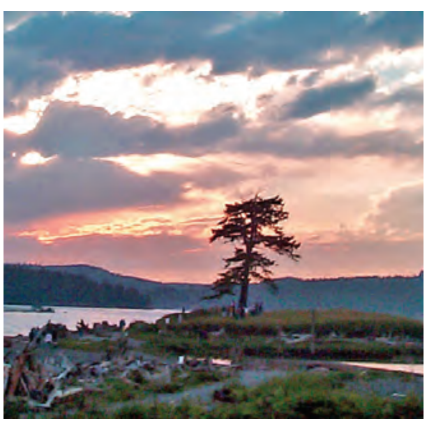
Swinomish Climate Change Initiative

Impact Assessment Technical Report



Swinomish Indian Tribal Community

Office of Planning and Community Development

La Conner, WA 98257

October 2009

CONTENTS

APPENDICES

Acknowledgements

Support for the Swinomish Climate Change Initiative was provided through a grant from the U.S. Department of Health & Human Services, Administration for Native Americans (ANA), which provided 80% of project funding.

Many people participated in technical assessment activities for this project and/or contributed to the preparation of this report. In performance of technical work for the project and preparation of this report, the Swinomish Indian Tribal Community would like to acknowledge contributions of the following individuals:

University of Washington, Center for Science in the Earth System, Climate Impacts Group:

Dr. Nathan Mantua, Co-Director and Associate Professor (overseeing science consultant)
Lara Whitely Binder, Outreach Specialist (advising science consultant)
Ingrid Tohver, Research Scientist (advising science consultant)

Swinomish Indian Tribal Community:

Ed Knight, AICP, Senior Planner (Project Coordinator)
Tara Tisdale, Associate Planner
Scott Andrews, Environmental Management Coordinator
Jeroldine Hallberg, Technical Writer
Eric Haskins, GIS Specialist

Special thanks also to the following individuals for their additional contributions and/or review:

Swinomish Indian Tribal Community:

Charles O'Hara, Planning Director
Elissa Fjellman, GIS Coordinator
Larry Campbell, Tribal Historic Preservation Officer
Shelly Vendiola, Communications/Outreach Facilitator
Todd Mitchell, Water Resources Coordinator
Jamie Donatuto, Environmental Specialist
Tiffany Hoyopatubbi, Water Resources Specialist
Sarah Akin, Water Resources Specialist
Debra Lekanof, Grants Coordinator
Office of Tribal Attorney

Skagit River System Cooperative:

Greg Hood, Scientist

Swinomish Utility Authority:

John Petrich, Director

This report is also available on the Swinomish Climate Change web site:
http://www.swinomish.org/departments/planning/climate_change/climate_main.html

List of Figures

List of Tables

1 EXECUTIVE SUMMARY

In recognition of a growing body of scientific evidence, and in response to certain specific local events, the Swinomish Indian Senate issued a proclamation in 2007 directing action to study the possible effects of climate change on the Swinomish Indian Reservation community, lands, and resources and determine appropriate responses.[1] Following this proclamation, the Tribe initiated a two-year project in late 2008 to assess how climate change may affect the Swinomish Indian Reservation and to develop strategies to address potential impacts.

The outcome of this project is the production of three key reports: this *Impact Assessment Technical Report*, a preliminary Adaptation Strategy Report, and a Community Action Plan with recommendations for future adaptation options and strategies. This technical report comprises the first milestone of the project. It represents the work of a multidisciplinary team led by staff of the Swinomish Office of Planning & Community Development, in partnership with the University of Washington Climate Impacts Group (CIG), and with further scientific assistance from Skagit River System Cooperative (SRSC). The report describes the scientific data and potential climate change scenarios, assesses possible local impacts, and identifies specific areas of potential risk and vulnerability to climate change effects.

Key Findings

The fourth assessment of climate change released in 2007 by the Intergovernmental Panel on Climate Change (IPCC) represents a consensus among scientists worldwide that rising greenhouse gas concentrations are unequivocally attributable to human activities. In an effort to understand the response of climate to increased greenhouse gas emissions in the future, the IPCC coordinated global climate change modeling experiments carried out by the international research community under various emissions scenarios. The models under all scenarios point to a warmer future climate, with the rate of warming correlated to the rate of greenhouse gas emissions.[2] The key to preparing for the potential impacts of climate change is to understand the extent of possible effects on our regional biological, physical and human systems under future scenarios of varying ranges. To assess the range of impacts and the potential risks posed to human and natural systems, this report considers several regional climate change scenarios, from low to high impacts, to accommodate the inherent uncertainty in the climate change models and future greenhouse gas emissions scenarios. This approach is consistent with similar analyses and efforts by other governmental entities, such as King County, Washington, and the California Coastal Commission.

Based on assessment of current documented models and scenarios, the principal areas and resources within the Swinomish Indian Reservation vulnerable to climate change impacts are shorelines, beaches, low-lying terrain, and forests, along with the assets within those areas. Impacts to some of these vulnerable areas are potentially high within 20-50 years, increasing

[1] See Appendix 1 for text of Proclamation.
[2] See Appendix 2 for more complete discussion of projected impacts.

through the end of the century and beyond.[3] Other areas and resources may have moderate impacts during this timeframe. Significant among these potential impacts are the following:

- Over 1,100 acres of Swinomish Reservation lands, or approximately 15% of Reservation uplands, are potentially at risk of inundation from increasing sea level rise, including the only agricultural lands within the Reservation, the Tribe's primary economic development lands, and sensitive shoreline areas.

- Approximately 160 residential structures are potentially at risk of inundation from sea level rise and/or tidal surge, with a total estimated value of over $83 million.

- Approximately 18 non-residential or commercial structures are potentially at risk of inundation from sea level rise and/or tidal surge, with a total estimated value of almost $19 million.

- Approximately 2,218 acres of uplands and over 1,500 properties are in a high risk zone for potential wildfire based on projected increase in temperatures; total value of structures and properties within this zone is estimated to be more than $518 million. Most other areas within the Reservation are at least at moderate risk of wildfire.

- Vital transportation links and access routes to the Reservation are at risk of inundation, with the potential to isolate the Reservation from the mainland during increasingly high tidal events.

- Beach seining sites and shellfish beds along the west shore of the Reservation, areas of traditional tribal harvest, are at significant risk of permanent inundation and potential loss. Important "keystone" species such as shellfish and salmon are at risk of higher levels of contamination from algal blooms and other diseases that may be exacerbated by increased temperature and other changes.

- The Reservation population as a whole, particularly those who are ill or elderly, are potentially at risk of a variety of heat-related illnesses during isolated or extended high heat episodes as average temperatures increase, and tribal members in particular may be at risk of increased incidence of respiratory ailments such as asthma from potential increase in synergistic impacts of pollutants.

- Sensitive cultural sites within low-lying areas may face permanent inundation, and traditional native species may be lost as they are forced to migrate or adapt to hotter, drier climatic conditions.

The risk of inundation of shorelines and low-lying areas is expected to increase over the long term with gradual sea level rise and projections of more frequent and intense storm/tidal surges. Global projections of sea level rise indicate a range from lower estimates of 18-59 cm (~1-1/2 to 2 feet) by the end of the century (IPCC, 2007) to higher estimates of up to 55-125 cm (~2 to 4+ feet) within the same timeframe (Rahmstorf, 2007; Pacific Institute, 2009). Regional estimates of sea level rise depend on the local effects of wind patterns, atmospheric pressure, and vertical land

[3] As discussed in following sections, models and scenarios examined for this report, as well as assessments of impacts, generally rely upon projections through 2100; most analyses agree, however, that climate change and associated impacts are expected to continue for some period of centuries or longer. See report discussion and technical appendices for information on models and scenarios.

movement caused by tectonic activity. Considering these local conditions, Mote et al. (2008) estimates regional sea level rise for the Puget Sound to span from very low estimates of 16 cm (6") to very high estimates of 128 cm (50") by the end of the 21st century.

Structures, roads, utilities, and other assets within nearshore or low-lying areas will be increasingly impacted by sea level rise and tidal surge events to the extent that adaptation measures will not be available or able to forestall, protect against, or prevent such impacts.

Based on projections of potential sea level rise and tidal surge, risk zones were mapped for the Reservation, and an inventory of properties and improvements within these risk zones identified almost 200 properties potentially at risk, including residential structures and non-residential facilities.[4] Any revenues generated from leasing or other commercial activity on these properties would also be at risk of loss. Low-lying agricultural and shellfish areas could ultimately be lost entirely, and primary economic development land could be significantly impacted. Certain impacts also carry potentially significant secondary consequences as well, such as inundated access routes causing isolation of the Reservation from the mainland, or inundation of low-lying development zones affecting or preventing implementation of critical economic development projects. Such secondary consequences have the potential to extend impacts to the entire Reservation population and stress the ability of Tribal and other governmental entities to respond.

Forested areas and resources are projected to experience different but equally significant impacts. Annual mean temperature is projected to increase in the northwest by up to 3-4°F by 2040 and perhaps as much as 7-8°F by the end of the century (DOE, 2006; CIG, 2009). Gradually increasing average and summer temperatures will decrease moisture content in soils and vegetation and increase the potential for devastating wildfire throughout forested areas of the Reservation, but with potentially greatest impact in the urban/forest interface.[5] Other impacts on forest resources include increasing drought stress with rising temperatures, and an associated proliferation of drought-tolerant species such as fir and decline in drought-susceptible species such as western red cedar. Changes in the species composition of large trees could also be accompanied by a shift in understory species and ground vegetation, potentially resulting in the loss or migration of certain native plants. Additionally, higher temperatures are projected to create a more suitable environment for the spread of forest pests and diseases, such as bark beetles and various fungi that would previously have been suppressed by colder winters.

Other significant or notable impacts include effects on public health, marine resources, and cultural resources. Increasing temperatures are projected to impact human health in numerous ways; heat stress will have a variety of impacts on the general population, as already seen in some parts of the globe, and rising temperatures will create a more suitable environment for pathogens and their vectors that is not normally prevalent in a colder regime. Likewise, rising ocean acidity and shifts in tidal zones will put additional stress on near-shore marine resources such as shellfish and viable habitats. Cultural resources may be impacted both positively and negatively by tidal inundation. Gradual sea level rise will increasingly submerge nearshore or low-lying buried artifacts and sites, both protecting them and making investigation more difficult, while strong storm surges may uncover some sites or artifacts, rendering them vulnerable to weathering and tampering. Cultural use areas may be impacted by either inundation in near-shore or low-lying areas or by wildfire in forested areas, rendering them unusable in either case for some extended period of time.

[4] See Section 6 for delineation of inundation zones.
[5] See Section 6 for delineation of urban/forest interface zone.

Report Disposition

This report is intended to lay a solid foundation for assessment of appropriate response strategies, and the ultimate intent of this and following reports is to provide a well-documented path to actions taken based on such strategy recommendations. Concurrent with this report, an advisory group has been working toward a broad planning and policy framework for preparedness response strategies and an assessment of critical issues and impacted disciplines.

The ultimate goal is to develop an action plan for the future by combining the results of this technical report with the advisory group's recommendations. The action plan will include a range of strategy recommendations for adaptation to potential climate change impacts. It will also describe areas of recommended or necessary coordination with local jurisdictions where common interests exist between the Tribe and other jurisdictions, and it will examine capacity and funding requirements for implementation. The final report will be shared as a model to assist other tribal governments and jurisdictions in planning for adaptation. It is expected that this project will be but the first in a continuing and long term series of steps to determine how best to cope with and adapt to some of the most significant issues to face the Tribe in their long history. Final publication of the action plan is scheduled for September 2010.

2 Key Terms

Adaptation (climate change): Actions to respond to and/or counter the effects of climate change; relocation and armoring are examples of adaptation actions.

Adaptive Capacity: The ability of a system to accommodate or respond to changes in climate with minimum disruption or cost.

Armoring: Shoreline erosion control practices using hardened structures intended to stabilize the shore; examples include bulkheads, revetments, concrete walls, and rip-rap. Armoring inhibits natural processes, leading to conflict between protection of built structures and protection of the environment.

Climate Change: Changes in the Earth's physical systems that occur over long time periods (decades, centuries, or even millions of years) rather than over shorter periods such as for annual or seasonal changes; climate change may include changes in natural cycles of variability such as seasonal, annual, multi-year, and/or multi-decade patterns of variability. As used in the Tribal project, climate change refers to those changes resulting from increase in greenhouse gas concentrations and changes in aerosol emissions that are deemed to be caused by human activities. Examples of global effects of climate change include increase in average atmospheric and sea temperatures, general melting and decrease in snow and ice, increased drought conditions, and rising sea levels.

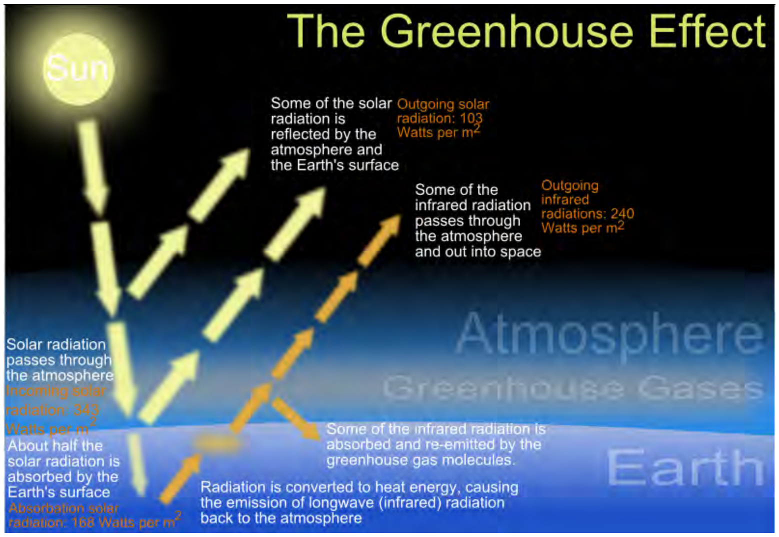
Datum: A mathematical model for describing and measuring elevation. Vertical datum describe upland elevation based on mathematical models of the earth's surface; tidal datum describe the range of tidal influence between low and high water based on analysis of historical data.

Estuary/estuarine: An estuary is a body of water formed where freshwater from rivers and streams flows into the ocean, mixing with the seawater. Estuaries and the lands surrounding them are places of transition from land to sea, and from freshwater to saltwater. Although influenced by the tides, estuaries are protected from the full force of ocean waves, winds, and storms by the reefs, barrier islands, or fingers of land, mud, or sand that surround them. *The entire Puget Sound is an estuary*, made up of a series of underwater valleys and ridges fed by more than 10,000 streams and rivers. The average depth is 450 feet. Puget Sound is surrounded by an array of beaches, bluffs, deltas, mudflats and wetlands teeming with plants, fish, birds and wildlife. (EPA National Estuary Program)

Fetch: The distance which the effect of seas (such as wind) can travel unobstructed by land before reaching the observer.

GIS: Geographic Information System, a means of location, mapping, and analysis of spatial data, such as for natural, environmental, and built features.

Greenhouse gas (GHG): Gases that trap heat within the Earth's atmosphere by absorbing and emitting infrared radiation; such gases include carbon dioxide, methane, nitrous oxide, ozone, and water vapor.



Increases in atmospheric gases such as carbon dioxide and ozone, caused mostly by human activity (IPCC 2007), in turn cause additional heating of the atmosphere; as heat builds in the atmosphere, more water vapor and other gases accumulate, which creates even more heating. This feedback cycle of heating amplifies the effects of warming due to CO_2 concentrations.

(Source: Wikipedia Commons)

Heat exhaustion: a condition that occurs when the body is producing or absorbing heat faster than heat can be dissipated, usually caused by prolonged exposure to high temperatures. Symptoms of heat exhaustion include headache, dizziness, dehydration, fainting, nausea, and lower blood pressure. Heat exhaustion can be a precursor to more severe hyperthermia (heat stroke), cardiac arrest, and other conditions.

Heat stroke: a severe condition, usually caused by prolonged exposure to heat, requiring immediate medical attention. Symptoms are typically more acute forms of those for heat exhaustion, with additional possibility of unconsciousness, cardiac arrest, convulsions, vomiting, and blindness.

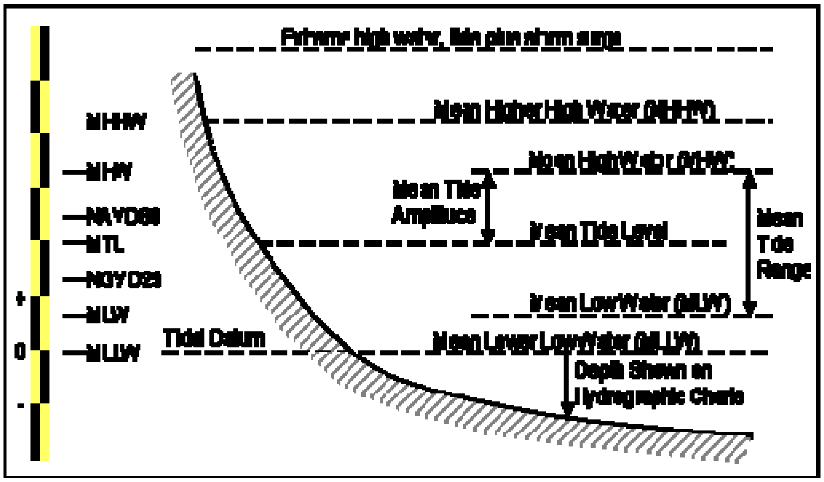
IPCC: International Panel on Climate Change, the assembly of scientists from around the world commissioned through the United Nations to study and report on the causes and impacts of global warming and climate change.

LiDAR (Light Detection and Ranging): a remote sensing tool that projects a laser pulse (usually attached to an airplane of helicopter) to measure distance and gather topographic data.

Mean Higher High Water (MHHW): The average of the higher high water height of each tidal day during a tidal epoch (19 years).[6]

Mean Lower Low Water (MLLW): The average of the lower low water height of each tidal day during a tidal epoch (19 years).[6]

[6]Some locations have diurnal tides, or one high tide and one low tide per day. Most locations are characterized by semidiurnal tides, in which the tide cycles through a high and low twice each day, with one of the two high tides being higher than the other and one of the two low tides being lower than the other. These more extreme tides are used to measure MHHW and MLLW. (NOAA)



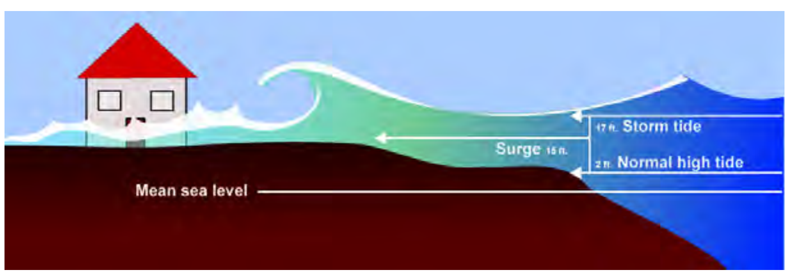
Generic Relation of Tidal Datums and Water Level Measurement
(Source: http://www.fhwa.dot.gov/engineering/hydraulics/images/h25_61.gif)

Mitigation (climate change): Actions to reduce the causes of climate change; emission reduction and energy efficiency programs are examples of mitigation actions.

Sector: Any policy area, planning discipline, management focus, resource, human system, or natural system that may be a subject of study.

Sensitivity (climate change): The degree to which a system is affected by changes in climate conditions.

Surge: An offshore rise of water associated with a low pressure weather system, caused by high winds pushing the surface of the water



Sustainability: The ability of a system to meet its needs on a continuing basis without harm to the environment and without compromising the ability of systems to do so in the future. In tribal traditions, the concept of "seven generation sustainability" is the idea that decisions should be considered for their impact on the seventh generation to come.

Vulnerability (climate change): Measurement of the level of impact on a system from the effects of climate change; vulnerability is an assessment of the consequences of climate changes, as a function of the sensitivity of a system to climate changes and the adaptive capacity of the system to respond to such changes.

3 Background

3.1 General Characteristics and History

The Swinomish Indian Reservation is located on the southeastern peninsula of Fidalgo Island, west of the Swinomish Channel and adjacent to low-lying mainland areas to the east (Figure 3-1). The Reservation regulatory boundary encompasses approximately 7,450 upland acres and approximately 2,900 acres of tidelands for a total of 10,350 acres. Roughly 4,700 acres is forested uplands with surrounding and interspersed urban and rural development. Approximately 7,675 acres are held by the Tribe or Tribal members, with the remaining 2,675 acres held in private non-tribal ownership (Figure 3-2). Tribal headquarters are located in the historic Swinomish Village in the southeast portion of the peninsula, across the channel from the Town of La Conner. Tribal enterprises, including a casino, gas station, and RV park, are located on the north end of the Reservation, adjacent to SR20, a state highway crossing the Reservation. There are upwards of 1,300 homes on the Reservation, and total Reservation population is estimated at approximately 3,000 (over 2,600 as of 2000 census).

Established in 1855 by the Treaty of Point Elliott, the Swinomish Reservation brought together several Coast Salish groups who shared a common language, a culture centered on fishing, and a ceremonial calendar revolving around cedar longhouses. Before the influence of European settlers, Coast Salish cultures derived their wealth from abundant natural resources and extensive inter-clan and lineage trade relationships that stretched well beyond the Puget Sound region. While salmon was a primary staple, Coast Salish people also harvested a wide variety of flora and fauna from the land, sea, and rivers, including a rich selection of shellfish species. Permanent villages consisted of longhouses that sheltered large extended families. The village provided a social support network during times of crisis and was used in celebrations and ceremonies that were an integral part of culture, health, governance, and the maintenance of kinship allegiances and exchange relationships important to the intensive harvesting required to accumulate the necessary foods and goods exchanged (Gunther and Haeberlin 1930, Roberts 1975, Suttles and Lane 1990).

With the formation of the Reservation and accompanying colonial restrictions on traditional cultural practices, tribal members faced decades of declining health, education, and community assets, along with increasing poverty, illness, drug abuse, and racism (Roberts 1975). Although the past 20 years have brought positive changes in economic and social conditions for the Tribe, many problems remain, including low graduation rates, high unemployment, lower income levels, and high rates of violence and drug abuse. Of the employed Swinomish workforce, more than 26 percent still live below the poverty line, which the Indian Health Service estimates is twice the poverty rate of the general U.S. population.[7] The average health of Native Americans is measurably worse than the US population as a whole (Indian Health Service 2000, US Commission on Civil Rights 2003), with morbidity and mortality rates often many times higher than the U.S. average.[8]

[7] Nationally the poverty rate for US population is 12.3 percent (DeNavas-Walt et al. 2007), while the Native American poverty rate is 26.6 percent (Webster, Jr. et al. 2007).
[8] According to the Indian Health Service's *Facts on Indian Health Disparities* (2007), "American Indians and Alaska Natives die at higher rates than other Americans from tuberculosis (500 percent higher),

Improving social conditions can be attributed in part to recognition of fishing rights in 1975, reasserting the rights of the tribal members to harvest the local waters and tidelands that provide culturally important food staples, one of which is shellfish (e.g., clams, crabs, oysters, shrimp, mussels). Traditional foods such as salmon and shellfish are "cultural keystone" species to the Tribe; much more than a food source, these foods are a vital contribution to cultural, spiritual, and social life (Garibaldi and Turner 2004). Shellfish can be harvested year-round, providing a stable, high protein food source. Individual beaches are treasured for their shellfish populations and are maintained to avoid over-harvest. Loss of a traditional food is directly related to loss of morale, and cultural health and well-being (Arquette et al. 2002; Kuhnlein and Receveur 1996).

In recent years, the Swinomish Tribe, like many other tribes, began to develop commercial enterprises and established a casino in the mid-1990's. The success of this and other enterprises has made it possible for the Tribe to begin reversing decades of social and economic decline, although unemployment rates often still exceed 30% and seldom drop below 20%. While these economic improvements have made it possible for the Tribe to provide amenities such as social and medical facilities, as well as new housing for its members, the Tribe still strongly embraces its resource-based traditions.

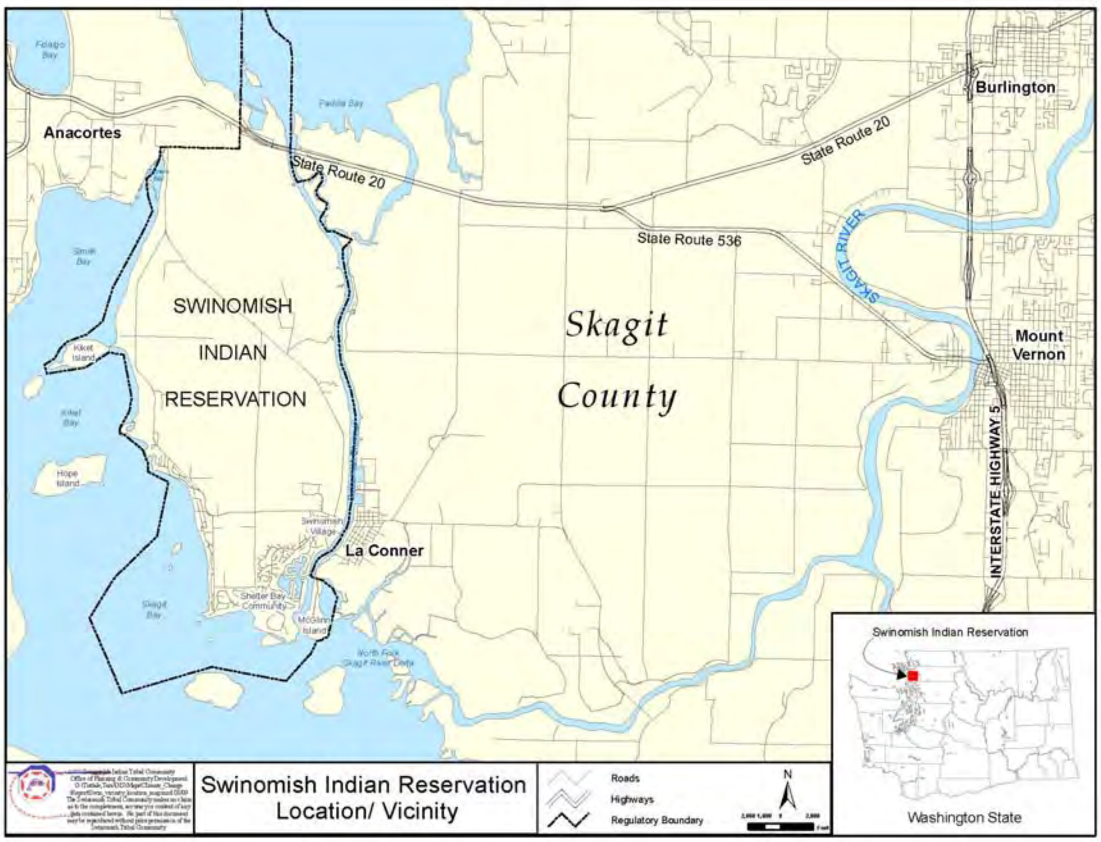


Figure 3-1. Location of Swinomish Indian Reservation.

alcoholism (550 percent higher), diabetes (200 percent higher), unintentional injuries (150 percent higher), homicide (100 percent higher) and suicide (60 percent higher)."

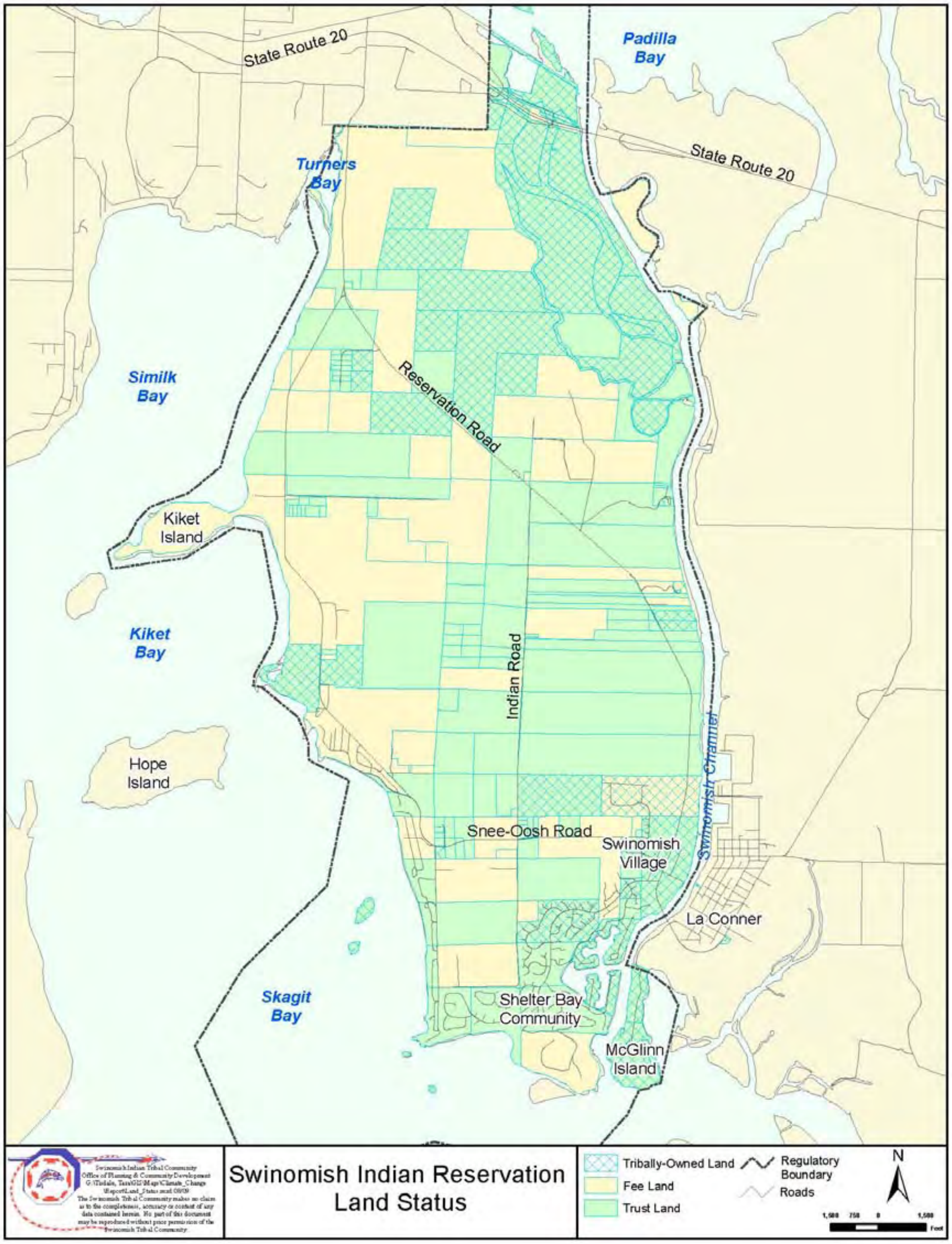


Figure 3-2. Land Status of Swinomish Indian Reservation.

3.2 Genesis of the Project

The geographic characteristics and coastal location of the Swinomish Indian Reservation place community assets, vital infrastructure, natural resources, sensitive cultural areas, low-lying economic development areas, and community health at risk from projected wide-ranging and long-term impacts of climate change. A climate change report issued by the State of Washington in 2006 identified the lower Skagit River area as a high risk for sea level rise; Figure 3-3 illustrates low-lying areas in the vicinity of the Swinomish Indian Reservation. The destructive potential of sea level rise was demonstrated in February 2006 when a strong storm surge pushed water levels several feet above normal, resulting in some flooding and damage to property on the Reservation and in La Conner. This was followed in November 2006, by a strong winter storm that downed trees and power lines across the Reservation, isolating the Reservation community for three days and prompting plans for evacuation of residents to the local Tribal gymnasium. These events heightened awareness of climate impacts in general and the lack of preparedness within the community, and they helped provide a catalyst for action to determine appropriate responses to climate impacts.

In recognition of this, the Swinomish Indian Senate issued a Proclamation in October of 2007 directing action to assess potential climate change challenges and develop appropriate responses. Following this Proclamation, the Tribe won funding through the U.S. Department of Health & Human Services, Administration for Native Americans (ANA), to support a major new $400,000 Climate Change Initiative. While the Tribe acknowledges the need for action toward mitigating the causes of climate change, the approach of this project has been consciously directed toward adaptation actions to counter the anticipated effects of climate change on the Reservation community. This is based in large part on the recognition that while society at large must play a part in mitigation, it primarily falls to each community and local government to determine needed action toward adaptation. As discussed below, this need is ever greater for tribal communities.

3.3 Broader context of Indigenous peoples and climate change

The impacts of global climate change fall disproportionately on Indigenous peoples, as acknowledged by the IPCC (IPCC 2007). The National Congress of American Indians (NCAI) finds that “Tribal cultures and life ways are intimately bound up with their homelands, natural resources and ecosystems which are directly threatened by the effects of climate change” (NCAI 2009). Notable examples already exist, as in Alaskan native villages on the North Slope that are being forced to relocate as pack ice thaws and exposes villages to damage from surging water and wind. On Washington’s Olympic Peninsula, the Hoh and Quileute have struggled to acquire additional land for relocation as increasing erosion wears away the edges of their villages (Hansen 2008 and 2009).

Conversely, resources available to Indigenous peoples and communities to address adaptation to climate impacts are disproportionately scarce. Lacking a tax base or other such revenue sources commonly available to non-tribal governments, tribal communities rely upon enterprises, natural resource development, and federal trust obligations for support of critical governmental functions and community programs. Given the long timeline of anticipated impacts, the long lead time required to address the impacts in many respects, and the substantial and continuing commitment of resources required to support adaptation efforts, even the wealthiest tribal communities may find themselves hard pressed to meet the challenges of climate change.

The NCAI further urges tribes, in keeping with the affirmative exercise of sovereign powers as stewards of natural resources, to use their traditional knowledge in promoting efforts to assess and address climate change through mitigation and adaptation. Free, prior, and informed consent are the principles sought by Indigenous peoples in responding to climate change. This is a human rights based approach to climate change that is considered fully compatible with an ecosystem approach (de Chavez and Tauli-Corpuz 2008).

The Swinomish Indian Tribal Community supports the global and national efforts of Indigenous peoples for a seat at the table to plan, implement, and allocate resources for climate change measures, acting as sovereign entities with the various U.S. government bodies. At the local level, this Technical Impact Assessment Report sets the stage for future climate adaptation measures in keeping with the spirit of NCAI principles and the rights and responsibilities of Indigenous peoples. In the broader socio-political context, any number of communities may benefit from application of the principles of Indigenous peoples and methodologies such as embodied within this project. Indeed, it is the hope and intent of the Swinomish to serve as a pioneer in addressing climate change as a tribal effort, and a key objective of this project is to provide a model and template for others to follow and adapt, tribal or non-tribal.

3.4 Project Participants

The project is managed by the Swinomish Office of Planning and Community Development under the coordination of a key staff team led by Senior Planner, Ed Knight, as the project lead. Since climate change impacts will cross jurisdictional boundaries and require coordinated action on some issues, local government and community representatives were invited to participate in the project and provide input on key issues and development of strategies and action plans. These participants include representatives of Skagit County, the Town of La Conner, Shelter Bay Community, and Skagit River System Cooperative, who work with Tribal departments and staff on a project strategy advisory group. In addition, a community engagement advisory group, with members representing various sectors of the tribal community, was established to assist in communicating issues to the tribal community and in evaluating and soliciting feedback from the tribal community on issues of interest or concern.

A key partner in the project is the University of Washington Climate Impacts Group (CIG), serving as expert scientific advisor. CIG is part of the Center for Science in the Earth System at the University of Washington's Joint Institute for the Study of the Atmosphere and Ocean, and is one of nine Regional Integrated Sciences and Assessment teams studying impacts of climate change in the United States. CIG staff played a crucial role in reviewing scientific data, reports, and project documents, advising on the use of scientific data and information in the project, and in identifying probable local impacts and climate change scenarios.

Scientific expertise was also provided by Skagit River System Cooperative, which partnered with Western Washington University and Battelle Northwest to model hydrologic impacts at the local level. An additional staff team provided critical GIS mapping and analysis support to the project, as well as administrative support to project tasks.

Figure 3-3. Low-Lying Areas Within the Swinomish Indian Reservation.

4 Assessment Process

The work plan for the project prescribed a specific step process for assessment of potential climate change impacts, vulnerability assessment, and risk analysis. To a large extent, the Tribe's approach and methodologies parallel those in the CIG/King County guidebook, **Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments**, although the Tribe modified process elements of the methodology to suit particular Tribal needs and objectives.

4.1 Data, Metadata, and Tools

There is an escalating volume of scientific data, reports, and models to survey when reviewing climate change data. For this assessment, the Tribe elected to rely upon a combination of peer-reviewed reports on global change and those reports that focused specifically on impacts to the Pacific Northwest. The climate change reports, sources, and associated models/scenarios evaluated for this project, including this impact assessment, are cited in the References.

This assessment employs output from climate model simulations organized and reported on by the IPCC (2007), including a wide range of potential greenhouse gas (GHG) emission scenarios that model varying degrees and types of technological development, industrial development, population growth, and response to issues. These emissions scenarios span the spectrum of response, from "minimum action" worst-case scenarios (i.e., "business as usual" or "do nothing" scenarios), where projected impacts are the greatest, to "maximum action" best-case scenarios, where projected impacts are reduced. The IPCC's 2007 report, which represents a consensus among climate change scientists worldwide, provides a benchmark for many other analyses and reports. The climate models reported on by the IPCC (2007) successfully capture the seasonality and temperature trends for the Pacific Northwest over the last century, an indication that they will reliably provide projections for future conditions. While the models agree on the projections of increased annual temperatures in the 21st century, forecasts for precipitation are more variable across the models, though the average of all models projects a seasonal signal of wetter winters and drier summers for this region.

Despite the general consensus represented in the IPCC data and analyses, some scientists dispute the IPCC estimates of sea level rise and point to the exclusion of direct observations of melting of ice caps and underestimated levels of thermal expansion as factors accelerating sea level rise. For example, one such changing condition relates to earlier reports that projected the disappearance of summer Arctic sea ice by the year 2100; due to rapid melting observed in recent years, some scientists now project that summer Arctic sea ice may disappear within the next 5 to 10 years.[9] Rahmstorf (2007) notes that observed sea level has followed the trajectory estimated by the uppermost uncertainty limit for global sea level rise of the IPCC's Third Assessment Report, and that the sea level rise values reported in the IPCC's Fourth Assessment Report now appear implausible in light of observed data. Rahmstorf (2007) advises that faster rates of sea level rise

[9] Zabarenko D. (2007) "Arctic ice cap melting 30 years ahead of forecast" Reuters New Service, 1 May 2007 http://news.yahoo.com/s/nm/20070501/sc_nm/globalwar..._ice_dc&printer=1;_ylt=Am_lMJ5hK0AxqrQPSg.gHMsiA NEA (2 of 2)5/1/2007 3:56:08 PM
Presse F. (2009) "Scientist find bigger than expected polar ice melt" CommonDreams.org 25 Feb 2009 http://www.commondreams.org/headline/2009/02/25-3
JuneauEmpire.com (2007) "Experts say rapidly increasing melt rate could leave Arctic Ocean ice-free by 2012" http://juneauempire.com/stories/121207/sta_20071212025.shtml 12/13/2007 1:08:54 AM

should be considered when planning for adaptation. For the purposes of risk analysis, this assessment employs a range of impacts from sea level rise, from mid-range scenarios modeled by the IPCC (2007) to higher levels estimated by Rahmstorf (2007) within a given timeframe.

It is acknowledged that all climate change models and scenarios are associated with ranges of uncertainty resulting from varying degrees of model sensitivity to climate change, and that there are notable differences among the models, although for temperature all models indicate an upward trend in the future. Likewise, there are natural cycles of climate variability that occur over seasonal, annual, or even decadal periods within the longer trends of extended climate change, and such natural variability and relatively shorter-term cycles do not provide sufficient indication of long-term changes or trends. One such observed variability cycle important for the Northwest region is the "Pacific Decadal Oscillation," an alternating inter-decadal climate pattern characterized by shifts in sea surface temperature, sea pressure and wind patterns (Mantua and Hare, 2002).

Data used to derive inundation zones was 2002 LiDAR elevation data for the Swinomish Reservation vicinity and Tidal Datums and Tidal Benchmark information from NOAA and the U.S. Army Corps of Engineers. Tidal and elevation data were processed, analyzed, and mapped using Swinomish GIS, and NOAA Vertical Datum Transformation Tool 2.2.4 for the tidal epoch 1983-2001 was used to convert NGVD29 vertical datum to LiDAR data. A more detailed description of data and GIS processing methodologies is contained in the Appendix 4.

4.2 Assessment Methodology

4.2.1 Initial Impact Identification

Initial identification of impacts was based on up-to-date, wide-ranging assessment of global climate change impacts, models, and data and in reports where data was downscaled to determine the regional effects of global climate change.[10] These reports were evaluated with the assistance of CIG science advisors and were aggregated to obtain a representative set of scenarios ranging from low to high impact, with varying degrees of probability and uncertainty. Data and reports were further evaluated against current reported direct observations of climate and environmental changes as a gauge of rate of change. Some selected discipline-specific sources may also be cited where discussion addresses specific aspects of climate change effects (e.g., behavior of pavement or bridge joints in various extreme conditions, or behavior of disease vectors under specified climate conditions).

The range of aggregated scenarios and associated general potential impacts was then evaluated across a range of policy sectors, beginning with a basic analysis matrix as presented and discussed in Section 5.1. This matrix served as a first-step visual guide to overall likely areas of impact, with a preliminary rough assessment of probability within general timeframes of 20-50 years and 50-100 years, drawn from consideration of scenarios. For analysis purposes, sectors were drawn from comparable planning areas as identified in other Tribal documents such as the Swinomish Comprehensive Plan, to facilitate the incorporation of report recommendations into a broad range of planning documents. A more detailed sector-by-sector analysis of impacts was then performed, identifying impacts of medium to high probability, which are summarized in a set of assessment tables presented in Section 5 of this report and further discussed in accompanying narrative.

[10] See Appendix 2 for discussion of data and scenarios analyzed by CIG for this assessment.

4.2.2 Vulnerability Assessment

Vulnerability assessment was undertaken in a 3-step process: 1) identification and mapping of potential impact areas (risk zones); 2) inventory of assets and resources within identified risk zones; and 3) evaluation of impact threshold and exposure (sensitivity and adaptive capacity). The intent of this analysis is to produce quantitative information on impacted assets and resources, along with specific local qualitative projections of impacts, resulting in computed level of impact, or consequence, for given sectors. Combining the derived consequences with probability projections provides a basis for further risk analysis. Mapping of impact areas resulted in three primary risk zones: a sea level rise inundation risk zone, a tidal surge inundation risk zone, and a wildfire risk zone. Additional specific risk areas were mapped where possible (e.g., potential erosion areas).

Current inundation zones were based on mapping of tidal range from Mean Lower Low Water (MLLW) to Mean Higher High Water (MHHW), developed from LIDAR data, Tidal Datums, and Tidal Benchmarks. <u>For the purpose of risk analysis</u>, projected inundation zones were derived by adding an increase of up to 5 feet for sea level rise (NWF 2007 upper range of surveyed scenarios) and an additional 3 feet beyond that for local tidal surge estimates (Zervas, 2005). The current MLLW and MHHW elevations were shifted accordingly to represent new projected levels of permanent inundation (MLLW) and maximum tidal influence (MHHW). <u>It should be emphasized that the projected zones indicate areas of increased risk for this report, not necessarily projections of actual impact.</u> Existing diking was represented as it exists in elevation mapping without consideration of potential adaptation measures. Initial risk zone mapping was developed to show potential impact with no presumed dike protection, to illustrate potential inundation in event of dike failure, intentional breach, or topping of dike by either higher projected tides or tidal surge. It should also be noted that not all areas subject to potential inundation are currently protected by dikes.

Urban/forest interface was evaluated using analysis of GIS and aerial photo data, correlating developed areas of varying densities to forested areas of given density. Forested areas cover the majority of Reservation uplands, while developed areas primarily lie within southeast, south, and west shore areas, although some scattered pockets of homes and homesites exist in interior uplands. Where denser developed and forested areas intersect, a wildfire risk zone was identified, as augmented by a 200-foot buffer around identified developed areas. While the entire Reservation is deemed to potentially be at risk of wildfire due to the extent of forestation, the identified urban/forest interface zones were considered to be at greatest risk, and for the purpose of risk evaluation and response strategy implementation, were designated as primary wildfire risk zones. The outcome of the vulnerability assessment is summarized and discussed in Section 6.

4.2.3 Risk Analysis

The ultimate outcome of this project is to identify and prioritize appropriate strategies to respond to climate change challenges. Choosing such strategies and assigning proper priorities necessarily relies upon the risk and probability of given events. Once vulnerability assessment is complete, risk analysis is a relatively straight-forward, computational exercise. The vulnerability assessment produces the level of impact, or "consequence," for impacts on given sectors, and this consequence is combined with previously estimated probability to derive the estimated risk. In mathematical terms, Consequence X Probability = Estimated Risk. This is demonstrated and summarized in Section 7.

5 Impact Assessment

5.1 Summary of General Climate Change Impacts

Based on review and evaluation of cited climate change reports and data, the following climate change effects and impacts were noted as may be generally applicable globally and regionally. Effects refer to observed and predicted changes in general environmental and climate conditions; impacts refer to those projections of impacts anticipated to result from the reported effects. These general effects and impacts have been further assessed for applicability to more localized conditions, as summarized and described in sections 5.2 and 5.3.

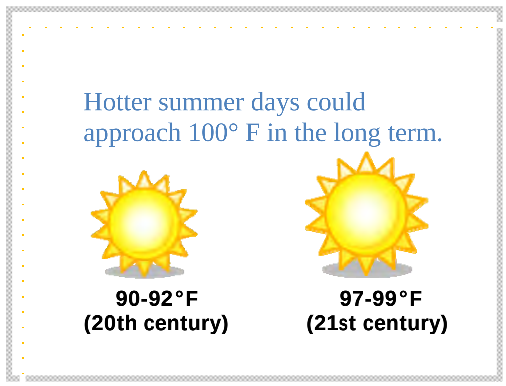
5.1.1 General climate change effects

Sea level (projected change through 2100):

- Conservative rise of 18-59 cm / 7-23 in. (IPCC, CIG)
- Accelerated rise of 55-125 cm / 22-49 in. (Rahmstorf, Pacific Institute)
- Increase in intensity and frequency of winter storm events/surges
- Increased/accelerated erosion, beach loss with sea level rise, storm events
- Increased salt water intrusion into coastal groundwater

Temperature:

- 1.5°- 4°C / 3°- 8°F increase by 2100 (IPCC, CIG)
- Heat stress on populations, species, facilities
- Increased pest/disease vectors
- Increased fire risk



Precipitation/Freshwater:

General regional effect
(balance of climate models, with large uncertainty)

- Slight increase in winter precipitation
- Decrease in summer precipitation

Rivers and streams

- Higher winter flows
- Lower summer flows

Mountains

- Decrease in snow-water equivalent (SWE), snowpack/glacial mass
- Upper elevation transition from snow-dominant to rain-dominant

Marine waters:

- Increased acidification (lower pH due to higher CO_2 absorption)
- Increasing changes in water chemistry and parameters (lower pH, higher temperature, etc.)

5.1.2 General Impacts

Natural systems/habitat/resources:

- Conversion of estuaries to tideflat/salt marsh
- Inundated marine habitat (shellfish, grasses)
- Stressed fishery habitat (lower flows, higher temps)
- Intrinsic nutrient changes
- Changes in species ranges/viability/distribution, migration of species
- Incursion of invasive species, pests/disease vectors
- Lower soil moisture, greater evapotranspiration, higher accumulation of fuel loads

Human systems/facilities:

- Reduced surface freshwater volume and availability in summer and early fall
- Inundation of low-lying/coastal facilities and structures
- Longer but drier growing season, increased drought conditions
- Increased heat stress on transportation systems, utilities
- Increased summer energy demand to counter heat effects, reduced winter demand
- Increased need for improvements to home cooling to counter effects of warmer summers

Human health:

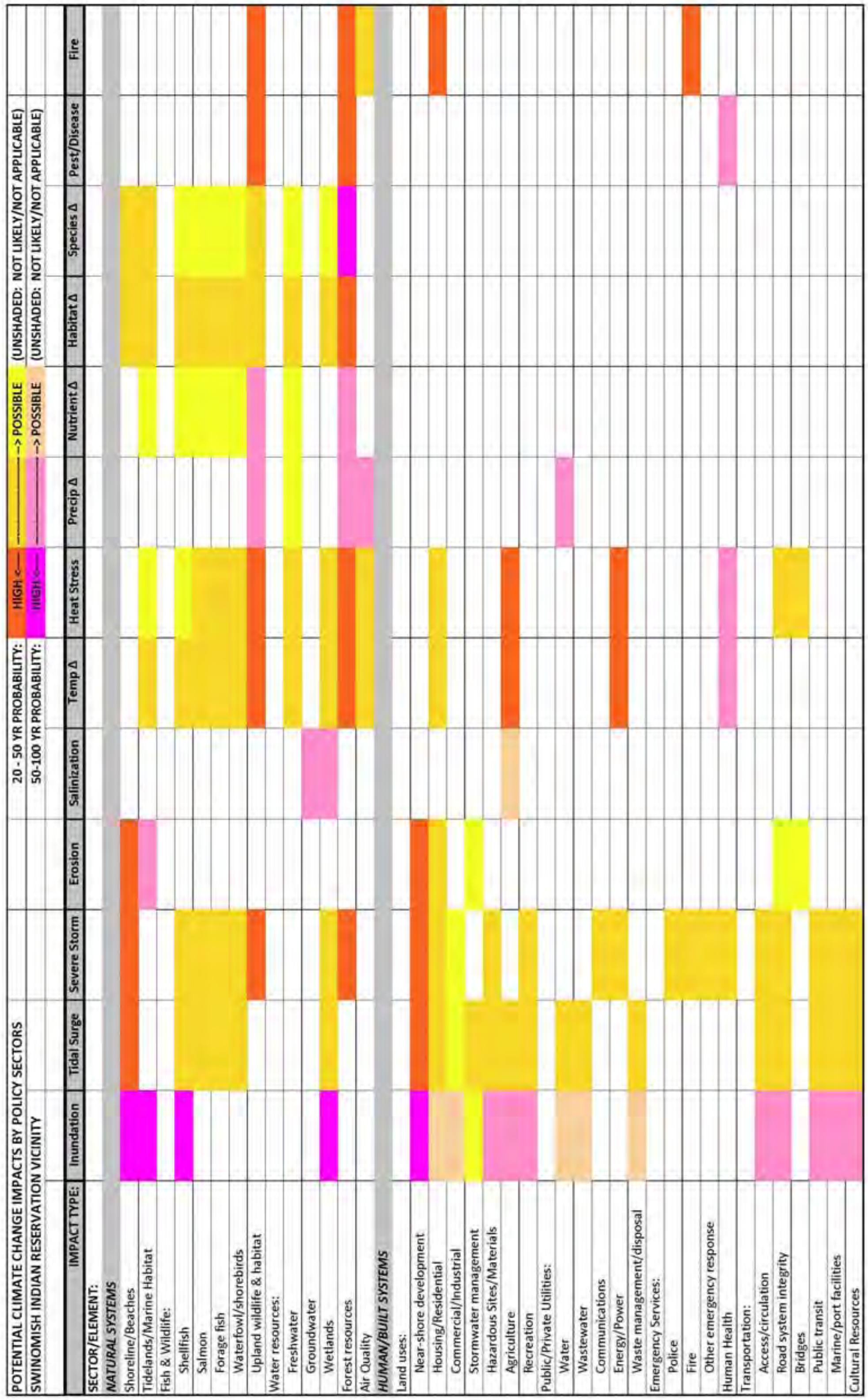
- Increased incidence of heat-related illness (exhaustion, heat stroke, etc.)
- Increased agitation/decreased functioning from prolonged heat exposure
- Increased incidence of respiratory ailments
- Opportunistic disease vectors

Cultural resources:

- Shrinking land base (sea level rise)
- Inundation of coastal sites/artifacts
- Exposure of burial sites and human remains from strong storm events
- Loss of cultural use plants
- Impacts within traditional use areas

5.1.3 Impact Assessment Matrix

As a precursor to assessment of impacts on the Reservation community, impacts as listed above were evaluated across a broad range of resources and sectors, as indicated in Table 5-1. Color shadings indicate the estimated probability of impact in the general timeframe of either 20-50 years or 50-100 years, as derived from projections in the evaluated models and data. Rather than simply listing each planning sector and itemizing selected anticipated impacts, the intent of the matrix is to provide for comprehensive sector-by-sector evaluation of all potential impacts, maximizing the opportunity to consider unanticipated risks.


POTENTIAL CLIMATE CHANGE IMPACTS BY POLICY SECTORS
SWINOMISH INDIAN RESERVATION VICINITY
20 - 50 YR PROBABILITY: HIGH <—— ——> POSSIBLE (UNSHADED: NOT LIKELY/NOT APPLICABLE)
50-100 YR PROBABILITY: HIGH <—— ——> POSSIBLE (UNSHADED: NOT LIKELY/NOT APPLICABLE)
IMPACT TYPE:
Inundation
Tidal Surge
Severe Storm
Erosion
Salinization
Temp Δ
Heat Stress
Precip Δ
Nutrient Δ
Habitat Δ
Species Δ
Pest/Disease
Fire
SECTOR/ELEMENT:
NATURAL SYSTEMS
Shoreline/Beaches
Tidelands/Marine Habitat
Fish & Wildlife:
Shellfish
Salmon
Forage fish
Waterfowl/shorebirds
Upland wildlife & habitat
Water resources:
Freshwater
Groundwater
Wetlands
Forest resources
Air Quality
HUMAN/BUILT SYSTEMS
Land uses:
Near-shore development
Housing/Residential
Commercial/Industrial
Stormwater management
Hazardous Sites/Materials
Agriculture
Recreation
Public/Private Utilities:
Water
Wastewater
Communications
Energy/Power
Waste management/disposal
Emergency Services:
Police
Fire
Other emergency response
Human Health
Transportation:
Access/circulation
Road system integrity
Bridges
Public transit
Marine/port facilities
Cultural Resources

5.1.4 Impact Assessment Tables

Based on the assessment evaluation matrix, a more detailed sector-by-sector analysis of impacts was performed to identify specific impact types, extent, approximate timeframes, and probability. This detailed assessment is summarized in Tables 5-2 and 5-3. More in-depth discussion of impacts summarized in the tables is contained in the following sections.

TABLE 5-2. SUMMARY OF POTENTIAL CLIMATE CHANGE IMPACTS, SWINOMISH RESERVATION VICINITY HUMAN/BUILT SYSTEMS

Sector	Element	Potential Impacts (Types)	Impact Extent	Estimated Timeframe	Probability/ Confidence
Land Use	Near-shore Development	Increasing tidal inundation from gradual sea level rise	Shoreline within 5 vertical feet of MHHW	Increasing to long-term	High/ High
		Increasing frequency and severity of storm/ tidal surges	Shoreline within 8 vertical feet of MHHW	Near-term potential	High/ High
		Beach erosion with increasing rise/surges	Shoreline within 8 vertical feet of MHHW	Increasing to long-term	High/ High
	Stormwater control	Inundation/backup of drainage lines and discharge points from higher tides, storm surges	Facilities within 8 vertical feet of MHHW	Near-term, increasing to long-term	Medium/ High
		Damage to discharge outfalls from bank erosion	Outfalls within 8 vertical feet of MHHW	Increasing to long-term	Medium/ High
	Hazardous Sites	Spread of contaminants through inundation/flooding from higher tides, storm surges	Sites within 8 vertical feet of MHHW	Near-term, increasing to long-term	Medium/ High
	Agriculture	Eventual inundation as increased high tides top dikes	Low-lying agricultural land (north end)	Increasing to long-term	High/ High
		Storm/tidal surges top out dikes	Low-lying agricultural land (north end)	Increasing to long-term	High/ High
		Increasing salinization from salt intrusion with rising sea levels	Low-lying agricultural land (north end)	Increasing to long-term	Medium/ Medium
	Housing/Residential	Increasing tidal inundation from gradual sea level rise and higher tides (where tides top dikes)	Units/buildable lots within 5 vertical feet of MHHW	Increasing to long-term	High/ High
		Storm/tidal surge flooding, gently sloping shoreline areas, or where surge tops bank/seawall/dikes	Units/lots within 8 vertical feet of MHHW	Near-term potential	Medium/ High
		Bank erosion, threatening near-bank structures	Lots with shoreline banks steeper than 3:1	Increasing to long-term	Medium/ High
		Increased risk of wildfire from increasingly drier conditions	Units within or near urban/forest interface	Near-term potential	High/ High

Sector	Element	Potential Impacts (Types)	Impact Extent	Estimated Timeframe	Probability/ Confidence
(Land Use, cont'd.)	Commercial/Industrial	Increasing tidal inundation from gradual sea level rise and higher tides (where tides top dikes)	Structures/lots within 5 vertical feet of MHHW	Increasing to long-term	High/ High
		Storm/tidal surge flooding, gently sloping shoreline areas, or where surge tops bank/seawall/dikes	Units/lots within 8 vertical feet of MHHW	Near-term potential	Medium/ High
		Bank erosion, threatening near-bank structures	Lots with shoreline banks steeper than 3:1	Increasing to long-term	Medium/ High
		Increased risk of wildfire from increasingly drier conditions	Structures within/near urban/forest interface	Near-term potential	High/ High
	Recreation	Increasing tidal inundation of public beaches/parks from gradual sea level rise and higher tides	Beaches/parks within 5 vertical feet of MHHW	Increasing to long-term	High/ High
		Storm/tidal surge flooding, gently sloping shoreline areas, or where surge tops bank/seawall/dikes	Beaches/parks within 8 vertical feet of MHHW	Near-term potential	Medium/ High
		Spread of contaminants through inundation/flooding from higher tides, storm surges	Sites within 8 vertical feet of MHHW	Near-term, increasing to long-term	Medium/ High
Public/Private Utilities	Water	Reduced summer supply from decreased source (river/ snowpack)	System-wide users	Increasing to long-term	Medium/ High
		Contamination of local supplies from inundation/flooding	Event-dependent	Increasing to long-term	Medium/ High
	Wastewater	Inundation of treatment facilities from higher tides, storm surges	Facilities within 8 vertical feet of OHWM	Increasing to long-term	Medium/ High
	Communications	Service disruption from severe storm events; duration of outage proportional to severity	Event-dependent, potentially area-wide	Near-term, increasing to long-term	Medium/ High
	Energy/Power	Service disruption from severe storm events; duration of outage proportional to severity	Event-dependent, potentially area-wide	Near-term, increasing to long-term	Medium/ High
		Increased summer demand to counter higher temperatures	System-wide users	Increasing to long-term	Medium/ High
	Waste Disposal	Spread of waste from local/loose containers during flooding from higher tides, storm surges	Sites within 8 vertical feet of MHHW	Near-term, increasing to long-term	Medium/ High

Sector	**Element**	**Potential Impacts (Types)**	**Impact Extent**	**Estimated Timeframe**	**Probability/ Confidence**
Emergency Services	Police	Increased demand for assistance/ emergency response during severe storm events, outages, flooding	Event-dependent, potentially area-wide	Near-term, increasing to long-term	Medium/ High
	Fire	Increased demand for assistance/ emergency response during severe storm events, outages, flooding	Event-dependent, potentially area-wide	Near-term, increasing to long-term	Medium/ High
	Other Emergency (disaster response, repair crews, etc.)	Increased demand for assistance/ emergency response during severe storm events, outages, flooding	Event-dependent, potentially area-wide	Near-term, increasing to long-term	Medium/ High
Human Health	Heat-related illness	Increased demand for and stress on services to treat heat-related health issues (heat exhaustion/stroke, etc.)	Area/event-dependent, potentially community-wide	Increasing to long-term	High/ High
	Disease vectors	New/increased disease vectors, and related outbreaks	Case/event-dependent, potentially community-wide	Increasing to long-term	Medium/ Medium
	Pollution-related illness	Increased pollution-related illness exacerbated by weather and climate conditions	Case/event-dependent, potentially community-wide	Increasing to long-term	Medium/ Medium
	Solar radiation issues	Increase in skin cancers from higher UV radiation levels[11]	Case-dependent	Decreasing to long-term	Medium/ Medium
	Respiratory disease	Increasing incidence of asthma, and allergen-related problems	Case/event-dependent	Increasing to long-term	Medium/ Medium
	Food-related illness from contaminated seafood	Increased incidence of poisoning from consuming toxin-laden seafood (PSP in shellfish, mercury in salmon)[12]	Case/event-dependent	Increasing to long-term	Medium/ Medium
Transportation	Access/Circulation	Inundation of access routes, travel disruption and isolation from mainland, as higher tides top dikes	Roads of 5 feet elevation or less	Increasing to long-term	High/ High
		Travel disruption/road closures due to stronger/more frequent storm/tidal surge events	Road sections of 8 feet elevation or less within shoreline vicinity	Near-term, increasing to long term	Medium/ High
		Incidental road closure/travel disruption from wildfire	Roads in heavily vegetated areas	Increasing to long-term	Medium/ High

[11] Not directly related to increased GHG but to reduction in atmospheric ozone; risk is stabilizing, expected to decline.
[12] Not exclusively related to climate change, but potentially exacerbated by it.

Sector	Element	Potential Impacts (Types)	Impact Extent	Estimated Timeframe	Probability/ Confidence
(Transportation, cont'd.)	Road System Integrity	Flooding damage from storm/tidal surge, buckling/cracking from higher temperatures	Roads within shoreline vicinity (surge), all roadways (heat)	Near-term, increasing to long term	Medium/ High
	Bridges	Erosion of bridge footings from higher tides/storm surges	Rainbow Bridge, SR20 Bridges	Increasing to long-term	Medium/ High
		Increased fatigue/deterioration of bridge joints from increased/ prolonged heat	Rainbow Bridge, SR20 Bridges	Increasing to long-term	Medium/ High
	Public Transit	Service disruption, impact-related closures	Routes serving the Reservation	Increasing to long-term	Medium/ High
	Marine transport facilities	Increasing inundation of marine facilities and ports from gradual sea level rise and higher tides	Shore-dependent facilities and structures	Increasing to long-term	High/ High
Cultural Resources & Traditions	Coastal sites/artifacts	Increasing inundation of sites from gradual sea level rise	Sites within 5 vertical feet of MHHW	Increasing to long-term	High/ High
	Burial sites/human remains	Disturbance/exposure from severe storm events	Sites within 8 vertical feet of MHHW	Near-term, increasing to long-term	Medium/ Medium
	Cultural use plants and animals	Loss/migration of traditional cultural use species	Site/species dependent	Increasing to long-term	Medium/ Medium
	Traditional use areas	Loss of treaty resources (e.g., fishing, hunting, gathering)	Site/resource dependent	Increasing to long-term	Medium/ High
	Shellfish harvesting	Potential loss of harvest sites and opportunities due to impacts to shellfish populations and habitat	All shellfish beds and habitat	Increasing to long-term	High/ High
	Beach seining	Potential loss of beach seining sites and opportunities	All current beach seine sites	Increasing to long-term	High/ High
	Marine facilities	Increasing impacts to dock facilities from rising sea level, impairing fishing activities	All dock facilities	Increasing to long-term	High/ High

TABLE 5-3. SUMMARY OF POTENTIAL CLIMATE CHANGE IMPACTS, SWINOMISH RESERVATION VICINITY NATURAL SYSTEMS

Sector	Element	Potential Impacts (Types)	Impact Extent	Estimated Timeframe	Probability/ Confidence
Shoreline/Beaches	(general)	Increasing tidal inundation from gradual sea level rise	Unprotected shoreline from MLLW to 5 feet above MHHW	Increasing to long-term	High/ High
	(general)	Increasing frequency and severity of storm/ tidal surges	Unprotected shoreline from MLLW to 8 feet above MHHW	Near-term potential	High/ High
	(general)	Beach erosion with increasing rise/surges	Shoreline within 8 vertical feet of MHHW	Increasing to long-term	High/ High
Tidelands/Marine Habitat	Habitat viability	Increasing inundation from sea level rise forcing gradual migration to maintain viability	Tideland habitat from MLLW to MHHW	Increasing to long-term	High/ High
	Estuarine beaches	Increasing inundation and loss from rising sea level	Estuarine beaches from MLLW to MHHW	Increasing to long-term	High/ High
Fish & Wildlife	Shellfish	Increasing inundation of shallows, estuaries	All populations	Increasing to long-term	High/ High
		Weakened viability due to habitat changes	All populations	Increasing to long-term	Medium/ Medium
	Fin Fish	Increasing inundation of shallows, estuaries	All populations	Increasing to long-term	High/ High
		Weakened viability due to habitat changes (temperature, acidification, etc.)	All populations	Increasing to long-term	Medium/ Medium
	Waterfowl/Shorebirds	Loss of forage opportunities and areas due to impacts on food sources	Marsh, wetland, and estuarine dependent species	Increasing to long-term	Medium/ Medium
	Upland wildlife/habitat	Degradation/conversion due to higher temperature and increased wildfire incidence	All populations	Increasing to long-term	Medium/ Medium
		Stressed viability from habitat and temperature changes, forced migration	All populations	Increasing to long-term	Medium/ Medium

Sector	Element	Potential Impacts (Types)	Impact Extent	Estimated Timeframe	Probability/ Confidence
Water Resources	Freshwater	Declining volume, consistency of instream flow	All streams/tributaries	Increasing to long-term	Medium/ High
	Groundwater	Increasing salinization from salt water intrusion	Where in proximity to salt water influence	Increasing to long-term	Medium/ High
	Wetlands	Increasing inundation from higher tides, storm surges	Wetlands within 8 vertical feet of MHHW	Increasing to long-term	High/ High
Forest Resources	(general)	Lower moisture content, increased fire risk	Stands with higher fuel loads, fuel ladders	Near-term, increasing to long-term	High/ High
		Heat stress, increase in drought-tolerant species (e.g., fir), decrease in drought-sensitive species (e.g., cedar)	Forest-wide	Increasing to long-term	Medium/ High
		Increasing pest infestations, disease vectors (bark beetles, fungus, etc.)	Forest-wide	Near-term, increasing to long-term	High/ High
Air Quality	(general)	Increasing stagnation, noxious elements/parameters due to higher average temperatures	Reservation-wide	Increasing to long-term	Medium/ Medium

5.1.5 Impacts on Specific Reservation Subareas

Projected impacts summarized in this section for Reservation subareas are primarily qualitative, and much depends on the rate of sea level rise and other factors effecting habitat conversion or transition to new conditions. Figure 5-1 illustrates subareas discussed below.

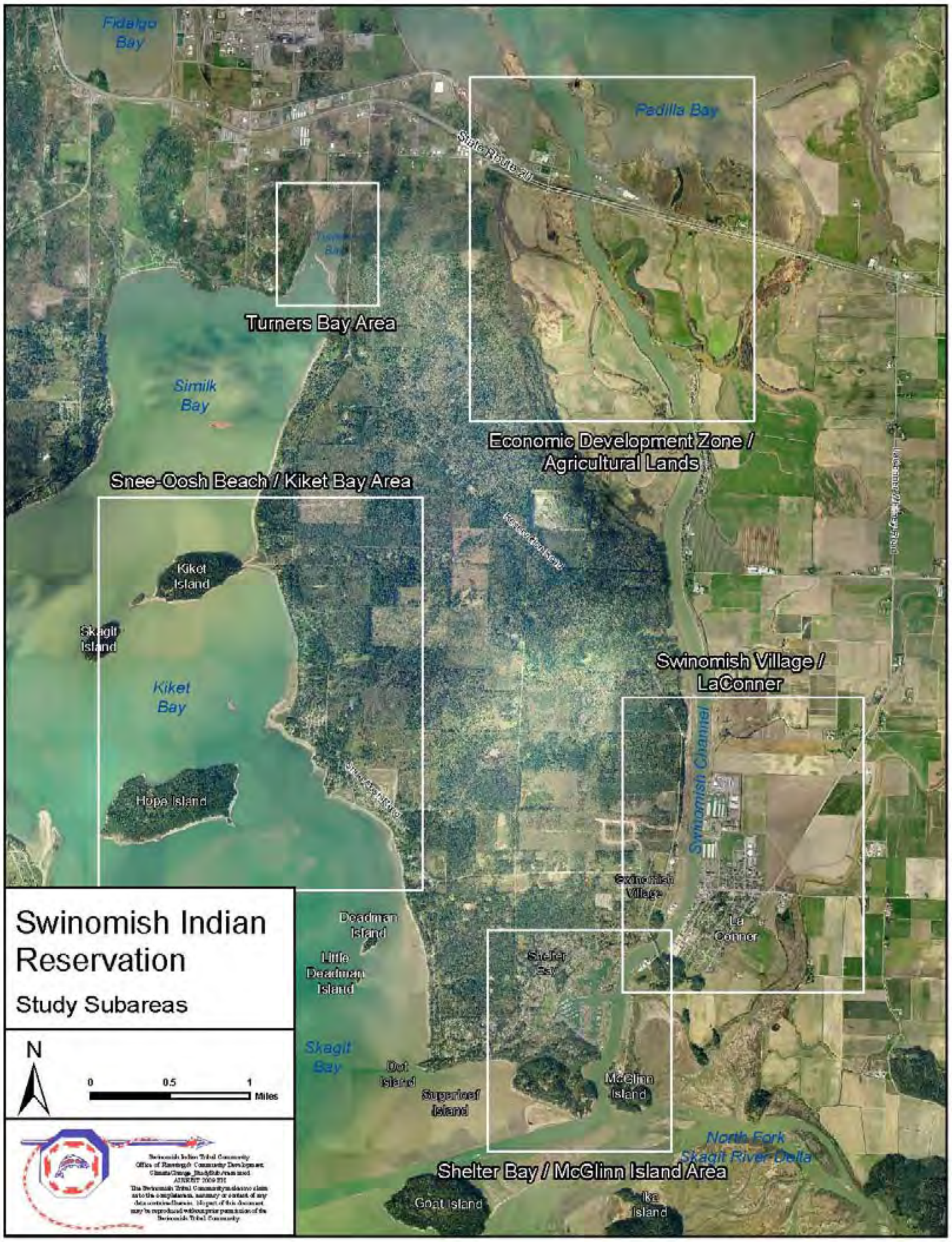


Figure 5-1. Study Sub-Areas, Swinomish Indian Reservation

a. Padilla Bay and North End of the Reservation.

The existing sand islands at the north end of the Reservation, in Padilla Bay, are important nesting habitat for shorebirds as well as an area for waterfowl hunting. Under all sea level rise scenarios, these islands will be inundated. As sea level rises, upland habitats will transition to tidal washed sand spits or possibly salt marsh. Some shorebird habitat may still be available moving from the beaches around the islands to the top of the islands, but the total nesting habitat will be greatly reduced.

The lagoon west of the Casino is currently estuarine marsh and tideflats. It may transition to salt marsh and possibly some tideflats with a commensurate loss of habitat productivity. This lagoon has current habitat value and is considered a priority for habitat restoration, assuming cleanup or protection from further contamination (see Hazardous Waste 5.3.1e) and increasing tidal exchange by opening up another breach in the railroad dike. However, study will be required to determine how sea level rise will impact this site long-term and what potential it has for restoration under such a scenario.

The Tribal economic development area north and south of the SR 20 is subject to tidal surge and potentially to inundation as higher tides begin to top existing dikes. Potential impacts to structures and other economic uses of this area are reviewed in more depth in sections 5.3.1, 6.1, and 6.2 of this report. Ultimate decisions on future land uses in this area will in turn determine other impacts. For example, to maintain the area as a Tribal Economic Zone, buildings would need to be raised and strengthened to survive storm events, and dikes would need to be raised or areas raised with fill, particularly south of SR 20. This would essentially "harden" the area for any future habitat use, and such protections would likely have only temporary usefulness. As discussed in section 6.2, however, the option to raise development areas south of SR20 with fill may not be available, due to complications with impacts of fill on existing major buried pipelines. If a determination is made to abandon the area in the future as the Tribe's key economic development zone and relocate such uses elsewhere, the area will have potential for restoration for various habitats depending on elevation and other factors. Intermediate planning may be done to determine the estimated safe lifetime of investments for economic development without substantial investment in protection, to allow some productive use of lands for some limited amount of time.

b. Swinomish Village and Swinomish Channel

On the Swinomish Village waterfront there are several Tribal buildings in the tidal surge zone, including the Planning Office, fishery management offices, and the fish processing plant. It may become necessary to raise and/or otherwise protect the fish processing plant and access to the Tribal fishing fleet docks, if they are to stay in this location adjacent to the water. Alternately, Tribal buildings could be relocated elsewhere within the Village away from the risk zone, although the high cost of doing so would require significant advance planning and investment.

On either side of the abandoned bridge abutment at the east end of Snee-Oosh Road, a pocket estuary restoration is planned. This will take up much of the waterfront area of the village itself and presages sea level rise in this area. Planning for this project should take long-term sea level rise into account and allow for inland migration of the habitat within the site.

A substantial length of shoreline along the Swinomish Channel is leased for log towing and storage operations. A strip along this shoreline will potentially be at increasing risk of inundation from sea level rise or subject to tidal surges. A somewhat wider section, nearly cutting the site in half, is subject to sea level rise and tidal surge. Along these areas, at the base of the bank, beaches and some wetlands will potentially be lost in narrow band running up the Channel. The wider inundation area may provide an opportunity for restored wetland habitat.

It should be noted that substantially more area is potentially subject to sea level rise and tidal surges off the Reservation across the Channel in La Conner and surrounding low-lying farmland areas. Potential inundation in the La Conner area could, if it were to top existing berms, impact all of lower La Conner, including an apartment building complex currently owned by the Tribe, as well as a key access point to the Reservation. Indeed, a strong storm/tidal surge in February, 2006, came within inches of topping the low berm in lower La Conner. Should such tidal surge flooding of lower La Conner occur in the future, the impacts would be significant not only for La Conner but also for the Tribe, as access to the Reservation could be cut off, and businesses, schools, and services in La Conner used by local residents could be impacted.

c. Shelter Bay

The marina portion of Shelter Bay and surrounding homes, along with community buildings, are potentially subject to storm and tidal surges. This area contains the greatest number of homes at risk on the Reservation, as well as storm drains affecting upland drainage. More specific information on impacted homes is presented in section 6.

Given the significant modification of the shoreline in the marina basin, sea level rise will have little real impact on habitat compared to other areas. On the other hand, the response to vulnerability of the homes around the marina could have more impacts. If a decision were made to retreat from areas at risk, some amount of area could be available for habitat restoration. With the substantial modifications and hardening of the area, this could be very expensive for any significant restoration. If, in order to protect homes, the area is raised or further hardened, there could be additional impacts on the environment and habitat. Much would depend on what options are pursued for this marina basin and surrounding homes.

Martha's Beach could eventually disappear, with most of the beach and backshore inundated. While estuarine beach habitat would be lost, it may be possible to reestablish it further upland along the base of the slope as the water rises, and an existing freshwater wetland could transition to a more brackish wetland. The existing wetland in Boathouse Cove would likely be inundated and possibly transition from an estuarine wetland to a salt marsh or similar habitat.

d. McGlinn Island

While the main headland of the island will remain above the rising sea level, much of the causeway connecting it to the mainland will be potentially inundated and the rest subject to tidal surges. Along the causeway itself this would not lead to much critical habitat loss, although it will create increasing problems with access to existing boat repair facilities on the south end of McGlinn Island. Dry sand dredge spoil uplands would be converted to tidal sand flats or estuarine habitat. This actually could happen on a portion of the causeway much sooner than projected, as a project is proposed to remove a portion of the causeway and create a pocket estuary restoration. The second phase of the proposed project, somewhat more speculative, would completely breach the causeway, allowing out-migrating salmon smolts to travel from the North Fork of the Skagit into the Swinomish Channel and up to Padilla Bay, increasing juvenile survival rate.

Breaching the causeway will, sooner or later, lead to transition of the freshwater tidal marsh of Dunlap Bay to be converted to a more saline system of transitional marsh or possibly estuarine tidal marsh. The riparian forest along the east side of the causeway would also be lost in a more saline environment.

Beaches around the main portion of McGlinn Island would likely be lost with sea level rise squeezing them out at the bottom of rocky cliffs. The jetty connecting McGlinn Island to Goat Island, and separating the Skagit River from the Swinomish Channel, would eventually be inundated allowing a more direct fish passage and freshwater inputs to the Channel. The outcome of this related to fish survival is unknown as the studies done to date have been on a static system, and did not include the effects of sea level rise and changes in water quality, salinity and acidity.

e. Snee-Oosh to Kiket

The Snee-Oosh Beach area is identified as a sensitive area for both sand lance and surf smelt spawning. Behind these beaches on the southern part is a flat graveled parking area for beach users on allotment land. The middle section abuts a rip-rap barrier protecting a section of county road with homes beyond that, and the rip-rap continues north, protecting a freshwater wetland as well as community lawn and tennis courts. Due to aspect and fetch, Snee-Oosh beach is also is a prime example of an area highly susceptible to potential future storm surge impacts. A storm event at high tide in February of 2006 drove waves and debris such as large logs over the county roadway and into the yards of a number of homes. Absent protective measures, a similar event starting from a higher future sea level could damage or destroy numerous homes, damage the road, and overtop the rip-rap dike, adding surges of saline water to the freshwater wetland (and eventual inundation and conversion to transitional or brackish wetland) and resulting in loss of a critical forage fish spawning beach.

The Thousand Trails Campground encompasses several areas of potential impact. The southern portion is low and subject to inundation from sea level rise and tidal surge. This area includes several rental cabins and other facilities as well as a partially filled freshwater wetland. Lone Tree creek, lagoon and spit would be impacted by sea level rise with much of the spit eventually inundated. The lagoon would become more saline, and inundation and surges would work part-way up the recently restored creek. These changes would affect juvenile salmon use of the lagoon and lower creek. The spit is also the site of a traditional tribal beach seine fishery. Whether this culturally and economically important activity could continue in the future may depend on the level and rapidity of sea level rise relative to accretion of the spit as well as the extent the activity can be adapted to higher water levels on the spit. Major tribal shellfish harvest areas could also be affected, unless the beds are able to migrate up onto the spit as sea level rise occurs. Existing beds will be accessible only at lower tides and some may not be accessible for harvest at all.

Kiket Bay is heavily armored along the bank, and with sea level rise it is likely to lose most of its beach habitat. Kiket Island is largely undeveloped and is surrounded by prime shellfish beds as well as other beach habitat. The tombolo[13] connecting the island with the main part of the Reservation is subject to storm surge and eventual inundation. This could result in migration of beach habitat up onto the tombolo preserving some of that habitat for the area. Kiket lagoon and estuarine marsh would likely become more saline, but a current grassy lawn area to the north has potential for conversion to higher marsh. Kiket Island uplands are being considered for a State Park.

[13] Tombolo: a narrow piece of land such as a spit or bar that attaches an island to the mainland

f. Turner's Bay

Turner's Bay is a natural pocket estuary with a sand spit nearly closing it off and a small freshwater stream entering the head of the bay from outside the Reservation regulatory boundaries. Turner's Bay spit will eventually be inundated by sea level rise. The current beach on the outside of the spit, a surf smelt spawning area as well as major shellfish harvest bed, might have room to migrate up onto the spit if sea level rise is not too rapid. The bay behind the spit, a critical pocket estuary, will generally become more saline with conversion of estuarine marsh to transitional marsh or salt marsh depending on elevation and depth of sea level rise. Estuarine marsh or swamp may remain in a narrow ring around the bay. At the head of the bay, higher ground may become estuarine marsh, thus replacing some lost estuarine march. This could occur with the proposed removal of Similk Bay Road, a county road and tide gate blocking the head of the bay from a mainly freshwater marsh just beyond the Reservation regulatory boundaries.

Increasing inundation and potential tidal surges also threaten another key point of access to the Reservation, where a low point on Reservation Road is adjacent to the north end of Turner's Bay. As almost occurred during the February 2006 event, flooding of this roadway would cut off access to the Reservation from the north; combined with concurrent flooding of access in La Conner, the Reservation could be entirely isolated from the mainland.

5.2 Natural Systems

5.2.1 Shorelines and Beaches

The primary impacts to shoreline resources will be from sea level rise and associated impacts of inundation, storm and tidal surge and shoreline erosion. This is true for impacts to natural systems and habitats as well as the human and built environment in the shoreline zone.

The potential inundation zones differ slightly from the regulatory shoreline zone as defined in the Swinomish Shorelines and Sensitive Areas (SSA) ordinance. The regulatory shoreline zone extends from extreme low water to 200 feet inland of the Ordinary High Water Mark (OHWM). This includes area between the Mean Lower Low Water Mark (MLLW, below which areas are generally inundated) and the Mean Higher High Water Mark (MHHW, above which areas are rarely inundated).

Potential sea level rise inundation zones and tidal surge zones were mapped for the Swinomish Indian Reservation, based on analysis of existing tidal data and projected range and probability of sea level rise, as shown in Figure 6-1 and Appendix 7. These maps indicate the potential shift in MLLW and MHHW through approximately 2100, and by inference the areas in which assets and resources may potentially be at risk from sea level rise and/or tidal surge.

As sea level rises, impacts occur in several ways:

- Areas between the current MLLW and MHHW shift from shallow habitat to deeper habitat conditions, and from occasional inundation to more frequent inundation;
- New areas become permanently inundated below the rising MLLW mark;
- Areas further inland not previously subject to inundation become periodically inundated from higher tides or from storm surges above the rising MHHW mark. With sea level rise those impacts begin from a higher base and create a risk to resources and structures higher above the current MHHW.

5.2.2 Tidelands and Marine Habitat

a. Habitat Viability and Migration

To continue to be viable, habitats within specific levels and frequencies of inundation will need to be reestablished higher up or migrate shoreward as the sea level rises. Those that can migrate or reestablish at a rate quickly enough to keep pace with sea level rise will survive, but they will require a place to migrate to without being blocked by steep banks, bulkheads, or other barriers. Bulkheads, rip-rap, and other types of shoreline armoring will make successful habitat migration difficult if not impossible. According to other Puget Sound studies, there will be losses of certain types of habitat and gains in others. In the general region of Padilla Bay, Skagit Bay, and Port Susan Bay, some of the key losses estimated by 2100 for projected sea level rise of 59 inches (NWF 2007, highest estimate) include the following:

- 87% loss of tidal freshwater marsh;
- 99% loss of estuarine beach; and
- 97% loss of brackish marsh.

General marine habitat types and associated tidal influence are illustrated in Figure 5-2.

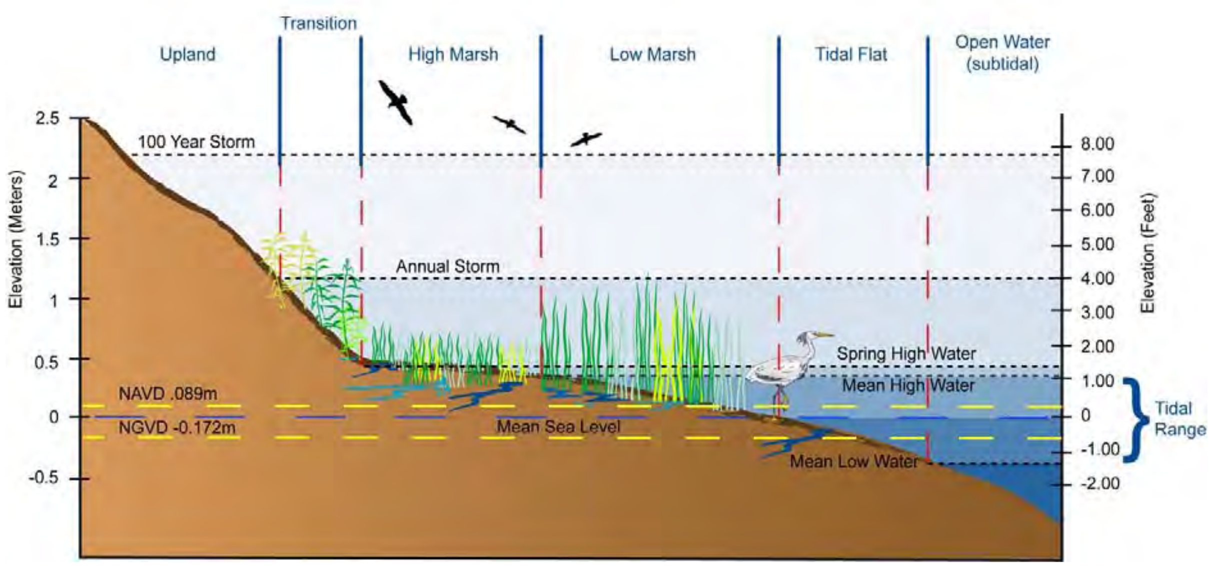


Figure 5-2. General marine habitat types and associated tidal influence.
(Source: http://maps.risingsea.net/wetland_loss/tides_wetlands_elevation.jpg)

Habitat losses in the Skagit River Delta will include loss of shrub-scrub marsh, riverine tidal scrub marsh and riverine tidal forest. Gains will include estuarine emergent marsh. (Hood, 2008). Comparing these studies with conditions on the Reservation yields similar projections where the habitats in question are similar. The Reservation will lose the outer edges of existing tidal flats as waters grow deeper, but some tidal mudflats and similar habitat will likely form shoreward of the existing areas where not blocked from doing so. Steeper banks along Similk Bay, Skagit Bay, Martha's Bay, and the Swinomish Channel, combined with shoreline armoring where it exists near upland development, will at some point limit migration of habitat. An accurate estimate of habitat gains and losses requires a more detailed analysis of the Reservation nearshore habitats. However, some rough estimates are possible in this analysis.

Eelgrass beds are of critical importance to herring spawning, juvenile salmon use and other marine species. Modeling simulations indicate a possible net increase in eelgrass beds in Padilla Bay as the habitat moves from the center of the bay shoreward with sea level rise (Kairas and Rybczk 2009). There may be similar losses of eelgrass on the outer edges of Reservation waters from sea level rise, but there appears to be room to shift shoreward in some areas. Greater impacts to this habitat may occur from other factors such as increases in water temperature, changes in water quality, or impacts from shoreline armoring and other development. If increases in armoring to protect shoreline properties from sea level rise are allowed, the impact on nearshore habitats such as eelgrass, especially as they migrate shoreward, could be significant.

b. Estuarine Beaches

One type of habitat most at risk is estuarine beaches, which may experience up to a 99% loss in the area under projected sea level rise of 59 inches (NWF, 2007). These areas, sandy and gravel beaches in the middle to upper tidal ranges, provide not only recreational and aesthetic uses but also critical areas for forage fish spawning habitat. Surf smelt and sand lance spawn on such beaches and provide much of the food for salmon and other species, including shorebirds. These beaches are considered a key component to maintaining a productive food web in the Puget Sound ecosystem. In general, estuarine beaches are in a relatively narrow band along the Reservation shoreline and are often at the base of steep slopes or are bordered by upland development, including bank protection structures such as rip-rap and bulkheads which would prevent their inland migration.

Where steep bluffs or easily eroded feeder bluffs exist above such beaches and are not protected by bulkheads or similar structures, it is possible that the erosion from the bluffs and contribution of sediments will allow a narrow strip of beach to be maintained. That depends, however, on a number of physical factors and processes and their relative speed of occurrence with climate change and sea level rise. Where beaches are backed by dikes, bulkheads, and other structures they will likely be lost, with lower tidal habitats extending up to the base of many such bulkheads.

5.2.3 Fish and Wildlife

a. Salmon

There are a number of potential impacts to salmon, including changes in conditions at sea, increased water temperature, loss of spawning and rearing habitat from decreased summer stream flows, and increased sedimentation and/or scouring during high winter and storm flows. Declining, warmer dry season streamflows will place additional stress on viability of stream habitat. Heavy runoff from more frequent intense storm events may cause greater sedimentation of stream and drainage channels or scour beds, adversely impacting fish passage, production, and survival. Fish may also become stranded during flooding or inundation events, further affecting their survival. Detailed assessment of these impacts is beyond the scope of this report and will require separate analysis, but intertidal and estuarine habitat loss from sea level rise will certainly be a factor. Loss of estuarine wetlands and other wetland types such as tidal swamp and brackish marsh will affect juvenile salmon survival. Juvenile Chinook may be especially affected due to extensive use of these habitats for rearing and migration. Reduction in forage fish populations will reduce food abundance and availability for salmon.

b. Forage Fish

Sand lance and surf smelt spawn in the upper half of the inundation zone on sand and gravel beaches with the right grain sizes. With the loss of estuarine beaches these species will be especially impacted. These forage fish provide a critical component of the food chain for adult salmon, shorebirds, and other species. Figure 5-3 illustrates general habitat areas for these species.

c. Shellfish

For shellfish, the projections of future climate change impacts on their life cycles and habitat are troubling. Factors such as water temperature and water quality, including potential acidification of marine waters, will be critical to future shellfish health. Shellfish may be vulnerable to diseases which become more prevalent as water temperatures rise. Impacts of this are believed to be involved in recent major mortality of young bivalves, known as spat (Cheney and Dewey 2009).

Increasing acidification of the ocean is already cited by some scientists as a possible factor in the decline of shellfish populations along the Pacific coast since 2002, some of which have declined by up to 80%.[14] Increased CO_2 concentrations in marine waters create conditions that contribute to lower pH levels, resulting in increased acidification. Populations most at risk are those with calcium carbonate shells, such as oysters and clams, since increasing acidification disrupts shell formation (Guinotte and Fabry, 2008). Should the pH level of local marine waters decline, local shellfish populations could likewise be at risk. Water quality sampling of marine waters by the Tribe during the 2008 tribal canoe journey (Appendix 5) indicated varying pH levels at different locations, but there is not yet sufficient data or analysis from which to draw conclusions.

Shellfish may also be impacted depending on whether or not habitat areas and water depth can be maintained by migrating landward as the sea rises. As indicated above, steeper bluffs adjacent to some areas containing shellfish beds will limit the ability to migrate, such as along Similk Bay. Tribal members have a long history of harvesting shellfish in beds on and adjacent to the Reservation. Access to these and other shellfish beds harvested by the Tribe may become more restricted as existing beds become situated in deeper water and eventually less accessible even at low tide. Crab populations may additionally be impacted by the loss of estuarine wetland habitat that serves as critical nurseries. Ultimately, the combination of the above impacts may be such that viability of shellfish populations, as well as the long tradition of shellfish harvesting by Tribal members, could be in jeopardy. Figure 5-3 illustrates general location of shellfish beds in the vicinity of the Reservation.

d. Shorebirds

Shorebirds will be impacted to some degree by loss of beaches and some tidal flats where they commonly forage. An important component of their food is the eggs of forage fish which will be heavily impacted from the loss of estuarine beaches.

---

[14] Welch C. (2009) "Oysters in deep trouble: Is Pacific Ocean's chemistry killing sea life?" Seattle Times, June 15, 2009.

e. Waterfowl

Impacts from loss of marshes and other wetland habitat types may be especially significant on the large wintering populations of waterfowl in the region. Impact on individual species may vary, as some are more dependent on fresh and estuarine habitats, others on tidelands. Diving ducks may be especially at risk, including canvasbacks, scaups, goldeneyes, and bufflehead. Figure 5-3 illustrates general waterfowl areas in the vicinity of the Reservation.

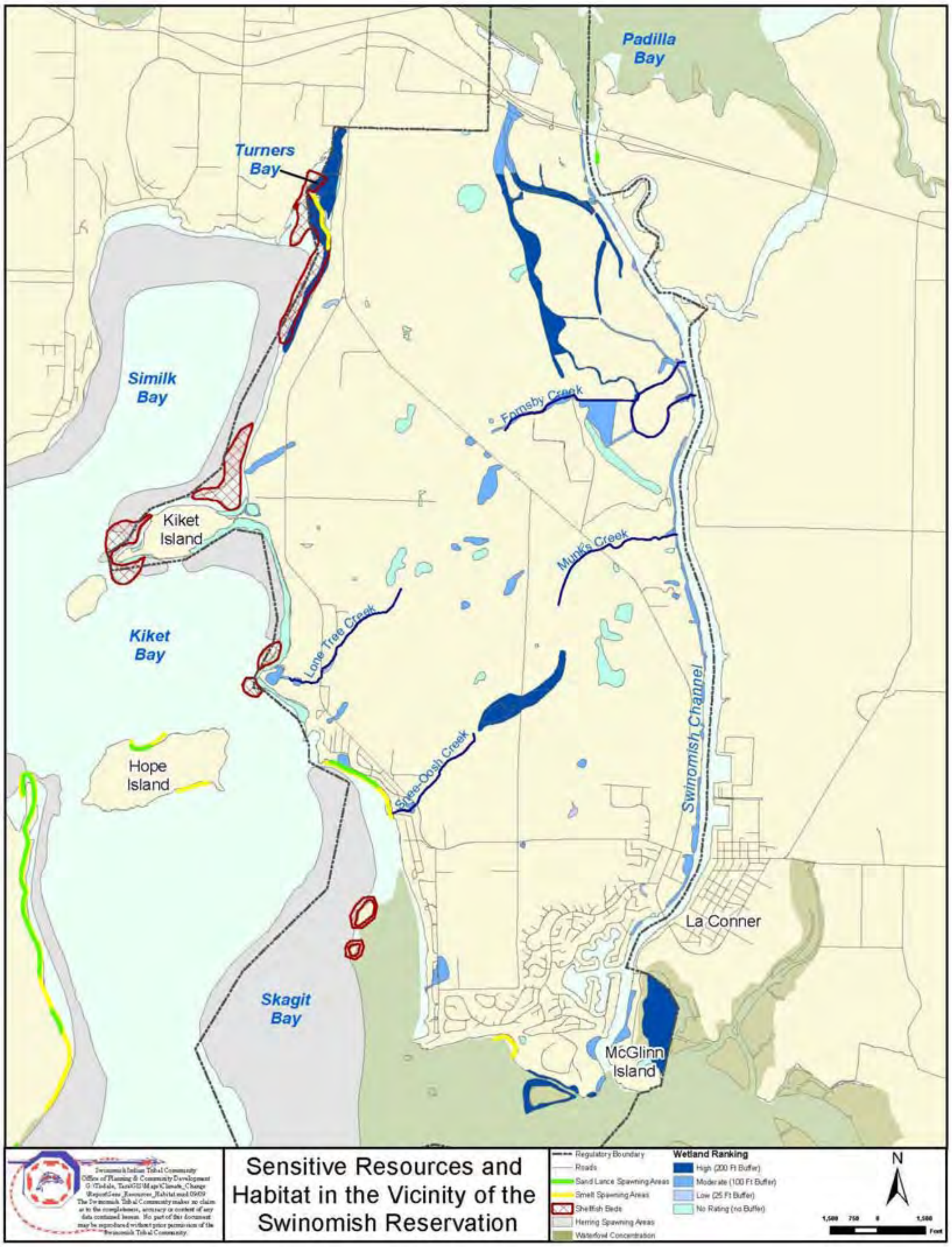


Figure 5-3. Sensitive Resources and Habitat within the Swinomish Indian Reservation.

f. Upland Wildlife

Impacts to upland species from climate change are expected to be related to changes in precipitation patterns, frequency of wildfires, changes in food sources and habitat, and other factors affecting viability. Although the Tribe has begun assessment of upland habitat in recent years, updated information on habitat characteristics and species is not yet available and determination of impacts rests largely on survey of archival records.

Representative upland bird species include hawks, falcons, and eagles. Bald Eagles and Peregrine Falcons roost and nest on the northern upland area and on Deadman and Ika Islands, among other Reservation areas. Other upland birds include owls, woodpeckers, swifts, perching birds, and pigeons. The shorelines and nearshore areas of the reservation provide habitat for a variety of marine birds, herons, waterfowl, and shorebirds as discussed elsewhere in this report. The Reservation lies close to the path of the Pacific Flyway, which hosts migrations of approximately 100,000 waterfowl annually. This includes dozens of species, including the Black brant, which gather by the tens of thousands in April to prepare for their northward migration. Among the species that nest on or near the Reservation is the Great Blue Heron, with rookeries of various sizes at given locations in the Reservation vicinity. Terrestrial mammals observed on the Reservation include black-tailed deer, bobcat, cougar, coyote, red fox, rabbit, raccoon, porcupine, bats, shrews, and numerous other small mammals.

5.2.4 Water Resources

a. Freshwater

Projections of climate change impacts on precipitation patterns and trends are complex and varied and contain a large degree of uncertainty, left unresolved by seasonal variations, natural variability in weather cycles, and other factors. On average, climate models project an overall long-term trend toward higher winter flows and lower summer flows, as well as a potential increase in intensity of isolated peak winter storm events, although it is difficult to predict precisely the net difference from current conditions.

Based on the general consensus of projections, though, it can be anticipated that increases in winter temperatures and the intensity of precipitation events may produce more runoff during winter months, and potentially more flooding. The general trend toward higher winter temperatures may reduce average snowpack accumulation, especially in drainages transitioning from snow dominant to rain dominant characteristics (WA DOE 2006, CIG 2009). During summer, the anticipated trend is toward decreasing and precipitation, with potentially heightened and/or prolonged periods of drought or reduced precipitation. The projected general decrease in precipitation during summer can be expected to reduce associated summertime runoff, causing reductions in in-stream flows and increases in summertime stream temperatures. Regional data indicates a trend toward declining northwest river flows during summer over the last several decades (WA DOE, 2006); relation of this decline to either climate change or natural variability is uncertain, however. For the four streams located on the Reservation (Figure 5-3), this may mean a long-term trend toward lower and potentially more intermittent flows in the summertime.

Implications of possible reduced summer flows for rivers that currently provide freshwater sources for public water supply are discussed under section 5.3.3. On-Reservation public water supplies are acquired from the City of Anacortes, which appropriates water from the Skagit River; if flows for the Skagit River follow the overall trend toward declining summer flows, availability and allocation of such reduced flows will no doubt become increasingly critical, when demand for surface water and ecosystems needs are at their seasonal peak.

b. Groundwater

Groundwater resources within the Swinomish Reservation are generally characterized by underlying aquifers which are presumed to have some degree of connectivity to or influence from adjacent marine waters around the perimeter. Studies of Reservation groundwater characteristics are ongoing, but some evidence exists of salt water intrusion in wells near shoreline areas. Such intrusion may be expected to increase as marine water levels rise, increasing the potential for increased influence on upland water supply wells.

While the Tribe, through the Swinomish Utility Authority, currently purchases much of its public water supply from the City of Anacortes, which appropriates water from the Skagit River, Tribally-owned Reservation wells are an important component of the Tribe's Water Supply Plan. To the extent that salt water intrusion increasingly impacts wells within the Reservation and/or availability of off-Reservation water supply is reduced due to declining river flow, reliance and pressure on Reservation groundwater supplies may be expected to increase. This may ultimately result in increased demand on a diminished resource, creating additional potential impacts on groundwater through added drawdown.

Conversely, increased salt water intrusion could potentially increase demand for connection to the Tribal public water system supplied primarily by the City of Anacortes, if such connections are feasible and able to be supplied through existing capacity. To the extent that increased connection to the public water supply reduces demand on groundwater supply, impacts from additional or excessive drawdown would be reduced accordingly.

An additional complicating factor in the above scenarios would be reduced recharge to aquifers within the Reservation. Should overall precipitation and/or hydrologically connected surface flows decline, aquifers would be deprived of needed recharge, further constraining this limited resource.

c. Wetlands

Wetlands of various types will be impacted and need to transition or migrate. In general, freshwater tidal marshes and brackish marshes will be subject to greater inundation, and occasional storm surges may introduce greater salinity into the systems. These estuarine marshes are especially productive, with great importance as nursery areas for a sea life, from juvenile salmon to crabs and a host of other species. Salt marshes and transitional marshes may increase in area at the expense of estuarine marshes, especially where shoreward migration is blocked by armoring.

Upland wetlands with connectivity to freshwater or groundwater sources will likely experience impacts similar to those sources; if quantity or supply declines, associated wetlands can be expected to decline, and if quality is changed or impacted, whether through salinity or other factors, wetlands may undergo transition commensurate to the changes in quality. Such impacts would have associated ramifications for any wetlands-dependent species of flora or fauna. Figure 5-3 illustrates wetlands identified within the Reservation.

5.2.5 Forest Resources

There are approximately 4,700 acres of forested land within the Swinomish Reservation, including areas designated as Forestry and forested areas within the Rural Residential zone. A review of the impact assessment matrix reveals that forested areas are projected to incur a number of probable and potentially significant impacts, some sooner than others. Impacts identified in section 5.1 that would affect forests include the following:

a. Urban/Forest Interface

Forested areas cover the majority of Reservation uplands, while developed areas primarily lie within southeastern, southern, and west shore areas, although some scattered pockets of homes and homesites exist in interior uplands. While the coastal climate of the Reservation may not generally be as conducive to wildfire as drier climate zones, with few wildfires in the Reservation in past years, wildfire poses a potential future risk to those who live or work adjacent to the forest. As for the forest habitat, fires are a natural part of the ecosystem turnover process. However, fires in the Swinomish forests are expected to increase as drier, warmer summers lead to lower soil moisture and greater evapotranspiration. When these summer conditions are combined with wetter, warmer winters, which could promote greater tree growth and fuel load accumulation, forests may become primed for larger and potentially more intense wildfires (Littell and McKenzie 2009). While the entire Reservation could be considered at risk of wildfire due to the extent of forestation, the urban/forest interface zones are considered to be at greatest risk due to the number and proximity of structures and greater potential for human-caused ignition. For the purpose of risk evaluation and response strategy implementation, therefore, these areas were designated primary wildfire risk zones. Figure 6-4 in Section 6 identifies the wildfire risk zone throughout the Reservation. The zone includes areas with a variety of residential densities, including urban and rural densities where the mix with forest stands was deemed significant.

Large, destructive wildfires in the early part of the 20th century prompted changes in forest management and fire suppression practices that in recent decades significantly reduced the number and size of wildfires. In spite of this, however, the National Interagency Fire Center (NIFC) reports that since about 1999 the size and frequency of wildfires increased dramatically; from 1960 through 1998 an average of 3 million acres burned annually nationwide, whereas since 1999 that average has increased to almost 7 million acres annually, with the last three years each averaging approximately 9 million acres.[15] While these same fire suppression activities have been cited as one possible reason for this, the documented increase in average temperatures during this time and associated decrease in forest moisture content, combined with past management practices, create ideal conditions and potential for highly destructive wildfire. Coupled with the spread of development into forested areas, the result in numerous cases has been destruction of hundreds of homes and structures and hundreds of thousands of acres burned.[16] The trend back toward large, destructive wildfires signals a growing threat for communities in or near forested areas, and the impact of such fires has been disastrous not only to property owners but also to the

[15] NIFC fire statistics, 2008, http://www.nifc.org/fire_main/fire_statistics.html.
[16] NIFC, 2008. Significant fires by year and state during the past ten years include (K=1,000's of acres): 1998, FL, 200K; 1999, NV, 288K; 2002, CO, 136K & 600 structures lost; 2002, AZ, 467K & 462 structures lost; 2002, OR, 500K; 2003, CA, 275K & 2400 structures lost; 2004, AK, 6.4 million acres (1.3 million in one complex); 2005, AZ, 248K; 2006, TX, 907K & 80 structures lost; 2007, GA, 388K; 2007, ID, 652K; 2008, CA, 1000 structures lost.

ability of forests to recover. Even fire-resistant species such as ponderosa pine have suffered total destruction, and in many cases the forest floor is virtually stripped of all nutrient material required for regeneration.

The advent of proactive efforts such as the Firewise Program has helped to reduce the threat of wildfire to participating owners and communities. Although even the best proactive efforts can be overwhelmed in a large fire event, such programs have proven to be useful and effective. The largest residential area within the Reservation, Shelter Bay Community, a development of approximately 900 homes, became a Firewise Community in 2006 after developing a plan with action items such as clearing excess fuel from its greenbelts and educating residents. The Firewise Communities approach emphasizes community responsibility for planning in the design of a safe community as well as effective emergency response, and individual responsibility for safer home construction and design, landscaping, and maintenance. The national Firewise Communities program is intended to serve as a resource for agencies, tribes, organizations, fire departments, and communities across the U.S. who are working toward a common goal: reduce loss of lives, property, and resources to wildland fire by building and maintaining communities in a way that is compatible with natural surroundings.

b. Forest Species

As average temperatures become warmer and precipitation patterns change, drought-susceptible species such as western red cedar may become less viable, and drought-tolerant species such as Douglas fir may become more dominant. Western red cedar is a culturally important species, having been used in many ways by tribes for centuries. In addition, understory and ground vegetation species may experience similar changes in response to higher temperatures and lower overall moisture content, and losses of these forest plants will likely include other culturally important species. The mix of such species is varied throughout forested areas, and given varying soil and moisture conditions, along with varying microclimate conditions, the type and rate of transition will not likely be the same throughout the Reservation, although the overall trend will be toward transition to drought-tolerant species. Transition away from cedar and other culturally important native plants would represent a significant loss for traditional uses carried on by tribal members.

c. Forest Insects and Diseases

Over the past decade, warmer temperatures persisting for longer periods annually have elevated the susceptibility of conifers to mountain pine beetle outbreaks (Littell et al 2009). Projections of future higher average annual temperatures will increasingly create conditions for enhancing the viability of forest insects and disease vectors, such as the mountain pine beetle, spruce budworm, and various forms of fungi. Generally warmer, drier summers increase water stress in trees, lowering their resistance to infestation. While most infestations are usually found in drier climate forests, such as east of the Cascade crest, the potential for outbreaks in west slope conifer and hardwood forests cannot be discounted. Likewise, certain fungi and arboreal diseases that would not normally thrive in slightly colder climatic conditions are now beginning to emerge with greater vigor. Combined with impacts from wildfire, the cumulative synergistic effects on forest species could potentially be much greater and may cause wide devastation, as seen in some areas of the northwest and the continent. Cumulative impacts from insects, disease, and fire may lead to "disease decline syndrome" in which large forested areas may suffer, even where individual trees may be initially healthy.

5.2.6 Air Quality

a. Effects of increasing temperature on the physical properties of air quality

Results of studies and modeling indicate that climate change will negatively impact air quality on the Swinomish Reservation based on several factors. The Reservation is down wind from the March's and Cherry Points Industrial areas. It also appears that the new Sierra Pacific Lumber mill wood boiler may be in part responsible for the high nitrogen dioxide (NO_2) that have been measured on the Swinomish Reservation. If NO_2 concentrations remain at their current levels or increase, this region will be in non-attainment with the EPA proposed new NO_2 standard (80 to 100 ppb 8-hour average). Ozone, a regional air pollutant, has also been trending upwards, periodically exceeding national standards. The trends indicate that the area could be in non-attainment for ozone as well as NOx. The reservation will likely be exposed to higher levels of air toxics as well from the four refineries to the north of the Reservation

b. Ozone

Ozone also will likely increase in the future due to temperature increases. The highest ozone episodes generally occur during late spring and summer months on the warmest sunny days. One of the reasons is increased biogenic[17] emissions on hot days. Natural sources of volatile organic compounds (VOC), such as coniferous forests, produce more on hot days. The rate of ozone synthesis from its precursors increases with increasing temperature (Zeng et al 2008). So, with hotter temperatures both more VOCs are produced and the rate of ozone synthesis from them is increased.

c. Effects of increasing temperature on the chemical properties of air quality

Air pollutants are deposited on the earth's surface in two forms: dry and wet. In the future, it is expected that dry deposition will increase due to the lack of precipitation. Gaseous pollutants will not get washed out close to the source and may have more impacts farther away from sources such as the March's Point industrial area. Wet deposition will decrease with increasing temperature. The number of precipitation events in the future is likely to decline. However, when precipitation events do occur, they will probably have relatively higher ionic (acidic) concentration due to less frequent opportunities to be diluted by heavy rains. Increased winter temperatures may result in an increased frequency of temperature inversions that cause ground level fog (Iacobellis, S.F and others 2009). Fog is up to forty times more acidic than water. Extremely high ammonium and sulfate concentrations were found in a 2003 fog water deposition study on the Reservation. The effects of acidic deposition can influence human health through several methods. Toxic metals can be released to the environment through acidification of soils, and end up in drinking water, crops, fish and eventual ingested by humans. Increased concentrations of sulfur dioxide and oxides of nitrogen have been correlated to increased hospital admissions for respiratory illness.

d. Respiratory disease

The relatively high NO_2 and ozone have shown to adversely impact sensitive asthmatics, and may in part be responsible for the high prevalence of asthma on the Reservation. These impacts may be exacerbated with higher temperatures and climate change.

---

[17] A **biogenic substance** is a substance produced by life processes. It may be either constituents or secretions of plants or animals.

5.3 Human Systems

5.3.1 Land Uses

a. Housing/Residential Development

Much of the residential housing and buildable platted lots within the Reservation are in upland and shoreline areas in the southeast, south, and west shore perimeter. A significant number of properties are subject to one or more potential impacts, as identified below.

<u>(1) Increasing tidal inundation from gradual sea level rise and higher tides:</u> Increasing sea levels could potentially inundate a number of housing units and undeveloped residential lots. The risk of inundation for existing housing units would require either relocation to other property or protection for existing property to avoid financial loss from property damage. The impact extent of increasing tidal inundation for the risk analyses used in this assessment are units and buildable lots that are within five vertical feet of the current Mean Higher High Water mark (MHHW). The estimated time frame for these impacts is long-term and increases in proportion to rising sea level.

<u>(2) Storm/tidal surge flooding:</u> A local storm/ tidal surge in 2006 flooded low-lying areas around the southern and western portion of the Reservation and La Conner and demonstrated vulnerability of this area to extreme weather events. Future sea level rise when combined with tidal storm surges will increase the impacts of flooding and its associated effects. Severe storm surges can push debris and water into residential homes and possibly damage housing units. This event could force residents to evacuate their homes and cause major destruction to housing units, resulting in loss of home and/or financial loss from property damage. Areas most likely to be affected are gently sloping shoreline areas, or where surge tops bank, seawall, and dikes. The impact extent of storm and tidal surge flooding are units and buildable lots that are within eight vertical feet of the MHHW for the analysis used in this study. The estimated timeframe for these impacts is near term potential.

<u>(3) Bank erosion:</u> Erosion of banks in the vicinity of structures may increase in certain areas from frequent, intense storm events and sea level rise as they occur. Increased soil saturation and undermined slope stability will destabilize banks, potentially decreasing their structural stability and increasing structure maintenance and cost. Areas that are most likely to be impacted are lots with shoreline banks steeper than a 3:1 ratio (slope height to slope length). The estimated timeframe for these impacts is long-term, but the rate of impact accelerates as flooding increases over time.

<u>(4) Increased wildfire risk:</u> Gradual increase in temperature, as a result of climate change, will create drier vegetation conditions from exposure to higher temperatures over a longer period of time. Drier conditions will increase the risk of wildfire, particularly in the urban/forest interface zone. Increased residential development within densely forested areas creates a significant fire risk, as forests are replaced with smaller vegetation allowing more sunlight to dry soils and accumulated fuel loads. The increased risk of wildfires to housing structures can result in resident evacuations and loss of property values. The impact extent of increased wildfire risk to residential areas is structures that are within or bordering the urban/forest interface zone. The timeframe for this occurrence is near-term and the likelihood of wildfires will increase over the long-term.

b. Commercial/Non-Residential Development

Commercial, industrial, and other non-residential development within the Swinomish Reservation is very limited, and as with other development, tends to occupy outlying areas of the Reservation. The primary center of commercial development is on the north end of the Reservation in the main Tribal Economic District, in which the Tribe's casino, gas station, RV park, and wastewater treatment plant are located. These facilities are built upon previously placed higher fill somewhat greater than 10 feet above current mean sea level, well above existing tidal influence. Low-lying areas on the north end in general, including agricultural areas to the south of the Economic District, are also ringed by a dike system generally sufficient to protect against tidal influence up to approximately 11 feet. A few other commercial operations are scattered at various locations along shorelines within the Reservation. These currently include Dunlap Towing along the west side of the Swinomish Channel, Thousand Trails campground facility at Lone Tree Point on the west shore, Hope Island Inn north of Snee-Oosh beach on the west shore, and Latitude Marine on McGlinn Island. Remaining non-residential development consists primarily of Tribal governmental offices and facilities, located in and around Swinomish Village.

Assessment of potential impacts on these facilities indicates possibility of impacts similar to those on residential structures, as detailed below:

<u>(1) Increasing tidal inundation from gradual sea level rise and higher tides:</u> Increasing sea levels have the potential to inundate certain facilities and suitable development areas in low-lying areas. Threatened inundation of existing facilities and lands would force action to either relocate economic development facilities and opportunities to other property or protect existing property. The impact extent of increasing tidal inundation for risk purposes are facilities and development property within five vertical feet of the current Mean Higher High Water mark (MHHW). The estimated time frame for these impacts is increasing to long-term in proportion to increased sea level rise.

<u>(2) Storm/tidal surge flooding:</u> Future sea level rise when combined with tidal storm surges will increase the impacts of flooding and its associated effects. Severe storm surges can push debris and water into facilities, resulting in financial loss from property damage. Areas most likely to be affected are gently sloping shoreline areas, or where surge tops bank, seawall, and dikes. The impact extents of storm and tidal surge flooding are facilities and development property within eight vertical feet of the MHHW. The estimated time frames for these impacts have a near term potential.

<u>(3) Bank erosion:</u> Erosion of banks in the vicinity of facilities may increase in certain areas from frequent, intense storm events as they occur. Increased soil saturation and undermined slope stability will destabilize banks, potentially decreasing structural stability and increasing structure maintenance and cost. Areas that are most likely to be impacted are lots with shoreline banks steeper than a 3:1 ratio. The estimated time frame for these impacts is increasing to long-term as flooding becomes more prevalent.

<u>(4) Increased wildfire risk:</u> Gradual increase in temperature, as a result of climate change, will create drier vegetation conditions from exposure to higher temperatures over a longer period of time. Drier conditions will increase the risk of wildfire, particularly in the urban/forest interface zone. Increased facility development within densely forested areas creates a significant fire risk. The impact extent of increased wildfire risk to residential areas is structures that are within or border the urban/forest interface zone. The timeframe for this occurrence is near-term and will increase over the long-term.

c. Stormwater Management

While climate models do not indicate a trend toward higher average annual precipitation, most models from IPCC's 4th Assessment agree that precipitation will increase during the winter seasons. This increase in precipitation is attributable to the northward shift and intensification of the Pacific storm track (Salathé 2006), pointing to a higher intensity and frequency of rain events in the Pacific Northwest (Tebaldi 2006). Increased intensity of the 24-hour design storm has been recorded over the last 50 years in some locations of western Washington (Rosenberg et al. 2009), however the links to climate change have not been verified. Regardless of the links to climate change, modeling and design for stormwater management may need to take this observed shift into account for future planning, likely leading to higher peak capacity stormwater systems. It is unclear whether higher capacity stormwater structures or designs are compatible with the environmental goals of Low Impact Development techniques for stormwater management. Low Impact Development techniques include methods to infiltrate stormwater near where it occurs.

With sea level rise some stormwater outfalls will be inundated and may need to be replaced at higher locations. This may also result in some systems being completely redesigned. For example, the outfall on Snee-Oosh beach collects runoff from a portion of Hope Island community and the county road in a freshwater wetland behind a rip rap dike before discharging it to the beach via a pipe through the dike. Residence and settling time in the freshwater wetland is intended to improve the water quality of the discharge. If the dike is breached and the wetland is inundated, this "finishing" function is eliminated and stormwater is essentially discharged directly to estuarine waters.

Additionally, heavy precipitation from more frequent intense storms could overwhelm drainage channels and create debris torrents that would block road culverts, resulting in overflow onto roadways and adjacent property and blocking critical fish passage through such culverts. Such blockages and overflow could cause significant damage to roadways and property from erosion potentially blowing out bridges.

d. Hazardous Sites

It is important to protect sites that are potential sources of toxic contamination from inundation or surges. As with other flood events, this can serve as a major pathway for resource contamination by toxic or hazardous materials. Any building or facilities within inundation risk zones should have hazardous materials removed and storage of such materials prohibited. New hazardous material (hazmat) collection and temporary storage sites should be located outside the inundation or surge risk zones. Currently, there are two sites with known or potentially hazardous materials located within these risk zones, one on McGlinn Island near an existing boat repair facility and one just north of SR20 near the west side of the Swinomish Channel at a former lime storage site. Several additional sites exist in the risk zones but are characterized by minimally hazardous materials and are scheduled for clean-up in the short-term future.

Adjacent to the Reservation's northwest corner is an abandoned County landfill site (the Whitmarsh dump site) where solid waste and material from the nearby refineries were dumped onto the tidelands over a number of years. The Tribe suspects that the site may be leaking toxic contamination into tidelands both on and off the Reservation. Studies have indicated elevated levels of PAHs (polycyclic aromatic hydrocarbons) and other contaminants in the vicinity of the site.

As noted in the discussion on Padilla Bay, this area will be subject to gradually rising sea levels as well as higher storm and tidal surges. The risk of leaking of toxic contaminants into Reservation tidelands would likely increase with a higher water table and overtopping of any protective barriers. While this site is being studied by the Washington Department of Ecology (DOE) for cleanup, proposed clean-up plans do not yet consider the increased risk to of sea level rise. If the site is capped or other actions taken to prevent further leaking of contaminants, proper planning to accommodate issues with sea level rise and tidal surges will need to occur.

e. Agriculture

Agricultural lands south of SR20 on the north end of the Reservation are protected by dikes and tide gates along the Swinomish Channel. With sea level rise, drainage will become increasingly difficult and costly as stormwater runoff will have to be pumped over the dikes rather than discharged through tide gates. Salinization and high water tables will also become an increasing problem for agricultural use of these areas.

Tidal surges may eventually overtop the dikes, unless they are raised substantially, and inundation of the area from sea level rise will follow. Agricultural lands and freshwater wetlands would then revert back to more saline or brackish habitats, as existed prior to conversion to agricultural use. Given the length of dikes currently required to protect these agricultural lands and the height to which dikes would have to be raised even for modest future protection, such diking work could prove to be prohibitively expensive for what might ultimately be a temporary fix. Lacking the means or political will to undertake such diking extension, agricultural lands and uses, being the only such within the Reservation, could entirely disappear, along with lease revenues currently generated by such uses.

Alternatively, a planned transition of the area may allow a more targeted transition to productive habitats. Additional study will need to be made to determine how to use breaches in the dike system to inundate areas of the agricultural lands along with other restoration work to gain optimal habitats in this area. Freshwater marsh will still be lost, but potential for restoration of brackish marshes and swamps may be facilitated by planned breaches and gradual transition rather than waiting for unplanned dike failures or waiting until sea level rise would make it difficult for habitat restoration.

f. Recreation

Officially designated recreational sites and facilities within the Swinomish Reservation are few, primarily being limited to a few isolated sites at specific locations on surrounding shorelines. Martha’s Beach, on the south end of the Reservation, is maintained by the Shelter Bay Community, operating under lease from the Tribe, and is used primarily by Shelter Bay residents. The Thousand Trails campground facility, also operating under lease from the Tribe and located at Lone Tree Point on the west shore, contains upper beaches used by Thousand Trails members, and these upper beaches are also used for Tribal activities, and by tribal members accessing lower tidelands.

With very few exceptions, the tidelands surrounding the Reservation are owned by the Tribe, and Tribal members access tidelands and shoreline areas for shellfish harvest and related activities (see Section 5.2.3 for discussion of activities such as shellfish harvest). A boat launch exists at Snee-Oosh Beach and other private docks or launches exist at certain other locations on Reservation shorelines (outside of the Tribe’s fishing docks across from La Conner), but these few isolated docks and launches may not be available for public use.

Such shoreline areas, as described above, are expected to be subject to increasing inundation as sea levels rise, as well as potential storm/tidal surge events, with consequent effects on extent of usable beach and tideland areas.

5.3.2 Cultural Resources and Traditions

In the broadest sense, Swinomish cultural resources are inseparable from the natural and human resources described in this paper. This section focuses on the potential impacts to tribal artifacts and archeology, including traditional village and camp sites. These sites are not limited to those within Reservation boundaries, but include the Tribe's traditional fishing, hunting, and gathering areas in the wider region. They are a vital link between the Swinomish heritage and its present and future prosperity.

A number of traditional village sites and camps within Reservation boundaries could face inundation due to the combined effects of sea level rise, increased wave action, destructive storm surges and increased erosion. Sites such as Qaliqet, Tosi, SDEEos, Lone Tree, near Eagles Nest, and others will be jeopardized within a few decades. The existing village (Twiwok) should remain above expected inundation levels, but may experience damage from storm surges.

Increased exposure of cultural archeological and cultural/societal artifacts and ancestral burial sites/human remains could occur throughout the coastal area. Because the Swinomish tribal members are marine-oriented, the majority of archeological sites tend to occur in shoreline areas, such that unintended exposure could significantly increase the potential for desecration and/or disturbance. At the same time, there could be increased pressure to conduct archeological excavations before sites are inundated, an action the Tribe generally opposes.

These potential impacts point to the need for continued vigilance on protection of cultural resources and for improved communication with neighboring jurisdictions on the requirements under Tribal, state and federal laws to protect on-site ancestral burial sites, human remains, and archaeological artifacts during private and public construction activities. RCW 27.44, the Indian Graves Record Act, provides civil penalties for disturbing any Indian grave and associated artifacts. Additionally, RCW 27.53 protects against disturbing archaeological resources or sites, including resources associated with Indian tribes, without a state permit and provides for criminal penalties for violations. On federal and tribal lands, the applicable law is known as Native American Graves Protection and Repatriation Act (NAGPRA) adopted in 1990 and codified at 25 U.S.C. §§ 3001-3013.

Tribal spiritual and cultural practices and norms emphasize protecting sacred sites and ancestral burial sites from any unnatural disturbance, including construction activities and archeological excavations.

Rising sea level will eventually jeopardize traditional clamming and beach seining activity historically performed on the west shore of the Reservation, for example at Lone Tree Point. As such tideland areas become increasingly inundated, as well as inundated for longer periods of time, the ability to conduct clamming and beach seining in such areas will be reduced, and possibly eliminated, with the result that an important aspect of the Tribe's cultural and historical identity will be further eroded.

5.3.3 Public/Private Utilities

a. Water

Although the Swinomish Utility Authority, as the primary water purveyor on the Reservation, maintains groundwater wells within the Reservation, these wells are currently reserved for emergency or backup water supply source. The Authority currently purchases water from the City of Anacortes as the primary source for public distribution. The Skagit River provides the source of supply for this public water system. This source and system are subject to three types of potential impacts:

(1) Water supply reductions. Should Skagit River flows follow the overall trend toward decline in summer, as documented over the past few decades for the region, allocation of public water among the various users and jurisdictions would become increasingly critical. Reduction and/or sporadic disruptions in summertime supply could impact availability of public water to the Reservation (and other users), forcing rationing measures, increased reliance on groundwater supplies, and/or other solutions.

(2) Increased well salinity. Similarly, increased salinity of groundwater supplies could force increased demand and reliance on other public water supplies.

(3) Impacts to treatment facilities. A third impact could result from inundation or other disruption of the treatment facility, with associated impacts on supply and distribution, although the potential for such disruption has not been assessed.

The Shelter Bay Community, a residential development of more than 900 homes, obtains public water supply via connection through the Town of La Conner. The Authority maintains an intertie with the Shelter Bay Community system through which Tribal supply could presumably be obtained should the Tribe's own supply from the City of Anacortes be reduced or disrupted. Should the Shelter Bay supply be disrupted, however, the ability of the Authority to supply Shelter Bay would be very limited.

While the Authority's service area is the entire Reservation, service does not currently extend to all areas within the Reservation, and private wells along with smaller community systems continue to fill the void. There are currently five small community water systems, two Tribal and three non-Tribal, serving over 170 residential users in such areas, which primarily rely on private wells for their source. The majority of these users are served by the three non-Tribal systems. Certain of these wells have proven to be occasionally unreliable, and future changing conditions will likely only exacerbate existing problems, motivating these community users to seek alternative supplies or connections.

The overall impact to public water supplies from any or all of the above could be potentially significant, although the severity and timeline for such impacts cannot be projected with any certainty. Ongoing monitoring of sources, usage, and changes in conditions will be required to provide as much lead time as possible for determination of any necessary response.

b. Wastewater

Public wastewater treatment facilities for the Reservation vicinity appear to be somewhat less impacted than water systems, at least for the immediate future, although long term prospects are less clear. Treatment for Swinomish Utility Authority customers in the southern portion of the Reservation is contracted through the Town of La Conner, and the treatment facility is located on a slightly higher bench area east of La Conner, on the edge of potential inundation zones. Other facilities currently serving the Reservation include a new state-of-the-art membrane reactor facility on the north end of the Reservation, serving north end development; the Shelter Bay treatment facility near the west foot of the Rainbow Bridge, serving Shelter Bay residences; and a spray lagoon septic system serving Thousand Trails campground. The treatment facility on the north end is within the potential tidal surge risk zone, although potential for impacts may be somewhat lessened by virtue of location. While the Shelter Bay treatment facility is outside of inundation zones, three lift stations in the vicinity of the Shelter Bay marina are within these inundation zones. The Thousand Trails treatment system is well above inundation zones but is inside the wildfire risk zone.

c. Communications

Impacts to communications facilities and lines, i.e., telephone, cable, and cell/wireless services, are expected to be limited to outages caused by severe storm events. A few such events in recent years have caused outages due to downed lines affecting telephone and some cable service. To the extent that severe storm events may increase in frequency and intensity, such outages may also be expected to continue and/or increase. There are two cell towers currently located on the Reservation, and impacts to cell and associated wireless services are expected to be less severe, barring damage to the towers themselves. The Swinomish Police Department maintains emergency communications links to off-Reservation jurisdictions, and the Tribe operates a local access cable station. Each of these may potentially provide backup communications capability during an outage, to the extent they are not impacted.

d. Energy and Power

As with communications, impacts to energy/power resources and supply will largely be as related to severe storm events. Electrical power is supplied to the majority of the Reservation via a single main transmission line from the mainland to the east, as fed through a network of distribution lines, although a small part of the Swinomish Village area receives power through a separate line feed from the La Conner vicinity. Backup energy sources are extremely limited, being largely confined to a few generators serving larger facilities. Storm events in recent years have caused widespread outages on the Reservation to homes and facilities, including a severe storm in November 2006 which caused an outage lasting several days, with many downed lines in various locations on the Reservation. Downed lines and trees also blocked roads throughout the Reservation, making it more difficult for emergency and repair crews to gain access to damage sites, further delaying repair work. Due to prolonged power outages and blockage of access to the Reservation, which occurred during cold winter months, emergency measures were begun to evacuate residents from some areas to community facilities such as the Tribal gymnasium. Evacuations were not supported, however, by advance planning for or stockpiling of emergency supplies of food, clothing, bedding, and such. Since the primary power lines to the majority of the Reservation are above ground, future storm events may be expected to repeat such damage and outages.

As average temperatures continue to increase, it can be expected that demand on summertime energy supplies will increase due to greater use of air conditioning and other means of cooling. Increased summer demand on energy systems and supply may ultimately stress systems and supply to capacity, especially when such demand occurs region-wide as might be the case during prolonged heat events. The result could be rolling brown-outs and/or failure of subsystems, as has occasionally occurred in larger metropolitan areas during extended heat waves. Lack of backup or alternate energy sources would leave the Reservation subject to the impacts of such events.

Alternative energy sources on the Reservation are virtually non-existent, except where small private systems may exist. The Tribe has undertaken a pilot project for development of roof-top solar energy for a single facility, but larger application of solar or other alternate technologies has yet to be developed. Although federal stimulus and other grant funding is becoming more available, issues of cost-effectiveness, feasibility, and ongoing funding support remain major impediments to further development of alternative energy sources.

e. Waste Management

Solid waste disposal for the Reservation is provided through regional collection services, and while Tribal facilities do some limited recycling collection, general “curbside” recycling is currently not implemented within the Reservation. Most impacts of climate change on waste disposal and management are related to potential dispersal and scattering of garbage and waste during tidal surge or other such flooding events, where private or public containers exist in potential inundation zones.

5.3.4 Emergency Services

Increased climate change impacts are expected to place increased demands on public emergency services. These services include emergency response to civil, environmental, and natural emergencies.

a. Police

<u>Increased demand for emergency response during severe storm events, outages, flooding:</u>
The Swinomish Police Department is typically the first responder to general emergencies occurring on the Reservation. The Swinomish Police Department has cooperative agreements with local law enforcement agencies for mutual backup and assistance. Increase of weather related emergencies as a consequence of climate change may add further strain to local police duties and squads. Severe weather events such as windstorms or flooding or emergencies such as power outages or wildfire may place extra burdens on police to take necessary actions, such as shutting off access to dangerous or damaged areas and roads and coordinating evacuation of local homes and businesses. While the Police Department coordinates with a broader network of authorities and responders for response to emergency events as needed, emergency events requiring intensified broader regional response may tax the ability of local authorities to adequately address the needs of local residents. Impact extent will be event-dependent and has the potential to affect the entire Reservation vicinity. The estimated time-frame for these impacts is the near-term increasing to long-term.

b. Fire

Increased demand for emergency response during wildfire, severe storms, outages, flooding: Skagit County Fire District #13 is the local fire agency that serves the Swinomish Reservation. The Fire District's responsibilities include fire suppression, emergency rescue, and emergency response. More frequent and unpredictable emergency events resulting from increased flooding, storms, and wildfires related to climate change impacts may place extra burdens on response crews, which are to a degree dependent upon volunteer services.

The Fire District coordinates with the Washington Department of Natural Resources, Bureau of Indian Affairs, and other agencies/responders as necessary in responding to and controlling wildfire on the Reservation. Given the potentially explosive fire conditions that could occur during heightened and/or prolonged heat waves and the extent of forested areas within the Reservation, including vulnerable urban/forest interface areas, quick and adequate response to wildfire outbreak will be vital to preventing major fire disasters. Increased temperatures resulting in drier conditions will increase the potential for wildfire and associated demand on firefighting facilities and crews. Frequent or larger fire events on or off the Reservation that require intensified or prolonged response may tax budgeted and/or logistical support for firefighting efforts.

Increases in flooding or other types of emergencies may additionally increase the demand on Fire District and volunteer response crews. The impact extent of these various events, including wildfire, is potentially Reservation-wide and is event-dependent. The estimated timeframe for these impacts will be near-term and increasing over longer time periods.

c. Other Emergency Response

Increased demand for assistance/ emergency response during wildfire, severe storm events, outages, flooding: Increased wildfire, flooding, storm, and heat events may require a greater demand on emergency response for health related emergencies. General disaster response organizations include Skagit County Emergency Medical Services, American Red Cross, Federal Emergency Management Agency, and utility repair crews. The closest hospitals near the Reservation are located in Anacortes and Mount Vernon. While the Tribe operates a medical facility for tribal members, there are currently no general emergency medical care facilities located on the Reservation. The impact extent is event-dependent and potentially community-wide. The estimated time-frame for these impacts is increasing to long-term.

5.3.5 Human Health

Following is a synopsis of human-health related issues that may be of concern in relation to climate change. Of particular importance is that many people participate in economic and/or subsistence harvesting and therefore spend more time outdoors than the average American.

Many Native communities, Swinomish included, define health on the community level, not the individual level (c.f., Arquette et al 2002; Swinomish Comprehensive Plan). All aspects of health are important: cultural, social, spiritual, mental, and physiological. Health is defined and prioritized based on a population or community's moral and cultural system (Airhihenbuwa 1995, Garrett 1999, Harris and Harper 1999). Just as the World Health Organization (WHO) defines health as "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity" (WHO 1946), so too do many indigenous groups such as the Swinomish. Further refining the WHO definition, many indigenous communities view heath in the following way:

> … as the status of 'being'; how we feel inside ourselves, and how we are seen from the outside, at a cosmic level and in comparison to others. 'Being' encompasses the totality of our relationships with ourselves and with all else. Therefore the health of human beings is contained in the nature and relationships to whatever surrounds them; the environment as totality—all there is (Honari 1999).

More information about community health is anticipated from community members during the final phase of this project.

a. Respiratory diseases

Fossil fuel combustion is a cause of both local air pollutants (especially particulates, ozone, methane, nitrogen oxides, and sulphur dioxide) and greenhouse gases (GHG's).It is possible that increasing impacts of GHG's may combine with local nonpoint source air pollution and local industrial pollution to significantly increase respiratory diseases in the Swinomish Community. Sources of local industrial pollution include two oil refineries near the north end of the Reservation and a large lumber processing mill a few miles to the east. Below are examples of some common respiratory-related problems that may be exacerbated by increased pollution effects.

- Ozone: Although more of an issue in concentrated city areas, increased ozone from fossil fuel combustion may also become an issue locally.
- Asthma: Some research suggests that there is a link to increasing asthma rates globally and climate change (e.g., Beggs and Bambrick 2005). Local asthma rates are higher than the national average and increasing air pollution may worsen the problem.
- Aeroallergens: Milder, longer growing seasons may increase the presence of aeroallergens such as pollen. These allergens may in turn exacerbate other respiratory illnesses such as asthma.

b. Heat-related illnesses

Increasing temperatures and intensity and duration of summer heat waves may increase the occurrence of heat-related illnesses such as heat exhaustion, heat stroke, and cardiac arrest. These issues are of particular concern for the many community members who are elderly, in poor health initially, or participate in economic and subsistence harvesting or other outdoor activities. Prolonged episodes of intense heat may result in widespread heat exhaustion among the local population where sufficient relief cannot be obtained, with associated effects of sleeplessness, fatigue, dizziness, loss of appetite, nausea, and dehydration. Prolonged heat exhaustion may lead to higher incidence of heat stroke, a serious and potentially deadly condition. Proper education about preventative measures is required.

c. Drowning

Research from the Climate Impact Group projects that increases in severe weather events that cause coastal storm surges and flooding are probable. Because many Swinomish fishermen spend time on the Skagit River, the regional bays and in the open ocean, drowning is of concern. Emergency preparedness and sufficient public education are required.

d. Vector-borne diseases

Most vector-borne diseases exhibit a distinct seasonal pattern, which clearly suggests that they are weather sensitive. Rainfall, temperature, and other weather variables affect in many ways both the vectors and the pathogens they transmit. For example, high temperatures can increase or reduce survival rate, depending on the vector, its behavior, ecology, and many other factors. Thus, the probability of transmission may or may not be increased by higher temperatures (Gubler et al 2001). The following are some examples of vector-borne diseases that are currently present in the PNW, or may become so with increasing temperatures and longer warmer seasons.

It is unlikely that these diseases will cause major epidemics in the United States if the public health infrastructure is maintained and improved (Gubler et al 2001).

Lyme disease: In the Pacific Northwest, the disease is spread by the western black-legged tick. The chances of being bitten by a tick are greatest during times of the year when ticks are most active. Deer ticks in the nymph stage are active from mid-May to mid-August. Adult ticks are most active in mid- to late fall and early spring (DHPE 2009). With less cold periods in the winter and longer warmer seasons, ticks may become more prevalent. A Lyme disease vaccine is under development but is not yet available. The only sure way to prevent the disease is to avoid exposure to infected ticks, which means to curtail time outdoors. Yet many tribal members spend time outdoors for economic and subsistence activities and cannot curtail these activities. Mosquito-borne diseases, such as dengue fever, show strong seasonal patterns; transmission is highest in the months of heavy rainfall and humidity (Patz 2002). Currently dengue occurs in most tropical areas of the world. Most U.S. cases occur in travelers returning from abroad, but the dengue risk is increasing for persons living along the Texas-Mexico border and in other parts of the southern United States (DHPE 2009). However, with increasing warming periods, these diseases may appear in the PNW.

The link between malaria and extreme climatic episodes has long been the subject of study in the Indian subcontinent. Historical analyses have shown that the risk of a malaria epidemic is increased approximately fivefold during the year after an El Niño in this region (Bouma and van der Kaay 1994). The potential also exists for malaria to become re-established in the United States. Currently, about 1,200 malaria cases are reported each year in the United States. Almost all occur in persons who were infected in other parts of the world (imported malaria). Small outbreaks of non-imported malaria, the result of transmission from imported cases, have also been reported. So far, the outbreaks have been quickly and easily contained. A continued increase in drug-resistant malaria throughout the world, however, could increase the number of cases of imported malaria and improve the chances for malaria to re-emerge in the United States (DHPE 2009).

West Nile virus, hantavirus and other vector-borne diseases may also increase in prevalence in the PNW with longer warmer seasons and less severe winters, increasing vector survival. It is unlikely that these diseases will cause major epidemics in the United States if the public health infrastructure is maintained and improved (Gubler et al 2001).

e. Enteric diseases

Bacterial and viral infections of the gastrointestinal tract account for a greatly underappreciated burden of morbidity and mortality. The enteric pathogens cause disease symptoms ranging from mild gastroenteritis to life-threatening systemic infections and severe dehydrating diarrhea. Many of these categories of diseases have been demonstrated to correlate with particular seasonal and/or weather patterns (Patz 2002).

Rotavirus: (as an example of an enteric disease currently affecting the US population) In the United States, rotavirus causes about 2.7 million cases of severe gastroenteritis in children, almost 60,000 hospitalizations, and around 37 deaths each year (Fischer 2007). Rotavirus affects primarily children; reported cases peak in the winter (Colwell and Patz 1998). Public health campaigns to combat rotavirus focus on providing oral rehydration therapy for infected children and vaccination to prevent the disease (Diggle 2007). Well functioning health clinics and more information about vaccination will aid in deterring additional cases of rotavirus.

Cholera: There is a biological basis for a link between sea surface temperature (SST), marine ecology, and human cholera (Colwell 1996). Copepods (or zooplankton), which feed on algae, serve as reservoirs for *Vibrio cholerae* and other enteric pathogens. This observation may explain why cholera follows seasonal warming of SST that can enhance plankton blooms. *Vibrio* in general is influenced by temperature and salinity (Lipp and Rose 1997), which, along with SST, is consistent with the role played by sea surface height (Lobitz et al 2000). Although once present in North America, cholera is now no longer considered a pressing health threat in Europe and North America due to filtering and chlorination of water supplies. However, if severe precipitation events occur, water supplies can be become contaminated, possibly with cholera.

f. Other emerging infectious diseases

There have been some few cases of other emerging infectious diseases reported in the PNW, but no cases reported at Swinomish to date. There is much uncertainty around emerging infectious diseases; funding and resources must be given to local health facilities to maintain the most up-to-information and track the spread and prevalence of this category of diseases. With proper planning and mitigation, it is hoped that pandemics can be avoided.

Cryptococcus gattii, a fungal pathogen found in air, water, soil and in association with numerous tree species on the Pacific Northwest coast in Washington and British Columbia, is an example of an emerging infectious disease. There is solid evidence for human-mediated dispersal of the pathogen, so continued dispersal is inevitable. Related pathogens are prevalent in tropical and subtropical climates, and more dormant strains are believed to have existed in the Pacific Northwest in a less virulent form. It is not known if the emergence of this disease is caused by climatic changes or is an invasive species dispersed via humans or animals (Bartlett et al 2008).

g. Diseases associated with shellfish and fin fish

Shellfish poisoning is a result of toxic algal blooms, the growth of naturally occurring bacteria and diatoms. There are four types of shellfish poisoning: neurotoxic, paralytic, diarrhoetic, and amnesic. With increasing effects of climate change and increased human density in the Puget Sound area, toxic algal blooms may increase in intensity and severity. Additionally, as eating shellfish is an important part of the Swinomish lifestyle, individuals may be inclined to ignore public health advisories against eating shellfish. A disease affecting fin fish that could increase with climate change is *ciguatera,* which is an illness typically associated with tropical fish. Ciguatera is not necessarily associated with toxic algal blooms.

h. Other food-related issues

Due to the importance of traditional foods at Swinomish, forced changes in diet from climate change may have significant negative impacts on health. Below are two possible issues.

Toxic contamination: According to recent research, increases in water temperature resulted in average increases in methyl mercury concentrations of 1.7% and 4.4% for projected ocean warming rates of 0.4°C and 1.0°C, respectively, per century (Booth and Zeller 2005). Since the Washington Department of Health (DOH) has already issued consumption limitations for salmon due to the presence of mercury, and many tribal members typically eat more than the DOH recommended amounts, increased mercury is of concern.
Malnutrition: reduced availability of traditional seafood, due to increased toxic algal blooms, increased seafood mortality, or other factors, may force a greater reliance on nutritionally poor commodity-type foods such as white flour and sugar-based foods.

i. Increased ultraviolet (UV) radiation

Increased UV radiation, resulting from depletion of stratospheric ozone layer, coupled with an increased frequency of extreme temperature events and high summer temperatures, will lead to increase in skin cancers, as more people spend more time outdoors (Diffey 2004). Many Swinomish already spend more time outdoors than the average American due to economic and subsistence fishing and hunting related activities. Although more people may spend more time outdoors with increasing warmer temperatures, temperature is not the primary factor determining whether people currently participate in these activities.

j. Children's health

The relationship between climate and child health has not been well investigated. This review discusses the role of climate change on child health and suggests 3 ways in which this relationship may manifest (Bunyavanich et al 2003).

- Environmental changes associated with anthropogenic greenhouse gases can lead to respiratory diseases, sunburn, melanoma, and immuno-suppression.
- Climate change may directly cause heat stroke, drowning, gastrointestinal diseases (e.g., rotavirus), and psychosocial mal-development (to be touched on with cultural issues)
- Ecologic alterations triggered by climate change can increase rates of malnutrition, allergies and exposure to mycotoxins, vector-borne diseases, and (other) emerging infectious diseases.

Potential issues range from low to high in probability of affecting the Swinomish community within these three categories. Malnutrition, respiratory infections, allergies and immuno-suppression are likely the most pressing issues for Swinomish children.

5.3.6 Transportation

Road integrity and regional accessibility is critical for the Swinomish Reservation since access is dependent on a few key vital road links, all of which are susceptible to potential impacts of climate change. The Reservation, part of Fidalgo Island, is primarily accessible from the east by bridges. These include two SR20 bridges across the north end of the Swinomish Channel and the "Rainbow Bridge" connecting La Conner and the Reservation. To the west is the larger portion of Fidalgo Island, which is accessible from the south via Deception Pass Bridge from Whidbey Island, which in turn is accessible from the mainland by the Mukilteo Ferry. In addition to State

Route 20, there are approximately 32 miles of public roads within the Reservation, 12 miles of which are Tribal or BIA roads and 20 miles of which are Skagit County roads (Figure 5-4). The Shelter Bay Community, a residential development of 900 homes, also contains numerous private roads serving that community. Predicted changes from climate change models include potentially increased and extreme precipitation events during winter periods, increasingly drier summers from higher temperatures, and prolonged periods of high temperatures (CIG 2009). Such changes are expected to have a number of different impacts on transportation mobility and facilities.

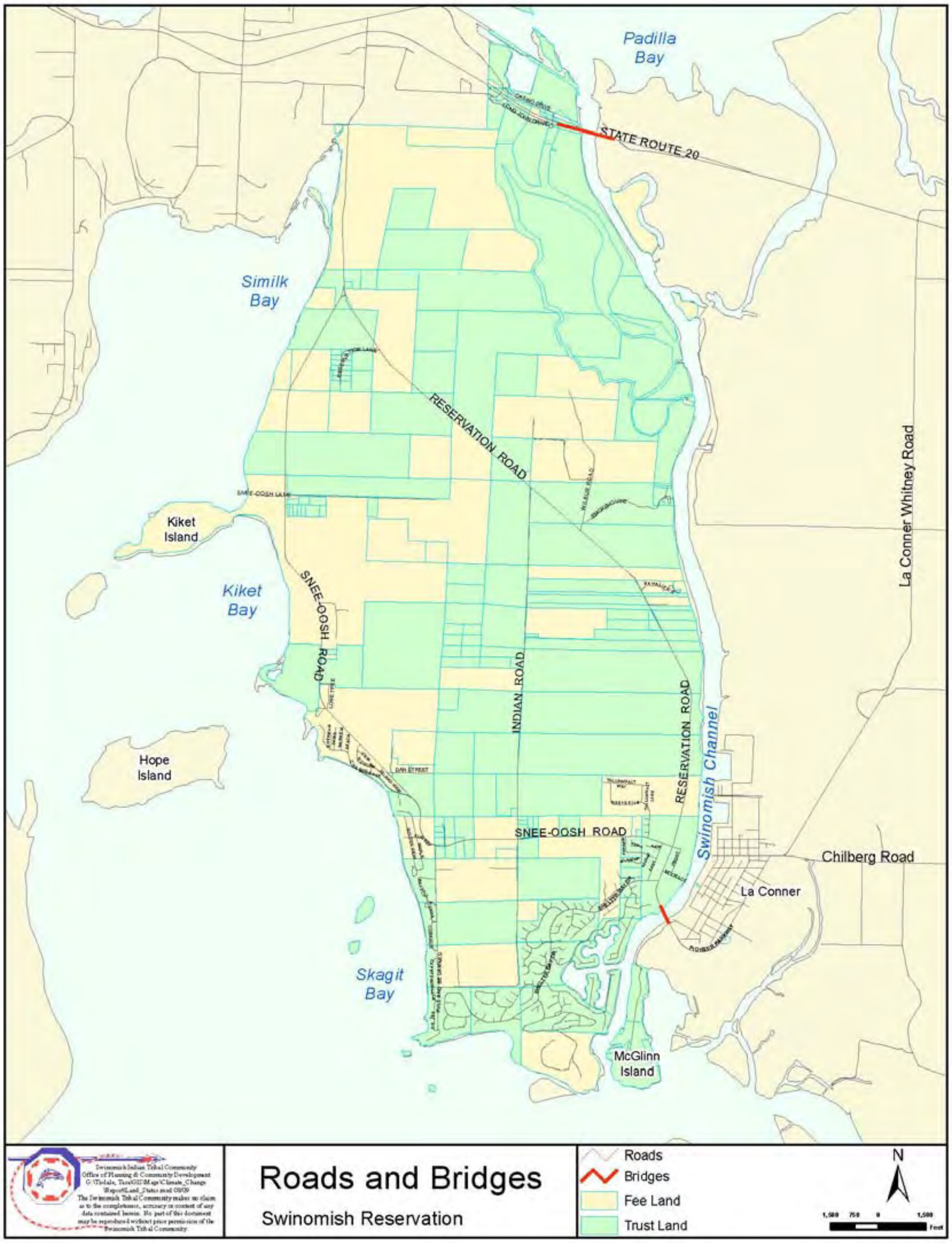


Figure 5-4. Roads and Bridges within the Swinomish Indian Reservation.

a. Road System Integrity

<u>(1) Damage from combined precipitation and temperature increases:</u> Increased precipitation and temperatures lead to premature deterioration of concrete road surfaces as a result of weathering (Wooler 2004). Changes in precipitation will speed up natural processes such as debris flow and rock fall. This increase is a potential road hazard and well as blocking the flow of traffic, creating delays for travelers. This has the immediate potential to affect existing roads where there is slope instability (Andre 2003). The impact extent will be paved and concrete roads. This is a near-term potential. Since many of the roads within the Swinomish Reservation already have pavement that has longitudinal and traverse cracking, as well as grade depression and asphalt bleeding during warmer periods, pavement weathering will increase with increased precipitation and temperature.

<u>(2) Damage from flooding:</u> Intensified flooding events will deteriorate pavement surfaces from loosening of aggregate due to water saturated road base, resulting in subsidence. Heavy precipitation from more frequent intense storms may overwhelm road drainage and create debris torrents blocking drainage channels and culverts, potentially resulting in overflow and significant damage from erosion of roadways. Future sea level rise will further exacerbate potential flooding events when combined with storm surges, reaching further inland (Titus 2008). The impact extent will affect roads that are in close proximity to coastal areas and have an elevation of five feet or less. The timeframe for this occurrence will be increasing to long-term potential.

<u>(3) Damage from intensified heat events:</u> High temperatures warp and deform asphalt that is not designed for intense heat temperatures. Exposure to increased temperatures will amplify buckling, rutting, and bleeding of roads (NRCAA 2008). Warmer summers will shorten road life from pavement softening, creating bucking and bumps, which may create future driving hazards. Extended periods of extreme heat events may result in rapid break-down of asphalt seal binders, damaging the structural integrity of roads and create road hazards by increasing the slipperiness of the road when wet (Hyman et al 2008). The potential impact extent is all paved roads. The estimated timeframe for these impacts is increasing to long-term in proportion to increased temperatures and heat waves.

<u>(4) Erosion of roadways:</u> Pavement/soil erosion and landslides in erosion-prone areas may increase from more frequent intense storm events and sea level rise. The impact extent of this event has the potential to affect earth, gravel, and paved roads on or near sloped areas, as well as roads on coastal areas.

<u>(5) Extended construction season:</u> Increased average annual temperature may result in a longer construction season, providing more opportunities for road repairs and possibly improving cost efficiencies (Andrey, 2003).

b. Access and Circulation

Impacts of climate change will also affect the operational capacity and accessibility for transportation routes and have the potential to directly affect the mobility of people and goods entering and leaving the Swinomish Reservation vicinity.

<u>(1) Inundation of roads from sea level rise:</u> Increasing sea levels have the potential to inundate roads on and leading to the Reservation where such roads are not adequately protected by dikes, or where rising sea levels eventually top dikes. If not protected from such inundation, resulting route closures would disrupt travel and transport of goods to and from the Reservation,

preventing access to services and potentially causing shortages of necessities. Prolonged inundation would result in isolation of the Reservation from the mainland. Potentially impacted areas are those within five feet above MHHW; this would include the two immediate access points to the Reservation, along Maple Avenue in La Conner and on Reservation Road adjacent to Turner's Bay, as well as large areas of farmland east of the Swinomish Channel through which run other access routes to the Reservation. Such disruption of access would also have potentially significant implications for evacuation routes in the event of an emergency or natural disaster.

<u>(2) Inundation of roads from storm/tidal surge:</u> Potentially higher and more frequent storm/tidal surges, such as seen in 2006, may cause temporary and somewhat localized inundation of roads on and leading to the Reservation where such roads are not adequately protected by dikes or where such surges top dikes. Resulting route closures would disrupt travel and transport of goods to and from the Reservation, preventing access to services and potentially causing shortages of necessities. While higher water levels would typically subside after some hours, surge inundation could still result in temporary isolation of the Reservation from the mainland. Potentially impacted areas are those within eight feet above MHHW, which would include all access routes to the Reservation. Such temporary disruption of access would again have potentially significant implications for evacuation routes in the event of an emergency or natural disaster.

<u>(3) Route closures from extreme flooding events:</u> Increasingly intense storm events have the potential to overload existing capacity of culverts and drainage systems, resulting in flooded roadways, directly affecting access and circulation of specific routes. Roads most affected would be those roads with existing drainages that currently experience clogging from garbage and organic material. Also affected would be those roads that currently have undersized culverts lacking capacity for large volume of water flow. Such flooding could result in subsidence and create long-term accessibility issues (NRCNA, 2008).

<u>(4) Route closures from fire:</u> Increase of wildfires due to higher temperatures may create accessibility and circulation issues such as temporary road closures and driving hazards. In potentially extreme circumstances, there may be need for residential evacuations. Roads in or near more heavily forested or vegetated areas have the potential to be the most affected (NRCNA 2008).

<u>(5) Reduced winter maintenance:</u> Reduced annual winter snowfall and warmer winter temperatures will alleviate winter maintenance, reducing snow and ice removal costs. Milder winters will also reduce environmental impacts from the use of salt and chemicals on roads and bridges and improve mobility and safety of passenger and freight travel through reduced winter hazards (NRCNA 2008; Andrey 2003).

c. Bridges

Due to the location of the Reservation, bridges are critical transportation links. The main routes to access the Reservation are over the "Rainbow Bridge" at La Conner and Washington State Route 20 bridges which cross the Swinomish Channel. There are also low-lying bridges to the west of the Reservation that also serve as critical routes.

<u>(1) Erosion of bridge footings:</u> Erosion of bridge footings and supports may occur from higher tides and storm surges. Increased flooding events can cause soil saturation and surface erosion of materials around bridge footings, potentially decreasing their structural stability and increasing maintenance and operational costs (NRCNA 2008). Erosion of bridge footings can also caused by

scour from increased water flow from flooding and tidal surges, resulting in structural instability. Scour is created when sediment is washed away from the bottom of a river, leaving a hole. This generally happens at any time but is more prominent during floods and increased water flow. This is a concern because if the rock or sediment that a bridge rests on is scoured, particularly local scour[18] can make bridges unsafe for travel because of degradation of structural base support (Warren 1993).

<u>(2) Increased fatigue and deterioration of bridge joints:</u> Increased temperatures create thermal expansion of bridge joints. Bridges are designed to accommodate movement from thermal expansion and contraction. However, significant temperature increases from climate change can exceed standards for the current design, causing it to reach its threshold for thermal expansion (Soo Hoo 2005). With increased and prolonged exposure to heat, parts of the bridge are heated and not allowed to further expand; creating stress to the structure that may either damage the bridge or elements that the bridge is constrained by. This will potentially increase maintenance costs and negatively affect operations.

d. Public Transit

Public transit currently available to the Reservation is a single fixed route bus. The existing route service is being expanded in the fall of 2009 to include additional daily runs and links between the north and south ends of the Reservation. Impacts affecting access, circulation, and road integrity as discussed above could create service disruption.

e. Marine/Port Facilities

Fishing and associated activities are vital to the Swinomish Community, as many tribal members depend on fishing for at least a portion of their livelihood. Access to functional docks and related facilities are important in helping preserve fishing activities. Rising tides from gradual sea level rise may result in dock facilities and access being impaired during extreme high tides; unless dock facilities are raised or otherwise adapted, continued rising tides may ultimately render dock facilities unusable for extended periods of time, hindering fishing and other activities dependent upon such facilities.

Marine transportation is also important to activities on leased tribal lands, such as log transport and recreational boating. Since these facilities are generally located along the shoreline, inundation from increasing sea level rise, as well as flooding from a combination of high tide and a storm surge event has a strong likelihood of occurring. This could result in temporary delays and interruptions of transporting services and destruction of property. Facilities may have to be rebuilt or relocated depending on circumstances. The impact of extent would be the Swinomish Channel and the Shelter Bay Marina.

[18] "Local scour is the removal of sediment from around bridge piers or abutment. (Piers and the pillars supporting a bridge. Abutments are the supports at each end of a bridge.) Water flowing past a pier or abutment may scoop out holes in the sediment; these holes become known as scour holes" (Warren 1993)

6. Vulnerability Assessment

Vulnerability assessment was undertaken in a 3-step process: 1) identification and mapping of impact areas (risk zones); 2) inventory of assets and resources within identified risk zones; and 3) evaluation of impact threshold and exposure (sensitivity and adaptive capacity). The intent of this analysis is to produce quantitative information on impacted assets and resources, along with specific local qualitative projections of impacts, resulting in computed level of impact, or consequence, for given sectors that, when combined with probability projections, will make further risk analysis possible. Mapping of impact areas resulted in three primary risk zones: a sea level rise inundation zone, a tidal surge inundation zone, and a wildfire risk zone. Additional specific impacted areas were mapped as possible for the given sector (e.g., shellfish). Based on such mapping, assets and resources within identified impact risk zones were identified.

Once potentially impacted assets and resources were identified, assessment was made of the degree to which such assets and resources were deemed to be sensitive to identified impacts, based largely on exposure and potential susceptibility to given impacts; rating of high, medium, or low sensitivity was assigned based on the assessment. Similar but reciprocal rated assessment was also made of the extent to which assets and resources could be adapted to prevent or protect against the given impacts, known as adaptive capacity. Sensitivity and adaptive capacity were combined to determine overall vulnerability to impacts, also rated as high, medium, or low. The reciprocal nature of sensitivity and adaptive capacity ratings are such that for high overall vulnerability, high sensitivity corresponds to low adaptive capacity, and conversely for low vulnerability, low sensitivity corresponds to high adaptive capacity. Table 6-1 summarizes vulnerability rating of all sectors for the given impacts identified.

TABLE 6-1. VULNERABILITY ASSESSMENT OF POTENTIAL IMPACTS BY SECTOR HUMAN/BUILT SYSTEMS

Sector	Element	Potential Impacts	Impact Sensitivity (exposure/susceptibility)	Adaptive Capacity	Complicating/ Key Factors	Vulnerability (impact level)
Land Use	Shoreline Development	Increasing inundation from gradual sea level rise	High, for properties within inundation zones	Low	Armoring, seawall to be restricted (?)	High
		Increasing frequency and severity of storm surges	High, for properties within inundation zones	Low	Armoring, seawall to be restricted (?)	High
		Beach/bluff erosion with increasing rise/surges	High where bluffs are susceptible	Low	Armoring, seawall to be restricted (?)	High
	Stormwater control	Inundation/backup of drainage lines and discharge points from higher tides, storm surges	Medium – High, depending on location	Medium	Conventional v. LID systems use	Medium
		Damage to discharge outfalls from bank erosion	High for sites subject to erosion	Low	Conventional v. LID systems use	High
	Hazardous Sites	Spread of contaminants through inundation/ flooding from higher tides, storm surges	High at sites subject to storm surges or higher ground water	Low	Critical site is adjacent to Reservation	High
	Agriculture	Eventual inundation as rising high tide tops dikes	High, given relative uniformity of elevation	Medium (temporary)	Dike extension costly, temporary	Medium-High
		Storm events push tidal surges over dikes	Medium, given prevailing direction of storms	Medium (temporary)	Dike extension costly, temporary	Medium
		Increasing salinization from salt intrusion with rising sea levels	Medium, depending of reach of tidal influence	Low	Old sloughs create subsurface flow possibility?	Medium
	Housing/ Residential	Increasing inundation from gradual sea level rise and higher tides	High, for residential units within inundation zone	Low	Dike protection questionable, costly, temporary	High
		Storm-tidal surge flooding, gently sloping shorelines, or where surge tops bank/seawall/dikes	High, for residential units within inundation zone	Low	Dike protection questionable, costly, temporary	High

Sector	Element	Potential Impacts	Impact Sensitivity (exposure/susceptibility)	Adaptive Capacity	Complicating/ Key Factors	Vulnerability (impact level)
(Land Use, cont'd.)	(Housing/ Residential, cont'd.)	Bank erosion, threatening near-bank structures	Medium, for residential units in erosion risk area	Low	Hard armoring of bank not likely; soft armoring?	Medium
		Increased risk of wildfire from increasingly drier conditions	High, for residential units within Primary Risk Zone	Medium	Fuel management may reduce risk	Medium-High
	Commercial/ Industrial	Increasing inundation from gradual sea level rise and higher tides	High, for structures and property within inundation zone	Low	Dike protection questionable, costly, temporary	High
		Storm-tidal surge flooding, gently sloping shorelines, or where surge tops bank/seawall/dikes	High, for structures and property within inundation zone	Low	Dike protection questionable, costly, temporary	High
		Bank erosion, threatening near-bank structures	Medium, for structures in erosion risk area	Low	Hard armoring of bank not likely; soft armoring?	Medium
		Increased risk of wildfire from increasingly drier conditions	High, for structures within Primary Risk Zone	Medium	Fuel management may reduce risk	Medium-High
	Recreation	Increasing inundation of public beaches, parks from gradual sea level rise	High, for areas within inundation zone	Low	Dike protection questionable, costly, temporary	High
		Storm-tidal surge flooding, gently sloping shorelines, or where surge tops bank/seawall/dikes	High, for areas within inundation zone	Low	Dike protection questionable, costly, temporary	High
		Spread of contaminants through inundation/ flooding from higher tides, storm surges	Medium, depending on sources of contaminants	High	Restricting on-site storage to control exposure	Low
Public/Private Utilities	Water	Reduced supply due to decreased source (river/ snowpack), increased demand	Medium-High, dependent on regional conditions	Medium (well backup supply)	Alternate supply, options limited; off-Reservation dependence	Medium

Sector	Element	Potential Impacts	Impact Sensitivity (exposure/susceptibility)	Adaptive Capacity	Complicating/ Key Factors	Vulnerability (impact level)
(Public/Private Utilities, cont'd.)		Contamination of local supplies from inundation, flooding	Medium, dependent on extent/severity	Low	Alternate supply, options limited	Medium
	Wastewater	Inundation of treatment facilities from higher tides, storm surges	Low, given location of local facilities	Medium	Long-term risk?	Low
	Communications	Service disruption from severe storm events; duration of outage proportional to severity	High, for land lines, based on past events, likely repeat	Low	Extent/severity affects response; cell/wireless likely less affected	High
	Energy/Power	Service disruption from severe storm events; duration of outage proportional to severity	High, based on past events, likely repeat	Low	Extent/severity affects response; preparedness lacking	High
		Increased energy demand to counter higher temperatures	Medium-High, event dependent	Medium	Energy efficiency improvements may offset	Medium
	Waste Disposal	Spread of waste from local/loose containers during flooding from higher tides, tidal surges, storm events	Medium-High, in vicinity of inundation zone	Medium	Tight control of storage to reduce potential	Medium
Emergency Services	Police	Increased demand for assistance/ response during storm events, outages, flooding	Medium, as weather related emergencies increase	Medium	Increase available force; regional support, access issues?	Medium
	Fire	Increased demand for assistance/ response to wildfire, storm events, outages, flooding	High, greater likelihood in wildfire risk zones	Medium	Stations located in risk zones; region wildfire support?	Medium- High
	Other Emergency (disaster, repair crews, etc.)	Increased demand for assistance/ response during storm events, outages, flooding	Medium, as weather related emergencies increases	Medium	Regional response coordination? Preparedness lacking; access issues?	Medium

Sector	Element	Potential Impacts	Impact Sensitivity (exposure/susceptibility)	Adaptive Capacity	Complicating/ Key Factors	Vulnerability (impact level)
Human Health	Heat-related illness	Increased demand for and stress on services to treat heat-related health issues (heat exhaustion, heat stroke, etc.)	High, more so for elderly, infirm	Medium	Education, cooling benefits may be limited	Medium-High
	Disease vectors	New/increased disease vectors, and related outbreaks	Medium	Medium		Medium
	Pollution-related illness	Increased pollution-related illness exacerbated by weather and climate conditions	Medium	Low	Traditional foods affected by pollution, heat stress	Medium- High
	Solar radiation issues	Increase in skin cancers from higher UV radiation levels	Medium	Medium	Education, access to health care, weather warning	Medium
	Respiratory disease	Increasing incidence of asthma, and allergen-related problems	Medium	Low		Medium- High
	Food-related illness from contaminated seafood	Increased incidence of poisoning from consuming toxin-laden seafood (PSP in shellfish, mercury in salmon)[19]	High	Medium	Other food sources available?	Medium
Transportation	Access/ Circulation	Inundation of access,travel disruption, isolation from sea level rise topping dikes	High, for roads within inundation zones	Low	Moving routes, diking costly, temporary	High
		Travel disruption/road closures, storm/tidal surge	Medium-High, for roads within inundation zones	Low	Lack of alternative routes?	Medium-High
		Incidental road closure/ travel disruption from wildfire	Medium-High, for roads within primary wildfire risk zone	Low	Alternative plan for evacuation critical, lacking?	Medium-High

[19] Not exclusively related to climate change, but potentially exacerbated by it.

Sector	Element	Potential Impacts	Impact Sensitivity (exposure/susceptibility)	Adaptive Capacity	Complicating/ Key Factors	Vulnerability (impact level)
(Transp., cont'd.)	Road System Integrity	Flooding damage from storm/tidal surge, buckling/cracking from higher temperatures	High, for roads within shoreline vicinity (surge), all roadways (heat)	Medium	Use of high-heat tolerant road materials	Medium
	Bridges	Erosion of bridge footings from high tides, surges	Medium, for bridge footings subject to scour	Medium	Possible armoring techniques?	Medium
		Increased deterioration/ fatigue of bridge joints	High, for extended heat spells	Medium	More frequent inspections, repair	Medium
	Public Transit	Service disruption, impact-related closures	High, for routes in affected zones	Low	Alternate routes to avoid issues?	High
	Marine transport facilities	Increasing inundation of marine facilities and ports from gradual sea level rise and higher tides	High, for facilities within inundation zones	Low	Cost/feasibility of rebuilding or relocating?	High
Cultural Resources	Coastal sites/ artifacts	Increasing inundation of sites from sea level rise	High	Low	Most sites within inundation zones	High
	Burial sites/ human remains	Disturbance/exposure from severe storm events	High, sites tend to occur along the shoreline	Low	Increased pressure for investigation	High
	Cultural use plants/animals	Loss/migration of traditional use species	High, loss/migration of species will increase as temperatures increase	Low		High
	Traditional use areas	Loss of treaty protected resources (e.g., fishing, hunting, gathering)	Presume High (outside project scope, TBD)	(TBD)		(TBD)
	Shellfish harvesting	Potential loss of harvest sites and opportunities	High	Low	Limited ability to migrate (?)	High
	Beach seining	Potential loss of seining sites and opportunities	High, given exposure	Low		High
	Marine facilities	Increasing impacts to dock facilities from rising sea level	High	Low	Relocation possible?	High

VULNERABILITY ASSESSMENT OF POTENTIAL IMPACTS BY SECTOR NATURAL SYSTEMS

Sector	Element	Potential Impacts	Impact Sensitivity (exposure/ susceptibility)	Adaptive Capacity	Complicating Factors	Vulnerability (impact level)
Shoreline/ Beaches	(general)	Increasing tidal inundation from gradual sea level rise	High	Low	Armoring/bulkhead restrictions?	High
	(general)	Increasing frequency and severity of storm/ tidal surges	High	Low	Armoring/bulkhead restrictions?	High
	(general)	Beach erosion with increasing rise/surges	High, depending on location	Low	Armoring/bulkhead restrictions?	High
Tidelands/ Marine Habitat	Habitat viability	Increasing inundation from sea level rise forcing gradual migration to maintain viability	High	Med	Armoring/bulkhead restrictions?	Medium-High
	Estuarine beaches	Increasing inundation and loss from rising sea level	High	Low	Armoring/bulkhead restrictions?	High
Fish & Wildlife	Shellfish	Increasing inundation of shallows, estuaries	Medium-High, depending on migration ability	Medium	Armoring/bulkhead restrictions?	Medium
		Weakened viability due to habitat changes	high	Low	Armoring/bulkhead restrictions?	High
	Fin Fish	Increasing inundation of shallows, estuaries, spawning grounds	Medium-High, depending on species	Low-Medium	Armoring/bulkhead restrictions?	Medium-High
		Weakened viability due to habitat changes	High	Low		High
	Waterfowl/ Shorebirds	Loss of forage areas and opportunities due to impacts on food sources	Med- high depending on species	Low - med		Medium-High
	Upland wildlife/ habitat	Degradation/conversion from higher temperature and increased wildfire incidence	High	Med	Urban forest interface and resources protecting structures	High
		Stressed viability from habitat and temperature changes, forced migration	Medium-High	Low	Habitat fragmentation blocking migration	High

Sector	Element	Potential Impacts	Impact Sensitivity (exposure/ susceptibility)	Adaptive Capacity	Complicating Factors	Vulnerability (impact level)
Water Resources	Freshwater	Declining consistency/ volume of in-stream flows, earlier peak runoff	Medium-High, greater as temperature rises	Low	More acute in snow-to-rain dominant transition areas	Medium-High
	Groundwater	Increasing salinization from salt water intrusion	Medium-High, wells near shoreline zones	Low	Greater drawdown exacerbates issues	Medium-High
	Wetlands	Increasing inundation from higher tides, storm surges (estuarine)	High, greater for estuarine, freshwater wetlands	Low	Conversion/loss proportional to inundation	High
		Decline/degradation of upland wetlands from reduced flow input	High, greater with increasing temperature and declining precipitation	Low	Increased loss may contribute to higher wildfire potential	High
Forest Resources	(general)	Lower moisture content, increased potential for destructive wildfire	High, greater in primary wildfire risk zone	Low	Fuel loads, declining precipitation and freshwater heighten potential intensity	High
		Heat stress, increase in drought-tolerant species, decrease in drought-sensitive species	High, greater with increasing temperature and declining precipitation	Medium	Some species may migrate; range of migration limited	Medium-High
		Greater pest infestations, disease vectors (bark beetles, fungus, etc.)	High, greater with warmer winter, reduced freezing	Medium	Natural defense and recovery keyed to severity/extent of infestation	Medium-High
Air Quality	(general)	Increasing stagnation, noxious elements/ parameters due to higher average temperatures	Medium	Low		Medium

6.1 Inundation Risk Zones

To identify and map inundation risk zones, it was necessary to first establish the level of the current inundation zone relative to land elevation. Current inundation zones were based on mapping of tidal range from Mean Lower Low Water (MLLW) to Mean Higher High Water (MHHW), as developed from LIDAR data, Tidal Datums, and Tidal Benchmarks. For the purpose of risk analysis, projected inundation zones were derived by adding increase of up to 5 feet for sea level rise (upper range of surveyed scenarios) and an additional 3 feet beyond that for tidal surge (Zervas, 2005). The current MLLW and MHHW elevations were shifted accordingly to represent new projected levels of permanent inundation (MLLW) and maximum tidal influence (MHHW). It should be emphasized that the projected zones indicate areas of increased risk for this report, not necessarily projections of actual impact. Existing diking was represented as it exists in elevation mapping. Initial risk zone mapping was developed to show potential impact with no presumed dike protection, to highlight potential inundation in event of dike failure, intentional breach, or topping of dike by either higher projected tides or tidal surge. It should also be noted that not all areas subject to potential inundation are currently protected by dikes. Figure 6-1 and associated subarea maps in Appendix 7 illustrate mapping of sea level rise and tidal surge zones.

Approximately 29 homes are currently located in areas at risk of inundation from projected sea level rise; value of residential properties in this risk zone is estimated at approximately $17,372,000. Eight commercial or non-residential facilities are also located within the sea level rise risk zone; value of these facilities is estimated at approximately $3,185,000. Approximately 131 homes are currently located in areas at risk of tidal surge; value of residential properties in this risk zone is estimated at approximately $66,012,000. Ten commercial/non-residential facilities are located in the potential tidal surge zone; value of these facilities is estimated at approximately $15,524,000. In addition, 17 currently vacant but buildable lots valued at approximately $5.1 million are located within either potential sea level rise or tidal surge zones. Table 6-2 provides a summary of properties identified within either sea level rise or tidal surge risk zones, with approximate values of identified properties, and Table 6-3 contains a listing of specific non-residential facilities identified.

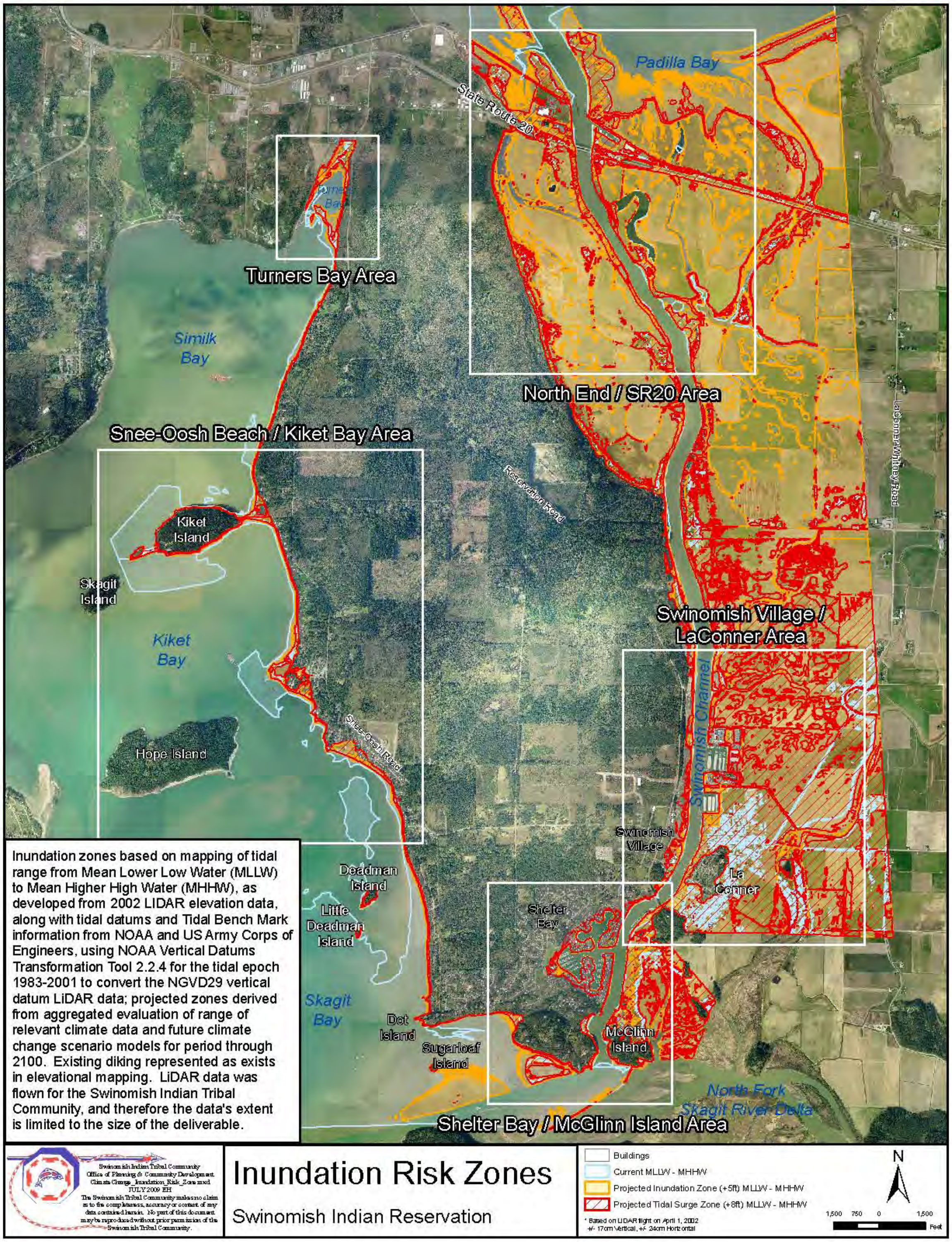


Figure 6-1. Inundation Risk Zones within the Swinomish Indian Reservation.

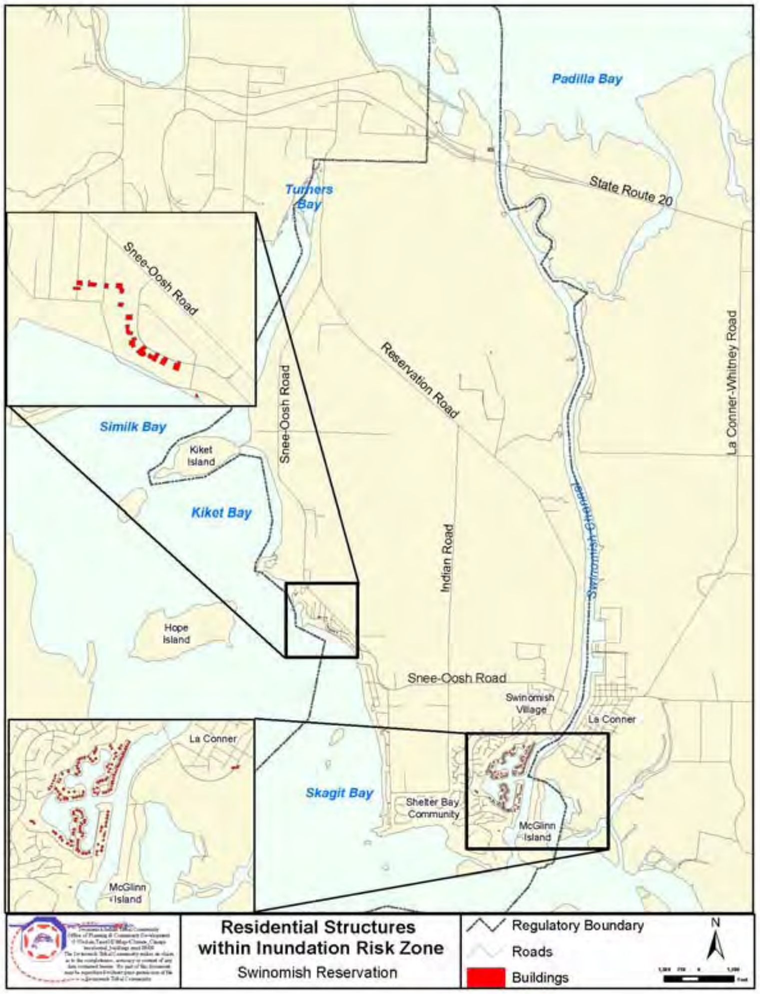


Figure 6-2. Residential Structures within Inundation Risk Zone

Structures and Lots Within Inundation Risk Zones										
Subarea:	**Swin. Village / Shelter Bay**		**Economic Zone / Agricultural**		**Snee-Oosh / Kiket Island**		**Similk Bay / Turner's Bay**		**Total All Areas**	
Sea Level Rise	**#**	**Approx. Value***	**#**	**Approx. Value***	**#**	**Approx. Value***	**#**	**Approx. Value***	**#**	**Approx. Value***
Residential	16	$12,259,500	4	$1,088,100	9	$4,024,400	0	$0	29	$17,372,000
Non-Residential	4	$1,720,760	2	$670,000	2	$794,700	0	$0	8	$3,185,460
Buildable Lots	1	$308,800	0	$0	9	$3,050,000	3	$1,044,500	13	$4,403,300
Subtotal	**21**	**$14,289,060**	**6**	**$1,758,100**	**20**	**$7,869,100**	**3**	**$1,044,500**	**50**	**$24,960,760**
Tidal Surge										
Residential	121	$63,282,900	1	$192,200	7	$2,228,300	2	$308,800	131	$66,012,200
Non-Residential	4	$1,124,000	5	$14,146,300	1	$253,200	0	$0	10	$15,523,500
Buildable Lots	3	$525,000	0	$0	1	$172,400	0	$0	4	$697,400
Subtotal	**128**	**$64,931,900**	**6**	**$14,338,500**	**9**	**$2,653,900**	**2**	**$308,800**	**145**	**$82,233,100**
Total Risk Zones										
Residential	137	$75,542,400	5	$1,280,300	16	$6,252,700	2	$308,800	160	$83,384,200
Non-Residential	8	$2,844,760	7	$14,816,300	3	$1,047,900	0	$0	18	$18,708,960
Buildable Lots	4	$833,800	0	$0	10	$3,222,400	3	$1,044,500	17	$5,100,700
TOTAL	**149**	**$79,220,960**	**12**	**$16,096,600**	**29**	**$10,523,000**	**5**	**$1,353,300**	**195**	**$107,193,860**

*Values based on Assessor's records of market value for fee properties, and Swinomish Tribal data for certain trust properties.

Table 6-2. Structures and Lots Within Inundation Risk Zones.

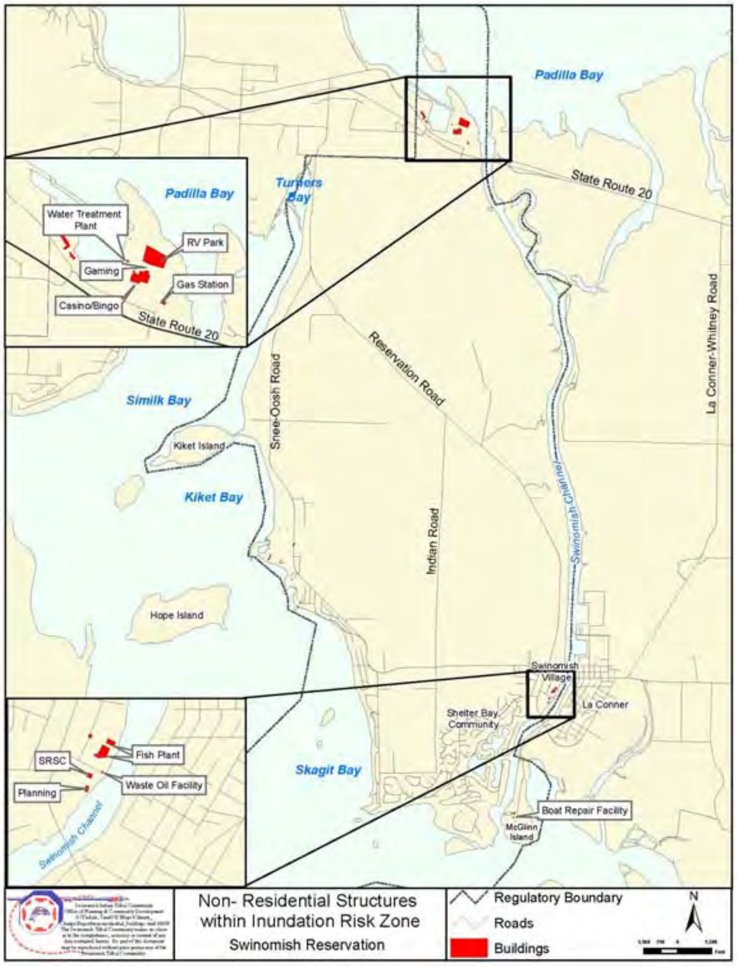


Figure 6-3. Non-Residential Structures within Inundation Risk Zone

Non-Residential Facilities Within Inundation Zones		
Sea Level Rise:	**Location**	**Approx. Value**
Fish Plant	Swinomish Village	$1,675,000
SITC Boat repair facility	McGlinn Island	$45,760
Smoke shop	North end commercial zone	$670,000
Hope Island Inn	Snee-Oosh Beach (west shore)	$783,800
Community pump station	Snee-Oosh Beach (west shore)	$10,900
	Total	**$3,182,460**
Tidal Surge:	**Location**	**Approx. Value**
Skagit River System Coop.	Swinomish Village	$284,000
SITC Planning Department	Swinomish Village	$575,000
SITC Waste Oil Facility	Swinomish Village	$15,000
Latitude Marine	McGlinn Island	$250,000
SITC Casino/Bingo	North end economic zone	$9,412,000
SITC Gas Station	North end economic zone	$2,000,000
SITC RV Park	North end economic zone	$584,300
SITC Water Treatment Plant	North end economic zone	$2,100,000
SITC Gaming Office	North end economic zone	$50,000
Fire District 13 station	Snee-Oosh Beach (west shore)	$253,200
	Total	**$15,523,500**

Table 6-3. Non-Residential Facilities Within Inundation Zones

Based on the identified exposure of properties within the sea level rise and/or tidal surge risk zone and the perceived susceptibility to eventual impacts, sensitivity of identified properties to projected impacts is deemed to be high in general, with limited and temporary reprieve where the few existing dikes may currently protect given areas (mostly on the north end). Given the perceived relative difficulty or potentially great expense of armoring or otherwise protecting properties from eventual impacts, adaptive capacity of most areas to inundation is deemed to be low. Seawalls, dikes, or other such protection may be constructed as a barrier to tidal inflow, but given the predicted continual rise, such measures will prove to be of relatively temporary benefit and will ultimately be a losing game over the long term; alternatives would be to raise or relocate structures away from shoreline areas, both of which entail considerable cost, or to abandon in favor of owner relocation. Given these alternatives, overall vulnerability to inundation is rated generally high where such impacts are anticipated.

6.2 Economic Development and Agricultural Lands

Projected impacts on economic development and agricultural lands within the Reservation merit special mention. The Tribe's economic development strategy has for some time targeted relatively low-lying areas on the north end of the Reservation in the vicinity of SR20 for existing and future development, and key Tribal enterprises including a casino and gas station are located there. Impacts to these areas will have potentially significant repercussions for the Tribe's infrastructure.

Existing enterprises are located just above projected impact zones, and presumably not directly subject to potential impacts, but business operations could yet be affected eventually by virtue of impacts to surrounding lower lying areas. While dikes currently protect other prime economic development land south of SR20, complicating factors with major oil and gas pipelines currently transecting that area are such that future business development will not likely have the advantage of fill height to put it above rising tidal influence, further raising the stakes and forcing increased reliance on diking or other means of protection. The overall ramifications of these circumstances are that, if such enterprises and future economic development remain in the present location, the Tribe is highly vulnerable to eventual impacts on, and potential disruption of, critical financial enterprises. This will require increasingly critical reconsideration of strategic options for economic development for the Tribe to preserve and sustain the viability of its financial engines.

While few improvements are located within Tribal agricultural lands and the Tribe does not directly engage in agricultural operations, the Tribe continues to garner revenue from leases for ongoing private agricultural operations. With these being the only agricultural lands within the Reservation, and being located exclusively in low-lying areas protected currently by dikes and tide gates, the Tribe is at risk of losing these lands entirely at some point in the future, should diking become insufficient for protection from encroaching inundation.

6.3 Infrastructure Vulnerabilities and Critical Off-Reservation Issues

If potential impacts loom at some point in the future from inundation to low-lying areas on the north end of the Reservation west of the Swinomish Channel, then the same may possibly be said of adjacent low-lying farmlands across the Swinomish Channel to the east, which lie at roughly the same elevation. This study did not examine potential off-Reservation impacts to any great extent, and the Tribe's available data for this area is confined to a limited amount of elevation data for a narrow strip east of the channel; despite that, there are potentially very significant potential vulnerabilities resulting from possible off-Reservation impacts.

One such primary vulnerability is derived from the fact that key access routes to the Reservation are located in these low-lying areas, and potential inundation of these routes could effectively isolate the Reservation from the mainland, disrupting travel and necessary access to services and goods. SR20, the sole state highway accessing the Reservation, has approaches through low-lying farmlands to the east, and similar vulnerabilities exist at Reservation Road next to Turner's Bay and in La Conner just north of the Rainbow Bridge. Indeed, a February 2006 storm surge event came within inches of inundating the latter two locations and cutting off access to the Reservation entirely; had the storm surge event occurred a few days earlier at a higher tide, such inundation of access might have happened. Estimates are that the event was approximately the equivalent of a 4-foot tidal surge above normal, within the range of projections for both sea level rise and surge events.

Other such vulnerabilities stem from the Tribe's connections to water and sewer service off-Reservation. Although the Tribe is the primary water purveyor within the Reservation, the Tribe largely purchases its supply from the City of Anacortes for distribution through the Tribal system. Likewise, the Tribe contracts with the Town of La Conner for wastewater service, which is handled by the treatment plant located just east of La Conner off Chilberg Road. While no clear impacts to either of these may currently be identified, such cannot be discounted entirely. If changing conditions were to negatively affect the Skagit River, which feeds water service for many local communities including Anacortes, and flows were reduced such that available water supply decreased, the Tribe's current source of water supply would be threatened. And though the La Conner wastewater treatment plant appears to mostly be above projected inundation elevations, a repeat of the February 2006 event high enough to top existing protection in La Conner could potentially result in disruption of service, in addition to other impacts.

6.4 Wildfire Risk Zone

The urban/forest interface was evaluated using analysis of GIS and aerial photo data, correlating developed areas of varying densities to forested areas of given density. Forested areas cover the majority of Reservation uplands, while developed areas primarily lie within southeastern, southern, and west shore areas, although some scattered pockets of homes and homesites exist in interior uplands. Where denser developed and forested areas intersect, a wildfire risk zone was identified, as augmented by a 200-foot buffer around identified developed areas. Consideration was also given to the direction of prevailing winds during dry seasons which could potentially blow and feed wildfire into downwind areas. While the entire Reservation is deemed to potentially be at risk of wildfire due to extent of forestation, the identified urban/forest interface zones were deemed to be at greatest risk, and for the purpose of risk evaluation and response strategy implementation, were designated primary wildfire risk zones. Approximately 2,218 acres of land and over 1,500 structures are currently located in this high risk wildfire zone. More than 1,300 residential structures, including associated detached accessory structures such as garages and workshops, are located within this zone, as are 9 non-residential facilities, in addition to 183 currently vacant but buildable lots. Figure 6-4 shows mapping of the primary wildfire risk zone and residential structures located within that zone; Figure 6-5 shows non-residential structures within the zone. Table 6-4 lists properties within this zone and their approximate market value; Table 6-5 lists specific non-residential facilities found within this zone.

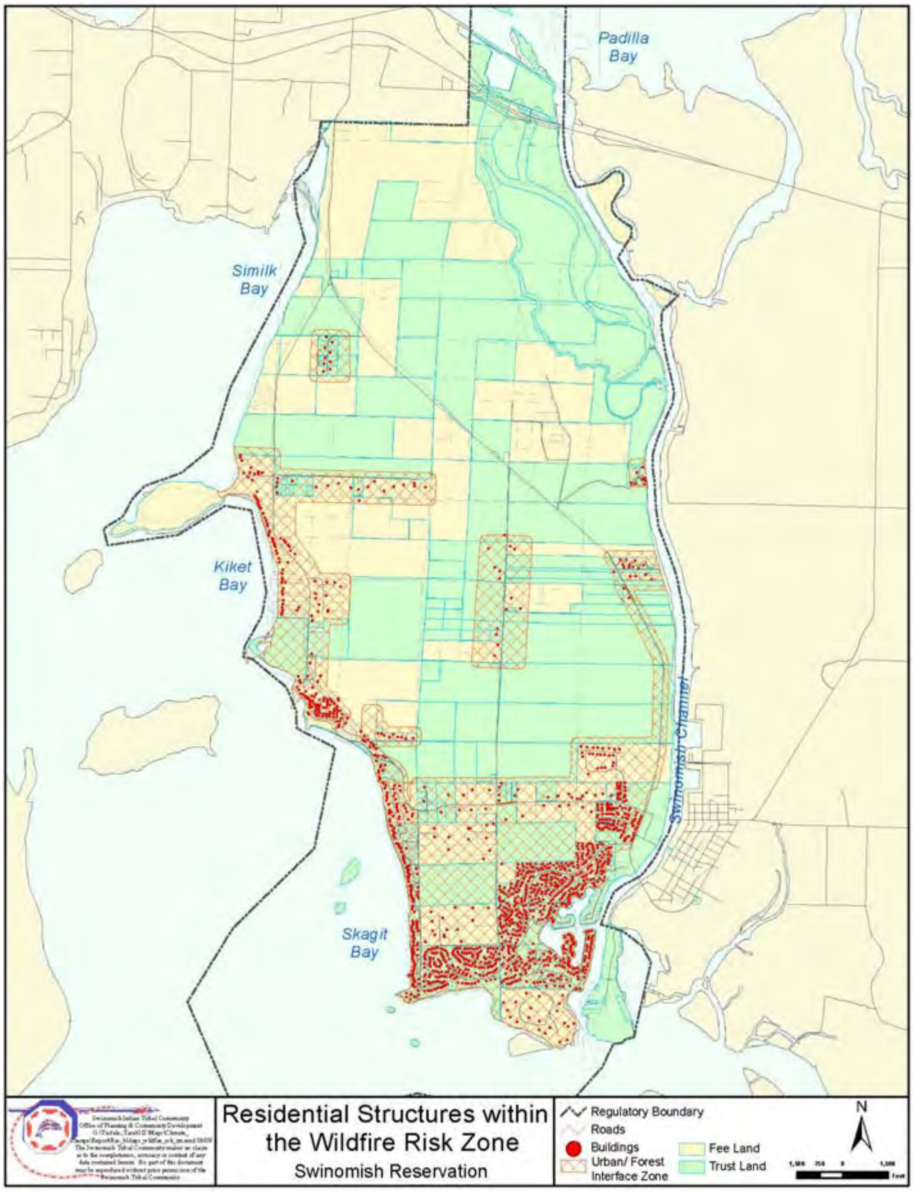


Figure 6-4. Residential Structures within Primary Wildfire Risk Zone.

PROPERTY WITHIN PRIMARY WILDFIRE RISK ZONES (Urban/Forest Interface)			
Property Type	**Number**	**Acres**	**Approx. Value**
Residential	1,368	1,995	$ 493,688,000
Non-Residential	9	143	$ 4,806,000
Buildable Lots	183	80	$ 19,918,000
TOTAL	**1,560**	**2,218**	**$ 518,412,000**

Table 6-4. Property Within Primary Wildfire Risk Zones.

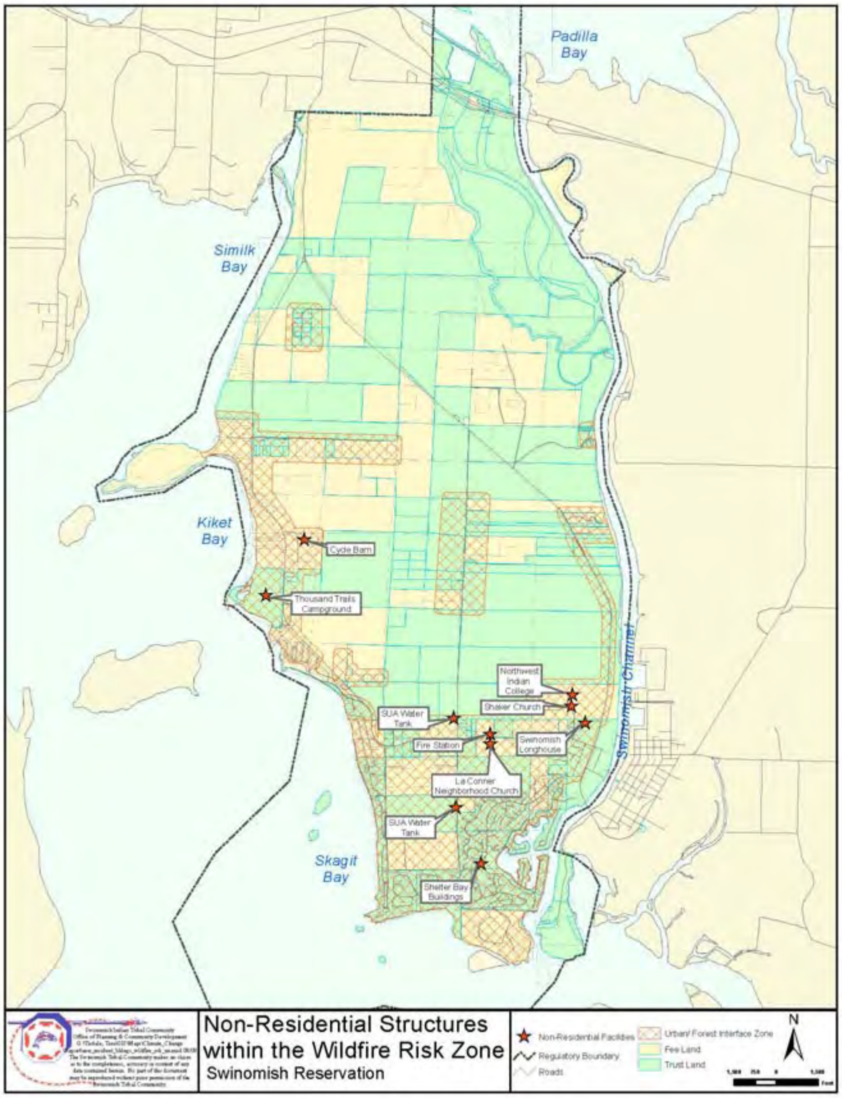


Figure 6-5. Non-Residential Structures within Primary Wildfire Risk Zone

Non-Residential Facilities Within Primary Wildfire Risk Zone		
Facility	**Location**	**Approx. Value**
Swinomish Longhouse	Swinomish Village	$250,000
Fire District 13 station (new)	Snee-Oosh Rd., west of Village	$320,000
LaConner Neighborhood Church	Snee-Oosh Rd., west of Village	$251,000
Shelter Bay Community buildings	Shelter Bay	$750,000
Thousand Trails Campground	Lone Tree Point	$1,444,000
Northwest Indian College	Tallawhalt	$550,000
Shaker Church (new)	Tallawhalt	$300,000
Swinomish Utility water tanks	Indian Rd.	$600,000
Cycle Barn	Mill Rd. Lane	$341,000
	TOTAL	**$4,806,000**

Table 6-5. Non-Residential Facilities Within Primary Wildfire Risk Zone.

The largest community within the zone, the Shelter Bay Community with approximately 900 lots, has taken steps to implement the "Firewise" program to reduce the risk of wildfire; while this is an important step toward minimizing the risk, many trees remain in Shelter Bay and denser stands exist to the west, a dangerous direction from which a fire outbreak could erupt, given prevailing winds. Given the examples of devastating fires in communities around the country and the similarity of conditions and potential within this risk zone, structures and communities within this zone are deemed to be highly vulnerable to potential wildfire.

6.5 On-Reservation Fishing and Shellfish Harvest

Beach seining and shellfish harvesting have long traditions with the Tribe and are important elements of Tribal cultural and historical identity. Salmon have an equally prominent place in Tribal traditions, and the Tribe, through its fisheries branch, has invested significant time and effort into enhancement and protection of salmon habitat on the Reservation. Much work has gone into enhancement of estuarine habitat for salmon at various shoreline locations, as well as protection of stream habitat that is vital to viability of salmon production and survival. Key pockets of estuarine habitat around the perimeter of the Reservation are at risk of loss from eventual sea level rise, and increased sedimentation from higher runoff will threaten stream viability of habitat. The few beach seining sites on the Reservation are highly vulnerable to eventual and permanent inundation from sea level rise, and lacking the ability to perform seining at somewhat higher elevation as sea level rises, such activity could eventually disappear entirely.

Shellfish beds on the Reservation were previously identified through mapping of sensitive areas under the Shoreline and Sensitive Areas ordinance. Productive shellfish beds are located along the west shore of the Reservation, as shown in Figure 5-3. By their nature, shellfish beds are found in existing intertidal zones periodically inundated by fluctuating tides, but are not permanently inundated. These shellfish beds are entirely at risk of loss through permanent inundation, being located in tidal zones projected to experience increasing sea level rise, as potential migration of shellfish beds will ultimately be blocked by steeper shorelines and bluffs. Such inundation would result in significant loss of long-standing traditional tribal shellfish harvest opportunities.

In addition, shellfish populations may be vulnerable to the effects of increasing acidification of marine waters, should such changes occur as is currently being observed in Pacific coastal waters. Increasing acidity would cause the calcium carbonate shells to dissolve, essentially destroying the viability of the organisms. Populations are considered to be highly vulnerable to such potential impacts.

6.6 Potential Erosion Areas

Some structures which appear to be well above likely sea level rise inundation or surge levels could be impacted by shoreline erosion. In areas where there is no bank protection such as rock outcrops or bulkheads, a rise in sea level could accelerate erosion and put structures at risk on both medium banks and on high marine bluffs where some structures have been constructed too close to the top of the bank or bluff. Strong storms and tidal surges could further exacerbate erosion and slumping of banks and bluffs, undermining and threatening structures. The general factors determining potential for erosion include degree of slope, fetch of shoreline grade, soil composition, and degree of stabilizing vegetation, but it must be noted that erosion of unprotected shorelines, bluffs and high banks within the Reservation has not been well studied or documented. While these processes and effects already occur, the extent to which they may be accelerated with sea level rise is uncertain; where the right combination of factors occurs, however, there is potential for erosion. It would seem prudent, therefore, to identify potential erosion areas, with the expectation that setback of structures within those zones will need to be determined with additional study. Figure 6-6 illustrates shoreline areas potentially susceptible to erosion from either sea level rise or storm/tidal surge, based on current knowledge of contributing factors.

The response of homeowners and others to such risks is key, not only to assessing potential impacts to those structures, but also to assessing the resulting impacts of home protection on adjacent habitat and resources when coupled with the effects of sea level rise. If homes at risk are allowed to construct or raise bulkheads for protection, those structures in turn will divert impacts onto nearby beaches and nearshore environments. Waves reflect off bulkheads, scouring the beach and impacting habitat such as forage fish spawning areas and eelgrass beds. Built structures along the shoreline can also interfere with longshore transport of sediment or with inputs of sediments from eroding bluffs. This could cause additional problems associated with shoreline impacts by starving the systems of sediments needed for accretion of beaches, making it harder for natural processes to keep ahead of sea level rise.

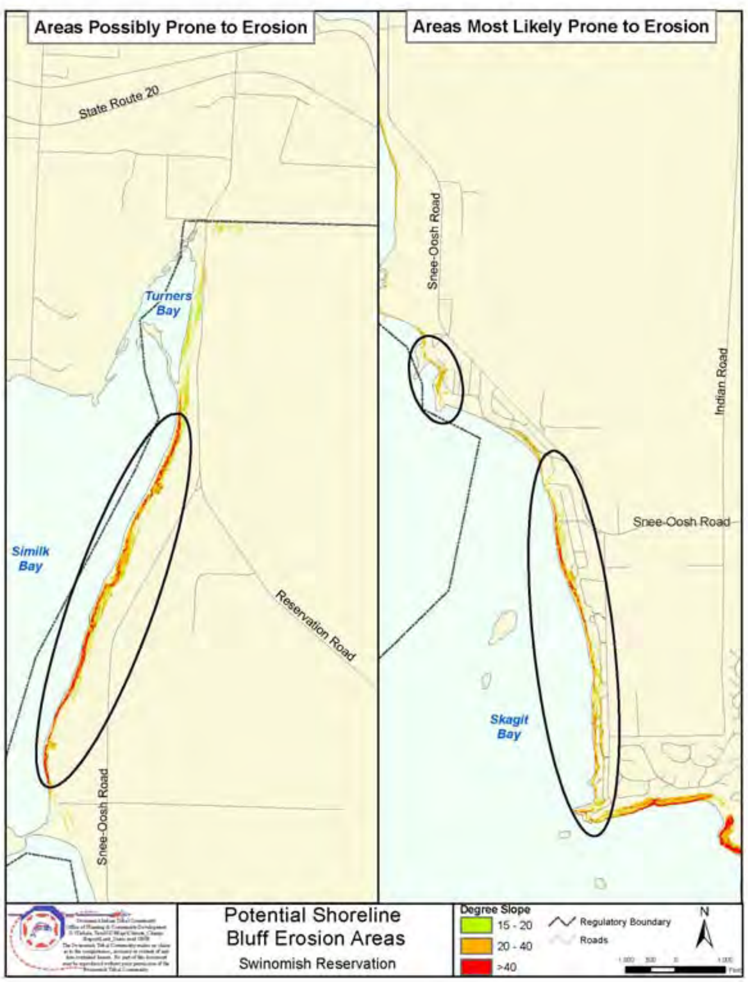


Figure 6-6. Potential Shoreline Bluff Erosion Areas.

7. Risk Analysis

The ultimate outcome of this project is to identify and prioritize appropriate strategies to respond to climate change challenges. Choosing such strategies and assigning proper priorities necessarily relies upon the risk and probability of given events. Once the vulnerability assessment is complete, risk analysis is a relatively straight-forward, quasi-computational exercise. The vulnerability assessment produces the level of impact, or "consequence," for impacts on given sectors, and this consequence is combined with previously estimated probability to derive the estimated risk. Following the methods in the King County guidebook, we estimate the risk with the following equation (CIG 2007):

Consequence X Probability = Estimated Risk.

Applying this methodology to vulnerable areas within the Reservation, a risk analysis was performed for identified impacts and vulnerabilities, as summarized in Table 7-1. This level of analysis is intended to inform and guide later critical decision-making on adaptation options and is not framed for the purposes presented here in the context of more traditional uses of risk, such as insurance estimating or financial planning. Financial issues are certainly a consideration in terms of cost of proposed actions, and will be considered as such in the ensuing phase of work to determine recommended actions, but risk as used here will be applied to help guide evaluation of adaptation policy options.

In that context, the analysis presented here is subject to further consideration and/or revision based on other factors such as timeframes for impacts/actions, geographic scope of impacts/ actions, and competing priorities. Much of this additional analysis will occur as part of the second phase of this project to evaluate potential strategies and actions. This later phase of work will involve input from a wide cross-section of interests, including Tribal departments and staff, community groups, advisory groups, and outside entities with whom coordination may be sought. The bottom line for decision-makers is that ultimate determination of perceived risk is not necessarily a fixed item but may also be subject to individual perceptions of issues including risk.

TABLE 7-1. RISK ANALYSIS OF POTENTIAL IMPACTS BY SECTOR HUMAN/BUILT SYSTEMS

Sector	Element	Potential Impacts	Vulnerability (impact level)	Probability of Impact	Estimated Risk
Land Use	Shoreline Development	Increasing inundation from gradual sea level rise	High	High	High
		Increasing frequency and severity of storm surges	High	High	High
		Beach/bluff erosion with increasing rise/surges	High	High	High
	Stormwater Control	Inundation/backup of drainage lines and discharge points from higher tides, storm surges	Medium	Medium	Medium
		Damage to discharge outfalls from bank erosion	High	Medium	Medium-High
	Hazardous Sites	Spread of contaminants through inundation/ flooding from higher tides, storm surges	High	Medium	Medium-High
	Agriculture	Eventual inundation as rising high tide tops dikes	Medium-High	High	Medium-High
		Storm events push tidal surges over dikes	Medium	High	Medium-High
		Increasing salinization from salt intrusion with rising sea levels	Medium	High	Medium-High
	Housing/ Residential	Increasing inundation from gradual sea level rise and higher tides	High	High	High
		Storm-tidal surge flooding, gently sloping shorelines, or where surge tops bank/seawall/dikes	High	Medium	Medium-High
		Bank erosion, threatening near-bank structures	Medium	Medium	Medium
		Increased risk of wildfire from increasingly drier conditions	Medium-High	High	Medium-High

Sector	Element	Potential Impacts	Vulnerability (impact level)	Probability of Impact	Estimated Risk
(Land Use cont'd.)	Commercial/ Industrial	Increasing inundation from gradual sea level rise and higher tides	High	High	High
		Storm-tidal surge flooding, gently sloping shorelines, or where surge tops bank/seawall/dikes	High	Medium	Medium-High
		Bank erosion, threatening near-bank structures	Medium	Medium	Medium
		Increased risk of wildfire from increasingly drier conditions	Medium-High	High	Medium-High
	Recreation	Increasing inundation of public beaches, parks from gradual sea level rise	High	High	High
		Storm-tidal surge flooding, gently sloping shorelines, or where surge tops bank/seawall/dikes	High	Medium	Medium-High
		Spread of contaminants through inundation/ flooding from higher tides, storm surges	Medium	Medium	Medium
Public/Private Utilities	Water	Reduced supply due to decreased source (river/ snowpack), increased demand	Medium	Medium	Medium
		Contamination of local supplies from inundation, flooding	Medium	Medium	Medium
	Wastewater	Inundation of treatment facilities from higher tides, storm surges	Low	Medium	Low- Medium
	Communications	Service disruption from severe storm events; duration of outage proportional to severity	High	Medium	Medium-High
	Energy/Power	Service disruption from severe storm events; duration of outage proportional to severity	High	Medium	Medium-High
		Increased energy demand to counter higher temperatures	Medium	Medium	Medium
	Waste Disposal	Spread of waste from during flooding from higher tides, tidal surges, storm events	Medium	Medium	Medium

Sector	Element	Potential Impacts	Vulnerability (impact level)	Probability of Impact	Estimated Risk
Emergency Services	Police	Increased demand for assistance/ response during storm events, outages, flooding	Medium	Medium	Medium
	Fire	Increased demand for assistance/ response to wildfire, storm events, outages, flooding	Medium- High	High	Medium-High
	Other Emergency (disaster, repair crews, etc.)	Increased demand for assistance/ response during storm events, outages, flooding	Medium	Medium	Medium
Human Health	Heat-related illness	Increased demand for and stress on services to treat heat-related health issues (heat exhaustion/stroke, etc.)	Medium-High	High	Medium-High
	Disease vectors	New/increased disease vectors, and related outbreaks	Medium	Medium	Medium
	Pollution-related illness	Increased pollution-related illness exacerbated by weather and climate conditions	Medium- High	Medium	Medium-High
	Solar radiation issues	Increase in skin cancers from higher UV radiation levels	Medium	Medium	Medium
	Respiratory disease	Increasing incidence of asthma, and allergen-related problems	Medium- High	Medium	Medium-High
	Food-related illness from contaminated seafood	Increased incidence of poisoning from consuming toxin-laden seafoods	Medium	Medium	Medium
Transportation	Access/ Circulation	Inundation of access routes, travel disruption, isolation from mainland, as higher tides top dikes	High	High	High
		Travel disruption/road closures due to stronger/ more frequent storm/tidal surge events	Medium-High	Medium	Medium
		Incidental road closure/ travel disruption from wildfire	Medium-High	Medium	Medium
	Road System Integrity	Flooding damage from storm/tidal surge, buckling/cracking from higher temperatures	Medium	Medium	Medium

Sector	Element	Potential Impacts	Vulnerability (impact level)	Probability of Impact	Estimated Risk
(Transportation cont'd.)	Bridges	Erosion of bridge footings from higher tides/storm surges	Medium	Medium	Medium
		Increased deterioration/ fatigue of bridge joints from increased or prolonged heat	Medium	Medium	Medium
	Public Transit	Service disruption, impact-related closures	High	Medium	Medium-High
	Marine transport facilities	Increasing inundation of marine facilities and ports from gradual sea level rise and higher tides	High	High	High
Cultural Resources	Coastal sites/ artifacts	Increasing inundation of sites from gradual sea level rise	High	High	High
	Cultural remains	Disturbance/exposure from severe storm events	High	Medium	Medium-High
	Cultural use plants	Loss/migration of traditional cultural use species	High	Medium	Medium-High
	Treaty areas	Impacts to "U & A" treaty resources (e.g., fishing, hunting)	(TBD)	Medium	(TBD)
	Shellfish harvesting	Potential loss of harvest sites and opportunities due to impacts to shellfish populations and habitat	High	High	High
	Beach seining	Potential loss of beach seining sites and opportunities	High	High	High
	Marine facilities	Increasing impacts to dock facilities from rising sea level, impairing fishing activities	High	High	High

RISK ANALYSIS OF POTENTIAL CLIMATE CHANGE IMPACTS BY SECTOR
NATURAL SYSTEMS

Sector	Element	Potential Impacts	Vulnerability (impact level)	Probability of impact	Estimated Risk
Shoreline/ Beaches	(general)	Increasing tidal inundation from gradual sea level rise	High	High	High
	(general)	Increasing frequency and severity of storm/ tidal surges	High	High	High
	(general)	Beach erosion with increasing rise/surges	High	High	High
Tidelands/ Marine Habitat	Habitat viability	Increasing inundation from sea level rise forcing gradual migration to maintain viability	Medium-High	High	Medium-High
	Estuarine beaches	Increasing inundation and loss from rising sea level	High	High	High
Fish & Wildlife	Shellfish	Increasing inundation of shallows, estuaries	Medium	High	Medium-High
		Weakened viability due to habitat changes	High	Medium	Medium-High
	Fin Fish	Increasing inundation of shallows, estuaries, spawning grounds	Medium-High	High	Medium-High
		Weakened viability due to habitat changes (temperature, acidification, etc.)	High	Medium	Medium-High
	Waterfowl/ Shorebirds	Loss of forage areas and opportunities due to impacts on food sources	Medium-High	Medium	Medium-High
	Upland wildlife/ habitat	Degradation/conversion from higher temperature and increased wildfire incidence	High	Medium	Medium-High
		Stressed viability from habitat and temperature changes, forced migration	High	Medium	Medium-High

Sector	Element	Potential Impacts	Vulnerability (impact level)	Probability of impact	Estimated Risk
Water Resources	Freshwater	Declining consistency/ volume of in-stream flows, earlier peak runoff	Medium-High	Medium	Medium-High
	Groundwater	Increasing salinization from salt water intrusion	Medium-High	Medium	Medium-High
	Wetlands	Increasing inundation from higher tides, storm surges (estuarine)	High	High	High
		Decline/degradation of upland wetlands from reduced flow input	High	Medium	Medium-High
Forest Resources	(general)	Lower moisture content, increased potential for destructive wildfire	High	High	High
		Heat stress, increase in drought-tolerant species, decrease in drought-sensitive species	Medium-High	Medium	Medium-High
		Greater pest infestations, disease vectors (bark beetles, fungus, etc.)	Medium-High	High	Medium-High
Air Quality	(general)	Increasing stagnation, noxious elements/ parameters due to higher average temperatures	Medium	Medium	Medium

8. Conclusions

The scientific evidence of climate change is increasingly abundant and convincing. Warmer global temperatures, melting glaciers, reduced mountain snow pack, rising sea levels, declining summer river flows, and other factors point to such evidence. Given the geographic location and characteristics of the Swinomish Indian Reservation, climate change impacts on the Reservation community are perceived to potentially be both significant and long-term.

Determining proper responses to climate change impacts is essentially a deliberative game of "what-if's." What if sea level rise eventually threatens to cut off access to the Reservation from the mainland? What if higher tides or tidal surges threaten valuable commercial, residential, or infrastructure investments? What if dock facilities for fishing or other commercial purposes became unusable? What if a serious wildfire broke out in a densely developed area of the Reservation during a searing heat wave? What if any or all of these were to happen sooner than predicted? This project attempts to address such critical questions, and this report is the first step toward the answers.

The scope of this assessment is broad by design to help ensure that this first look at potential issues will be properly comprehensive and will allow for the fullest consideration and prioritization of issues. The range of potential impacts identified in this assessment therefore affects a broad cross-section of interests and assets. While numerous impacts were ranked as significant, the broad scope of the project and identified issues necessarily limited the depth to which any single issue or group of issues could be examined, and a number of issues warrant such further examination. The need for further study, coupled with the expected long-term duration of climate changes, mandates that considered responses will need to be crafted over timeframes much longer than is customary for conventional planning efforts. The extended timeframes needed for planning and implementing responses will present new and possibly unique challenges for those responsible for undertaking response, including how to institutionalize and adapt response to changing information and conditions over time.

Building upon the results of this analysis, risk and vulnerability can be used together to inform and guide the process of prioritizing planning areas (sectors) for strategy development and implementation, which will be a key component of the final action plan. Table 8-1 below is a generalized version of the vulnerability-risk prioritizing methodology. This prioritization task will be an important component of the next phase of work during the second year of the project.

PLANNING AREAS WITH SYSTEMS THAT ARE...

	Low Vulnerability	**High Vulnerability**
High Risk	***May be** priority planning areas*	***Should be** priority planning areas*
Low Risk	***Are unlikely to be** priority planning areas*	***May be** priority planning areas*

Source: Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments

Table 8-1. Sample Vulnerability-Risk Matrix for Identifying Priority Planning Areas

9. References

The following reports have been reviewed under this project for the purpose of assessing climate change impacts; references in boldface indicate primary sources cited:

Andrey J, Mills B (2003) Climate change and the Canadian transportation system: vulnerabilities and adaptations. In: Andrey J, Knapper J (eds) Weather and transportation in Canada. Department of Geography, University of Waterloo. Ontario, Canada

Bartlett KH, Kidd SE, Kronstad JW (2008) The emergence of *Cryptococcus gattii* in British Columbia and the Pacific Northwest. Current Infectious Disease Reports 10:58-65.

Beggs PJ, Bambrick HJ (2005) Is the global rise of asthma an early impact of anthropogenic climate change? Environmental Health Perspectives 113:915-919. Doi:10.1289/ehp.7724. Available via http://dx.doi.org/ Accessed 20 April 2005

Booth S, Zeller D (2006) Mercury, food webs, and marine mammals: Implications of diet and climate change for human health. Environmental Health Perspectives 113(5):521-526. Published online 2005 February 2. Doi:10.1289/ehp.7603

Bouma MJ, van der Kaay HJ (1994) Epidemic malaria in India and the El Niño southern oscillation. Lancet 344:1638–1639, Pmid:7984012.

Bunyavanich S, Landrigan C, McMichael A, Epstein P (2003) The impact of climate change on child health. Ambulatory Pediatrics, Volume 3, Issue 1, Pages 44-52

Colwell RR (1996) Global climate and infectious disease: The cholera paradigm. Science 274:2025–2031. Pmid:8953025

Cheney D, Dewey B (2009) Shellfish and climate change: Ecological and economic effects. Presentation at the Washington Climate Change Impacts Assessment Conference Feb. 12, 2009. Climate Impacts Group, University of Washington. Seattle, WA

Colwell RR, Patz JA (1998) Climate, infectious disease and human health: An interdisciplinary perspective, American Society for Microbiology. Washington, DC

de Chavez R, Tauli-Corpuz V (2008) Guide on climate change & Indigenous Peoples. Tebtebba Foundation Indigenous Peoples' International Centre for Policy Research and Education, Baguio City, Philippines

DHPE (Directors of Health Promotion and Education). Internet resource site for infectious diseases. http://www.dhpe.org/infect/index.html Accessed 23 March 2009

Diffey B (2004) Climate change, ozone depletion and the impact on ultraviolet exposure of human skin. Physics in medicine and biology 49 R1-R11

Diggle L (2007) Rotavirus diarrhea and future prospects for prevention. British Journal of Nursing 16(16):970–4. Pmid:18026034

Duffy A, (1999) Temperature and thermal expansion. Boston University Physics Department. http://physics.bu.edu/~duffy/py105/Temperature.html Accessed 9 April, 2009

Fischer TK, Viboud C, Parashar U et al (2007) Hospitalizations and deaths from diarrhea and rotavirus among children <5 years of age in the United States, 1993–2003. Journal of Infectious Diseases. 195 (8): 1117–25. Doi:10.1086/512863. Pmid:17357047

Gleick PH, Cooley H, Heberger M, Herrera P, Moore E (2009) The impacts of sea-level rise on the California coast. Pacific Institute CEC-500-2009-024-D

Glick P, Clough J, Nunley B (2007) Sea level rise and coastal habitats in the Pacific Northwest: An analysis for Puget Sound, Southwestern Washington, and Northwestern Oregon. National Wildlife Federation

Gubler DJ, Reiter P, Ebi KL, Yap W, Nasci R, Patz JA (2001) Climate variability and change in the United States: Potential impacts on vector- and rodent-borne diseases. Environmental Health Perspectives 109 Suppl 2:223-33

Guinotte J, Fabry V (2008) Ocean acidification and its potential effects on marine ecosystems. Annals of the New York Academy of Sciences 1134:320-342, Doi:10.1196/1439.013

Hansen T (2008-2009) NW coastal nations at risk of climate change disruption. News from Indian Country 28 Apr 2008. http://indiancountrynews.net/index.php?option=com_content&task=view&id=3080&Itemid=5. Accessed 7 July, 2009

Hood WG, (2008) Estuarine habitat restoration with global climate change and rising sea-level. Skagit River Systems Cooperative, Powerpoint presentation at Skagit Basin Climate Change Workshop, March 5-6, 2009

Hyman RC, Potter JR, Savonis MJ, Burkett VR, Tump JE (2008) Impacts of climate change and variability on transportation systems and infrastructure: Gulf Coast Study, Phase I. U.S. Climate Change Science Program (USCCSP), Subcommittee on Global Change Research, Committee on the Environment and Natural Resources, Executive Office of the President, Washington, DC.

Iacobellis, S.F., J. R. Norris, M. Kanamitsu, M. Tyree and D. R. Cayan. 2009. Climate variability and California low level temperature inversions (Draft). Scripts Institute of Oceanography. 47 pages.

IPCC Working Group I (2007) Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Solomon S, Qin D, Manning M, Chen Z, Marquis M, Avery KB, Tignor M, Miller HL, (eds) Cambridge University Press, Cambridge, United Kingdom and New York, NY

IPCC Working Group II (2007) Climate change 2007: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry ML, Canziani OF, Palutikof LP, van der Linden PJ, Hanson CE (eds), Cambridge University Press, Cambridge, United Kingdom and New York, NY

Kairas P, Rybczk J, (2009) Sea Level Rise and eelgrass (Zostera marina) production: A spatially explicit relative elevation model for Padilla Bay, WA Science Direct website

Lipp EK, Rose JB (1997) "The role of seafood in foodborne diseases in the United States of America" Rev Sci Tech 16:620–640, Pmid:9501377

Littell, JS, Elsner MM, Whitely Binder LC, and Snover AK (eds) (2009) "The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate" Climate Impacts Group, University of Washington, Seattle, WA

Lobitz B, Beck L, Huq A, Wood B, Fuchs G, Faruque AS, Colwell R (2000) Climate and infectious disease: Use of remote sensing for detection of Vibrio cholerae by indirect measurement. Proceedings of the National Academy of Science USA 97:1438–1443, Pmid:10677480

Mantua N, Hare S (2002) "The Pacific Decadal Oscillation" Journal of Oceanography 58:35-44.

Mote P, Salathé Jr. E (2009) Future climate change in the Pacific Northwest. In: The Washington Climate Change Impacts Assessment: Evaluating Washington's future in a changing climate. Climate Impacts Group, University of Washington, Seattle, WA.

Mote P, Petersen A, Reeder S, Shipman H, Whitely Binder LC (2008) Sea level rise in the coastal waters of Washington State" Climate Impacts Group, University of Washington, Seattle, WA

NCAI (National Congress of American Indians) (2009) 2009 mid-year session, Resolution NGF-09-031. http://www.ncai.org/index.php?id=105&selectpro_resid=42. Accessed 7-9-09.

National Research Council of the National Academies (US) (2008) The potential impacts of climate change on U.S transportation. Committee on Climate Change and U.S. Transportation. Transportation Research Board Special Report 290. Transportation Research Board and Division on Earth and Life Studies. Washington, D.C.

Patz JA, Engelberg D, Last J (2000) "The effects of changing weather on public health." Annual Review of Public Health 21:271–307, Pmid:10884955

Patz, JA. (2002) "A human disease indicator for the effects of recent global climate change" Proceedings of the National Academy of Sciences

Rahmstorf, S. (2007) "A semi-empirical approach to projecting future sea-level rise" Science 315:368-370, Pmid:1135456

Snover AK, Whitely Binder LC, Lopez J, Willmott E, Kay J, Howell D, Simmonds J (2007) *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments.* In association with and published by ICLEI, Oakland, CA.

Soo Hoo, WK, and Sumitani M (2005) Climate change will impact the Seattle Department of Transportation. Office of City Auditor, August 9, 2005

Swinomish Indian Tribal Community (1991) A gathering of wisdoms: tribal mental health: a cultural perspective. Swinomish Tribal Mental Health Project, La Conner, WA

Swinomish Indian Tribal Community (1996) The Swinomish Comprehensive Plan: the official land use comprehensive plan for the Swinomish Indian Reservation. La Conner, WA

Tebaldi C, Hayhoe K, Arblaster JM, Meehl GA (2006) Going to the extremes. Climatic Change, 79, 185-211.

Titus J (2008) Does sea level rise matter to transportation along the Atlantic coast? In: The potential impacts of climate change on U.S transportation. The National Research Council of the National Academies, Transportation Research Board and Department of Earth Science and Life Sciences, Washington, D.C.

van Wijngaarden, W. A. and L. A. Vincent. 2004. Bulletin of the American Meteorological Society.

Vizuete, Will, V. Junquera, V., Mcdonald-Buller, E., McGaughey, G., Yarwood, G. and Allen, D. 2002. Effects of temperature and land use on predictions of biogenic emissions in Eastern Texas. Atmospheric Environment. Vol. 36 No. 20. 3321-3337.

Warren, LP (1993) Scour at bridges- What's it all about? U.S. Geological Survey and Massachusetts Highway Department. Open File Report 93-480 http://ma.water.usgs.gov/publications/ofr/scour.htm Accessed 9 April 2009

Washington Department of Ecology (2006) Impacts of climate change on Washington's economy: A preliminary assessment of risks and opportunities. Publication No. 07-01-010.

White, M. L., R. S. Russo, Y. Shao, J. L. Ambrose, K. Haase, E.K. Frinak, R.K. Varner, O. W. Wingenter, H. Mao, R. Talbot and B. C. Sive. 2009. Are biogenic emissions a significant source of summertime atmospheric toluene in the rural Northeastern United States?. Atmospheric Chemistry and Physics, Volume 9, Issue 1, pp 81- 92.

Willet, K. M., P.D. Jones, N.P., Gillette and P. W. Thome. 2008. Recent changes in surface humidity: development of HadCRUGH Dataset. Journal of Climate.

Williams T, Hardison P (2006) Impacts on Indigenous peoples. In: Climate change and Pacific rim Indigenous nations. Northwest Indian Applied Research Institute (NIARI). The Evergreen State College, Olympia, WA

Wooler S (2004) The changing climate: Impact on the Department for Transport. Department for Transport, London, United Kingdom

Zeng, G. J.A. Pyle, and P. J. Young. 2008. Impact of climate change on tropospheric ozone and its global budgets. Atmos. Chem. Phys., Vol. 8, 369-387.

Zervas C (2005) Response of extreme storm tide levels to long-term sea level change. National Oceanic Atmospheric Administration (NOAA) Center for Operational Oceanographic Products and Services.

SWINOMISH CLIMATE CHANGE INITIATIVE
IMPACT ASSESSMENT TECHNICAL REPORT

APPENDIX 1

PROCLAMATION
OF
THE SWINOMISH INDIAN SENATE
ON
A SWINOMISH CLIMATE CHANGE INITIATIVE

WHEREAS, there is overwhelming evidence of climate change occurring both globally and regionally, as supported by scientific documentation of the effects of climate change and global warming; and

WHEREAS, the effects of climate change, while evident globally and regionally, have the potential for significant impacts on the local community, including the Swinomish Indian Tribal Community, the Swinomish Indian Reservation, and Swinomish Usual and Accustomed areas, due to projected impacts from rising temperatures, rising sea level, and other associated effects on the local environment, natural resources, water supplies, fish and wildlife, and critical infrastructure on which the Swinomish Indian Tribal Community has traditionally relied; and

WHEREAS, the projected impacts of climate change may include loss of tidelands and habitat, reduced viability of fish and wildlife species, damage to shoreline property and forest resources, damage to infrastructure and facilities, and associated risks to public health and welfare; and

WHEREAS, it is the duty and responsibility of the Swinomish Indian Senate to provide for the well-being of the Swinomish Indian Tribal Community, as well as attend to the well-being of those resources, natural systems, and human systems which provide crucial support to the Swinomish Indian Tribal Community and the Swinomish Indian Reservation; and

WHEREAS, the Senate has considered the potential effects and impacts of climate change on the Swinomish Indian Tribal Community, the Swinomish Indian Reservation, and attendant resources, natural systems, and human systems sustaining the community, and has registered concern for such effects and impacts;

NOW THEREFORE, THE SENATE HEREBY PROCLAIMS support for a Swinomish Climate Change Initiative and declares the intent and commitment of the Senate to address the potential effects of climate change, and also hereby declares and directs the following actions to be taken under this Initiative:

To undertake efforts as possible to determine the potential local effects of climate change as may affect the Swinomish Indian Tribal Community and the Swinomish Indian Reservation, including effects and projected impacts on the local environment, forestry resources, agriculture, fish and wildlife, water resources, and shorelines, as well as critical infrastructure and public health;

To develop appropriate policies and strategies for addressing effects and projected impacts of climate change on the Tribe and the Swinomish Indian Reservation and for contributing to reduction of the causes of climate change and global warming;

To develop appropriate goals for addressing effects of climate change and for contributing to reduction of the causes of climate change;

To develop potential programmatic and/or regulatory actions and changes consistent with said policies, strategies, and goals as appropriate to addressing the effects of climate change and contributing to reduction of the causes;

To communicate and coordinate with local, state, regional, and national entities and jurisdictions on addressing projected impacts of climate change, including government-to-government cooperation and identification of funding sources and opportunities as possible and available; and

To communicate to and with the local community about issues and concerns regarding the effects and projected impacts of climate change; and

BE IT FURTHER PROCLAIMED that all Swinomish governmental committees and departments shall assess how best to implement the actions under this Initiative as specified above, how best to incorporate such actions into ongoing programs and activities or into such new activities as may be proposed, and that the Senate hereby designates a Swinomish Climate Change Task Force to be comprised of designated representatives of the Swinomish Office of Planning and Swinomish Public Works Department, working in cooperation with the Swinomish Utility Authority and Skagit River System Cooperative, to coordinate implementation of this Initiative and to provide support for Swinomish governmental committees and departments in this effort, under the guidance and direction of the Senate.

By the authority vested in the Swinomish Indian Senate, this Proclamation is made this 2nd day of October, 2007.

M. Brian Cladoosby

M. Brian Cladoosby, Chairman
Swinomish Indian Senate

SWINOMISH CLIMATE CHANGE INITIATIVE
IMPACT ASSESSMENT TECHNICAL REPORT

APPENDIX 2

Climate Change Impacts in the Pacific Northwest: Implications for the Swinomish Indian Reservation

Prepared for the Swinomish Indian Tribal Community
by
Ingrid M. Tohver and Nathan Mantua, PhD
Climate Impacts Group
University of Washington, Center for Science in the Earth System

Climate Change Impacts in the Pacific Northwest: Implications for the Swinomish Indian Reservation

by
Ingrid M. Tohver and Nathan Mantua, PhD
Climate Impacts Group
University of Washington, Center for Science in the Earth System

I. Global climate change impacts on temperature and precipitation

A. Temperature

The projections of climate change vary depending on future greenhouse gas emissions and global climate model used. The Intergovernmental Panel on Climate Change (IPCC) considered a range of possible emissions scenarios (SRES) based on socioeconomic and energy production developments to generate global projections of future temperature and precipitation. Here we focus on the "A1B" emissions scenario, which is considered the middle-of-the-road scenario, where population peaks mid-century and there is an intermediate rate of adopting clean energy initiatives. The Climate Impacts Group (CIG) at the University of Washington has created regional projections from 20 global climate models used in the IPCC's fourth assessment report (Mote and Salathé 2009). Mote and Salathé's (2009) estimates for the average increases in temperature for the Pacific Northwest under the A1B scenario are 1.3 ^{o}C (2.3 ^{o}F) by the 2020s, 2.3 ^{o}C (4.1 ^{o}F) by the 2040s and 4 ^{o}C (7.1 ^{o}F) by the 2080s, with the greatest increases occurring in summer months[1]. Other analyses attempt to capture the local effects of topography and coastal-terrain on regional climate to determine the temperature projections on 6x6 km grids (Elsner, Cuo et al. 2009; Salathé, Leung et al. 2009). From the resulting projections of these latter analyses, we can determine the average change in temperature using 12 models under the A1B scenario for the gridpoint containing the Swinomish Reservation. Monthly average temperature changes from the 1970-99 average are shown for each of 12 global climate models in Figure 1. It is worth noting that individual projections differ by as much as +/- 2 °C for any given year or decade, with the short-term variations reflecting both the "natural variability" and differences in each model's response to the same specified changes in greenhouse gas emissions. The heavy black line shows the ensemble average, which is approximately 3.5 °C by the year 2100, while the majority of individual model projections range between 2 and 4 °C for 2100.

[1] Projected changes are relative to the 1970-99 averages.

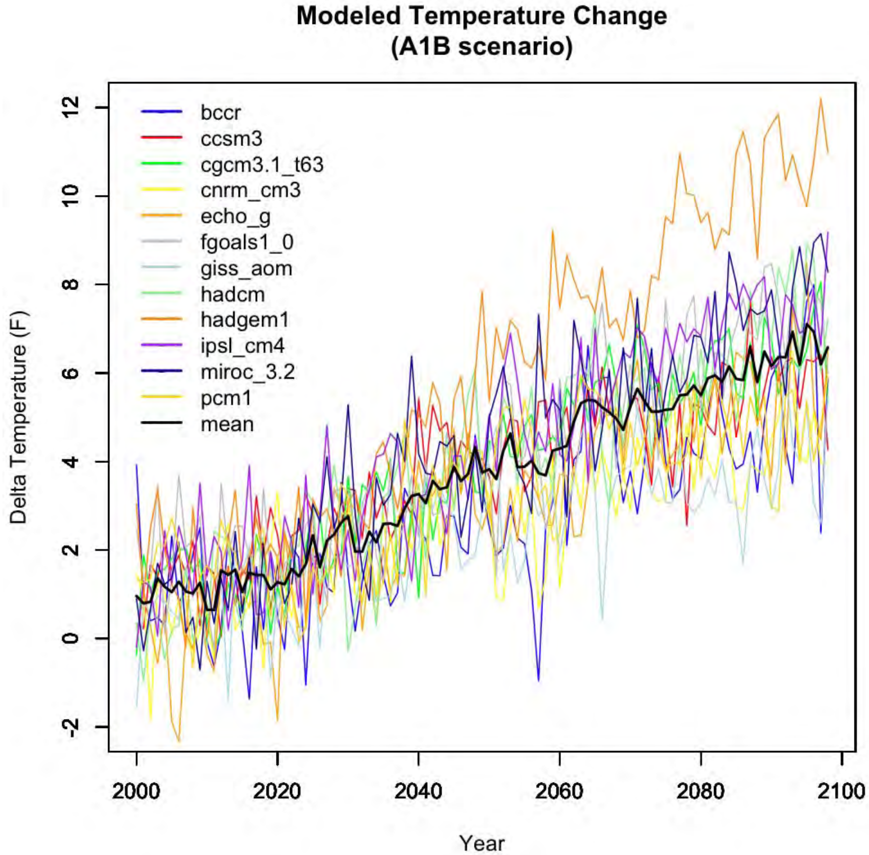


Figure 1: Average change in annual mean temperature compared to the 1970-1999 levels.

B. Precipitation

Although the uncertainties for precipitation trends are greater than for temperature, most projections agree that the changes in precipitation will have a seasonal signal in the Pacific Northwest region. In general, the projected changes in regional precipitation are minimal, but on balance climate models indicate wetter winter months and drier summer months (Thomson, Bornhold et al. 2008; Casola, Cuo et al. 2009; Mote and Salathé 2009). Specifically for the A1B scenario, regional models estimate an average 4.2% increase in winter precipitation and a 11.2% decrease in summer precipitation by the 2040s, compared to the 1980s (Mote and Salathé 2009). These future precipitation patterns have implications for snowmelt and freshwater flows (discussed later in this report).

Much like Figure 1 for temperature, Figure 2 shows the change in average precipitation compared to the 1970-1999 levels for the gridpoint overlying the Swinomish Reservation. Notably, the trend is less detectable for precipitation than for temperature in the future, where the simulated interannual variations for any given model are much larger than the longer-term trends. One way to interpret these scenarios is that future years will continue to see large variations that make it difficult to identify an obvious trend due to human-caused climate change.

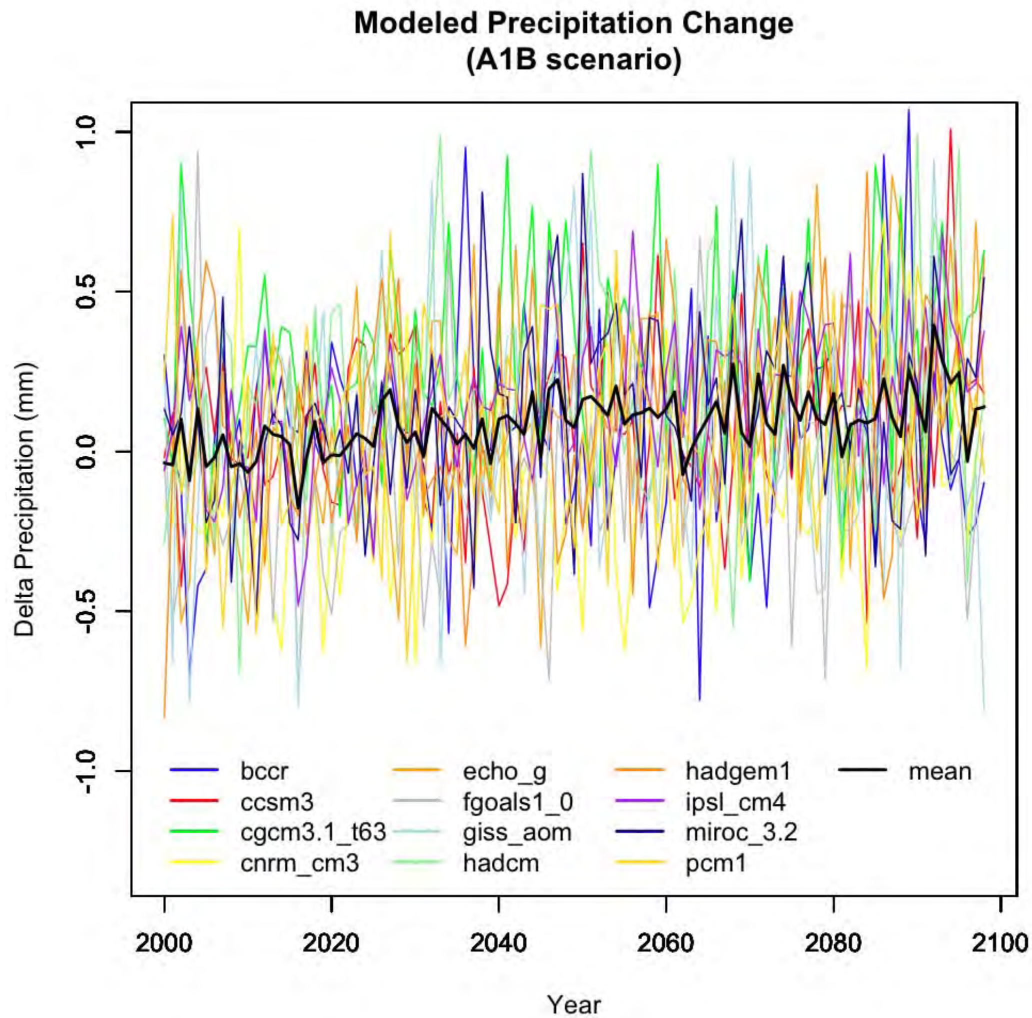


Figure 2: Monthly average changes in precipitation for 12 models (A1B scenario) compared to 1970-1999 levels.

II. Coastal vulnerabilities

A. Global sea level rise

Projections of global sea level rise (SLR) vary considerably among studies. The magnitudes of contributing factors to global SLR, like melting glaciers and ice sheets and thermal expansion, contain sizeable uncertainties. In 2007 the IPCC released projections of global SLR in its fourth Assessment Report (IPCC 2007). These projections of SLR over the 21st century range from 18-38 cm (7-15”) for the low emissions scenario to 26-59 cm (10-23”) for the high emissions scenario (Table 1). Recent studies indicate that the IPCC underestimates the role of accelerated melting of the Greenland and Antarctic ice sheets (Thomas, Rignot et al. 2004; Zwally, Gioveinetto et al. 2005; Murray 2006; Velicogna and Wahr 2006) and the role of thermal expansion (Rahmstorf 2007), thereby pointing to more rapid rates of SLR.

IPCC emissions scenario	90% probability of SLR by 2100 relative to 1980-1999 levels
B1 (population growth peaks at 2050, rapid measures of mitigation)	18-38 cm (7-15”)
A1T (population growth peaks at 2050, implementation of non-fossil fuel-based technologies)	20-45 cm (8-18”)
B2 (intermediate population and economic growth, locally implemented measures of mitigation)	20-43 cm (8-17”)
A1B (population growth peaks at 2050, intermediate response to mitigate)	21-48 cm (8-19”)
A2 (high population growth, slow economic development and response to mitigate)	23-51 cm (9-20”)
A1FI (population growth peaks at 2050, fossil fuel intensive energy use)	26-59 cm (10-23”)

Table 1: Projections of global SLR by 2100 (IPCC 2007).

B. Regional sea level rise

Various factors influence regional estimates of SLR, including local atmospheric pressure and circulation (changes in wind patterns can force coastal waters towards or away from shore) and local vertical land movement (VLM) resulting from tectonic activity and isostatic rebound. A recent Canadian technical report considers these factors to conduct a province-wide assessment of SLR in British Columbia (Thomson, Bornhold et al. 2008). Of the areas investigated, this report draws attention to the extreme rise of sea levels in the Fraser River delta (50 ± 20 cm) by 2100 as a result of local subsidence, and an even greater rise (120 cm) by 2100 under a scenario of rapid the ice sheet melt. Another factor contributing to the more extreme rates of SLR in the Fraser River delta is the effect of urbanization and river management that prevents sedimentation deposits in the delta, which would normally elevate the delta bottom. Along the coastal regions in the Pacific Ocean, El Niño Southern Oscillation (ENSO) events increase the thermal expansion of oceanic waters, elevating local SLR. Strong northward winds can contribute ~50 cm (20”) in the winter along the Washington coast (Mote et al. 2008); this phenomenon is exacerbated during El Niño years elevating sea levels by an additional 30 cm (12”), on average, for the entire winter. Estimates of the VLM in the Puget Sound range from low-to-medium subsidence rates of 1-2 mm/year (Holdahl, Faucher et al. 1989) to greater magnitudes of subsidence in the future, resulting in 10 cm (4”) by 2050 and 20 cm (8”) by 2100 (Verdonck 2006). Mote et al. (2008) approximated local SLR in the Puget Sound by applying these contributions of regional atmospheric dynamics and VLM to the average of 18 IPCC global model projections of SLR (Table 2). These estimates range from very low, 8 cm (3”), by 2050 to very high, 128 cm (50”), by 2100.

Scenario	Factors	2050	2100
Very low	Global SLR	9 cm (3.5”)	18 cm (7”)
	Atmospheric	-1 (0.5”)	-2 (1”)
	VLM	0	0
	Total	8 cm (3”)	16 cm (6”)
Medium	Global SLR	15 cm (6”)	34 cm (12”)
	Atmospheric	0	0
	VLM	0	0
	Total	15 cm (6”)	34 cm (12”)
Very high	Global SLR	38 cm (15”)	93 cm (36”)
	Atmospheric	7 cm (3”)	15 cm (6”)
	VLM	10 cm (4”)	20 cm (8”)
	Total	55 cm (22”)	128 cm (50”)

Table 2: Projections of regional SLR for the Puget Sound

C. Tidal surges

On a smaller time scale, from hours to days, storm surges can also rapidly elevate sea levels. The combination of a storm surge event during high tide can have devastating effects, particularly in areas of low elevation, as occurred in 2006) in the Swinomish Reservation and the adjacent town of La Conner. When these events are coupled with projections of SLR, the effects are even more alarming. In 2008 the King County, WA released a report describing a tool that considers the range of possibilities of storm surge events, tide levels and SLR projections (DNR 2008). The resulting range of sea levels can be overlaid onto the elevations of known facilities to determine the possibilities of inundating of facilities of interest. The National Oceanic and Atmospheric Administration (NOAA) monitors tide levels can be found for various sites in WA and their data can be found at the following web link:
http://tidesandcurrents.noaa.gov/station_retrieve.shtml?type=Historic%20Tide%20Data&state=Washington&id1=944

The closest tidal stations in this dataset to the Swinomish Reservation with a long-term record (1 year) are LaConner/Swinomish Slough (station ID 9448558) and Snee-Oosh/Skagit Bay (station ID 9448576). A study by Zervas (Zervas 2005) calculated the water level above the Mean High High Water (MHHW) for various sites in WA when a 100-year storm occurs (a storm with a 1% chance exceedance in any given year). The MHHW is the average of the higher high water height of each tidal day during a tidal epoch (19 years). Since many coastal locations have semidiurnal tides, or a cycle of two low and two high tides per day, the higher high water height refers to the higher of two daily high tides. Zervas’ (2005) study indicates that for sites near the Swinomish Reservation (Friday Harbor, Cherry Point, Port Townsend and Port Angeles) the range of increase in water levels from MHHW resulting from a 100 year storm surge is from 1 m (3’) to 1.19 (3.6’). The elevations of facilities and sites of cultural importance on the Swinomish Reservation can then be mapped onto the areas at risk of inundation to determine the vulnerability of these sites of importance.

D. Sea level rise impacts on coastal habitats in Skagit, Padilla, Port Susan Bays

National Wildlife Federation conducted a study in 2007, investigating the effects of sea level rise (SLR) for 11 sites on the Pacific Northwest coast, including the Skagit, Padilla and Port Susan Bays. The study applied SLR scenarios projected by the IPCC (2001), accounting for local effects of land elevation changes resulting from geological uplift and subsidence, and from sedimentation and marsh accretion. This study also considered a more rapid, drastic SLR scenario for 2100 not included in the IPCC report. Subsequent studies indicate that the rates of SLR revealed in the 2001 IPCC report are too low and that higher levels of SLR should be considered (Chen, Wilson et al. 2006; Otto-Bliesner, Marshall et al. 2006; Overpeck, Otto-Bliesner et al. 2006; Rahmstorf 2007). The model used to determine habitat shifts and erosion rates is the Sea Level Affecting Marshes Model (SLAMM), designed to incorporate seawater inundation, topography characteristics and long-term SLR into its projections. Taking into consideration the effects of diking, models were executed with and without dikes. This report shows the results from the SLAMM applications of SLR levels from IPCC (2001) A1B scenario, adjusted to address the concerns that the rates were too low: 0.28 m (11.2 in) by 2050, 0.69 m (27.3 in) by 2100 and 1.5 m (59.1 in) by 2100. For the Skagit, Padilla and Port Susan Bays region, the regional forecasts of SLR are 0.35 m (13.6 in) by 2050, and 0.78 m (30.8 in) or 1.59 (62.5 in) by 2100 (Glick, Clough et al. 2007). The wetland habitats in this region have been extensively altered by dikes and drainage for agricultural purposes. Marsh and beach habitats near sea walls are particularly vulnerable to saltmarsh or tidal flat conversion, although the dry land will be protected from inundation. The major habitat shifts in this region resulting from seawater inundation are the conversion of brackish marsh to saltmarsh and smaller tracts of dry land conversion to transitional marsh. Padilla Bay hosts a productive Dungeness crab industry because of its abundant eelgrass population. In the Skagit Bay area, estuarine beach habitats are particularly vulnerable to permanent inundation under all scenarios, shifting to estuarine open water or tidal flats.

Table 3. Nearshore Marine and Estuarine Habitat Use by Salmonid Species in Pacific Northwest

	Nearshore Marine and Estuary Use		
Species	**Adult Residence**	**Adult and Juvenile Migration**	**Juvenile Rearing**
Chinook Salmon	**Extensive Use**	**Extensive Use**	**Extensive Use**
Chum Salmon	Little or Unknown	**Extensive Use**	**Extensive Use**
Coho Salmon	Some Use	**Extensive Use**	Some Use
Sockeye Salmon	Little or Unknown	**Extensive Use**	Little or Unknown
Pink Salmon	Little or Unknown	**Extensive Use**	**Extensive Use**
Cutthroat Trout	**Extensive Use**	**Extensive Use**	**Extensive Use**
Steelhead	Little or Unknown	**Extensive Use**	Some Use
Bull Trout	**Extensive Use**	**Extensive Use**	**Extensive Use**

Source: Williams, G.D. and R.M. Thom. 2001. *Marine and Estuarine Shoreline Modification Issues* (Sequim, WA: Battelle Marine Sciences Laboratory/Pacific Northwest National Laboratory), p. 14.

Table 3 From Glick (2007) Sea-level Rise and Coastal Habitats in the Pacific Northwest.

E. Ocean acidification

Of growing concern in the ocean environment is the rising acidity of marine waters associated with increases in atmospheric carbon dioxide. The full suite of implications for the marine ecosystems is not fully understood, but some well-established effects of ocean acidification include reduced calcification and growth rates for shell-forming organisms and increased photosynthetic carbon fixation rates (Doney, Fabry et al. 2009). For the past 200 years, the ocean has absorbed about one-third of anthropogenic CO_2 (Sabine, Feely et al. 2004), changing the chemistry of the ocean from a slightly alkaline to a more acidic environment through a process that decreases carbonate availability for shell formation. Rising acidity of marine waters will further negatively impact shell-forming organisms because the higher acid concentrations dissolve the calcium carbonate from which shells are constructed. The evidence for ocean acidification inhibiting shell formation is particularly conspicuous at higher latitudes, where cooler water temperatures and higher pressure zones increase the solubility of calcium carbonate (Fabry, Seibel et al. 2008; Feely, Fabry et al. 2008). The implications of losing populations of shellfish species are widespread in the marine food chain, ranging from Pacific king salmon to the shellfish industry in Puget Sound. The shellfish industry may have already undergone some detrimental repercussions from crab and clam population declines in the Puget Sound (OSU 2008; Welch 2009).

III. Freshwater timing and quality

A. Changes in spring snowpack

Any changes in snowpack are strongly linked to shifts in temperature and precipitation, although historically temperature has had a greater effect on snowpack than precipitation in the Cascades (Hamlet and Lettenmaier 1999; Mote, Peterson et al. 2008; Mote and Salathé 2009). The conventional method to determine changes in snowpack is by measuring the snow water equivalent (SWE) on April 1. Mote et al. (2008) reported losses of up to 35% of springtime SWE from the mid-20th century to 2006 in Washington's Cascade Mountains. Using projections of temperatures and precipitation, Elsner et al. (2009) models the changes in SWE on April 1 for three future time horizons for the Pacific Northwest. According to their results, across the state of Washington under the A1B scenario, April 1 SWE declines by 29% in the 2020s, by 44% in the 2040s and by 65% in the 2080s, compared to the 1980s levels. The most sensitive areas are at elevations with warmer temperatures during the winter months, so lower elevations will undergo greater decreases in snowpack. In an analysis conducted by Casola et al. (2009), the variability in precipitation was removed to isolate the effects of warming temperatures on snowpack. Using this approach, the SWE losses for the Skagit River Basin is 19% for 1^{o} C increase in temperature.

B. Freshwater timing (flood/low flow shifts)

The implications of a diminishing snowpack and rising temperatures are widespread for watersheds in Washington State. Many watersheds will shift from a snow dominant to transient basins, or ones fed by a mixture of rainfall and snowmelt. Snow dominant basins are supplied primarily by snowmelt and undergo peak flows in the spring and summer. As temperatures increase and snowpack declines, peak flows will be lower in the summer and rainfall will play an increasing role in contributing to runoff in the Skagit watershed, elevating streamflows in the fall and winter and diminishing them in summer and early fall. Figure 3 depicts a hydrograph of modeled monthly average flows for the Skagit River at Mount Vernon comparing patterns of historical (1970-1999) flow to three future time horizons. In this simulated hydrograph the peak flows in the summer months from melting snow decline as snowpack decreases and the winter flows fed by rainfall increase under the A1B scenario. The magnitude of flooding is projected to rise for any given recurrence interval in the future, becoming increasingly severe at the end of the century.

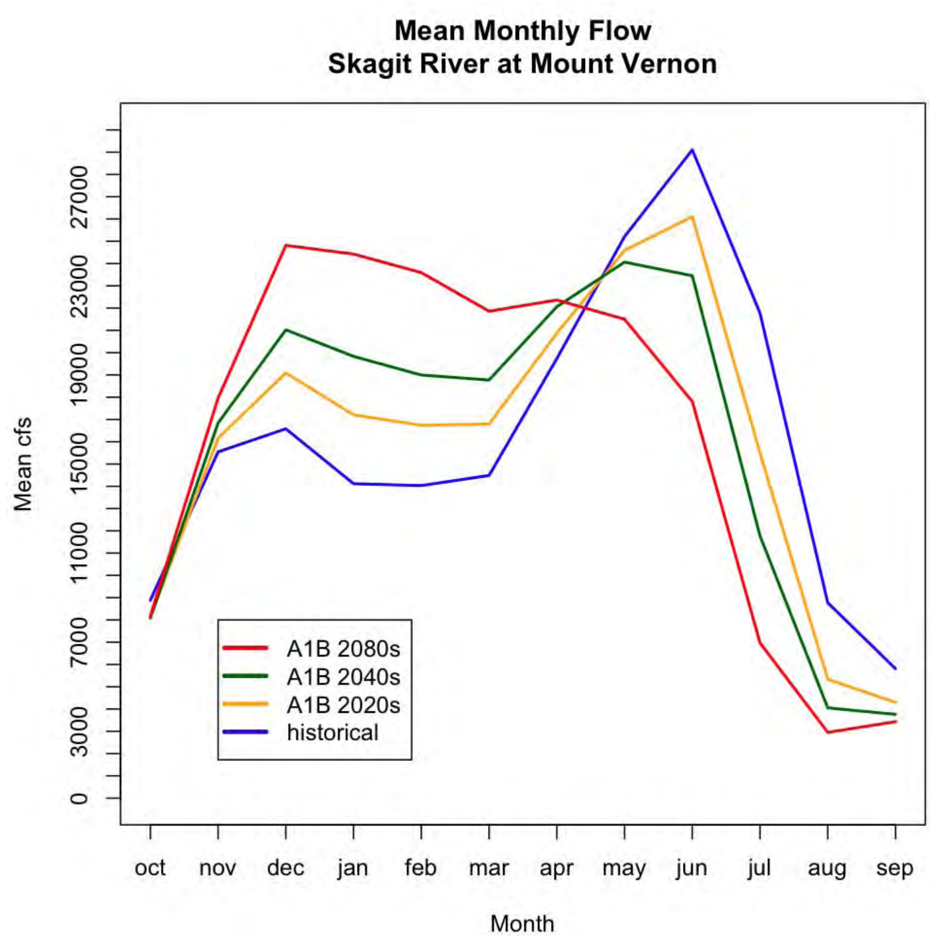


Figure 3: Hydrograph of the Skagit River at Mount Vernon based on monthly average flows (cubic feet per second) for the historical and 3 future time horizons projected by the A1B scenario.

IV. Forest impacts

A. Rise in Fire risk

The seasonal changes in temperature and amount of precipitation are major factors in the forest fire susceptibility. Projected conditions of warmer, wetter winters combined with increased temperatures and lower precipitation in the summer months trigger greater wintertime vegetation production and summertime accumulations of woody and leafy debris on the forest floor (Littell, McKenzie et al. 2009) Prolonged hot, dry summers provoke fuel loads to dry and build up, elevating the risk of more frequent and severe forest fires. Under future climate change scenarios, the median area of forest projected to burn increases from 0.5 million acres during the 1916-2006 period to 2.0 million acres by the end of the 21st century (Littell, Oneil et al. 2009). Among the regions at the greatest risk of forest fires are the lower elevations, particularly in the drier forests east of the Cascade Range.

B. Changes in species distribution/composition

Also under warmer, drier conditions, trees undergo an increase in Vapor Pressure Deficit (VPD), which provokes them to draw more water from their roots. The projected area of Washington state forestland that is severely water-limited will rise by 32% in the 2020s, by 44% in the 2040s and by 66% in the 2080s (Littell, Oneil et al. 2009). Although the severity of water limitations is expected to be greater east of the Cascades, the forest disturbance in areas west of the Cascades is projected to arise from higher temperatures and lower soil moisture in the summer. These unfavorable conditions increase the potential evapotranspiration (PET), inducing water stress in many forest species. Species that are less adapted to drought conditions, like Western Red cedar *(Thuja plicata)* and Sitka spruce *(Picea sitchensis),* might suffer extensive population losses due to stressful conditions, particularly during the summer months. The area suitable for an economically important forest species, Douglas-fir (*Pseudotsuga menzaiesii),* was estimated to decrease by 32% by the mid-21st century. Projections for pine forests are a loss of 1 species in 85% of their current range and a loss of 2 species in 11% of their current range.

C. MPB outbreaks

Trees that are more physiologically stressed by drought become more susceptible to infestation from Mountain Pine Beetles (MPB), fungi and blights. Drought conditions tend to create positive feedback loops that exacerbate water stress among trees. Higher summer temperatures coupled with precipitation declines in the summer months increase the vapor pressure deficit (VPD) and PET among forest trees. Hot, dry conditions are conducive to MPB outbreaks. These outbreaks are projected to be more severe and concentrated in the higher elevation forests.

References

Casola, J. H., L. Cuo, et al. (2009). "Assessing the impacts of global warming on snowpack in the Washington Cascades." Journal of Climate **22**: 2758-2772.

Chen, D. J., C. R. Wilson, et al. (2006). "Satellite Gravity Measurements Confirm Accelerated Melting of Greenland Ice Sheet." Science **313**(5795): 1958-1960.

DNR (2008). Vulnerability of Major Wastewater Facilities to Flooding from Sea-Level Rise. Seattle, Department of Natural Resources and Parks**:** 1-13.

Doney, S. C., V. J. Fabry, et al. (2009). "Ocean Acidification: The Other CO2 Problem." Annual Review of Marine Science **1**(1): 169-192.

Elsner, M. M., L. Cuo, et al. (2009). Implications of 21st Century Climate Change for the Hydrology of Washington State. The Washington Climate Change Impacts Assessment. M. M. Elsner, J. Littell and L. W. Binder. Seattle, University of Washington Climate Impacts Group**:** 69-106.

Fabry, V. J., B. A. Seibel, et al. (2008). "Impacts of ocean acidification on marine fauna and ecosystem processes." ICES J. Mar. Sci. **65**(3): 414-432.

Feely, R. A., V. J. Fabry, et al. (2008). "Ocean acidification of the North Pacific Ocean." PICES Press **16**(1): 22-26.

Glick, P., J. S. Clough, et al. (2007). Sea-level Rise and Coastal Habitats in the Pacific Northwest. Seattle, National Wildlife Federation.

Hamlet, A. F. and D. P. Lettenmaier (1999). "Effects of Climate Change on Hydrology and Water Resources in the Columbia River Basin." Journal of the American Water Resources Association **35**(6): 1597-1623.

Holdahl, S. R., F. Faucher, et al. (1989). Slow deformation and transmission of stress in the earth. Contemporary vertical crustal motion in the Pacific Northwest. Choen and Vanicek, American Geophysical Union, Geophysical Monograph 49.

IPCC (2001). Contribution of Working Group I to the Third Assessment Report o fhte Intergovernmental Panel on Climate Change. Climate Change 2001: The Scientific Basis. C. U. Press. Cambridge, UK and New York.

IPCC (2007). Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Climate Change 2007: The Physical Science Basis. S. Slomon, D. Qim, M. Manninget al. Cambridge, IPCC.

Littell, J. S., D. McKenzie, et al. (2009). "Climate and wildfire area burned in western U.S. ecoprovinces, 1916-2003." Ecological Applications **19**(4): 1003-1021.

Littell, J. S., E. E. Oneil, et al. (2009). Forest Ecosystems, Disturbances, and Climatic Change in Washington State, USA. The Washington Climate Change Impacts Assessment. M. M. Elsner, J. Littell and L. W. Binder. Seattle, University of Washington Climate Impacts Group**:** 255-284.

Mote, P. W., A. Peterson, et al. (2008). Sea level rise in the coastal waters of Washington State. Seattle, Climate Impacts Group; Dept. of Ecology, State of Washington**:** 11 p.

Mote, P. W. and E. P. Salathé (2009). Future climate in the Pacific Northwest. The Washington Climate Change Impacts Assessment. M. M. Elsner, J. Littell and L. W. Binder. Seattle, University of Washington Climate Impacts Group**:** 21-43.

Murray, T. (2006). "Climate change: Greenland's ice on the scales." Nature **443**: 277-278.
OSU (2008). U.S. Pacific Coast Waters Turning More Acidic. ScienceDaily.
Otto-Bliesner, B. L., S. J. Marshall, et al. (2006). "Simulating Arctic Climate Warmth and Icefield Retreat in the Last Interglaciation." Science **311**(5768): 1751-1753.
Overpeck, J. T., B. L. Otto-Bliesner, et al. (2006). "Paleoclimatic Evidence for Future Ice-Sheet Instability and Rapid Sea-Level Rise." Science **311**: 1747-1755.
Rahmstorf, S. (2007). "A Semi-Empirical Approach to Projecting Future Sea_levle Rise." Science **315**: 368-370.
Sabine, C. L., R. A. Feely, et al. (2004). "The Oceanic Sink for Anthropogenic CO2." Science **305**(5682): 367-371.
Salathé, E. P., L. R. Leung, et al. (2009). Regional climate model projections for the State of Washington. The Washington Climate Change Impacts Assessment. M. M. Elsner, J. Littell and L. W. Binder. Seattle, University of Washington Climate Impacts Group**:** 45-67.
Thomas, R., E. Rignot, et al. (2004). "Accelerated sea-level rise from West Antarctica." Science **306**: 255-258.
Thomson, R. E., B. D. Bornhold, et al. (2008). An Examination of the Factors Affecting Relative and Absolute Sea Level in Coastal British Columbia. Canadian Technical Report of Hydrogrphy and Ocean Science. Sidney, BC, Fisheries and Oceans Canada. **260:** 1-48.
Velicogna, I. and J. Wahr (2006). "Acceleration of Greenland ice mass loss in spring 2004." Nature **443**: 329-331.
Verdonck, D. (2006). "Contemporary vertical crustal deformation in Cascadia." Technophysics **417**: 221-230.
Welch, C. (2009). Oysters in Trouble. Seattle Times. Seattle, The Seattle Times Company.
Zervas, C. E. (2005). Response of Extreme Storm Tide Levels to Long-term Sea Level Change. NOAA Technical Report NOS CO-OPS 36. Seattle, National Oceanic and Atmospheric Administration
National Ocean Service
Center for Operational Oceanographic Products and Services**:** 1-6.
Zwally, H. J., M. B. Gioveinetto, et al. (2005). "Mass changes of the Greenland and Antarctic ice sheets and shelves and contributions to sea level rise:1992-2002." Journal of Glaciology **51**: 509-527.

SWINOMISH CLIMATE CHANGE INITIATIVE
IMPACT ASSESSMENT TECHNICAL REPORT

APPENDIX 3

 Source: http://tidesandcurrents.noaa.gov/datum_options.html

TIDAL DATUMS

In general, a datum is a base elevation used as a reference from which to reckon heights or depths. A tidal datum is a standard elevation defined by a certain phase of the tide. Tidal datums are used as references to measure local water levels and should not be extended into areas having differing oceanographic characteristics without substantiating measurements. In order that they may be recovered when needed, such datums are referenced to fixed points known as bench marks. Tidal datums are also the basis for establishing privately owned land, state owned land, territorial sea, exclusive economic zone, and high seas boundaries. Below are definitions of tidal datums maintained by the Center for Operational Oceanographic Products and Services.

MHHW* Mean Higher High Water	The average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch. For stations with shorter series, comparison of simultaneous observations with a control tide station is made in order to derive the equivalent datum of the National Tidal Datum Epoch.
MHW Mean High Water	The average of all the high water heights observed over the National Tidal Datum Epoch. For stations with shorter series, comparison of simultaneous observations with a control tide station is made in order to derive the equivalent datum of the National Tidal Datum Epoch.
DTL Diurnal Tide Level	The arithmetic mean of mean higher high water and mean lower low water.
MTL Mean Tide Level	The arithmetic mean of mean high water and mean low water.
MSL Mean Sea Level	The arithmetic mean of hourly heights observed over the National Tidal Datum Epoch. Shorter series are specified in the name; e.g. monthly mean sea level and yearly mean sea level.
MLW Mean Low Water	The average of all the low water heights observed over the National Tidal Datum Epoch. For stations with shorter series, comparison of simultaneous observations with a control tide station is made in order to derive the equivalent datum of the National Tidal Datum Epoch.
MLLW* Mean Lower Low Water	The average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch. For stations with shorter series, comparison of simultaneous observations with a control tide station is made in order to derive the equivalent datum of the National Tidal Datum Epoch.
GT Great Diurnal Range	The difference in height between mean higher high water and mean lower low water.
MN Mean Range of Tide	The difference in height between mean high water and mean low water.
DHQ Mean Diurnal High Water Inequality	The difference in height of the two high waters of each tidal day for a mixed or semidiurnal tide.
DLQ Mean Diurnal Low Water Inequality	The difference in height of the two low waters of each tidal day for a mixed or semidiurnal tide.
HWI Greenwich High Water Interval	The average interval (in hours) between the moon's transit over the Greenwich meridian and the following high water at a location.

LWI Greenwich Low Water Interval	The average interval (in hours) between the moon's transit over the Greenwich meridian and the following low water at a location.
Station Datum	A fixed base elevation at a tide station to which all water level measurements are referred. The datum is unique to each station and is established at a lower elevation than the water is ever expected to reach. It is referenced to the primary bench mark at the station and is held constant regardless of changes to the water level gauge or tide staff. The datum of tabulation is most often at the zero of the first tide staff installed.
National Tidal Datum Epoch	The specific 19-year period adopted by the National Ocean Service as the official time segment over which tide observations are taken and reduced to obtain mean values (e.g., mean lower low water, etc.) for tidal datums. It is necessary for standardization because of periodic and apparent secular trends in sea level. The present NTDE is 1983 through 2001 and is actively considered for revision every 20-25 years. Tidal datums in certain regions with anomolous sea level changes (Alaska, Gulf of Mexico) are calculated on a Modified 5-Year Epoch.

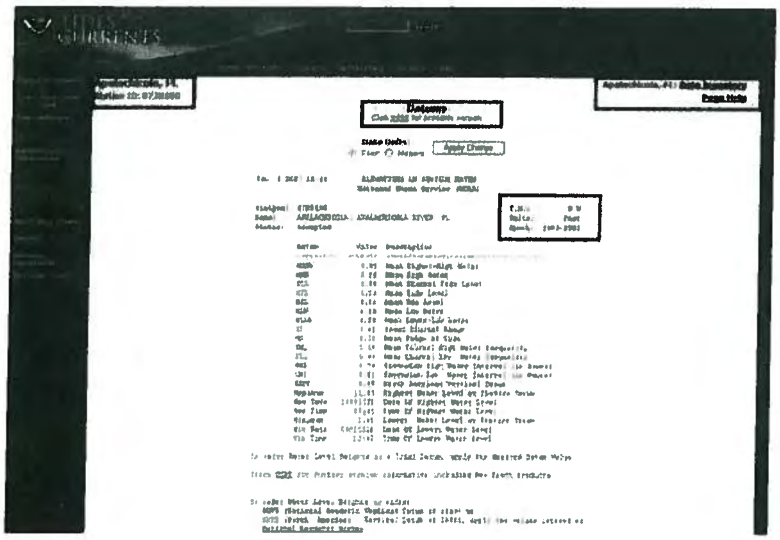
*Some locations have diurnal tides--one high tide and one low tide per day. At most locations, there are semidiurnal tides--the tide cycles through a high and low twice each day, with one of the two high tides being higher than the other and one of the two low tides being lower than the other.

References

1. (Get PDF reader) Tide Datums and Their Applications - NOAA Special Publication NOS CO-OPS 1
2. (Get PDF reader) Computational Techniques for Tidal Datums Handbook - NOAA Special Publication NOS CO-OPS 2
3. (Get PDF reader) Tide and Current Glossary (Get PDF reader)

All documents available at http://tidesandcurrents.noaa.gov/pub.html

Navigating the Datums Page



Click the link at the top of the page for a printer-friendly version of the page. Scroll down the page to see all the datums available for the station. Link to other types of data for the same station using the links on the left. Links are highlighted only for data types that are available for the station.

The Datums page (example at left) provides access to established datums for the station indicated in the upper left corner of the page. The tidal datums on this page are referenced to an arbitrary station datum. In order to apply these datums for surveying or coastal management they must be reduced to Mean Lower Low Water (MLLW), which is the reference datum for predictions, bench mark publication and nautical charting. Other tidal (Mean High Water (MHW)) and geodetic (North American Vertical Datum 1988 (NAVD 88)) datums may also be used for specific reasons. The time meridian (TM) is the reference meridian used to calculate time. An epoch is a 19-year tidal cycle used to calculate datums. **The present National Tidal Datum Epoch (NTDE) is 1983 through 2001.** Tidal datums in certain regions with anomolous sea level changes (Alaska, Gulf of Mexico) are calculated on a Modified 5-Year Epoch.

Data Units: ◉ Feet ○ Meters [Apply Change]

The data can be displayed in either feet or meters. Click the Apply Change button to apply the selected unit to the table of values for tidal datums. The heading of the table will reflect the units currently applied to the table.

•

GEODETIC DATUMS

The National Geodetic Survey (NGS) defines a geodetic datum as: 1. "A set of constants used for calculating the coordinates of points on the Earth." Generally a datum is a reference from which measurements are made. In surveying and geodesy, a datum is a reference point on the earth's surface against which position measurements are made, and an associated model of the shape of the earth for computing positions. Horizontal datums are used for describing a point on the earth's surface, in latitude and longitude. Vertical datums are used to measure elevations or underwater depths.

North American Vertical Datum of 1988	A fixed reference for elevations determined by geodetic leveling. The datum was derived from a general adjustment of the first-order terrestrial leveling nets of the United States, Canada, and Mexico. In the adjustment, only the height of the primary tidal bench mark, referenced to the International Great Lakes Datum of 1985 (IGLD 85) local mean sea level height value, at Father Point, Rimouski, Quebec, Canada was held fixed, thus providing minimum constraint. NAVD 88 and IGLD 85 are identical. However, NAVD 88 bench mark values are given in Helmert orthometric height units while IGLD 85 values are in dynamic

(NAVD 88)	heights. See International Great Lakes Datum of 1985, National Geodetic Vertical Datum of 1929, and geopotential difference. NAVD 88 should not be used as Mean Sea Level.
National Geodetic Vertical Datum of 1929 (NGVD 29)	A fixed reference adopted as a standard geodetic datum for elevations determined by leveling. The datum was derived for surveys from a general adjustment of the first-order leveling nets of both the United States and Canada. In the adjustment, mean sea level was held fixed as observed at 21 tide stations in the United States and 5 in Canada. The year indicates the time of the general adjustment. A synonym for Sea-level Datum of 1929. The geodetic datum is fixed and does not take into account the changing stands of sea level. Because there are many variables affecting sea level, and because the geodetic datum represents a best fit over a broad area, the relationship between the geodetic datum and local mean sea level is not consistent from one location to another in either time or space. For this reason, the National Geodetic Vertical Datum should not be confused with mean sea level. See North American Vertical Datum of 1988 (NAVD 88). NGVD 29 should not be used as Mean Sea Level. NGVD 29 is no longer supported by NGS.

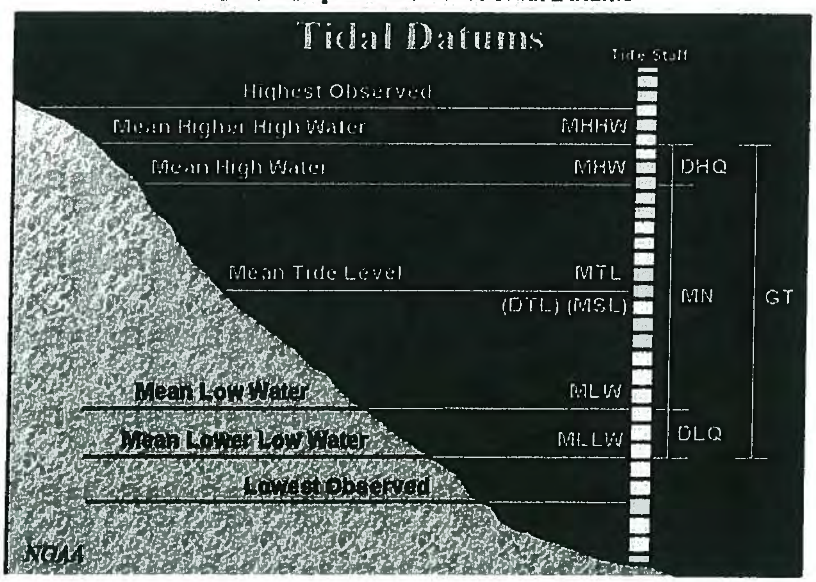
References

1. Frequently asked questions at http://www.ngs.noaa.gov/faq.shtml
2. NGS Publications at http://www.ngs.noaa.gov/PUBS_LIB/pub_index.html

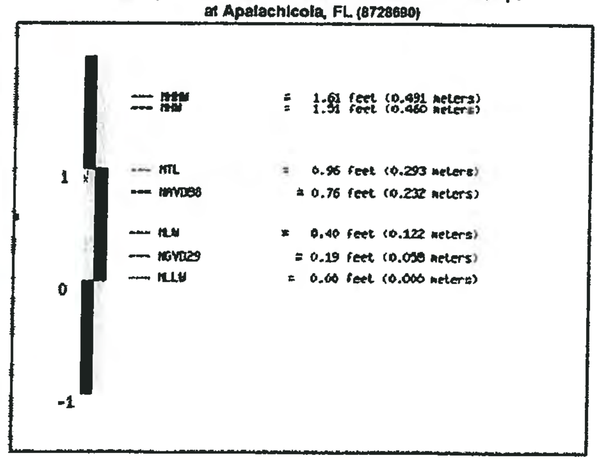
TIDAL AND GEODETIC RELATIONSHIPS

Geodetic datum relationships to tidal datums are established at tide stations by connecting tidal bench mark networks to the National Spatial Reference System (NSRS) maintained by NGS. There are two survey procedures used to make this connection. The first is to connect the tidal bench marks with traditional differential levels to nearby geodetic bench marks with known geodetic elevations. The second is to occupy the tidal bench marks using a static GPS survey to determine the geodetic elevations of the bench marks directly. In all cases it is advised to make the connections to more than one bench mark, preferably to three marks, in order to confirm the connection and identify unstable bench marks. The elevation relationship between geodetic datums and tidal datums should not be extrapolated away from a particular location without correction or interpolation as the relationships vary with parameters such as variations in range of tide, bathymetry, topography, geoid variations, and vertical land movement. Any interpolation should be done carefully, and where possible guided by the use of the National Ocean Service VDatum tool which can be obtained at: http://www.nauticalcharts.noaa.gov/csdl/vdatum.htm.

CO-OPS Representation of Tidal Datums



NGS Representation of Tidal and Geodetic Relationships at Apalachicola, FL (8728680)



Elevation Information

PID: TR0236
VM: 9253
Station ID: 9448558
Epoch: 1983-2001
Date: Mon Jun 15 21:09:13 EDT 2009

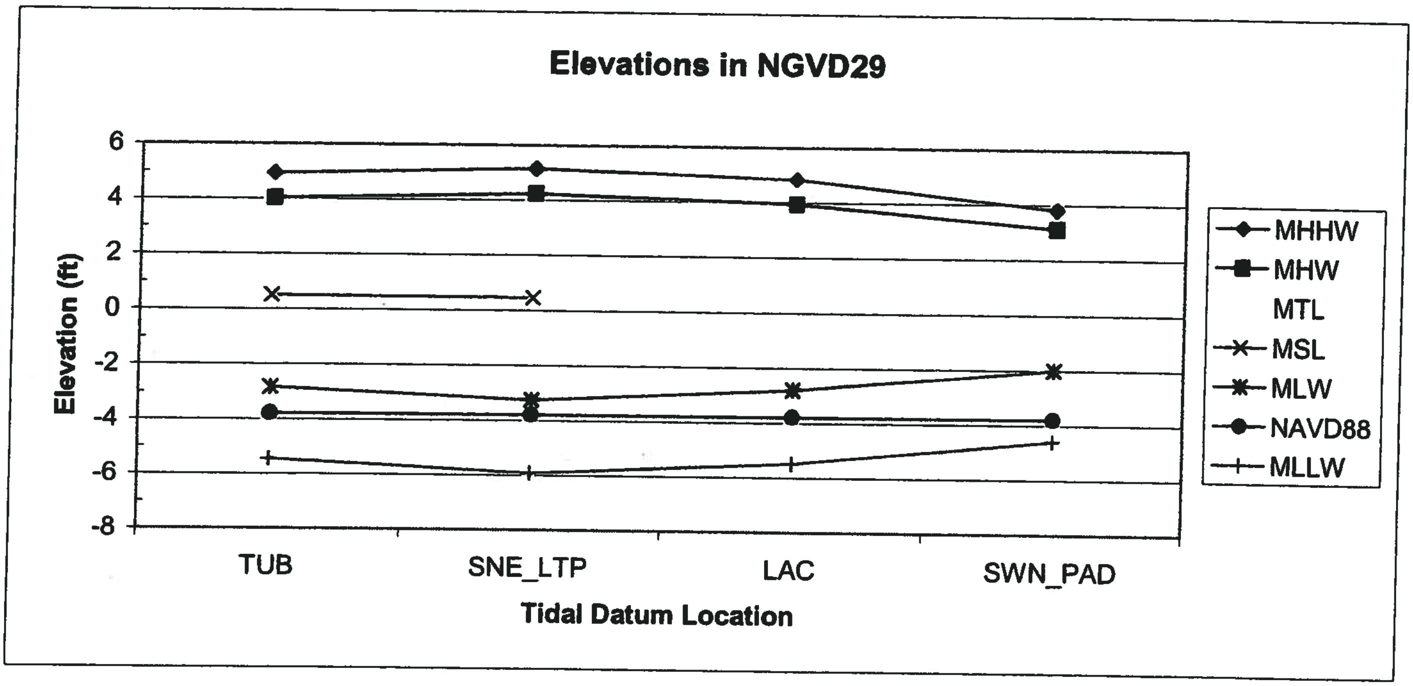
+8 = Tidal surge zone
+5 = future inundation zone

MHHW	=	10.35 feet (3.154 meters)
MHW	=	9.43 feet (2.874 meters)
MTL	=	6.06 feet (1.848 meters)
MSL	=	5.96 feet (1.817 meters)
NGVD29	=	5.30 feet (1.615 meters)
MLW	=	2.70 feet (0.822 meters)
NAVD88	=	1.51 feet (0.461 meters)
MLLW	=	0.00 feet (0.000 meters)

The NAVD 88 and the NGVD 29 elevations related to MLLW were computed from Bench Mark, TIDAL 3, at the station.

Displayed tidal datums are Mean Higher High Water(MHHW), Mean High Water (MHW), Mean Tide Level(MTL), Mean Sea Level (MSL), Mean Low Water(MLW), and Mean Lower Low Water(MLLW) referenced on 1983-2001 Epoch.

Elevation (Ft) Above (NGVD29)	SITC NAVD88 TURNERSPIT TUB	SITC NAVD88 LONETREE SNE_LTP	SITC NAVD88 LONGHOUSE LAC	SITC NAVD88 TRAINBRIDGE SWN_PAD
MHHW	4.94	5.16	4.85	3.81
MHW	4.02	4.24	3.94	3.11
MTL	0.59	0.50	0.57	0.56
MSL	0.51	0.46		
MLW	-2.84	-3.25	-2.80	-1.99
NAVD88	-3.79	-3.79	-3.79	-3.79
MLLW	-5.45	-5.92	-5.49	-4.59



May 11 2009 20:42

ELEVATIONS ON STATION DATUM
National Ocean Service (NOAA)

Station:	9448576	T.M.:	0 W
Name:	SNEEOOSH POINT, SKAGIT BAY, WA	Units:	Feet
Status:	Accepted	Epoch:	1983-2001

Datum	Value	Description
MHHW	14.57	Mean Higher-High Water
MHW	13.71	Mean High Water
DTL	9.04	Mean Diurnal Tide Level
MTL	9.90	Mean Tide Level
MSL	9.90	Mean Sea Level
MLW	6.08	Mean Low Water
MLLW	3.51	Mean Lower-Low Water
GT	11.05	Great Diurnal Range
MN	7.63	Mean Range of Tide
DHQ	0.86	Mean Diurnal High Water Inequality
DLQ	2.56	Mean Diurnal Low Water Inequality
HWI	0.93	Greenwich High Water Interval (in Hours)
LWI	7.29	Greenwich Low Water Interval (in Hours)
NAVD	5.53	North American Vertical Datum
Maximum	15.55	Highest Water Level on Station Datum
Max Date	20000609	Date Of Highest Water Level
Max Time	07:06	Time Of Highest Water Level
Minimum	0.04	Lowest Water Level on Station Datum
Min Date	20000702	Date Of Lowest Water Level
Min Time	19:30	Time Of Lowest Water Level

To refer Water Level Heights to a Tidal Datum, apply the desired Datum Value.

Click HERE for further station information including New Epoch products.

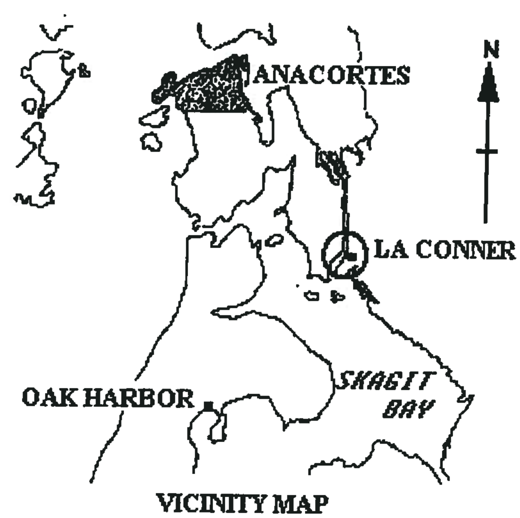
Tide Datums

Tidal Datum Regions, Whidbey Island Region
108 - La Conner

Relation Between Various Datum Planes				
Datum Plane	**MLLW**	**NGVD**	**NAVD88**	**COE**
Highest Estimated Tide	13.00 +/- 0.5			
Mean Higher High Water	10.00	4.62	8.40	
Mean High Water	9.10	3.72	7.50	
Mean (Half) Tide Level	5.58	0.20	3.98	
NGVD	5.38	0.00	3.78	
Mean Low Water	2.60	-2.78	1.00	
Mean Lower Low Water	0.00	-5.38	-1.60	
Lowest Estimated Tide	-4.50 +/- 0.5			

Record Levels (MLLW)	
Highest Observed Tide	13.15
Date	12/22/72
Lowest Observed Tide	-2.30
Date	12/19/72
Period of Record	Dec 1972 - Jan 1972
Epoch	1960-78
Index Gage	Seattle (944 7130)

Local Area Map



All Data Provided is Provisional

Home // Mail // Search
Last Updates on Thursday, January 06, 2000

Tidal Datum Regions, San Juan Islands Region

109 - Swinomish Slough

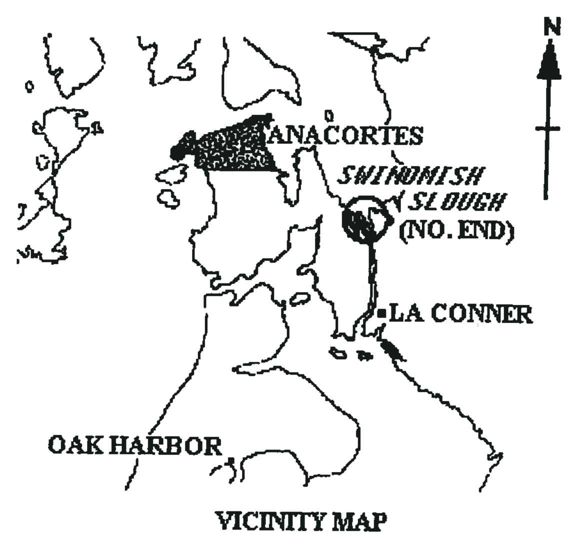
Relation Between Various Datum Planes

Datum Plane	MLLW	NGVD	NAVD88	COE
Highest Estimated Tide	11.50 +/- 0.5			
Mean Higher High Water	8.40	3.85	7.63	
Mean High Water	7.70	3.15	6.93	
Mean (Half) Tide Level	5.15	0.60	4.38	
NGVD	4.55	0.00	3.78	
Mean Low Water	2.60	-1.95	1.83	
Mean Lower Low Water	0.00	-4.55	-0.77	
Lowest Estimated Tide	-4.50 +/- 0.5			

Record Levels (MLLW)

Highest Observed Tide	
Date	
Lowest Observed Tide	
Date	
Period of Record	
Epoch	May - Aug 1955
Index Gage	

Local AREA alt="map" Map



All Data Provided is Provisional

Last Updates on Thursday, January 06, 2000

SWINOMISH CLIMATE CHANGE INITIATIVE
IMPACT ASSESSMENT TECHNICAL REPORT

APPENDIX 4

Coast Salish and U.S. Geological Survey: Tribal Journey Water Quality Project

Data Results

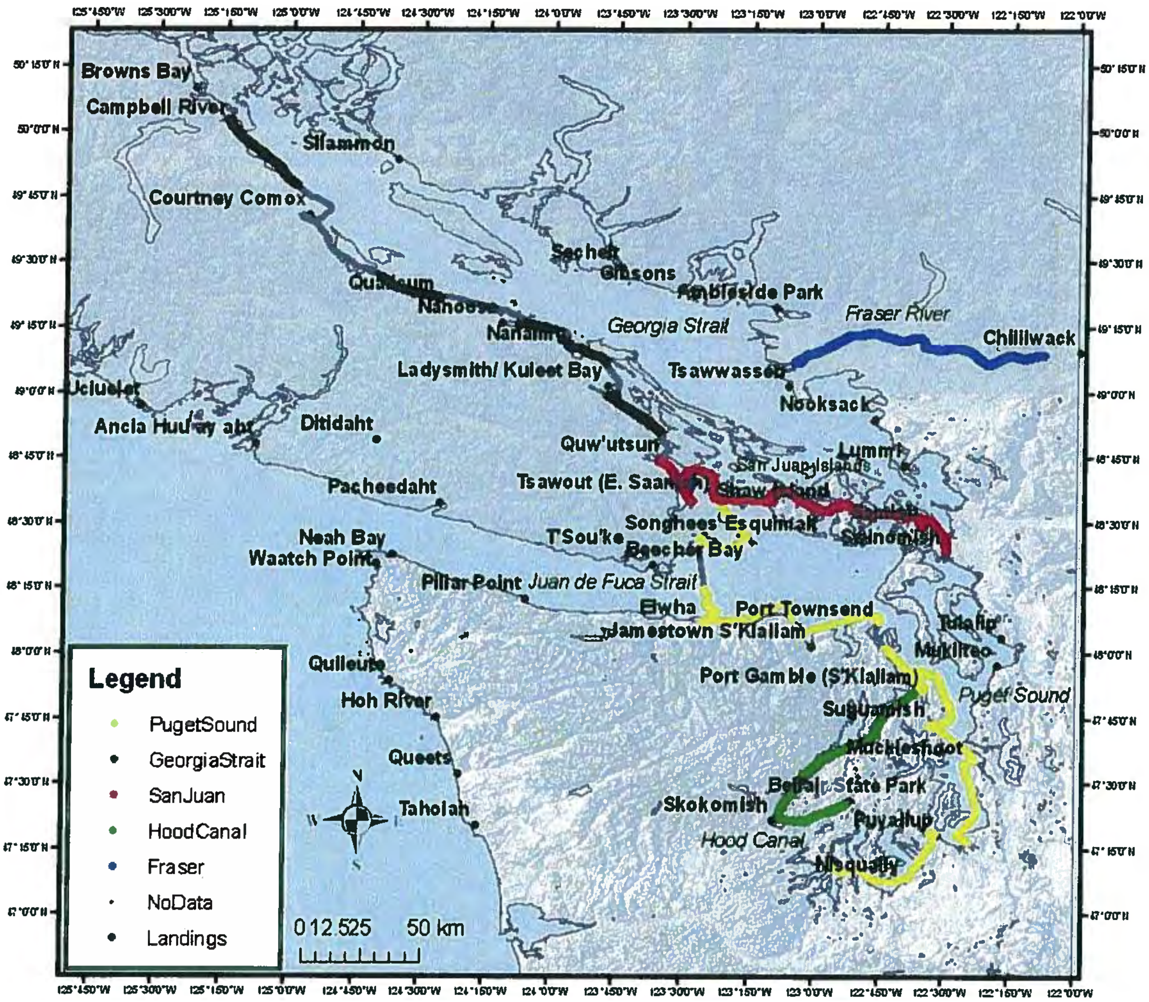


Figure 1. Tribal Journey routes that collected water quality data. Colored areas indicate successful data collection and grey lines indicate missing data.

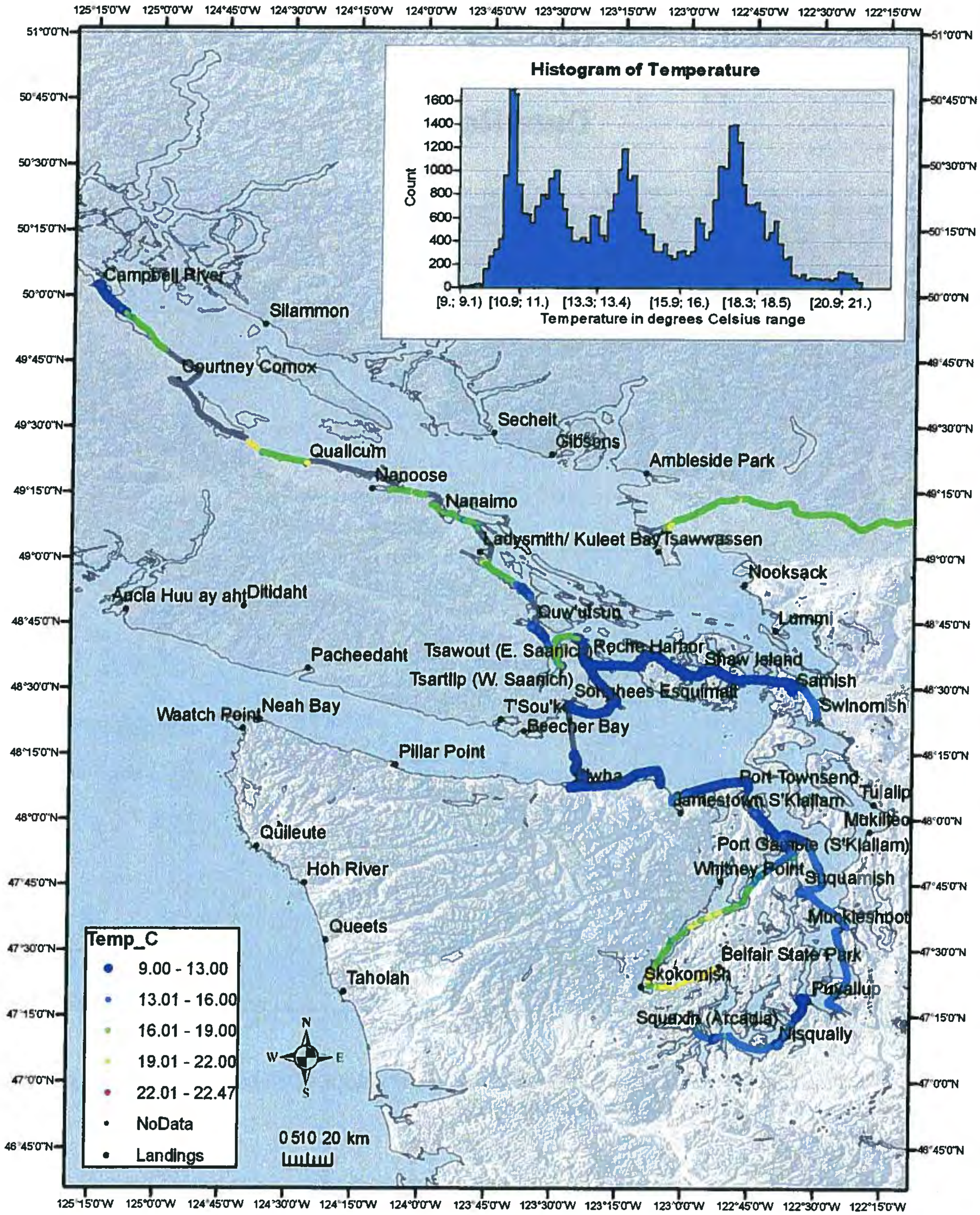


Figure 2. Temperature results from the July 2008 Tribal Journey Water Quality Project. Temperature is recorded in °C and broken out into Washington State Water Quality Criteria temperature limits for marine water bodies.

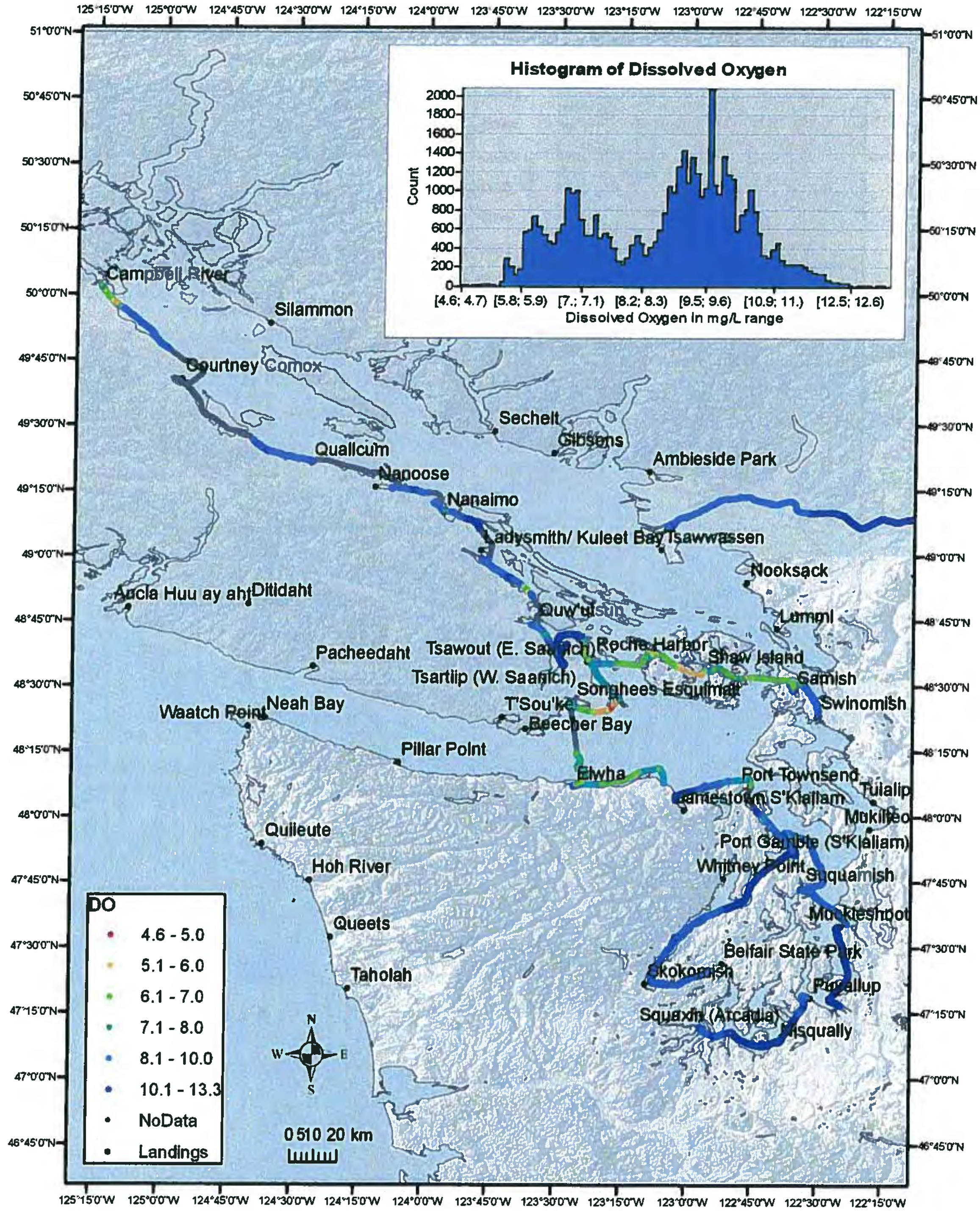


Figure 3. Dissolved oxygen results from the July 2008 Tribal Journey Water Quality Project. Dissolved oxygen is recorded in milligrams per liter (mg/L) and broken out into Washington State Water Quality Criteria temperature limits for marine water bodies.

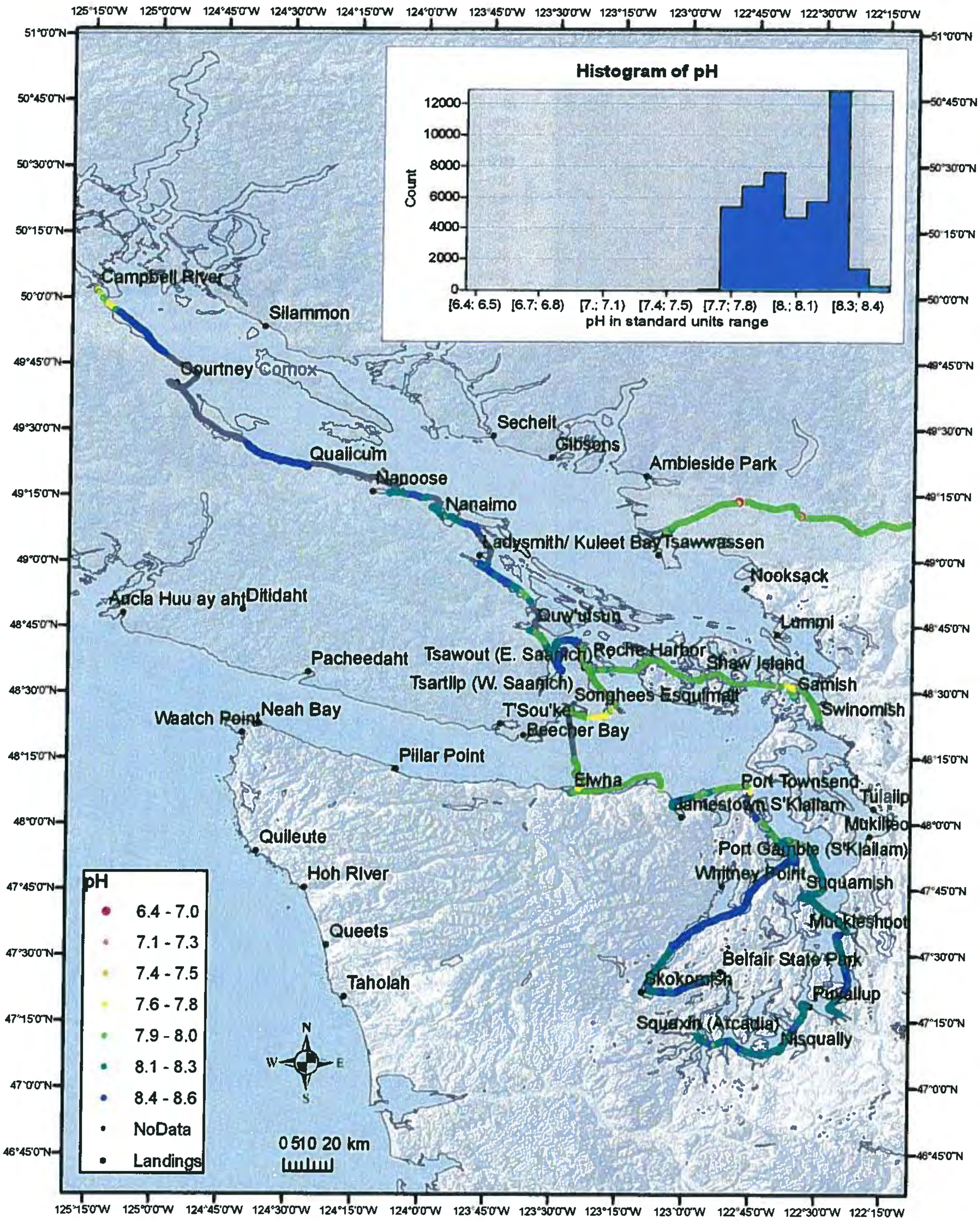


Figure 4. pH results from the July 2008 Tribal Journey Water Quality Project. pH is recorded in standard units and broken out into Washington State Water Quality Criteria temperature limits for marine water bodies

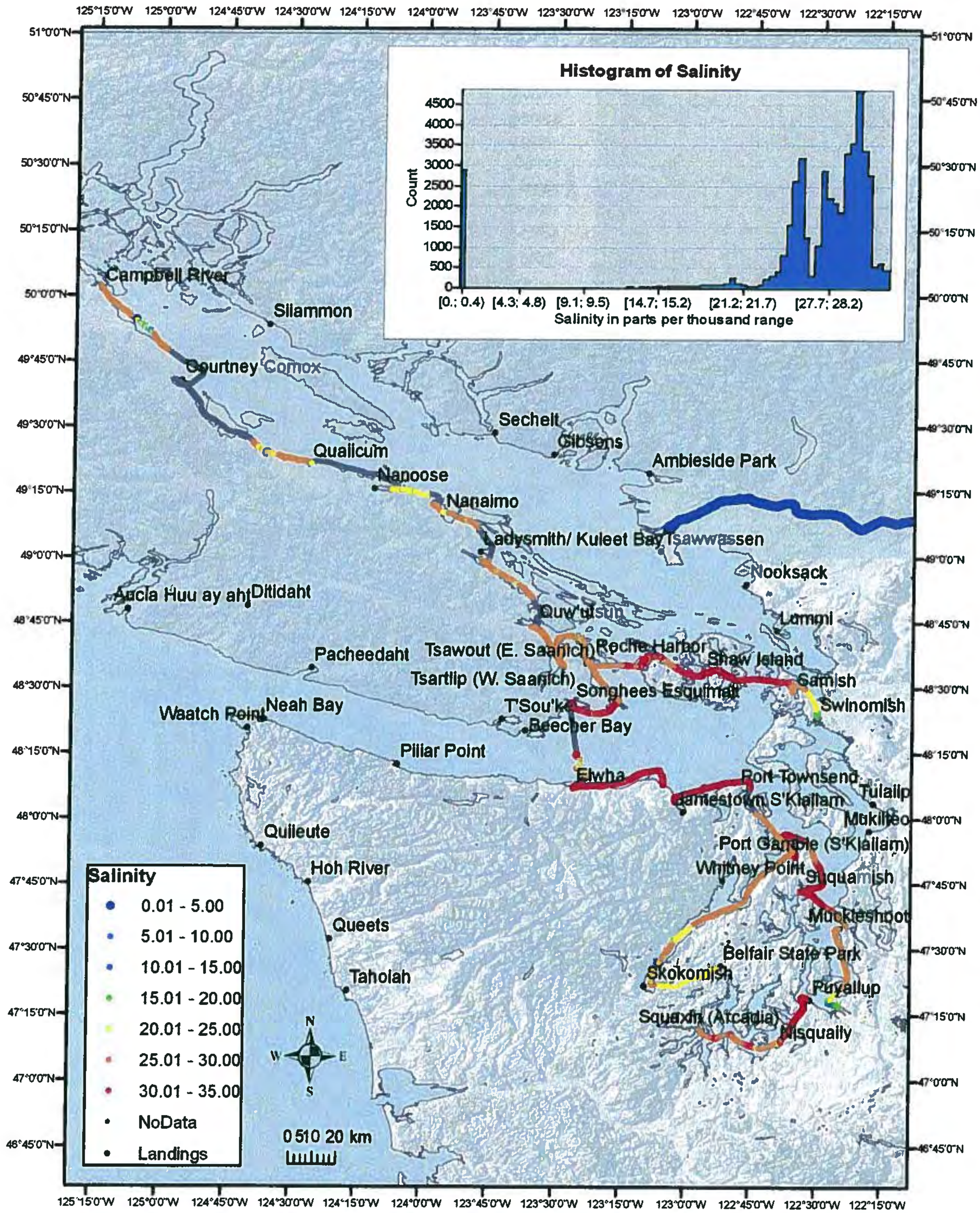


Figure 5. Salinity results from the July 2008 Tribal Journey Water Quality Project. Salinity is reported in parts per thousand (ppt).

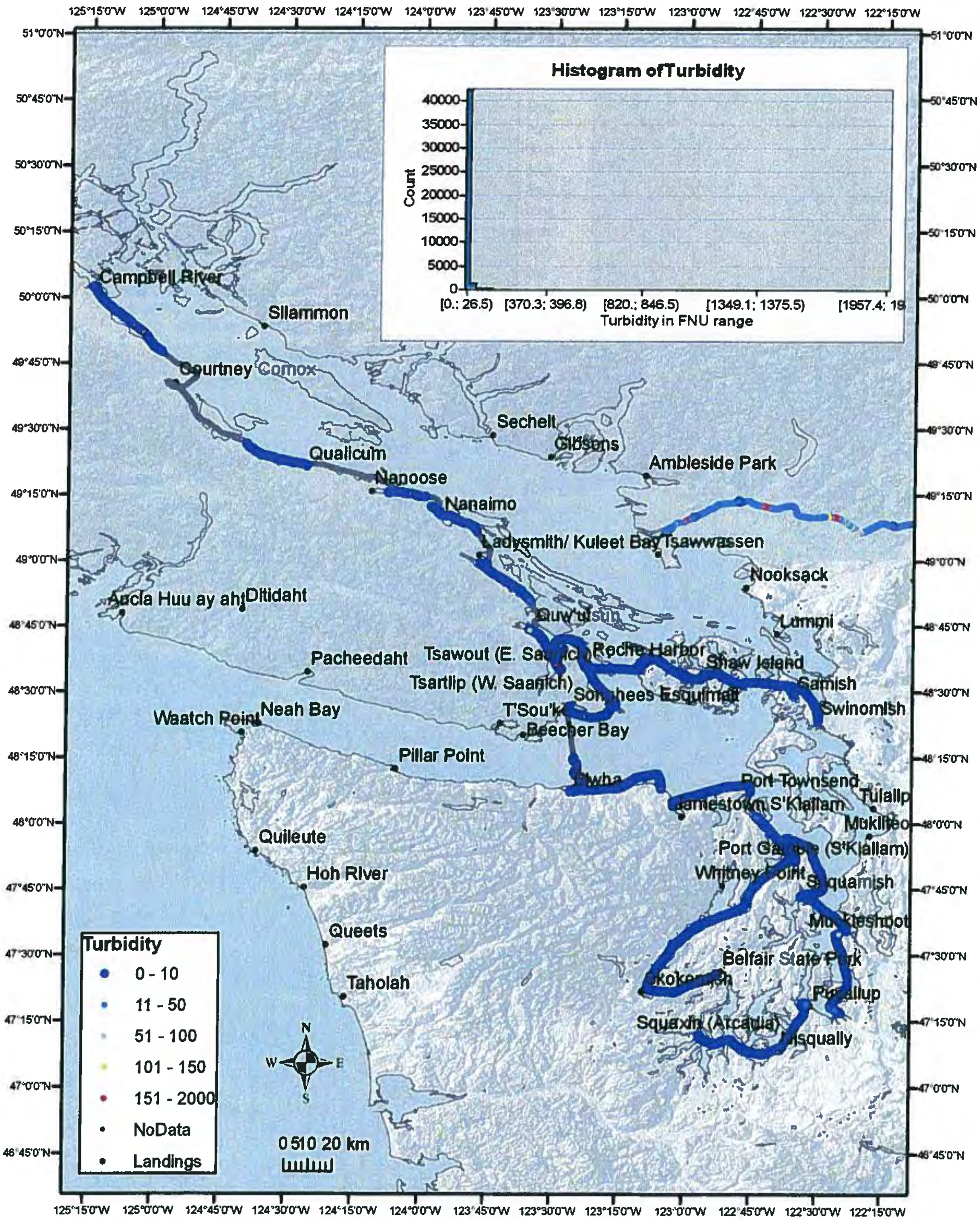


Figure 2. Turbidity results from the July 2008 Tribal Journey Water Quality Project. Turbidity is reported in Formazin Nephelometric Units.

SWINOMISH CLIMATE CHANGE INITIATIVE
IMPACT ASSESSMENT TECHNICAL REPORT

APPENDIX 5

Jurisdiction Summary
Swinomish Indian Tribal Community:
Swinomish Reservation

Jurisdiction Profile

Land area within the existing jurisdiction:	(upland) 7,450 acres
Land area within urban growth area/residential zone:	1,618 acres
Land area of park, forest, and/or open space:	4,845 acres
Land area set aside as resource lands:	350 acres
Land area designated commercial/economic zone:	615 acres
Current population:	3,100 residents
Expected population in 2025:	4,000+ residents
Approximate Annual Budget:	$27,000,000

Current and Anticipated Development and Population Trends: Slow to moderate increase in mixed use commercial and residential development is projected.

Jurisdiction Infrastructure Summary

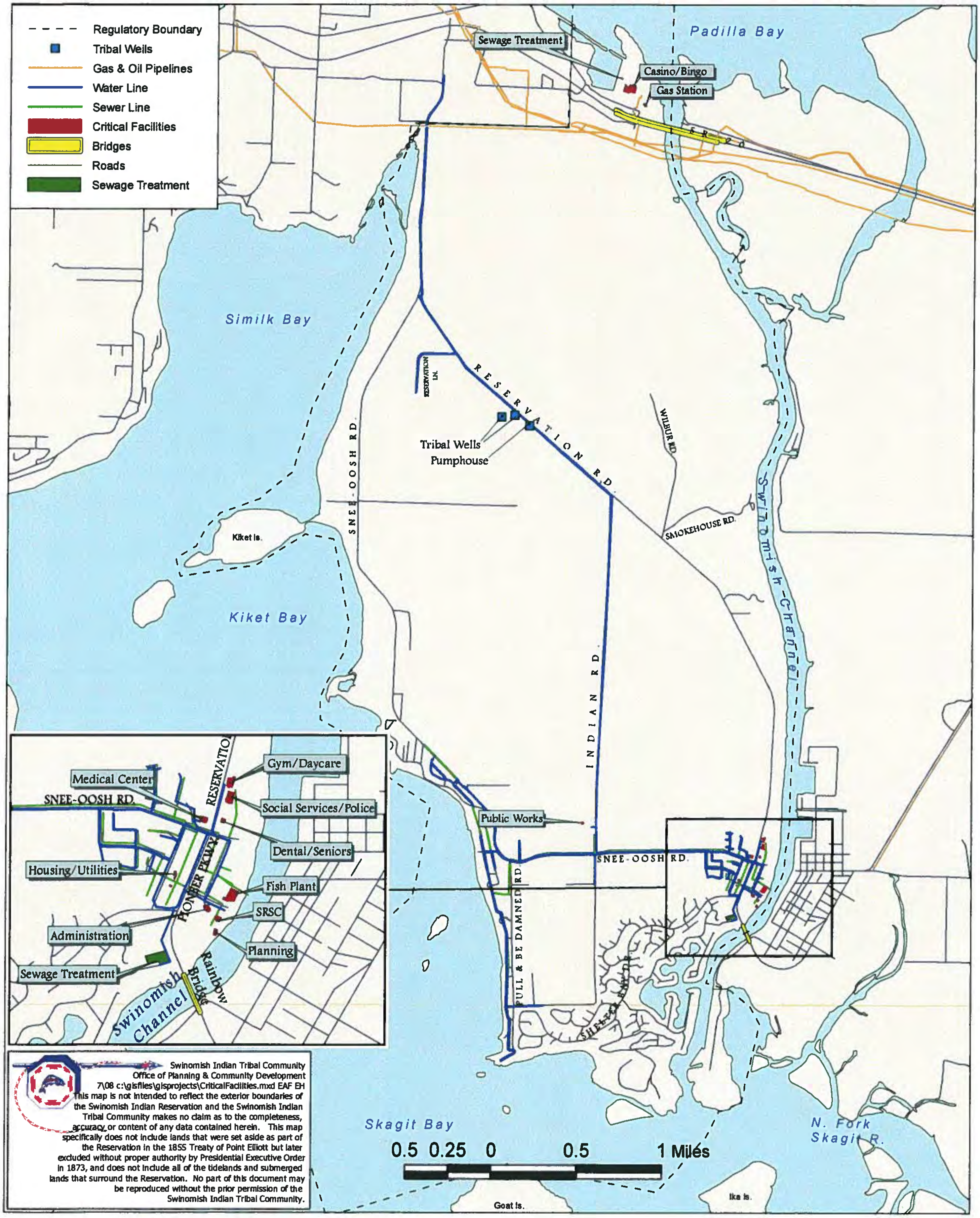
Miles of Streets/Road:	42	approximate value:	$30,450,000
Number of Bridges:	3	approximate value:	$21,000,000
Miles of Sanitary Sewer:	7	approximate value:	$ (below)
Miles of Storm Sewer:	4	approximate value:	$ 600,000
Miles of Water Line:	16	approximate value:	$ (below)
Other: Docks/ Pier		approximate value:	$ 673,000
Other: Oil Spill Building		approximate value:	$ 15,000

Critical Facilities:

1.	Social Services/ Police Station	approximate value:	$ 3,860,000
2.	Medical Center	approximate value:	$ 1,527,000
3.	Dental Clinic/ Senior Center	approximate value:	$ 928,000
4.	Tribal Administration Office	approximate value:	$ 663,000
5.	Planning Department	approximate value:	$ 575,000
6.	Housing Department/Utility Office	approximate value:	$ 209,000
7.	Gymnasium/ Daycare/ Community Center	approximate value:	$ 1,828,000
8.	Fisheries (Skagit River Systems Cooperative)	approximate value:	$ 284,000
9.	Sewage Treatment Plant/System	approximate value:	$ 4,000,000
10.	Swinomish Casino	approximate value:	$ 9,412,000
11.	Fish Plant	approximate value:	$ 1,675,000
12.	Water System	approximate value:	$ 2,100,000
13.	Public Works Department	approximate value:	$ 201,000
14.	Gas Station	approximate value:	$ 2,000,000

Total estimated value of relevant municipal infrastructure: $82,000,000

Critical Facilities Map, Swinomish Indian Reservation



SWINOMISH CLIMATE CHANGE INITIATIVE
IMPACT ASSESSMENT TECHNICAL REPORT

APPENDIX 6

Swinomish Indian Tribal Community
Office of Planning & Community Development
ClimateChange_Inundation_Risk_Zone.mxd
JULY 2009 EH

Inundation Risk Zone

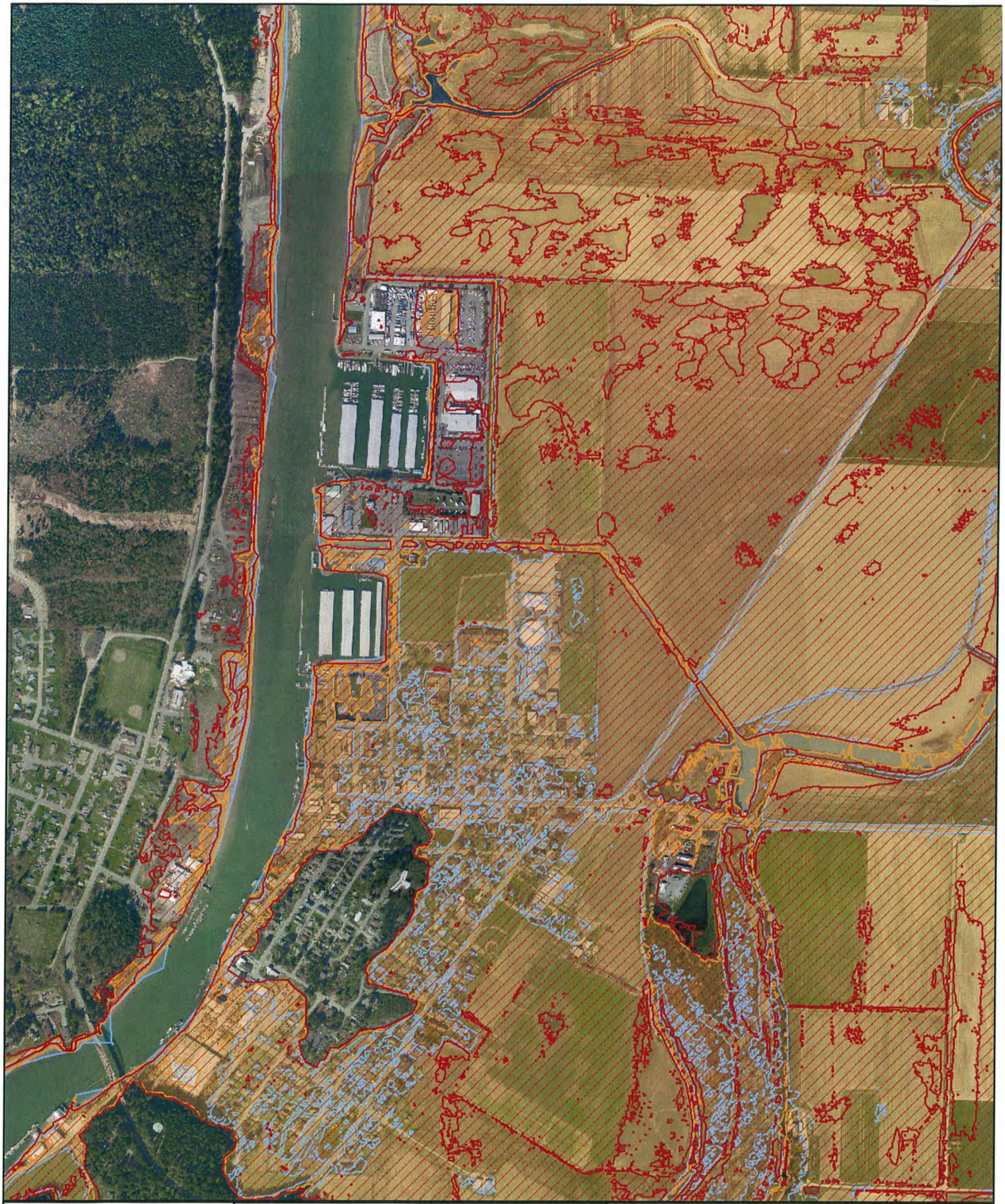
North End / SR20 Area

- Current MLLW - MHHW
- Projected Inundation Zone (+5ft) MLLW - MHHW
- Projected Tidal Surge Zone (+8ft) MLLW - MHHW

* Based on LiDAR flight on April 1, 2002
+/- 17cm Vertical, +/- 24cm Horizontal

200100 0 200
Feet

N



Swinomish Indian Tribal Community
Office of Planning & Community Development
ClimateChange_Inundation_Risk_Zone.mxd
JULY 2009 EH

Inundation Risk Zone

Swinomish Village / LaConner Area

Current MLLW - MHHW
Projected Inundation Zone (+5ft) MLLW - MHHW
Projected Tidal Surge Zone (+8ft) MLLW - MHHW

* Based on LiDAR flight on April 1, 2002
+/- 17cm Vertical, +/- 24cm Horizontal

200 100 0 200
Feet

N

Swinomish Indian Tribal Community
Office of Planning & Community Development
ClimateChange_Inundation_Risk_Zone.mxd
JULY 2009 EH

Inundation Risk Zone

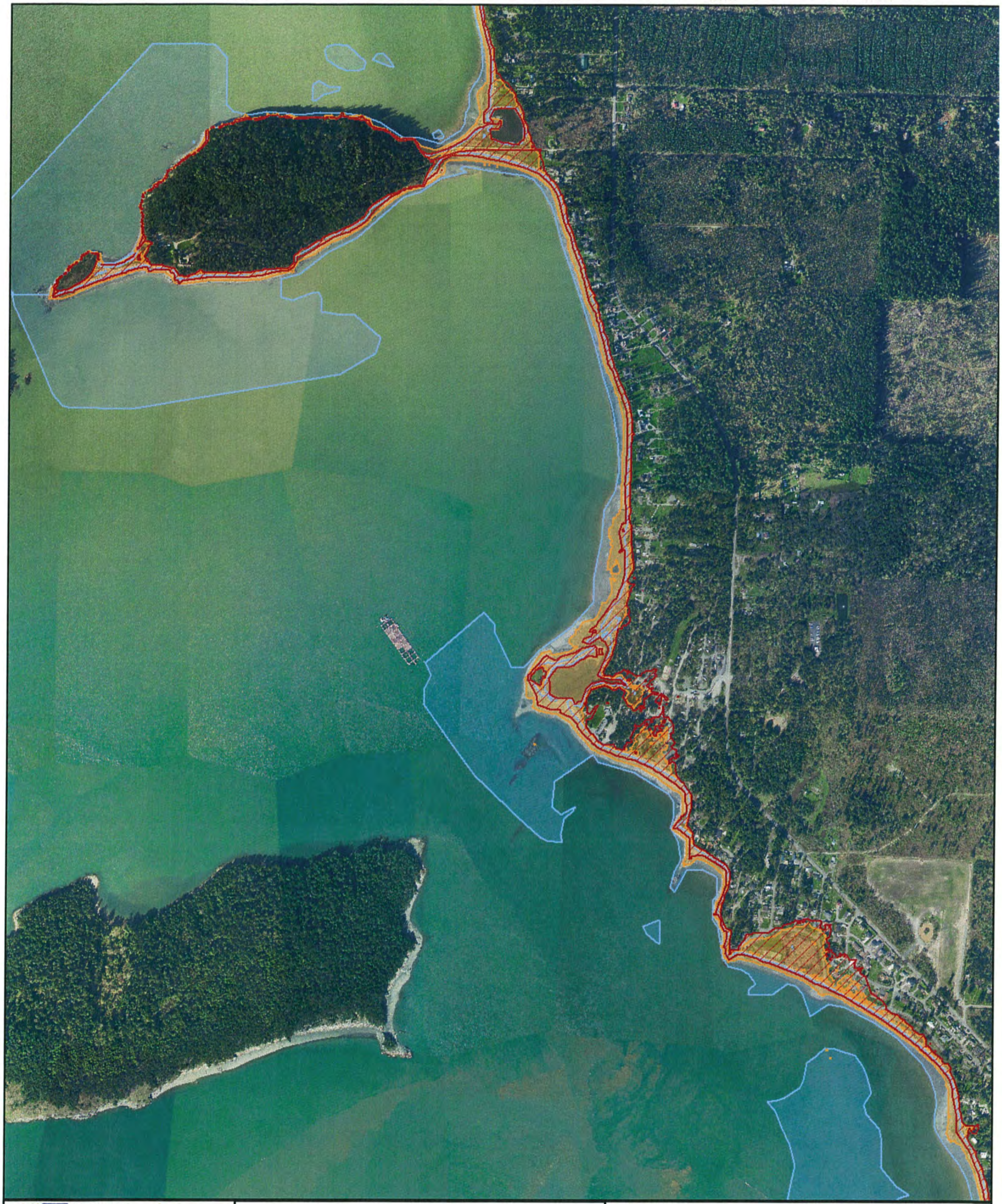
Shelter Bay / McGlinn Island Area

Current MLLW - MHHW
Projected Inundation Zone (+5ft) MLLW - MHHW
Projected Tidal Surge Zone (+8ft) MLLW - MHHW

* Based on LiDAR flight on April 1, 2002
+/- 17cm Vertical, +/- 24cm Horizontal

N

200 100 0 200
Feet



Swinomish Indian Tribal Community
Office of Planning & Community Development
ClimateChange_Inundation_Risk_Zone.mxd
JULY 2009 EH

Inundation Risk Zone

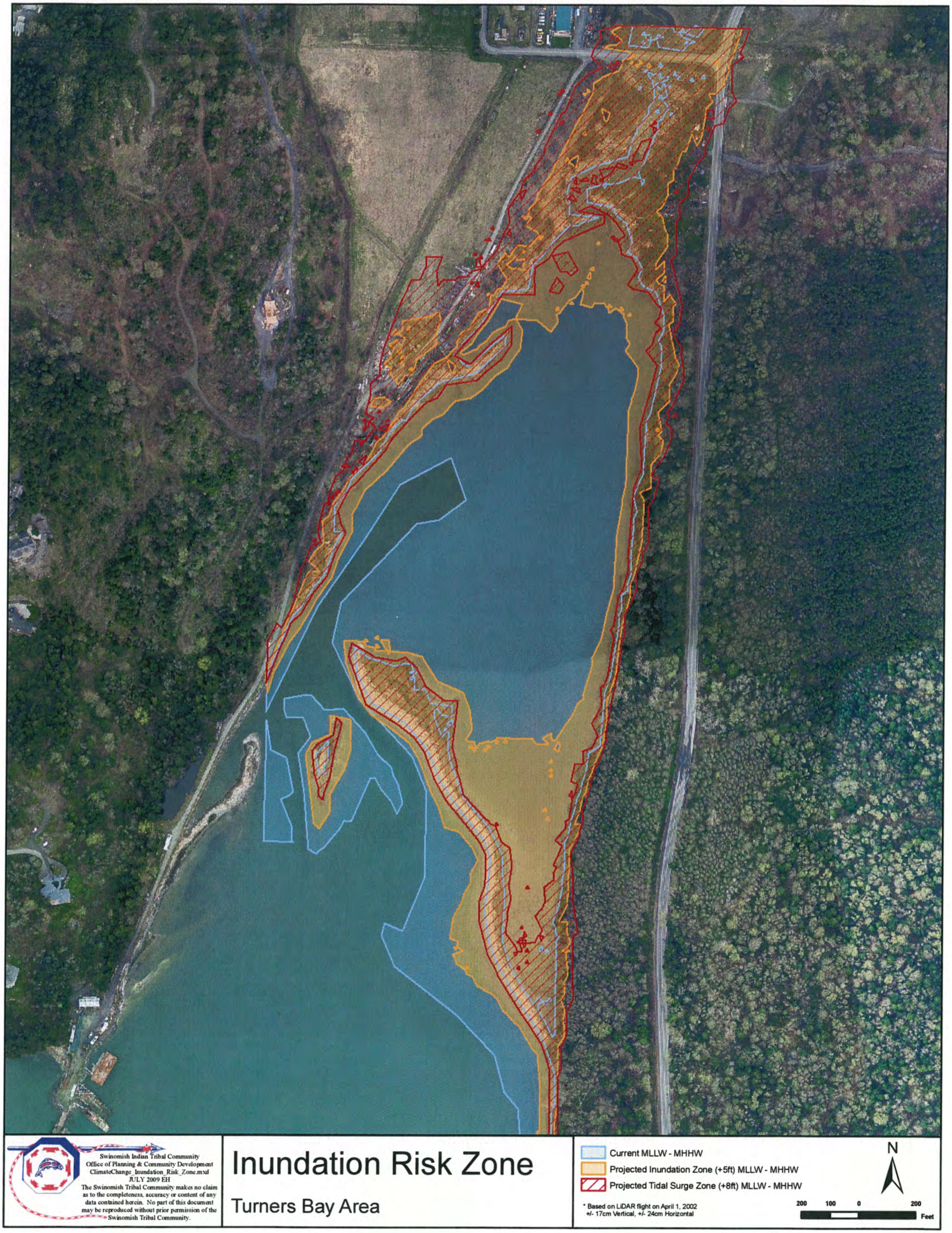
Snee-Oosh Beach / Kiket Bay Area

Current MLLW - MHHW
Projected Inundation Zone (+5ft) MLLW - MHHW
Projected Tidal Surge Zone (+8ft) MLLW - MHHW

* Based on LiDAR flight on April 1, 2002
+/- 17cm Vertical, +/- 24cm Horizontal

N

400 200 0 400 Feet


Swinomish Indian Tribal Community
Office of Planning & Community Development
ClimateChange_Inundation_Risk_Zone.mxd
JULY 2009 EH
The Swinomish Tribal Community makes no claim as to the completeness, accuracy or content of any data contained herein. No part of this document may be reproduced without prior permission of the Swinomish Tribal Community.
Inundation Risk Zone
Turners Bay Area
Current MLLW - MHHW
Projected Inundation Zone (+5ft) MLLW - MHHW
Projected Tidal Surge Zone (+8ft) MLLW - MHHW
* Based on LiDAR flight on April 1, 2002
+/- 17cm Vertical, +/- 24cm Horizontal
N
200 100 0 200
Feet