Project Safe Haven: Vertical Evacuation Opportunities on the Washington Coast

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The Pacific County communities on the Washington coast lack natural high ground and sit within close proximity to the Cascadia subduction zone. The communities are vulnerable to significant damage from a tsunami triggered by a Cascadia subduction zone earthquake. Students from the University of Washington, with support from state, county and tribal emergency management officials, created a community-driven public process to identify potential locations for vertical evacuation structures. Vertical evacuation allows residents and visitors to move upwards to safety during a tsunami warning and is particularly important in Pacific County and other coastal counties where traditional evacuation measures are not feasible. Project Safe Haven is the first of its kind. This report documents the methodology and results from the project's work within Pacific County. In the sections below, the report provides a profile of the hazard, a description of vertical evacuation and associated cost estimates, a description of the process to develop vertical evacuation strategies for Pacific County, and the preferred strategy table.

Tsunami Hazard and Vertical Evacuation

A tsunami is a series of sea waves, commonly caused by an undersea earthquake. Pacific County is vulnerable to two types of tsunamis; those created by a distant seismic event and those created by a local, offshore earthquake. After a distant earthquake, Pacific 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 Pacific 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 Pacific County delegated assembly areas. A local earthquake will cause tremendous destruction and leave little time for people to evacuate to high ground before the subsequent tsunami waves arrive. A short evacuation window and lack of natural high ground necessitates the development of a vertical evacuation strategy in Pacific County. To analyze the effects of a worst-case scenario tsunami, the team referenced a modeled subduction zone earthquake scenario.[1] The referenced scenario is a local Cascadia subduction zone magnitude 9.1 earthquake. An earthquake of this size occurs off the Washington coast every 300-500 years, on average. The last one took place in January 1700 CE.[2] The modeled local subduction zone earthquake will:

- Originate approximately 80 miles off of the Pacific Northwest coast
- Cause six feet of land subsidence along the coast
- Last five to six minutes
- Trigger a tsunami that will reach Pacific County's coast 40 minutes after cessation of shaking

Though the model suggests 40 minutes 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 to infrastructure and buildings and leave tremendous debris on roadways and other property. Most residents 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. According to the model, the primary tsunami wave will have a wave-height of approximately 22 feet (National Geodetic Vertical Datum: NGVD) at the western shore with some variation depending upon localized bathymetry and topography. Vertical evacuation options must to be feasible for up to 24 hours after the earthquake in order to provide safety from multiple tsunami waves.

Typically, tsunami warnings trigger horizontal evacuation, either by car or on foot. A horizontal evacuation strategy is appropriate when communities have natural high ground that is easily accessible. When a community has little or no natural high ground, however, horizontal evacuation may not be an option. Vertical evacuation provides engineered, artificial high ground in communities that lack natural and accessible high ground. The project team and community members evaluated three vertical

[1] Priest and others, 1997; and Walsh and others, 2000
[2] Satake and others, 2003; Atwater and others, 2005; CREW 2005

evacuation structure options, berms, towers or buildings, as defined in *FEMA P646: Guidelines for Design of Structures for Vertical Evacuation from Tsunamis*.

Berms are artificial high ground created from soil. 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 has three component parts: a rounded front portion and gabion mound, the elevated safe haven area, and the access ramp. A berm can range in size from 1,000 square feet for 125 people up to 100,000 square feet for 12,500 people. The costs used for berm design were based primarily on RSMeans Unit Cost Data for 2010. According to this design, the cost of a berm increases equally with the addition of height or capacity. Estimated costs range from $300,000 – $900,000 depending on the required height and square footage.

Towers 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. A 500 square foot tower can hold 62 people and a 1,000 square foot tower can hold 125 people. The tower design used for construction cost estimates has five components: the foundation, a base isolation system, the support structure, superstructure, and methods of access. Two access options are included in the estimates; a breakaway stair system designed for daily use and for use to access the tower following a major earthquake. Following the tsunami event, evacuees would use a retractable staircase to leave the tower. The costs used for tower design were based primarily on RSMeans Building Construction Cost Data for 2010. Based on this generalized conceptual design, towers were determined to be the lowest cost. The cost of towers varies more greatly with increased capacity than with increased height. Estimated costs range from $110,000 - $170,000 depending on the required height and square footage.

A building used as a tsunami evacuation structure has a ground floor that allows the tsunami wave to move through it or is faced in a manner that the structural integrity of the building would 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. For this project, the design used for construction cost estimates was based on citizen comments and preferences for two parking garages in the Tokeland area. In order to increase the likelihood of withstanding a tsunami, the first level of the building is considered "transparent," having little surface area so as to reduce resistance against the force of the tsunami. The cost of a building depends greatly on the design requirements of the building's primary use. The cost was based on parking garage cost according to the RSMeans Square Foot Costs Reference for 2010.

Methodology

In 2008, FEMA and NOAA released guidance on vertical evacuation. Several at-risk Pacific Coast communities began efforts to apply the FEMA guidance locally. In Pacific County, local officials documented their tsunami risk in the Pacific County Hazard Mitigation Plan. Under the direction of the state Earthquake and Tsunami Program Officer, Pacific County's Emergency Manager, and the University of Washington Project Safe Haven, Pacific County was selected as the pilot community to conduct the first safe haven identification project. A steering committee composed of local and state officials, emergency managers, and scientists was established to guide the project and to select the targeted communities. Four Pacific County communities were selected as the project's focus.

The team conducted site surveys in each of the four communities before initiating the public process. Unique community attributes such as geography and land use were recognized and noted. Surveyed community attributes guided preparation for the first public meeting in each community and assisted with the development of approaches.

A series of two initial meetings were conducted in each community. The first meeting utilized the World Café meeting process to identify and discuss the concept of vertical evacuation, various structure types, and conceptual site locations. The project team presented and discussed the alternatives that had been synthesized from the first meeting at the second meeting.

World Café meetings use "café style" conversations to facilitate small group brainstorming. During meeting #1 participants referenced large table maps of the community, in combination with walking circles and Lego models of vertical evacuation structures, to determine ideal placement locations.

Each station represented a different type of vertical evacuation structure: berm, tower, or building. At the end of the World Café participants shared their discussion points and preferences for specific structure types and placement locations.

At meeting #2, the project team presented the alternatives derived from meeting #1 using maps and graphics. Next, the team facilitated a large group brainstorming session regarding the strengths and weaknesses of each alternative using a strengths and weaknesses analysis technique. The goal of the meeting was to build consensus among those present and to develop a preferred strategy.

After the series of initial community meetings were complete, the project team allowed time for the community to mull and accept the preferred community strategies. The mulling process provided opportunities for both formal and informal community discussions about the preferred strategies. The project team occupied a booth at a Pacific County Emergency Preparedness Fair and presented preliminary strategies to the general public in the form of brochures and community profiles. The preliminary findings contributed to the community mulling process because it served as an educational component for residents who were unaware of Project Safe Haven. Ground-truth research at the site level for each proposed vertical evacuation site and solicitation of walking volunteers to confirm walking speed assumptions also took place during the community mulling process. Volunteers from all four communities participated in the walking study by walking from their home to the nearest proposed berm, tower, or buildings or assembly location and recording the time, distance, walking path, age, and any potential obstructions. This particular component of the project was essential in encouraging discussion, acceptance and excitement about the project. After the community was given time to mull, the project team reconvened to analyze data and develop the final strategy to be presented to the community. The team utilized new LiDAR elevation data in combination with wave height data for each conceptual site to determine necessary structure heights. Each conceptual site was designated berm, tower, parking structure, high ground, or assembly area. Some proposed berm sites were changed to high ground to reflect the new LiDAR elevation data.

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. The maps were presented at the countywide meetings along with estimated capacities for each vertical evacuation site or structure. Two countywide meetings were held to confirm the preferred strategy and to receive further feedback about the project. Information about estimated costs, community processes, the tsunami hazard, and the intensive design workshops, commonly referred to as charrettes, was also presented.

Mid-process, the project team increased opportunities for public feedback and participation with the addition of an urban design team from the University of Washington. The design team conducted two charrettes in Pacific County to discuss how the proposed vertical evacuation structures will best fit into the context of the community and possible everyday uses for the structures. The design charrettes resulted in participant derived graphics that represent how the proposed structures could look and function as a positive addition to the community.

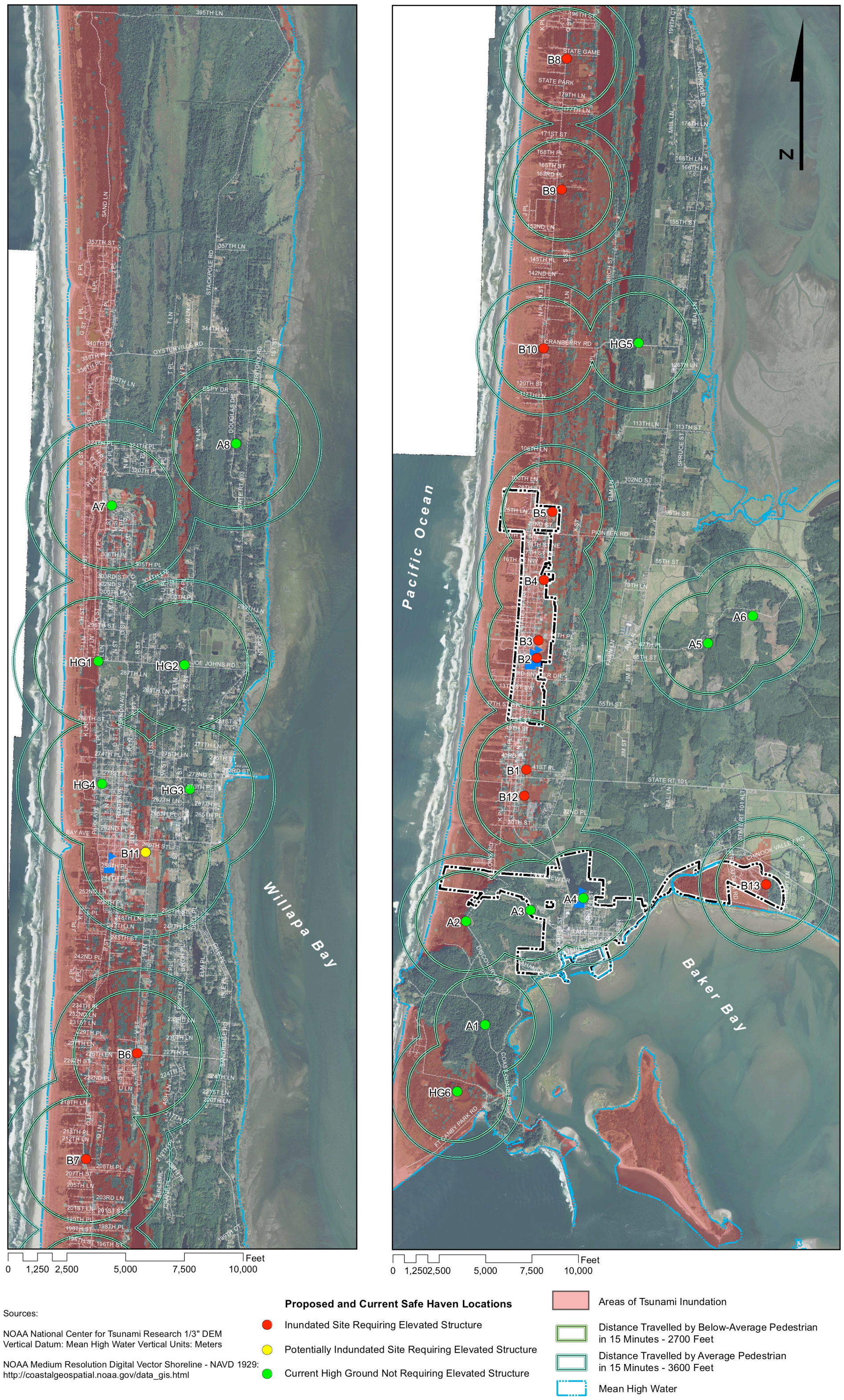
Conclusions and Next Steps

The preferred strategies developed for Pacific County communities reduces their vulnerabilities by proposing vertical safe havens that are accessible to a significant amount of the population. The strategy was derived during an intensive public participation process. 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.

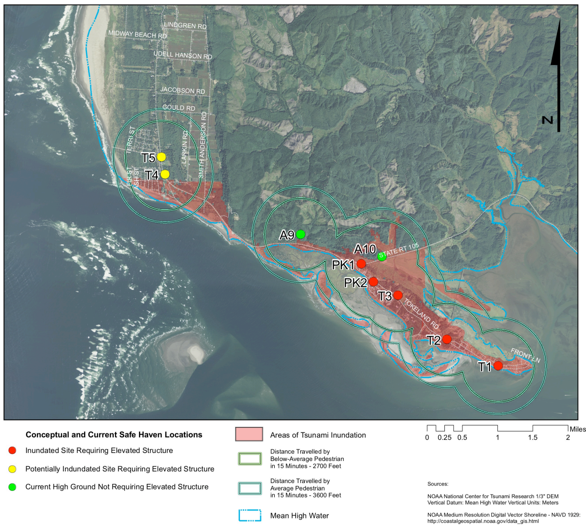
Project Safe Haven's next step will be to repeat the process in a second county, Grays Harbor, with continued emphasis on grassroots, public participation and guidance. Funding has not yet been secured but release of the Pacific County report will hopefully solicit funding in the future and local implementation measures will be taken. A similar attempt to look at vertical evacuation in Cannon Beach, Oregon is in place but lacks public input and participation. Project Safe Haven is the first of its kind to explore vertical evacuation strategies with significant emphasis on resident input.

Appendix A: Pacific County Preferred Strategy table and maps

Long Beach Peninsula, Washington
Conceptual Vertical Evacuation Locations



Tokeland/North Cove, Washington
Conceptual Vertical Evacuation Locations



	Type	Community	Height (feet)	Capacity	Estimated Cost
B1	Berm	Long Beach	12	600	$644,095
B2	Berm	Long Beach	9	1000	$706,266
B3	Berm	Long Beach	12	400	$509,621
B4	Berm	Long Beach	9	700	$546,830
B5	Berm	Long Beach	9	500	$440,540
B6	Berm	Ocean Park	9	600	$493,685
B7	Berm	Ocean Park	12	200	$375,147
B8	Berm	Ocean Park	16	200	$522,162
B9	Berm	Ocean Park	25	150	$879,152
B10	Berm	Ocean Park	9	400	$387,394
B11	Berm	Ocean Park	20	800	$1,322,779
B12	Berm	Seaview	12	400	$509,621
B13	Berm	Ilwaco	16	300	$608,188
T1	Tower	Tokeland	19	100	$104,218
T2	Tower	Tokeland	19	150	$112,770
T3	Tower	Tokeland	19	75	$99,942
T4	Tower	North Cove	21	100	$105,929
T5	Tower	North Cove	23	100	$107,639
PK1	Parking structure	Tokeland	25	1000	$828,403
PK2	Parking structure	Tokeland	19	500	$414,201