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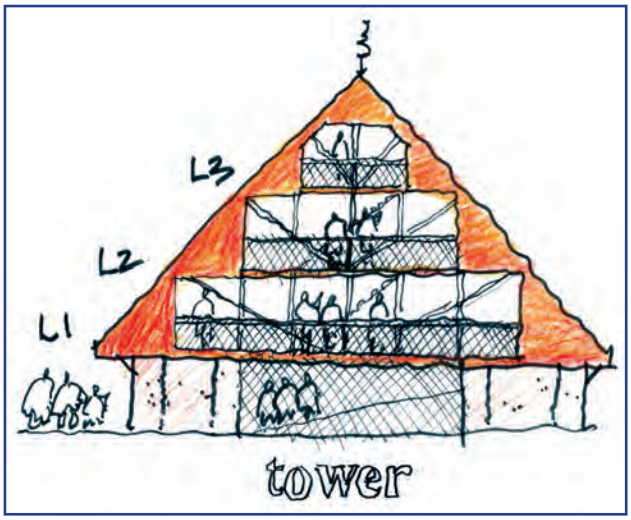
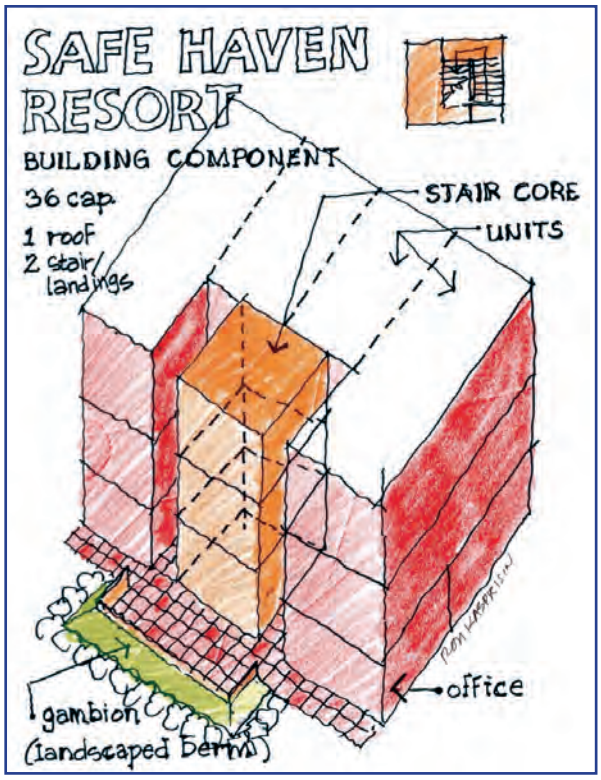
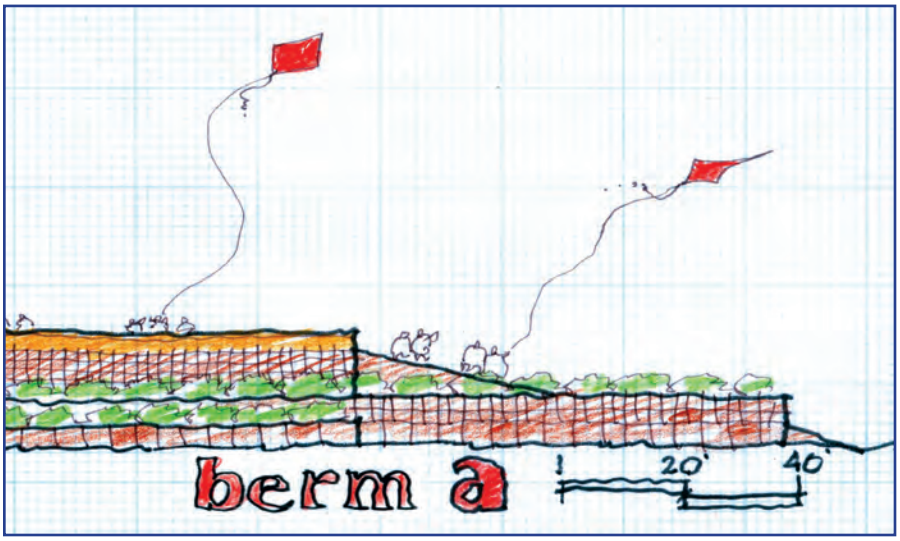
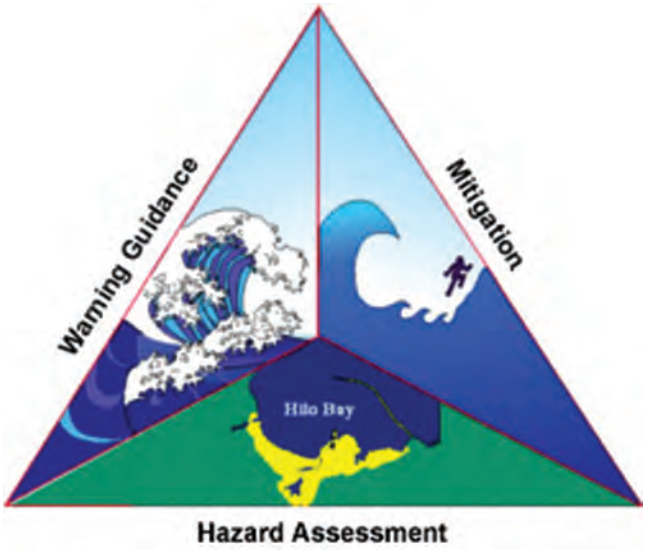


Tsunami Vertical Evacuation on the Washington Coast





Grays Harbor County



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1. Executive Summary

A magnitude 9+ Cascadia earthquake and tsunami — last experienced in 1700 AD — will endanger the low-lying communities along the Washington coast. Grays Harbor County's vulnerability to a tsunami combined with the difficulty of typical horizontal evacuation spurred interest in the exploration of alternative evacuation methods. Graduate students from the University of Washington, with support from county, tribal and state emergency management officials, created a community-driven process to identify potential locations for vertical evacuation in Grays Harbor County. This project addresses three of the most vulnerable coastal communities in Grays Harbor County: South Beach, Ocean Shores, and Taholah. In the future, the project team will work with additional Washington coast counties.

This report outlines the process, strategies, and scientific data used by the team for the project.

Project Safe Haven, a grassroots process to develop ideas and strategies about vertical evacuation, is the first of its kind. A large emphasis on public participation and local knowledge differentiates Project Safe Haven with other vertical evacuation exploration projects. The vertical evacuation strategies were derived from a series of four public meetings in each at-risk community and then confirmed by a team of experts.

The project team adopted a six-phase methodology to accomplish its task.

1. A Steering Committee composed of local and state officials, emergency managers, and scientists was created to guide the project.
2. A team site visit to each community helped to identify opportunities for, and barriers to, potential vertical evacuation projects.
3. Ideas and comments about vertical evacuation were solicited at the first public meeting, using World Café methodology. Community members were encouraged to discuss the strengths and weaknesses of each three vertical evacuation option: berm, tower, or building. Meeting participants used interactive hazard maps to discuss conceptual locations for the structures, and the pros and cons of each structure type.
4. The project team translated community members' ideas into a preliminary strategy. At a second meeting, the preliminary strategy was presented back to the participants, using maps and text. The strengths and weaknesses of each component of the strategy were discussed. Ultimately, a preferred strategy emerged for each community.
5. Community design charrettes were conducted to identify site specific design constraints and opportunities. Day-to-day functions and uses of each proposed vertical evacuation site/structure were also explored and identified. Opportunity was given to refine the preferred strategy due to site specific considerations.
6. Once each community developed a preferred strategy, the sixth phase was to conduct two communitywide meetings: one in South Beach and one in Ocean Shores. Each meeting was widely publicized and open to the public. The meetings allowed community members a final opportunity to reassess the strategy. The strategy was presented to allow for review of comprehensiveness, redundancy, and coordination of efforts.
7. The final version of the Grays Harbor County preferred strategy includes:

- Berms
- Towers
- Parking garages
- Tower/berm combinations
- Private development opportunities.

8. The residents of Grays Harbor County have suggested 32 facilities offering tsunami safe havens for 18,450 residents through the construction of 3 berms, 18 towers, 8 tower-berm combination and 3 buildings. Total costs could could be in the neighborhood of $40 million.

2. Project Safe Haven: Grays Harbor County

The Grays Harbor County communities on the Washington coast lack natural high ground and sit within close proximity to the Cascadia subduction zone. This makes the communities vulnerable to significant damage from a tsunami triggered by a Cascadia subduction zone earthquake. The goal of Project Safe Haven is to determine vertical evacuation options for the coastal communities of Grays Harbor County in cooperation with coastal stakeholders (see Figure 1).

Vertical evacuation allows residents and visitors to move upwards to safety and is particularly important in areas where traditional evacuation measures are not feasible. This report documents the methodology and results from the project's work in South Beach, Ocean Shores, and Taholah.

In the sections below, the report provides a profile of the hazard, an overview of the three communities, the process to develop and refine vertical evacuation strategies for Grays Harbor County, and descriptions and assessments of the preferred strategies.

Figure 1: Grays Harbor County context map

3. Background

A. Hazard profile and modeled scenario

A tsunami is a series of sea waves, commonly caused by an undersea earthquake. Grays Harbor County is vulnerable to two types of tsunamis:

- Those created by a *distant* seismic event (such as the 2011 earthquake near Japan).
- Those created by a *local,* offshore earthquake.

After a *distant* earthquake, Grays Harbor County may be far enough from the epicenter so that there is no damage to evacuation infrastructure, such as roadways. A distant tsunami will not reach Grays Harbor County for several hours. Residents will have time to receive warning from the AHAB (all-hazards alert broadcast) system and evacuate by car, using standard tsunami evacuation routes to Grays Harbor County assembly areas.

A *local* earthquake, however, will cause tremendous destruction and leave little time for people to evacuate to high ground before the subsequent tsunami waves arrive. This short timeframe and lack of natural high ground requires the development of vertical evacuation strategies; constructed areas of high ground, whether made of soil or using buildings, give people a place for evacuation. These areas should be easily accessible on foot within fifteen minutes after the earthquake.

To analyze the effects of a worst-case scenario tsunami, Project Safe Haven referenced a modeled subduction zone earthquake hazard scenario (developed in part by Priest and others, 1997; and Walsh and others, 2000). Additional information published by the Cascadia Region Earthquake Workgroup (CREW, 2005) was combined with the model.

The referenced scenario is a local Cascadia subduction zone magnitude 9.1 earthquake (see Figure 2). An earthquake of this size occurs off the Washington coast every 400 years, on average. The last one took place in January 1700 AD. Evidence for the magnitude of the 1700 event is found in historic and geologic records of a tsunami that struck Japan following the earthquake (Satake and others, 2003; Atwater and others, 2005; CREW, 2005). A local subduction zone earthquake will:

- Originate approximately 80 miles off of the Pacific Northwest coast.
- Likely cause six feet of land subsidence along the coast.
- Last five to six minutes.
- Create a tsunami that will reach the Grays Harbor County coast approximately 40 minutes after shaking stops.

Though the model suggests about half an hour is available for evacuation, only 25 minutes of that time can be expected to remain after people reorient themselves after the earthquake and prepare to evacuate. The earthquake will cause extensive destruction of infrastructure and buildings and

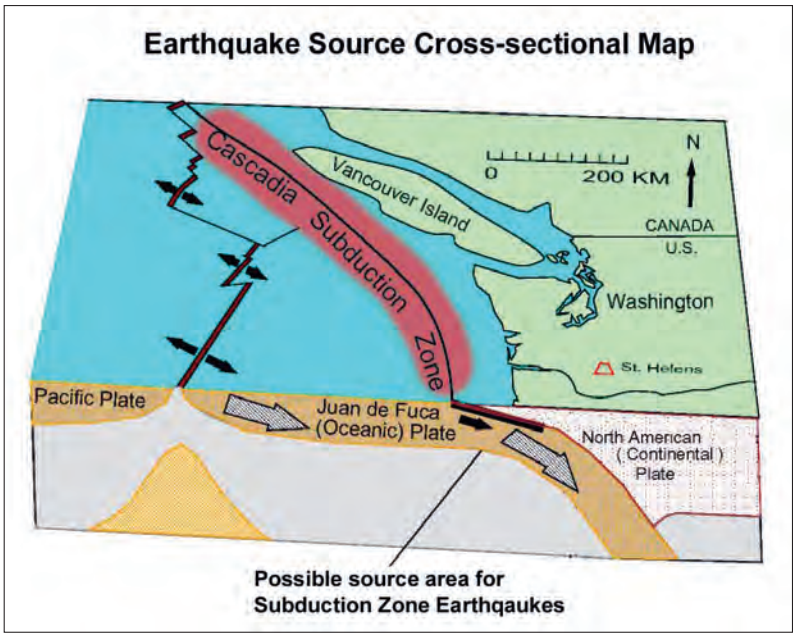


Figure 2: Subduction zone earthquake source
The Washington Coast can be affected by local or distant earthquakes and tsunamis.

leave tremendous debris on roadways and other property. People at most locations on the Grays Harbor County coast will only be able to evacuate on foot. As an additional margin of safety, the estimated evacuation time was reduced to 15 minutes, to take into account the physical and emotional turmoil people experience during and after a major earthquake (see Figure 3).

Figure 3: Grays Harbor County Hazard map

According to the model, the primary tsunami wave will have a wave-height of approximately 22 – 30 feet (National Geodetic Vertical Datum or NGVD) at the western shore, with some variation depending upon localized bathymetry and topography. Several other abnormally large waves will likely follow the initial wave, and the danger of recurring waves will persist throughout one entire tide cycle after the earthquake, 12 hours minimum. The 2010 Chile earthquake (magnitude 8.8) produced at least three consecutive local waves. Of the three, the third wave was the largest and most destructive (Warren and Vergara, 2010). Vertical evacuation options need to be feasible for up to 24 hours after the earthquake in order to provide safety from multiple tsunami waves.

Currently, the scenario model does not include wave height information for South Beach, Taholah or the interior of Grays Harbor. As a result, minimum necessary safe haven floor heights have been estimated for South Beach and Taholah. The project team hopes to have access to accurate modeling of these areas in the future.

B. Community profiles

South Beach

There is very little natural high ground in the South Beach area. Despite two Grays Harbor County designated assembly areas located on the

eastside of the South Beach vicinity, the majority of residents do not live within reasonable walking distance to these locations or other areas of natural high ground. They will not reach them on foot in the 15-minute evacuation window.

Project Safe Haven has emphasized the consideration of capabilities and limitations of the area's aging population. A large percentage of South Beach residents are over the age of 50 and many will likely require ramps to access a vertical evacuation structure. Many of the conceptual designs for vertical evacuation structures include ramps specifically for the purposes of providing access to individuals with limited mobility. The project team worked with local residents to address concerns about issues regarding access to the proposed structures.

Permanent residents on the peninsula are familiar with the threat of a tsunami. Multiple tsunami evacuation signs are located along major arterials and thoroughfares directing people to one of two Grays Harbor County designated assembly areas. Public awareness efforts organized by Grays Harbor County Emergency Management such as the Grays Harbor County All-Hazards Guide elevate public awareness and education levels.

South Beach experiences substantial seasonal population fluxes because of its natural coastal amenities and emphasis on tourism. During the seasonal peaks, thousands of visitors flock to South Beach to attend festivals or to stay in one of the many vacation homes that dot the area. Local tourism efforts, such as the Westport Tourism website (www.westportwa.com) and a recent ad campaign by Experience Westport (www.experiencewestport.com), promote the region as "your porthole to what's happening at the beach" and as a premier regional vacation destination. The Westport-Grayland Chamber of Commerce website (www.westportgrayland-chamber.org/) also promotes the region as a place for, "fishing, surfing, and fun at the beach." In addition to significantly contributing to the population numbers, seasonal visitors are often not aware of the tsunami hazard.

The Project Safe Haven process to develop vertical evacuation strategies considered both resident and tourist populations in the estimated necessary structure capacities. Attention was also given to locating structures in areas to serve full-time residents and tourists. The project team used an "average summer day" as a basis for population estimates.

Westport

Westport is well known for its festivals and attractions such as the annual Westport Charter Association Fishing Derby, Eastside Street Rods Show and Shine, and the Westport Art Festival. The majority of Westport's populated areas are not within a 15-minute walking distance to the area's designated assembly area at Ocosta High School on the eastside of the peninsula. The annual population of Westport fluctuates considerably from 2,600 during the off-season to 4,000 to 5,000 during the peak season (see Table 1). The housing stock reflects this. Only 67% of the housing stock is lived in year round; vacation rentals comprise 32% of the housing. The city contains 350+ recreational vehicle (R. V.) parking spaces, 800+ hotel rooms, and 200+ campground spaces to accommodate seasonal tourists and visitors.

Geographically, Westport is more diverse than other coastal Grays Harbor County communities. Westport has a series of three dunes that run north-south on the peninsula. The first dune, closest to the ocean, is very small. It will likely not provide much protection from tsunami waves; however, it will absorb some energy. The second dune is

Table 1: Westport demographics

Westport	
Age	**Percentage**
< 24	34%
25 – 44	23%
45 – 64	25%
> 65	18%
37	*Median age*
Source: U.S. Census, 2000	

larger than the first and is located in the middle of the peninsula with several homes and hotels located on it. This dune will provide some protection from the tsunami waves and will also absorb some of the wave energy. The final dune is located on the eastside of the peninsula and is the tallest of all three. Ocosta High School is built on top of the dune and due to the height, the area around the school has been designated as a tsunami evacuation location. It is unclear if the third dune will be high enough as it is to provide refuge following a Cascadia subduction zone near-earthquake with resulting tsunami waves. *(See Appendix A for the Westport context map.)*

Grayland

Grayland is an unincorporated community located at the southern end of Grays Harbor County and is most well known for its abundant cranberry production. Grayland is a bit 'sleepier' than its neighbor, Westport, to the north and thus does not experience seasonal population fluxes as significant as Westport. The year-round population of Grayland is 1,000 with seasonal fluxes up to 2,000 (see Table 2). The housing stock reflects this. Nearly 90% of all houses are occupied year round with only 10% left vacant for seasonal uses. Grayland has several annual events that attract tourists such as the Windrider's Kite Festival and the Cranberry Harvest Festival. The area contains 100+ recreational vehicle (R. V.) parking spaces and 80+ hotel rooms.

Grayland's most populated topography is low-lying; however, due east there is abundant natural high ground. Unfortunately, much of the natural high ground is outside of a fifteen minute walking distance for almost all of the lowland population. There are also numerous cranberry bogs situated between populated lowlands and the natural high ground. The bogs pose accessibility problems as they will become lake-like from subsidence following an earthquake. *(See Appendix A for the Grayland context map.)*

Ocean Shores

The City of Ocean Shores is one of the most popular beach destinations on the Washington Coast. The city promotes itself as the one beach destination in Western Washington with 6 miles of easily accessible sandy beach. There are numerous annual events that also draw tourists to the area such as the Razor Clam Festival, Fire O'er the Water, and Celtic Music Festival. In fact, the Ocean Shores Tourism Board boasts an annual visitor and tourist total of nearly 4 million.

The permanent population of Ocean Shores is over 5,000 with seasonal population fluxes up to 14,000 to 15,000 (see Table 3). Ocean Shores' housing stock reflects the distinction between annual and seasonal populations. Only 60% of the housing stock is occupied year-round and 40% functions as vacation rentals.

Ocean Shores is one of the most, if not the most, vulnerable Washington coastal community due

Table 2: Grayland demographics

Grayland	
Age	Percentage
< 24	25%
25 – 44	17%
45 – 64	36%
> 65	23%
53	*Median age*
Source: U.S. Census, 2000	

Table 3: Ocean Shores demographics

Ocean shores	
Age	Percentage
< 24	12%
25 – 44	18%
45 – 64	44%
> 65	27%
56	*Median age*
Source: U.S. Census, 2000	

to its average elevation of six feet and limited access on and off of the peninsula. Ocean Shores is located on a sand spit that forms the northern entry to Grays Harbor. The area has an impressive man-made system of lakes and canals located in the eastern portion of the peninsula. On a day to day basis the canal and lake system provides an opportunity for lake front property and recreation opportunities. In the event of a large earthquake and subsequent tsunami waves the water features pose a significant threat due to the immediate seepage triggered by the earthquake and subsidence. The Ocean Shores vertical evacuation strategy development was significantly influenced by connectivity concerns. There are several existing bridges that will likely become compromised during an earthquake and would result in several neighborhoods becoming isolated. *(See Appendix A for the Ocean Shores context map.)*

Taholah (Quinault Indian Nation)

Taholah is an unincorporated area in Grays Harbor County. It is home to the Quinault Indian Nation and Taholah High School. Taholah is mostly residential with several businesses located near the waterfront. The permanent population of Taholah is 824 with very little seasonal change (see Table 4). Taholah's population is almost exclusively year-round residents. There is not much tourism which presents an opportunity as most all residents are familiar with the tsunami hazard. Almost 90% of the housing stock is occupied year-round with only 10% serving seasonal needs.

Table 4: Taholah demographics

Taholah	
Age	**Percentage**
< 24	40%
25 – 44	28%
45 – 64	18%
> 65	14%
30	*Median age*
Source: U.S. Census, 2000	

Geographically, Taholah can be divided into two areas: town center lowlands and high ground to the east. A majority of the population lives in the low, tsunami zone. Naturally occurring, high ground, surrounds Taholah to the north, east and south. The Quinault tribal headquarters is located on high ground to the south of the town center. There are suggestions of a future relocation of housing from the low, town center to the surrounding areas of high ground. *(See Appendix A for the Taholah Context map.)*

C. Vertical Evacuation

After a tsunami warning, residents of the affected area typically evacuate horizontally, either by car or on foot. A *horizontal* evacuation strategy is appropriate when communities have natural high ground that is easily accessible. The traditional advice is, "go uphill or inland."

However, if a community has little or no natural high ground, horizontal evacuation may not be an option. A different strategy is necessary. A *vertical* evacuation strategy provides artificial high ground in communities that lack natural high ground.

Structure types

In order to accommodate vertical evacuation, the project team and coastal stakeholders evaluated three potential options defined in *FEMA P646: Guidelines for Design of Structures for Vertical Evacuation from Tsunamis*. These options are berms, towers, and buildings. The minimum space for each is based on allotting every person ten square feet of space.

The conceptual designs for the structures, explained below, are intended as generalized designs to work under most conditions. These designs take into consideration the forces of both the earthquake ground shaking (anticipated to reach up to 1g, defined as 100% of the force of gravity) and the immense lateral forces of a tsunami. All conceptual designs reference and rely on design considerations for vertical evacuation structures found in *FEMA P646.*

Cost

The cost of a vertical evacuation structure is a function of structure type, required safe haven area, and required structure height. The required height of the structure includes:

- The height required at each location in order to meet the wave height projections
- Consideration of post-event subsidence
- A factor of safety.

The required safe floor area is ten times the number of estimated evacuees for each structure (based on a 10 square feet per person standard).

The costs include design, construction, and materials. Land cost is not included in these estimations.* *(See Appendix G for a summary of cost estimates for two projects described in this report.)*

Berm

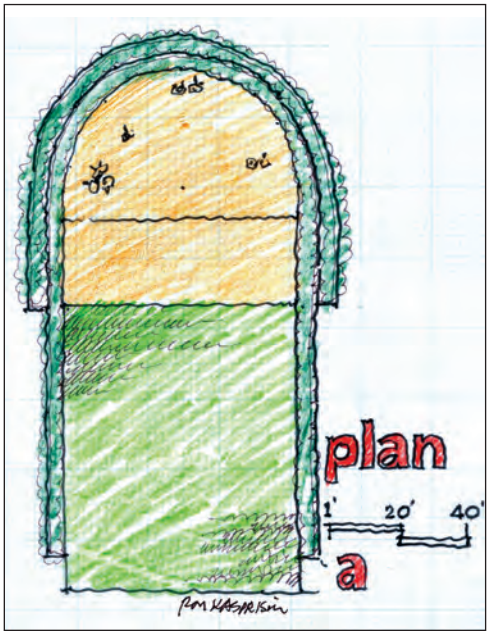
Berms are artificial high ground created from soil (see Figure 5). They typically have ramps at a 1:4 slope providing access from the ground to the elevated surface. Berms have a large footprint on the landscape, giving the appearance of an engineered and designed hill. A berm can range in size from 1,000 square feet for 100 people up to 100,000 square feet for 10,000 people.

**See supplementary* Safe Haven Vertical Evacuation Structures Conceptual Cost Analysis *report for detailed cost estimates for four proposed vertical evacuation structures.*

Figure 5: Constructed berm with stair access

The conceptual design for berms was based on the guidelines provided in *FEMA P646.* A berm has three component parts: a rounded front portion and gabion mound, the elevated safe haven area, and the access ramp (see Figure 4).

In order to reinforce the earthen mound from the forces of tsunami impact and scour, the entire berm will be surrounded by sheet metal or concrete. Sheet piling or concrete walls also add additional strength. The gabion mounds in front of the berm are intended to break the oncoming tsunami impact force. The access ramp is at a 1:4 slope to allow for access for limited mobility individuals.



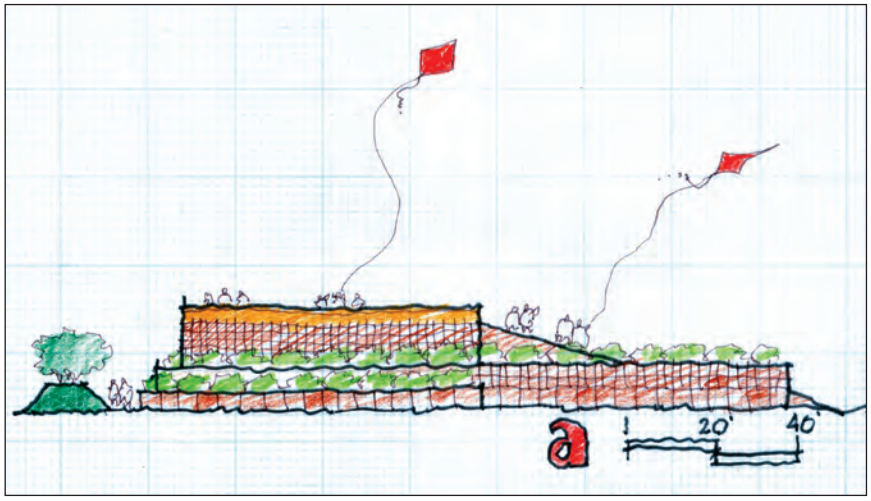


Figure 4: Basic berm conceptual designs, with front and side views

Advantages:

- Easy access for many people including those with limited mobility
- Allows people to follow natural instinct to evacuate to high ground
- Eliminates fear of entering a structure that may not be safe
- Multifunctional.

Tower

A tsunami evacuation tower can take the form of a simple elevated platform above the projected tsunami wave height, or a form such as a lighthouse, that has a ramp or stairs leading to an elevation above projected wave height (see Figure 6). A 500 square foot tower can accommodate 50 people and a 1,000 square foot tower can accommodate 100 people. The conceptual design for vertical evacuation towers was modeled after a bird watching tower from Holland.

The design consists of a four-legged base with a driven pile foundation stabilized by grade beams. This type of foundation is necessary to ensure the structure remains safe for occupation while still being able to withstand the immense lateral forces from the tsunami (see Figure 7).

Figure 6: Basic tower for tsunami refuge
This metal tower is used in Japan.

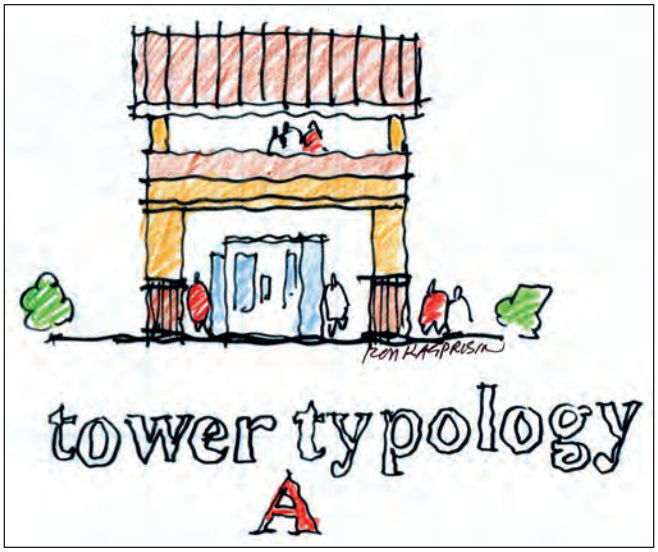


Figure 7: Towers have small footprints compared to berms

Hardened towers can have a false wooden exterior that blends in with the existing urban design found in most coastal communities. The superstructure can be sized in order to provide the required safe haven area. Two access options are available; the first is a breakaway stair system designed for daily use and for use to access the safe haven area following a major earthquake. In the case of a tsunami, however, the stair system will breakaway freely from the structure. Following the tsunami event evacuees would use a retractable staircase to leave the tower.

Advantages:

- Economical
- Small footprint
- Due to lower cost, more towers could be distributed throughout the affected areas to increase accessibility and availability
- Multifunctional.

Building

A building used as a tsunami evacuation structure has several lower levels that allow the tsunami wave to flow through it or the building is faced in a manner that the structural integrity of the building will support the force of the wave. Tsunami refugees seek safety in the upper floors of the building. Typical tsunami evacuation buildings are hotels or parking structures (see Figure 8).

Figure 8: Building for vertical evacuation. Buildings can be used for other functions when not needed for evacuation.

A variety of building types can be used for vertical evacuation. A vertical evacuation building will likely be constructed with reinforced concrete. This material has proven to be strong against both earthquake and tsunami forces. In order to increase the likelihood of withstanding a tsunami, the first level is considered "transparent," having little surface area to create resistance against the force of the tsunami (see Figure 9).

Advantages

- Lower levels of a building can be designed as "open space," allowing the water to flow through without compromising the engineering
- Multifunctional
- Top level of a parking structure could provide a helicopter landing pad after the event to deliver much needed supplies
- Buildings have the potential to generate money through other, non-tsunami uses.

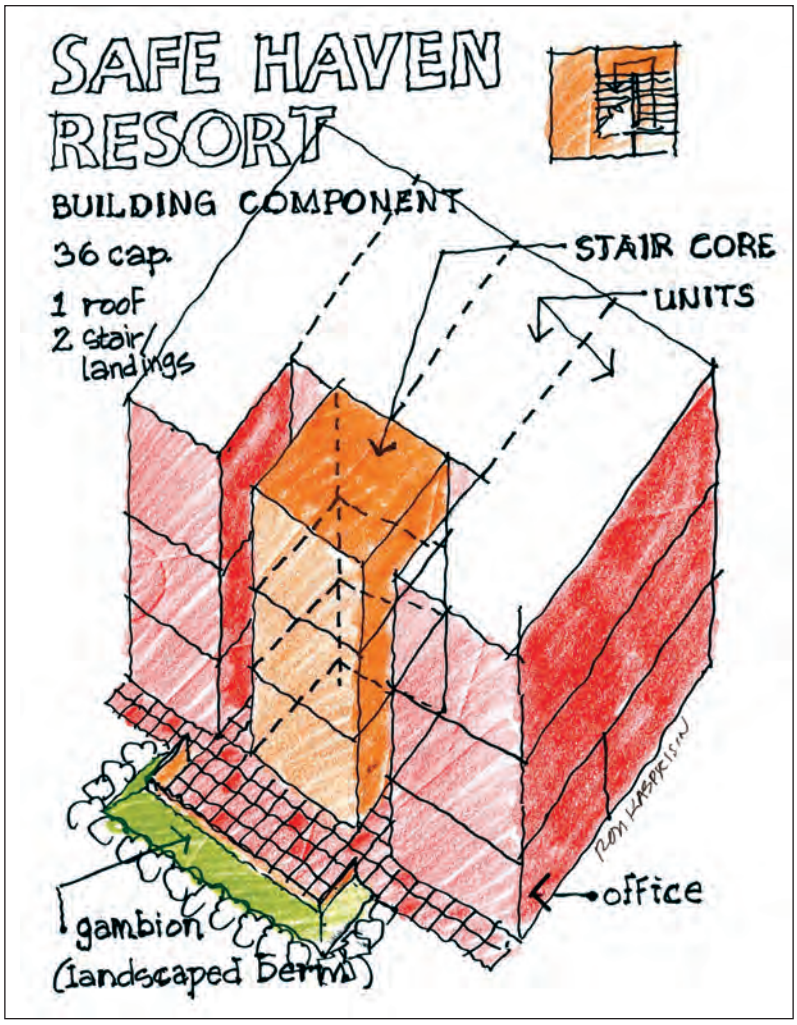


Figure 9: Conceptual design Potential building with tsunami vertical evacuation capability.

4. Methodology and Results

Project Safe Haven used a six-phased methodology to assess the vertical evacuation needs in each of the three Grays Harbor County communities. The six phases included selection of communities, site survey and development of approach, identification of alternatives and preferred strategies, community mulling and acceptance of preferred strategy, community design charrettes, and reassessment of final preferred strategy.

A. Selection of communities

Project Safe Haven is the result of concern arising from the 2004 Indonesian tsunami. Tragic lessons were learned about the difficulty communities with little or no high ground have of evacuating after a local, offshore earthquake. The southwestern coast of Washington fits this definition. In 2008, FEMA and NOAA released guidance on vertical evacuation *(FEMA P646: Guidelines for Design of Structures for Vertical Evacuation from Tsunamis).* Several at-risk Pacific Coast communities began efforts to apply the FEMA guidance locally. For example, the city of Cannon Beach, Oregon held a workshop on the feasibility of building an elevated city hall that would serve as a tsunami safe haven and has since moved forward with their plans to complete the structure. In Pacific County, Washington, local officials documented their tsunami risk and identified the potential for future vertical evacuation structures in the *Pacific County Hazard Mitigation Plan.*

Under the direction of the state Earthquake and Tsunami Program, Grays Harbor County's Emergency Manager, and the University of Washington Institute for Hazards Mitigation Planning and Research, Grays Harbor County was selected as the second county to carry out the Project Safe Haven Vertical Evacuation Identification project.

Three Grays Harbor County communities — South Beach, Ocean Shores, and Taholah — were selected as the project's focus and as locations to hold community meetings. The communities were selected due to their geographical attributes, low-lying areas, population densities, and lack of natural tsunami mitigation features. The purpose of the project was to take a unique approach to vertical evacuation planning — one with greater community involvement and input.

B. Site survey and development of approach

South Beach

In March 2011 the project team visited South Beach for a site survey. The project team toured Westport and Grayland, visited the local school, and assessed the existing viewing tower at the waterfront and marina district. Geographical attributes were noted: low elevation in most populated areas, dune series, and existing high ground. Vacant parcels were noted as potential locations for vertical evacuation structures. Westport's waterfront can be classified as a 'working waterfront' due to the large amount of industry, fishing, recreation, and tourism that takes place there. The waterfront/marina district appears to be the main area of town. Grayland is located a few miles south of Westport near the Pacific County countyline. Grayland's relatively low population density was noted as well as a lack of available parcels for future vertical evacuation structure placement.

Ocean Shores

The project team visited Ocean Shores in March 2011. The team toured the entire peninsula as well as north of the peninsula to Moclips, Ocean City and Pacific Beach. The project team noted easily accessible, natural high ground located near all three communities north of Ocean Shores. The high ground is located within a 15 minute walking distance of the populated low areas. Ocean Shores proper was noted as appearing nearly flat with little to no high ground other than a sliver at the southern end. An additional concern was the single road going in and out of Ocean Shores. In the event of a tsunami, the accessibility out of the area will likely be almost non-existent. A slight primary dune was noted at the beach but will do

very little to reduce the energy of tsunami waves. Additionally, many house foundations have 'cut into' the dune, thus reducing the effectiveness of the little protection of the dune's natural defense against tsunamis. A system of pedestrian and automobile bridges on the peninsula is vulnerable to failure during an intense earthquake event. This is critical because the destruction of the bridges will lead to isolation. There is also a series of man-made lakes and canals in the area of the bridges that pose a risk during an earthquake as they will seep into the surrounding neighborhoods due to subsidence immediately following the earthquake. Bridge damage combined with flooding from the lakes and canals poses a significant risk to the surrounding neighborhoods. The Ocean Shores vertical evacuation strategy must address these issues with a site specific approach.

Taholah

The project team visited Taholah in April 2011. The lack of natural high ground in the town center was noted as well as the river channel that forms the northern border. The river poses a risk for upland areas as rivers focus tsunami wave energy and direction. Several vacant parcels of land were noted as opportunities for future vertical evacuation structure development. Also, several potentially underused buildings were noted as opportunities for future implementation of a Taholah vertical evacuation strategy. Areas to the north, east and south were all noted as being out of the tsunami risk zone.

C. Identification of alternatives, assessment of alternatives, and development of preferred strategies

Community meetings

A series of four meetings were conducted in each of the three communities to develop a vertical evacuation strategy. The first meeting used the World Café meeting process to identify and discuss the concept of vertical evacuation, various structure types, and conceptual site locations. In the second community meeting the project team presented the alternatives that had been synthesized from the first meeting and conducted discussions about the strengths and weaknesses of each alternative and conceptual vertical evacuation structure location. Third, community design charrettes were led by an accomplished urban designer from the University of Washington to identify everyday uses for the proposed vertical evacuation strategies. Lastly, community open house meetings were held at the end of the project to confirm the final preferred strategies and to receive further feedback.

Meeting 1: World Café

The World Café process is a "café style" conversation to facilitate small group brainstorming. It is commonly referred to as encouraging "conversations that matter." Participants discussed key issues at one of three stations, with one participant at each station facilitating the discussion and taking notes. A participant, rather than a meeting facilitator, facilitates the table discussions to avoid trust issues between residents and meeting facilitators. As the rounds progress the table groups incorporate prior round topics into each round so during the last round the participants have incorporated discussion of all three topics into one discussion.

Before the meetings, project team members prepared for the role of facilitator by taking small group dynamics training. They were facilitators, not leaders of discussion. They took notes throughout the rounds to record participant's comments.

Each station represented a different type of vertical evacuation structure: berm, tower, or building. Each station used large table maps of the community, in combination with walking circles and Lego models of vertical evacuation structures, to determine ideal placement locations. When the allotted time ended, station participants rotated to another station, leaving one member behind to facilitate and share notes with the incoming group. This process typically continued until every participant had a turn at each station.

Meeting 2: Discussion of strengths and weaknesses

The purpose of the second meeting was to present results from the first meeting and to discuss the strengths and weaknesses of each conceptual site and vertical evacuation type. The project team presented the alternatives derived from the first meeting using maps and graphics. Next, the team facilitated a large group brainstorming session regarding the strengths and weaknesses of each alternative using SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis techniques. The goal of the meeting was to build consensus among those present and to develop a preferred strategy. *(See Appendix B for a complete description of SWOT analysis.)*

Meeting 3: Community design charrettes

A design team, led by an urban designer from the University of Washington, joined Project Safe Haven to look at alternative community uses for the proposed vertical evacuation structures. The design team conducted three intensive, community design charrettes in Grays Harbor County to encourage local residents to consider how the proposed vertical evacuation structures might fit into the context of the existing built environment and how the proposed structures could contribute to and even enhance the communities.

Meeting 4: Open houses

At the two countywide meetings, the final preferred strategies and the accompanying maps for each community were presented. The project team encouraged verbal and written comments. The team also presented additional information about estimated costs, community processes and the tsunami hazard.

South Beach meeting 1: World Café

The first South Beach meeting was held on March 4th, 2011 at the Chateau Westport Hotel. The meeting was open to the general public and was publicized through local radio, newspaper, email, Facebook and Twitter. Over twelve community members attended the meeting and were assigned to one of three groups. State Emergency Management representatives, one State Department of Natural Resources representative, and University of Washington Institute for Hazards Mitigation Planning and Research representatives facilitated the meeting and assisted with the World Café process.

The meeting began with a 30-minute risk overview by Tim Walsh, State of Washington Department of Natural Resources in order to provide basic, background information about tsunamis and South Beach's tsunami risk. The lead UW facilitator introduced the assumption that despite a warning time of approximately 40 minutes for a local tsunami, the expected earthquake shaking, road/sidewalk conditions, and general confusion would reduce the amount of time a person had to evacuate to 15 minutes. Each station was given a table-sized hazard map of South Beach and was asked to examine one of three types of vertical structures (berm, tower, and building). The purpose of the stations was to propose and discuss possible sites and sizes for the structures. Each station was given Lego representations of their assigned structure type. Station participants were also given two walking circles to determine how many people each proposed structure will serve based on walking speeds: (from Kaeser and Laplante, 2007)

- One circle represented a radius of 3,600 feet, the distance a person at average walking speed can cover in 15 minutes (four feet per second, 3,600 feet in 15 minutes)
- One circle represented a radius of 2,700 feet, the distance a person at below average walking speed can cover in 15 minutes (three feet per second, 2,700 feet in 15 minutes).

The participants moved the walking circles to different places on the map to analyze the accessibility of different locations for berms, towers, and buildings.

Participants at the first station were allotted 25 minutes to discuss structure placement alternatives. The second session lasted 20 minutes, and the third session lasted 10 minutes. After completing

three rounds, the meeting participants reconvened to discuss the outcomes of each of the stations to inform the next step, assessment of alternative.

Comments recorded during the rounds were:

- Cost is a factor
- Cheapest solution may be the best solution
- Less populated areas = small towers
- New, private development (i.e. restaurant) on berm
- Elevate Montesano road and reinforce to be evacuation point for tsunami safe haven
- ADA accessibility for towers?
- Easy maintenance
- Coordinate with Coast Guard in the waterfront district
- Partner with senior house for ADA accessible VE structure
- Baseball field in downtown area
- Major population concentrations at northern tip of the peninsula.

The World Café process allowed meeting participants to provide the project team with an abundance of local knowledge about South Beach such as where elderly concentrations are, dune stability, and local heritage markers. Participants recorded their input and suggestions on the table maps by drawing arrows, identifying areas with a higher density of senior citizens, and correcting and adding labels to better identify important areas for consideration. The large maps at each table facilitated participation by providing a way for people to actively manipulate the Lego representations and walking circles. After completing three rounds, the meeting participants reconvened to discuss the outcomes of each of the stations. UW representatives recorded the information and input from this meeting to inform the next step, preliminary strategy assessment.

South Beach meeting 2: Evaluation of preliminary strategy

After generating the preliminary strategy, a second meeting was held on March 31st, 2011 at the Chateau Westport with the participants from the first meeting. UW representatives presented and explained the preliminary strategy, and then asked the participants to conduct a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis of the strategy. When used as a planning tool, a SWOT analysis can help identify supporting and unfavorable internal and external factors of a project. Students gave participants a SWOT matrix worksheet to facilitate group brainstorming and evaluation. Participants noted the strengths and weaknesses of each proposed vertical evacuation structure location and typology. Strengths and weaknesses were recorded and shared with the larger group at the end of the meeting and informed the development of the preferred strategy.

Comments regarding the strengths and weaknesses about the preliminary strategy are as follows:

- Park improvements to be connected with vertical evacuation implementation
- Reinforce linkages to existing high ground
- Incorporate with future school improvements
- Incorporate with future lighthouse improvements
- Coordinate berm implementation with RV parks and campground (Twin Harbors Beach State Park)
- Move southern most tower north to fire station (Grayland Fire Station)
- Take advantage of existing high ground
- Relocate building 2 inland to include more people in the walking circle
- Coordinate with Coast Guard observation tower improvements at waterfront
- Move 6 south to provide more coverage for beach residents (Grayland)
- Concern about 'untrained' tourist population
- Make sure berm at school is big enough to accommodate all school kids and nearby residents
- Keep VE structures and access roads away from bogs
- Debris concerns near north end of peninsula
- Bathrooms on berms/tower
- Seafood processing plant parking structure.

Figure 10: South Beach preferred strategy map

South Beach: Description of preferred strategy

The South Beach preferred strategy is made up of a combination of towers, tower/berm combinations, berms and buildings. In total there are 9 proposed vertical evacuation sites and structures. The major concentration of structures can be found in the most densely populated areas of the peninsula and where the man made water features are to address isolation issues. For a complete description of the strategy see Figure 10, the South Beach Preferred Strategy map.

Ocean Shores meeting 1: World Café

The first Ocean Shores World Café meeting was held on March 10th, 2011 at the Ocean Shores Shilo Inn. The meeting was open to the general public and was publicized through local radio, newspaper, email, Facebook and Twitter. Over fifty people attended, making the attendance our highest to that point.

The meeting began with a 30-minute risk overview by Tim Walsh, State of Washington Department of Natural Resources in order to provide basic, background information about tsunamis and Ocean Shores' tsunami risk. The World Café process was explained, then attendees were divided into six groups of six to ten group members. Each of the six table groups began the first round looking at the Ocean Shores hazard map and only one vertical evacuation structure type. As the groups moved to rounds two and three all of the structure(s) from previous rounds were brought into the discussion. During the last round, each table group considered all structure types in order to arrive at the most appropriate use of a combination of different vertical evacuation structure types.

The high attendance at this meeting required the meeting facilitators to take a different approach with the management of the meeting. Each table group had at least six people and unfortunately the World Café conversations are most effective with four people per group. Each project team member was required to join a table group to help facilitate and discuss vertical evacuation options for Ocean Shores. Overall, the meeting was very productive as a lot of input and comments were gathered, recorded and discussed.

Comments recorded during the rounds were:

- Multi-story, multi-use parking near downtown
- Community Club-owned parks
- Berm or elevated soccer park at Chinook Park
- Tower at Spinnaker Park
- Incentives for tsunami building codes (new buildings)
- Pyramid shaped berms — use all four sides for access
- Senior citizen accessibility and general mobility issues
- Take advantage of existing high ground.

At the World Café meeting, local knowledge about Ocean Shores was collected. After the meeting, the project team incorporated the local knowledge into their analysis of potential vertical evacuation strategies.

Ocean Shores meeting 2: Evaluation of preliminary strategy

The Ocean Shores evaluation of the preliminary strategy meeting was held on April 1st, 2011. The meeting again took place at the Ocean Shores Shilo Inn and at least 50 people attended. The purpose of the meeting was to present the strategy derived from the World Café meeting and to evaluate it in terms of strengths and weaknesses. The meeting began with a welcome and a segment regarding the hazard and scenario assumptions. *(See Appendix C for project assumptions.)*

The high meeting attendance encouraged the meeting facilitators to alter the organization of the meeting. Rather than have a large discussion about the strengths and weaknesses of each proposed vertical evacuation location the meeting participants sat in small groups to discuss strengths and weaknesses. The small groups reported back to the large group and the end of the meeting and also shared their favorite or considered to be most

important proposed vertical evacuation structure/location.

Strengths of the preliminary strategy discussed were:

- Coordinate with school needs to develop multi-use vertical evacuation structure
- Recreational berm opportunity at park
- Interpretive center VE structure to integrate with existing trail system
- Incentivize private development
- Access easement along existing power lines.

Weakness:

- Isolation concerns near bridges and waterways — need more structures
- Implementation concerns about funding
- Local taxes will be contentious (i.e. past LID).

Ocean Shores: Description of preferred strategy

The Ocean Shores preferred strategy is made up of a combination of towers, tower/berm combinations, berms and buildings. In total there are 20 proposed vertical evacuation sites and structures. The major concentration of structures can be found in the most densely populated areas of the peninsula and where the man made water features are to address isolation issues. For a complete description of the strategy see Figure 11, the Ocean Shores Preferred Strategy map.

Taholah meeting 1: World Café

The first Taholah meeting was held on April 5th, 2011. The meeting took place at the Taholah Community Center. The project team coordinated with Connie Wilson of the Quinault Nation to plan the meeting. Connie helped publicize the meeting through tribal publications and community posted flyers. In order to encourage participation a community dinner was held before the meeting. At least twenty-five people attended the meeting.

The meeting was conducted using the World Café method. Prior to the World Café segment, a presentation about the hazard was given by Tim Walsh. In addition, a short presentation about the project/scenario assumptions was given to inform the attendees about the assumptions that the project team has used.

The meeting was conducted in the standard World Café process with several small groups. The groups worked together with the assistance of a Taholah hazard map and Legos to represent vertical evacuation structures. After the first round, the groups rotated tables until three rounds were completed.

After the World Café rounds the groups came together as a large group and each table group shared their ideas, concerns, and suggestions based on local knowledge of Taholah. Some of the comments are as follows:

- Two viewing towers at least 40 feet tall
  - One at community center and one at football field
- Tower for elders (old daycare) with accessibility
- Concerns about elder safety — limited mobility
- Building near community center could double as a multi-cultural facility
- Building at gravel area near school
  - Want to get away from ocean
  - Most people live in the tsunami inundation area
  - Towers seem like a bad idea — trees may knock down?
- Tower near senior housing with a spiral staircase for wheelchairs.

Taholah meeting 2: Strengths and weaknesses evaluation

The Taholah preliminary strategy strengths and weaknesses evaluation meeting was held in conjunction with the Taholah design charrette due to travel considerations. For further explanation about the meeting, see the Taholah design charrette section below.

Taholah: Description of preferred strategy

The preferred strategy for Taholah was derived by a combination of resident input and expert review. The strategy, as seen in Figure 12, includes

Figure 11: Ocean Shores preferred strategy map

Figure 12: Taholah preferred strategy map

Table 5: Complete list of preferred strategy conceptual sites

Map	Community	Site	Type	Minimum Safe Zone Floor Height	Safe Zone Square Footage	Capacity (# of people)
1	South Beach	Marina	Building	17 feet	15,000	1,500
2	South Beach	Adams & Washington	Building	17 feet	10,000	1,000
3	South Beach	Forrest & Newell	Tower	14 feet	9,000	900
4	South Beach	Surf & Ocean	Tower	17 feet	9,000	900
5	South Beach	Ocosta School	Berm	11 feet	15,000	1,500
6	South Beach	HWY 105 & W Bonge	Tower	14 feet	9,000	900
7	South Beach	Wood Lane	Tower	14 feet	5,500	550
8	South Beach	HWY 105	Tower	17 feet	5,500	550
9	South Beach	McDermott Lane	Tower	10 feet	5,500	550
1	Ocean Shores	Ocean City	Tower	14 feet	3,000	300
2	Ocean Shores	Quinault Beach Resort	Tower	14 feet	5,000	500
3	Ocean Shores	North Beach Junior/Senior High School berm	Berm	10 feet	8,000	800
4	Ocean Shores	Downtown Ocean Shores	Building	10 feet	17,000	1,700
5	Ocean Shores	Golf Course	Tower/Berm	10 feet	3,500	350
6	Ocean Shores	Ocean Shores Airport	Tower	10 feet	3,500	350
7	Ocean Shores	Ocean Shores Elementary Civic Complex	Tower	10 feet	3,500	350
8	Ocean Shores	Ocean Shores Blvd & Taurus Blvd SW	Tower	17 feet	3,500	350
9	Ocean Shores	Blue Wing Loop SE & Duck Lake Drive SW	Tower/Berm	10 feet	3,500	350
10	Ocean Shores	Cormorant Street	Tower	10 feet	3,500	350
11	Ocean Shores	Ocean Shores Blvd & Marine View Drive SW	Tower	14 feet	3,500	350
12	Ocean Shores	Emeritus Senior Living	Tower	10 feet	5,000	500
13	Ocean Shores	Wowona Ave SE & Tonquin Ave SW	Tower	14 feet	3,500	350
14	Ocean Shores	Spinnaker Park	Tower/Berm	17 feet	5,000	500
15	Ocean Shores	Ocean City State Park Campground	Tower/Berm	14 feet	3,500	350
16	Ocean Shores	Duck Lake Drive	Tower	10 feet	3,500	350
17	Ocean Shores	Trois Court & Inlet Avenue NW	Tower	10 feet	3,500	350
18	Ocean Shores	Ocean Lake Way & N Port Loop	Tower/Berm	17 feet	3,500	350
19	Ocean Shores	North Razor Clam Drive & Butterclam St SW	Tower/Berm	10 feet	3,500	350
20	Ocean Shores	Mt. Olympus	Tower	10 feet	3,500	350
1	Taholah	2nd Ave & Spruce St	Tower/Berm	16 feet	3,000	300
2	Taholah	5th Ave & Commux St	Berm	16 feet	4,000	400
3	Taholah	Park Place Neighborhood	Tower	16 feet	2,000	200

three proposed sites for future vertical evacuation structures. Two locations in the town center were selected. One site is near the school and one site is near senior housing. A third site was selected on the east side of the highway to provide a safe haven for residents of a small neighborhood.

D. Community mulling and acceptance of preferred strategy

After the series of initial community meetings were complete, the project team allowed time for the community to mull over and accept the preferred community strategies (see Table 5). This period lasted for approximately two months. The mulling process provided opportunities for informal community discussions about the preferred strategies as the strategies were available on the Project Safe Haven website and Facebook page. Several articles about vertical evacuation in Grays Harbor County were published in Aberdeen's newspaper, *The Daily World.* The *Seattle Times* also published an article following the March 2011 tsunami in Japan and its relevance in Ocean Shores. The newspaper articles and a short piece on Seattle's KIRO TV increased exposure to the project and the general concept of vertical evacuation.

Grays Harbor County ground-truthing trip

At the end of March, one project team member traveled to the study area in Grays Harbor County to perform ground-truth research at the site level for each proposed vertical evacuation site. There were a combined total of 32 sites in the three focus communities to inspect during the ground-truth trip. Each site was photo documented as well as significant attributes noted. Additionally, seemingly safe routes to natural high ground were noted throughout the area and mapped. It is important to note that these sites are conceptual locations only, not proposed locations. Particular parcels were not selected at this point. The overall preference is to find publicly owned parcels; however if not available, then potential willing property owners will be identified. If private parcels are used, the process would include assembling multiple parcels and negotiating with property owners. *(See Appendix D for site analysis.)*

After the ground-truthing trip was completed and the community given time to mull, the project team reconvened to analyze data and confirm the final strategy to be presented at the community design charrettes. In order to create the final strategy, the team utilized LiDAR elevation data in combination with wave height data for each conceptual site. Each conceptual site was designated berm, tower, or parking structure.

Final conceptual sites

The final conceptual sites were derived from the community participation processes with guidance from the project team. The sites and strategies were confirmed during the community mulling process and ground-truthing trip. Maps were presented at the community design charrettes and the open house meetings along with estimated capacities for each vertical evacuation site or structure.

It is important to understand how the necessary recommended minimum heights and capacities were calculated. Recommended minimum heights for structures were calculated by taking existing elevation, projected wave inundation depth, subsidence, and a margin of safety into consideration. For example, the minimum height of the structure refers to the minimum height of the top, safe zone, floor in order to ensure that the safe zone is *above* the wave. As implementation moves forward each community will have the option to increase the margin of safety and/or minimum height of the safe zone top floor. *(See Appendix E for structure calculations.)*

E. Community design charrettes

Safe haven design charrette process

A charrette is a product driven intensive design process guided by community input on vertical evacuation structure design and alternative uses. Through a series of exercises, design team interpretations and explorations, and discussions, community members guide and critique the

design process. Their ideas are interpreted and illustrated by urban designers from the University of Washington and cycled back to the community for approval and modification. The products of the safe haven charrette include design drawings such as plans, site sections, axonometric drawings, perspective drawings and three-dimensional models. These can be used as a basis for future detailed structure design.

The charrette process is designed to help foster creative and innovative thinking that is grounded within the feasible limits of community resources. The charrette phase addressed both the initially preferred structures identified in phase one; and explored hybrids and combinations as each specific site was assessed.

Tasks accomplished during the community design process:

- Refinement of site
- Refinement of structure type
- Determination of alternative uses
- Design of the form
- Discussion of access, amenities, facilities.

Preliminary potential sites were chosen for the charrette process based on an assessment of site conditions, populations served, and structure typologies. The charrette provided feedback regarding the strengths and weaknesses of these sites and offered opportunities for detailed site refinement. In addition, topics such as community amenities, emergency provisions, and methods of access to the structures were discussed.

The process for the Grays Harbor County community design charrette consisted of a three-day design charrette in South Beach and North Beach, and a two-day design charrette in Taholah, on the Quinault Indian Nation Reservation. The charrette outcomes include site location modifications and site-specific structure design concepts. Each concept is accompanied by urban design guidelines based on interactions between the design team from the University of Washington in Seattle, Washington, and Grays Harbor County community members.

The design process builds upon the vertical evacuation strategies that were developed during the first two public meeting series. Each developed strategy includes: target sites, human safe zone capacities, recommended safe zone heights to avoid inundation, and structure type community preferences. Locations and structure types were determined in association with the urban design implications of physical and planning contexts surrounding each site.

During the design phase, community members worked hand-in-hand with urban design faculty and students from the University of Washington, Department of Urban Design and Planning, College of Built Environments, to determine design options for the integration of vertical evacuation structures into the communities' existing and emerging built form. The design charrettes allowed community members to assist the design team in generating ideas for alternative community-benefit uses as well as designs for the vertical evacuation structures that fit the needs and desire of the local community while providing a safe and effective haven in the event of a near-generated tsunami.

The role of urban design in Project Safe Haven

Vertical evacuation structures are engineered towers, horizontal platforms, berms, or buildings designed to protect human life in the case of a near-shore generated tsunami. The physical impacts of the structures can have potentially negative impacts on these visitor-oriented communities and economies.

The University of Washington urban design team explored means and methods to embed the tsunami vertical evacuation structures into the existing and emerging built form with reduced negative physical impacts on neighborhoods, schools, commercial districts, parks and open space, etc. The community design process had three key objectives:

Table 6: Structure typologies

Structure Typologies			
Berm typologies	**Tower typologies**	**Combination typologies**	**Building typologies**
A. Single berm	A. Single tower	A. Berm-Tower Combinations	A. Full building
B. Segmented or clustered berm(s)	B. Modular tower	B. Berm-Building Combinations	B. Building component
	C. Tiered tower	C. Tower-Building Combinations	C. Basic shed
	D. Tower bridge		
	E. Horizontal platforms		

1. *To assess each site and surrounding area* for constraints and opportunities regarding the location of safe haven structures
2. *To identify alternative uses* for the safe haven structures that provide additional community benefit
3. *To incorporate or embed the safe haven structures into the community built form in a compatible manner,* supporting local uses and physical context.

Through the design process, impacts from these large structures can be visually modified and integrated or embedded into communities with multiple use community forms and facilities. The final design concepts presented in this report are guidelines for the community to follow during the implementation stages. In some situations, the vertical evacuation structures can be simple safe zone towers, platforms or berms with minimal design enhancement. In other applications, they can be significant public or private community activity nodes and centers.

Structure typologies

During the first Project Safe Haven public meeting phases, community members offered input as to which structure type is appropriate or preferred for each proposed vertical evacuation site: tower, horizontal platform, berm, or building/building component (see Table 6). The community design process was used to expand on this discussion in order to build a more in-depth understanding of which structure types are appropriate for specific sites. During the community design charrette, four basic structure typologies were identified; berms, towers, buildings/building components and combination structures. These typologies are the basic applications and are available for many multiple use applications.

All structure typologies will be engineered to withstand both earthquake and tsunami forces. The safe zones on structures are the areas above the inundation elevation. The design heights and capacities used are conceptual and have been determined according to the most recent tsunami modeling. A significant amount of site-specific scientific and engineering research will be done for each site prior to implementation. All designs presented in this report are conceptual in nature.

As such, individual details such as methods of ingress and egress and railing height and materials require further exploration. Design details can be sacrificial (damaged or destroyed during an event) with the hardened safe zone structure remaining intact. Shelters, non-motorized winches, and other climate protection features are optional components and can serve as community amenities for everyday use. Bathroom and storage facilities for basic supplies such as water, medical supplies, and tarps are additional options.

Berm structures

Berm structures are artificial mounds comprised of earth, rock and steel components (see Figures 13 and 14). Berms are generally accessed by means of

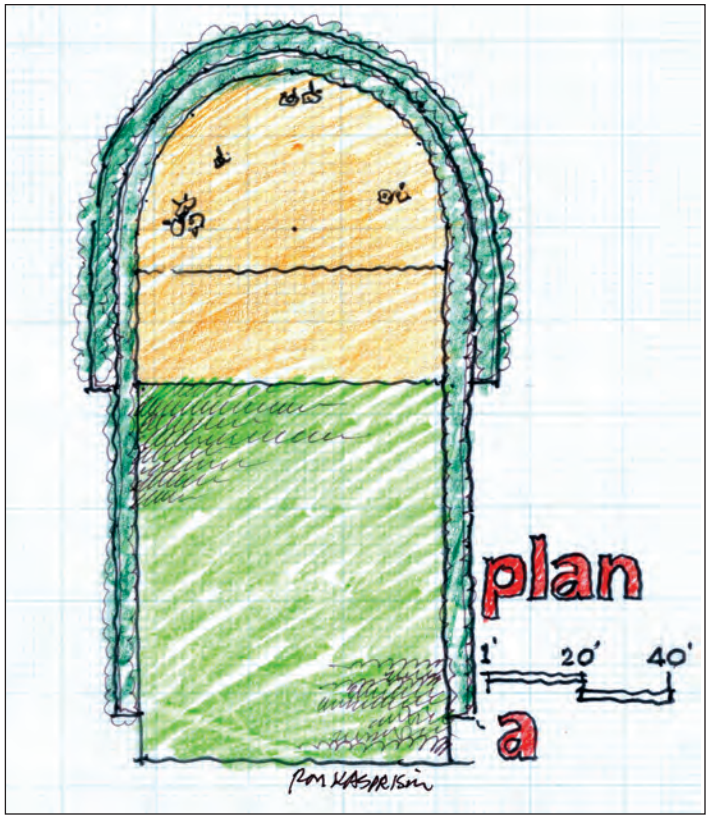


Figure 13: Basic berm structure in plan view
The basic single berm structure is a mounded buttress composed of a hardened front façade (rock, steel and/or concrete) and rear sloping access ramp. These basic single berms provide accessible entry and can be integrated as a natural feature in less developed areas with available open space. A modified version of the basic berm is also included to exemplify the many variations that are possible, based on site and cost constraints.

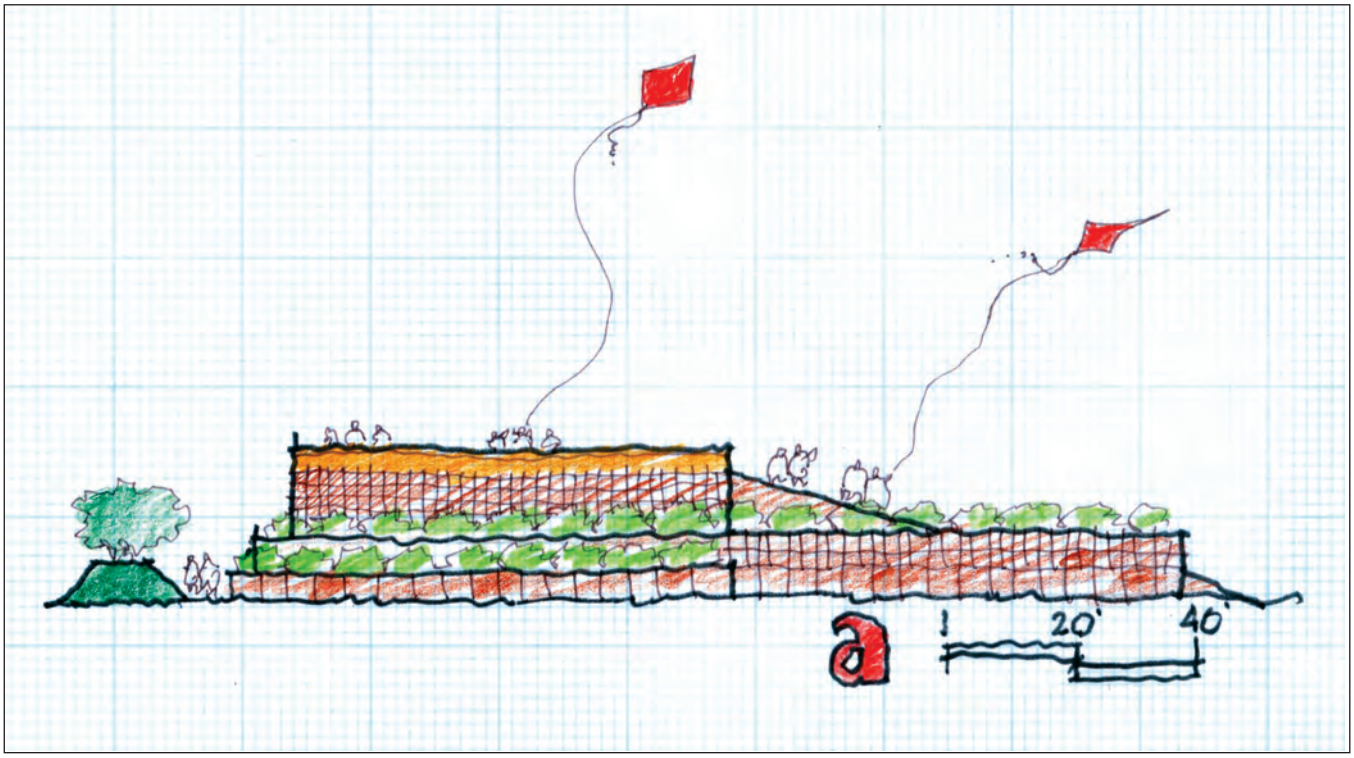


Figure 14: Basic berm structure in profile view
The basic single berm structure can be modified to enhance its visual appearance and utility. There are many variations based on local need and budgets and can include the addition of recreational facilities, landscaping and weather protection.

a sloped walkway or ramp incorporated into the berm structure. The berms can be entirely hardened as safe zones; or, they can have sacrificial components surrounding the safe zone that are subject to damage during an emergency event. Berms can be incorporated as natural features such as land forms in less developed areas; as viewing and seating areas for athletic fields, as play areas and parks, as visitor attractions and event facilities or as noise barriers near airports and industrial areas.

The sloped sides of the berm allow for a wider range of human physical capabilities than any of the structure types. The sloping conditions of all or part of the berms can greatly expand the footprint of the safe zone. The footprints for the higher berms can have a significant negative impact on the built form of smaller communities and areas of limited land availability. These factors were considered in more detail during the design charrette.

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. Alternate uses vary according to location and context. Single berms can be effective in reducing negative visual urban design impacts when sufficient land area is provided for the base footprint. They are less suited for smaller urban sites. The design of individual berms can incorporate numerous features to improve compatibility with the surrounding area including landscape features and natural features such as wetlands, ponds, etc.; and formal forms as sculpted mounds or pyramids.

Berm typology B: segmented/clustered berm(s)

Segmented berms are separated structures, possibly clustered, that disperse safe zones within a given site to reduce the size of the footprint or to adapt to site-specific form-functions. 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 and undeveloped open space.

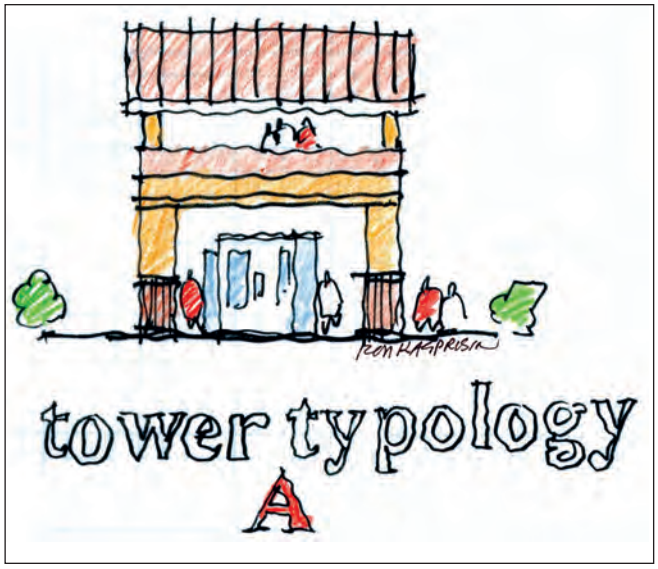


Figure 15: Basic tower structure
A basic tower structure is a horizontal platform elevated above inundation levels by vertical supports. The at-grade level is open and can have additional rock or concrete barriers to break up wave-born debris. This sketch depicts a basic tower with second level viewing platform and optional shelter or roof. Lower level is used as an information area with breakaway or items that can be sacrificed in the event of a tsunami.

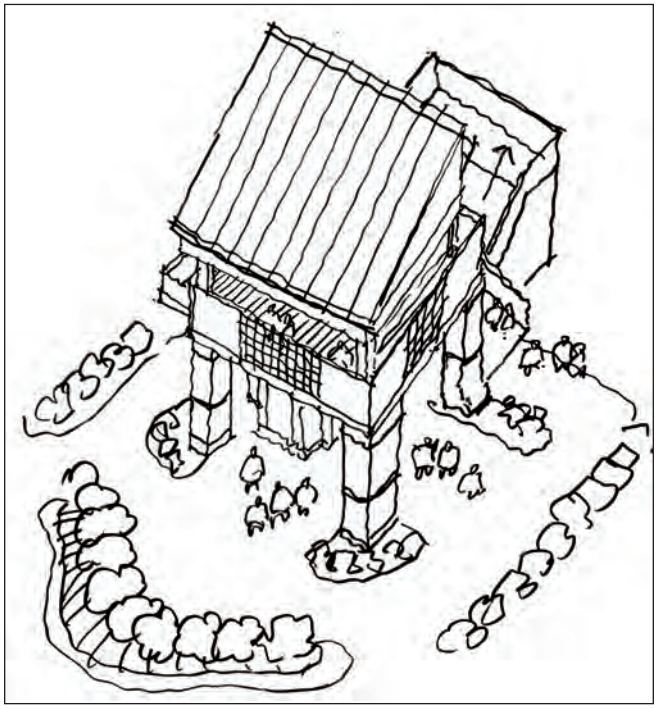


Figure 16: Basic tower structure in axonometric view
Basic design improvements can add temporary activities on the ground level such as an information booth, landscaping, cladding materials for appearance, and a roof shelter.

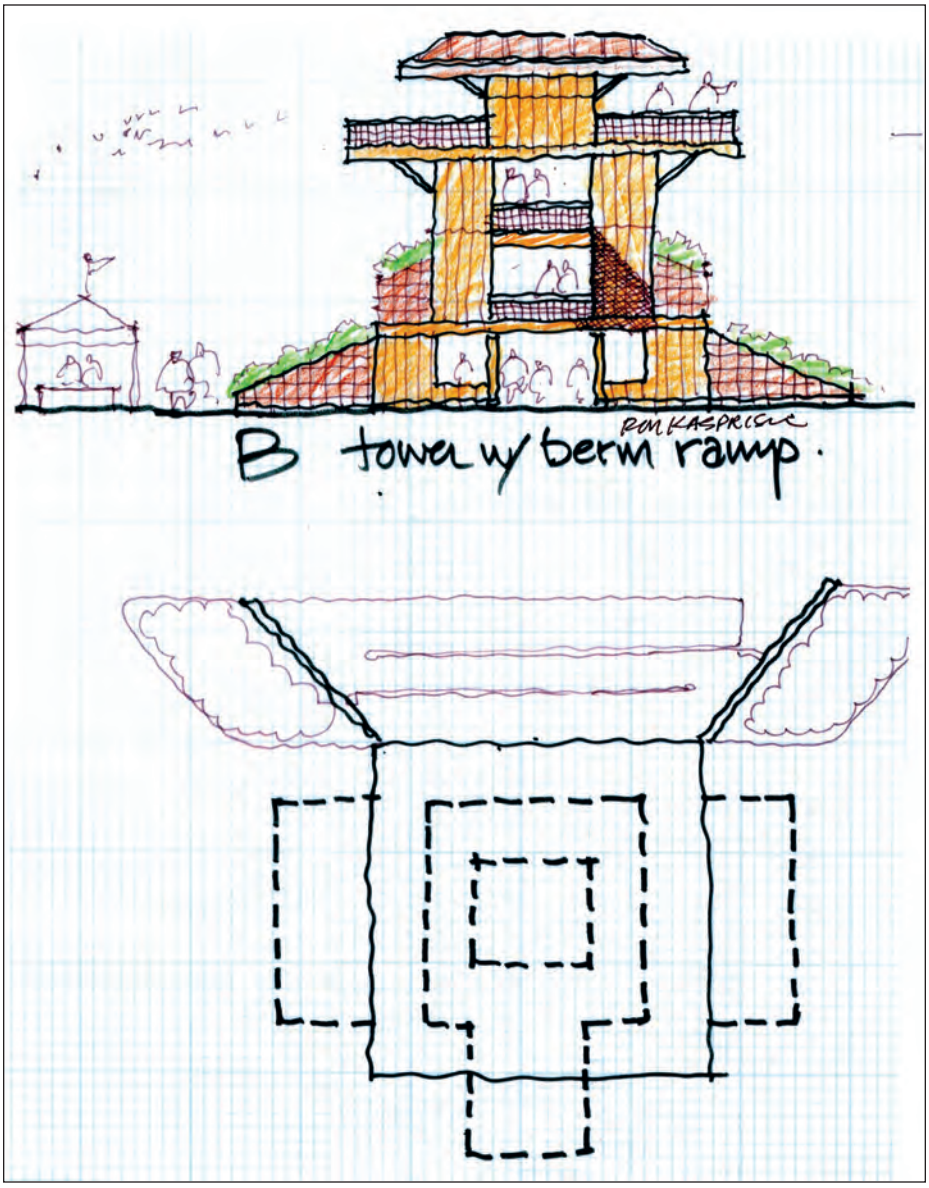


Figure 17: Tower ramp concepts
In this drawing, a basic access core is comprised of a series of four to six feet wide ramps with accompanying landings. In the example, the ramps each gain four feet height over 16 feet horizontal run to provide adequate head room on the access core. The core can be compacted or configured into a larger square geometry depending on the size of the safe zone levels.

Tower structures

Tower structures are elevated safe zone platforms with the height greater than the width, supported by vertical structural members. The platforms can be freestanding in geometries such as a square, rectangle, circle, and other geometric shapes depending upon local use and context. Towers have a smaller footprint than berm structures for the same number of people and can be accessed by stairs, ramps, and mechanical vertical assists in non-emergency situations; and, manual vertical assists such as winches for emergency events. Access to tower structures can be restrictive to physically challenged and aged people if stairs are the only access provided.

Towers can accommodate a wide variety of alternative uses: visitor centers, in which the at-grade level acts as sacrificial office or display areas, viewing platforms for scenic and/or wildlife areas, in conjunction with community water towers, festival entry structures, elevated pedestrian bridges, among other uses (see Figures 15 and 16).

Tower typology A: single tower

Single towers may be the most appropriate structure type where alternative uses are not feasible and/or land is limited. A wide range of alternative uses with the basic tower are possible such as shops, information booths, storage areas, etc. The

ground level floor area can be accommodated as open space or with sacrificial uses ornamentation. In most tower designs, the grade level is open or occupied with elements that can be sacrificed.

Tower typology B: modular towers

Modular towers break the estimated tower size into smaller components. These towers are ideal for phased construction or to spread out the austere impacts of larger towers; and are appropriate where small pockets of land are available as scattered parcels throughout a community or where access within the walking radius is restricted due to physical barriers. They can either be segmented or clustered and contain multiple safe haven platforms within a given project site. In order to enhance integration into the desired built form the tower levels 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: tower bridge

A tower bridge structure connects 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 water course crossings, or as a connection between free-standing building connections. The tower bridge can either be affixed to two structures designed to withstand earthquake and tsunami forces or can have an independent support structure.

Tower typology D: tiered towers

Tiered towers can reduce the size of the safe zone imprint on smaller sites by stacking safe zones vertically with a number of levels. The lowest platform level exceeds the minimum inundation elevation and provides access for physically challenged persons using a ramp core design. Upper tiers can be available for physically able persons to access by stairs or ladders to reduce overall footprint.

Tower ramp issues

Towers have the smallest footprint when compared to berms and tower-berm combinations. Their standard means of access are stairs that present a design issue with access for elderly and physically challenged people. The following design concepts explore the incorporation of ramp-landings in tower structures to replace or complement stair structures (see Figure 17).

Horizontal platforms

Platforms are horizontal planes on vertical supports. They differ from towers in that the horizontal dimension greatly exceeds the vertical dimension and may have a significant footprint within the built form, particularly with larger safe zone capacities. A platform can accommodate a large capacity of people and presents design challenges with light blockage and security issues for the at-grade space.

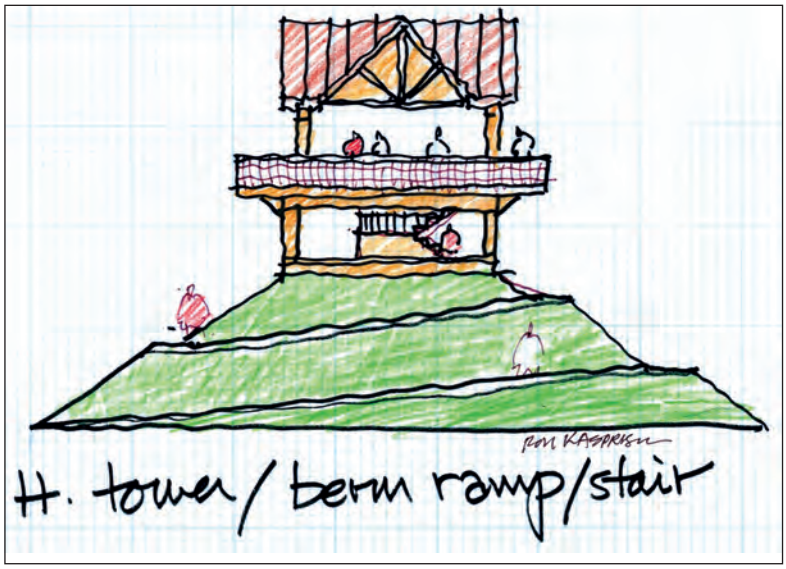


Figure 18: Combination berm-tower structure in profile view
Combination structures offer the advantages of two types of structures: berm and tower. In the berm-tower combination, the footprint in reduced by creating a tower platform that is accessed by a series of ramps and/or sloping berms and can reduce visual impacts of hardened towers or large berms.

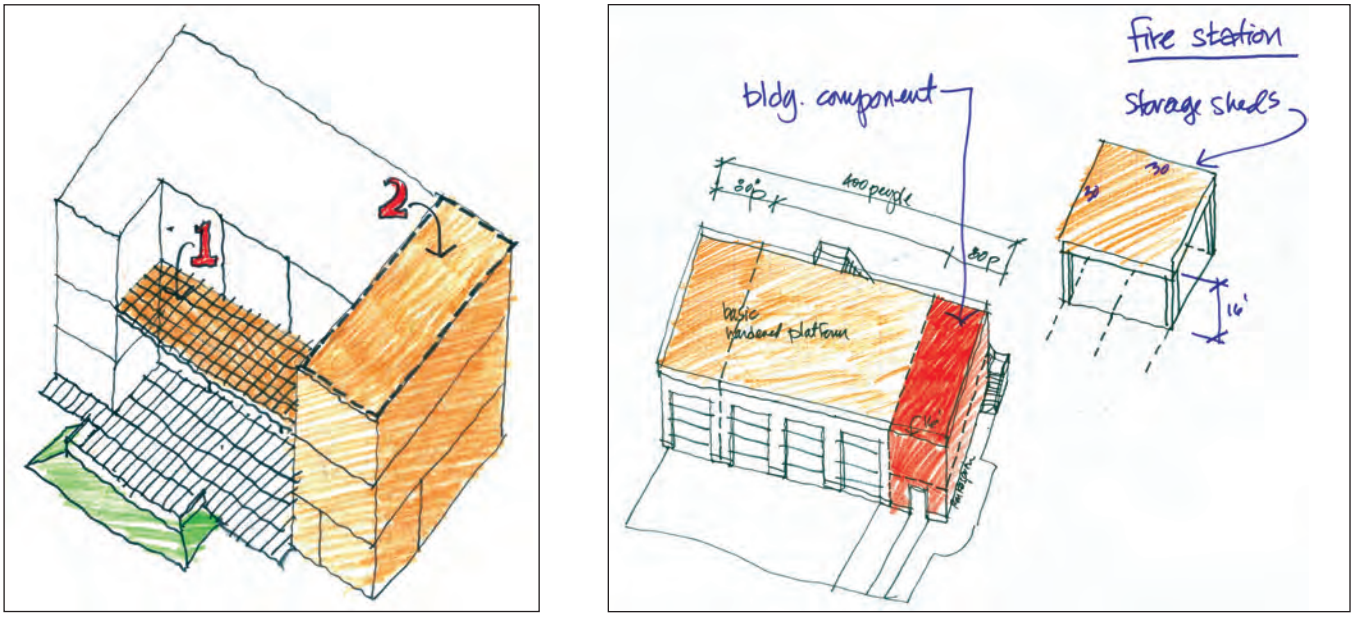


Figure 19: Basic building structure as safe haven
Basic building structures such as fire stations, and public works facilities such as garages and maintenance buildings, without more costly public spaces and amenities, can provide safe haven zones on the roofs and upper storage lofts, etc.

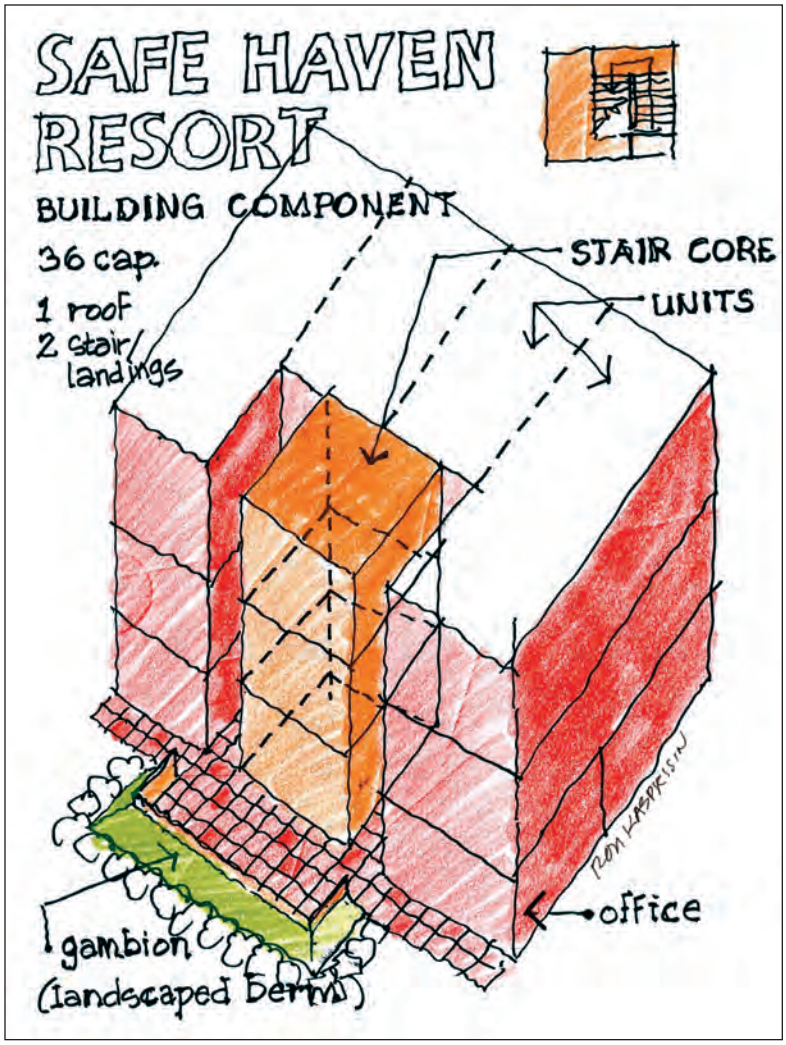


Figure 20: Building components can serve as safe havens

Combinations

There are a number of design alternatives that offer hybridized 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, increasing access capabilities for physically challenged persons (see Figure 18).

Combination typology A: 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.

Combination typology B: 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, fire stations, public works garages, industrial buildings, pedestrian overpasses, etc.

Combination typology C: tower-building combinations

Tower structures can be incorporated into new buildings to provide safe zones and reduce the construction costs of safe zone hardening for the entire building. Examples include entryway-lobby areas in public buildings such as city halls, swimming pools, basketball gymnasiums, convention centers, etc.; private commercial buildings such as shopping malls, office buildings; hotel and resort buildings; and stair towers, elevator cores, etc.

Buildings

Building designs can incorporate safe havens into an entire building or a building component. Hardening an entire building structure can be cost prohibitive for smaller communities, thus the recommendation for building components. Examples of complete building safe havens include fire stations, public works garages and other basic building structures.

Building typology A: entire building

Hardening an entire building is an opportunity to provide safe haven for a large number of people in a centralized area. Example applications include new civic buildings, parking structures, public works buildings and fire stations.

Building typology B: building component

Building components allow for decentralized and smaller safe haven structures. Safe haven building components reduce costs for both public and private construction. Stairwells, entry lobbies as towers within a building, and second level uses are examples of building components that provide opportunities for safe havens (see Figure 20).

Building typology C: basic shed

The basic shed is a simple structure, similar to the basic tower, that is semi-enclosed with a flat roof as the safe haven or interior loft with shed roof. The grade level uses and materials are designed to break away in a tsunami event. The basic shed can include: facilities sheds, public restrooms, farmers' markets sheds, covered outdoor recreational shelters, viewing platforms, and picnic shelters.

F. Grays Harbor County tsunami vertical evacuation structures

Site-specific and multiple use design concepts

South Beach

Introduction

The area commonly referred to as South Beach is located on a peninsula in Grays Harbor County, along the southwestern Washington coast. The peninsula is situated between the south bay of Grays Harbor, Grays Harbor to the west, and the Pacific Ocean. The peninsula is approximately 7 miles long and 1 mile wide. Approximately 2,700 people reside in the City of Westport and the population of entire South Beach area is approximately 4,000 people. Westport is the home to a commercial and sport fishing fleet under the auspices of the Port of Grays Harbor.

Figure 21: South Beach preferred community strategy
The map shows the vertical evacuation structures located throughout the peninsula, with their accompanying identification numbers.

The peninsula is exposed to the weather systems of the Pacific Ocean with significant low land area elevations in populated areas. The area is susceptible to tide, wind, wave and tsunami conditions and combinations. The existing high ground in the southern area of South Beach has steep slopes and limited accessibility.

Westport and South Beach vicinity design charrette

The Department of Urban Design and Planning within the University of Washington's College of Built Environments, Seattle, Washington, conducted a three-day design charrette in South Beach on April 13th, 14th, and 15th, 2011. The design team consisted of an architect/urban planner faculty member and two graduate students. In addition to the design team, staff from the State of Washington Emergency Management Division and Grays Harbor County Emergency Management assisted with the charrette operations.

The design team engaged community members through a series of open discussions and hands-on interactive activities to both familiarize attendees with preliminary site selection and elicit comments and suggestions for design and alternative site review. During the first day community members offered feedback on the preferred community strategy that was derived during the initial phases of Project Safe Haven and identified, in more detail, opportunities and constraints for site selection and alternative uses for the proposed vertical evacuation structures.

During day two, April 15th, the design team developed concepts for vertical evacuation structures identified on day one and interviewed representatives from the Port of Grays Harbor County, the City of Westport and volunteer firefighters in order to determine potential projects for vertical evacuation structures. Community members provided feedback during the open-house phase of the session. In the evening meeting, community members provided additional feedback on the strengths and weakness of each design conceptualization for the team's assessment on day three.

On day three, April 16th, the design team refined conceptual designs from the previous meetings based on community feedback. In the final evening meeting, community members provided final feedback on the strengths and weakness of new design conceptualization as well discussion of overall preferences for type and locations.

Further analysis is required on all design concepts in order to determine the final safe zone heights, engineering and cost feasibility. No specific sites or projects have been identified for construction.

Overall strategy

The preferred community strategy developed in the initial phases of Project Safe Haven includes nine sites for future vertical evacuation structures (see Figure 21). The estimated capacities for the South Beach area structures range from 550-1,500 persons. The larger of these capacities require prohibitively large structures, resulting in additional design conceptualizations to divide them into a number of smaller structures.

G. Design concepts by selected sites: South Beach

The design concepts for each site discussed during the design charrette are detailed below, in order from north to south.

Site 1: Port of Grays Harbor

Marina Uplands/Marina Retail District

- Elevation: 17 feet
- Capacity: 1,500 people
- Safe Zone area: 15,000 square feet

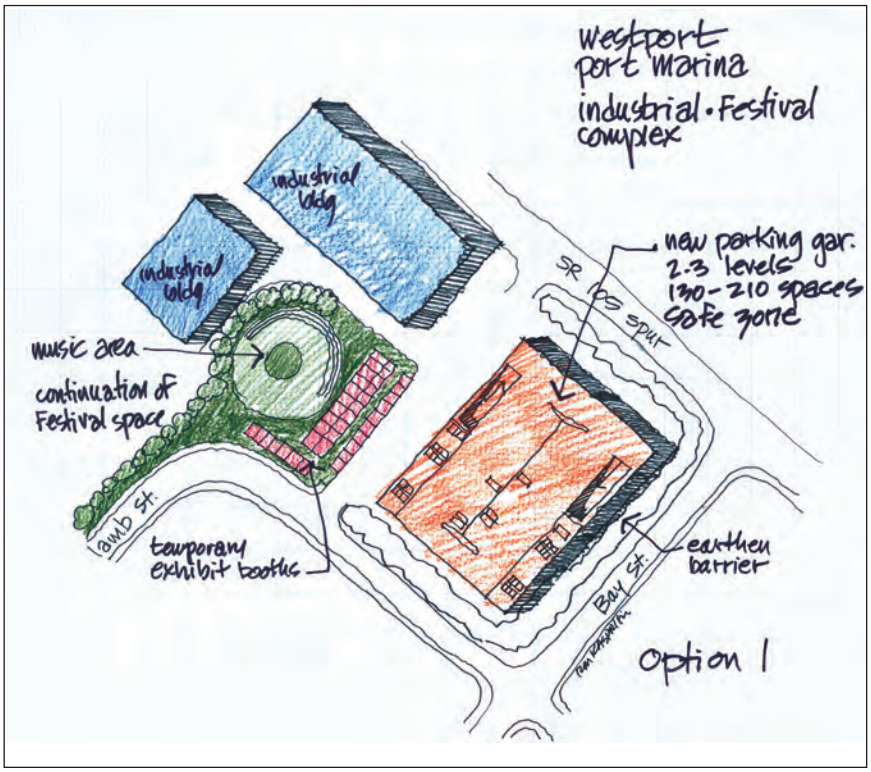


Figure 22: Industrial park/parking garage/festival complex
This illustration depicts a two to three level parking garage surrounded by earthen debris deflection barriers.
A small festival market area can be incorporated into a new building complex with a widened walkway along Lamb Street connecting the complex to the waterfront.

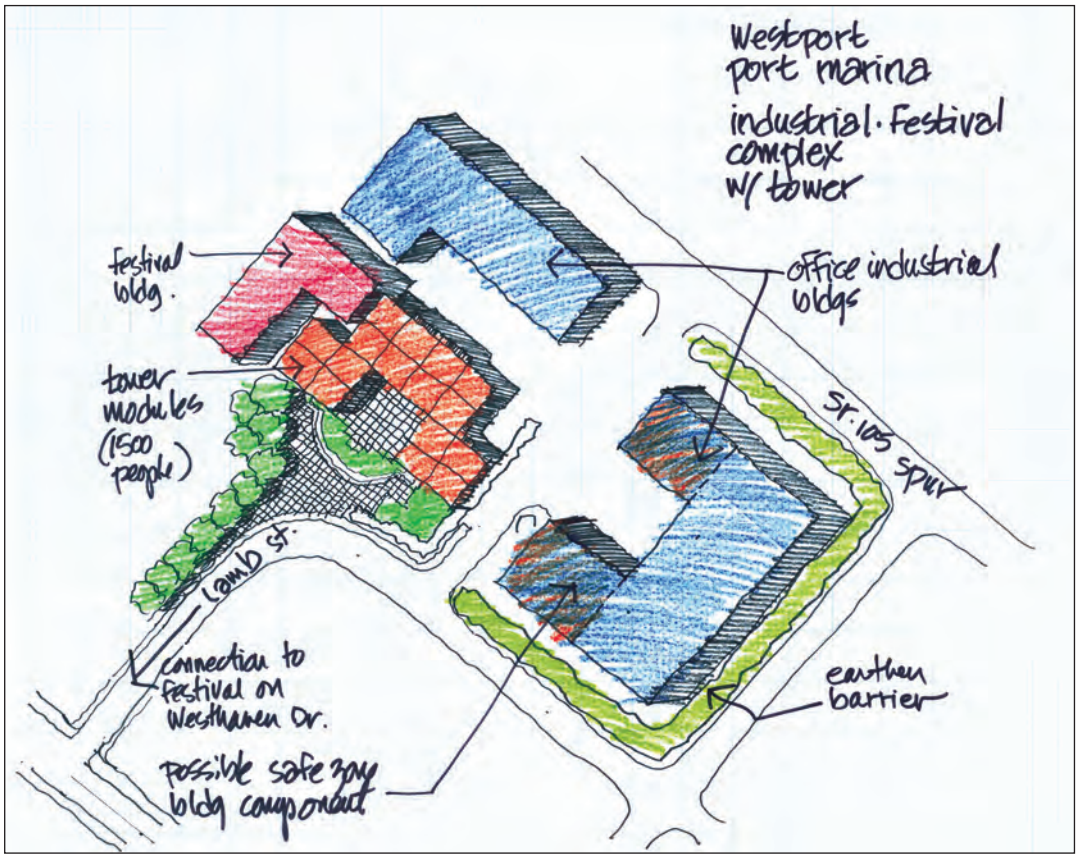


Figure 23: Industrial festival complex
A festival market facility as a part of a new industrial park.

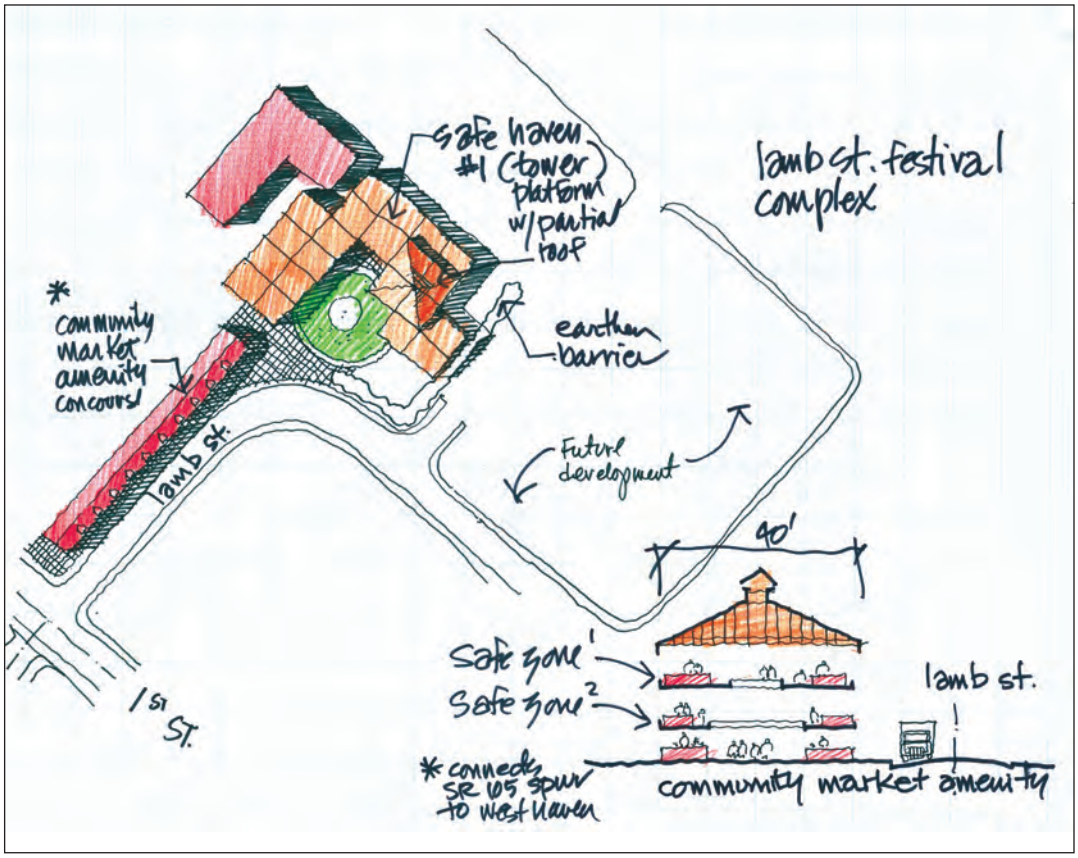


Figure 24: Lamb Street festival complex
Festival market facility connecting to the waterfront tourism area.

Site characteristics

The Marina uplands and retail district is a grid street pattern on flat and filled lands at the northern tip of the peninsula at the southerly entrance to Grays Harbor. Retail buildings are essentially one story in height and industrial and marine related commercial can approximate three stories in wooden and concrete tilt-up buildings. Urban blocks to the southwest of the established retail area consist of vacant undeveloped parcels and paved parking areas, particularly along Third and Fourth Avenues and SR 105 Spur.

The design team and the participating community members reviewed the phase one recommendations for capacities on the Westport structures and determined that the platform structures required to accommodate these capacities presented a negative impact regarding size and area covered. The following describes the explorations for accommodating the 1,500 person capacity in single platforms and dispersed platforms and tower sheds.

Design concept 1: New industrial park with parking structure and festival complex

A new industrial park can provide impetus for a parking garage as safe haven structure, with significant capacity (1,500) people or more. Incorporated into the new complex is space for a temporary or seasonal festival market area with booth and exhibit area as a part of the industrial complex; and connecting that complex to the waterfront via Lamb Street (see Figure 22).

Design concept 2: Industrial festival complex

A new office/warehouse complex can incorporate safe haven building components into the new warehouse construction. A permanent festival

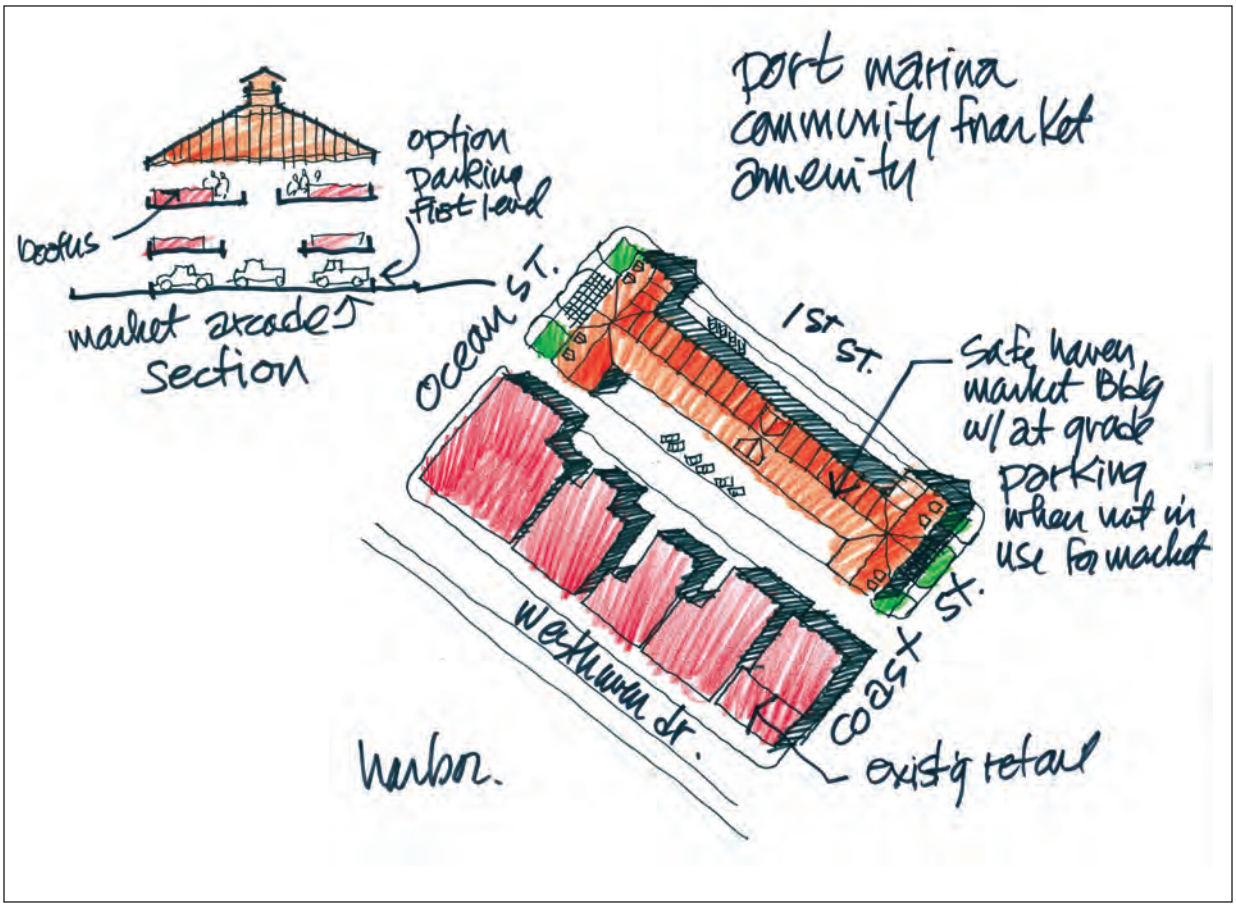


Figure 25: First Avenue community market and parking lot
Use of the existing parking lot for a safe haven market festival complex

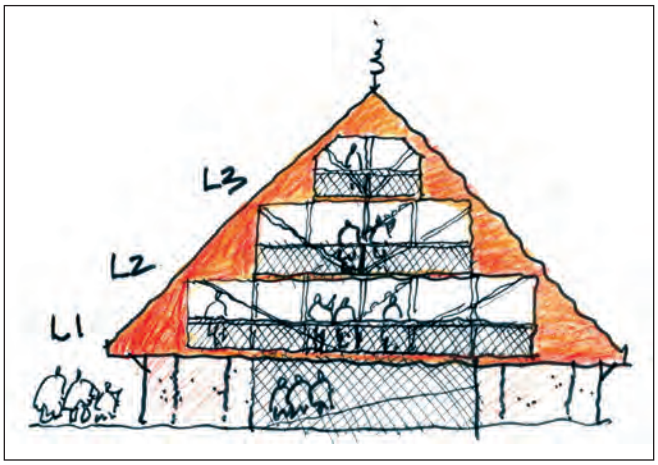


Figure 26: Observation tower/open warehouse facility Semi-enclosed ground level storage uses with fenced siding materials. The upper level is pyramid shaped to reduce mass of the structure.

building forms a complex with tower modules that comprise a covered festival/flea market complex constructed of modular platforms that can be phased in over time, with a total capacity of 1,500 people. A pedestrian and festival open space for music venues etc. is at the curved corner of Lamb Street with a major pedestrian connection to the waterfront (see Figure 23).

Design concept 3: Lamb Street festival complex

Comments from community members repeated a desire for a permanent location for seasonal festivals celebrating the fishing and crabbing industry, local arts, and area merchants. This concept uses a tiered market shed structure with multiple safe zones in a semi-enclosed exhibit structure. The building has a permanent roof and open sides with removable weather protection materials, all of which can be sacrificed in a tsunami. A tower can be a part of the market complex for viewing, informal dining, etc. Finally, a one-story market shed concourse connects the larger complex to the waterfront area along Lamb Street, energizing that street with stalls and booths. Alternate uses for off-season include covered parking, and net and pot storage areas (see Figure 24).

Design concept 4: First Avenue community market/parking lot

First Avenue Community Market is constructed on existing surface parking lots behind the commercial strip on Westhaven Drive and retains those parking lots for use when festivals are not in session. The market sheds are constructed to allow for a parking space grid under the canopies. Safe haven safe zones can be limited to the two end sheds, each with a second level as safe zone; or the entire facility can have a loft safe haven (see Figure 25).

Design concept 5: Observation tower/warehouse facility

Located between 3rd and 4th Avenues, a marine related warehouse facility can accommodate fishery and crab fishing equipment in a fenced in semi-enclosed area on the ground level with concrete structure up to and including the second floor safe zone; above that level the structure is heavy timber construction serving as additional storage area and/or safe zones (see Figure 26).

Site 2: Downtown building structure

Site variable

- Elevation: 17 feet
- Capacity: 1,000 people
- Safe Zone area: 10,000 square feet

Design concepts

A number of new buildings are possible for downtown Westport, ranging from a new city hall to a parking garage to a new fire station. Downtown Westport is spread out and low in development intensity due to the street and circulation pattern (SR 105 Spur, Grant Avenue, Spokane Avenue, and Forrest Street. Fire stations are a preferred safe haven building component in that one or more bays can be hardened as safe haven components rather than an entire and costly structure such as a parking garage.

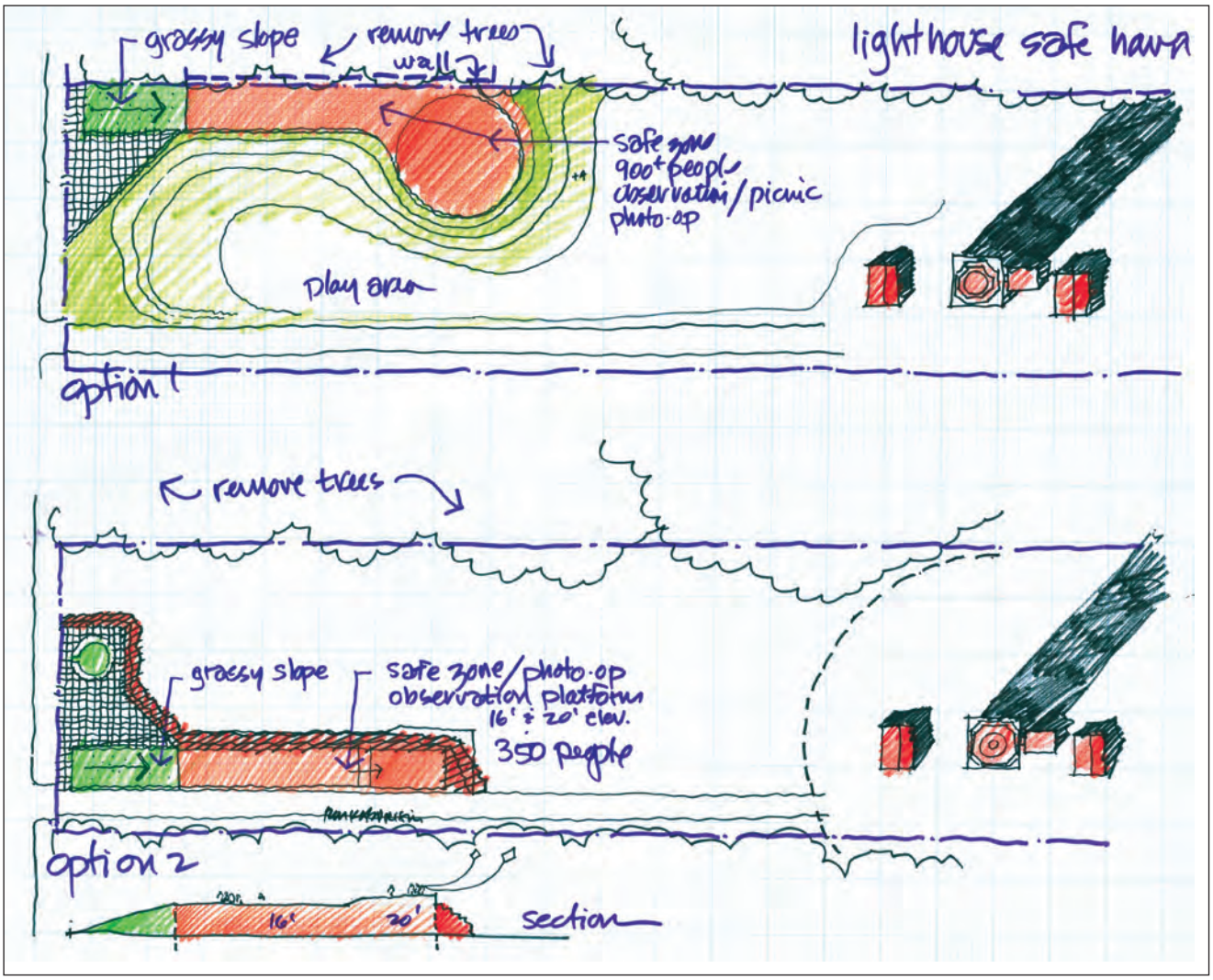


Figure 27: Westport Lighthouse photo-op concepts
Concepts 1 and 2 portray to ideas on providing photo-viewing areas as safe havens without blocking or negatively impacting the views of the historic lighthouse.

Site 3: Westport Lighthouse State Park

Grant Avenue and Surf Street vicinity

- Elevation: 17 feet
- Capacity: 900 people
- Safe Zone area: 9,000 square feet

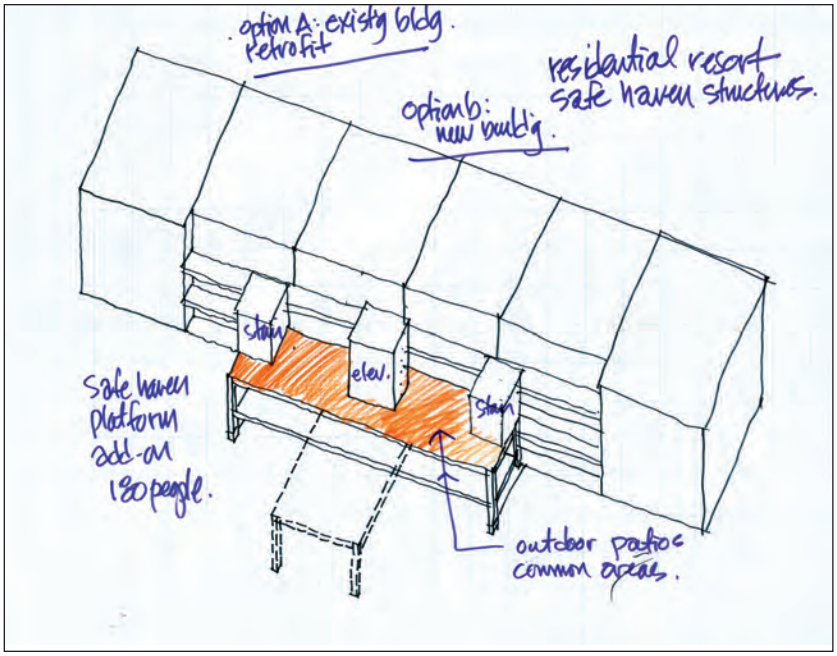
Site characteristics

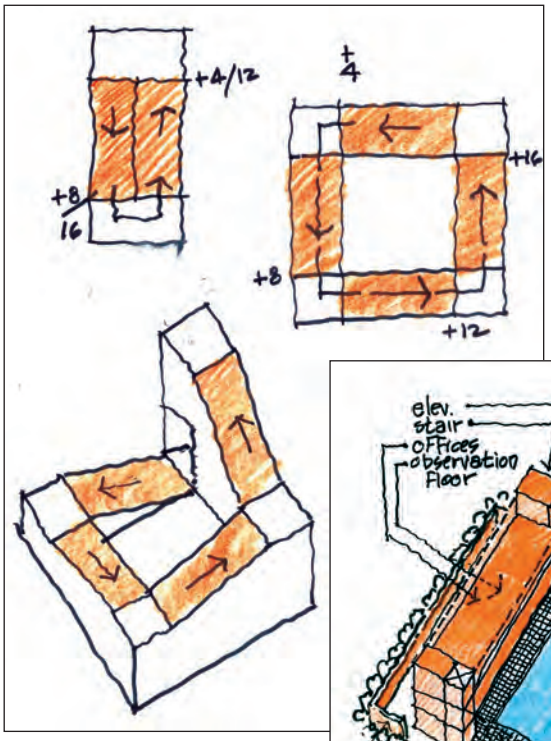
The site is a narrow slice of land, approximately 200 feet wide and over 800 feet in depth. The site drops to the northwest and north and rises again at the historic Westport Lighthouse tower and outbuildings in the northern portion of the site. A service access road connects Grant Avenue to the lighthouse along the eastern site boundary. US Coast Guard recreational properties occupy lands to the west, north and east (ballfields and covered recreational area) of the site. A forested area occupies the land to the west and immediate east. A small seating and viewing area is located at the southern edge of the site on Grant Avenue.

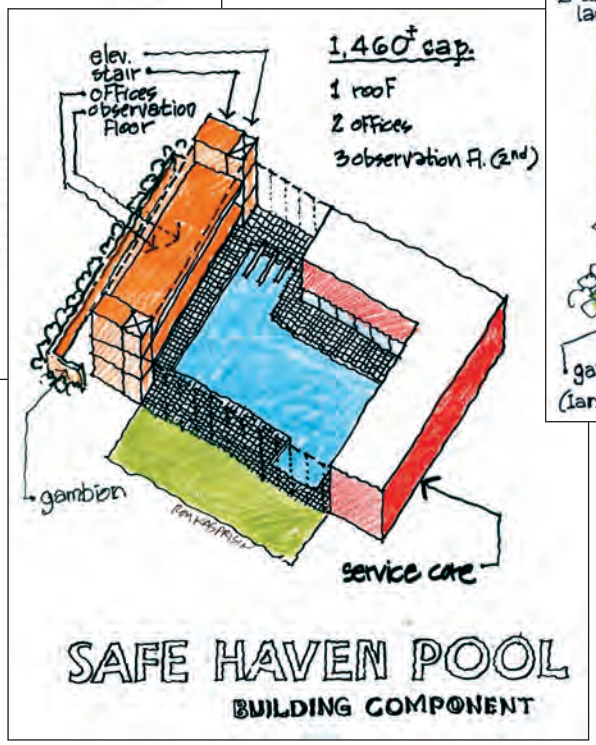
Design concept 1: Photo-op knoll

The historic Westport Lighthouse is a visually attractive feature in Westport and dominates the site as the structure is framed by the long narrow site bounded by thick tree cover. Placing a tower or platform on the site can significantly damage

Figure 28: Concept 1 — Hardening existing multi-story buildings
(drawing to right) Existing multi-story building structures, most of wood-frame construction, may not withstand both an earthquake and a tsunami event due to soil conditions, foundation design, and other factors. Hardening the entire building may be cost prohibitive in most cases due to insufficient foundation structures regarding wave action. This illustration (plan and axonometric drawing) depicts safe zone additions to existing buildings: additions such as recreation decks, entry canopies, and other community spaces that can be attached to or placed adjacent to existing buildings.







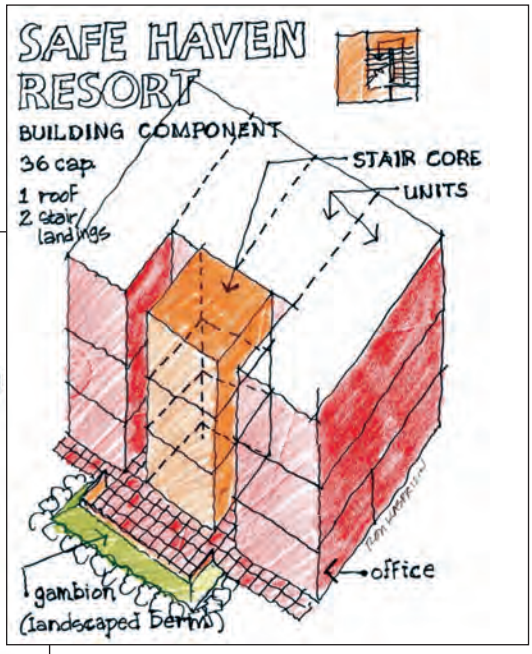


Figure 29: Concept 2 — Building components in new construction
(three drawings above) Key components of new resort, hotel and multi-story residential buildings can include entry lobbies, recreational decks (1), end unit stacks (2), elevator and stair cores. Tax credits and zoning incentives may assist private sector developments attain and incorporate safe zones in portions of new building complexes.

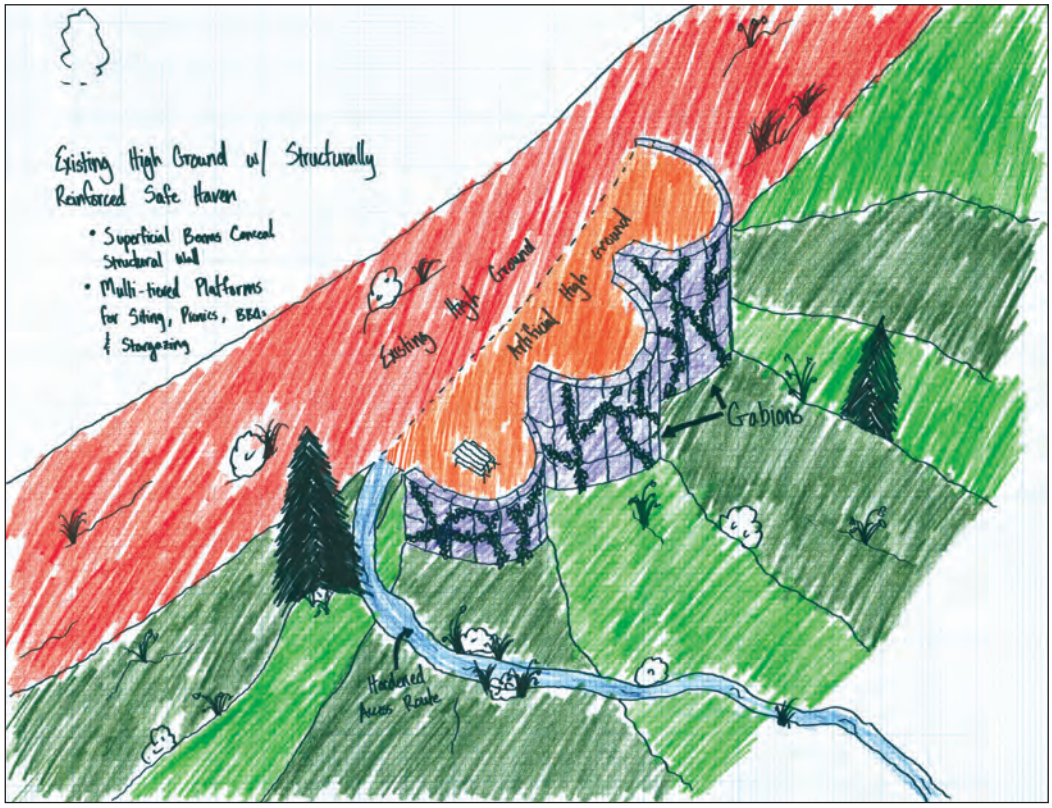


Figure 30: Concept 3 — Reinforced sand dune as safe haven
The north-south sand dune through the central Westport peninsula offers vertical zones for safe haven. The dunes may or may not be of sufficient structural integrity to withstand both earthquake and tsunami events. This illustration depicts a concept discussed during the charrette regarding the reinforcement of key locations within the sand dune for safe zones. By using reinforced rock or textured concrete walls, with planter options in stepped or tiered configurations, the safe zone can be a part of the land form with hardened trail-ramp access, providing recreational space for neighborhood picnics, barbeque areas, fire pits and general play and community gathering areas.

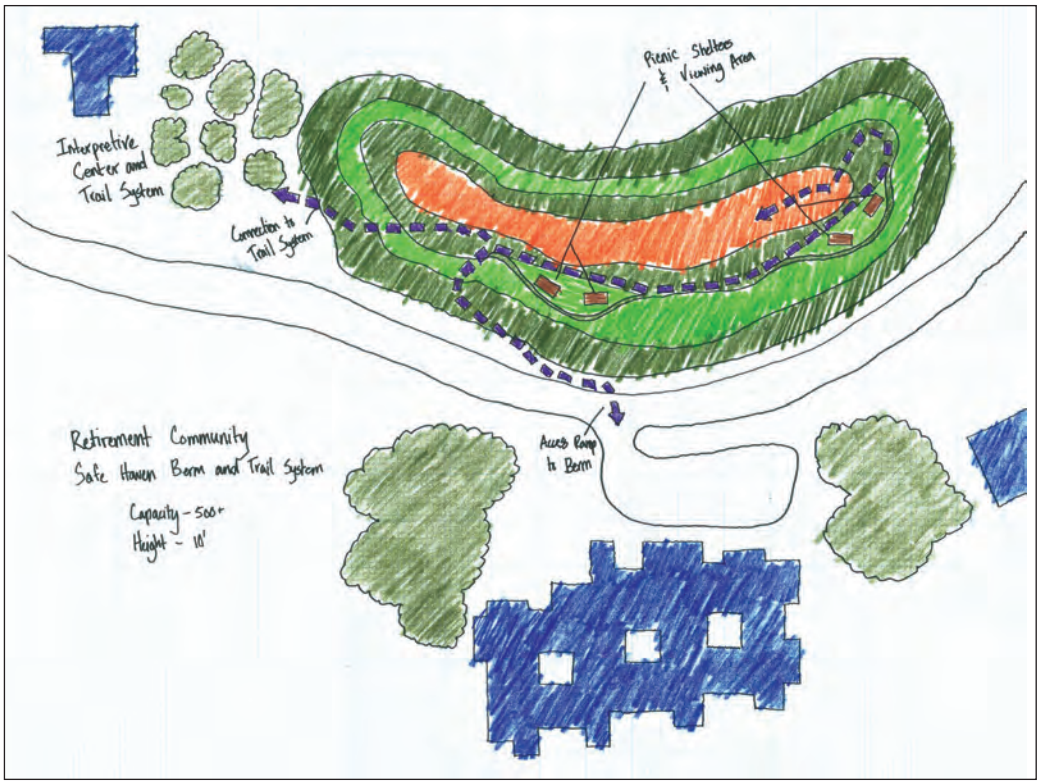


Figure 31: Concept 4 — Retirement community dune
Another variation of dune reinforcement consists of adding a structured berm adjacent to the natural n-s sand dune with a safe zone. The new "dune" berm can contain an interpretive center, trail connections, and other amenities for neighborhood activities.

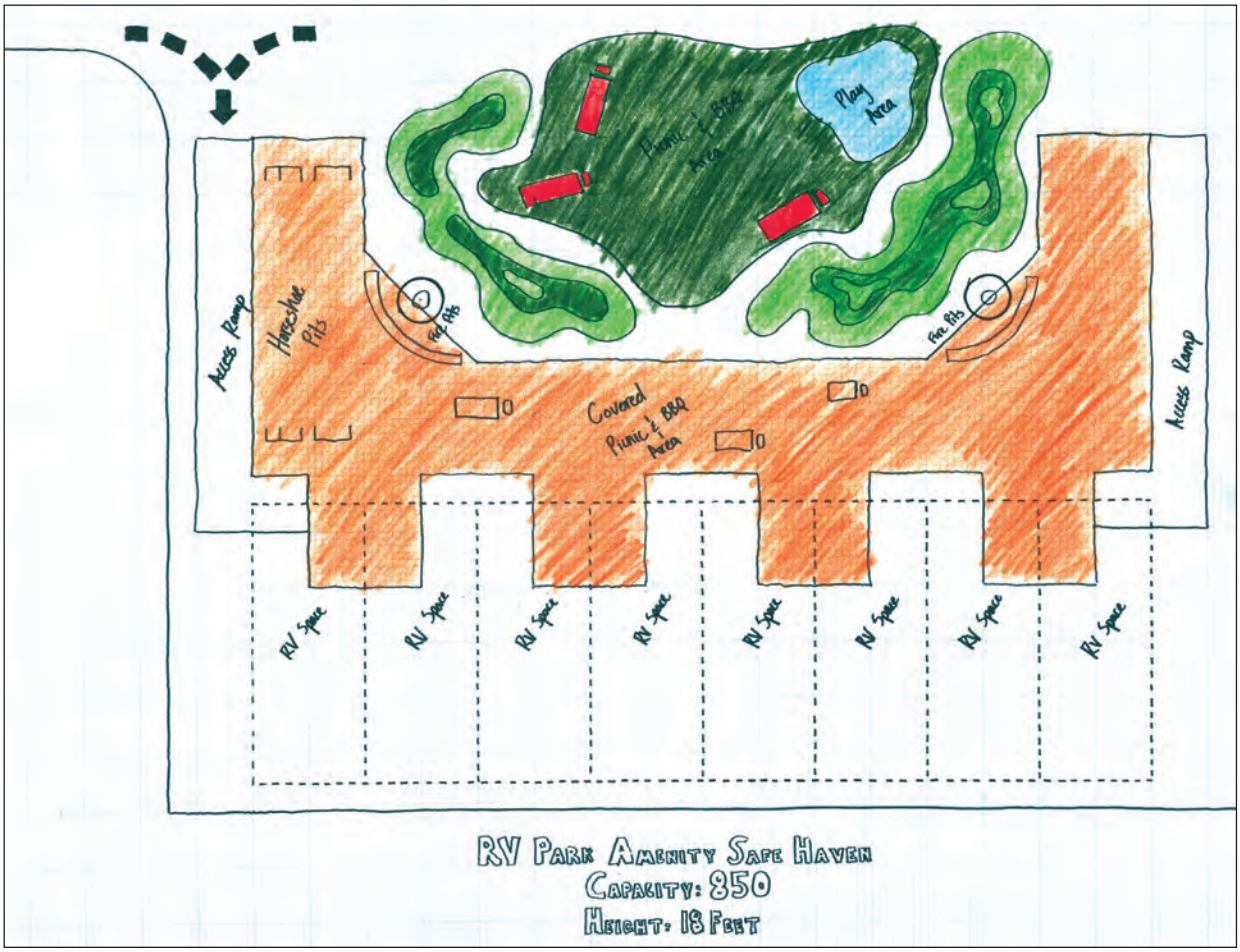


Figure 32: Modular platforms
Smaller modular platforms can be incorporated into the numerous recreational vehicle parks and facilities typical throughout the Westport area. The platforms can be used as a covering for protected play, picnic areas, restroom and bathing facilities, and integrated with outdoor recreational facilities.

the scenic value of the historic structures and the site. In design concept 1, an elongated knoll is located along the western site boundary with a grassy slope access ramp (one feet vertical to four feet horizontal) rising to a 40 feet wide concourse-safe zone that terminates into an observation and picnic knoll for the lighthouse; all without blocking views of the historic lighthouse complex.

A gentle slope descends to the north and east into the lighthouse site and foreground area for further picnic and passive recreation activities. Design concept 1 is better suited if the existing trees to the west are removed a safe distance from the safe haven structure due to debris affects; or, a debris deflector berm-wall is constructed along the western edge of the structure.

Design concept 2: Photo-op ramp

Similar to concept 1, the second idea expands the viewing area at Grant Avenue and portrays the safe zone as an elongated observation and photo-op platform constructed along the western edge of the existing service access road into the site. A sloped ramp provides access to the 17 feet level that continues to an additional 20 feet high by 50 feet long level at the end of the ramp and closest to the lighthouse complex. This concept is long and narrow due to the location of the lighthouse complex on the northeastern portion of the site; reducing any view blockage of that complex (see Figure 27).

Site 3: Forrest and Newell

Resort and residential complex developments

- Elevation: 14 feet
- Capacity: 900 people
- Safe Zone area: 9,000 square feet

Site characteristics

A high sand dune feature traverses the Westport area in a north-south direction from north of the lighthouse site along and south to approximately Schaefer Road. The area is occupied by multi-story (3-4 stories) resorts, hotels and residential complexes, as well as a number of recreational vehicle parks.

Design concepts 1 through 4

There are a number of approaches illustrated here that flow from the design charrette process and include: (1) hardening the construction of existing multi-story resort and/or residential buildings in this north central area of the Westport area; (2) constructing hardened building components as a part of new private sector multi-story developments; (3), reinforcing the existing north-south sand dune in key areas as safe haven; and, adding to the dune with a new "dune" berm structure (see Figures 28 through 31).

Site 5: Ocosta School

Montesano Street S. and Woodhill Avenue E. Vicinity

- Elevation: 11 feet
- Capacity: 1,500 people
- Safe Zone area: 15,000 square feet

Design concepts

As in other elementary and high school sites in coastal communities, there is sufficient land and opportunities for safe haven vertical evacuation structures of considerable size. The potentials with the Ocosta School Site include and are not limited to the following:

- Covered outdoor recreational sports and play areas, with the roof structures serving as the safe zone platforms

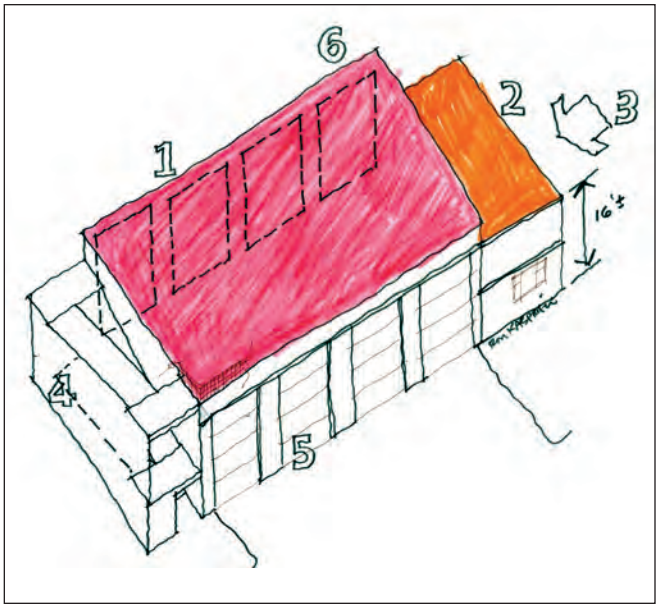


Figure 33: Grayland Fire Station concept

- Play berms
- Building components
- Maintenance buildings and sheds (tower sheds)

Sites 6 through 8:

Twin Harbors Beach State Park, Wood Lane, and SR 105 and Rockney Place vicinity

- Elevation: 14 to 17 feet
- Capacity: 550 to 900 people
- Safe Zone area: 5,500 to 9,000 square feet

Design concept

These sites are suitable for tower structures that can serve as community amenities such as viewing towers and covered outdoor recreation areas. Modular tower platforms may be appropriate for the larger capacities, clustered or dispersed along the SR 105 corridor. Based on the design charrette community comments, more smaller tower structures are preferred rather than large platform structures that have a large footprint with lesser community benefit.

Examples of modular platform use include recreational vehicle parks and covered play areas (see Figure 32).

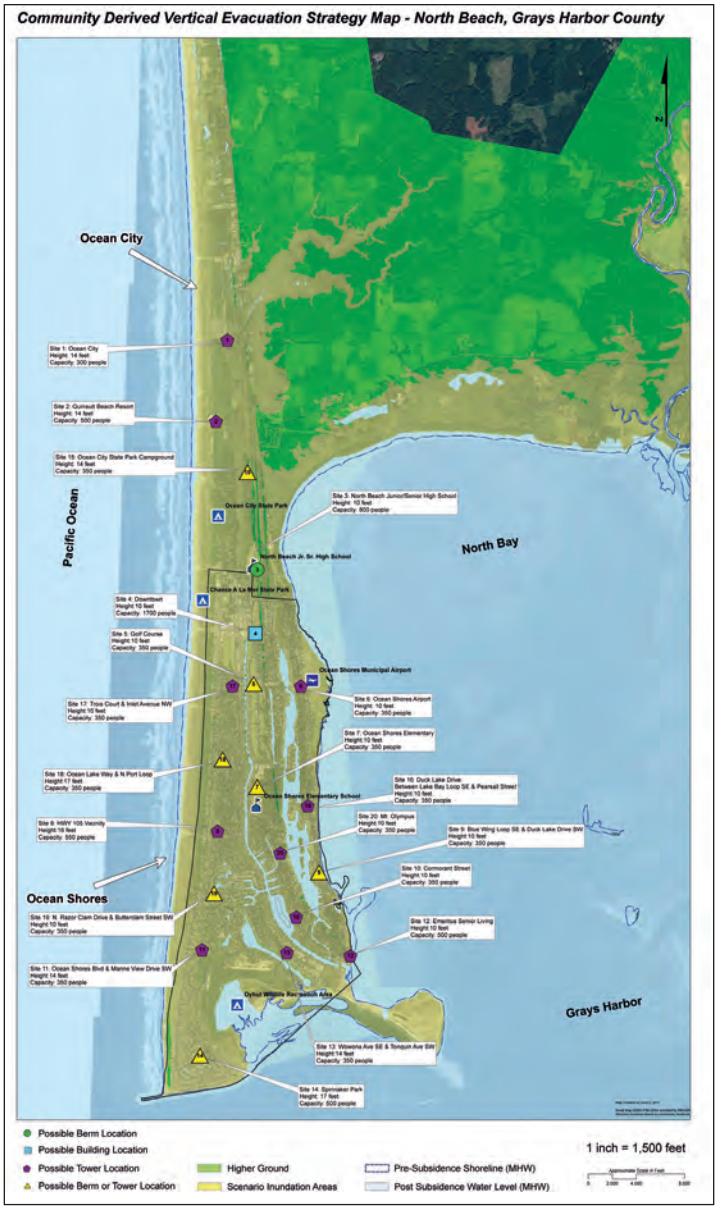


Figure 34: Ocean Shores preferred strategy
The map portrays the vertical evacuation structures located throughout the peninsula in phase one, with their accompanying identification numbers. Some structure locations have been modified based on the charrette process.

Site 9: Grayland Fire Station McDermott Lane vicinity

- Elevation: 10 feet
- Capacity: 550 people
- Safe Zone area: 5,500 square feet

Design concept

Fire station buildings can consist of a safe haven component (one or more bays or loft area) or a fully hardened building structure with flat roof safe zone. Access can be by ramps at the rear and/or sides of the building structure. A two story component in part of the building can be used for offices, firefighter facilities, etc. in addition, maintenance and storage sheds can also be used as safe haven structures as accessory buildings (see Figure 33).

Fire stations in smaller communities provide vertical evacuation structure opportunities as functioning community service/emergency facilities. Basic dimensions of fire stations for smaller communities are generally in the dimensions listed below, subject to site conditions and changing local and state standards:

- Bay size: 16 feet x 40 feet, essentially providing a four feet space around all sides of rigs
- Garage doors front and back at 12 feet x 18 feet, sacrificial (blow-out) design
- Building height approximating 20 feet interior to 22 feet overall
- Attached office and support service space
- Pedestrian entry to side wall with interior stair to roof (3).

Safe zones

- Vertical evacuation facilities can be accommodated by roof structures (1), approximately 20 to 22 feet high; or, roof of office complex (2) if inundation level and capacity are lower
- Blow-out doors front and rear (5, 6)
- Ramp to side (example illustrates a six feet wide ramp with 6 x 12 feet landings) (4)
- Safe zone can contain emergency supplies, ladders, and shelters
- Side walls of building are composed of unit materials such as split concrete block or panels for blow-out

H. Ocean Shores

Introduction

Ocean Shores is located on a peninsula in Grays Harbor County, along the southwestern Washington coast. The peninsula is situated between the north bay of Grays Harbor and the Pacific Ocean.

The peninsula is approximately 10 miles long and 1 mile wide. Approximately 5,000 people permanently reside in the City of Ocean Shores with up to 14,000 people, including tourists, during summer months.

The peninsula is exposed to the weather systems of the Pacific Ocean and has developed areas, downtown area, residential neighborhoods, and casino resort area all located on lowland elevations; making the overall community vulnerable to tide, wind, wave, and tsunami conditions. Ocean Shores is particularly vulnerable to a tsunami because of the city's location further west than any of the other communities. Evacuation routes via vehicles are extensive and all go through the single community entry point at SR 115, making evacuation difficult due to road disruptions and damages, traffic jams, etc.

Ocean Shores design charrette

The Department of Urban Design and Planning within the University of Washington's College of Built Environments, Seattle, Washington, conducted a three-day design charrette in Ocean Shores, Washington on April 27th, 28th, and 29th, 2011. The design team consisted of an architect/urban planner faculty member and two graduate students. In addition, staff from the State of Washington Emergency Management Division (EMD) provided assistance during the charrette operations.

The design team engaged community members through a series of open discussions and hands-on interactive activities to both familiarize attendees with preliminary site selection and elicit comments and suggestions for design and alternative site review. During the first day, April 27th, community members offered feedback on the preferred community strategy, developed in the initial phases of Project Safe Haven; and identified, in more detail, opportunities and constraints for site selection and alternative uses for the safe haven structures.

During day two, April 28th, the design team developed concepts for vertical evacuation structures identified on day one; interviewed representatives from the City of Ocean Shores including elected officials, planning commission members, planning staff, firefighters and Public Works Director to determine potential projects for a safe haven structures. Community members provided feedback during the Open House phase of the design session for the team's assessment on day three.

On day three, April 28th, the design team refined conceptual designs from the previous meetings based on community feedback. In the final evening meeting, community members provided final feedback on the strengths and weakness of new design conceptualization as well discussion of overall preferences for type and locations.

Further analysis is required on all design concepts in order to determine the final safe zone heights, engineering and cost feasibility. No specific sites or projects have been identified for construction.

Overall strategy

Based on the preferred community strategy developed in the initial phases of Project Safe Haven: Grays Harbor County, 20 sites were identified for potential vertical evacuation structures (see Figure 34). The estimated capacities for the Ocean Shores structures range from 100-1,700 persons. The larger of these capacities require prohibitively large structures, resulting in additional design conceptualizations to divide them into a number of smaller structures.

I. Design concepts by selected sites: Ocean Shores

The design concepts for each site developed during the design charrette are detailed below in order from north to south. These are conceptualizations of potential vertical evacuation structures and associated urban design impacts. Further detailed study is required for implementation on any given site. No specific sites or alternatives have been selected safe havens development. The concepts provide each respective community a basis for reference, prioritization, and can be adjusted as needed.

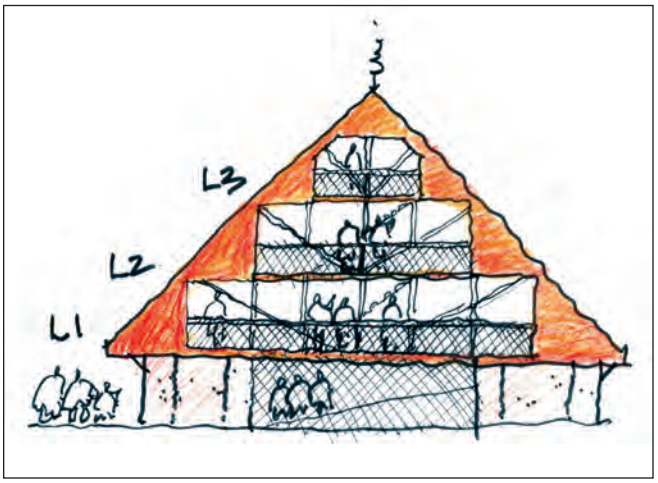


Figure 35: Ocean City and Quinault Resort pyramids
The pyramid design provides a multiple tiered structure for both physically challenged (first level) and able-bodied persons (second level). The timber and concrete designs are less susceptible to ocean air and water erosion factors and can be full pyramids (2) or truncated at the top (1) to further reduce height.

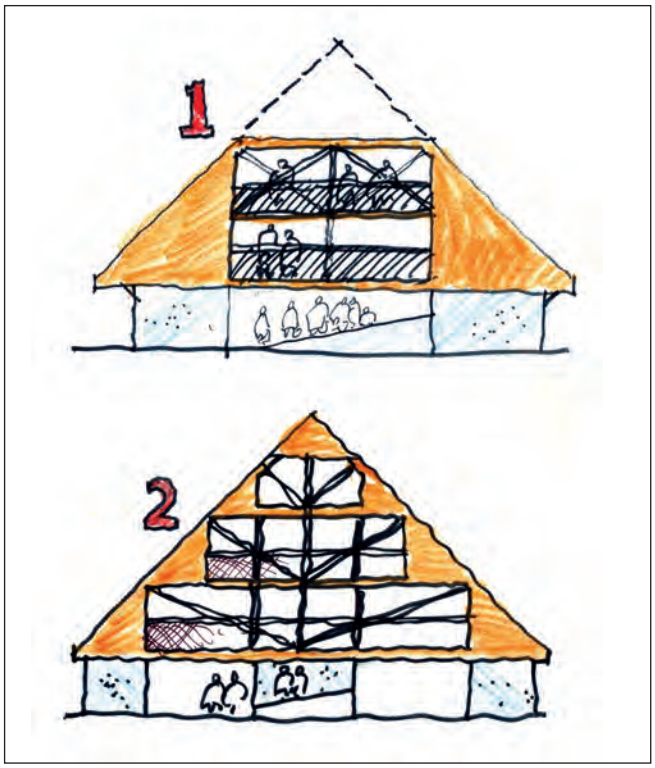


Figure 36: North Beach School site
Berms are recommended for most school sites given the more extensive open space in association with play and sport areas. This illustration depicts a berm-tower combination to extend the safe zone and conserve land area. The tower component can be used as a stage area, a shelter for a music stage, and other outdoor events in conjunction with a safe zone on the berm itself.

Sites 1 and 2: Ocean City and Quinault Beach Resort

North of Ocean Shores city limits

- Elevation: 14 feet
- Capacities: 300 and 500 people respectively
- Safe Zone areas: 3,000 and 5,000 square feet

Design concepts

Both sites are appropriate for tower vertical evacuation structures, as designated in the prior phases. The towers can range in footprint from 55 feet square to 70 feet square at the resort. In order to reduce the size of the footprint, each site is recommended for a tiered pyramid structure with concrete ground level structural members and heavy timber members for upper levels (2). The first level is accessed by a ramp core and the second by a ladder or steep stair for non-physically challenged people. In a tiered design, the base footprint of the resort tower, 5,000 square feet in total Safe Zone area, can be reduced to 60 feet square with an upper level of 38 feet square using the pyramid shape structure (see Figure 35).

Site 3: North Beach Junior/Senior High School

- Elevation: 10 feet
- Capacity: 800 people
- Safe Zone area: 8,000 square feet

Design concepts

As in other elementary and high school sites in coastal communities, there is sufficient land and opportunities for safe haven vertical evacuation structures of considerable size (see Figure 36). The possibilities for the North Beach School Site include and are not limited to the following:

- Covered outdoor recreational sports and play areas, with the roof structures serving as the safe zone platforms
- Berms with event seating, event stage on safe zone or surrounded by berm at grade
- Berm-tower combinations with tower used as outdoor weather protection for events
- Play berms
- Building components
- Maintenance buildings and sheds (tower sheds).

Site 4A: Downtown series

- Elevation: 10 – 14 feet
- Capacity: 1,700 people total

Note: One large structure required to accommodate 1,700 to 2,000 people can be as large in footprint as 20,000 square feet, the size of a small athletic arena such as the Tacoma Dome. Construction of this type of facility in Ocean Shores is not feasible

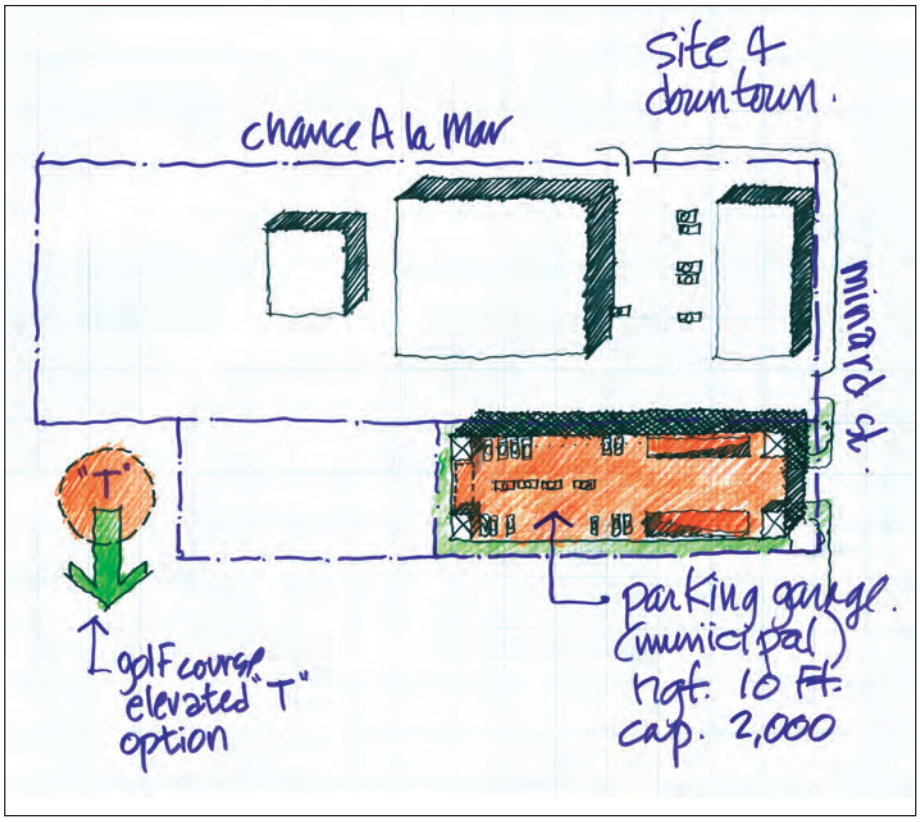


Figure 37: Parking Garage/Golf Course
The parking structure is accessed from Minard Street. A second option for this site includes a golf tee area that can incorporate a 10 feet high tee-off berm with ramps for pedestrians and golf carts, capacity variable 200 to 300 persons.

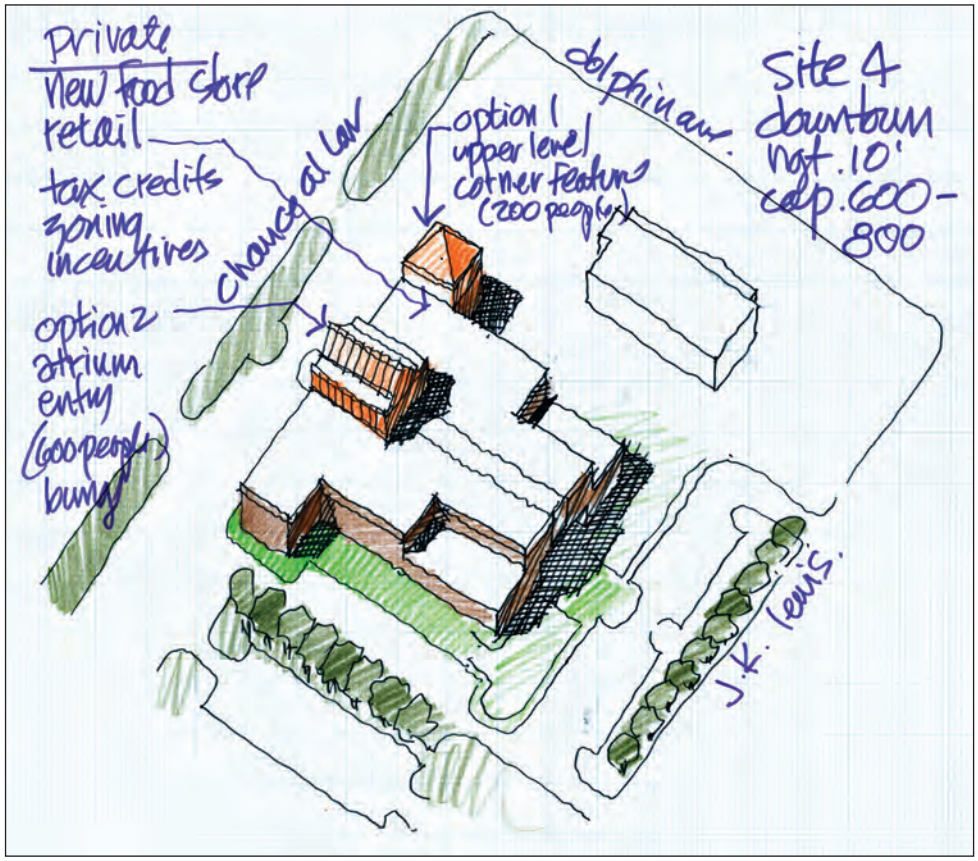


Figure 38: Retail development The illustration depicts a new grocery store complex with two examples of safe havens embedded into the building complex: an entry lobby with atrium and upper mezzanine and/or safe roof; and, an upper level feature such as lounge, restaurant, etc. designed as an architectural corner feature.

with costs, use, etc. A parking garage, proposed in prior phases, is a possibility given the budget and site feasibility — and also may be a long-term project. The design team focused on dispersing the safe haven structures within the downtown to provide multiple and more cost-affective starting points for safe havens.

Design concept 1: Downtown parking garage/golf course

A number of sites in downtown were identified by City staff and citizens for potential parking garage locations. The type of structure suitable for downtown Ocean Shores may incorporate two levels with the top level as the safe zone. Floor heights may be extended to accommodate a two-story 10 to 14 feet safe zone height. If retail commercial is incorporated into a part of the structure, a 13 feet first floor height is usually required for grade level retail uses, thus extending the height to a safe level. The site selected as a test case for a parking garage is a city-owned strip of land at the northern edge of a city golf course. The structure size for this site is approximately 20,000 square feet with a capacity of 2,000 people (see Figure 37).

Site 4B: Downtown (private sector) commercial development

Various sites available (example on Chance La Mer Avenue)

- Elevation: 10 – 14 feet
- Capacity: 600 to 800 persons

Design concept

Significant vacant land is available in downtown Ocean Shores for retail, commercial and office development. With development incentives such as tax credits and zoning incentives, developers may incorporate safe have structures into future developments as functioning retail components using building components for safe haven structures (see Figure 38).

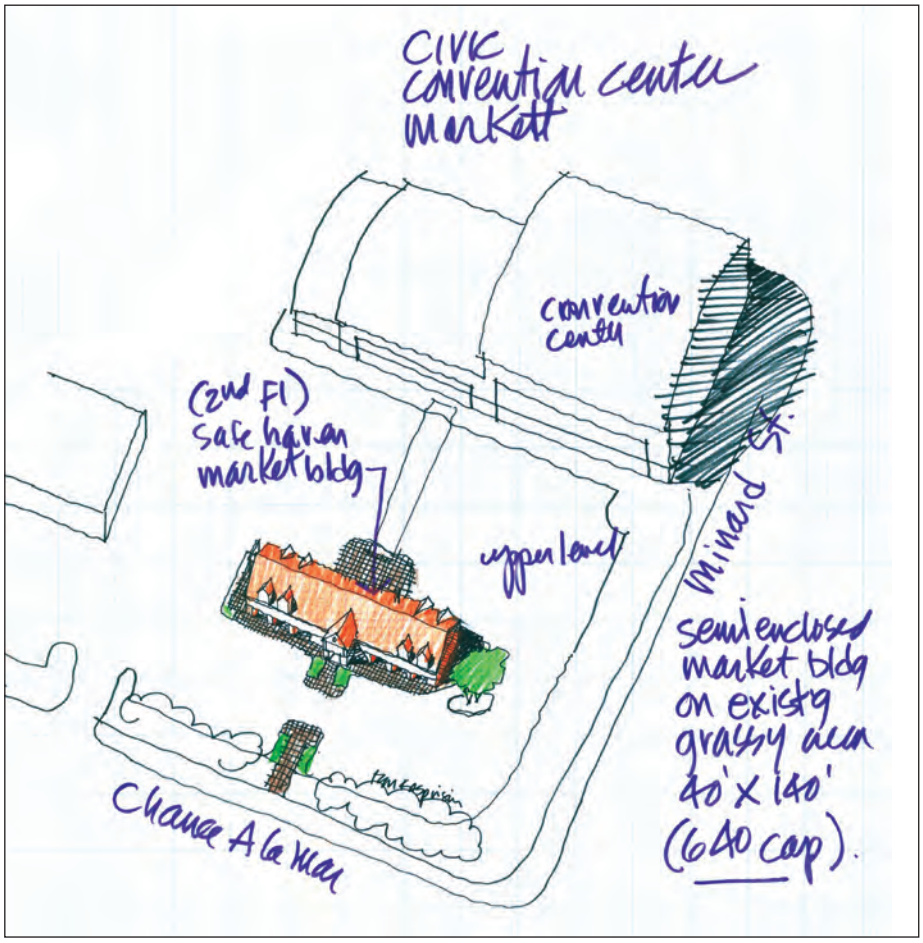


Figure 39: Convention Center Market
The concept of a market within the convention center parking lot is compatible with Center functions. Farmers markets, flea markets, auto and boat shows all can benefit by an outdoor semi-enclosed structure that also provides safe haven on lofts, mezzanines and/or roofs. Size is variable.

Site 4C: Convention Center Farmers Market and Flea Market
Convention Center parking lot
Chance La Mer and Minard Street

- Elevation: 10 to 14 feet
- Capacity: 640 people
- Safe Zone area: 6,400 square feet

Site characteristics

The site is flat and consists of a paved parking lot. This example selects an existing grass area near Chance La Mer Avenue as a test site, without removing any parking spaces.

Design concept

The minimal market footprint occupies the existing grassy area that connects the existing Convention Center to the commercial street (Chance La Mer). This example provides a semi-enclosed Tower Shed approximately 40 feet by 140 feet with a capacity on the roof or upper loft of 640 people. The concept can be enlarged significantly given the large expanse of parking surface dedicated to the center (see Figure 39).

Site 5 and variable: Golf Course(s)

- Elevation: 10 – 14 feet
- Capacity: variable

Site characteristics

Golf courses provide a major open space structure for the Ocean Shores peninsula, along with the inland waterway and the Pacific Ocean, beaches and bay. The golf course is city land and extends throughout the northern to central northern portion of the community in a north south direction. The golf course connects the downtown area with the proposed civic center in central Ocean Shores (see Figures 40 and 41).

Design concept

Golf courses provide opportunity for safe havens in numerous ways, including:

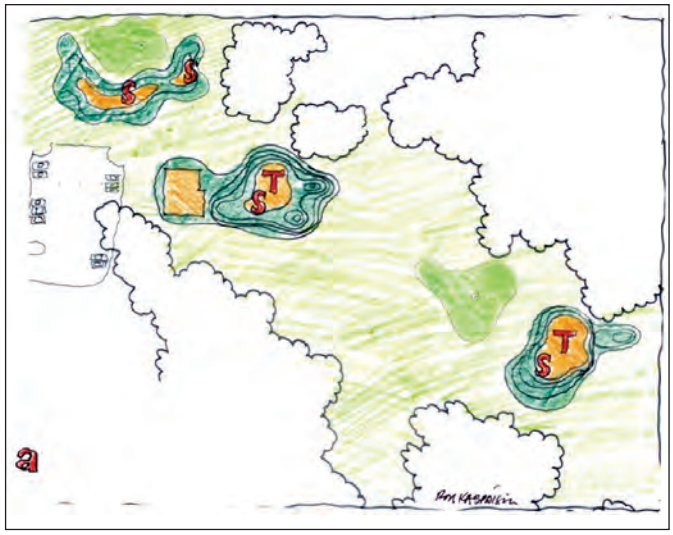


Figure 40: Golf course structures
Golf courses are compatible with berm and some types of tower structures due to their extensive open space and functional components such as tee-areas, hazard areas, and building types. The illustration portrays a larger berm mound with safe zone that also defines picnic areas, tee-off areas, and other landforms.

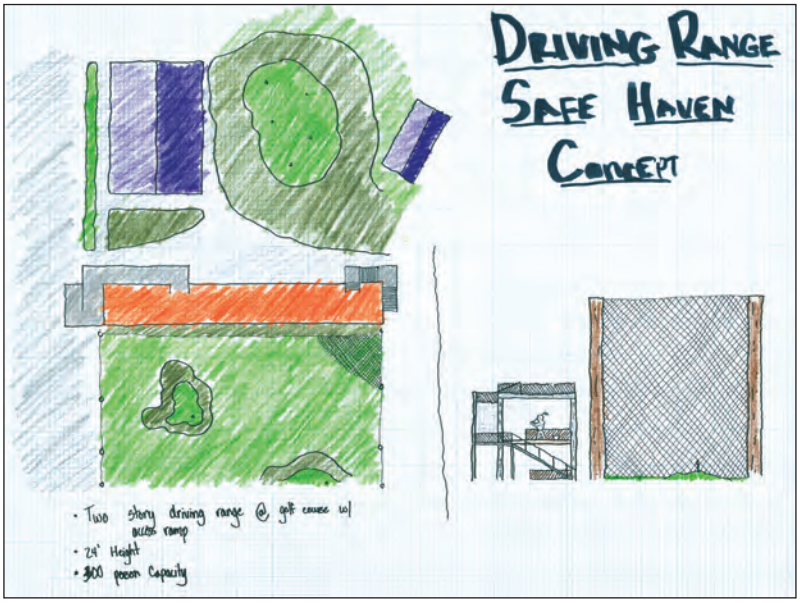


Figure 41: Golf driving range
Two-story driving range structures are common elements on golf courses or as free-standing attractions, particularly in resort communities. The second story and roof areas are all potential safe haven zones.

- Tee-off areas using sloping berms
- Hazard areas using perimeter berms around sand traps, etc.
- Landscape forms within the fairways
- 18th hole 'bleachers' or viewing stands
- Maintenance and clubhouse structures using tower sheds and other building components.

Site 6: Ocean Shores Airport

- Elevation: 10 feet
- Capacity: 350 people
- Safe Zone area: 3,500 square feet

Design concept

The airport presents a number of safe haven opportunities within the limitations of height restrictions in certain areas relative to landing and take-off patterns for aircraft. These include:

- A noise berm along the perimeter of the airport that can be an elongated berm easily accessible with ramps
- Maintenance sheds and hangers that can be constructed as safe havens
- An airport viewing tower, given the ten feet height designation that can be located at the perimeter of the airport grounds.

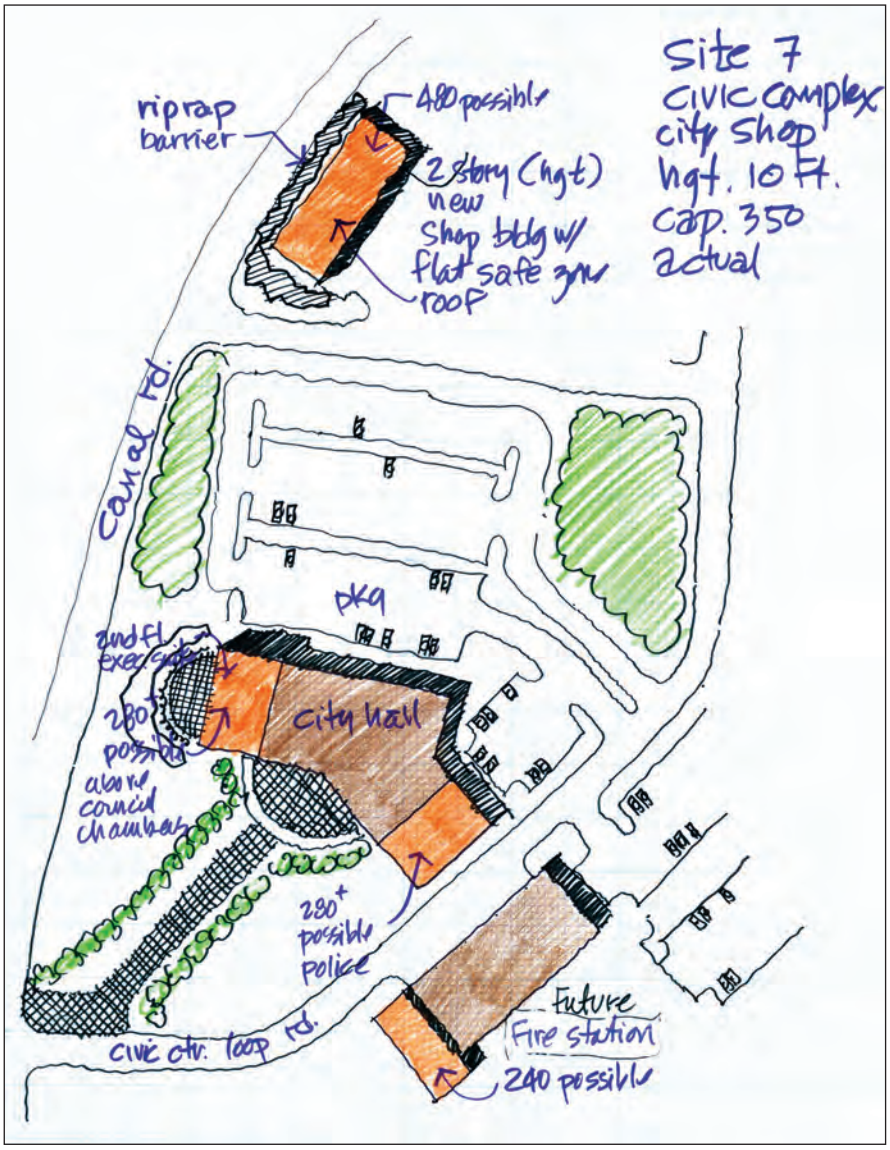


Figure 42: Civic Center
The illustration identifies a number of building components suitable for safe haven structures: City Council chambers (usually high ceiling spaces) with a safe roof; police headquarters on upper levels; maintenance garages and work/storage sheds with safe roofs. Smaller berms can be designed into the landscape components as debris-field deflectors. Partial ramps can be attached to maintenance garages etc. for improved access for physically challenged persons.

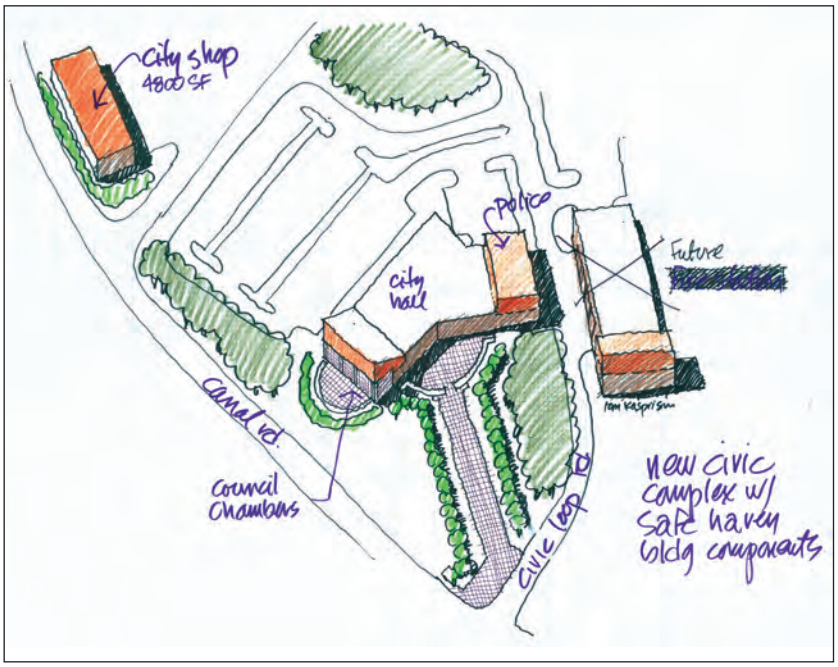


Figure 43: Civic Center axonometric drawing

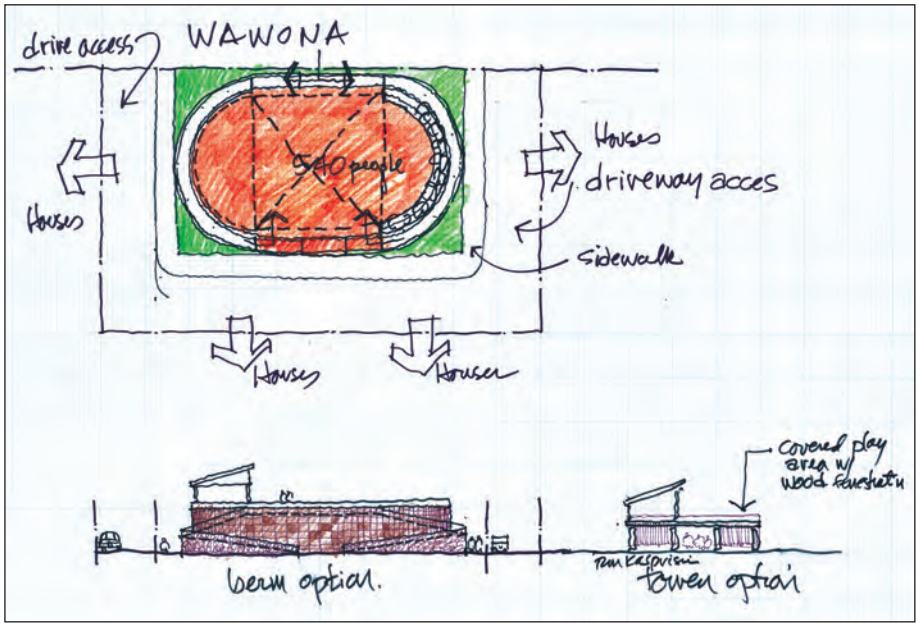


Figure 44: Loop/Court berms 1 and 2
Many courts are distributed within the residential areas of Ocean Shores, providing space for safe haven structures ranging from berms, to platforms (functioning as boat and car storage) and recreational towers.

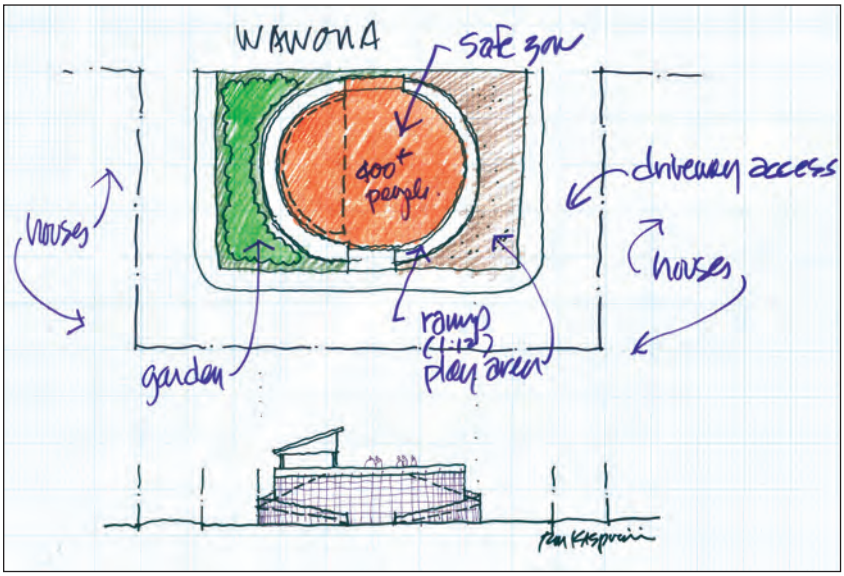


Figure 45: Raised gardens
The courts and loop road open spaces provide opportunity for raised community gardens that are also structural safe havens. This example sketch, drawn during the Ocean Shores charrette process, conceptualizes a stepped garden structure with passive community space at the top. Further design study can provide ramps and improved access to the stepped garden levels and safe zone.

Site 7: Civic Center

Civic Center Loop Road and Canal Road

- Elevation: 10 feet
- Capacity: 350 persons
- Safe Zone area: 3,500 square feet

Site characteristics

The site is located in central Ocean Shores on city property. The property is flat, sparsely wooded with wetlands to the east, an elementary school to the south, waste treatment plant to the north; and bounded by vacant land, Civic Center Road (future) to the south and east and Canal Road to the west.

Design concept

A new civic center is a community vision for the future and may contain a new City Hall, Courts, Police and Public Works facilities. This concept is premised on a phased approach to the civic center with public works facilities as first priorities for the site. Maintenance garages, storage sheds and other utilitarian buildings can provide safe haven building component structures. Future civic center buildings with more public access and visibility include the City Hall, Police and Court buildings. In all of these structures, building components—parts of the buildings such as entry lobbies, record storage areas, and police headquarters can provide hardened components as safe havens (see Figure 42 and 43).

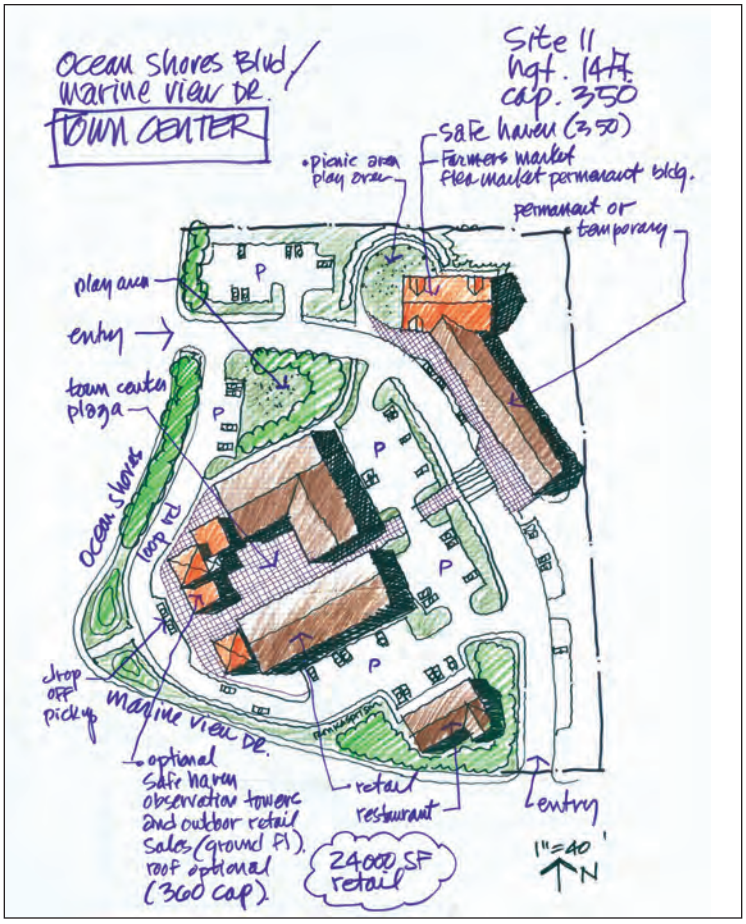


Figure 46: Town or Leisure Center concept

Site (Neighborhood): Access loops, courts, cul de sacs

Typical for many neighborhoods

- Elevation: 16 feet
- Capacity: 200 to 540 people
- Safe Zone areas: range from 2,000 to 5,400 square feet depending on size of court

Site characteristics

Many cul de sacs or shared entry drives for residential areas include an open area in the center, referred to as loops or courts and are public (City) spaces. They are flat, easily accessible, paved or graveled and underused as usable open space.

Design concept

Two versions of the design concept are presented as guides for safe haven structures within the loop areas: berm-play-recreational areas. Tower structures are also compatible with the loop areas and can provide more ground level recreation space due to a smaller footprint; and, are less accessible for physically challenged people — thus the berm design in these examples.

Design concept 1 fills the loop area with a rock wall berm with two access ramps, each 1 foot per twelve feet horizontal. The safe zone serves as a recreational facility for adjacent residences with possible fire pit, shelter, landscaping, seating, trellis, etc. The vertical walls of the ramps and main

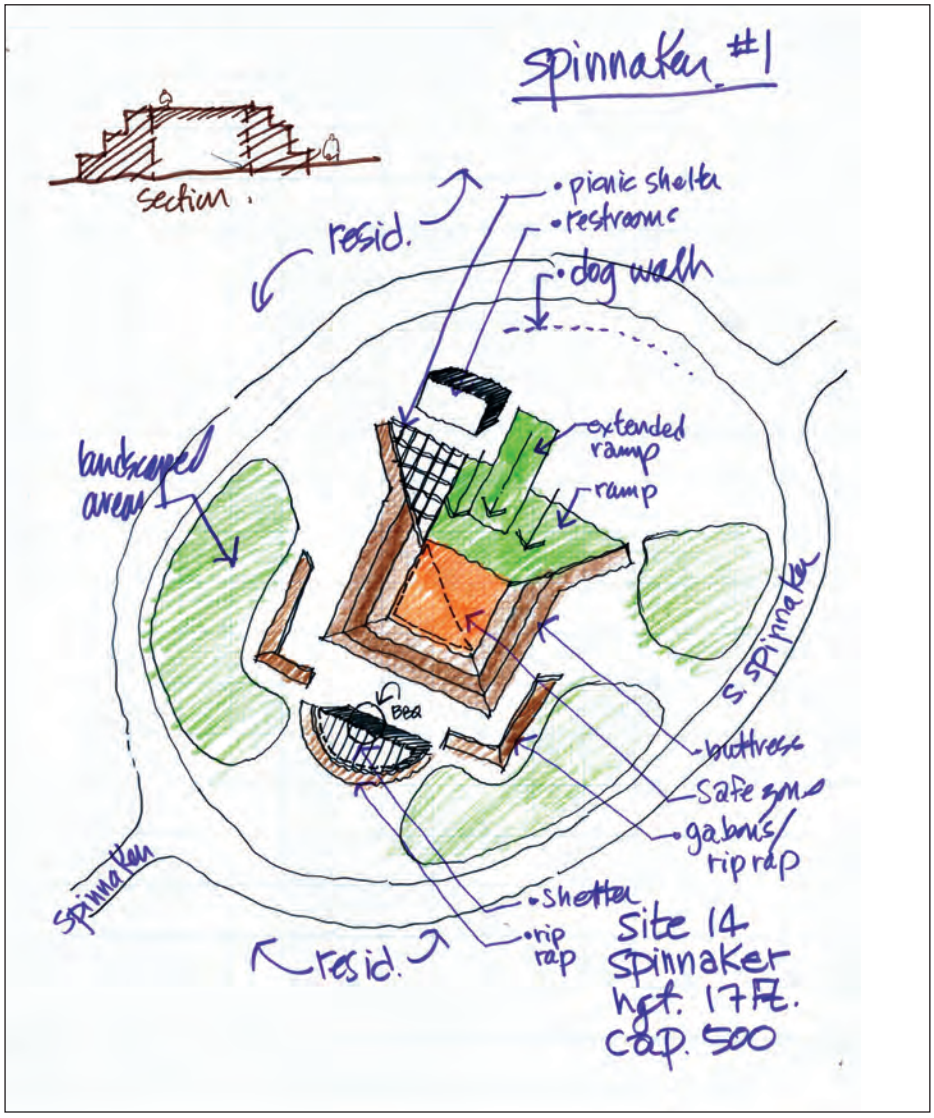


Figure 47: Spinnaker Park concept 1 The plan view demonstrates how park and recreation facilities, including dog walking activities, can be incorporated into the safe haven berm structure. A more formal design configuration can reduce the berm footprint.

berm can be in stone, textured concrete, brick or wood veneers and other design materials. In Design concept 2, the berm footprint is smaller with more expansive at-grade landscaping and play areas (see Figure 44 and 45).

Site 11: Retail site — Town or Leisure Center concept

Ocean Shores Blvd. and Marine View Drive

- Elevation: 14 feet
- Capacity: 350 (actual 700 plus people)
- Safe Zone areas: range from 3,500 to 7,200 square feet

Site characteristics

A flat vacant retail site is located at Ocean Shores Blvd. and Marine View Drive in the southern portion of Ocean Shores. The site is oriented toward the west and south with frontages on Ocean Shores Blvd. and Marine View Drive. Residential areas abut the site on the north and east.

Design concept

A neighborhood retail center can develop as a town or leisure center, a smaller shopping complex with accompanying leisure activities such as small plaza or park, strong pedestrian gathering space and walkways, dispersed parking in smaller lots, café, bookstore, etc. A number of safe haven options are available in these leisure centers, ranging from a Tower Shed as a part of a farmers market to observation towers and entry lobbies for the semi-enclosed shopping complex (see Figure 46).

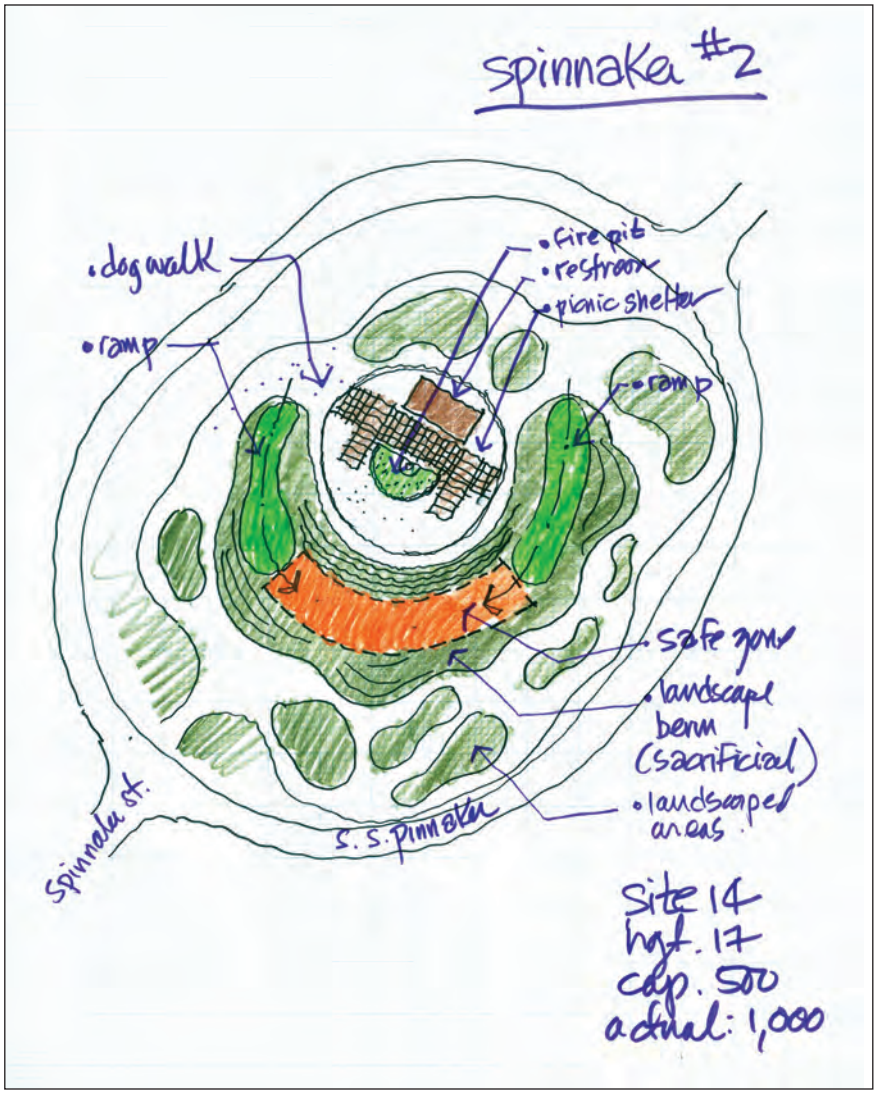


Figure 48: Spinnaker Park concept 2 Similar to concept 1, this concept has an organic berm shape with centralized recreation facilities and an elongated safe zone at the top of the berm.

Major features include:

- Town or leisure center retail complex, approximately 24,000 square feet
- Semi-enclosed town center plaza
- Dispersed parking into small clustered lots
- Drop-off pick-up areas near main intersection
- Peripheral restaurant
- Protected play area
- Farmers market and flea market with tower shed and permanent semi-enclosed building for stalls and events
- Picnic area associated with market area
- Pedestrian connections between and among major site activity areas
- Safe haven in tower shed in market area
- Safe haven in observation towers and outdoor retail sales areas at base of towers
- Small platforms as viewing areas/safe haven zones.

Site 14: Spinnaker Park

Spinnaker Street and Storm King Avenue

- Elevation: 17 feet
- Capacity: 500 (actual 560 people)
- Safe Zone area: 5,000 square feet (actual 5,600 square feet max.)

Site characteristics

Spinnaker Park is an oval shape designated open space within a south peninsula residential enclave, aligned along Spinnaker Street. The site is vacant of structures and park facilities, essentially a vacant grassy area. The site is susceptible to wave action from three directions: west from the Pacific Ocean

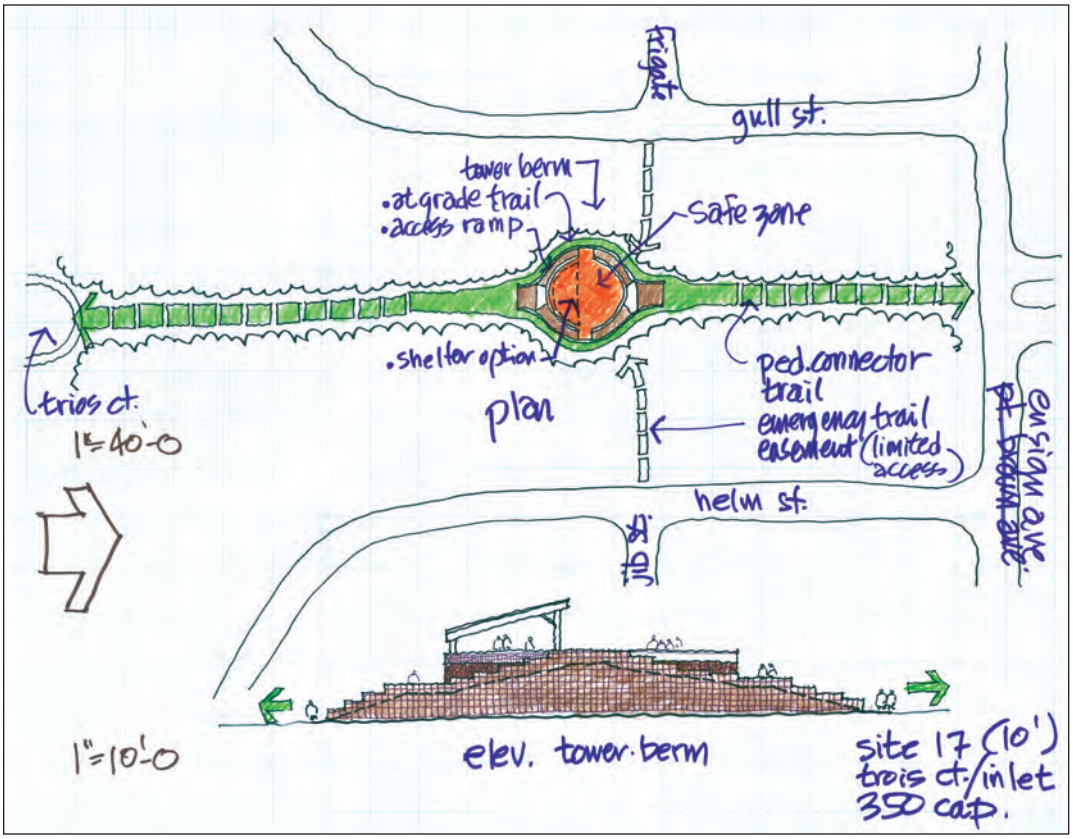


Figure 49: Pedestrian trail-berm combination

beaches; south from Grays Harbor; and, east from Grays Harbor and the Oyehut Game Reserve.

Design concept 1

Two similar concepts illustrate various approaches to the design of a safe haven park structure that can serve the surrounding residential neighborhood and provide safe haven. In option 1, a fortified berm structure with a formalized stepped pyramid-type design contains the following (see Figure 47):

- A safe zone of 5,600 square feet (can vary from 5,000 square feet and larger), essentially 70 feet by 80 feet
- Stepped stone buttress on three sides (west, south, east)
- Standard sloped berm/ramp (1 feet vertical rise per 4 feet horizontal)
- Extended ramp (1 to 8) feature
- Picnic shelter embedded into berm
- Restroom facility (alternate safe haven facility)
- Recreational shelter with barbeque fire pit
- Accessory deflection rip rap mounds to west, south and east
- Dog walking area both as perimeter activity and play areas with fences within interior of park
- Landscaped green surface play areas.

Design concept 2

- The second Spinnaker Park design concept is an organic version of option 1 with the following characteristics (see Figure 48):
- Berm safe zone at top of "U" shape berm
- Two sloping ramps each at 1 foot vertical per ten feet horizontal
- Landscape berm/buffers on west, south and east
- Central recreational area with fire pit, restrooms, picnic shelter/trellis
- Green play areas
- Dog walking/play areas.

Site 17: Drainage channel/pedestrian connector

Trois Court to Ensign Avenue

- Elevation: 10 feet
- Capacity: 350 people
- Safe Zone area: 3,500 square feet

Site characteristics

The site is a location in the vicinity of Trois Court and Ensign Avenue. In this example, a city drainage channel was selected for study as the corridor may provide a pedestrian connector within the neighborhood. The corridor is approximately 20 feet wide but may be expanded in the center to accommodate a safe haven structure, incorporating the drainage channel functions around the base of the berm.

Design concept

The design concept is a stone or concrete berm located near the center of a potential pedestrian connector from Trois Court to Ensign Avenue with secondary connectors to Jib and Frigate Streets. The berm can be part of a trail parkway with sloping ramps, viewing and picnic areas, recreational shelter and fire pit (see Figure 49).

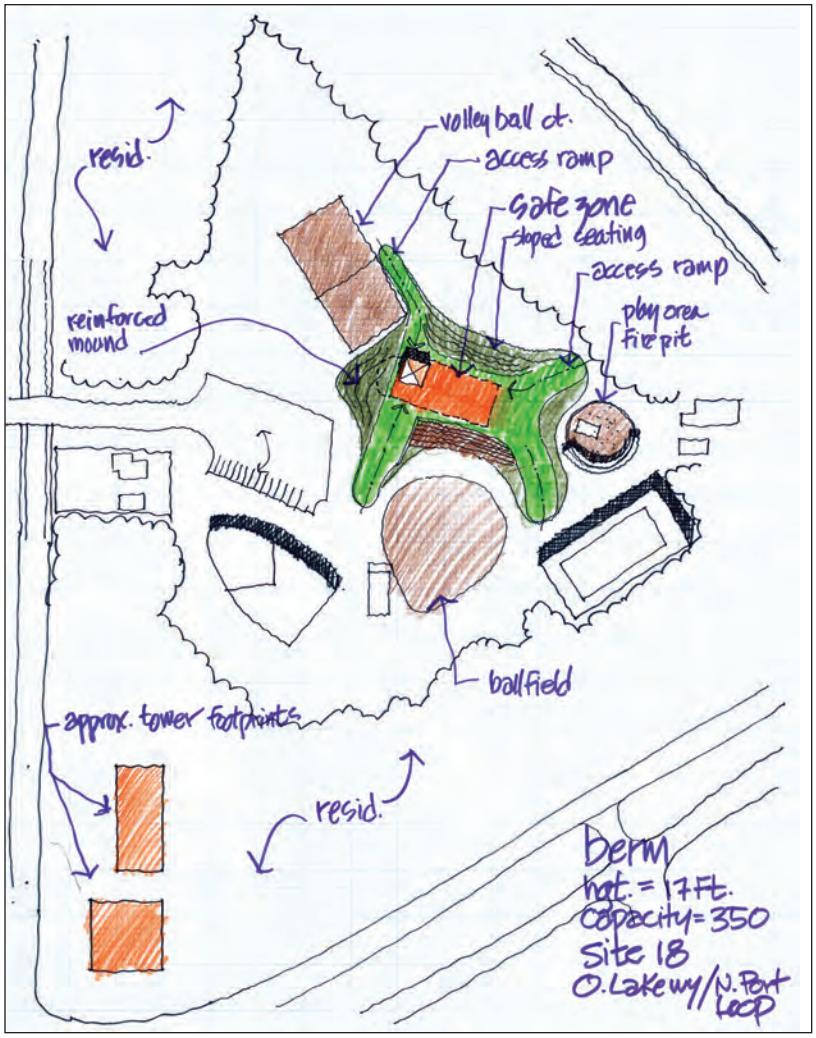


Figure 50: Playfield concept

Site 18: Park Facility

Ocean Lakeway and N. Port Loop

- Elevation: 17 feet
- Capacity: 350 people
- Safe Zone area: 3,500 square feet

Site characteristics

The flat site is located in west central Ocean Shores approximately one block east of the beach and the Pacific Ocean. The site has a pedestrian and driveway connection for interior site parking on the west to Ocean Shores Blvd and is surrounded by residential dwellings. The neighboring community desires a ballfield and passive play areas.

Design concept

The safe haven structure is a landscaped berm with a safe zone on top, access ramps on two to four sides with the ramps on the east side having priority away from the wave direction, with each ramp at 1 feet vertical per 12 feet horizontal (see Figure 50). Other features include:

- Optional shelter in safe zone
- Volleyball court to northeast of berm
- Play area and fire pit with trellis covered parent watch area
- Sloped berm seating on north side
- Stepped berm seating on south side overlooking ball field.

J. Taholah

Introduction

Taholah is within the sovereign Quinault Indian Nation located on the Quinault Indian Reservation on the southwestern Washington coast. The historic tribal town center of Taholah is a low-lying area at the confluence of the Quinault River

Figure 51: Taholah preferred community strategy
The map portrays the vertical evacuation structures for Taholah, with their accompanying identification numbers.

and the Pacific Ocean. The original settlement area is home to approximately 600 people, contains a general store, gas station, community center and associated recreational facilities, recreational fields, residential neighborhoods, and waterfront marine-oriented industrial facilities. The Nation is focusing new development to the areas of high ground south and southeast of the original settlement including the high school, senior center, administrative offices along with the Bureau of Indian Affairs offices and a number of new residential neighborhoods.

The historic settlement area in the lowlands is in a state of physical change, with older residential structures abandoned or in physical deterioration and newer residential neighborhoods located south of the original settlement at the base of the higher ground. During the charrette process, discussions regarding the future of the original settlement area suggested a gradual relocation of residential dwellings to higher ground, retaining the lowlands for cultural and art facilities related to the tribe's history and culture, and water dependent industrial and commercial activities. The development examples in this section build upon those discussions: discouraging additional residential development in the lowlands and increasing cultural, recreational, visitor and marine related commercial and industrial uses along the river.

Taholah design charrette

The Department of Urban Design and Planning within the University of Washington's College of Built Environments based in Seattle, Washington conducted a two-day design charrette in Taholah on May 11th and 12th, 2011. The design team consisted of an architect/urban planner faculty member and two graduate students. In addition to the design team, staff from the Quinault planning department assisted in the workshop.

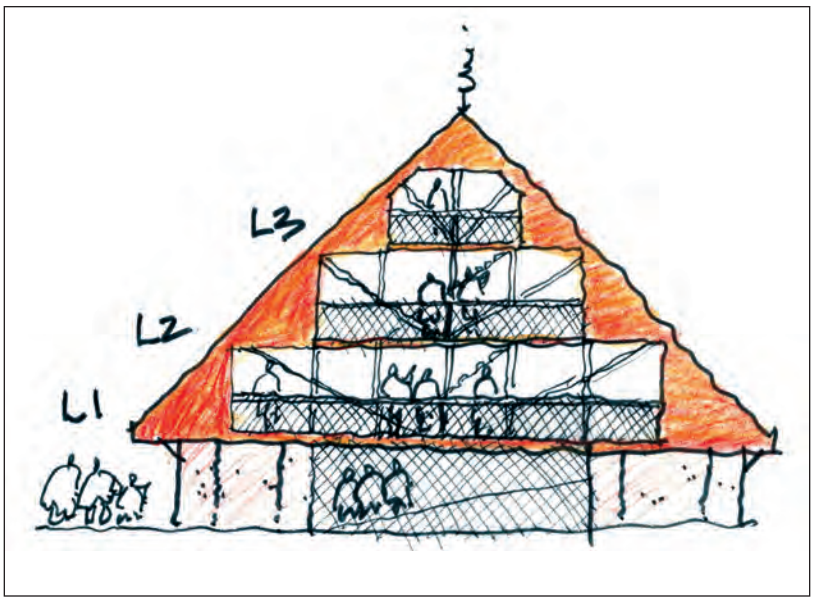


Figure 52: Taholah Senior Center and Elementary School tower design
A tower design for these sites incorporates a number of new features including: a concrete base or ground floor structure, a timber frame upper area to reduce the use of steel in the marine climate, and access ramps to increase accessibility for physically challenged people. This design proposes at least two tiers of safe zones—the first served by ramps and the second and higher zone(s) served by ladders or steep stairs.

The charrette engaged community members through a series of open discussions and hands-on site exploration activities. During day one, May 11th, community members contributed to a SWOT (strengths, weaknesses, opportunities, and threats) analysis of the preferred community strategy based on feedback from the phase one community meeting in March. The design team and community members also discussed opportunities and constraints for site selection and alternative uses for the safe haven structures in more detail.

During day two of the design charrette, May 12th, the team developed concepts for vertical evacuation structures for the identified site areas with alternative uses. Community members offered feedback during the open house in the afternoon. At the evening meeting, community members critiqued and provided feedback on the strengths and weakness of the design concepts and indicated their overall preferences. The major consensus of participating community members and Quinault staff focused on the long-term relocation of residential uses to high ground and the development of a tribal arts and cultural complex in the original settlement area, complete with safe haven structures.

The concepts all require further analysis to determine the engineering and final design specifications of each design. No specific sites or projects have been identified for construction.

Overall strategy

Based on the preferred community strategy developed in the first phases of Project Safe Haven: Grays Harbor County, three sites were identified for vertical evacuation structures: the senior center vicinity, the elementary school vicinity, and center of the Riverside housing development on the northeast side of the highway (see Figure 51). As a result of the charrette process, a number of alternatives were explored that include a community and cultural arts center in coordination with an existing baseball field in the heart of the village. This center can also include a facility for emergency vehicles within the reconstituted historic village.

K. Design concepts by selected sites: Taholah

The design concepts for each site discussed during the design charrette are detailed below. These concepts are intended to provide direction for

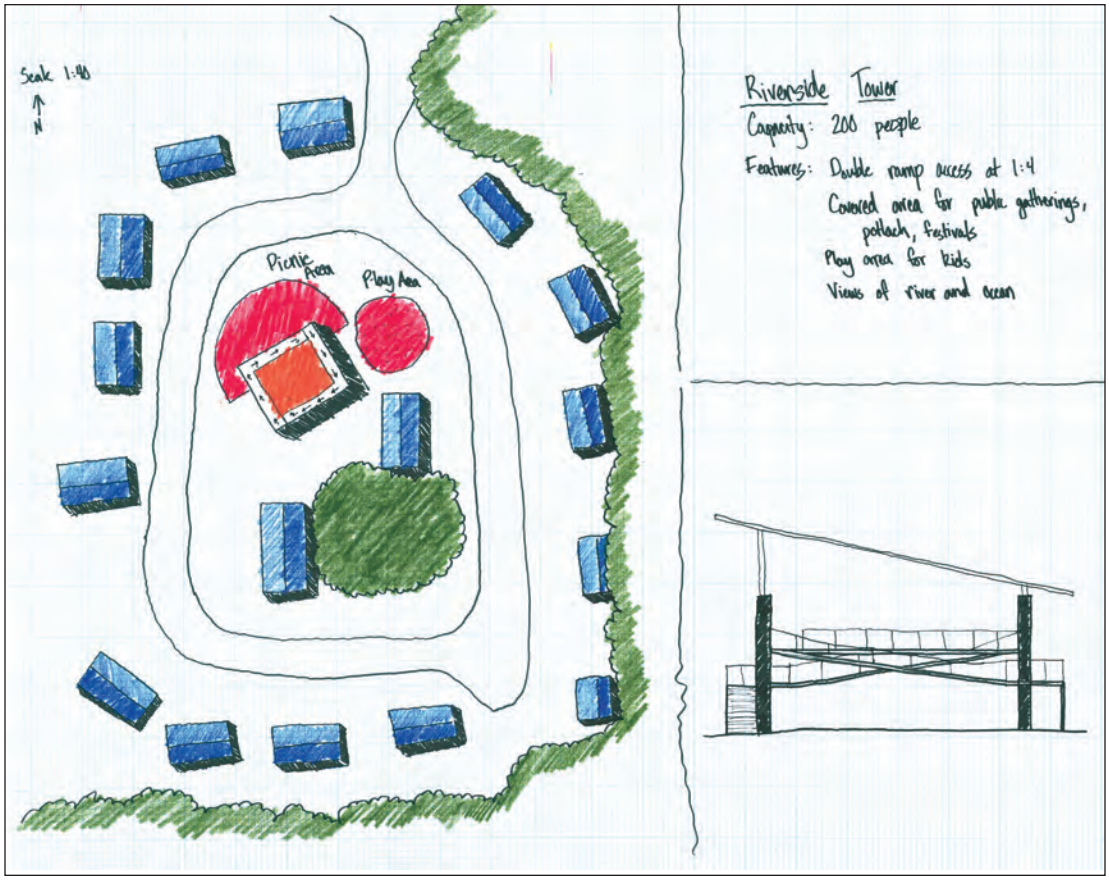


Figure 53: Riverside housing development

community action regarding safe haven structures beginning with a prioritization of structures with final site and design adjustments completed as needed.

Tower designs are recommended for a number of sites in Taholah due to limited land in the original settlement area. They include: Site 1, Senior Center Vicinity; Site 2, Elementary School vicinity; and Site 3, the Riverside neighborhood east of the highway.

Site 1: Senior Center vicinity and Site 2: Elementary School vicinity

- Elevation: 16 feet for both
- Capacity: 400
- Safe Zone area: 4,000

A potential site has been discussed for the former daycare site near the senior center. This site offers increased access for the village elders.

For the school vicinity, a site has been identified on the old gravel pit behind the school. Opportunities for safe havens at the school are many and are best coordinated with future additions, including a berm playfield, and a covered basketball court, and outdoor play area using tower sheds (see Figure 52).

Site 3: Riverside housing development

Park Place Street and Cuitan Street vicinity

- Elevation: 16 feet
- Capacity: 200 people
- Safe Zone area: 2,000 square feet

Site characteristics

The Riverside housing development east of the highway has limited access to high ground or the new village center. The neighborhood has a semi-open area centrally located in the cul de sac loop drive. The neighborhood is immediately adjacent to the highway as it begins to rise to the south with high ground. An approximate minimum safe height can be reached via the highway corridor at the existing trail crossing. These site features present two possibilities for safe haven facilities: a basic tower similar to the towers at the senior

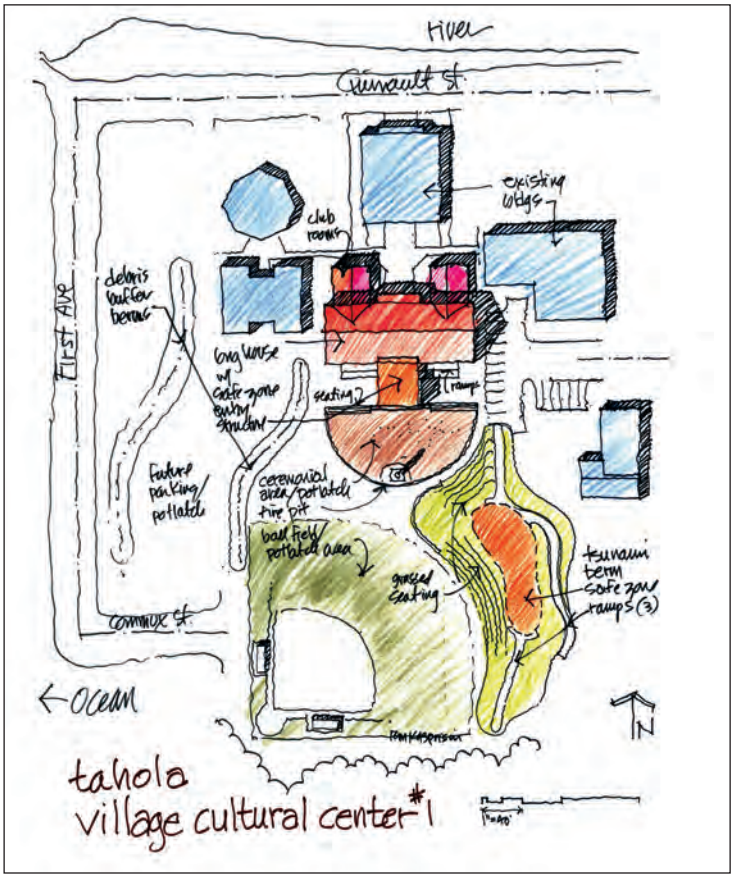
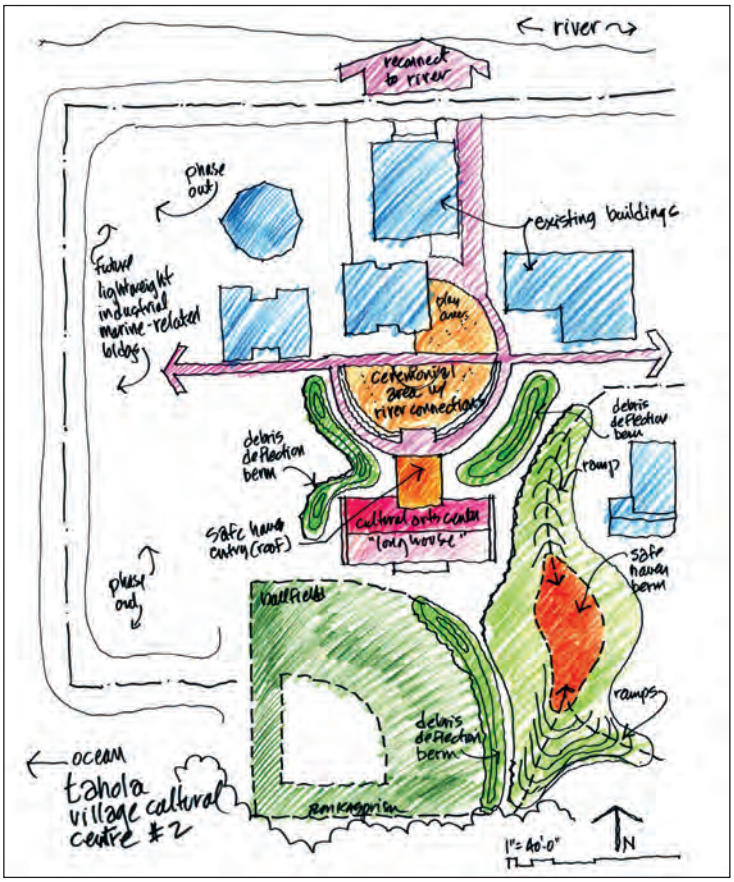


Figure 54: Design concept 1: Village Cultural Center
In concept 1, two safe haven structures are depicted: The first is a new building component of the center/ longhouse building that serves as a southern ceremonial entry to the potlatch area, carving area and a safe haven berm structure along the east side of the ballfield that can serve as grassed seating for both the ballfield and the outdoor ceremonial areas. Three ramps serve the berm with one feet vertical rise to twelve feet horizontal.



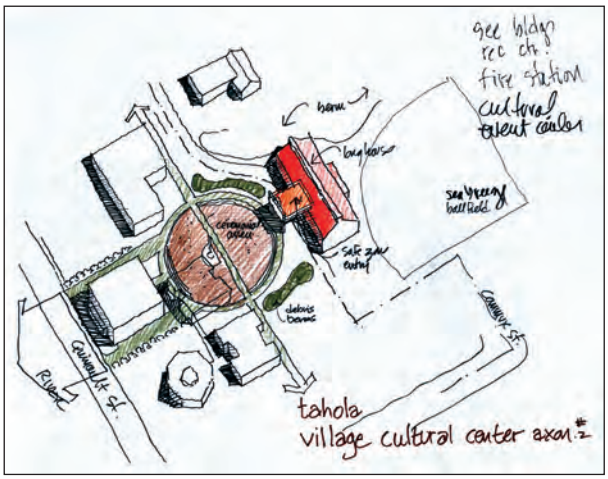


Figure 55: Design concept 2: Village Cultural Center
Similar to concept 1, this idea locates the outdoor ceremonial area to the north as a connecting space for new and existing community buildings and retains the berm option to the east along with debris deflector berms at key locations. Also, axonometric view of concepts 1 and 2 above.

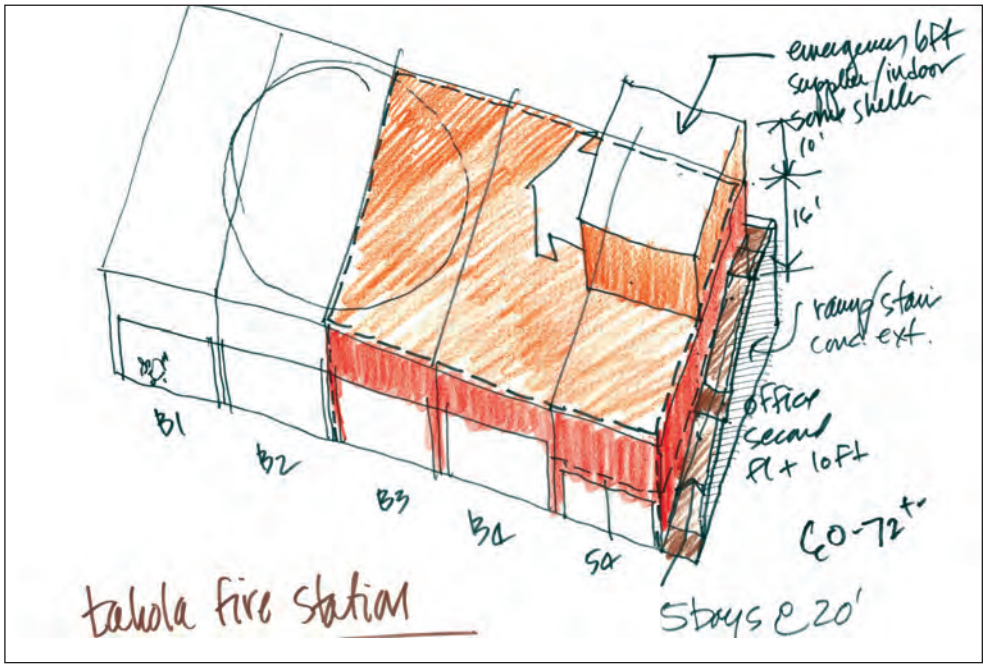


Figure 56: Fire station concept

center and the school vicinity, with coordinated timber design; and an access ramp from the southwest portion of the neighborhood along and possibly within the highway right of way to the trail crossing and higher ground. This option can serve as an immediate design solution (see Figure 53).

Alternative concept 1: Community and Cultural Arts Center

Quinault Street, First Avenue, Commux Street area

- Elevation: 16 feet
- Capacity: variable—250 to 700 plus people
- Safe Zone area: variable—2,500 to 7,000 square feet depending on structure components introduced into future center

Site characteristics

The site is bounded by Quinault Street, First Avenue, Commux Street with a number of existing community facility buildings: existing community center, recreation building and boxing club, police headquarters and fire station. An underused baseball field to the south completes the site.

Design concepts

All design concepts utilize most existing community facilities as a part of an expanded community and cultural arts "village" center; and, retain the existing ballfield with ancillary use as potlatch parking and exhibit area (see Figures 54 and 55). A new cultural center/longhouse building is incorporated in both design concepts, with two orientations: one to the north, related to the existing complex of community buildings; and two, to the south with new ceremonial facilities, potlatch fire pit, outdoor seating, carving areas, etc.

Alternative concept 2: Facility for emergency vehicles

Community Center vicinity

- Elevation: 16 feet
- Capacity: variable
- Safe Zone area: variable

The Taholah community and original settlement area has no shelter for emergency vehicles. A parking and maintenance garage presents an opportunity for a safe haven zone in an upper loft-office area and/or on the roof. Access can be via a series of ramps along the rear and sides of the new building (see Figure 56).

L. Reassessment of preferred strategy: Open House meetings

Two open house meetings were held in South Beach and Ocean Shores in June 2011. The meetings were open to the general public, including those who were not familiar with Project Safe Haven. The open house meeting method was selected for

the final meetings because it creates a casual, not intimidating, atmosphere and facilitates discussion among all participants. The purpose of the meetings was to serve as a concluding meeting to present the final, community derived, preferred vertical evacuation strategy. Additionally, we asked meeting attendees to fill out a survey to indicate their level of knowledge about tsunamis in general and to provide the project team with feedback about the meeting itself and the presented strategy.

The meetings operated in an open house style with four stations: Tsunami Hazard, Preferred Vertical Evacuation Strategy, Community Design Charrettes, and Site Voting Preference. The meeting did not have an official opening or closing. Rather, meeting attendees were allowed to come and go at any point during the two-hour allotted meeting time. Each station used a combination of maps and handouts to display the community strategies or tsunami hazard and educational brochures to represent the process of the project in Grays Harbor County and to inform residents about vertical evacuation. Project team members were located at all four stations and interacted with local residents throughout the open house by answering questions and explaining the process and purpose of Project Safe Haven. Residents were asked to vote for their top two conceptual locations to prioritize for future planning efforts, those locations that are most needed or most important in their opinion.

Results

The results from the two countywide meetings took the form of survey responses, voting for top two preferred vertical evacuation sites and general impressions of the successes and potential shortcomings of the meetings.

Survey responses

Participants were asked to fill out a survey at each countywide meeting to provide feedback to the project team about the meeting itself, participant's knowledge of tsunamis, final strategy and conceptual sites, and likelihood of implementation. Overall, most of the respondents had an average knowledge of tsunamis before attending the

Table 7: South Beach voting results

South Beach Results	
Site	Votes
1	2
3	2
5	6
9	2

Table 8: Ocean Shores voting results

Ocean Shores Results	
Site	Votes
1	1
2	1
4	10
5	5
6	6
7	4
8	5
9	6
10	6
11	6
12	4
14	19
15	1
16	3
17	3
18	2
19	4

Table 9: Typology voting results

Ocean Shores Typologies	
Typology	Votes
Driving Range	5
Residential Cul-De-Sac	5
**Towers are the preferred typology in Ocean Shores	

meeting and recorded an increase in knowledge as they exited. Almost all respondents appreciated the format of the meeting using thematic stations but only about half agreed fully with the proposed strategy. Many of those who only agreed partially with the presented strategy were concerned with funding and implementation. *(See Appendix F for complete survey responses.)*

Site voting results

The project team requested meeting attendees to vote, with sticky dots, for their top two favorite or deemed most important vertical evacuation structure locations. The results reflect the interests of the attendees. In the future, decision makers will take their preferences into consideration as well as consider which conceptual vertical evacuation locations are the best for the community (see Tables 7 through 9).

M. Conceptual cost estimates

Detailed cost estimates for four representative structures were developed. These estimates are included in the *Safe Haven Vertical Evacuation Structures Conceptual Cost Analysis. (See Appendix G.)* Because of site differences, facility height, and design it is difficult to offer an accurate total costs for all safe haven facilities. However, having said this, the residents of Grays Harbor County have suggested 32 facilities offering tsunami safe havens for 18,450 residents through the construction of 3 berms, 18 towers, 8 tower-berm combination and 3 buildings. If construction costs for all facilities are representative of those per person capacity estimates that have been developed, the total cost for the 32 safe haven facilities could be in the neighborhood of $40 million.

5. Conclusions and Next Steps

Grays Harbor County has high risk/low frequency tsunamis triggered by a magnitude 9+ Cascadia subduction zone earthquake. The last Cascadia earthquake to trigger such a tsunami was recorded in 1700 AD. The rate of occurrence is every 400 years. As a result, the concept of vertical evacuation as a strategy to provide refuge and high ground for evacuation along Washington's coast could not be timelier. The preferred strategies developed for the four Grays Harbor County communities reduce their vulnerability by proposing vertical refuges that are accessible to a significant amount of the population. The strategy was created through a process that builds upon the community's strengths and minimizes its weaknesses, to make them safer and more prepared. In the future, the preferred strategies may be revisited and modified as needed. In the future, funding opportunities will be researched and solicited to implement the preferred strategies. Implementation will take place at a local level with possible state assistance, based on community needs, preferences and response to public input gathered during the duration of Project Safe Haven.

Recent international earthquake and tsunami events

The Pacific County Project Safe Haven report was in the process of being developed at the time of the February 27th, 2010 Chilean earthquake and tsunami. The March 11th, 2011 earthquake and tsunami in Japan took place during the same evening of a Project Safe Haven workshop in Grays Harbor County. As a result, the processes and report development has been influenced by both international earthquake and tsunami events.

Both events in Chile and Japan teach us the importance of tsunami preparedness and mitigation. Several of the structures in Japan, intended for vertical evacuation, saved lives while some did not function as well because of prior assumptions about the size of the event. Therefore, it is imperative that the assumptions in these reports are dutifully revisited following any significant earthquake and/or tsunami to ensure that they remain valid and the conclusions reached in the reports are still applicable. Some of the items that may be revisited are: pedestrian travel times, engineering assumptions, subsidence, i.e.. On a related note, it is important to note that both reports are based on either existing tsunami inundation modeling and/or interpolation of existing modeling by technical experts.

Prior to construction of any proposed vertical evacuation refuge, additional and/or comprehensive tsunami inundation modeling is required. The approach recommended by this study is to use what is known as an ensemble modeling approach, which uses multiple tsunami inundation models and sources to determine the amount of flooding and the velocities of currents from a Cascadia event. The existing models, while good for traditional evacuation planning purposes, are not recommended for determining the final necessary height or elevation of a life-safety structure, such as a vertical evacuation refuge.

Tsunami vertical evacuation refuges

It is important to communicate 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 refuge. However, for day-to-day uses, vertical evacuation refuges should consider the needs of disabled occupants to the extent possible and the extent required by law, in the event of an emergency evacuation. During a tsunami evacuation, following a near-source earthquake, disabled evacuees may need additional assistance accessing refuge areas in vertical evacuation structures.

Throughout the public process of Project Safe Haven it has been the sincerest desire of the communities to incorporate accessibility features into the refuges to the greatest extent possible. For

example, a hybrid tower-berm vertical evacuation structure typology was developed to specifically address the needs of those with limited mobility as the berm portion of the structure includes ramps for wheelchair access. All drawings included in this report are conceptual in nature and as a result no engineered drawings for permitting have been developed. In later stages of vertical evacuation structure development additional accessibility features may be incorporated into the existing conceptual designs. Ultimately, 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.

Future social science research

Additional social science research is necessary before implementation takes place. The research should look at how the proposed vertical evacuation refuges will be phased in over a number of years and how the refuges should be incorporated into existing evacuation planning and messaging. A strategy and methodology for how to conduct public education about evacuation to vertical evacuation refuges needs to be created with updated, accompanying evacuation maps.

Implementation and funding opportunities for vertical evacuation refuges

Tsunami vertical evacuation refuges have been developed over the course of decades in countries like Japan that historically had many significant tsunami incidents. Elsewhere, in countries that have also been recently impacted by devastating tsunamis, like Indonesia, tsunami vertical evacuation refuges are currently in the process of being implemented through the development of outdoor elevated parks. Funding for these projects has largely come from government or private sources. Intentionally designing any type of structure to serve as a tsunami safe haven is a relatively new concept for the United States and no official guidance for engineers or planners existed until late 2008. Traditional funding sources for structural mitigation activities, such as FEMA's Hazard Mitigation Grant Program (HMGP) and Pre-Disaster Mitigation (PDM), do not yet consider tsunami vertical evacuation refuges eligible projects; however, Washington Emergency Management is currently working with FEMA and other stakeholders regarding this issue. It is likely that funding for implementation of this plan will require a combination of federal, state, local, private, and/or non-profit sources to realize full implementation in a timely manner. A variety of incentives may also be considered in order to leverage privately funded development projects. Therefore, project team members and local residents have begun to identify viable options to bring tsunami vertical evacuation to fruition in vulnerable communities along the coast. These 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 facilities
- Incorporation of safe haven structures or components into new civic and recreational facilities.

Private:

- Internal Revenue Service tax credits similar to Historic and/or Architecturally Significant tax credits
- Business improvement areas
- Local and state tax credits
- Zoning incentives in permitting, site requirements and building program (density, parking, square feet, building heights)
- Private donations.

Conclusion

In conclusion, it is important to note and remember that Project Safe Haven is merely a starting point. A collective community vision has been facilitated, recorded and presented. This report will serve as a guide and tool for how tsunami

vertical evacuation may be incorporated into the community over a prolonged period of time with continued community support and direction.

Appendix A: Community Context Maps

Figure 57: South Beach (Westport and Grayland) community context map

Figure 58: Ocean Shores community context map

Figure 59: Taholah community context map

Appendix B: SWOT Analysis Description

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. 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. Categories of strengths include: financial; mobility; preparedness and awareness; and built and natural environment. The preferred alternative builds on the community's strengths.

Weaknesses are impacts, exposures, or vulnerabilities

They are internal to the community and represent items to overcome. Categories of weaknesses include: financial; mobility; preparedness and awareness; and built and natural environment. The preferred alternative helps overcome the community's weaknesses.

Opportunities are capabilities

They are external to the community and represent items to exploit or enhance. Categories of opportunities include: business and economic; human and social capacity; natural and environmental; and 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.

Appendix C: Project Assumptions

To carry out the vertical evacuation community analysis, the project team made assumptions about the tsunami hazard, berm construction and design, and capabilities of the Grays Harbor County population.

Assumptions about the tsunami hazard

1. The scenario event will be a 9.1 magnitude subduction zone earthquake approximately 80 miles off the coast of the Grays Harbor County.
2. The earthquake will last five to six minutes and will create a tsunami.
3. Six feet of subsidence is expected.
4. The modeled tsunami will have a wave-height of approximately 22 feet (NGVD) at the peninsula's western shore, depending upon localized bathymetry, topography and the built environment.
5. The warning before the tsunami will be the earthquake.
6. There will be about 40 minutes between the cessation of shaking and arrival of the first tsunami wave.
7. Although subduction zone earthquake models propose a tsunami warning time of 40 minutes, the creation of the preferred strategies are based on a 15 minute warning time. This reduced warning time takes into account delayed response time of citizens, poor road and sidewalk conditions resulting from the earthquake, as well as possible panic among citizens. Additionally, evacuees will need 5 to 10 minutes to reorient themselves after the earthquake and will ultimately have 15 minutes to walk to a safe haven.
8. Several other tsunami waves will likely follow the initial wave, and there will be danger of recurring waves throughout the entire post-event tide cycle.
9. Tsunami refugees will remain on the structure for two full tide cycles, or up to 24 hours.
10. Routes to vertical evacuation structures will be available and discernible after the earthquake.
11. Those evacuating will walk to the vertical evacuation structures — travel by car will not be possible.
12. Communication will be limited to voice.
13. There are natural lines of defense.
14. Some natural lines of defense have been destroyed.
15. Lines of defense that have been removed can be restored.

Assumptions about the capabilities of the Grays Harbor County population

1. The majority of the Grays Harbor population is physically mobile and can walk to the proposed tsunami evacuation sites.
2. An average walking speed individual can walk 3,600 feet in 15 minutes and a slower walking speed individual can walk 2,700 feet in 15 minutes.
3. People on the beach have average to high physical mobility.
4. There is an awareness of tsunami risk in Grays Harbor County.

Assumptions about the berm construction and design

1. Save havens can be provided.
2. The margin of safety (distance between the height of the tsunami and the floor of the berm) is factored to be 10 feet [Height above inundation level (4 feet) plus margin of safety (3 feet) plus allowance for climate change (3 feet)].

3. If the vertical evacuation structures are constructed on sites where wetlands are compromised, new wetlands will be developed or the compromised wetland will be mitigated in another way.
4. Each vertical evacuation structure will provide ten square feet of space per person.

Appendix D: Site Analysis

Ocean Shores
(From North to South)

General Notes

Ocean Shores presents some unique opportunities that might require deviation from the existing typologies developed in previous communities. Most of the buildable land on the peninsula is already developed or subdivided. There is also an abundance of "vacant" lots, private property with little or no permanent development. The lots are only partially cleared. These lots are used by RVs (presumably in the summer months). If towers to accommodate fewer people could be designed and developed and distributed throughout the peninsula on private property, it would provide both a refuge for neighboring residents and a private benefit for the landowner who chooses (either voluntarily or through an incentive program) to accomplish the long-term goals of sufficient artificial high ground (see Tables 10 and 11, Figures 60 through 83).

Figure 60: Ocean Shores reference map

Table 10: Site analysis of Ocean Shores

Ocean Shores	
Location	**Comment**
1. Dunes Lane & Sand Road (Tower)	Appropriate site. A tower would likely work here. There is a large (permanent) RV Park.
2. Quinault Beach Resort (Tower)	Appropriate site. Private land. Plenty of room for a tower or structure.
3. Oyehut Road (Berm)	Inappropriate site. The proposed site at the end of Oyehut Road is separated from the high school by a marsh/canal. Any structure here would only serve people that live on Oyehut Road. Move site closer to school and main road.
4. Shores Bowl (Parking Structure)	Appropriate site for parking structure. (Must determine if additional parking would benefit community.)
5. Ocean Shores Golf Course (Berm/Tower)	Appropriate site for either a berm or a tower.
6. Hutton St SE & Olympic View Ave (Tower)	Appropriate site. Large parcels of land east of Olympic View Ave and smaller parcels to the west.
7. Ocean Shores Elementary School (Berm/Tower)	Appropriate site for tower.
8. Community Club @ Ocean Shores Blvd & Taurus Blvd SW (Tower)	Appropriate site. Tower could serve multiple purposes.
9. Chinook Park (Berm/Tower)	Appropriate site. Enough room for a tower. A berm would completely reshape the property and change the available uses.
10. Cormorant St (Tower)	Challenging site. Limited available land in the immediate area. Tower would work if property owners cooperate.
11. Texmar St SW & Seashore St SW (Tower)	Challenging site. Limited available land in the immediate area. Tower would work if property owners cooperate.
12. Emeritus @ Harbor Pointe (Tower)	Appropriate site. Berm or tower would both work.
13. Wowona Ave SE & Tonquin Ave SW (Tower)	Challenging site. Limited available land in the immediate area. Tower would work if property owners cooperate.
14. Spinnaker Park (Berm/Tower)	Appropriate site. Berm or tower would both work.

Figure 61: Site 1

1. Dunes Lane & Sand Road (Tower)

The proposed tower at Dune Lane and Sand Road would serve a permanent RV Park and a few houses between the RV Park and the Casino. There is land available to develop berms as well as towers. There is a small lake at the south end of the RV Park that could be part of a natural berm feature. The RV Park was closed to visitors at the time of the site visit and information about the ownership and availability of land can be obtained later.

Figure 62: Site 2

Figure 63: Site 4

2. Quinault Beach Resort Casino (Tower)

The Quinault Indian Nation, which owns and operates the Quinault Beach Resort Casino, has the land available to explore tower, berm, or structure alternatives.

3. Oyehut Road (Berm)

The site identified at the end of Oyehut Road will not appropriately serve the areas designated in the community meeting. Any structure here would only serve people that live on Oyehut Road. A wetland, channels, and mini-lakes separate the road and the High School. Prior to the next meeting in Ocean Shores, the project team can take an opportunity to explore alternatives. The High School property is large enough to accommodate a structure and benefits by placement along the main road in and out of town. Perhaps this site is better if divided into two sites to serve the different communities.

4. Shores Bowl (Parking Structure)

Shores Bowl is located near the main intersection in Ocean Shores, across the street south of the Convention Center. The parking lot in front of the strip mall is narrow. There is access to a back gravel parking lot (most likely overflow parking for summer tourism) on both sides of the building. The gravel lot abuts the golf course to the south. There is currently a skate park in the southeast corner of the lot. If the location is considered for a parking structure, it should be noted that the Convention Center across the street has a large lot and during non-peak seasons any additional parking will likely be unused or underused.

5. Ocean Shores Golf Course (Berm/Tower)

The Ocean Shores Golf Course is located in the center of the peninsula. The clubhouse/pro shop is at the intersection of Canal Dr NE and Albatross St SE. The course, in general, is straight and flat, without too much additional land along the fringe of the course. There are opportunities for berms throughout to enhance the character of the course, similar to the bermed tees and greens discussed at Long Beach and Tokeland community meetings. However, a multilevel tower driving range tee is also a viable, alternative typology.

6. Hutton St SE & Olympic View Ave (Tower)

There is a large vacant lot on the north side of

Figure 64: Site 5

Figure 65: Site 6

Hutton St SE and east of Olympic View Ave. It appears to be a collection of lots that are for sale either individually or as a group. The area is relatively flat and between single-family residences and the surrounding neighborhood is an area of newer single-family homes. There might be resistance to a tower in this location and the space is large enough to consider multiple alternatives. On the west side of Olympic View Ave there is another undeveloped area. There are two or three lots prepared for RVs. West of these three sites, up to Fisher Ave, there is a forested area. This site might also have some potential. West of Fisher there is another vacant lot, much smaller and perhaps only half the width of the block. Not as many options available.

7. Ocean Shores Elementary School (Berm/Tower)

Ocean Shores Elementary School has limited available land to build a berm. Baseball/soccer/play fields are on the north side of the campus. There is also an undercover outdoor basketball court attached to the north side of the school building. The school and parking lot cover much of the available land. There is a thin, undeveloped grass area on the south side of the school building. There is a potential opportunity at the church that borders the north side of the location.

Figure 66: Site 7

Figure 67: Site 8

8. Community Club at Ocean Shores Blvd & Taurus Blvd SW (Tower)

The community club has soccer fields, tennis and basketball courts, and an outdoor picnic area. There is a water tower in the southwest corner. There might be an opportunity to replace the existing covered seating in the picnic area with a functional tower that serves the purpose of an outdoor food/gathering area.

Figure 68: Site 9

9. Chinook Park (Berm/Tower)

Chinook Park has a basketball court, soccer field, playground and boat launch. Without changing the existing use of the park (primarily the soccer field), it would be difficult to site a berm at this location.

10. Cormorant St (Tower)

Cormorant St runs east-west across the peninsula and crosses a manmade canal that runs north-south. The parcels appear to be mostly subdivided for single-family homes and smaller lots for trailers and RVs. There are "vacant" lots, but these appear to be private property with little or no development *(see General Notes)*. As such, locating vacant land is difficult. There are smaller lots at the intersection of Cormorant St and Albion Ave SE, Cormorant and Island Circle, and Cormorant and Mt. Olympus Ave S.

11. Texmar St SW & Seashore St SW (Tower)

Similar to Cormorant St *(see General Notes)*. Available land appears to be owned. Limited development with the exception of fences, sheds, RV covers, and picnic tables. Land just north of the intersection appears to be vacant. There are no visible driveways or RV areas on the west side of Texmar St until a cleared lot south of the intersection of Texmar St and S Wynoochee Dr SW.

12. Emeritus at Harbor Pointe (Tower)

The assisted living community at Harbor Pointe is south of a Community Club location. There is a wooded area south of the Emeritus that might be a potential structure location. The area across the street is also undeveloped, with the exception of a single-family home for sale. The land, however, appears to be owned and is currently for sale.

13. Wowona Ave SE & Tonquin Ave SW (Tower)

There is little available land near the intersection. The development is similar to sites at Cormorant and Texmar *(see General Notes)*. A survey of available properties along the roads in all directions from the intersection found little vacant land. There is a large area of undeveloped land further southeast, however, this area likely extends beyond the walking circles (unless planning for summer population to provide refuge for the large RV parks near Damon Point State Park). There might be some available property between

Figure 69: Site 10

Figure 70: Site 11

Figure 71: Site 12

Figure 72: Site 13

Tonquin Ave and Coyote Ct on Wowona Ave on both sides of the road.

14. Spinnaker Park (Berm/Tower)

Large circular land area at the center of subdivision loops. The area is flat and appears not to be intended for development. A berm could potentially work.

Figure 73: South Beach (Westport and Grayland) reference map

Table 11: Site analysis of Westport and Grayland

Westport and Grayland	
Location	**Comment**
Westport (From North to South)	
1. Marina Area (Tower/Berm/Building)	Several appropriate sites. There are several potential sites for a tower or building in the marina area at the northern end of the peninsula. Each site would be suitable for a variety of uses. See expanded report for additional info.
2. 2nd and Washington (Building)	Challenging site. The undeveloped land at the northwestern corner of 2nd and Washington is suitable for a building or tower. Water drains through the property. There are several other sites nearby that would offer separate opportunities.
3. Surf and Ocean (Tower)	Appropriate site selection. Many options. There is available land around the lighthouse and Coast Guard housing and adjacent to Vacations by the Sea on Sherman Ave.
4. Forrest and Newell (Tower)	Challenging Site. The nearest parcel to Forrest and Newell is on the east side of a steep hill. The slope could present a challenge to some structure, but might be allow a berm to be set against the existing natural features. See expanded report for additional info.
5. Ocosta School (Berm)	Ocosta School is on existing high ground and could be reinforced. In addition to a football field, soccer field, undercover basketball courts, and academic buildings, there is a large parking lot, playgrounds, and areas.
6. SR 105 and W Bonge Ave (Tower)	Good potential sites near intersection. Variety of options and structure types.
Grayland (From North to South)	
7. SR 105 and Marine Drive (Tower)	Good potential site north of intersection. Variety of options and structures.
8. SR 105 and Jado Place (Tower)	Challenging location. Not much available land near intersection. Private property restricts movement/land.
9. SR 105 and McDermott Lane (Tower)	Challenging site. Small site on McDermott Lane that might be able to accommodate a tower. There might be additional opportunities in the surrounding areas. Access to these sites was restricted by gated drives.

Figure 74: Site 1

Westport (From North to South)

1. Marina Area (Tower/Berm/Building)

There are several potential sites for a tower or building in the marina area at the northern end of the peninsula. There is a vacant lot at the intersection between Harms St and Dock Ave large enough to accommodate a tower, structure or potentially a berm. There is another vacant lot to the south near industrial buildings. Similar to proposed structures in Tokeland, an industrial typology could be a reasonable alternative. The final site is the golf course. The proposed design places the 18th hole and 10th tee box on the north side of the course nearest the ocean. The developer could build natural berm features or a structure.

2. 2nd and Washington (Building)

The undeveloped land at the northwestern corner of 2nd and Washington is suitable for a building or tower. There are channels that drain through the property. There are other potential sites near the airport and the corner of Montesano and Wilson Road. There is another potential site at Harm's Field. These four sites could accommodate a variety of potential capacities, uses, and typologies.

3. Surf and Ocean (Tower)

The available land around the lighthouse, Coast Guard housing, and adjacent to Vacations by the Sea on Sherman Ave allows for a wide variety of building types. The area immediately around the

Figure 75: Site 2

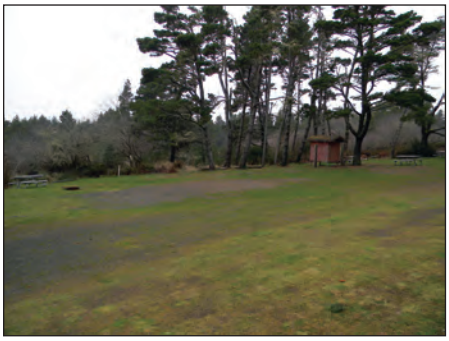


Figure 76: Site 3

Figure 77: Site 3 (additional photos)

Figure 78: Site 4

lighthouse could accommodate another tower, as suggested at the community meeting. A series of berms around the natural water features near Vacations could benefit residents and tourists. The area is well accessed by roads and a series of trails through the park (which could provide necessary routes from the beach and park if an earthquake occurred during the high season).

4. Forrest and Newell (Tower)

The nearest parcel to Forrest and Newell is on the east side of a steep hill. The slope could present a challenge to some structures, but might allow a berm to be set against the existing natural features. The undeveloped land stretches to the north and flattens. A tower is feasible on the street side of the property. There are no obvious shared uses at this location.

5. Ocosta School (Berm)

Ocosta School is on existing high ground. In addition to a football field, soccer field, undercover basketball courts, academic buildings, there is a large parking lot, playgrounds, and areas.

6. SR 105 and W Bonge Ave (Tower)

There are two potential sites near the intersection of SR 105 and W Bonge Ave. The first site is on the east side of SR 105. There is a large lot with a few abandoned industrial or agricultural buildings. It appears to be an ideal site for an evacuation structure. The second available group of parcels is about 500 feet to the south on the west side of the road. The area appears ready for residential development.

Grayland

(From North to South)

General Notes

The challenge in Grayland will be to identify alternative uses for vertical evacuation structures. While there is available land for a variety of purposes, there are likely not enough residents to support intense land uses. This is exacerbated by limited land between the cranberry bogs and the ocean.

Figure 79: Site 5

Figure 80: Site 6

Figure 81: Site 7

7. SR 105 and Marine Drive (Tower)

There is a large area of undeveloped land on the north side of the church near Marine Drive. While the community prefers a tower at this location, there is opportunity to use the expansive land for more diverse purposes.

Figure 82: Site 8

8. SR 105 and Jado Place (Tower)

There is an open field that can accommodate a tower and berm behind the houses at the western end of Jado Place. There is limited available land near the intersection. This site might require a second look at some point.

Figure 83: Site 9

9. SR 105 and McDermott Lane (Tower)

There is a small site on McDermott Lane that might be able to accommodate a tower. There might be additional opportunities in the surrounding areas. Access to these sites was restricted by gated drives.

Appendix E: Structure Calculations Formula Tables

Table 12: Westport and Grayland calculations

Map Number	Community	Type	Location	Existing Site Elevation	Wave Inundation Depth at Site	Margin of Safety	Existing Elevation + Wave Inundation + Margin of Safety	Safe Zone Floor Height	Minimum Structure Height (rounded up)	Structure Capacity
1	Westport	Building	Marina	9.84 feet	7.15 feet	10 feet	27 feet	17.15 feet	17 feet	1,500
2	Westport	Building	Adams & Washington	9.84 feet	7.15 feet	10 feet	27 feet	17.15 feet	17 feet	1,000
4	Westport	Tower	Surf & Ocean	9.84 feet	7.15 feet	10 feet	27 feet	17.15 feet	17 feet	900
3	Westport	Tower	Forrest & Newell	13.12 feet	3.87 feet	10 feet	27 feet	13.87 feet	14 feet	900
5	Westport	Berm	Ocosta School	16.40 feet	0.59 feet	10 feet	27 feet	10.59 feet	11 feet	1,500
6	Westport	Tower	HWY 105 & W Bonge	13.12 feet	3.87 feet	10 feet	27 feet	13.87 feet	14 feet	900
7	Grayland	Tower	Wood Lane	13.12 feet	3.87 feet	10 feet	27 feet	13.87 feet	14 feet	550
8	Grayland	Tower	HWY 105	9.84 feet	7.15 feet	10 feet	27 feet	17.15 feet	17 feet	550
9	Grayland	Tower	McDermott Lane	19.68 feet	0.00 feet	10 feet	29.68 feet	10.00 feet	10 feet	550

Table 13: Taholah calculations

Map Number	Community	Type	Name	Location	Existing Site Elevation	Highest inundated elevation (assumption)	Wave Inundation depth	Margin of Safety	Existing Elevation + Wave Inundation + Margin of Safety	Safe Zone Floor Height	Minimum Structure Height (rounded up)	Structure Capacity
1	Taholah	Tower / Berm	Senior Apartments	2nd Ave & Spruce St	13.12 feet	19 feet	5.87 feet	10 feet	29 feet	15.87 feet	16 feet	300 people
2	Taholah	Berm	Elementary School	5th Ave & Commux St	13.12 feet	19 feet	5.87 feet	10 feet	29 feet	15.87 feet	16 feet	400 people
3	Taholah	Tower	Park Place	Park Place (Trailer Park)	13.12 feet	19 feet	5.87 feet	10 feet	29 feet	15.87 feet	16 feet	200 people

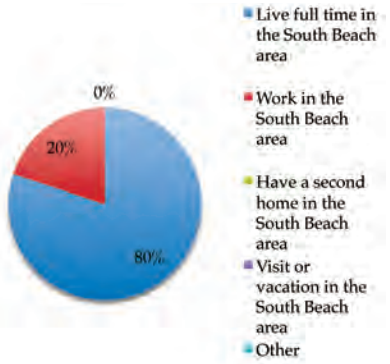
Table 14: Ocean Shores calculations

Map Number	Community	Type	Location	Existing Site Elevation	Wave Inundation Depth at Site	Margin of Safety	Existing Elevation + Wave Inundation + Margin of Safety	Safe Zone Floor Height	Minimum Structure Height (rounded up)	Structure Capacity
1	Ocean Shores	Tower	Ocean City	16.40 feet	3.28 feet	10.00 feet	29.68 feet	13.28 feet	14 feet	300
2	Ocean Shores	Tower	Quinault Beach Resort	16.40 feet	3.28 feet	10.00 feet	29.68 feet	13.28 feet	14 feet	500
4	Ocean Shores	Berm	North Beach Junior/ Senior High School berm	16.40 feet	0.00 feet	10.00 feet	26.40 feet	10.00 feet	10 feet	800
3	Ocean Shores	Tower	Downtown Ocean Shores	16.40 feet	0.00 feet	10.00 feet	26.40 feet	10.00 feet	10 feet	1,700
5	Ocean Shores	Tower/ Berm	Golf Course	13.12 feet	0.00 feet	10.00 feet	23.12 feet	10.00 feet	10 feet	350
6	Ocean Shores	Tower	Ocean Shores Airport	13.12 feet	nd	10.00 feet	23.12 feet	10.00 feet	10 feet	350
7	Ocean Shores	Tower/ Berm	Ocean Shores Elementary Civic Complex	13.12 feet	0.00 feet	10.00 feet	23.12 feet	10.00 feet	10 feet	350
8	Ocean Shores	Tower	Ocean Shores Blvd & Taurus Blvd SW	9.84 feet	6.56 feet	10.00 feet	26.40 feet	16.56 feet	17 feet	350
9	Ocean Shores	Tower/ Berm	Blue Wing Loop SE & Duck Lake Drive SW	13.12 feet	nd	10.00 feet	23.12 feet	10.00 feet	10 feet	350
10	Ocean Shores	Tower	Cormorant Street	9.84 feet	nd	10.00 feet	19.84 feet	10.00 feet	10 feet	350
11	Ocean Shores	Tower	Ocean Shores Blvd & Marine View Drive SW	9.84 feet	3.28 feet	10.00 feet	23.12 feet	13.28 feet	14 feet	350
12	Ocean Shores	Tower	Emeritus Senior Living	13.12 feet	nd	10.00 feet	23.12 feet	10.00 feet	10 feet	500
13	Ocean Shores	Tower	Wowona Ave SE & Tonquin Ave SW	13.12 feet	3.28 feet	10.00 feet	26.40 feet	13.28 feet	14 feet	350
14	Ocean Shores	Tower/ Berm	Spinnaker Park	13.12 feet	6.56 feet	10.00 feet	29.68 feet	16.56 feet	17 feet	500
15	Ocean Shores	Tower/ Berm	Ocean City State Park Campground	22.96 feet	3.28 feet	10.00 feet	36.24 feet	13.28 feet	14 feet	350
16	Ocean Shores	Tower	Duck Lake Drive	13.12 feet	nd	10.00 feet	23.12 feet	10.00 feet	10 feet	350
17	Ocean Shores	Tower	Trois Court & Inlet Avenue NW	13.12 feet	0.00 feet	10.00 feet	23.12 feet	10.00 feet	10 feet	350
18	Ocean Shores	Tower/ Berm	Ocean Lake Way & N Port Loop	13.12 feet	6.56 feet	10.00 feet	29.68 feet	16.56 feet	17 feet	350
19	Ocean Shores	Tower/ Berm	North Razor Clam Drive & Butterclam St SW	13.12 feet	0.00 feet	10.00 feet	23.12 feet	10.00 feet	10 feet	350
20	Ocean Shores	Tower	Mt. Olympus	13.12 feet	nd	10.00 feet	23.12 feet	10.00 feet	10 feet	350

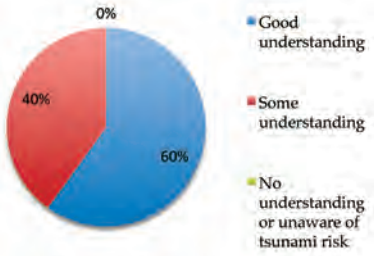
Appendix F: Survey Responses

South Beach Survey Questions

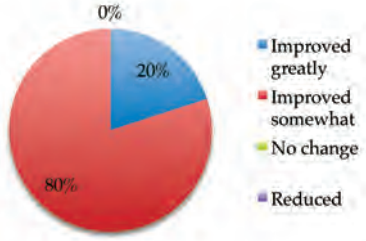
1. Do you: (circle all that apply)
   A. Live full time in the South Beach area
   B. Work in the South Beach area
   C. Have a second home in the South Beach area
   D. Visit or vacation in the South Beach area
   E. Other



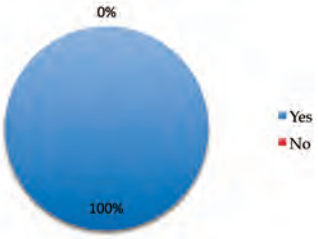
2. Prior to this Open House, what was your understanding of your tsunami risk? (circle one)
   A. Good understanding
   B. Some understanding
   C. No understanding or unaware of tsunami risk



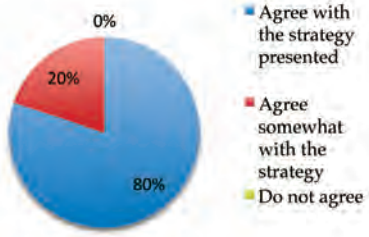
3. After this Open House, how has your understanding of your tsunami risk changed? (circle one)
   A. Improved greatly
   B. Improved somewhat
   C. No change
   D. Reduced



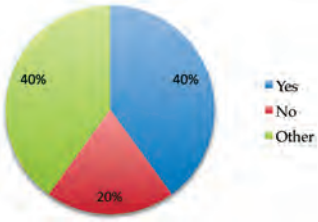
4. Would you support private development incentives to build according to vertical evacuation standards? (circle one)
   A. Yes
   B. No



5. A vertical evacuation strategy was presented at this Open House. Do you: (circle one)
   A. Agree with the strategy presented
   B. Agree somewhat with the strategy
   C. Do not agree



6. Would you support local taxes to help fund implementation of the strategy presented tonight?
   A. Yes
   B. No
   C. Other



Appendix G: Summary of Cost Estimates

Safe haven vertical evacuation structure cost analysis: Grays Harbor County

(Excerpt from the Safe Haven Vertical Evacuation Structures Conceptual Cost Analysis *report, available as a separate report)*

Executive Summary

Detailed within this report [the *Safe Haven Vertical Evacuation Structures Conceptual Cost Analysis* report] are the construction cost estimates for select vertical evacuation structures designed for the Project Safe Haven: Grays Harbor County. The purpose of the estimates was to start developing further information into the economic feasibility of constructing tsunami safe haven structures for various local communities at the Washington State coast that could withstand the forces of a magnitude 9.1 Cascadia Subduction Zone earthquake, and the resulting tsunami inundation. Two conceptual structures sited in Grays Harbor County were estimated: a berm design and a fire station. These structures not only will act as safe havens during the tsunami event but will also be active facilities that serve their local communities on a daily basis.

The first safe haven is the Grayland Fire Station located at the vicinity of McDermott Lane in the city of Grayland. The fire station includes a two-story portion for offices and firefighter facilities, as well as four 16 feet x 40 feet bays to accommodate emergency vehicles. The safe zone area is achieved by using its roof section that will be accessible by a ramp at the side of the building structure. This building will sit on a foundation of battered piles. The estimated cost for this building is $1,384,013 with the majority of the costs attributed to the pile foundation and robust structural system (see Table 15).

The second safe haven is the Spinnaker Park berm structure located at Spinnaker Street and Storm King Avenue in Ocean Shores (see Table 16). It consists of a berm with reinforced concrete walls providing a barrier from tsunami inundation. This berm will be part of a park facility that serves as play areas, seating areas for neighborhood events, kite flying mounds, viewing areas, children's forts, and dog walking areas. The berm has a stepped planting structure located at the base of the safe zone, and serves as a debris deflection barrier. The berm also has two hardened access ramp-slopes protected from both ocean and bay inundation sources. The estimated cost for the berm with reinforced concrete walls is $1,163,272. An option of providing a berm structure using sheet piling instead of reinforced concrete walls was analyzed but it was not economically viable when compared to the concrete wall option.

Conclusions

For each site, certain challenges showed up that affect the estimated costs of the safe haven structures. The challenges typical to each site are due to the remote location of the Washington Coast and more limited options in material supply and builder competition. Listed below are the individual cost estimates for the sites.

The cost associated with the Grayland Fire Station is $1,384,013 with the majority of costs associated with the foundation and structure of the building. In order for this structure to withstand the design seismic event and remain suitable for a vertical evacuation structure, it requires battered pile foundations and a robust structural system. Adding to the costs are the functionality requirements of an active fire station that include features such as garage doors, extensive site work, and operation spaces for the tenants of the building. Since this project does not require a large amount of imported or exported fill materials, this project is not as affected by the earthwork cost as the other projects listed in this report.

The costs associated with the Spinnaker Park berm with reinforced concrete walls option are $1,163,272. The earthwork contributes a significant amount of costs for the berm and the reinforced concrete wall and stepped landscaping also contribute.

Table 15: Grayland Fire Station cost estimate

Grayland Fire Station	
Scope	**Cost**
Site utilities	$36,509
Excavation-backfill	$26,578
Foundation	$254,012
Structure	$188,273
Exterior walls	$96,042
Roofing	$14,094
Stairs	$54,727
Interior finishes	$36,786
Mechanical	$74,647
Electrical	$35,482
Plumbing	$44,934
Fire protection	$19,155
Landscaping	$53,903
Total	**$935,144**
Design Fees (8%)	$74,811
General conditions (10%)	$93,514
Contractor fees, O & P (15%)	$140,272
Construction contingency (5%)	$46,757
Estimate/design contingency (10%)	$93,514
Project total	**$1,384,013**

Table 16: Spinnaker Park berm cost estimate

Spinnaker Park berm	
Scope	**Cost**
Site utilities	$55,725
Excavation-backfill	$385,762
Concrete retaining wall surrounding berm	$173,075
Landscaping concrete	$100,323
Stairs/Ramps/Guardrails	$11,498
Landscaping	$59,612
Total	**$785,995**
Design Fees (8%)	$62,880
General conditions (10%)	$78,599
Contractor fees, O & P (15%)	$117,899
Construction contingency (5%)	$39,300
Estimate/design contingency (10%)	$78,599
Project total	**$1,163,272**

Appendix H: 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 was 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.

Jeana C. Wiser:

Jeana C. Wiser is a research assistant at the Institute for Hazards Mitigation Planning and Research at the University of Washington. She is the Planning and Outreach Project Lead for Project Safe Haven. Jeana has specialized experience in the following areas: hazard mitigation planning, historic preservation, adaptive re-use, community outreach and project management. She recently graduated in June 2011 from the University of Washington with a Master's of Urban Planning. In addition to the master's degree, Jeana also earned a Certificate of Historic Preservation. Her thesis research addressed the integration of Historic Preservation and Hazard Mitigation especially regarding Seattle's unreinforced masonry buildings. Jeana also has two Bachelors' of Science degrees in Ethnic Studies and Liberal Studies from Oregon State University.

Amanda Engstfeld:

Amanda Engstfeld is a graduate of the Institute for Hazards Mitigation Planning and Research and holds a Masters Degree in Urban Planning, with a focus on hazard mitigation planning and land use from the University of Washington. Amanda is currently a Risk Analyst in the Mitigation Division for FEMA Region X. Prior to working for FEMA, Amanda worked as an Emergency Planner for the City of Redmond, Washington.

Katherine Killebrew:

Katherine Killebrew received her Master of Urban Planning and Master of Public Administration from the University of Washington in 2010. She now works as a policy analyst for the U.S. Government Accountability Office in the agency's Seattle field office.

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.

Tricia DeMarco:

Tricia DeMarco has recently graduated from the University of Washington with a Master in Urban Planning and a Master in Civil Engineering. Her specialization is in building the connection between engineering projects and their community context. Past projects include brownfield redevelopment, transportation impact reduction, and small town systems planning primarily in developing countries throughout South America, Asia, and Eastern Europe. DeMarco is a LEED A.P. and E.I.T. She now works for Magnusson Klemencic in Seattle, WA as a site designer.

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 resiliency 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 Masters of Science in Construction Management. Before attending UW he worked for General Contractors in Seattle and the San Francisco Bay Area. His main expertise comes in healthcare, 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 and just welcomed their brand new baby, Lucile, into this word in June.

Washington State Emergency Management Division (EMD)

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.

Jamie Mooney:

Jamie Mooney is the State Hazard Mitigation Strategist for Washington at the Emergency Management Division. Prior to this position, she was a NOAA Sea Grant Fellow at Emergency Management focusing on building community resilience to coastal hazards. Jamie received her Masters of Marine Affairs from the University of Washington's School of Marine Affairs.

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.

Tyree Wilde:

Tyree Wilde is the Warning Coordination Meteorologist for the National Weather Service (NWS) in Portland, OR. He works toward enhancing the forecast and warning system by closely tying the agency's mission of protecting lives and property, and enhancing the region's economy, with its customers, such as emergency managers, the media, land and water managers, and the marine community. Tyree holds a Masters degree in Meteorology from the University of Utah and has been a professional meteorologist for 28 years. Prior to his present position in Portland, he served as the Warning Coordination Meteorologist in Flagstaff, AZ. He has also worked in weather stations in Omaha, NE, Phoenix, AZ, and Cape Canaveral, FL while serving as a Weather Officer in the US Air Force.

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).

Grays Harbor County Emergency Management

Charles Wallace

Charles Wallace is the Deputy Director of Emergency Management for Grays Harbor County, WA. He is a member of the Professional Development Workgroup for Region 3 Homeland Security, WA and an elected Fire Commissioner for Grays Harbor Fire District #11 in Grayland, WA. He retired from the Philadelphia Fire Department in 2007 after more than 24 years of service as a Fire Captain and Acting Battalion Chief.

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 I: References

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