Sea Level Rise Adaptation Cost-Benefit Analysis Case Study Project

January 2017

Introduction and Purpose

Friends of the San Juans (Friends) recently worked with Coastal Geologic Services Inc. (CGS) to investigate feasible alternatives for coastal property owners dealing with sea level rise in San Juan County. Sea level rise poses serious risks to coastal communities around the globe. In San Juan County, many homes are built on eroding bluffs or low-lying beaches, making them particularly vulnerable to rising seas in the future, which can exacerbate erosion and landslides and lead to increased flooding risk.

In 2013, CGS prepared a *Sea Level Rise Vulnerability Report* for San Juan County (County) to provide better tools to resource managers and planners anticipating changes due to rising seas. This study used a SLR of 4.69 FT by 2100, based on the chosen "high" scenario by the project's Technical Advisory Group. Results were used to estimate projected inundation and bluff erosion for the two sites examined below. Currently, CGS with County Public Works is estimating 4.69 FT of sea level rise for 2100, for work near MacKaye Harbor on Lopez Island. Prior to the NAS study (2012) on SLR in Puget Sound, San Juan County had used 4.3–4.4 FT of rise as a standard. It is important to note that all projections of SLR for 2100 have high uncertainty — often more than ±2 FT.

Two sites were selected through collaboration between CGS and Friends to serve as case studies investigating appropriate actions for dealing with sea level rise. This memo provides a brief discussion of the general site conditions for the two properties (generalized and made anonymous), investigates alternatives for each, and provides a description of anticipated costs, habitat impacts, and indirect effects for each. The results of this analysis are designed to apply to a wide range of properties and may be used in public outreach materials.

Case Study Sites

Two anonymized case studies were used to explore different methods of adapting to sea level rise in San Juan County. Case study sites were selected based on their location on two different shoreforms that are common in San Juan County, with the intention that recommendations may be applied on a wider scale. The first site is a house on a coastal bluff, chosen to represent landslide and coastal erosion risks, and the second site is a house on a low barrier beach, chosen to represent coastal flooding as well as the landward shifting of the beach risks.

Brief site conditions and two appropriate responses are described below, along with estimated direct costs, habitat impacts, and indirect consequences associated with each particular response. Each site has feasible alternatives and informative graphics that may be adapted for use in outreach materials.

Case Study 1: Bluff-Top Home

Site Conditions

The first case study focuses on a house atop a coastal bluff. The bluff is approximately 30 FT high. The site is located in a divergence zone between two net shore-drift cells; therefore, sediment is carried away from the site in both directions alongshore. Recession is relatively slow on the order of 1–2 inches each year over the long term, although bank recession events themselves are not gradual and likely occur as localized landslide events and through bank toe erosion.

The *Sea Level Rise Vulnerability in San Juan County* study prepared by CGS (Coastal Geologic Services, 2013) projected 4.69 FT of SLR to cause greatly increased erosion and landslides, with an total estimated recession of the new shore by up to 160 FT by 2100. This automated estimate is likely too high, but it is likely that bluffs will respond dramatically to SLR.

Wave exposure for this site is moderate for San Juan County conditions, with a fetch (over-water distance over which wind-generated waves form) of just under 5 miles. The site serves as important habitat for forage fish spawning (on the upper intertidal beach), herring, and salmonids, with extensive eelgrass beds, and is associated with several nearby salt marshes.

Recommended Actions and Alternatives Analysis

The best option for this site is to relocate the house about 75 FT inland from the current location (Figure 1). This setback distance is sufficient to allow for anticipated bank recession through the year 2100. This is an expensive option, but will protect the house for many decades and prevent the cost and maintenance of a bulkhead (shore armor) and other measures.

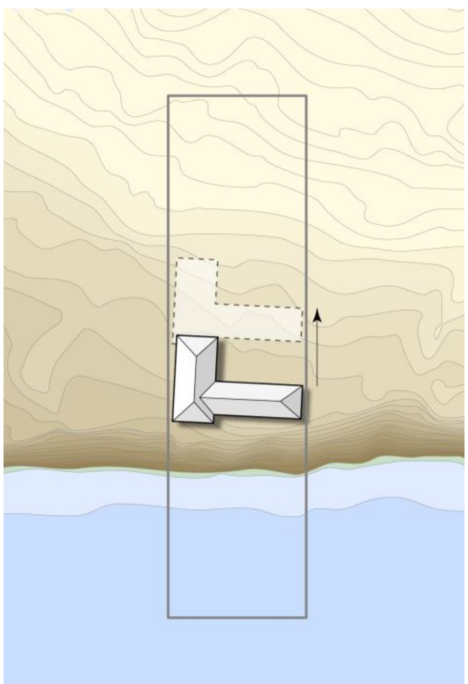

Figure 1. Stylized map showing possible relocation 75 FT landward for the bluff site.

A bulkhead (armor such as a rock revetment, wood or concrete seawall, or similar) is not recommended for this site. Construction of a bulkhead at the site may be temporarily effective at halting erosion due to wave action at the bluff toe, but long-term exposure to harsh wave action and projected higher seas can lead to wave overtopping and eventual bulkhead failure, leading to costly repair and replacement work. If about 4.69 FT of SLR is anticipated by 2100, that would require the bulkhead be periodically repaired and rebuilt to accommodate the shifting shoreline with rising tidal levels. Bulkheads also impede sediment input to the beach from the bluff, causing increased erosion on this and down-drift properties — this is especially important in a drift divergence zone. Bulkheads have some of the lowest scores in terms of providing benefits to the property itself (Johannessen et al., 2014). Furthermore, new bulkheads on feeder bluffs are difficult or impossible to permit, and would at minimum require a series of geological and biological reports, SEPA process, and other permit requirements.

Soft shore protection measures such as beach nourishment (the addition of appropriate-sized sediment to the beach) can be effective at slowing erosion at many low to moderate wave energy sites, but is not an appropriate long-term approach for this site. Beach nourishment in the form of fine or coarse gravel would not withstand increased erosive action due to sea level rise. This is also true for the use of large wood such as large anchored logs and root wads near the bank toe (the *Marine Shoreline Design Guidelines* outlines the suitability requirements for the use of these techniques at different sites, Johannessen et al. 2014). The house at this site is already closer to the bank than is safe under current conditions, and soft shore protection techniques located at the toe of the bluff will not provide adequate short-term or long-term (to the year 2100) protection needed.

Revegetation and drainage management are other alternative methods to slow bluff erosion, but this site is already well-vegetated. Revegetation can accompany structure relocation to maintain a native plant buffer between the bluff crest and house for ameliorating bluff instability. Revegetation by itself is not an adequate long-term protection measure for this site, as trees here have a limited ability to slow erosion and provide bank stability at a chronically receding bluff (Johannessen et al., 2014). See Menashe (1993) for a comprehensive guide to vegetation management in the Puget Sound region. Surface water and roof runoff can exacerbate bluff erosion, but at this site drainage is already collected and routed away from the bluff crest.

Project Costs

Table 1 shows a cost estimate for the various alternatives Case Study 1. These numbers are rough estimates meant to apply to a range of “typical” houses, and should not be applied to any one property without an actual site visit by qualified professionals. Unique characteristics of each site, house, and associated utilities can cause cost estimates to vary considerably. For example, area of high wave energy and/or important nearshore habitats would have potentially higher costs for design, permitting, and construction of soft or hard shore projection. Large houses and ones with extensive masonry would have higher costs for relocation of elevation. Also very old houses without proper structural design can be difficult to elevate or relocate. Wood frame houses without large fireplaces are typically easiest and cheapest to move.

Table 1. Cost estimates for Case Study 1, assuming a shore length of approximately 100 FT and a planning horizon of 2100. Very approximately, costs “$” are $0–20,000, costs “$$” are $20,000–40,000, and costs “$$$” are $40,000–100,000. Site-specific factors may change costs by over 50%. No Action means no immediate action.

Construction Alternative	Design & Permitting Cost & Difficulty	Initial Cost	Maintenance Costs Every 15–30 years	Nearshore Habitat Impacts	Notes
No action	0	0	$$$+	None	Likely home destruction before 2100, or extensive future work needed (anticipated in costs)
Beach nourishment, large wood	$–$$	$–$$	$	Minor disruption of nearshore habitat	Likely home destruction before 2100, or extensive future work needed
Bulkhead	$$–$$$	$$$	$$–$$$	Severe disruption of nearshore habitat; reduced sediment supply to net shore-drift cell	Likely not permitable
Relocation landward and uphill	$	$$$	0	No coastal effects	Disruptive to residents; view of water from higher up but farther away

Habitat Impacts

Structure relocation is not anticipated to cause an appreciable amount of negative impacts to adjacent nearshore habitats. This option avoids the need to build hard shore protection such as bulkheads or rock revetments, which are known to be damaging to forage fish spawning habitat, backshore vegetation and log zones impacting prey and cover, and also the input and exchange of organic material and sediment

(Dethier et al., 2016; Shipman et al., 2010). If a bulkhead is placed at the base of the bluff, backshore habitats and forage fish spawning substrate may be lost due to a phenomenon known as the "coastal squeeze", whereby intertidal, upper beach and dune habitats are lost between a static backshore and a rising sea level (Cooper and McKenna, 2008).

Tree removal to accommodate the landward translation of the house may upset the local conditions on the property. It is recommended to plant and maintain a native vegetation buffer between the bluff crest and the new location of the house to ameliorate this loss and provide further slope stability benefits. Native vegetation may be chosen and shaped through careful pruning to provide a clear view of the water while stabilizing the former house site.

Indirect Impacts

Several minor indirect impacts may result from the landward relocation of the structure. Moving away from the bluff crest will likely diminish the field of view toward the water. In our case study, the new home location is much higher, and it could be raised farther if its new foundation was taller. This will improve the vantage, providing better views of distant scenery. Vegetation management could maintain some views indefinitely.

A bulkhead would not be needed (along with ongoing maintenance) if the structure was moved landward, and its absence could be considered a benefit to home relocation. The bluff at a feeder bluff site such as this one is an important source of sediment for shores on either side of the property due, in part, to its location in a divergence zone. Armor in this area could restrict sediment transport and cause beach loss and further erosion on adjacent properties.

Case Study 2: Barrier Beach or No-Bank Beach Home

Site Conditions

The second case study focuses on a house on a low-lying barrier beach with a low backshore berm. This site is within a drift cell that transports sediment to down-drift beaches. The site is not chronically erosional, but does experience some overwash and minor storm damage on occasion. There is no recent damage evident, but every 5–10 years a severe storm deposits debris on the backshore, which in turn can damage the natural and landscaped vegetation at the site — as is typical for most barrier beach home sites in San Juan County. Sea level rise will likely lead to increased temporary flood and inundation risk due to SLR and overwash during large storms. As a natural response to rising seas, the beach profile will progressively shift landward transforming the waterward yard into beach and likely eventually undermining the house, with no action taken.

This site has a fetch distance of over 15 miles, placing it at a higher risk for overwash and storm damage when waves align with strong southerly winds (see Cumulative Risk Model, Chapter 3, *Marine Shoreline Design Guidelines,*(Johannessen et al., 2014). The current minimum house setback is between 40 to 45 FT from the berm to the closest point on the building.

In the future, the active beach will shift closer to the current house site and rising sea levels will likely decrease the time interval between overwash events from storms, and the area will be subject to likely more frequent inundation, which could last longer than during current conditions. Progressive loss of the yard and potentially the house will occur as SLR increases after approximately the year 2030.

Recommended Actions and Alternatives Analysis

Two feasible alternatives exist at this site. The first is to elevate the house in place so that the lowest floor is above the projected base flood elevation plus the height of storm waves with sea level rise. The house may be placed on engineered stilts or columns, and the ground level could be used for seasonal/temporary storage for some decades, although codes typically require water be able to freely pass under the structure when in a coastal floodplain.

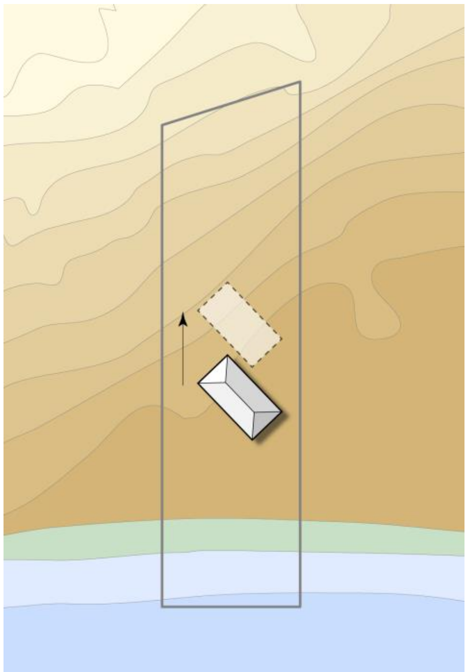

Figure 2. Stylized map showing possible relocation 70 FT landward for the no-bank site.

Another option is to relocate the structure landward on the order of 70 FT, which would also elevate the structure by moving it uphill (Figure 2). This has sometimes been referred to as “managed realignment” when it happens on larger scales, when development must move landward to accommodate an encroaching water line and subsequent storm waves and habitat shift.

A bulkhead is not recommended for this site. Since this site is a very low-lying barrier beach, water levels on the waterward side of the bulkhead would be higher in elevation than the ground on the landward side — and with no bank or a continuous flood barrier along the entire beach, a bulkhead could not prevent coastal flooding. For the same reason, beach nourishment and/or anchored large wood would not be sufficient measures to preventing flooding and erosion.

Project Costs

Table 2 shows a cost estimate for the various alternatives for Case Study 2. These numbers are rough estimates meant to apply to a range of houses, and should not be applied to any one property without an actual site visit by a qualified professional. Unique characteristics of each site, house, and associated utilities can cause cost estimates to vary considerably (As further detailed for Case Study 1 above).

Habitat Impacts

A bulkhead and soft shore protection would increasingly cause the reduction of the beach width and area (the Coastal Squeeze), with increasing negative impacts on beach and backshore habitat on-site. At this site, a bulkhead is neither feasible nor beneficial. Unnecessary placement of a hard shore armor structure would also negatively affect down-drift and adjacent shores, potentially exacerbating forage fish habitat loss and further beach erosion on- and off-site.

Table 2. Cost estimates for Case Study 2, assuming a shore length of approximately 100 FT and a planning horizon of 2100. Very approximately, costs "$" are $0–20,000, costs "$$" are $20,000–40,000, and costs "$$$" are $40,000–100,000. Site-specific factors may change costs by over 50%. No Action means no immediate action.

Construction Alternative	Design & Permitting Cost & Difficulty	Initial Cost	Maintenance Costs Every 10–30 years	Nearshore Habitat Impacts	Notes
No action	0	0	$$$+	None now; increasing as beach moves towards house in future	Will not prevent home flooding, damage likely without extensive future work (anticipated here)
Beach nourishment, large wood	$$	$–$$	$	Minor disruption of nearshore habitat	Will not prevent home flooding
Bulkhead	$$$	$$$+	$$–$$$+	Severe disruption of nearshore habitat; reduced alongshore sediment transport in net shore-drift cell	Will not prevent home flooding
Relocation landward and uphill	$	$$$	0	No coastal effects	Disruptive to residents; view of water from higher up but farther away
Elevate in place	$	$$$	$-$$$	None	Possibly disruptive to view of water from other locations

Indirect Impacts

As with Case Study 1, landward relocation may slightly decrease the field of view toward the water but improve the vantage by slightly elevating the house. The view can be maintained indefinitely through properly selected and pruned vegetation.

House elevation (in place) may improve visibility of the water but could decrease general accessibility. The new foundation may require maintenance or protection from coastal flooding.

Summary and Suggested Outreach

Sea level rise is occurring at an accelerating rate, demanding a response from many coastal homeowners. The case studies discussed in this memo can help frame long-term decisions. More detailed and quantitative analysis of sites would advance the understanding of impacts, benefits, and costs.

The example outreach statements below reflect recent best practices in SLR communication.

Focus on observable effects to tell a story:

> *Have you noticed coastal flooding, damage, or bluff erosion? Slowly but surely these high water events will become more common and more damaging.*

Responsible management, protection, and stewardship are concepts proven to resonate with Americans:

> *A long-term solution respects future owners of this home and preserves value — without creating a problem 20 years down the road.*
>
> *Responsible property management will consider interconnected ecosystem effects.*

Protect your home and protect local wildlife at the same time.

If possible, connect coastal homeowners with recent home elevation and relocation projects — even if the homes were not moved because of coastal erosion or inundation.

Some of your neighbors are experts in home relocation. Learn more about their experiences.

Did you know that San Juan County moved a long portion of the Deer Harbor Road on Orcas Island away from an eroding bluff approximately 20 years ago, a portion of Cattle Point Road was moved back a few years ago, and that MacKaye Harbor Road is the subject of a current road relocation project?

Did you know that houses and roads have been moved back away from eroding bluffs and beaches in all surrounding counties?

References

Coastal Geologic Services, 2013. Sea Level Rise Vulnerability in San Juan County (Prepared for Friends of the San Juans).

Cooper, J.A.G., McKenna, J., 2008. Working with natural processes: the challenge for coastal protection strategies. The Geographical Journal 174, 315–331.

Dethier, M.N., Raymond, W.W., McBride, A.N., Toft, J.D., Cordell, J.R., Ogston, A.S., Heerhartz, S.M., Berry, H.D., 2016. Multiscale impacts of armoring on Salish Sea shorelines: Evidence for cumulative and threshold effects. Estuarine, Coastal and Shelf Science, 175, 106–117.

Johannessen, J., MacLennan, A., Blue, A., Waggoner, J., Williams, S., Gerstel, W., Barnard, R., Carman, R., Shipman, H., 2014. Marine Shoreline Design Guidelines. Department of Fish and Wildlife, Olympia, WA.

Menashe, E., 1993. Vegetation management: A guide for Puget Sound bluff property owners. Shorelands and Coastal Management Program, Washington Department of Ecology. 93–31.

National Research Council, 2012. Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future. National Academies Press, Washington, D.C.

Shipman, H., Dethier, M.N., Gelfenbaum, G., Fresh, K.L., Dinicola, R.S., 2010. Puget Sound Shorelines and the Impacts of Armoring--Proceedings of a State of the Science Workshop, May 2009. (Scientific Investigations Report No. 2010–5254). U.S. Department of the Interior, U.S. Geological Survey.