Jamestown S'Klallam Tribe

Climate Vulnerability Assessment and Adaptation Plan

Appendices

April 2013

Jamestown S'Klallam Tribe

adaptation international

Acknowledgements

Thank You

This project would not have been successful with out the combined efforts of all the individuals listed below. The collaborative approach taken by the Jamestown S'Klallam Tribe, Adaptation International, and Washington Sea Grant proved extremely valuable in identifying the key areas of concern, evaluating potential climate impacts, and developing a suite of adaptation strategies to help the Tribe begin preparing for climate change. With this project, the Jamestown S'Klallam Tribe has created a foundation for on-going climate action and made a crucial step towards becoming climate resilient.

Climate Change Working Group

Liz Mueller	Tribal Vice Chair, Family Support Services Director
Marlin Holden	Tribal Elder, Chair Fish and Game Subcommittee
Elaine Grinnell	Tribal Elder
Robin Allen	Tribal Elder
Kathy Duncan	Tribal Elder
Annette Nesse	Chief Operations Officer
Diane Gange	Chief Financial Officer
Leanne Jenkins	Planning Director
Scott Chitwood	Natural Resources Director
Doug Sellon	Executive Director - Economic Development Authority
Cindy Lowe	Health Administrator and Dental Clinic Manager
Byron Rot	Natural Resources Manager, Adaptation Project Manager
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A. Appendix A: Sea Level Rise & Storm Surge Projections

Climate change, primarily through increasing ocean temperature and the melting of land-grounded ice, is increasing the volume of water in the ocean basins, raising the average level of the surface of the ocean (termed "mean" sea level; Figure A-1).

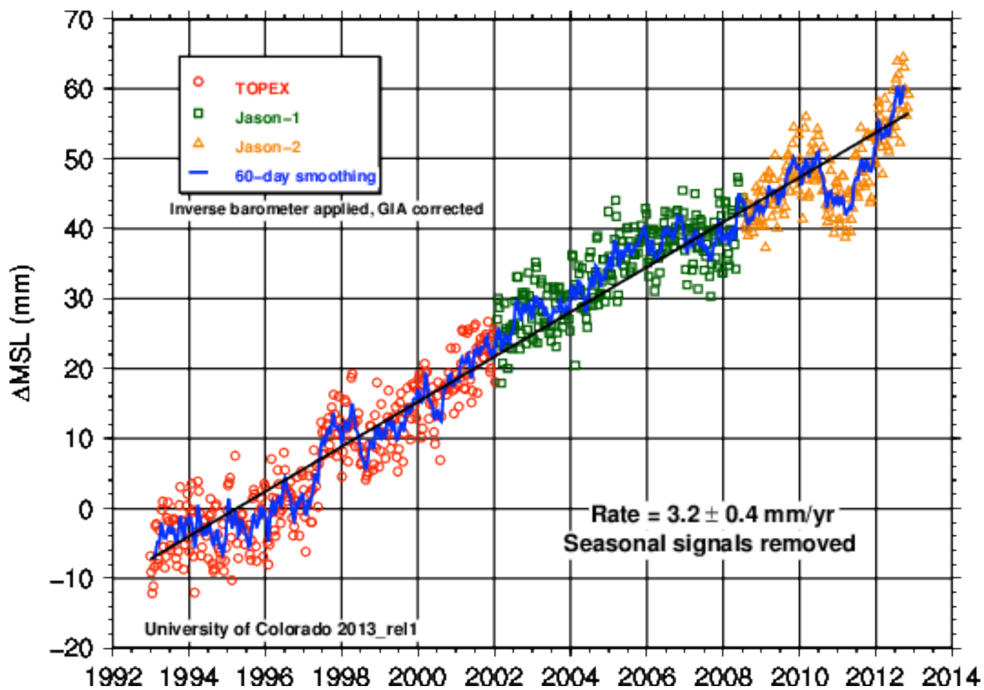

Figure A-1: Global mean sea level has risen at a rate of 1.0 feet/century (3.2 mm/yr) since 1993 based on satellite altimetry[1].

More specifically of concern to coastal communities is "relative" sea level, or the level of the sea relative to the level of the land, which is a function of both mean sea level, as well as the vertical motion of the land itself:

Relative Sea Level Change = Mean Sea Level Change – Vertical Land Movement

In the Pacific Northwest, the elevation of the land is not stable. Instead, the land's surface is being forced upwards or downwards by a combination, primarily, of tectonic forcing and adjustment to the loss of continental glaciers at the end of the last ice age (Figure 9 main report). It is the combination of these two factors, rising mean sea level and complex patterns of vertical land movement (Figure 9 main report) that lead to complex patterns of relative sea level change in the Pacific Northwest (Figure A-2). As a result, projecting relative sea level rise into the future requires a local perspective – the best available projections of regional mean sea level rise must be coupled with local information on vertical land movement in order to provide the best information for planning.

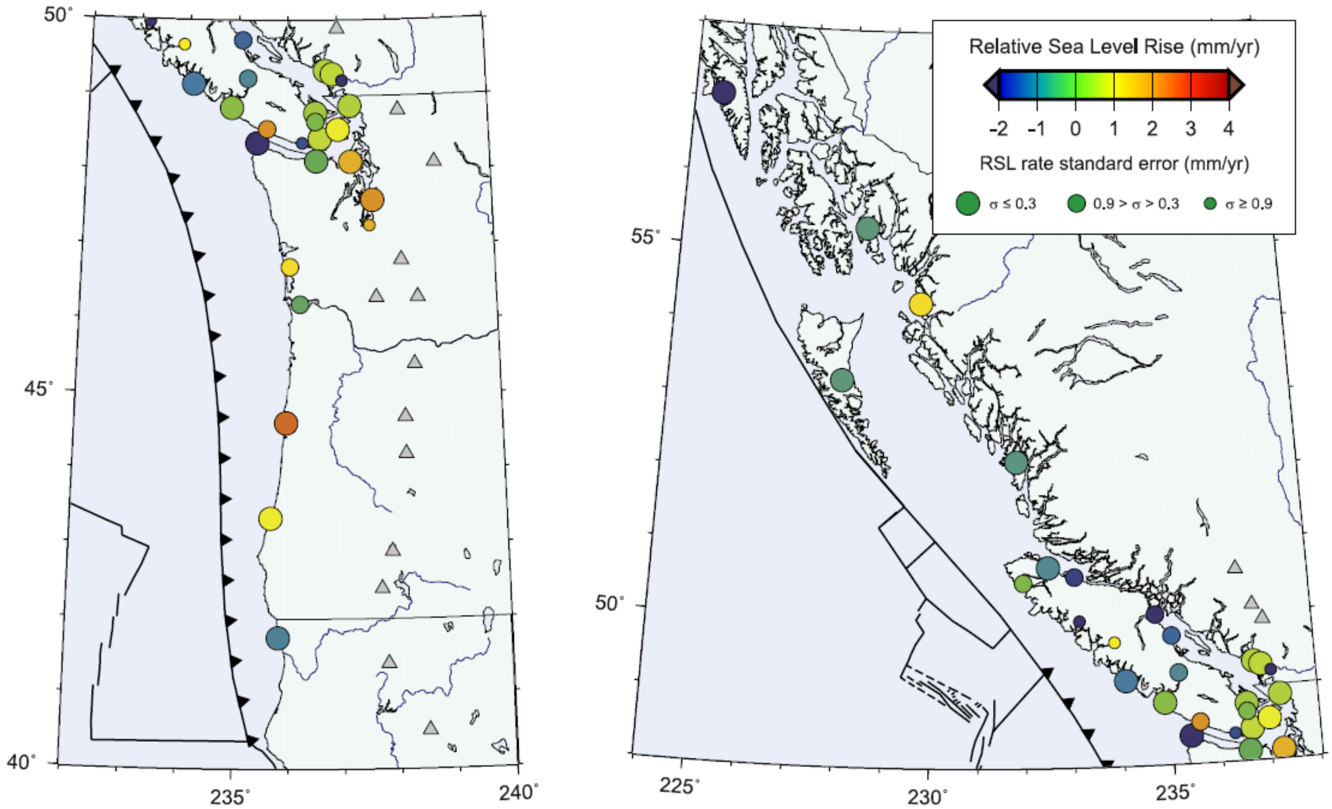

Figure A-2: Relative sea level rise rates from tide gauges in the Pacific Northwest. Circle size indicates the uncertainty in the rates (standard error). Blue to green circles are area with falling or stable relative sea level, while yellow through red circles indicate area with rising relative sea level[2].

Relative rates of sea level rise can be seen in the tide gauge records from various sites across the Pacific Northwest (Figure A-2). The tide gauges record the relative sea level where they are located. They capture the daily changes of tidal heights along with month-to-month variability driven in part by periodic climate anomalies like the El Nino-Southern Oscillation, and the Pacific Decadal Oscillation. The tide gauges also capture long term trends in sea level. Examples of the tide gauge data is shown in Figure A-3. It is easy to determine the overall observed rate of sea level rise for Port Townsend (the closest tide gauge to Sequim Bay) and Seattle (the longest operational tide gauge in the Pacific Northwest) (Figure A-3).

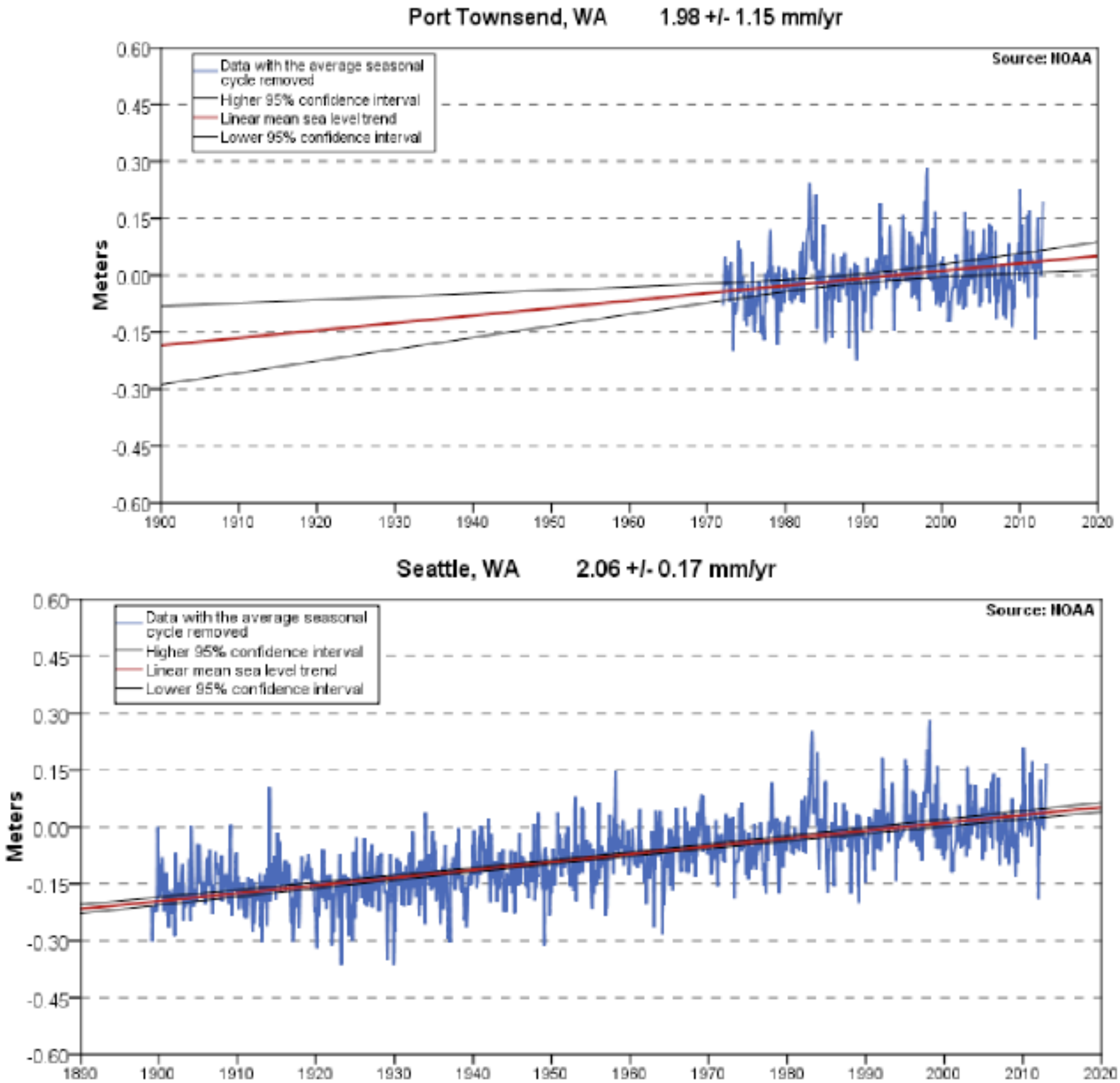

Figure A-3: Tide gauge data from Port Townsend and Seattle. Sea level trends at Port Townsend (top panel) tide gauge site adjacent to the Sequim Bay region and Seattle (lower panel), as estimated using NOAA CO-OPS water level data[3].

Projections of future changes and climate exposure

For this assessment, a local relative sea level curve was derived for Sequim Bay by combining recent projections of mean sea level published by the National Academies of Science[4] with estimates of vertical land movement for the Sequim Bay region. The NAS projections suggest mean sea level rise of 0.6 to 1.6 feet by 2050, and 1.6 to 4.6 feet by 2100, with the ranges in projections driven, primarily, by uncertainty regarding future greenhouse gas emissions. Estimates of vertical land movement were taken from three GPS stations, part of the PANGA network (http://www.geodesy.cwu.edu/), adjacent to Sequim Bay (Table A-1). These three stations suggest average vertical land movement in the Sequim Bay region of -0.7 feet/century (-2.11 mm/yr).

Table A-1: Estimates of vertical land movement. Estimates of vertical land movement from three PANGA stations adjacent to Sequim Bay.

PANGA Station	Vertical Best Estimate (mm/yr)	Uncertainty[1] (mm)	Record Start (yrs)
BLYN	-2.75	0.23	2001
SQIM	-2.88	0.16	2007
P436	-1.22	0.08	2006

This average rate of vertical land movement was applied to the NAS mean sea level projections as a linear trend; with an assumption that this rate is uniform in time. It should be noted that there is uncertainty associated with these measurements of vertical land movement (Table A-1), but this uncertainty was not quantitatively integrated into the final relative sea level curve for Sequim Bay for this assessment.

In addition to the mapped layer of mean sea level influence, an impact layer was added to reflect the probable reach of water under winter storm conditions. This was accomplished using an analysis of the return frequency (in years) of "storm surges" of various water levels based on measurements made at NOAA's Seattle water level gauging station (Figure A-4). For mapping purposes the 50-year return interval "storm surge" (3.1 feet) was selected.

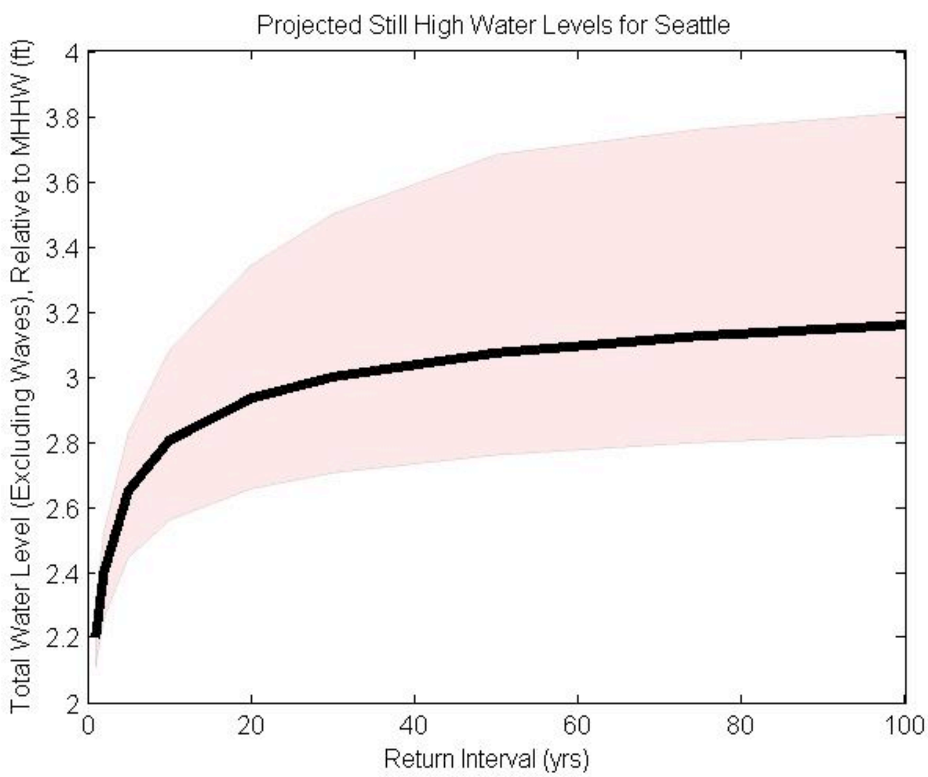

Figure A-4: Storm surge return intervals. Return Interval of storm surges of various elevations relative to Mean Higher High Water, based on water level observations from Seattle, WA. Data from Tebaldi et al. 2012[5].

[1] Root mean squared uncertainty

There are a number of assumptions made in selecting this "storm surge" level for this mapping exercise: that storm surge patterns at Seattle are similar to those in the Sequim Bay region; that storm surge patterns are not significantly influenced by climate change; and, therefore, that historical patterns can be used to predict future conditions, an assumption that is the subject of current research[6]. Additionally, these "storm surge" return intervals do not include the influence of waves on water level, which can be a significant determinant of the total water level interacting with shoreline areas during a storm surge[7].

B. Appendix B: Ocean Acidification

The severity of ocean acidification can be characterized using the parameter $\Omega_{aragonite}$, which measures the relative availability of aragonite (a form of $CaCO_3$ frequently used by marine organisms) in solution in seawater. $\Omega_{aragonite}$ is a function of the concentration of CO_2, water temperature, and pressure. In general, $\Omega_{aragonite}$ values of less than 1 suggest conditions that make it difficult for organisms to take up calcium carbonate without significant expenditures of energy. As a result, some organisms, especially small plankters, will start to show degradation at $\Omega_{aragonite}$ values less than 1 (Figure 13 above[8]). Waters with $\Omega_{aragonite}$ values less than 1 are generally termed "corrosive", a convention that is used in this report. Corrosive waters have already been documented in the Strait of Juan de Fuca (Figure 13 main report, bottom panel).

Projections of future changes and climate exposure

Modeled projections for coastal zones of Northern California (Figure B-1) suggest that, as the century progresses, parts of the continental shelf will be almost continuously bathed in corrosive waters (the red areas in Figure B-1, representing the volume of seawater with $\Omega_{aragonite} < 1$). Surface waters will experience increasingly frequent corrosive water masses (Figure B-1, top panel) while the twilight or middle zone (Figure B-1, middle panel) and bottom layers (Figure B-1, lower panel) will be almost entirely corrosive by the later half of the 21st century.

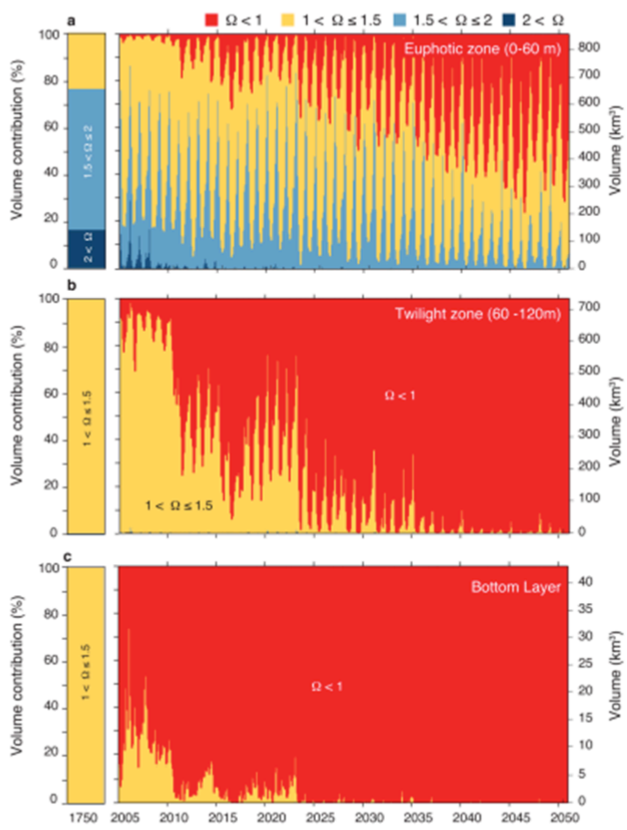

Figure B-1: Projected changes to $\Omega_{aragonit}$ in coastal waters. Projected change in the extent (expressed as volume) of seawater on the continental shelf off of the Northern California coast with different levels of $\Omega_{aragonite}$ for a) the euphotic zone above 60 m, b) the twilight zone between 60-120 m, and c) the bottom layer below 120 m. Projections based on the SRES A2 scenario[9].

C. Appendix C: Workshop Materials & Detailed Results

1. Climate Change Workshop Summary

Over the course of two mornings, Thursday January 31st and Friday February 1st, the Jamestown S'Klallam Climate Change Project Working Group members participated in a workshop to assess and prioritize potential impacts from climate related exposures. The workshop started with an overview of key climate related exposures and impacts for the community but quickly shifted into analysis and discussion of how those climate exposures would affect key areas of concern for the Tribe. Using a combination of breakout sessions and large group discussions, the working group refined the list of key areas of concern, assessed and prioritized vulnerabilities, and began to develop adaptation strategies.

Climate Change Working Group Participants

Marlin Holden	Annette Nesse
Elaine Grinnell	Byron Rot
Leanne Jenkins	Hansi Hals
Scott Chitwood	Cindy Lowe
Doug Sellon	Sascha Petersen (AI Project Team)
Diane Gange	Ian Miller (AI Project Team)

The diverse mix of stakeholders provided an excellent multi-disciplinary view of the climate exposure concerns. The outcomes of this workshop were made possible through this broad mix of sector representatives and diverse set of expertise and experience represented by the members of the working group.

2. Key Areas of Concern

Building off information gathered so far in our rapid assessment of climate exposures and the discussions during the workshop, the working group refined the key areas of concern. This set of key areas of concern is as specific as possible in order to best facilitate detailed planning to increase climate resilience.

- Jamestown Beach Water Supply
- Salmon
- NR Lab & Planning Dept. Bldgs.
- Tribal Campus Water/Wastewater
- Inter-Tidal Bivalves (Clams & Oysters)
- Casino & Longhouse Market
- Transportation (Hwy 101)
- Cedar Harvest
- Wildfire
- Shellfish Biotoxins

3. Summary of Vulnerability Rankings

During day one of the workshop, Sascha Petersen and Ian Miller from the Adaptation International project team provided an overview of the key climate exposures for the Jamestown S'Klallam Tribal Community. These included increasing temperatures, changing precipitation patterns, sea level rise, ocean warming and acidification, forest habitat changes, and human health concerns.

Overall climate related vulnerability depends on exposure, sensitivity, and adaptive capacity (as show in Figure 15). ***Climate exposure*** is the extent and magnitude of a climate and weather event.

Sensitivity is the degree to which that area of concern is susceptible to a climate impact. ***Adaptive capacity*** it the ability of the area of concern to adjust to or respond to the changing conditions.

Vulnerability = Exposure • (Sensitivity • Adaptive Capacity)

The working group separated into two breakout groups in order to determine the sensitivity and adaptive capacity for each of the key areas of concern. Each group worked through a series of two exercises to assign a sensitivity and adaptive capacity ranking. The detailed rankings are described in the main report (Table 2).

Vulnerability Workshop

	Exercise One: Exposure and Sensitivity				
Changing Climate Condition	**What Built, Natural, Social, or Cultural Assets Could be Affected By These Changes**	**How Do Weather or Climate Currently Affect This System**	**What Additional Non-Climate Factors Currently Affect This System?**	**What is the Significance of This System to the Tribe?**	**Sensitivity Ranking**
Temperature Increases Between 1-5°F	**Example:** Natural Systems: Red Cedar trees & bark	Trees may no longer be found in traditional locations. Optimal harvest times earlier	Invasive species, overharvesting	Red cedar provides culturally important resources including bark for basket weaving	**S2**
	Public Health: higher asthma and pathogen rates	Growing asthma rates have been a concern in the region for sometime	Growing rates of obesity, lower rates of physical activity, and higher pollution rates	Good health is critical to happiness and wellbeing	**S3**

Vulnerability Workshop

Exercise Two: Assessing Adaptive Capacity					
Changing Climate Condition	**Built, social, natural, or cultural asset from Exercise One**	**What Does This Person or System Currently Have That Will Help it to Adapt**	**What Does This System or Person Need in Order to Adapt**	**Of These Needs Which Are of the Highest Priority**	**Adaptive Capacity Ranking**
Temperature Increases Between 1-5°F	**Example:** Natural Systems: Red Cedar Trees and Bark	Natural systems: large protected areas for species migration	Natural systems: removal of invasive species & monitoring	Removal of invasive species	Natural: **AC1**
	Public Health: Asthma	Health: high social connectivity allowing for easy distribution of educational materials	Health: more physical-activity programming, education, change outdoor rec. times.	Education	Health: **AC2**

Figure C-1: **Examples of workshop exercises.** ***The two exercises completed by the groups during the breakout sessions in order to determine a sensitivity ranking (exercise one in blue top) and an adaptive capacity (exercise two in green bottom) for each of the key areas of concern.***

The key areas of concern were then placed in a vulnerability matrix to determine the relative vulnerability between areas of concern (Figure 16 main report). Those that are the most vulnerable have the highest sensitivity and the lowest adaptive capacity (Salmon long-term). Those that were the least vulnerable have lower sensitivity and higher adaptive capacity (Natural Resources Lab and Planning Department buildings).

4. Prioritizing Vulnerabilities and Key Areas of Concern

As discussed in the body of the report, day two of the workshop focused on prioritizing the vulnerabilities in order to determine where best to focus their limited resources. Prioritization moves beyond vulnerability rankings and allows the working group members to differentiate between key areas of concern at the same or similar vulnerability levels. The prioritization criteria included:

Magnitude of Impacts: Reflection of the scale and intensity of a climate impact

Timing of Impacts: Reflection of when the climate impact is likely to occur

Persistence and Reversibility: How persistent or irreversible the impacts are

Likelihood of Impacts: How likely it is for the impact to occur

Distributional Nature of Impacts: Indication of how specific groups or segments of the community may be impacted

Importance of System at Risk: Measure of the cultural, economic, social value of the system affected

Potential for Adaptation: Availability of actions to prepare for or respond to the climate impacts.

The detailed scoring from the two different breakout groups is shown below. For the key areas of concern addressed by both groups, one groups scores are shown in red with the other's scores in green. The averaged scores between the groups are shown in the "Total Score" Column. For all columns (except for Potential to Adapt) scores range from 1 to 5 with 5 being high and 1 being low.

Table C-1: Prioritization of vulnerabilities. Each key area of concern was scored based on a number of criteria. Scores for each criteria (columns) went from 1 to 5 with 1 being low and five being high (except for Potential to Adapt where scoring was reversed). Total scores are the sum of all individual scores and in the cases where both breakout groups provided scores, the total scores are averaged. Key areas of concern are grouped into three categories: 1) very high priorities (red shading); 2) high priority (dark orange shading); and 3) medium (light orange shading).

Exercise 3: Prioritizing Key Vulnerabilities

Vulnerability Identified	Magnitude of Impact	Timing of Impact	Persistence and Reversibility of Impacts	Likelihood of Impacts	Importance of the System at Risk	Distribution of Impacts	Potential to Adapt	Avg Score
Jamestown Beach Water Supply	3 2	2 4	3 5	5 5	5 4	1 1	1 1	21
Salmon	5 3	5 4	3 5	5 5	5 5	5 3	4 5	31
NR Lab & Planning Dept. Bldg.	1	4	5	5	2	1	1	19
Wastewater Tanks - Blyn	1	4	5	5	2	1	1	19
Intertidal Bivalves (Clams & Oysters)	5 3	5 5	4 5	5 5	5 5	5 3	4 5	32
Water Supplies – Blyn	5 4	5 3	3 3	5 4	5 5	4 4	2 3	27.5
Casino & Longhouse Market	5 5	3 1	3 2	3 3	5 5	4 5	3 2	24.5
Transportation Hwy 101	5	2	2	4	5	5	2	25
Cedar Harvest	5	4	5	4	5	3	4	30
Wildfire	5	4	5	4	5	5	3	31
Shellfish Biotoxins	4	5	5	5	5	2	4	30

5. Results of Dot Voting Exercise

Working group members were asked to participate in a dot voting exercise to identify their top personal key areas of concern. Each member was given four dots and was asked to place the dots in any combination on their key areas of concern. This exercise allowed for individual expression of key concerns and helped validate or "ground truth" the results of the priority rankings. The results of that exercise are listed below.

Table C-2: Results of the Dot Voting exercise on priorities.

Areas of Concern	Number of Dots
Salmon	9
Transportation	6
Casino & Longhouse Market	4
Cedar Harvest	4
Wildfire	3
Water – Blyn	2
NR Lab & Planning Dept. Bldg.	2
Intertidal Shellfish	1
Jamestown Beach Well	1
Wastewater Tanks – Blyn	0
Shellfish Biotoxins	0

For the most part, these results are consistent with the more detailed quantitative prioritizations completed by the breakout groups. There are a few areas of concern where there are some interesting discrepancies that will require further exploration. Both transportation and the Casino and Longhouse market ranked significantly higher in the dot voting exercise than they did in the breakout sessions and shellfish biotoxins that ranked in the top group during the breakout sessions did not receive any votes during the dot voting exercise.

D. Appendix D: List of all recommended adaptation strategies

To be completed once the resilience strategies have been evaluated and discussed by the climate change working group[2].

	Cost	Ease of Implementation	Political/ Community Support	Timing of Action	Partnerships Required
Salmon (focus on addressing other stressors)					
Reduce other stressors to salmon stream habitats, including: urbanization, sedimentation and pollution of streams, changes in streamside vegetation, erosion due to land-use practices such as road building and clear cutting, and the draining of wetlands (Mote et al., 2003; Reed et al., 2011).	Medium	Moderate	Low	Immediate-to-Medium Term	Yes (surrounding communities, Counties, State, private land owners)
Restore stream habitats (Mote et al., 2003) and enhance instream survivability (Reed et al. 2011)	High	Moderate (Tribal Land) Hard (Non-tribal Land)	Medium	Medium-to-Long-Term	Yes (Forest Service, National Park Service, private land owners)
Ensure sustainable harvesting of salmon. This includes ensuring that a diversity of species are caught via monitoring programs (to the extent possible given current population levels) as opposed to unevenly catching one species (Reed et al., 2011).	Low	Moderate	Medium	Immediate	Yes (surrounding communities, Tribes, State, private industry)
Managing hatchery programs to minimize harm done to wild stocks (Mote et al., 1999)	Low	Easy	High	Moderate	Yes
Create a habitat conservation plan and ensure that climate change and associated affects are integrated into the plan (Mote et al., 2003)	Medium	Easy		Immediate	No
Remove or lessen obstructions to migratory routes (Reed et al., 2011; Mote et al., 1999)	Medium	Moderate	Medium	Medium	Yes (surrounding communities, State, private land owners)
Clams & Oysters (focus on limiting other stressors)					
Monitor and continue to improve local water-quality since a significant amount of bivalve species decline is associated with water-quality degradation (Kreeger et al., 2010). Consider expanding monitoring to include continuous water temperature and pH.	Medium	Hard	High	Medium-Term	Yes (surrounding communities, State, private land owners)

[2] Actions highlighted in green are those recommended in the report. Those not highlighted are provided for additional considerations.

Ensure sustainable harvesting of clams and oysters (Kreeger et al., 2010)	Low	Moderate	High	Immediate	Yes (with State, industry, other Tribes)
Rebuild stocks (i.e., restoration) (Kreeger et al., 2010)	Medium	Moderate	Medium	Medium-Term	Yes (with State DNR)
Hatchery propagation and restocking of populations in areas where natural reproduction of native bivalves is limited. If this is pursued, ensure replaced stocks are indigenous to the area (Kreeger et al., 2010)	Medium	Easy	Medium	Immediate	Yes (with State DNR)
Transplanting adult clams and oysters (assisted migration) from remnant populations into areas that are more suitable for reproductive success (Kreeger et al., 2010)	Medium	Moderate	Medium	Immediate	Yes (with State DNR)
Develop cultural center and traditional Longhouse around Harvest Beach in Blyn to enhance understanding of shellfish heritage and engage more Trial Citizens in the harvest of clams and oysters (Holden personal communication 2013).	Medium	Easy	Medium	Immediate	No
Riparian and stream restoration and preservation programs (Kreeger et al., 2010)	High	Moderate		Medium-to-Long-Term	Yes (surrounding communities)
Ensure appropriate water flow by removing any upstream barriers and decreasing beachfront armoring (Kreeger et al., 2010)	Medium	Moderate		Medium	Yes (surrounding communities and state)

Shellfish Biotoxins

Continuation and extension of monitoring program. This includes working with academic community to identify or develop environmental predictors of harmful algal blooms.	Low	Easy	High	Immediate	Yes (with State)
Decrease other potential stressors that increase the likelihood of a HAB occurring, such as large nitrogen or phosphorous loading (eutrophication) from agricultural run-off.	Medium	Hard	Medium	Immediate	Yes (private land owners)
Enhance beach alert system, including the posting of signs in Blyn, in the newspaper, and on the Tribe website.	Medium	Moderate	Medium	Immediate to Medium-Term	No
Revisit public health response to beach closure or biotoxin events through coordination State and County Public Health Officers.	Low	Easy	Medium	Immediate	Yes (with County & State)

Wildfire

Expand or adjust the region's protected areas to incorporate greater landscape diversity. This facilitates range-shifts in terrestrial communities and enhances ecosystem resilience to change (Mote et al., 2003)	High	Moderate	Medium	Medium-to Long- term	Yes (with private, State, and Federal land owners)
Manage forest density for reduced susceptibility to drought stress (Mote et al., 2003; Mote et al., 1999). This includes developing a strategy to reduce fuel in the wildfire-urban interface.	Moderate	Moderate	Medium	Immediate	
Monitoring trends in forest condition and climate to proactively identify areas with high susceptibility to wildfire (Mote et al., 2003; Mote et al., 1999)	Low	Easy	High	Immediate	Yes, State and Federal Agencies
Start a public communication effort concerning strategies to reduce personal harm from fire. Highlight activities such as the use of fire resistant building materials, keeping vegetation and trees a minimum distance from houses (Columbia Basin Trust)	Low	Easy	Medium	Immediate	No
Update Building Codes to require or provide incentives for FireSmart building standards for new builds and renovations (Columbia Basin Trust)	Medium	Moderate	High	Immediate to Medium-Term	No
Establish a community evacuation plan and ensure the community knows about the plan (i.e., integrate into all Tribal emergency management plans) (Columbia Basin Trust)	Low	Easy	High	Immediate	No
For critical facilities, establish a back-up power supply in the event that electric water pumps are unavailable (Columbia Basin Trust)	High	Moderate	Medium	Medium-Term	No
Create defensible space around essential infrastructure, communication towers, power lines, wastewater treatment, water, emergency response facilities, key transportation corridors (per Hazard Mitigation Plan)	Medium to High	Moderate	Medium	Immediate to Medium-Term	No
Update Tribal Public Health and Safety Code to include Wildfire and Air Pollution response	Low	Easy	High	Immediate to Long-Term	No
Reduce the risk of large or high-severity fires by allowing fires to burn more frequently, using prescribed fires, and decreasing stand densities (Halofsky et al. 2011)	Medium	Moderate	Medium	Immediate	Yes ONP, ONF, State
Maintain biodiversity by planting trees whose genotypes have a broad range of environmental tolerances (Mote et al., 2003)	Medium	Easy - Tribal Lands. Moderate Non-Tribal Lands	Medium	Immediate to Medium-Term	No on Tribal Yes non-tribal
Use prescribed fire to reduce vulnerability of large fires (Mote et al., 2003; Mote et al., 1999)	Medium	Easy		Immediate to Medium-Term	No

Undertake a "Firewise" evaluation (Columbia Basin Trust)	Low	Easy		Immediate	No
Update zoning bylaws to incorporate fire hazard objectives such as restricting development in high-and-extreme risk fire zones (Columbia Basin Trust)	Low	Moderate		Immediate to Medium-Term	No
Update the Subdivision and Servicing Bylaw to address wildfire risk including requiring underground wiring and locating sidewalks, boulevards, and highways to act as firebreaks and evacuation routes (Columbia Basin Trust)	Low	Moderate		Immediate to Medium term	No
Improve connections and relationships with the nearest fire center (Columbia Basin Trust)	Low	Easy	High	Immediate	Yes, with surrounding fire stattions

Cedar Harvests

Make sure that future plantings happen in areas that are protected and have high soil moisture content.	Low	Medium	High	Immediate to Long-Term	Yes with State & Federal
Consider assisted migration, or helping cedar trees grow in regions where they have not historically been located, but where they are likely to survive given climate change (Aitken et al., 2008)	Medium	Moderate	Medium	Immediate to Long-Term	Not required but could be helpful
Create a monitoring and reporting system to track how cedar abundance and yields are changing. Partner with traditional harvesters to gather on-the-ground observations.	Low	Easy	High	Immediate	No
Look to see what species currently thrive in the Tribes projected future climate zone and begin planting these species (Aitken et al., 2008)	Low	Easy		Immediate	No
Modifications to thinning schedules (Aitken et al., 2008)	Low	Easy		Immediate	No

Casino and Longhouse Market

Flood proof the buildings by increasing ground floor elevation or building protective barriers.	Medium to High	Moderate	Low	Medium-Term	No
Providing multiple points of entry & egress to the facilities, including a route that is less vulnerable to flooding and wildfire.	High	Moderate to Hard	Low	Medium to Long-term	Yes, likely with DOT
Move critical systems to higher levels (off the ground floor or out of the basement) (CCAP, 2011).	Medium to High	Moderate	Low	Immediate	No
Consider protective green infrastructure in front of the facilities to create a natural buffer to storm surge and flooding.	Low to Medium	Easy to Moderate	Medium	Immediate	Yes, likely with State

Ensure that any future buildings associated with the Casino and/or Longhouse Market (i.e., parking lots, hotels) are built at higher elevation and outside the floodzone (National Academies of Sciences, 2009).	Medium	Easy	Medium	Long-term	No
Use of permeable paving techniques to manage water onsite (Connelly, 2011; CCAP, 2011).	Medium	Easy	Low	Medium	No
Consider relocating the buildings to areas outside of the floodplain/floodzone	High	Hard	Low	Medium to Long-term	No
Skills training (To ensure that employees are well trained to perform in their current role and well qualified for future employment opportunities should anything happen to the Casino and Longhouse Market).	Medium	Easy	Medium	Immediate	No

Transportation Hwy 101

Identify roads/bridge must susceptible to flooding and work with Washington DOT to identify finding to raise these vulnerable pieces of infrastructure, especially in conjunction with future repairs (National Academies of Sciences, 2009).	High	Moderate	Medium	Immediate to Long-Term	Yes (DOT)
Work with residents to create a home emergency kit that ensures that all residents have the resources they need to survive in the event of a temporary closure of Hwy 101. A particular focus should be paid to Elders and other more vulnerable segments of the population. This kit should include back-up medications, rations of food, and secondary communication technologies.	Low	Easy	High	Immediate	No
Clearly identify evacuation routes (including through the use of signage) and make sure all residents are aware of these routes (National Academies of Sciences, 2009).	Low	Easy	High	Immediate	No
Create bioswalls to store water and help with natural drainage alongside roads, particularly in the Blyn and along Discovery Bay (CCAP, 2011).	Medium	Moderate	Medium	Immediate to Medium - Term	Yes (DOT)
Re-naturalize floodplains (Northwest Climate Change Adaptation Group, 2010).	Medium	Moderate to Hard	Medium	Medium to Long-Term	Yes (private land owners and business owners)
Organize community check-ins with neighbors, especially with elderly and vulnerable populations during extreme weather events. This could include an education/outreach program with the local schools.	Low	Easy		Immediate	No

Tribal Campus Water Supplies

Initiate rainwater capture and reuse programs.	Low	Easy	Medium	Immediate	No

Ensure that new wells are sited outside of coastal and riverine flood zones and the a hydraulic assessment is completed to assess and limit impact of potentially elevated water table due to sea level rise.	Medium	Medium	Medium	Immediate to Medium-Term	No
Enhance water efficiency/conservation programs.	Low	Easy	Medium	Immediate	No
Design planting and landscaping to use native and drought tolerant vegetation and provide summer shade for buildings where appropriate.	Medium	Easy	High	Immediate	No
Install water efficient fixtures, fittings, and appliances throughout the Tribal Campus.	Low to Medium	Easy	Medium	Immediate	No

Jamestown Beach Water Supplies

Conduct a hydrological connectivity groundwater assessment to evaluate the potential for saltwater intrusion with an elevated water table as sea levels rise.	Medium	Medium	Medium	Immediate	No
Evaluate the potential for connecting the residences in the area to a secondary water supply.	Low	Medium	High	Immediate to Medium-Term	No
Ensure that any new well(s) are sited outside of coastal flood zones. Include this concern when requesting funding from the Indian Health Service or others for replacement and relocation of the well.	Low	Medium	High	Medium-Term	No on Tribal Land
Following any major flood event, conduct well water sampling to ensure water safety standards are being met.	Low	Easy	High	Immediate	No

Tribal Campus Buildings

Develop a relocation and business continuity plan in the event that the buildings are temporarily unable to be used due to near term flooding.	Low	Easy	High	Immediate	No
Consider a Tribal policy of "managed retreat" from higher risk coastal flood zones so that over time, as buildings are renovated or replaced, they are moved out of the future flood risk zones.	Medium	Medium	Medium	Medium - Term to Long - Term	No
Ensure that any new buildings are sited outside of coastal flood zones.	Medium	Medium	High	Medium - Term	No

Tribal Campus Wastewater Tanks

As the wastewater collection tanks near the end of useful life, plan to relocate new tanks out of the future coastal flood risk zone.	Low	Medium	High	Medium - Term	No
Consider a Tribal policy of "managed retreat" from higher risk coastal flood zones so that over time as buildings are renovated or replaced they are moved out of the future flood risk zones.	Medium	Medium	Medium	Medium - Term to Long - Term	No
Incorporate consideration of current and future coastal flood risk zones into any utility or wastewater mater plan.	Low	Easy	High	Immediate	No

E. Appendix E: Complete set of sea level rise maps

A complete set of sea level rise inundation maps is provided alongside this report. At total of 12 maps were created specifically for this project. The maps cover the Low Severity, Medium Severity, and High Severity scenarios for four different areas: the Blyn basin area, greater Jamestown Beach region, Jamestown Beach, and Discovery Bay.

Blyn Basin	**Greater Jamestown**	**Jamestown**	**Discovery Bay**
Low Severity	Low Severity	Low Severity	Low Severity
Medium Severity	Medium Severity	Medium Severity	Medium Severity
High Severity	High Severity	High Severity	High Severity

F. Appendix F: GIS mapping methodology

This appendix summarizes the data sources and processes used to develop GIS mapping and analysis for the Jamestown S'Klallam Climate Change Vulnerability Assessment and Adaptation Plan. All GIS data and maps developed as part of the project have been provided to the Tribal staff for future reference and use.

Adaptation International staff developed locally specific relative sea level rise projections based on the best available climate change science. These projections were mapped for the project area using data collected by the Federal Emergency Management Agency (FEMA) and available through the Puget Sound LIDAR Consortium (PSLC). LIDAR (**LI**ght **D**istance **A**nd **R**anging, also known as Airborne Laser Swath Mapping or ALSM) is a technology that employs an airborne scanning laser rangefinder to produce high-resolution topographic surveys of unparalleled detail. In particular, this project uses data from the 2012 Jefferson – Clallam LIDAR Project. Note that registration is required to access PSLC data[10]. The inundation layers were modified to accurately reflect not just the elevation, but also the presence of a tide gate on the outlet of Gray's Marsh. Thus, inundation depicted will occur when the beach berm is overtopped, not just when the sea level reaches certain elevations.

Aerial orthoimagery was obtained through the United Stated Geological Survey (USGS) via the nationalmap.gov web portal. The analysis used the most recently available imagery with 1-foot resolution, which was recorded in 2009. The metadata for the aerial imagery is available[11].

Finally, key resources, landmarks, and infrastructure were mapped via a combination of GIS data provided by the Tribe, information provided to the consultant team, and through review of orthoimagery. The precise location of community resources were confirmed through review of Tribal staff and stakeholder meetings held during the project.

Map layout and design are the product of Adaptation International staff, and were created using ArcGIS 10.0 software.

[1] Figure courtesy of the University of Colorado Sea Level Research Group.

[2] Mazzotti, S., Jones, C., Thomson, R., 2008. *Relative and absolute sea level rise in western Canada and northwestern United States from a combined tide gauge-GPS analysis.* J. Geophys. Res., 113. C11019. Doi:10.1029/2008JC004835.

[3] Data from NOAA CO-OPS (tidesandcurrents.noaa.gov). Tide Gauge data with sea level rise trends for Port Townsend and Seattle tide gauges.

[4] BESR (Board on Earth Sciences and Resources) & OSB (Ocean Studies Board), 2012. *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future*. The National Academies Press.

[5] Tebaldi, C., Strauss, B., Zervas, C., 2012. Modelling sea level rise impacts on storm surges along US coasts. *Environmental Research Letters.* **7**(2012) 014032 (11 pp).

[6] Bromirski, P.D., Flick, R.E., Cayan, D.R., 2003. Storminess variability along the California coast: 1858-2000. Journal of Climate 16, 982-993.

[7] Ruggiero, P., 2008. Impacts of Climate Change on Coastal Erosion and Flood Probability in the US Pacific Northwest. Solutions to Coastal Disasters. Oahu, Hawaii.

[8] Feely, R.A., Klinger, T., Newton, J.A., Chadsey, M., 2012. Scientific Summary of Ocean Acidification in Washington State Marine Waters. Washington State Blue Ribbon Panel on Ocean Acidification. Technical summary available at: https://fortress.wa.gov/ecy/publications/SummaryPages/1201016.html

[9] Figure from Gruber, N., Hauri, C., Lachkar, Z., Loher, D., Frolicher, T.L., Plattner, G.K., 2012. Rapid Progression of Ocean Acidification in the California Current System. Science 337, 220-223Hake, R., 2012. Semi-Annual Project Highlights. Tribal Government Human Resources Department. Published September, 8th 2012. 3pp.

[10] Puget Sound LiDAR Consortium. 2012. Jefferson and Clallam County Shoreline survey flown by FEMA and available on-line: http://pugetsoundlidar.ess.washington.edu/lidardata/restricted/projects/2012jefferson_clallam.html

[11] USGS. 2009. Ortho-imagery for the key Jamestown S'Klallam Tribal areas mapped. http://extract.cr.usgs.gov/distmeta/servlet/gov.usgs.edc.MetaBuilder?TYPE=HTML&DATASET=WA_00008.