony and vertical access tower. Various portions of the larger building can be hardened as safe zones, such as stair towers, office core, observation balconies. Elevators and emergency stair vertical assists are available depending upon the nature of the emergency (tsunami with localized earthquake and without).

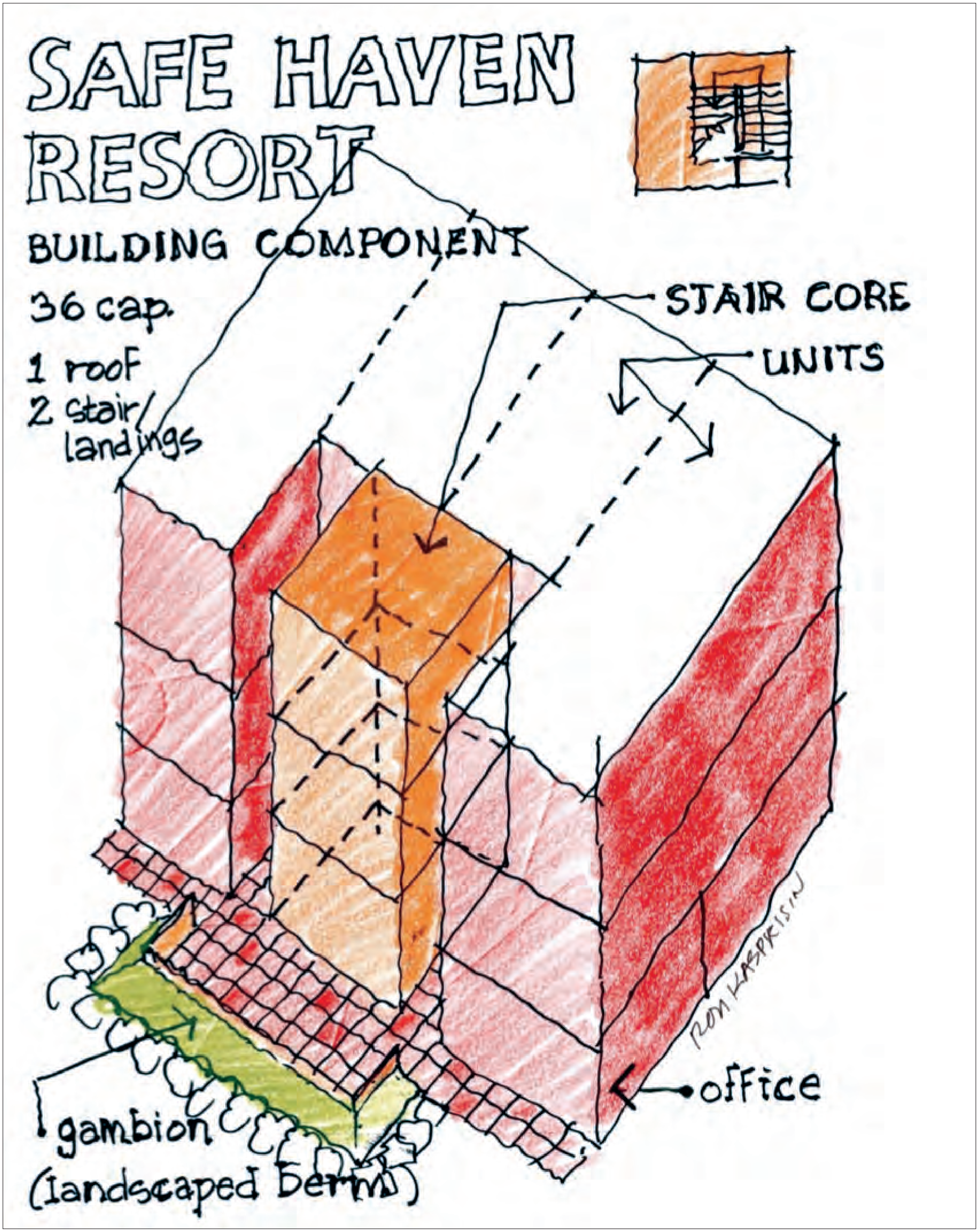


Figure 46: Safe haven building components
The safe haven building component (hotels, resorts, multiple family residences) principle applies to private buildings such as hotels, resorts, etc. In the illustration, an enlarged stair tower is the hardened safe zone that can accommodate thirty or more people depending on the size of the overall structure. In this case, the building is a three story multiple family residential/hotel type building that accommodates 36 plus people.

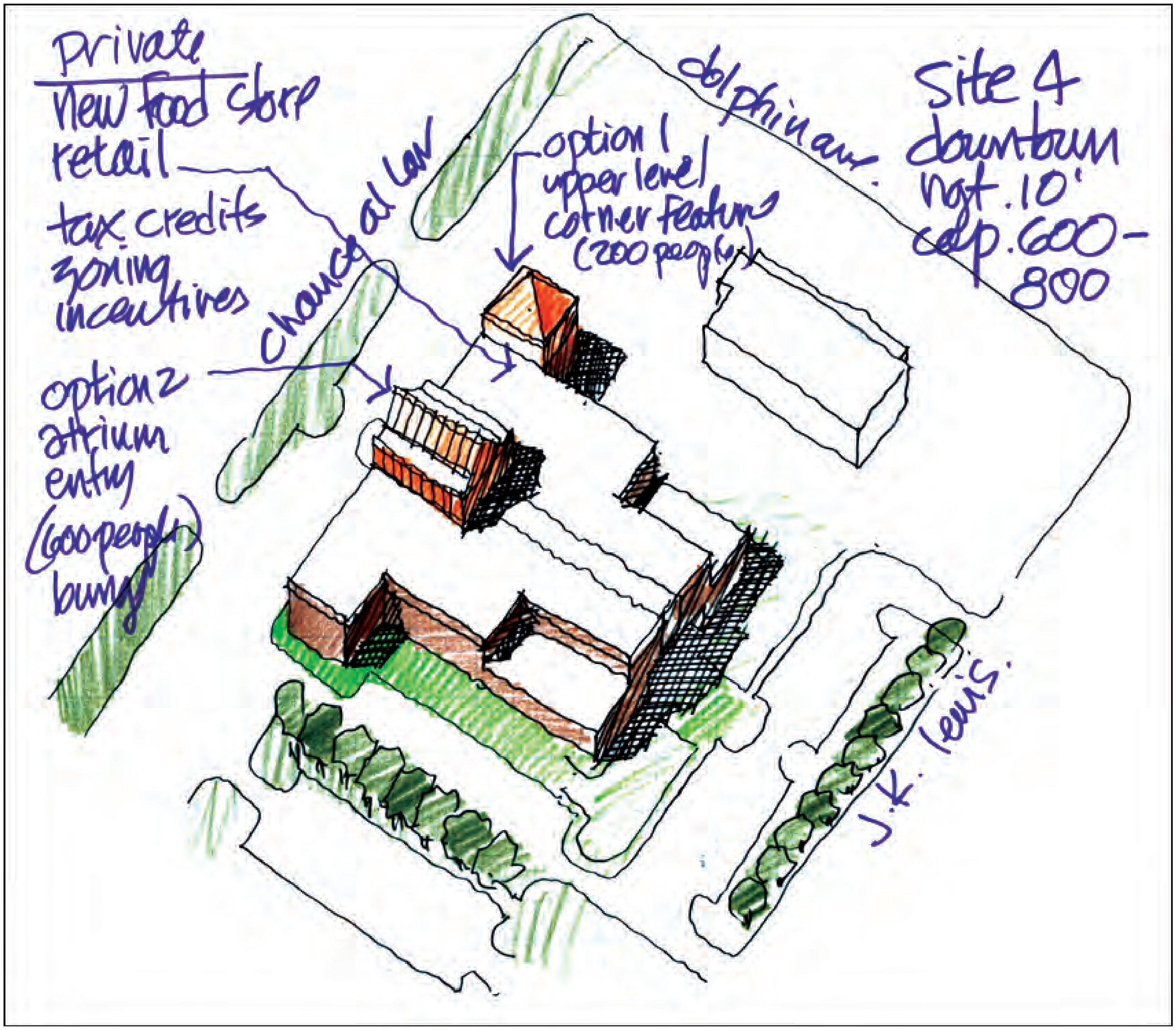


Figure 47: Safe haven components
This conceptual illustration depicts a grocery store complex with two examples of safe havens embedded into a building complex: an entry lobby with atrium and upper mezzanine and/or safe roof; and, an upper level feature such as lounge, restaurant, etc. designed as an architectural corner feature. Drawing by Ron Kasprisin

Appendix B: SWOT Analysis

SWOT stands for Strengths, Weaknesses, Opportunities, and Threats. The project team used SWOT analysis for Project Safe Haven to identify the features of the preferred alternative that address underlying characteristics of the community (Figure 48). The SWOT analysis helps demonstrate that the preferred alternative builds on the community's strengths, overcomes weaknesses, takes advantage of opportunities, and minimizes threats. A version of the SWOT analysis was carried out during the second community meeting in annotated form of strengths and weaknesses evaluation. Meeting participants were given strengths and weaknesses forms to fill out for each conceptual vertical evacuation site. The following represents the underlying assumptions and definitions of each: strengths, weaknesses, opportunities, and threats:

Strengths are capabilities

They are internal to the community and represent items to build upon. Strengths may be financial, mobility, preparedness and awareness, or the built and natural environment. The preferred alternative should build on the community's strengths.

Weaknesses are impacts, exposures, or vulnerabilities

They are internal to the community and represent items to overcome. Weaknesses could be financial, mobility, preparedness and awareness, or in the built and natural environment. The preferred alternative helps overcome the community's weaknesses.

Opportunities are openings for positive change

They are external to the community and represent items to exploit or enhance. Opportunities may be business and economic, human and social capacity, natural and environmental, or found for the built environment. The preferred alternative exploits opportunities available to the community.

Threats are hazards

They are external and generally out of the community's control. Categories of threats relate to geography, built environment, and demographics. The preferred alternative helps minimize the threat presented by a tsunami.

Figure 48: Discussing post-tsunami life
Though Project Safe Haven is focused on vertical evacuation strategies, the Makah and Quileute Tribes also spent time planning for a post-Cascadia subduction zone earthquake and tsunami life. This will help the Tribes survive even if their cities cannot be physically rebuilt because of significant land subsidence.

Neah Bay

Strengths of preferred strategy

- Makes natural high ground easier to access with trail system.
- Locates shelter closest to vulnerable populations.
- Partner with new development in Neah Bay.
- Provide amenities to the school.

Weaknesses

- Long-term plans to change land uses in Neah Bay may change needs.

Opportunities

- High land exists
- Wetlands will buffer debris

Threats

- Tsunami
- Boats and debris
- Wetlands block evacuation

Comments from Neah Bay Evaluation Meeting on Alternatives

Strengths

- Community evacuation drills
- Makah EOC
- School land is not trust land

Weaknesses

- Senior Center
- Communications from East to West (Cape Flattery)--signals are blocked

Opportunities

- Detailed evacuation plan with map for citizen guidance
- Development principles of a Tsunami Ready Community planning structure exists
- Mitigate lack of elevated sites for evacuation
- Capitalize from present-day tsunami events

Threats

- Land owners for trail system behind the village
- Flat, broad downtown area furthest away from elevated areas

La Push

Strengths of preferred strategy

- Smaller investment than multiple-shelter solution
- Makes natural high ground easier to access with trail system
- Locates shelter closest to vulnerable populations
- Partner with new development in La Push
- Provide amenities to the school

Weaknesses

- Long-term plans to change land uses in La Push may change needs

Opportunities

- High ground is available
- Land exchange underway
- Forest acts as debris buffer

Threats

- Tsunami and earthquake
- Debris from fishing fleet

Appendix C: Summary of Cost Analysis

Project: Neah Bay School RC
Location: Neah Bay, WA

Date: 6/11/12
Estimator: Kirk Hochstatter - University of Washington

Structure Type	Tower	Minimum Structure Height (ft)	20	Safe Haven SF	6,600
Overal Site Square Footage	39375	Structure Capacity	660	Volume of Berm Materials (LCY)	3,200
Levels	1	Piles per Column	2	Columns Required	12
Grass Slope SF	8450				

	Description	Quantity	Unit	Installation Cost Cost	Equipment Cost Cost	Material Costs Cost	Adjusted Total for Location Factors	Notes
330000	Site Utilities	1	LS	$24,843.44	$12,118.15	$19,350.00	$61,847.18	See Divisions
312300	Excavation/Backfill	1	LS	$33,594.64	$62,290.49	$78,500.49	$197,299.90	See Divisions
03000	Concrete	1	LS	$179,378.61	$15,295.94	$229,360.89	$450,109.86	See Divisions
05000	Steel	1	LS	$4,900.00	$0.00	$68,500.00	$80,673.94	See Divisions
32000	Landscaping	1	LS	$13,167.24	$323.00	$43,866.67	$60,576.03	See Divisions
	Subtotal			$255,883.94	$90,027.59	$439,578.04	$850,506.90	

SUBTOTAL DIVISIONS		**$850,507**
Design/Engineering	8.00%	$68,040.55
General Conditions	10.00%	$85,050.69
Contractor Fees, O&P	15.00%	$127,576.04
Construction Contingency	5.00%	$42,525.35
Estimate/Design Contingency	10.00%	$85,050.69
Inflation Factor (2011 to 2012)	4.00%	$34,020.28
TOTAL ESTIMATED CONSTRUCTION COST		**$408,243**
Washington State Sales Tax	9.50%	$38,783
TOTAL ESTIMATED COST		**$447,026**

Location Factors	Rate
Contractor Equipment	101.3%
Site & Infrastructure, Demolition	108.0%
Concrete Forming & Accessories	102.6%
Concrete Reinforcing	104.2%
Cast-in-Place Concrete	105.7%
Concrete	100.9%
Masonry	113.7%
Metals	104.7%
Wood, Plastics & Composites	98.3%
Thermal & Moisture Protection	101.5%
Openings	102.8%
Plaster & Gypsum Board	104.8%
Ceilings & Acoustic Treatment	104.5%
Flooring	111.9%
Wall Finishes & Painting/Coating	97.5%
Finishes	104.8%
Divs. 10-14, 25, 28, 41, 43, 44	100.3%
Fire Suppression, Plumbing & HVAC	99.7%
Electrical, Communications & Util.	100.2%
Weighted Average	102.8%

Rough Order of Magnitude Estimate

Project:	La Push Berm	Structure Type	Berm	Minimum Structure Height (ft)	30	Safe Haven SF
Location:	La Push, WA	Overal Site Square Footage	39375	Structure Capacity	845	Volume of Berm Ma

Date: 6/11/12
Estimator: Kirk Hochstatter - University of Washington

	Description	Quantity	Unit	Installation Cost	Equipment Cost	Material Costs	Adjusted Total for Location Factors	Notes
				Cost	Cost	Cost		
01000	Site Utilities	1	LS	$20,043.44	$12,118.15	$13,650.00	$51,862.73	See Divisions
02000	Excavation/Backfill	1	LS	$267,980.11	$512,597.48	$560,220.49	$1,461,845.33	See Divisions
03000	Concrete	1	LS	$224,304.27	$98,082.00	$127,847.39	$464,028.59	See Divisions
03000	Landscaping	1	LS	$40,033.31	$768.00	$55,908.19	$104,662.01	See Divisions
	Subtotal			$552,361.13	$623,565.63	$757,626.07	$2,082,398.66	

SUBTOTAL DIVISIONS		$2,082,399
Design/Engineering	8.00%	$166,591.89
General Conditions	10.00%	$208,239.87
Contractor Fees, O&P	15.00%	$312,359.80
Construction Contingency	5.00%	$104,119.93
Estimate/Design Contingency	10.00%	$208,239.87
Inflation Factor (2011 to 2012)	4.00%	$83,295.95
TOTAL ESTIMATED CONSTRUCTION COST		$3,165,246

Rough Order of Magnitude Estimate

Project:	La Push Berm	Structure Type	Berm	Minimum Structure Height (ft)	30
Location:	La Push, WA	Overal Site Square Footage	39375	Structure Capacity	845

Date: 6/11/12
Estimator: Kirk Hochstatter - University of Washington

	Description	Quantity	Unit	Installation Cost	Equipment Cost	Material Costs	Adjusted Total for Location Factors
				Cost	Cost	Cost	
01000	Site Utilities	1	LS	$20,043.44	$12,118.15	$13,650.00	$51,862.73
02000	Excavation/Backfill	1	LS	$209,882.31	$400,453.34	$444,149.38	$1,149,683.94
03000	Concrete	1	LS	$312,537.32	$143,637.40	$315,326.99	$796,724.46
03000	Landscaping	1	LS	$39,321.60	$262.50	$46,224.50	$93,273.63
00000	Optional Shelter	1	LS	$0.00	$0.00	$0.00	$20,097.62
	Subtotal			$581,784.67	$556,471.39	$819,350.87	$2,111,642.39

SUBTOTAL DIVISIONS		$2,111,642
Design/Engineering	8.00%	$168,931.39
General Conditions	10.00%	$211,164.24
Contractor Fees, O&P	15.00%	$316,746.36
Construction Contingency	5.00%	$105,582.12
Estimate/Design Contingency	10.00%	$211,164.24
Inflation Factor (2011 to 2012)	4.00%	$84,465.70

Rough Order of Magnitude Estimate

Project:	La Push Berm	Structure Type	Berm	Minimum Structure Height (ft)	30
Location:	La Push, WA	Overal Site Square Footage	39375	Structure Capacity	845

Date: 6/11/12
Estimator: Kirk Hochstatter - University of Washington

	Description	Quantity	Unit	Installation Cost Cost	Equipment Cost Cost	Material Costs Cost	Adjusted Total for Location Factors
01000	Site Utilities	1	LS	$20,043.44	$12,118.15	$13,650.00	$51,862.73
02000	Excavation/Backfill	1	LS	$209,882.31	$400,453.34	$444,149.38	$1,149,683.94
03000	Concrete	1	LS	$312,537.32	$143,637.40	$315,326.99	$796,724.46
03000	Landscaping	1	LS	$39,321.60	$262.50	$46,224.50	$93,273.63
00000	Optional Shelter	1	LS	$0.00	$0.00	$0.00	$20,097.62
	Subtotal			**$581,784.67**	**$556,471.39**	**$819,350.87**	**$2,111,642.39**

SUBTOTAL DIVISIONS		**$2,111,642**
Design/Engineering	8.00%	$168,931.39
General Conditions	10.00%	$211,164.24
Contractor Fees, O&P	15.00%	$316,746.36
Construction Contingency	5.00%	$105,582.12
Estimate/Design Contingency	10.00%	$211,164.24
Inflation Factor (2011 to 2012)	4.00%	$84,465.70
TOTAL ESTIMATED CONSTRUCTION COST		**$3,209,696**

Project:	Neah Bay & La Push Access "Trees"	Structure Type	Access Trees	Minimum Structure Height (ft)	8	Safe Haven SF
Location:	Clallam County, WA	Overal Site Square Footage	2500	Structure Capacity	25	Volume of Berm Ma
		Levels	1	Piles per Column	0	Columns Required
		Grass Slope SF	0			

Date: 6/11/12
Estimator: Kirk Hochstatter - University of Washington

	Description	Quantity	Unit	Installation Cost Cost	Equipment Cost Cost	Material Costs Cost	Adjusted Total for Location Factors	Notes
312300	Excavation/Backfill	1	LS	$1,177.40	$916.10	$432.50	$5,254.08	See Divisions
03000	Concrete	1	LS	$772.00	$3.92	$1,056.00	$8,141.97	See Divisions
06000	Woods & Plastics	1	LS	$14,993.76	$7,499.20	$63,237.40	$101,567.50	See Divisions
32000	Landscaping	1	LS	$250.00	$150.00	$500.00	$1,197.00	See Divisions
	Subtotal			**$17,193.16**	**$8,569.22**	**$65,225.90**	**$116,160.55**	

SUBTOTAL DIVISIONS		**$116,161**
Design/Engineering	8.00%	$9,292.84
General Conditions	10.00%	$11,616.05
Contractor Fees, O&P	15.00%	$17,424.08
Construction Contingency	5.00%	$5,808.03
Estimate/Design Contingency	10.00%	$11,616.05
Inflation Factor (2011 to 2012)	4.00%	$4,646.42
TOTAL ESTIMATED CONSTRUCTION COST		**$176,564**

Project: La Push Tower
Location: Clallam County, WA

Date: 6/11/12
Estimator: Kirk Hochstatter - University of Washington

Structure Type	Tower	Minimum Structure Height (ft)	26	Safe Haven SF
Overal Site Square Footage	5000	Structure Capacity	250	Volume of Berm Ma
Levels	2	Piles per Column	3	Columns Required
Grass Slope SF	0			

	Description	Quantity	Unit	Installation/Labor Cost	Equipment Cost	Material Costs	Adjusted Total for	Notes
				Cost	Cost	Cost	Location Factors	
312300	Excavation/Backfill	1	LS	$2,751.00	$8,392.00	$532.50	$12,209.54	See Divisions
03000	Concrete	1	LS	$102,022.00	$36,325.28	$101,440.00	$253,487.27	See Divisions
05000	Steel	1	LS	$4,782.40	$1,000.00	$15,860.00	$22,509.72	See Divisions
06000	Woods & Plastics	1	LS	$11,033.60	$1,500.00	$21,948.00	$37,445.77	See Divisions
07000	Roofing	1	LS	$23,200.00	$0.00	$38,000.00	$65,118.00	See Divisions
32000	Landscaping	1	LS	$250.00	$400.00	$500.00	$1,222.00	See Divisions
	Subtotal			**$144,039.00**	**$47,617.28**	**$178,280.50**	**$391,992.29**	

SUBTOTAL DIVISIONS		**$391,992**
Design/Engineering	8.00%	$31,359.38
General Conditions	10.00%	$39,199.23
Contractor Fees, O&P	15.00%	$58,798.84
Construction Contingency	5.00%	$19,599.61
Estimate/Design Contingency	10.00%	$39,199.23
Inflation Factor (2011 to 2012)	4.00%	$15,679.69
TOTAL ESTIMATED CONSTRUCTION COST		**$595,828**

Project: La Push Tower
Location: Clallam County, WA

Date: 6/11/12
Estimator: Kirk Hochstatter - University of Washington

Structure Type	Tower	Minimum Structure Height (ft)	26	Safe Haven SF
Overal Site Square Footage	5000	Structure Capacity	250	Volume of Berm Ma
Levels	2	Piles per Column	3	Columns Required
Grass Slope SF	0			

	Description	Quantity	Unit	Installation/Labor Cost	Equipment Cost	Material Costs	Adjusted Total for	Notes
				Cost	Cost	Cost	Location Factors	
312300	Excavation/Backfill	1	LS	$2,751.00	$6,392.00	$532.50	$10,209.54	See Divisions
03000	Concrete	1	LS	$36,470.00	$1,656.60	$67,165.00	$117,722.62	See Divisions
05000	Steel	1	LS	$4,782.40	$1,000.00	$15,860.00	$22,612.59	See Divisions
06000	Woods & Plastics	1	LS	$25,338.97	$13,250.00	$49,162.14	$94,469.60	See Divisions
07000	Roofing	1	LS	$23,200.00	$3,000.00	$38,000.00	$65,118.00	See Divisions
32000	Landscaping	1	LS	$250.00	$400.00	$500.00	$1,222.00	See Divisions
	Subtotal			**$92,792.37**	**$25,698.60**	**$171,219.64**	**$311,354.35**	

SUBTOTAL DIVISIONS		**$311,354**
Design/Engineering	8.00%	$24,908.35
General Conditions	10.00%	$31,135.44
Contractor Fees, O&P	15.00%	$46,703.15
Construction Contingency	5.00%	$15,567.72
Estimate/Design Contingency	10.00%	$31,135.44
Inflation Factor (2011 to 2012)	4.00%	$12,454.17
TOTAL ESTIMATED CONSTRUCTION COST		**$473,259**

Project: La Push Tower
Location: Clallam County, WA

Structure Type	Tower	Minimum Structure Height (ft)	26	Safe Haven SF	2,500
Overal Site Square Footage	5000	Structure Capacity	250	Volume of Berm Materials (LCY)	0
Levels	2	Piles per Column	3	Columns Required	4
Grass Slope SF	0				

Date: 7/10/12
Estimator: Kirk Hochstatter - University of Washington

	Description	Quantity	Unit	Installation/Labor Cost Cost	Equipment Cost Cost	Material Costs Cost	Adjusted Total for Location Factors	Notes
312300	Excavation/Backfill	1	LS	$2,751.00	$6,392.00	$532.50	$10,209.54	See Divisions
03000	Concrete	1	LS	$36,470.00	$1,656.60	$67,165.00	$117,722.62	See Divisions
05000	Steel	1	LS	$4,782.40	$1,000.00	$15,860.00	$22,612.59	See Divisions
06000	Woods & Plastics	1	LS	$25,338.97	$13,250.00	$49,162.14	$94,469.60	See Divisions
07000	Roofing	1	LS	$23,200.00	$3,000.00	$38,000.00	$65,118.00	See Divisions
32000	Landscaping	1	LS	$250.00	$400.00	$500.00	$1,222.00	See Divisions
	Subtotal			**$92,792.37**	**$25,698.60**	**$171,219.64**	**$311,354.35**	

SUBTOTAL DIVISIONS		**$311,354**
Design/Engineering	8.00%	$24,908.35
General Conditions	10.00%	$31,135.44
Contractor Fees, O&P	15.00%	$46,703.15
Construction Contingency	5.00%	$15,567.72
Estimate/Design Contingency	10.00%	$31,135.44
Inflation Factor (2011 to 2012)	4.00%	$12,454.17
TOTAL ESTIMATED CONSTRUCTION COST		**$473,259**

Project: La Push Tower
Location: Clallam County, WA

Structure Type	Tower	Minimum Structure Height (ft)	26	Safe Haven SF	2,500
Overal Site Square Footage	5000	Structure Capacity	250	Volume of Berm Materials (LCY)	0
Levels	2	Piles per Column	3	Columns Required	4
Grass Slope SF	0				

Date: 7/10/12
Estimator: Kirk Hochstatter - University of Washington

	Description	Quantity	Unit	Installation/Labor Cost Cost	Equipment Cost Cost	Material Costs Cost	Adjusted Total for Location Factors	Notes
312300	Excavation/Backfill	1	LS	$2,751.00	$6,392.00	$532.50	$10,209.54	See Divisions
03000	Concrete	1	LS	$36,470.00	$1,656.60	$67,165.00	$117,722.62	See Divisions
05000	Steel	1	LS	$4,782.40	$1,000.00	$15,860.00	$22,612.59	See Divisions
06000	Woods & Plastics	1	LS	$25,338.97	$13,250.00	$49,162.14	$94,469.60	See Divisions
07000	Roofing	1	LS	$23,200.00	$3,000.00	$38,000.00	$65,118.00	See Divisions
32000	Landscaping	1	LS	$250.00	$400.00	$500.00	$1,222.00	See Divisions
	Subtotal			**$92,792.37**	**$25,698.60**	**$171,219.64**	**$311,354.35**	

SUBTOTAL DIVISIONS		**$311,354**
Design/Engineering	8.00%	$24,908.35
General Conditions	10.00%	$31,135.44
Contractor Fees, O&P	15.00%	$46,703.15
Construction Contingency	5.00%	$15,567.72
Estimate/Design Contingency	10.00%	$31,135.44
Inflation Factor (2011 to 2012)	4.00%	$12,454.17
TOTAL ESTIMATED CONSTRUCTION COST		**$473,259**

Appendix D: Project Safe Haven Submitted Biographies

College of Built Environments, University of Washington

Oversight Team:

Bob Freitag CFM

Bob Freitag is Director of the Institute for Hazards Mitigation Planning and Research, and Affiliate Faculty at the University of Washington. The Institute promotes hazards mitigation principles through courses, student intern opportunities and research. Freitag is currently serving on the Board of Directors for the Association of State Floodplain Managers (ASFPM) and is past Director of the Cascadia Region Earthquake Workgroup (CREW). He is coauthor of "Floodplain Management: A new approach for a new era" (Island Press 2009). In coming to the University, he left a 25-year career with the Federal Emergency Management Agency (FEMA) serving as Federal Coordinating Officer (FCO); Public Assistance, Mitigation and Education Officer. Before coming to FEMA, he was employed by several private architectural and engineering firms in Hawaii and Australia, and taught science as a Peace Corps Volunteer in the Philippines. Freitag received his Master of Urban Planning degree from the University of Washington.

Margaret Olson

Margaret Olson is a graduate student in the Urban Planning and Civil and Environmental Engineering Departments at the University of Washington, with focuses in hazard mitigation, land use and infrastructure, and hydrology and water resources. Margaret received her B.S. in mechanical engineering from the University of Virginia, and worked in intellectual property for four years prior to returning to graduate school. She has been employed on projects for the Institute for Hazard Mitigation Planning and Research since January, 2011.

David Smolker

David Smolker is an urban planning student at the University of Washington. His interests are in urban design and advocacy and in social media as a tool for community engagement. He has lived in Philadelphia, the Bay area, and is currently working for the National Park Service on San Juan island

Christopher A. Scott

Christopher Scott is a Master of Urban Planning student at the University of Washington, studying natural hazard and environmental resource planning. He holds a Bachelor of Arts in environmental studies from the University of Washington Bothell, where he focused on natural hazards and restoration ecology. Before continuing his education, Christopher was employed by several private environmental and geotechnical engineering firms where he served as a GIS and CAD specialist.

Urban Design Team

Ron Kasprisin AIA/APA

Ron Kasprisin is a Professor in Urban Design and Planning, College of Built Environments, University of Washington, Seattle WA. Ron is an architect, urban planner and watercolor artist who is the principal designer on the Tsunami Vertical Evacuation Structures Charrette team. Ron is also a principal in Kasprisin Pettinari Design, Langley WA, since 1975. He has authored four books including: *Urban Design—the composition of complexity*, Routledge Press UK 2011; *Design Media*, John Wiley & Sons NY 1999; *Visual Thinking for Architects and Designers* with Professor James Pettinari UO, John Wiley & Sons NY 1995; and, *Watercolor in Architectural Design*, Van Nostrand Reinhold NY 1989.

Daniel Benjamin Abramson, PhD

Dan Abramson is Associate Professor in Urban Design and Planning at the University of Washington. Dan led the Urban Design Studio that developed the longer-term community-scaled adaptive strategies for Neah Bay described in this report. Prior to this project, Dan has led numerous university-community participatory design partnerships in international settings, including earthquake recovery projects in Kobe, Japan, and Sichuan, China. He has published on pedagogy and technology for cross-cultural communication in urban design, in *Journal of Planning Education and Research and Habitat International*, as well as regional-local interactions in disaster recovery policy, in *Pacific Affairs*, and given numerous presentations on these topics, including at the 2010 Pacific Rim Community Design Network conference in Awaji Island, Japan; and the 6th Association of Pacific Rim Universities Research Symposium on Multi-Hazards around the Pacific Rim, in Beijing. He is currently writing with Bob Freitag on hazard mitigation planning specifically with indigenous minority cultural groups, and advises doctoral students on functions of traditional/local ecological knowledge in planning for community resilience.

Josh Vitulli

Josh Vitulli graduated from the University of Washington in 2012 with a Master of Urban Design and Planning and an Urban Design Certificate. He spent two years as the student design lead for the Safe Haven Project. In addition to hazard mitigation, he researches the relationship between urban design and real estate development. Josh completed undergraduate studies at Willamette University in 2005 with a double major in economics and rhetoric and media studies. In the years between undergraduate and graduate school, Josh travelled the world, including two years with the United States Peace Corps in Bulgaria.

Cost Estimating Team

Dr. Omar El-Anwar

Dr. El-Anwar is an assistant professor in the Department of Construction Management at the University of Washington. He earned his Ph.D. in civil engineering from the University of Illinois at Urbana-Champaign, and both his M.Sc. in structural engineering and B.Sc. in civil engineering from Cairo University. Dr. El-Anwar's general area of research is to develop of robust IT-based decision support systems for increasing the sustainability and reliance of civil infrastructure systems and building, with specific focus on quantifying and optimizing the social, economic, safety, and environmental impacts of planning for post-disaster housing and tsunami vertical evacuation. This research resulted in eight peer-reviewed journal publications in *Disasters, Journal of Earthquake Engineering, Journal of Automation in Construction,* as well as the *ASCE Journals of Infrastructure Systems, Computing in Civil Engineering, and Construction Engineering and Management.* Moreover, the findings of this research were incorporated in the development of two temporary housing decision-making modules, which are integrated in MAEviz software.

Kirk Hochstatter

Kirk is a graduate student at the University of Washington pursuing his MS in Construction Management. Before attending UW he worked for General Contractors in Seattle and the San Francisco Bay Area. His main expertise comes in health care, commercial and biopharmaceutical projects and he is LEED-AP. He is also and volunteer leader with Seattle Inner City Outings, which takes youth from low-income school districts on outdoor activities throughout the Puget Sound region. Kirk and his wife Megan live in Seattle with their baby, Lucile.

Washington State Emergency Management Division (EMD)

Dave Nelson

Dave Nelson is the Earthquake Program Coordinator for Washington State Emergency Management Division. He coordinates the efforts in the state through the earthquake, tsunami, volcano programs and the State/Local Tsunami Work Group which is developing the approaches for tsunami preparedness and mitigation efforts in tsunami hazard zones. He also concentrates his efforts on partnerships with National Oceanic and Atmospheric Administration, United States Geological Survey, Department of Natural Resources, and tribal and local county emergency managers in developing mitigation, preparedness, and planning strategies for the many communities that surround the state's natural hazards. He is responsible for the processing and installation of 63 All Hazard Alert Broadcast (AHAB) warning sirens throughout the Washington coast and around Mt. Rainier. Dave received his Bachelor's degree from Central Washington University.

John D. Schelling

John D. Schelling is the Earthquake/Tsunami Program Manager for Washington State Emergency Management Division. He is responsible for managing the seismic and natural hazard safety efforts in the state through the earthquake, tsunami, and volcano programs. He serves on the Washington State Seismic Safety Committee, Chairs the State/Local Tsunami Work Group, which coordinates efforts to improve tsunami preparedness and mitigation efforts in tsunami hazard zones, and is currently serving as the State Co-Chair of the National Tsunami Hazard Mitigation Program's Mitigation & Education Subcommittee. In addition to emergency management expertise, John has an extensive background in state and local government with an emphasis on policy analysis, land use planning, and implementation of smart growth management strategies. John received his Bachelor of Science degree from the University of West Florida and Master's Degree from the University of South Florida.

Washington State Department of Natural Resources (DNR)

Tim Walsh

Tim Walsh is a licensed engineering geologist and Geologic Hazards Program manager for the Washington Division of Geology and Earth Resources of the Department of Natural Resources. He has practiced geology in Washington for more than 30 years and taught at South Puget Sound Community College for 25 years. Tim has done extensive geologic mapping in all parts of the state and has done tsunami hazard mapping, active fault characterization, landslide, and abandoned coal mine hazard assessments. He has also directed and participated in a broad range of geologic hazard assessments and maps for land use and emergency management planning. Tim received Bachelor's and Masters degrees in geology from UCLA.

United States Geological Survey (USGS)

Nathan Wood

Nathan Wood is a research geographer at the U.S. Geological Survey Western Geographic Science Center. Dr. Wood earned a Ph.D. in geography from Oregon State University. His research focuses on characterizing and communicating societal vulnerability to natural hazards, with emphasis on tsunamis in the Pacific Northwest. He uses GIS software, collaborative community-based processes, and perception surveys to better understand how communities are vulnerable to tsunamis. He recently served on a National Research Council committee to evaluate the U.S. tsunami warning system and national preparedness for tsunamis.

National Oceanic And Atmospheric Association (NOAA)

Frank I. González:

Dr. González served as Leader of the Tsunami Research Program at the Pacific Marine Environmental Laboratory of the National Oceanic and Atmospheric Administration from 1985 until 2006, and was the founding Director of the NOAA Center for Tsunami Research. His work focused on the development of the NOAA Tsunami Forecast System, which integrates deep-ocean measurement and tsunami modeling technologies to produce real-time forecasts of tsunami impact on coastal communities. He has participated in field surveys of three devastating tsunamis that occurred in Nicaragua (1992), Indonesia (1992) and Japan (1993). As an affiliate Professor at the University of Washington, he continues to focus on tsunami research and education.

Degenkolb Engineers

Cale Ash, PE, SE

Cale Ash is a Project Engineer with Degenkolb Engineers in Seattle and is a licensed Structural Engineer in Washington and California. He joined Degenkolb in 2003 after graduating with his BSCE and MSCE from the University of Illinois at Urbana-Champaign. His project experience at Degenkolb has focused on the seismic evaluation and rehabilitation of existing buildings. Cale is Vice President of the Cascadia Region Earthquake Workgroup (CREW) and chair of their Education & Outreach Committee. He is also a Board Member with the Seattle Chapter of the Structural Engineers Association of Washington (SEAW).

Makah Tribe

Andrew Winck

Andrew Winck has been the Emergency Management Coordinator for the Makah Tribe since 2009. He is responsible to ensure that the Makah Tribal government and Makah Nation community members are adequately prepared for any potential hazard the Makah Nation may face and to oversee the management of the Makah Emergency Operations Center (EOC) during any disasters or emergencies that impact the Makah Nation. This mission is accomplished through emergency planning, staff training, emergency drills & exercises, workshops, public education campaigns, and foster professional relationships with federal, state, and county emergency management agencies. As a member of the Washington State Tsunami Workgroup, Winck provides a Tribal perspective for tsunami preparedness and response. Winck also oversees several volunteer organizations such as the local Red Cross Disaster Action Team and the Makah Community Emergency Response Team. Currently Winck is working towards earning his A.A. in Emergency Management-Homeland Security and was recently awarded the Joel Aggergaard Scholarship Award by the Washington State Emergency Managers Association.

Quileute Tribe

Larry Burtness

Larry Burtness works for the Quileute Tribe as a Planner and Grant Writer. Before coming to the Quileute Tribe, he worked in the same capacity for the Hoh Tribe. A native of Washington State, much of his career has been spent on the Olympic Peninsula, in education as a teacher for the Port Angeles School District and ten years with Peninsula College. His career as an educator also includes eight years as the Director of the Northwest Educational Technology Center, a regional program for teacher training and curriculum development. His experience in the area of educational technology applications led to work with IBM Education Systems and subsequent development of a company focused on development of educational software products. Larry was the project manager of the UW/IMLS sponsored Northwest Olympic Peninsula Community Museum Project, an online museum of the history and culture of the northwest Olympic Peninsula. The author of two books and a dozen educational software products, Larry continues to pursue opportunities for development of books and software.

Editor

Julie Clark

Julie Clark is a geologist and author. With a BA in political science and an MS in geology, she has worked in areas that combine these disciplines. Past positions include working at the Oregon State Legislature, several state agencies, managing political campaigns, and serving as an elected school board member. She has written several publication on geologic hazards, including books and articles on earthquakes, tsunamis, and flooding.

Appendix E References

Atwater, Brian F. and others. 2005. *The Orphan Tsunami Of 1700 — Japanese Clues To A Parent Earthquake In North America.* U.S. Geological Survey Professional Paper 1707. Retrieved from: http://Pubs.Usgs.Gov/Pp/Pp1707/

Cascadia Earthquake. "Tsunami Vertical Evacuation: Lessons Learned from Japan, 12, 09, 2011." Retrieved May 11, 2012 from www.youtube.com/watch?v=q0uhVas3L6w.

Cascadia Region Earthquake Workgroup (CREW). 2005. *Cascadia Subduction Zone Earthquakes: A magnitude 9.0 earthquake scenario.* Retrieved from: http://www.crew.org/PDFs/CREWSubductionZoneSmall.pdf

Federal Emergency Management Agency & National Oceanic and Atmospheric Administration. 2008. *Guidelines for Design of Structures for Vertical Evacuation from Tsunamis. FEMA P646*.

Fraser, S.; Leonard, G.S.; Matsuo, I. and Murakami, H. 2012. "Tsunami evacuation: Lessons from the Great East Japan earthquake and tsunami of March 11th 2011," *GNS Science Report* 2012/17. 89 p. Retrieved May 11, 2012 from http://www.crew.org/sites/default/files/SR%202012-017.pdf.

Fraser, Stuart. "Tsunami Vertical Evacuation: Lessons Learned from Japan, 12, 09, 2011." Retrieved from http://www.youtube.com/watch?v=q0uhVas3L6w.

Hotakainen, Rob. "Quileutes applaud Congress acting on school." *Seattle Times*. February 15, 2012. Page B5.

Kaeser, Thomas, and Laplante, John. 2007. "A History of Pedestrian Signal Walking Speed Assumptions." *3rd Urban Street Symposium: June 24-27*, Seattle: WA, p. 1-8.

Makah Tribe. 2012. "Home of the Makah People." Retrieved from http://makah.com/index.html.

Priest, G. R.; Myers, E. P., III; Baptista, A. M.; Flück, Paul; Wang, Kelin; Kamphaus, R. A.; Peterson, C. D. 1997. *Cascadia subduction zone tsunamis: Hazard mapping at Yaquina Bay, Oregon*. Oregon Department of Geology and Mineral Industries Open-File Report O-97-34, 144 p.

Project Safe Haven (A). 2011. *Tsunami Vertical Evacuation on the Washington Coast: Grays Harbor County.* College of Built Environments, University of Washington and the Washington Emergency Management Division.

Project Safe Haven (B). 2011. *Tsunami Vertical Evacuation on the Washington Coast: Pacific County.* College of Built Environments, University of Washington and the Washington Emergency Management Division.

RSMeans Assemblies Cost Data, 36th Annual Edition. 2011. RSMeans, A division of Reed Construction Data, Construction Publishers & Consultants. MA: USA.

RSMeans Square Foot Costs, 32nd Annual Edition. 2011. RSMeans, A division of Reed Construction Data, Construction Publishers & Consultants. MA: USA.

RSMeans Building Construction Cost Data, 69th Annual Edition. 2011. RSMeans, A division of Reed Construction Data, Construction Publishers & Consultants. MA: USA.

Satake, Kenji; Shimazaki, Kunihiko; Tsuji, Yoshinobu; Ueda, Kazue. 1996. *Time and size of a giant earthquake in Cascadia inferred from Japanese tsunami records of January 1700.* Nature, v. 379, no. 6562, p. 246-249.

Walsh, Timothy J.; Caruthers, Charles G.; Heinitz, Anne C.; Myers, Edward P., III;

Baptista, Antonio M.; Erdakos, Garnet B.; Kamphaus, Robert A. 2000. *Tsunami hazard map of the southern Washington coast--Modeled tsunami inundation from a Cascadia subduction zone earthquake.* Washington Division of Geology and Earth Resources Geologic Map GM-49, 1 sheet, scale 1:100,000, with 12 p. text.

Washington State Department of Natural Resources (A). 2003. *Tsunami Inundation Map of the Quileute, Washington, Area.* Retrieved from http://www.dnr.wa.gov/Publications/ger_ofr2003-1_tsunami_hazard_quileute.pdf.

Washington State Department of Natural Resources (B). 2003. *Tsunami Inundation Map of the Neah Bay, Washington, Area.* Retrieved from http://www.dnr.wa.gov/Publications/ger_ofr2003-2_tsunami_hazard_neahbay.pdf.

Yardley, William. "Washington Outpost Draws Those Hungry for Slap of Sea-spray." *New York Times*. January 5, 2012. Retrieved from http://www.nytimes.com/2012/01/06/us/washington-outpost-draws-those-seeking-slap-of-sea-spray.html?_r=2.