PUGET SOUND NEARSHORE ECOSYSTEM RESTORATION STUDY

APPENDIX F

SUPPLEMENTAL INFORMATION ON AFFECTED ENVIRONMENT

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Puget Sound Nearshore Ecosystem Restoration Study

Appendix F – Supplemental Information on the Affected Environment

Contents

List of Tables

1 Introduction

The information presented in Chapter 3 of the Feasibility Report/Environmental Impact Statement focuses on resources of high ecological, cultural, and/or socio-economic value. This appendix provides further information on these resources that were analyzed during the plan formulation and decision-making process.

2 Rare and Unique Habitats

2.1 Rocky Shorelines

The only land form type that PSNERP objectives do not address is the rocky shoreline. This is largely because the rocky shoreline have remained unchanged from historic conditions due difficulty in modifying bedrock. These rocky shorelines host diverse communities of kelp, invertebrates and fish species. These communities can be affected by the degraded conditions of other adjacent land forms by way of degraded water quality (including temperature, siltation, and turbidity). The highest macro-invertebrate diversity in Puget Sound is found along the rocky shoreline. These diverse communities can be attributed largely to the combination of three-dimensional structure and primary production provided by floating and understory kelp (see table 1 for a summary of kelp species), and the hard substrate provided by bedrock. Many of these invertebrates are anchored to the bottom to avoid being swept away by the swift currents and surge that bring a constant source of nutrients and oxygen to kelp and algae beds. Assemblages and richness of invertebrates in the rocky shoreline tend to increase with length of tidal inundation. The table 2 summarizes invertebrate communities typical of rocky shorelines of Puget Sound, the Strait of Juan de Fuca and the San Juan Islands.

Table 1 Rocky Shoreline Vegetation (Kozloff 1973)

Zone (MLLW)	Vegetation
Zone 1 (+9 to +7)	Lichens, seaside plantain, thrift, and the occasional green alga
Zone 2 (+7 to +4)	Black lichens, rockweed (*Fucus* sp.), soda straws (*Scytosiphon* sp.), a variety of red algae, sea lettuce (*Ulva* sp.*),* sea tuft (*Cladophora).*
Zone 3 (+4 to 0)	Sea lettuce and rockweed, sea cauliflower (*Leathesia* sp.), sea sac (*Halosaccion* sp.), and sea lace (*Microcladia*).
Zone 4 (0 to -3.5)	Giant kelp (*Macrocystis*) along the Strait of Juan de Fuca, sugar kelp (*Laminaria)*, shotgun kelp (*Agarum* sp.), feather boa kelp (*Egregia* sp.), winged kelp (*Alaria* sp.), common bull kelp (*Nereocystis*), coralline algae, Turkish towel (*Chondracanthus* sp.), sea brush (*Odonthalia* sp.), purple laver (*Porphyra* sp.), and veined blade (*Hymenena* sp.).
Zone 5 (-3.5 to extent of photic zone)	Similar to zone 4

Table 2 Rocky Shoreline Invertebrates (Kozloff 1973, 1993)

Zone (MLLW)	Invertebrates
Zone 1 (+9 to +7)	Small herbivorous and carnivorous mollusks such as periwinkles, dogwinkles, whelks, and limpets, and crustaceans such as barnacles, isopods, and hermit crabs
Zone 2 (+7 to +4)	Similar to zone 1
Zone 3 (+4 to 0)	California mussel (*Mytilus californianus*) and goose barnacle (*Pollicipes polymerus*) where there is significant wave action, edible mussels (*Mytilus edulis*) in protected areas, chitons, whelks, and other snail and slug like organisms (*Granulina* and *Onchidella* sp), purple and green shore crabs, hermit crabs, porcelain crabs, black clawed crabs and ochre sea stars (*Pisaster ochraceus*) found in purple and orange morphs
Zone 4 (0 to -3.5)	-Giant nudibranch, sea lemons, dorids, dorinas, and shag mouse sea slugs -Chitons, northern abalone, scallops, whelks, and tritons -Giant pacific octopus, red octopus - Sea cucumbers, sunflower stars, bat star, ochre stars, brittle stars, red and green sea urchins - Plumose anemones, green anemones, strawberry anemones, various pelagic jelly fish, ascidians, sea squirts -barnacles, crabs (such as hermit, decorator and kelp crabs), isopods, and shrimp
Zone 5 (-3.5 to extent of light)	Similar to zone 5

Fishes found along the rocky shoreline include larger benthic species such as lingcod, kelp greenlings, cabezon, Irish lords, buffalo sculpin, many species of rock fish, and numerous smaller fish including sail fin and tidepool sculpin, clingfish, blennys, pricklebacks, and gunnels. Bird use of rocky shorelines varies among species, as well as the time of year. Some birds, such as the black oyster catcher, are year-round residents where they feed on mussels, limpets, barnacles, and other mollusks and crustaceans that are unique to rocky shorelines. Other birds typical of rocky shorelines include harlequin ducks, turnstones, surfbirds, pigeon guillemots, auklets, and belted kingfishers.

2.2 Rare Plant Communities

The coastline of Puget Sound is host to a variety of plant communities. Some of these communities have become sparse due to human-related factors, while others are naturally rare on the landscape. The Washington Natural Heritage Program has compiled a list of plant associations in Washington State that are considered rare. In addition, they have identified ecological communities that are "rare" based on vulnerability and percent decline. The following sections describe the Puget Sound shoreline's ecological communities that are considered highly vulnerable with very large, large, or substantial decline, along with communities that have not necessarily been identified as vulnerable, but contain rare plant associations (Crawford, WA Natural Heritage Program, pers. comm.; Natural Heritage Program 2008).

2.2.1 Coastal Prairies

Coastal prairies are among the most imperiled plant communities of western Washington and reflect a biological heritage unique to this region. The Washington Natural Heritage Program identifies prairie and savannah as highly vulnerable with a decline of greater than 90 percent. Historically, coastal and lowland prairies spread for hundreds to thousands of acres throughout western Washington; coastal prairies lie on high bluffs of Whidbey and the San Juan Islands and parts of Clallam, Whatcom, and Skagit Counties. Less than one percent remains of about 8,000 acres of prairie originally present on Whidbey Island (Whidbey-Camano Land Trust 2008). Once maintained by Native American burning practices (Chappell 2006a), these grasslands supported a wide variety of species of plants and animals, many found nowhere else. Prairie soils are typically shallow and very dry, often with southern or western exposure. Dominant plants in these environments included grasses (*Festuca rubra* and *F. idahoensis v. roemeri* most consistently present) and small herbaceous (e.g., *Grindelia integrifolia* and *Cerastium arvense*) and bulbous perennials (*Camassia leichtlinii*). Golden paintbrush (*Castilleja levisecta*) symbolizes these coastal grasslands, but has become threatened federally and critically imperiled globally. The Washington Natural Heritage Program identifies two Puget Sound shoreline prairie communities as rare: red-fescue-great camas-Oregon gumweed (shoreline grasslands) and Roemer's fescue-field chickweed-prairie junegrass (coastal bluffs and balds). Only nine occurrences of good quality fescue-gumweed-great camas communities remain in Puget Sound (Chappell 2006a). While historically coastal prairie distribution was limited historically by natural conditions (soil type, hydrology, ect.), factors such as development, recreation, invasive species, and the fire suppression that leads to native lowland forest colonization have left few remaining occurrences of these ecological communities.

2.2.2 Pacific Madrone

Three Pacific madrone-dominated associations, described as critically imperiled or imperiled in the state of Washington (Chappell 2006b) are found in a similar landscape as coastal prairies. Sites are often very dry, with shallow soils of relatively low nutrient status and sunny aspects adjacent to saltwater. Fewer than 30 occurrences are known throughout the Puget Sound region. Often co-dominated with Douglas fir (*Pseudotsuga menziesii*), madrone (*Arbutus menziesii*) forms a sub-canopy below the taller fir. Composition of the understory varies by location and association but may include salal (*Gaultheria shallon*), evergreen huckleberry (*Vaccinium ovatum*), ocean spray (*Holodiscus discolor*), and snowberry (*Symphoricarpos albus*). The Washington Natural Heritage Program identifies the following madrone associations as rare: Douglas fir-Pacific madrone-hairy honeysuckle and Douglas fir-Pacific madrone-salal. While it is likely that these were naturally rare associations, poor timber practices, fire suppression, and fungal diseases are all potential threats. Madrone responds positively to high-intensity fire and will re-sprout after logging; Douglas fir subordinance or even absence is a consequence of fire, clear-cutting, or selective Douglas fir logging. Douglas fir appears to increase in abundance without disturbance but is not thought to out-compete madrone. Non-native fungal diseases are likely implicated in the overall decline of madrone-dominated associations. Madrones provide an important source of fall and winter fruit forage for birds.

2.2.3 Tidal Freshwater Wetlands

Freshwater tidal or surge plain wetlands were once common throughout the Puget Sound nearshore zone. Unique to the freshwater extent of river deltas, the water levels rise and fall with the tides but the water is fresh (less than 0.5 parts per trillion salt). Generally these are high-nutrient and high-energy systems (Kunze 1994). Some historical logging data on stream-side and tidally influenced stream-side trees indicate spruce (*Picea sitchensis*) dominated plant communities. Spruce is not considered a dominant tree species in this region (Brennan 2007). Vegetation communities are varied and depend on substrate and flood regime characteristics. In the very rare undeveloped locations, forested swamps of spruce, alder (*Alnus rubra*), or occasionally pine (*Pinus contorta contorta*) may be found in upstream tidal areas (Boule 1981). Associated understory species could include dogwood (*Cornus sericea*), hardhack (*Spiraea douglassi*), and salmonberry (*Rubus spectabilis*). The analysis of changes in distributions of wetlands between the late 1800s and circa 2000 indicates that less than 10 percent of the historical area of tidal freshwater wetlands remains in Puget Sound (Simenstad et al. 2009). The Washington Natural Heritage Program identifies freshwater tidal wetlands as highly vulnerable with a substantial decline. Loss of freshwater tidal wetlands can be attributed to sea dikes and levees, filling of estuaries for agriculture production, and commercial and residential development.

2.2.4 Spit Berms

Backshore spit/berm habitats are found on sand spits that are not regularly inundated but receive some salt influence from spray or high tides. The substrate is usually a mix of sand and gravel, and drift logs are often present. Dominant plants include dunegrass (*Elymus mollis*), gumweed (*Grindelia integrifolia*), and yarrow (*Achillea millefolium*) (Ritter et al. 1996). The Washington Natural Heritage Program identifies the following spit berm plant associations as rare: American dunegrass-beach pea and red fescue-silver burr ragweed. The effect of the waves and wind creates a relatively unstable substrate.

3 Other Nearshore Species

The species described below where not described in Chapter 2, but warrant some discussion due to their reliance on the nearshore zone and/or their cultural and recreational significance in the region.

3.1 Anadromous Fish

3.1.1 Sturgeon

White sturgeon are long-lived broadcast spawners that spawn in high flow areas of large rivers. The young are found only in freshwater, while adults move freely between freshwater, estuary, and marine environments. It is rare to find white sturgeon in southern Puget Sound or Hood Canal; they are, however, seasonally common especially in shallow nearshore waters of the northern river deltas, namely the Skagit, Stillaguamish, and Snohomish Rivers. Those that are present in Puget Sound are migrants searching for food, and likely to have hatched in the Columbia or Fraser Rivers (Pacific States Marine Fisheries Commission 1996).

Green sturgeon may enter Puget Sound to forage in the nearshore zones of bays and estuaries; however, no spawning occur in Puget Sound rivers (see Rare, Threatened, and Endangered Species for more detailed information on green sturgeon).

3.1.2 Lamprey

Pacific and river lamprey are found in rivers and streams of Puget Sound and Hood Canal. Like other anadromous fish, lampreys migrate from marine to freshwater to spawn. The larvae, or juveniles, live in silt and mud substrate until they metamorphose. The young adults then migrate to saltwater where they will begin actively feeding. Adult lamprey are usually found at depths deeper than the nearshore zone; however, they do transit the nearshore during their migration to and from freshwater (Wydoski and Whitney 2003).

3.1.3 Forage Fish

There are two anadromous species of forage fish in Puget Sound: longfin smelt and eulachon. They spend a portion of their life in marine waters, but spawn in the substrate of rivers. Only longfin smelt spawn throughout Puget Sound rivers and streams, including the Nooksack, Duwamish, and Cedar Rivers. The Lake Washington population is landlocked, with individuals of this species spending their entire lives in freshwater (Fresh 2006). Longfin smelt are thought to have the most geographically restricted spawning habitat of all anadromous fish in Puget Sound (Wydoski and Whitney 2003). When longfin smelt are in marine waters, they generally inhabit the deeper pelagic zone, so they are not consistent tenants of the nearshore zone. The only documented eulachon spawning near Puget Sound is in the Fraser River in southern British Columbia (Wydoski and Whitney 2003). More details on eulachon are discussed under the Rare, Threatened, and Endangered Species sections.

3.2 Marine Fish

3.2.1 Rockfish

Rockfish are part of the family Scorpaenidae, and also belong to an informal group referred to as “bottomfish” along with species such as pacific cod, lingcod, and flatfish. There are more than 27 species of rockfish recorded within Puget Sound, with additional species found in the Strait of Juan de Fuca (PSP, 2008). Many of these species occupy shallow waters during some portion of their life history. Rockfish are typically associated with areas of various amounts of hard, complex substrate (reef habitat); making them an attraction for scuba divers in the region. They are common in the kelp covered rocky shorelines of the San Juan Islands and the Strait of Juan de Fuca and are also present in Puget Sound proper in and around boulder-cobble substrate and artificial reef structures such as sunken boats. Kelp and eelgrass beds function as valuable nursery habitat for the juveniles of many rockfish species. Fertilization is internal in rockfish and embryos develop within the female until they are released as pelagic larvae. These larvae drift for three to six months at varying depths (depending on the species) before settling on the benthos. Once settled they have a high fidelity to the site, rarely moving far from their home range. Many species of rockfish are long-lived (yelloweye have been aged at 100+ years old) and late maturing; only successfully producing offspring every decade or so (Love et. al, 2002). These life history strategies have made some species extremely vulnerable to fishing pressures, ultimately leading to the listing of three species in Puget Sound under the Federal Endangered Species Act (ESA).

4 Additional Information on Significant Species

The information presented in Chapter 2 on forage fish, salmon, and ESA listed species focuses on their use of the nearshore zone. Below is further discussion on their status in Puget Sound.

4.1 Forage Fish

Although forage fish in Puget Sound are not considered in peril, the stock status of two species, Pacific sand lance and surf smelt, is not tracked and largely unknown. Pacific herring are the only forage fish stock in Washington State monitored by WDFW. The cumulative abundance of south and central Puget Sound herring stocks in recent years is comparable to that observed in the 1970s and 1980s, while the Cherry Point stock, and north Puget Sound (excluding the Cherry Point stock) and Strait of Juan de Fuca regional spawning biomasses are at low levels of abundance. WDFW classifies forage fish spawning grounds as “marine habitat of special concern” and has a no net loss policy. Herring and surfsmelt are harvested commercially, but harvest of sandlance has been banned due to the importance of their role in the food web (Penttila 2007).

4.2 Salmon

Over the past few decades, salmon runs have severely declined for reasons including hydropower and water diversion, hatcheries, loss of estuarine and freshwater habitat, chemical contamination, fishing pressure, and ocean conditions warranting protection of certain Evolutionary Significant Units (ESUs) and Distinct Populations Segments (DPSs) under State and Federal Endangered Species Acts (see following section for more information on ESA listed salmonids). WDFW monitors the status of all runs of salmon and steelhead in Washington State and characterizes them as healthy, depressed, critical, or unknown. Critical stocks are defined as those that have declined to the point that the stocks are in danger of significant loss of genetic diversity, or are at risk of extinction. Depressed stocks are defined as those whose production is below expected levels, based on available habitat and natural variation in survival rates, but above where permanent damage is likely. The results are released every 10 years in Salmonid and Steelhead Stock Inventory reports. Table 3, below, contains a list of all Pacific salmon and steelhead runs in the Puget Sound Area and Strait of Juan de Fuca as of 2002 (WDFW and WWTIT 2002). In 2002, 22% of the stocks were depressed, 4% were critical, and 42% were of unknown status.

Table 3 Salmon Stocks in Puget Sound, by sub-basin (WDFW and WWTIT 2002)

SUB-BASIN	SPECIES	TOTAL NUMBER OF STOCKS	NUMBER OF DEPRESSED STOCKS	NUMBER OF CRITICAL STOCKS
San Juan Georgia Strait	Chinook	2	0	2
	Chum	3	0	0
	Coho	4	0	0
	Pink	1	0	0
	Steelhead	6	0	0
Whidbey	Chinook	8	7	0
	Steelhead	16	6	0
	Coho	7	0	0
	Sockeye	1	0	0
	Chum	5	0	0
	Pink	3	0	0
South Central	Chinook	7	1	1
	Coho	6	2	0
	Sockeye	3	2	0
	Steelhead	7	4	1
	Pink	1	1	0
	Chum	10	0	0
South	Chinook	1	1	0
	Steelhead		1	0
	Coho	3	1	1

SUB-BASIN	SPECIES	TOTAL NUMBER OF STOCKS	NUMBER OF DEPRESSED STOCKS	NUMBER OF CRITICAL STOCKS
	Chum	13	1	0
	Pink	1	0	0
	Steelhead	4	0	0
Hood Canal	Steelhead	11	6	0
	Chinook	2	1	1
	Chum	21	4	1
	Pink	3	2	0
	Coho	8	1	0
Strait of Juan de Fuca	Chum	9	2	1
	Coho	11	2	1
	Chinook	3	2	1
	Pink	3	1	2
	Steelhead	14	2	0
North Central	Coho	2	0	0
	Chum	1	0	0

4.3 Rare, Threatened, and Endangered Species

Information presented in Chapter 2 on Rare, Threatened and Endangered Species focuses on their listing status, use of the nearshore zone of Puget Sound, and factors that have led to their decline. Additional details of their life history, including feeding habits and reproductive strategies, as well as any ongoing recovery efforts in the region appear below.

4.3.1 Northern Abalone

Northern abalone feed on benthic diatoms as juveniles, and on kelp and other macroalgae as adults. Reproduction occurs by way of broadcast spawning, and once fertilized, the larvae drift with the currents for roughly one week until they receive a cue to settle on the substrate. The crustose coralline algae that commonly grow on subtidal rocks (referred to as pink rock) of the San Juan Islands and Strait of Juan de Fuca have been shown to exhibit a chemical cue that induces larval settlement and metamorphosis (Daume et al. 1999).

Joint efforts between WDFW, the University of Washington, and several other private and non-profit groups have experimented with outplanting juvenile northern abalone in the San Juan Islands and the Strait of Juan de Fuca (Save Our Abalone 2009).

4.3.2 Olympia Oysters

Olympia oysters are filter feeders, feeding primarily on phytoplankton. Spawning occurs in the summer when the males release sperm into the water column and females filter it through their gills, leading to internal fertilization. The larvae are brooded for two weeks and then released into the water column as plankton for 11 to 16 days, feeding on phytoplankton. Larval settlement requires a hard substrate such as shell, wood, or rocks (Dethier 2006).

A variety of agencies, including Puget Sound Restoration Fund and WDFW, are working to restore the Olympia oysters in Puget Sound through reseeding and reef building efforts with oyster shell.

4.3.3 Boccacio, Canary, and Yelloweye Rockfish

Larval bocaccio are pelagic, drifting at the mercy of the currents, usually occupying surface waters. By age 3.5 months, the young will settle and recruit to nearshore habitat. Juveniles are found in much shallower water over rocky substrate with various understory kelps and/or sandy bottoms with eelgrass. Adults generally occupy water 150 to 800 feet deep over rocky outcroppings, boulder fields, and sloping walls and will school with conspecifics and other species of rockfish. Occasionally, these adults will migrate onto mudflats adjacent to rocky substrates. Adult bocaccio were once quite common on steep rocky walls in deeper water of Puget Sound. They can also be found well off the substrata up in the water column. Adults and large juveniles feed on small fish and squid, whereas larvae and small juveniles feed on copepods, krill, diatoms, dinoflagellates, and various larvae (Love et al. 2002).

Larval canary rockfish are pelagic, drifting at the mercy of the currents, and tend to be present in the upper 300 feet of the water column. After 3 to 4 months, the pelagic juveniles settle onto shallow benthic substrates such as tide pools and kelp beds. As juveniles grow, they start to group and move into depths of 50 to 70 feet at the interface between rock and sand during the day and then disperse onto the sand flats at night. The juveniles gradually move from shallower to deeper areas towards the end of summer. Adults occupy depths of 250 to 650 meters in areas with considerable current around pinnacles and high relief rock, often schooling with conspecifics and other species of rockfish. Adults and sub-adults feed on small fish and invertebrates while juveniles feed on copepods, krill eggs, and various larvae (Love et al. 2002).

Very little is known about the larval stage of yelloweye rockfish (year 1), but young juveniles can be found on vertical walls with cloud sponges and anemones at depths greater than 50 feet. Adults and sub-adults occupy rocky nearshore areas with refuge such as crevices, caves, and boulder piles. Occasionally, they will wander onto mudflats adjacent to rocky areas, sometimes in shallower waters. Yelloweye rockfish spend the majority of their time on the substrata where they feed on small fish, shrimp, crab, and lingcod eggs (Love et al. 2002).

There are no Federal recovery efforts for these three species of rockfish. WDFW has a Rockfish Conservation Plan that focuses on managing fisheries, establishing marine conservation areas, reporting and removing fishing gear, and exploring hatchery program and artificial reefs. They also publish recommendations to limit bycatch and mortality from recreational angling (WDFW, 2012). However, this plan and recommendations are for all species of rockfish and do not focus on the specific requirements of ESA listed species.

4.3.4 Eulachon

Eulachon spend most of their lives in the nearshore zone before migrating into the major river systems along the west coast of North America to spawn in the early spring (late February to May). It is believed that eulachon return to the estuary of their birth, but it is not known if they return to the same river from where they hatched. After hatching, larvae are carried downstream and out into the estuary where they feed on zooplankton. As a schooling fish, eulachon travel together in the ocean. They have been found to live near the ocean bottom at depths of 60 to 500 meters (Hay and McCarter 2000) as well as nearshore areas and coastal inlets.

There are no formal recovery plans for eulachon, state or otherwise, although fishing restrictions may partially aid in recovery.

4.3.5 Hood Canal Summer Chum

Chum are anadromous and semelparous (spawn once and die). Chum have evolved to migrate immediately to marine waters upon hatching, limiting their freshwater life history phase. This life history strategy, which chum salmon share with pink salmon (*Oncorhynchus gorbuscha*), reduces the mortality associated with the variable freshwater environment, but makes chum more dependent on estuarine and marine habitats. When the fry first enter saltwater, they assemble in small schools and reside close to shore where they can avoid predators and forage on epibenthic prey. Juvenile chum salmon often use small coastal embayments and eelgrass beds as foraging grounds and refuge from predators. As the young fish grow, they gradually move to deeper water and generally migrate towards open ocean. Some chum salmon juveniles will remain in the nearshore zone until late in their second year before migrating to the open ocean. Mortalities during this early marine life period are primarily the result of predation by birds and other fish species. Adult chum usually return to their natal estuary to spawn (Fresh 2006).

There is no Federal recovery plan for Hood Canal Summer Chum, however WDFW along with Point No Point Treaty Tribes developed a Summer Chum Salmon Conservation Inititive that focuses on elements such as habitat restoration and harvest management (WDFW and Point No Point Treaty Tribes, 2008).

4.3.6 Puget Sound Chinook Salmon

Chinook are anadromous and semelparous (spawn once and die). Within this general life history strategy, Chinook display a wide range of variation including variation in age at seaward migration; variation in length of freshwater, estuarine, and oceanic residence; variation in ocean distribution and ocean migratory patterns; and variation in age of spawning migrations. Two predominant life history patterns exist in the eastern North Pacific populations: stream-type and ocean-type (Healey 1991). Stream-type populations may rear as juveniles in streams for one to three years prior to migrating out to marine waters, but they most commonly do so as yearlings. Ocean-type populations migrate within their first year, although exact migration timing probably integrates genetic and environmental factors. Among the ocean-type populations of the Skagit River, Beamer and Larson (2004) found a variety of delta-rearing strategies exhibiting a density-dependent relationship and displacement of fry migrants due to lack of habitat capacity.

The primary prey of resident Chinook are forage fish including surf smelt and herring. Adult Chinook return to their natal estuary and migrate upriver to spawn. Reproductive strategies such as fecundity and run timing vary greatly in Chinook salmon and are influenced by a variety of genetic and environmental factors. Chinook viability is tied to the presence of local and landscape-level functioning habitats that can support populations through feeding, migration, and predator avoidance (Fresh 2006).

The Shared Strategy for Puget Sound submitted a plan for Puget Sound salmon recovery organized by local watershed planning areas. The plan has been adopted by NMFS and focuses on habitat restoration, harvest regulations, and interaction with hatchery fish (Shared Strategy Development Committee, 2007). Local responsibility for the plan transferred to the Puget Sound Partnership in 2008.

4.3.7 Puget Sound/ Strait of Georgia Coho Salmon

Coho are anadromous and semelparous (spawn once and die). Coho from British Columbia southward predominantly have a three-year life history cycle. Adults spawn by mid-winter and juveniles either rear in freshwater for up to 15 months before migrating out to the ocean as yearlings, or in some cases migrate immediately to estuarine rearing habitats where they may reside for several months. In British Columbia and Puget Sound, coho exhibit two types of saltwater life history phases: “ocean” types that occupy the outer coastal areas and the “inshore” types that spend their time in the more inland locale. Some coho may exhibit both types and travel to open coastal waters for brief periods and then return to the inland reaches (Groot and Margolis 1997; Goetz, pers. comm., 2009a). Coho are included in the plan for Puget Sound Salmon recovery that has been adopted by NMFS as described above (Shared Strategy Development Committee, 2007).

4.3.8 Coastal/Puget Sound Bull Trout

Bull trout are iteroparous (spawn more than once). They are a wide-ranging species with multiple life history forms and a complex population structure reflecting a high degree of local site fidelity (Kanda and Allendorf 2001) and substantial genetic divergence between breeding populations (Dunham and Rieman 1999; Spruell and Maxwell 2002). Temperatures above 59 °F are believed to limit bull trout freshwater distribution, which may explain their patchy distribution (Fraley and Shepard 1989; Rieman and McIntyre 1993). Bull trout have migratory and resident life history strategies. Residents spend their entire life cycle in the tributary streams in which they spawn and rear, whereas migratory forms rear in freshwater and then migrate to either a lake (adfluvial), river (fluvial), or saltwater (anadromous) (USFWS 2004). Primary prey items include surf smelt, sand lance, Pacific herring and juvenile salmonids.

According to the USFWS Draft Recovery Plan, bull trout use eight core areas along the eastern side of Puget Sound (Chester Morse Lake, Upper Skagit , Lower Skagit, Nooksack, Puyallup, Snohomish/Skykomish, Stilliguamish, and Chilliwack which is a transboundary river partly in Canada), and six populations on the Olympic Peninsula are limited to the Strait of Juan de Fuca and Hood Canal (Dungeness, Elwha, Hoh, Queets, Quinault, and Skokomish). Each core area has associated populations within it that exhibit varying life history types and spawning areas. Currently, no bull trout populations use tributaries or estuaries on the western side of Puget Sound. However, sub-adults and adults may occasionally migrate across Puget Sound to use the nearshore zone for foraging (Goetz, pers. comm., 2009b). The Federal Draft Recovery Plan for Puget Sound Bull Trout focuses primarily on habitat, including water quality parameters like temperature (USFWS, 2004).

4.3.9 Puget Sound Steelhead

Steelhead are an iteroparous (spawn more than once) species, whereas the Pacific salmon are semelparous (spawn once and die). Anadromous steelhead can spend up to 7 years in freshwater prior to smoltification and then three years in saltwater prior to first spawning. Steelhead usually return to their natal estuary to migrate upstream to spawn, and may spawn up to three times. Steelhead have a complicated life history, and differing combinations of freshwater/saltwater periods lead to many different possible life cycles (Barnhart 1986). All life history stages of steelhead can be present in rivers and estuaries year-round at varying numbers. In Hood Canal, steelhead smolts reside an average of 15 to25 days prior to migrating to the ocean (Moore et al. 2009). Once in saltwater, they quickly move into deeper water, often only spending a couple of weeks in Puget Sound. Their diet while in Puget Sound is largely unknown due to lack of samples, but they are thought to eat squid and small fish (Goetz,pers. comm., 2012). There are no recovery plans for Puget Sound steelhead, Federal or otherwise. However, they would benefit from the recovery efforts for Puget Sound salmon.

4.3.10 Green Sturgeon

This species is a long-lived fish that spends the majority of its time foraging along the coasts and in the large bays and estuaries of California, Oregon, and Washington for benthic dwelling prey such as shrimp, mollusks, amphipods, and small fish. Sturgeon enter freshwater to spawn in the deep turbulent pools of mainstem rivers where they broadcast their eggs onto clean cobble substrate (Moyle et al. 1995). No spawning habitat occurs in Puget Sound. There are no recovery plans for Green Sturgeon, Federal or otherwise.

4.3.11 Steller Sea Lion

Steller sea lions may be observed along the Washington coast year around, but they are least abundant in May through July, which corresponds to the breeding time off Oregon and British Columbia. Females begin breeding between at an age three and seven years, males at eight years. They give birth to one pup in late May to early July and breed annually due to high reproductive failures (Clakins and Pitcher 1982; NMFS 2008a). There are no Steller sea lion breeding rookeries in Washington waters. According to Jeffries et al. (2000), peak monthly counts indicate that they are most abundant off Washington's coast during March through April and August through November. Prey items include rockfish, skate, hake, salmon, halibut, black cod, squid, and octopus (Pike and Maxwell 1958). A Recovery Plan for the Steller Sea Lion was revised by NMFS in 2008. The plan focuses on rookery performance and protections, and intentional and illegal harvest (NMFS 2008).

4.3.12 Southern Resident Killer Whale (Orca)

Orcas are a long-lived species; up to 80-90 years old for females and 60-70 years old for males. Reproductive males mate with females outside their own pod, but always return to their maternal pod. Most females give birth to their first calf between the ages of 12-17 years, producing a calf on an average of every five to eight years (NMFS, 2008b). Calf mortality is high (37-50% in the first six months). Females average 2.2-4.1 surviving calves over a reproductive life span (Olesiuk et al. 1990, NMFS 2008).

The survival of these whales has been shown to positively correlate with Chinook salmon abundance (Ford et al. 2010). Chinook are apparently the key prey item for resident killer whales (Ford et al. 1998). Indeed, 72.2 percent of the 396 salmon taken by killer whales that were sampled from 1974 to 2004 were Chinook, despite the much higher abundance of the other species (Ford and Ellis 2005).

Southern Resident killer whales are some of the most chemically contaminated marine mammals in the world (second only to north pacific transient killer whales) as a result of their dependence on fish that originate from the industrial shorelines of Puget Sound, Vancouver, and Victoria (Ross 2004; Kriete 2007). These chemicals, which bio-accumulate up the food chain, are still used and continue to leach into the environment; others have been banned but still persist in sediments and the tissue of marine biota. Females tend to have lower levels of contamination than males due to offloading during gestation and lactation. This offloading exposes calves to high levels of toxic chemicals ranging from endocrine disrupters to carcinogens (Ross 2000).

A Recovery Plan for Southern Resident Killer Whale was issued by NMFS in 2008. This plan acknowledges that no one threat can solely be linked to the decline in the population or would have a significant impact on recovery. It points to the need for ongoing research and monitoring needs to address data gaps and answer questions regarding threats (NMFS 2008).

4.3.13 Marbled Murrelet

Marbled murrelets breed in the early spring. Both males and females share the incubation of a single egg. During breeding season and chick rearing phase marbled murrelets will make daily trips between marine feeding areas and their nests in old growth forests, feeding their chicks up to eight times per day. Common prey items are forage fish like sand lance, smelt, and herring (USFWS 1997). All nest locations in Washington have been located in old-growth trees that were greater than 32 inches in diameter at breast height (Ralph et al. 1995). Nests are usually located near the coast, but distances up to 50 miles inland have been found in Washington (Hamer and Nelson 1995). Reproductive success tends to be low, which is largely attributed to high levels of predation as their predators are able to adapt to habitat modifications whereas murrelets are not (USFWS 1997).

A Federal Recovery Plan for Marbled Murrelet was completed in 1997. The plan focuses on the protection of habitat in the terrestrial environment, and acknowledges the need to do so in the marine environment. In addition, it discusses reduction of mortality from the net fisheries, minimizing the occurrence of oil spills, implementing silviculture techniques to speed up development of new habitat, and the need for research and monitoring (USFWS, 1997).

Table 4. Rare, Threatened, and Endangered Species and Their Use of the Nearshore Zone

Species	Federal Listing Status and Date[1]	State Listing[1]	Critical Habitat Status and Date	Recovery Plan	Use of the Puget Sound Nearshore Zone	Dependence on the Nearshore Zone
Northern Abalone	SC	SCan	n/a	n/a	Inhabit rocky shorelines with ample kelp cover around the San Juan Islands and the Strait of Juan de Fuca where they graze on diatoms and kelp.	Direct
Olympia Oyster	None	SCan	n/a	n/a	Oyster reefs are often situated between eelgrass beds and mudflats.	Direct
Bocaccio	E, April 28, 2010	SCan	no	no	Planktonic larvae may drift through the nearshore zone. Juvenile rearing in shallow water over rocky substrate with kelps or sandy bottoms with eelgrass. Juveniles and adults occasionally wander into the nearshore zone for foraging.	Direct
Canary Rockfish	T, April 28, 2010	SCan	no	no	Planktonic larvae may drift through the nearshore zone. Juvenile rearing in shallow sand and/or rocky interfaces and kelp.	Direct
Yelloweye Rockfish	T, April 28, 2010	SCan	no	no	Planktonic larvae may drift through the nearshore zone. Juveniles and adults occasionally wander into the nearshore zone for foraging.	Intermittent
Eulachon	T, March 18, 2010	SCan	no	no	Spawning in natal estuaries. Use of shallow nearshore habitat for foraging, particularly in the northern Sound.	Direct
Hood Canal Summer Chum	T, March 25, 1999	SCan	yes, September 2, 2005	yes	Rearing and smoltification in natal estuaries. Migration and foraging in shallow nearshore areas. Use of coastal embayments for foraging and refuge from predators. Use of natal estuary for acclimatization to freshwater re-entry before upstream migration to spawning grounds.	Direct

Species	Federal Listing Status and Date[1]	State Listing[1]	Critical Habitat Status and Date	Recovery Plan	Use of the Puget Sound Nearshore Zone	Dependence on the Nearshore Zone
Puget Sound Chinook Salmon	T, March 24, 1999	SCan	yes, September 2, 2005	yes	Rearing and smoltification in natal estuaries, migration and foraging in shallow nearshore areas. Use of coastal embayments for foraging and refuge from predators. Use of natal estuary for acclimatization to freshwater re-entry before upstream migration to spawning grounds.	Direct
Puget Sound/ Strait of Georgia Coho	SC	none	n/a	n/a	Rearing and smoltification in natal estuaries, migration and foraging in shallow nearshore areas. Use of natal estuary as adults for acclimatization to freshwater re-entry before migrating upstream to spawning grounds.	Direct
Coastal/ Puget Sound Bull Trout	T, November 1, 1999	SCan	yes, October 18, 2010	yes	Foraging in shallow nearshore areas and estuaries as sub-adults and adults. Use of natal estuary as adults as a migratory corridor to upstream foraging areas and spawning grounds. Use of natal and non-natal estuaries for access to freshwater overwintering habitats.	Direct
Puget Sound Steelhead	T, May 11, 2007	none	no	no	Rearing and smoltification in natal estuaries, migration and foraging in shallow nearshore areas. Use of estuaries as adults for upstream migration.	Direct
Green Sturgeon	T, April 7, 2006	none	yes October 9, 2009	no	Foraging in nearshore and estuarine shallow water for benthic-dwelling prey such as shrimp, mollusks, amphipods, and small fish.	Intermittent

Species	Federal Listing Status and Date[1]	State Listing[1]	Critical Habitat Status and Date	Recovery Plan	Use of the Puget Sound Nearshore Zone	Dependence on the Nearshore Zone
Sea Otter	none	E	n/a	yes	Inhabit the shallow kelp forests of the nearshore zone, which they almost never leave, where they feed on a variety of benthic invertebrates.	Direct
Southern Resident Killer Whales (Orca)	E, November 18, 2005	E	yes, November 29, 2006	yes	Food source is almost 100% salmon at certain times of the year, mostly chum and Chinook, which are highly dependent on the nearshore zone as juveniles. Killer whales play and pursue prey in kelp beds.	Indirect
Humpback Whale	E, December 2, 1970	E	no	yes	The humpback whale is a rare visitor of the inland water of Puget Sound.	Minimal
Marbled Murrelet	T, October 1, 1992	none	yes, October 5, 2011	yes	Forage in deeper water of entrance channels of rocky shores, estuaries, and protected bays where they dive in pursuit of prey fish such as Pacific herring, sand lance, and surf smelt.	Indirect
California Buttercup[2]	none	none	n/a	n/a	Grows on open grassy areas and rocky slopes along the shoreline.	Direct
Sharpfruited Peppergrass[2]	none	none	n/a	n/a	Occurs in moist cracks and vernal pools, and sand or saline soil in direct sunlight.	Direct
Golden Paintbrush	T, June 11 1997	none	no	yes	Occurs in open grasslands at elevations below 100 meters around the perimeter of the Puget Sound.	Direct

1. Abbreviations: SC = Species of Concern, T =Threatened, E=Endangered, PT = Proposed Threatened, PE = Proposed Endangered, SCan = State Candidate
2. Identified as rare by the Washington Department of Natural Resources Natural Heritage Website.

4.4 Aquatic Invasive Species Identified as Risks to Puget Sound Ecosystems

The most threatening aquatic invasive animals to Puget Sound restoration efforts are the following (Ray 2005):

- Asian corbula clam (*Pomatocorbula amurensis*)
- Asian date mussel (*Musculista senhousia*)
- Atlantic oyster drill (*Urosalpinx cinerea*)
- Atlantic salmon (*Salmo salar*)
- Boring sponge (*Cliona thoosina*)
- Copepod sp. (*Pseudodiaptomus inopinus*)
- Eastern mud snail (*Nassarius obsoleta*)
- European green crab (*Carcinus maenas*)
- Japanese false cerith (*Batillaria attramentaria*)
- Japanese oyster drill (*Ceratostoma inornatum*)
- Japanese purple varnish clam (*Nuttalia obscurata*)
- Ribbed mussel (*Geukensia demissa*)

There are nine invasive marine plant species present in Washington identified in the Washington State Aquatic Nuisance Species Management Plan (Meacham 2001).

- Diatomaceous algae
  - *Pseudo-nitzchia australis*
- Macro algae
  - Dead man's fingers (*Codium fragile tometosoides*)
  - Japanese weed (*Sargassum muticum*)
  - Lomentaria (*Lomentaria hakodatensis*)
  - Tocoroten red algae (*Gelidium vagum*)
- Vascular plants
  - Common cordgrass (*Spartina anglica*)
  - Saltmeadow cordgrass (*Spartina patens*)
  - Smooth cordgrass (*Spartina alterniflora*)
  - Japanese eelgrass (*Zostera japonica*)

5 Hazardous, Toxic, and Radioactive Waste (HTRW)

The following land use types are known to cause concern for chemical contaminants and these land uses are found in one or more project locations of the Tentatively Selected Plan.

5.1 Stormwater and Urban Runoff

Polluted surface runoff in developed areas is the most common pathway for chemical contaminants to reach Puget Sound. Rain hits the roofs, roads, paved areas, and other hard surfaces and runs into storm drains, then passes mostly untreated into lakes, streams, and rivers that drain to Puget Sound. The heaviest concentrations of toxic substances come from developed areas of commercial/industrial and residential land uses due to their impervious surfaces such as pavement and roofs, which prevent rainwater from soaking into the ground and allow chemical contaminants to drift away in runoff, and from agricultural runoff.

Urban and homeowner use of pesticides and fertilizers that contain copper contributes up to one-third of the estimated release of copper into Puget Sound. Residential plumbing components leach copper to aquatic ecosystems as well. About another one-third of copper detected in runoff came equally from brake pad wear, roofing materials, and boat paint (WDOE 2011). Other chemicals of concern entering the Sound include flame retardants such as PBDEs, phthalates (a family of chemicals commonly found in plastics and roofing materials), triclopyr (a pesticide commonly used in urban areas), cadmium (from asphalt composite shingles), and zinc. More than 80% of zinc releases come from roofing materials.

Furniture, computer monitors, and other components of residential and commercial indoor environments release PBDEs, which are transported to treatment works as dust particles or runoff (which can then reach Puget Sound through combined sewer overflows). PBDEs were the only chemical of concern for which direct deposition from air appeared to be the largest delivery pathway to Puget Sound.

5.2 Marinas and Ports

More than 170 marinas cover approximately 0.3% (1,483 acres) of Puget Sound shoreline (Pearson et al. 2011b). Recreational boats and small commercial vessels contribute PAHs due to chronic spills, drips, and leaks during fueling and transition into and out of marinas and ports. Vessel anti-fouling paint leaches copper and tributyltin (though banned in 1988) to the water column and sediments. PAHs appeared in relatively high concentrations in phytoplankton from non-urbanized basins, and in particular from samples collected near marinas, ferry terminals, and shoreline roadways (Pearson et al. 2011b).

5.3 Agricultural Areas

Contaminants from agricultural practices include nutrients such as nitrogen and phosphorus commonly found in fertilizers, metals including cadmium and zinc), a variety of insecticides (DDT, DDE, DDD) and herbicides used for agriculture and lawn maintenance, and fecal coliform from livestock. Agricultural pollution in Puget Sound mainly occurs around the large river deltas where former wetland acreage has been converted to farmlands and pasture. Copper-based pesticides and fertilizers are used in agricultural as well as urban applications. Herbicide use on crops and golf courses includes the chemical triclopyr (a broad-leaf herbicide used primarily for rice crops, pasture and rangeland, rights-of-way, and turf, which is permitted under WDOE's Aquatic Pesticide General Permit to control nuisance vegetation in lakes). Agricultural areas produced the highest concentrations for several metals due to historical releases. Abandoned and current storage tanks, used for fueling farm equipment, are another source of contaminants.

5.4 Commercial/Industrial Areas

Some of the chemical contaminants associated with commercial and industrial discharges and runoff include PCBs from transformers and old paints, sealants and caulks in buildings (PCBs were banned in 1979 and are no longer used), phthalates from various personal care products, petroleum-based contaminants, nonylphenol (a compound often found when commercial detergents break down), and mercury (thermostat and fluorescent lamp disposals), among others. In addition, the weathering of pigments and paints on buildings can contribute cadmium, copper, lead, tributyltin tin, and PCBs to the environment. Wastewater treatment plants are a major pathway for PBDEs, and appear to transport larger annual quantities to Puget Sound than surface runoff. The Asarco Smelter in Tacoma emitted arsenic for decades and may have resulted in large swaths of the Puget Sound area with elevated arsenic. Historically, a large source of mercury to Puget Sound was a now-defunct chloralkali plant in Bellingham, although numerous other industrial and combustion sources still release mercury. Data from 2003 showed that at Fourmile Rock, located near Elliott Bay, mussel tissues had especially high PCB levels in the early 1980s (more than 1,500 parts per billion [ppb] dry weight) followed by a decline to 262 ppb in 2002. This lower level, however, is still more than five times the national median for PCBs in mussels (PSAT 2007a).

5.5 Pulp and Wood Industry

Creosote, a tarry substance formed as coke distillate, is used to preserve wood and has historically been a major source of PAHs in Puget Sound, particularly in areas with pole treating operations adjacent to marine waters. PAHs from creosote-treated wood are detrimental to fish eggs and embryogenesis and can affect early life stages of fish such as herring. Researchers with the Skagit Marine Resources Committee found that 60-year-old pilings were continuing to leach creosote daily into the marine environment; one cubic foot of creosote-treated wood contains at least 20 pounds of creosote (PSAT 2007a). Other sources of PAHs come from wood smoke and vehicle exhaust. Median concentration of PAHs in mussel tissue from Puget Sound sites ranged from 200 to 4,000 ppb dry weight. These concentrations range from one to more than 10 times the national median value of 220 ppm dry weight (PSAT 2007a). Wood treatment facilities also were a historical significant source of arsenic contamination. Pulp mill emissions include lead and dioxins. In the Puget Sound region, the major historical sources of dioxins (PCDD/Fs) are from the use of elemental chlorine in pulp bleaching, pentachlorophenol wood treatment operations, and the combustion of saltwater-infused hog fuel (unprocessed mix of coarse chips of bark and wood fiber) (WDOE 2011).

5.6 Utility Lines

Utility lines include electric and underground fuel bearing lines. Telephone lines historically used creosote-treated poles, many of which remain today including those that either cross stream courses or are adjacent to water bodies. A component of electric lines included transformers that contained PCB liquids, which resulted in releases to the environment due to equipment spills and leakage. Herbicides containing arsenic were applied historically along rights-of-way to control vegetation. PCBs and arsenic likely are still contaminating the sites where they were used.

5.7 Transportation Corridors

Transportation corridors include roadways, commercial vessel corridors, and railroads. Vessel traffic associated with petroleum refining and transportation facilities may release PAHs to the water and sediment. PAH concentrations were relatively high in sediments near Anacortes, an urbanized area in north Puget Sound with significant petroleum refining and transport facilities (PSWQAT 2002). Roadways are a source of petroleum-related compounds from minor fuel and oil spills, and drips and leaks from cars and trucks. Pollutants from roadways can enter the Sound from dust (50% is transported off-roadways as fugitive dust) and stormwater runoff. Chemicals entering the aquatic ecosystem include copper from brake pad abrasion, zinc from vehicle tire abrasion, and incomplete combustion of fuels resulting in atmospheric deposition of contaminants into the marine environment. Incomplete combustion causes releases of arsenic, cadmium, lead, mercury, PAHs, and in some instances dioxins. Creosote-treated wood accounts for one-third of the PAH release, with marine pilings (54 t/yr), railroad ties (43 t/yr), and utility poles (17 t/yr) representing the major sources (WDOE 2011).

6 Summary of Cultural Resources in Puget Sound

Puget Sound has played a vital role in the development and growth of Native American settlement within the Northwest Coast region. Native American tribes relied heavily upon Puget Sound and its vast marine and lacustrine resources as an integral part of their culture by contributing heavily to subsistence strategies as well as transportation and trading routes. Hundreds of prehistoric and historic archaeological sites have been found on the historical shorelines of Puget Sound, providing insight about these coastal-based cultures. Distinguishing characteristics of prehistoric groups include a heavy reliance on abundant marine organisms and anadromous fish, highly skilled woodworking and fishing technology, and complex social organization.

Between 14,000 and 15,000 years ago, the glaciers surrounding the Northwest Coast began to recede, allowing the settlement of the region by migrating people from the north and the south. However, while much of the region was ice free, little, if any, cultural material dates from within this period. Early sites throughout the region are composed primarily of lithic assemblages that become increasingly complex through time. Due to a lack of faunal material at these sites, it is believed that subsistence strategies during this period focused primarily on terrestrial mammals, with increased reliance on marine food sources over time. The first large shell midden sites date from the period between 5,500 and 3,500 years before present, accompanying an increase in population, a diversification of artifact types, specialized technological adaptations for fishing and marine mammal hunting, woodworking, artwork, and wealth and status objects. This pattern of increased specialization in technology and site composition continued until approximately 1,500 years before present, when artifact diversity began to decline, while Coast Salish structures and cultural practices began to emerge.

6.1 Site Types

An archaeological site can be defined generally as a place where past human activity has left a mark or materials behind. Sites are classified as prehistoric when such activities occurred prior to the advent of written records in a particular area. In Puget Sound, prehistoric sites range from the Paleolithic era (from 15,000 years before present) and continuing until the period of European exploration and colonization initiated in the late 18th century.

Prehistoric site types and frequencies vary through space and time, mirroring changes in subsistence strategies, occupational patterns, and evolving social structure. Throughout the Puget Sound region, sites can generally be broken down into five main types: occupation sites, food processing centers and middens, lithic assemblages, traditional cultural places, and burial grounds.

6.1.1 Occupation Sites

Prehistoric occupation sites include temporary and permanent sites. Temporary sites, such as hunting camps, leave a relatively small archaeological footprint and are characterized by small assemblages that include fire cracked rocks, lithic scatters, and faunal materials. Permanent sites, such as winter villages, leave a large archaeological footprint, and are representative of multi-generational use over an extended period.

The selection of a winter village location depended primarily on topographic considerations and proximity to food and other resources. Due to their dependency on marine and lacustrine resources, Northwest Coast villages were generally located close to a beach or along a river, while riverine villages were most often located at the junction of two river tributaries. Houses in south Puget Sound often were constructed on higher ground to allow for drainage, whereas groups in north Puget Sound constructed winter houses on shores where the beach is full of sand or gravel and where there is a layer of earth to be trodden down as a floor. Villages within Puget Sound generally consisted of several family groups occupying one or more large plank houses and sometimes one or more smaller structures. House floors, consisting primarily of trampled and pounded earth, may be identified as well as fire hearths or pits and various smaller structures that vary among cultures, seasons, and village populations.

6.1.2 Food Processing Centers and Middens

The most common site type found on the shores of Puget Sound is a midden deposit. Most commonly associated with shell, middens represent domestic subsistence waste and are invaluable in discovering subsistence strategies of prehistoric cultures. In the Puget Sound region, midden deposits are the result of annual harvest preparation and preservation of food for winter storage, as well as a means of immediate food supply.

Salmon was a primary food source for all groups that lived along Puget Sound as well as its tributaries and drainages. The use of other resources to supplement their diet varied among groups. Chinook, coho, chum, pink, steelhead, and sockeye were caught by various methods including spears, gill nets, dip nets, traps, weirs, clubs, hook and line, and gaffs. Salmon either was prepared fresh for immediate consumption or was preserved by smoking over open fires to be stored for winter use. Other fish, such as cod, flounder, perch, skate, trout, smelt, herring, halibut, and sturgeon were used in a variety of different ways.

Shellfish provided an important supplement to native diets in Puget Sound, and were highly prized as trade items as far away as Eastern Washington. Common species found include a variety of clams (horse clam, butter clam, littleneck, cockle, and geoduck), mussels, oysters, and barnacles, all of which were obtained with digging sticks or by hand. Large game, small fur bearing mammals, birds, and marine mammals (porpoise, seal, and whale) were consumed and used, either through opportunistic harvesting or through planned hunts. Plant foods were an important part of native subsistence and health, including herbs, roots, nuts, bulbs, sprouts, berries, and tubers.

6.1.3 Lithic Assemblages

Stones that have been shaped or modified by humans form an important part of the archaeological record within the Pacific Northwest. Archaeological stone tools may be found in isolation, but are most often discovered in a loose association known as an assemblage, and can be made from a variety of materials. Lithic assemblages can consist of tools such as end and side scrapers, weapon points such as arrow and spear heads, fire modified rock, ground stone tools such as mauls and adzes, and manufacturing byproduct known as debitage.

6.1.4 Traditional Cultural Properties

Places of cultural significance, generally termed traditional cultural properties, refer to sites connected to the beliefs, customs, and practices of a living community of people that have been passed down through the generations, usually orally or through practice. The significance of these traditional places derives from the role the property plays in a community's historically rooted beliefs, customs, and practices. Examples include locations with artistic, religious, and ceremonial significance to Native American groups such as treaty locations, and locations associated with aboriginal stories.

6.1.5 Burial Grounds

A burial can be described as a deliberate deposit or final stage in a funerary ritual that is likely to result in the placement of human remains. While individual inhumation sites and group cemeteries are most likely to manifest themselves archaeologically, excarnations such as above ground canoe burials were also present within the Puget Sound region.

6.2 Historic Resources

In common with other frontier regions in the Pacific Northwest, explorers and fur traders made the first non-native expeditions to the Puget Sound region. British explorer George Vancouver led the way in 1792. British and American fur traders infrequently worked the Puget Sound before the British-owned Hudson Bay Company made the first non-native structural presence, a trading post and stockade built on the Sound’s southern shores. In the early 1850s, Euro-Americans started venturing into the Puget Sound region in increased numbers. The draw for most was the region’s vast forests of giant fir, spruce, cedar, and hardwoods, building materials that were in high demand down the Pacific Coast at the burgeoning California city of San Francisco. In 1852, the fledgling settlement that became Seattle took root at the Sound’s premier inlet, Elliot Bay. A lumber mill was in operation at Seattle within a year, and logging camps and mills soon dotted the landscape throughout the region.

Agriculture settlement and production in the Puget Sound region also took hold in the early 1850s. The timber industry significantly aided early agricultural activities as loggers cleared fertile bottomlands of trees. Many loggers and mill workers turned to subsistence farming as means to feed their family. By the mid-1860s, only a few settlers had looked to the low-lying river deltas, estuaries, and sloughs along the coast as potential farmland. Preparing those otherwise swampy tidal lands for agricultural uses required the construction of ditches and earthen dikes to drain and hold back rising tides and the seasonal floodwater of rivers. Once converted, tidal lands proved ideal for pasturing cattle and raising high-yield fodder crops of oats and hay. Draining and diking of tidal lands at a larger scale waited until the 1870s when most of the prime upland agricultural area had been taken.

While timber was the primary industry and agriculture was second, other endeavors contributed to early economic and population growth in the Puget Sound region. Commercial fishermen heavily exploited the natural bounty of salmon and shellfish, and processed and packaged their catches locally for shipment to San Francisco and other distant markets. By 1880, Seattle and Tacoma supported shipyards that used local lumber to construct maritime vessels as well as small steamers and other boats suited to ferrying people, cargo, and mail to and from waterfront communities around the Sound.

Agricultural activities in the Puget Sound region began to shift to meet the demands of a growing urban population. Dairy farming became increasing prevalent aided, in part, by the introduction of new technologies for processing milk. Reclaimed tidal lands, where oats and hay grew in abundance, almost exclusively became devoted to dairy farming. By 1920, dairying ranked as the primary agriculture activity in Puget Sound and Western Washington.

A network of roads and highways started to evolve around the region after the introduction of the automobile in the first decade of the twentieth century. Compared to other parts of Washington, progress moved slowly. The late 1920s and early 1930s saw the completion of two major highway systems, which together encircle the entire Puget Sound coastline—the Pacific Coast Highway and Highway 101.

Examples of Puget Sound's current collection of historic buildings and structures are listed below. Examples are limited to just the broad categories of function or use most common to tidal lands: industry, agriculture, and transportation.

- Port Gamble Historic District. A logging and milling community containing one of Puget Sound's oldest collections of buildings and structures, dating to 1853.
- Salina Fisheries Company Cannery, Anacortes. A salmon cannery initially constructed in the mid- to late-1910s.
- John and Annie Larson Farm House, Livingston Bay, Camano Island. Constructed in 1891.
- Deepwater Slough Dikes, Island County. System of earthen agricultural dikes, developed between 1885 and 1909.
- Steilacoom Creek (Northern Pacific) Railroad Bridge, Chamber Bay, Steilacoom vicinity. The only surviving vertical-lift bridge of the Strauss design in the nation, constructed in 1913-14.
- North and South Hamma Hamma River Bridges, Old US Highway 101, Eldon vicinity. Two rainbow arch concrete bridges, constructed in 1924.

7 Future Risk Assessment Approach and Assumptions

7.1 Projected Scenarios for Land Development

Three future scenarios for land development—Status Quo, Managed Growth, and Unconstrained Growth—were applied to Puget Sound and examined using the ENVISION computer modeling program. These scenarios, described in Table 2-5, were developed to examine what is considered the range of realistic possible future conditions. The ENVISION analysis was conducted to provide projections for the most-expected land-development scenario (Status Quo), as well as for two additional scenarios that generally represent the range of differences that could occur if more stringent (Managed Growth) or more lax (Unconstrained Growth) land management policies were in place. In the modeling simulations, researchers held human population growth constant among the scenarios while applying a different set of development-policy rules for each of the three scenarios to allocate development across each Puget Sound sub-basin.

Table 5. ENVISION Puget Sound Scenarios Descriptions (Bolte and Vache 2010)

Scenario	Description
Status Quo	This scenario reflects a continuation of current trends in the region. In this scenario, continuation of current policies would allow moderate levels of development in most areas. No development would be allowed on deltas, within floodplains, or in areas with unstable slopes; development on wetlands would be limited. This development pattern would emphasize moderate density uses.
Managed Growth	This scenario reflects the adoption of an aggressive set of land use management policies focusing on protecting and restoring ecosystem function and concentrating growth within Urban Growth Areas (UGA) and near regional growth centers. No new development would be allowed within 200 feet of the shoreline. Outside the 200-foot zone, development would be severely restricted in areas near sensitive lands, including current and historical wetlands, lands with significant conservation opportunities, deltas, unstable slopes, or lands adjacent to streams. Water views would be protected. In developed areas, the focus would be on increasing density.
Unmanaged Growth	This scenario models a relaxation of current land use restrictions, with limited protection of ecosystem functions. The Unmanaged Growth scenario would allow significant new development in the nearshore zone. No development is allowed on deltas or on unstable slopes, but other landforms would be developable. This development pattern would emphasize low-density uses.

ENVISION was used to allocate the projected population growth in 10-year (decadal) time increments under each of the three land development scenarios. These population estimates were in turn used as inputs for modeling subsequent effects on land use/land cover. The projected population growth is expected to lead to an expansion of developed areas in the Nearshore Study area. Changes in distribution and amounts of a subset of shoreline attributes were also projected.

7.2 Assumptions in the Forecast of Process Degradation

7.2.1 Landform Transition Assumptions

- No Landform Transitions are Included in the Future Projections. The transition of one natural landform type (e.g., bluff-backed beach, barrier estuary) to another natural landform type or an artificial landform type is the result of either significant landscape-scale modification of the processes sustaining a given landform or the construction of several stressors that cumulatively function to completely change the shoreline configuration and character. Landforms resulting from the latter type of landform transitions are termed artificial landforms. Observations from the analysis of landform changes, from historical to current, indicate that nearly 92% of the landform transitions (665 of 719) involved transition from a natural landform to an artificial landform or became absent. It is assumed that new shoreline alterations on the scale necessary to cause transitions to artificial landforms are unlikely because of a combination of more restrictive regulatory controls than were in place historically and increased community resistance to such projects. That is, major alterations leading to transitions of landforms, from natural to artificial or absent, in the Puget Sound nearshore zone are largely a legacy of previous actions. While transitions from one natural landform type to another natural landform type could occur because of long-term degradation of landform-forming processes, these transitions were rare historically (54 transitions between historical and current). If this assumption, that there will be no new landform transitions, is incorrect, then it is reasonable to assume that landform transitions will occur in association with existing stressors or forecasted shoreline armoring.

7.2.2 Shoreline Alterations Assumptions

- Shoreline alterations in the future are adequately estimated by the forecasted distributions of armoring, marinas (subset of overwater structures), and wetland losses. All of the other types of shoreline alterations (additions of tidal barriers, breakwaters/jetties, nearshore fill, roads, railroads) are either unlikely to occur in large quantities and/or if they do occur they will be co-located with one of the stressors that is forecasted to expand or already exists.
- Few if any new tidal barrier structures will be constructed. If any are constructed, it is assumed they will be co-located with increases in armoring or wetland loss. Construction of barriers to tidal inundation (dikes and levees) is strongly regulated by Federal and State laws, due to the impacts on high-value coastal wetlands.
- Breakwaters/jetties are often constructed to protect marinas. It is assumed that any new breakwaters/jetties will be co-located with a new marina and/or existing or new armoring.
- Placement of new nearshore fill for purposes of access or land reclamation will not be widespread due to the increased scrutiny and enforcement of regulations intended to restrict such actions. If this assumption is incorrect, it is likely that any new areas of fill will be co-located with future or existing shoreline armoring. Material may be placed for purposes of beach or bank nourishment.
- Widespread extension of nearshore roads (within 80 feet of shoreline) will not occur. Assuming very limited expansion of nearshore roads is questionable, but unavoidable. A satisfactory approach to projecting the Sound-wide distributions of new nearshore roads was not identified. If another model or method of projecting expansion of road network is identified at a later stage of the study, this assumption may be revisited, and process degradation that includes calculation of nearshore roads re-evaluated. While some road relocations are proposed as

features in the final array of alternatives, they are not anticipated to be within 80 feet of the shoreline and are intended to restore nearshore processes, not impede them.

- No increase in railroad distribution along the nearshore zone will occur. This assumption was applied because railroads already span long stretches of shoreline, and regulatory agencies and the community would exert strong resistance. At present, although there is pressure to increase rail traffic in Puget Sound in support of coal and oil production, there have been no definite plans from Burlington Northern Santa Fe (BNSF) Railroad for the addition of rail lines. However, rail lines are experiencing increased traffic and upgrades to existing rail lines are taking place. If this assumption is incorrect, then it is assumed that the shorelines with new railroads would be characterized adequately by the projected new armoring and/or stressors already along the shoreline. Because of how the evaluation framework is designed, the co-location of any future railroads with other stressors means that the associated process degradation will be included in the analysis despite the absence of future railroad data.
- The conversion of tidal wetlands to conditions that fall within a developed land cover category will result in lost wetlands. A projection for loss of tidal wetlands was created based on this assumption. Land cover data from Bolte and Vache (2010) were used to identify areas of tidal wetlands that are forecasted to be converted to developed lands. These areas were calculated as the area of lost wetlands in the analysis of the future. The rationale for this scenario is based on the observation that the regulatory environment of Washington does not fully prevent wetland loss due to development. It is true that if wetlands are impacted then compensatory mitigation is required. However, the habitat functions of a restored wetland do not immediately match the functions of a natural wetland and sometimes never achieve comparable function (Stevens and Vanbianchi 1993; Johnson et al. 2002). Furthermore, enforcement of wetland mitigation is a discretionary expenditure of the regulating agencies and only covers a small fraction of all development permits. The assumption of lost wetlands with development is based on the uncertainty of successful wetland mitigation as well as lack of enforcement. The implications of an overestimate of wetland loss will not result in overstatement of the proposed project benefits because such benefits are based on the area added by a given project, not a percentage change from existing wetland area.

7.2.3 Adjacent Uplands and Watershed Area Assumptions

- Forecasts of impervious surfaces are in preparation. Impervious surfaces (e.g., roads, roofs) in the adjacent uplands and watershed area are included in the evaluation of nearshore processes. Bolte and Vache (2010) are preparing an impervious surfaces dataset that could be included in the Preconstruction, Engineering and Design (PED) phase if warranted. The data from the change analysis were applied to the degradation projections.

- Forecasts of stream crossings may be included in PED. Stream crossings in the watershed area are included in the evaluation of nearshore processes. A projection of stream crossings can be prepared when a roads model is created (see above). The data from the change analysis were applied to the future degradation analysis.
- No new dams will be constructed. It is anticipated that regulatory requirements and community resistance will reduce the possibility of new dams. The data from the change analysis were applied to the degradation projections.

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