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Assessment of Coastal Water Resources and Watershed Conditions at Lewis and Clark National Historical Park, Oregon and Washington

Natural Resource Report NPS/NRPC/WRD/NRTR—2007/055

ON THE COVER
Upper left, Fort Clatsop, NPS Photograph
Upper right, Cape Disappointment, Photograph by Kristen Keteles
Center left, Ecola, NPS Photograph
Lower left, Corps at Ecola, NPS Photograph
Lower right, Young’s Bay, Photograph by Kristen Keteles

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Dr. Terrie Klinger
School of Marine Affairs
University of Washington
Seattle, WA 98105-6715

Rachel M. Gregg
School of Marine Affairs
University of Washington
Seattle, WA 98105-6715

Jessi Kershner
School of Marine Affairs
University of Washington
Seattle, WA 98105-6715

Jill Coyle
School of Marine Affairs
University of Washington
Seattle, WA 98105-6715

Dr. David Fluharty
School of Marine Affairs
University of Washington
Seattle, WA 98105-6715

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Acronyms & Abbreviations

ACOE	Army Corps of Engineers
ASP	Amnesic Shellfish Poisoning
BEACH	Beach Environmental Assessment Community and Health Program
BEACON	Beach Advisory and Closing Online Notification Program
CIG	Climate Impacts Group
CRK	Columbia Riverkeeper
CRP	Columbia River Plume
DA	Domoic Acid
DAP	Domoic Acid Poisoning
DG	Data Gap
EPA	Environmental Protection Agency
GIS	Geographic Information System
HAB	Harmful Algal Bloom
HUC	Hydrologic Unit Code
LCRANS	Lower Columbia River Aquatic Nonindigenous Species Survey
LCRE	Lower Columbia River Estuary
LCREP	Lower Columbia River Estuary Partnership
LEWI	Lewis and Clark National Historic Park
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRDC	National Resources Defense Council
ODA	Oregon Department of Agriculture
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish and Wildlife
OHS	Oregon Historical Society
OWQI	Oregon Water Quality Index
PNW	Pacific Northwest
PSP	Paralytic Shellfish Poisoning
STORET	Environmental Protection Agency's STOrage and RETrieval database for water quality, biological, and physical data sets contributed by state environmental agencies, EPA and other federal agencies, universities, private citizens, and others.
TMDL	Total Maximum Daily Loads
USGS	U.S. Geological Survey
UW	University of Washington
WDOE	Washington Department of Ecology
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington Department of Natural Resources
WRD	Water Resources Division
WRIA	Water Resources Inventory Area

Executive Summary

The purpose of this report is to provide a better understanding of the coastal water resources and watershed conditions of Lewis and Clark National Historical Park (LEWI). To accomplish this task we review the existing literature and summarize what is known about the current condition of the coastal water resources of the park and the degree to which they may be affected by natural and anthropogenic factors. As a result, this report provides both a status report on water resource conditions as well as an assessment of the present state of knowledge pertaining to environmental indicators and stressors. We further identify information gaps, topics where data are sparse and inadequate to fully assess resource condition, and make recommendations to fill information gaps necessary to support resource management. While the focus of this effort is on coastal resources, watershed conditions and surface and groundwater in the adjacent watersheds are also considered to a limited extent.

The current condition of the water-related coastal resources within LEWI is based upon an assessment of common ecological indicators and stressors including water quality (e.g., nutrients, dissolved oxygen, fecal bacteria, metals and toxic contaminants), land use (e.g., timber practices, coastal development), habitat modification (e.g. coastal erosion), recreational use (e.g., fishing, shellfish harvesting, collection of marine organisms), and other concerns such as the introduction of non-native and invasive species, harmful algal blooms, and oil and fuel spills.

We begin by describing the coastlines that characterize LEWI, which is situated within the Lower Columbia River Estuary (LCRE) region where it discharges into the Pacific Ocean. The park is comprised of twelve sites that are located on both sides of the Columbia River in Washington and Oregon. Originally established as Fort Clatsop National Memorial in 1958, LEWI was expanded in 2004 to include multiple sites that account for approximately 3,200 acres spread over forty miles of coastline. LEWI was established to commemorate the Lewis and Clark Expedition of the early 1800s. This assessment focuses on those units within the context of the LCRE, as well as the Lewis and Clark River, a tributary of the Columbia River; coastal sites within LEWI that lie outside the estuary are not focused on in this report.

We review the site history and human utilization of the region in Section A. Prior to European contact in 1792, the Chinook peoples occupied much of the region. The Lewis and Clark Expedition party wintered over at Fort Clatsop from 1805-1806. European settlement of Washington and Oregon increased around 1846, following the signing of a boundary treaty with Great Britain (Lavender 1956). The primary emphasis in resource management for the park has been on reforestation in order to restore the dense forest canopy and thickets described by Lewis and Clark in their journals.

The coastal region that influences LEWI is part of an eastern boundary current system. The Columbia River empties into the Pacific Ocean in an oceanographic region dominated by prevailing currents including the California Current, flowing southward; the Davidson Current, flowing northward in the winter; and the California Undercurrent, flowing northward at intermediate depth. These currents can create complex eddy fields, as well as upwelling and downwelling patterns. In addition, topographic features such as submarine canyons influence circulation; among these is Astoria Canyon, located offshore of the mouth of the Columbia

River. The most conspicuous oceanographic feature in the region is the Columbia River Plume (CRP). It reaches as far south as 38°N and as far north as 49°N, and varies in strength and directionality both annually and seasonally as the result of changes in wind, rain, and snowmelt (Thomas and Weatherbee 2006). The tidal plume generates significant mixing and downwelling, bringing nutrients into the water column and increasing primary productivity.

LEWI is situated in the Lower Columbia/Youngs Bay and the Necanicum Subbasins. Water resources in the region include lakes, ponds, seeps, seasonal streams, small upland streams, and several rivers. Youngs Bay and Baker Bay are prominent features of the lower estuary. Youngs Bay is located on the south side of the river, between Astoria and Warrenton, Oregon. The bay is fed by four rivers: the Lewis and Clark, Youngs, Klaskanine, and Wallooskee (Walluski). Baker Bay, on the north side of the river, is fed by the Chinook River; this water body has been significantly altered by anthropogenic activities, which have reduced wave and current energy.

Aquatic habitats within LEWI generally are comprised of soft sediments, although substantial variation in sediment type and grain size occurs across locations. Tidal flats, epibenthic communities, and channel bottom habitat dominate the estuary's entrance. These aquatic habitats support a variety of wildlife, including marine and freshwater fish species, birds, and mammals, and are influenced by both natural processes and human activities, especially by the extensive hydropower system in place on the river.

With respect to water quality, it is apparent that there is a lack of consistent sampling and analysis over time in the region of LEWI. We reviewed existing data for bacterial contamination, contaminants, and marine biotoxins/harmful algal blooms. Regional water quality appears to be generally acceptable; however, some water quality standards have been exceeded in some places at some times. Toxics appear to be of the most concern in the region, especially pesticides (DDE and DDT), PCBs, dioxin/furans, radionuclides, PAHs, and metals (aluminium, iron, copper, lead, etc.). These contaminants have been found in both fish tissue and sediments.

Sources of pollution in the LCRE and the Lewis and Clark River include non-point and point sources such as municipal and industrial wastewater discharges, stormwater runoff, timber harvesting, agricultural activities, landfill operations, sand and gravel pit activities, recreational use, marine watercraft traffic, and atmospheric deposition (NPS WRD 2000). Each of these sources has the potential to degrade water quality. For example, discharges from paper and pulp mills located along the Columbia River have been blamed for high levels of dioxins, found in both sediment and tissue samples. High water temperatures are believed to be caused by discharges from mills, dams, and industrial and municipal facilities.

Other areas of concern include harmful algal blooms, non-native and invasive species, harvest and collection of organisms, water withdrawals, hydropower activities, habitat modification, oil and fuel spills, recreation, tsunami hazards, and climate change.

Harmful algal blooms (HABs) are known to occur off the Oregon-Washington coast and are often produced by phytoplankton that can cause paralytic shellfish poisoning or domoic acid poisoning. The potential health impacts of HABs in commercially- and recreationally-harvested shellfish have motivated monitoring and research activities.

Non-native and invasive species are established in the LCRE. At least 81 organisms have been introduced into the region since the mid-1800s, the majority of which are fish, aquatic plants, and crustaceans. Over the past ten years, a new invertebrate species has been discovered about every five months. This likely reflects increasing rates of introduction, coupled with higher rates of reporting. Ballast water is believed to be the primary vector responsible for these introductions.

The largest water withdrawals in the vicinity of LEWI are for municipal, domestic, and agricultural uses. It is estimated that these withdrawals have reduced flows within the Columbia River, affecting both timing and magnitude. Flow has also been affected by hydropower activity within the region. More than 400 dams exist within the Columbia River Basin, comprising one of the largest hydropower systems in the country. These dams have restricted fish passage, reduced river flow levels, and destroyed fish habitat, especially for anadromous fish.

Aquatic habitats in the region have been modified by dike and jetty construction as well as by dredging. Dikes were constructed in Youngs Bay and the Lewis and Clark River between 1917 and 1939, and jetty construction in the region began as early as the 1800s near the mouth of the Columbia River. These activities have reduced wave action and currents throughout the estuary. Dredging is regularly used to maintain the Columbia River’s navigability. For example, the Columbia River Channel Improvement Project will deepen the river by 43 feet in order to increase access by larger container ships. There is concern that such intensive dredging will resuspend contaminants buried in bottom sediments thereby increasing the chances for exposure to fish and other wildlife.

Oil and fuel spills pose a chronic low-level threat to LEWI, as do seismic events that could generate tsunamis or landslides. Climate change is projected to intensify present stresses within the ecosystem through sea level rise, increased storm frequency and intensity, increased rates of erosion, and increased stream and river flow, all of which could impact biological communities and ecosystem function.

We summarize the condition of water resources in and around LEWI in Table i.

Table i. Condition of water resources in and around LEWI.

Stressor/ Environmental Indicator	Lower Columbia River Estuary	Youngs Bay Watershed	Wetlands, Lakes, Streams	Outer Coastal Waters
WATER QUALITY INDICATOR				
Nutrients	**ID**	**EP**	**ID**	**OK**
Dissolved Oxygen	**EP**	**EP**	**ID**	**ID**
Fecal Bacteria	**EP**	**EP**	**ID**	**OK**
Toxic Compounds	**EP**	**EP**	**ID**	**OK**
LAND-USE RELATED STRESSORS				
Septic / Wastewater	**IP**	**IP**	**EP**	**OK**
Stormwater Runoff	**IP**	**IP**	**EP**	**OK**
Agricultural Runoff	**IP**	**IP**	**EP**	**OK**
HABITAT MODIFICATION				
Upland Habitat Modification	**EP**	**EP**	**EP**	**OK**
Shoreline/Aquatic Habitat Modification	**EP**	**EP**	**EP**	**EP**
Erosion	**EP**	**EP**	**EP**	**EP**
RECREATIONAL USAGE				
Harvest/Collection of Organisms	**OK**	**OK**	**OK**	**OK**
OTHER STRESSORS/ INDICATORS				
Non-Native Invasive Species	**EP**	**EP**	**EP**	**OK**
Harmful Algal Blooms	**ID**	**ID**	**ID**	**ID**
Fuel / Oil Spills	**PP**	**PP**	**OK**	**PP**

Legend:
EP= existing problem

PP= potential problem

IP= intermittent problem

OK= no detectable problem

ID= insufficient data to evaluate

Based on our review and assessment of water resource condition and threats in coastal areas of LEWI, we offer the following specific recommendations. More general recommendations are offered in Section D.2.a.

Table ii. Specific Recommendations

- Maintain and expand the current water quality monitoring program to include new park sites.
- Integrate the water quality monitoring program with regional programs (e.g., LCREP monitoring program).
- Determine feasibility of restoring aquatic habitats within LEWI to the approximate conditions encountered by Lewis and Clark; prioritize habitats by feasibility, and modify management goals for aquatic habitats deemed not feasible for restoration.
- Where feasible, partner with local groups and tribes to restore degraded freshwater and estuarine habitats, especially those that provide essential fish habitat.
- Develop a plan for managing non-indigenous marine, estuarine, and freshwater species.
- Work with other agencies and entities to reduce the impacts of hydropower and land use on water resources within LEWI.
- Encourage NACP to update the Oil Spill Geographic Response Plans for the Lower Columbia River Estuary and outer coastal regions. Consider whether the definition of sensitive areas under existing Oil Spill Contingency Plan rules could be expanded to include sensitive areas within LEWI.
- Measure stormwater runoff and manage to reduce impacts to estuarine environments.
- Measure the amounts of toxins and contaminants introduced to coastal streams and rivers and to beach areas by surface water flow from primary and secondary roadways and parking areas. Determine whether toxins and contaminants from roadway sources impair water resources in LEWI.
- Plan for impacts due to climate change, including impacts to restoration sites.

A. Park and Regional Description

The physical, biological, and cultural attributes of terrestrial and aquatic habitats within Lewis and Clark National Historical Park (LEWI) are described in excellent detail by Wetherbee and Hall (2006), and we guide the reader to that source for an overview of terrestrial and aquatic resources and habitats within and around the park. Here we focus more narrowly on attributes of water resources within and adjacent to LEWI.

A.1. Background

This section provides an overview of the location of LEWI, describes its general features, reviews the history of the site, and covers human uses of the area through time.

A.1.a Setting

The Columbia River forms the boundary between the states of Oregon and Washington, both of which are located in the Pacific Northwest region of the United States (Figure 1).

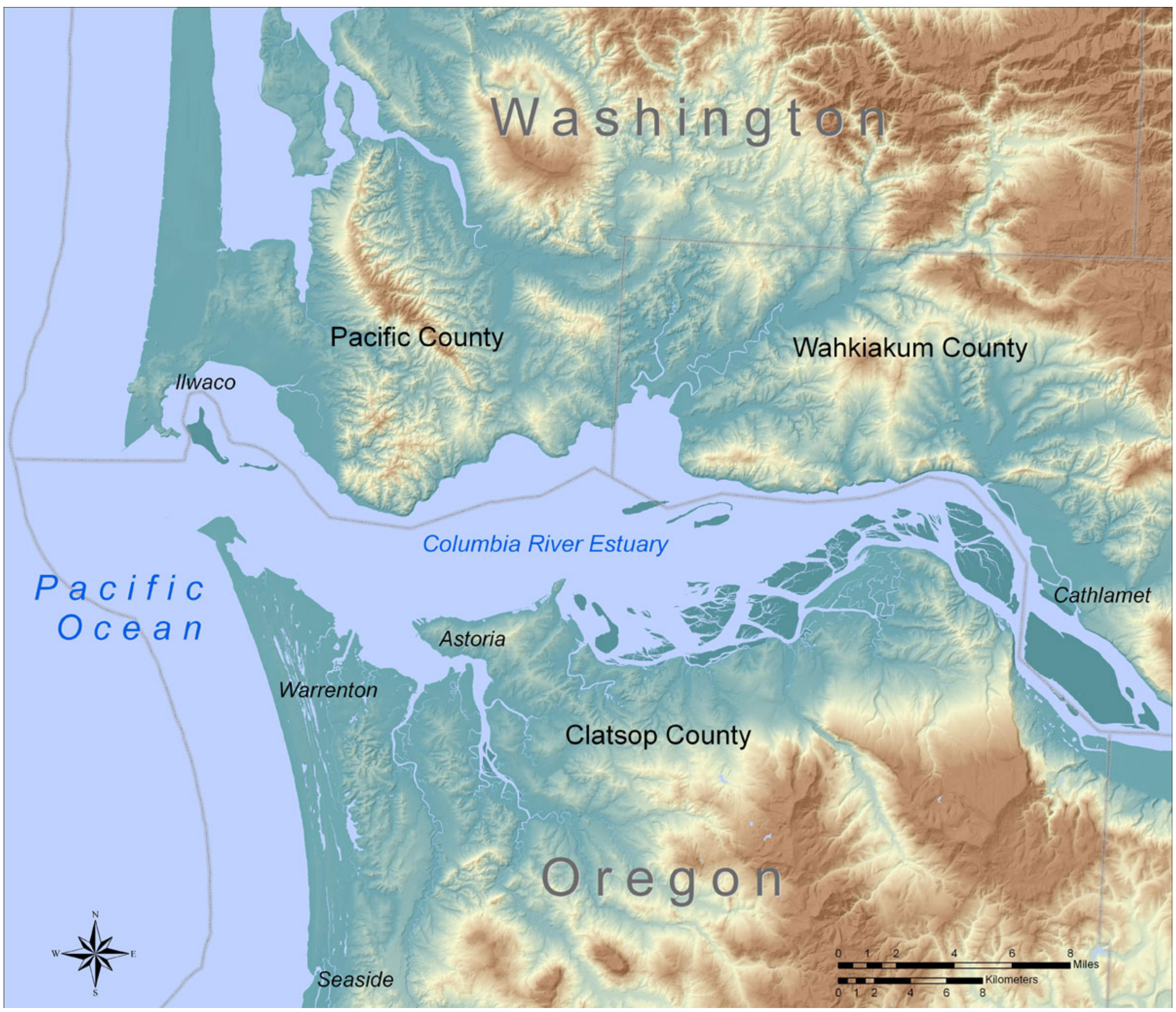

Figure 1. The Lower Columbia River Estuary (www.columbiaestuary.org).

LEWI straddles the banks of the Lower Columbia River Estuary (LCRE) as it discharges into the Pacific Ocean and includes several disjunct sites located on the outer coast (Figure 2).

Figure 2. Park sites within LEWI. Source: Map created by authors.

Originally established as Fort Clatsop National Memorial on 125 acres in 1958, LEWI was expanded in 2004 to approximately 3,200 acres extending across 40 miles of the coast. LEWI is made up of 12 units under national or state administration. The units are significant sites as recorded during the December 1805 to March 1806 winter encampment of the Lewis and Clark Expedition. They include Fort Clatsop National Memorial, Dismal Nitch, Station Camp, Netul Landing, Salt Works, Cape Disappointment, Fort Columbia, Fort Stevens, Sunset Beach, Ecola, the Fort to Sea Trail (from Fort Clatsop National Memorial out to Sunset Beach), and the memorial to Thomas Jefferson (Cannon 1995).

Fort Clatsop National Memorial was established "for the purpose of commemorating the culmination, and the winter encampment, of the Lewis and Clark Expedition following its successful crossing of the North American Continent" (PL 85-435, 72 Stat. 153). Fort Clatsop National Memorial was the first U.S. military post west of the Rocky Mountains, although the expeditionary party only occupied it for a little over three months. The work done by the party in collecting and reporting flora and fauna contributed to an early understanding of the natural resources of the United States. The depiction of the Chinook peoples as recorded in the expedition's reports is considered to be among the best-documented post-contact views of daily life and culture among these tribes (Cannon 1995).

In addition to the obvious historic importance of LEWI, the various units contain a variety of ecosystems ranging from soft sediment intertidal areas in the estuary, extensive sandy shorelines and dunes, rocky headlands, temperate rainforests, riparian zones, and swamps, as well as rural land used for farming, dairying, and grazing (NPS 2006a). This water resources assessment focuses on the National Park units within the context of the LCRE, as well as the Lewis and Clark River, a tributary of the Columbia. The inventory includes freshwater springs, streams, marshes and ponds, brackish water sloughs, salt marshes, and intertidal areas. Some of these freshwater features are ephemeral, appearing during the wet fall, winter, and spring seasons, but disappearing in the dry summer.

Geologically, LEWI is within the Columbia embayment of the Coast Range Province. This area is characterized by Cenozoic era sediment strata capped by Eocene and Oligocene basaltic lavas that are exceptionally thick (McKee 1972). The surface geology that is currently visible consists of Tertiary marine and non-marine sediments and basalts from the Miocene (NPS 2006a). Alteration of the estuary by dredging, diking, and jetty construction has changed the form of the estuary and affected sediment transport. No minerals of economic importance have been located although clay, sand, and gravel do exist in commercial quantities. The combination of deep sediments and thick basalt cap rock has induced several rounds of petroleum and natural gas exploratory drilling with only partially successful results (McKee 1972).

The combination of landforms, hydrology, and vegetation creates habitats for a diversity of resident species of mammals, birds, fish, amphibians, and reptiles as well as migrating species (NPS 2006a).

A.1.b. Site History

This section is abstracted from the Fort Clatsop Administrative History (Cannon 1995) except where otherwise noted.

Chinook peoples occupied many sites on the coast and in the Columbia River estuary prior to the first recorded European contact in 1792 with explorers and traders on ships. The Lewis and Clark Expedition party wintered-over at Fort Clatsop from 1805-1806. The next settlement attempt came from the Pacific Fur Company, which established Fort Astor in 1811.

Fort Clatsop

Fur traders and other visitors curious about the Lewis and Clark Expedition sought out the site of the abandoned Fort Clatsop. They reported that as late as 1821, remains of the original walls of the encampment could be found. Two houses occupied by Clatsop tribe members were also found. European settlement of Washington and Oregon increased following the signing of a boundary treaty with Great Britain in 1846 (Lavender 1956). Claims were staked on the Fort Clatsop site and it was transferred into private ownership in 1850. As the property passed through various hands, the original forests were cleared. Over time and with changes in land use, the exact location of the Fort Clatsop site became subject to speculation. Various efforts were made to relocate the site around 1900, the most serious being that by the Oregon Historical Society (OHS) which purchased three acres determined to be the most likely site. In 1912, the OHS installed a bronze marker at the site. The society acquired two more acres in 1928 that included the spring thought most likely to be the source of water for Fort Clatsop. Controversy still surrounded the exact location of Fort Clatsop, however, so the OHS asked the National Park Service (NPS) to perform an archeological survey of the area; this survey was completed in 1948. A replica of Fort Clatsop was constructed in 1955 through the actions of a state, civic, and private collaboration to commemorate the 150th anniversary of the Lewis and Clark encampment.

Calls for national recognition of Fort Clatsop began as early as 1906 when Congress was petitioned to purchase the site and to construct a commemorative monument. The NPS reviewed the site in collaboration with the Oregon State Parks Board in 1935 and made the determination that it should be a state park. The question arose again in 1937 and the same result was attained. More requests were made to Congress until 1955 when a bill to reexamine the question of Fort Clatsop’s national significance was passed. The resulting report recommended designation as a “Memorial” and not a “Monument” because a monument designation required physical features to remain. In 1958, Congress designated the Fort Clatsop National Memorial. Concerns still were expressed regarding whether or not this was the exact location of the site, that the designation removed property from tax rolls, and that the designation did not recognize the Lewis and Clark sites on the Washington side of the river at Dismal Nitch, Station Camp, and Fort Canby (now Cape Disappointment).

Salt Works and Netul Landing

Efforts were made to locate the Salt Works site where salt was distilled for the expedition party. This site proved easy to locate based on the oral and family histories of Clatsop elders. The OHS marked the site with permission of the property owner, and in 1910 the owner donated the site to the people of Oregon. In 1978 the Salt Works site was added to Fort Clatsop National Memorial after repeated efforts to introduce and pass such legislation in Congress. Archaeological digs to locate traces of the Chinook longhouses were unsuccessful.

There had been long-term interest in locating the route of the trail taken by the Lewis and Clark Expedition party from Fort Clatsop across the Coast Range to the Salt Works site (Hussey 1958).

In 2002, Congress authorized the NPS to enter into a land exchange with Crown Zellerback Timber Company for lands it owned along the proposed route. The lands contained a trail (now know as Netul Landing) from Fort Clatsop to Salt Works (P.L. No. 107-221). In 2006, the trail was dedicated with the successful additions of other lands.

Dismal Nitch, Station Camp, Cape Disappointment, Fort Columbia, and Fort Stevens
As the bicentennial of the Lewis and Clark Expedition approached in 2003, interest grew in recognizing and protecting other significant areas used by the party. In 2002, Congress authorized the NPS to study the expansion of Fort Clatsop National Memorial (PL 107-122 116 Stat. 1333). The study was completed in 2003 with the preferred alternative to include Dismal Nitch (Megler's Rest), Station Camp, Fort Canby (now Cape Disappointment), and Fort Columbia in Washington with Fort Clatsop National Memorial (NPS 2003). Congress accepted these recommendations in 2004 with the passage of the Lewis and Clark National Historical Park Designation Act (PL 108-387 118 Stat. 2234).

Fort Stevens is a Civil War era fortification that is now an Oregon State Park. Fort Columbia and Fort Canby (now Cape Disappointment) were former military sites designed to defend the mouth of the Columbia River from 1896 to 1947. They were later surplused to Washington as state parks. Station Camp is the former site of an important Chinook tribal trading center that had been acquired by Washington for a park commemorating the site and its importance for trade development. The Megler Rest Area (Dismal Nitch) is owned and operated by the Washington Department of Transportation (NPS 2006b). Since LEWI's designation in 2004, the NPS has been engaged in negotiations with property owners, the Washington State Parks and Recreation Commission, and the Washington State Department of Transportation on how best to secure and interpret these sites. In addition, the NPS is seeking to obtain conservation easements on several privately held lands adjacent to some sites for long-term resource and scenic protection.

Resource management plans have been produced since 1973, most recently in 1995. The primary objectives for management include 1) re-creation of native plant communities where ecologically feasible; 2) re-creation of traditional animal populations where ecologically feasible; 3) measuring the impact of humans on the environment; and 4) monitoring the impact of humans on the environment. The major resource management emphasis has been on reforestation of the site to regain the dense forest canopy and thickets that Lewis and Clark described in their journals. Thousands of trees have been planted to revegetate the sites, and as a result, current visitors now see a much different environment than those who visited in 1958.

A.1.c. Human Utilization

The name Chinook has been applied to four groups of native peoples occupying the Lower Columbia River (the Chinooks, Wahkiakums, Clatsops, and Cathlamets) who were among the first tribes encountered by European traders arriving by sea and later by fur traders and early settlers to the region (Ruby and Brown 1976). The Chinooks on the north side of the estuary and the Clatsops on the south are the native groups most closely associated with LEWI. These peoples were renowned for their canoe carving abilities and for the extensive trade networks that they maintained up and down the Columbia River for thousands of years prior to European contact. Coastal and river mouth areas were sites of fairly dense settlements by Chinooks.

Disease, however, had greatly diminished their numbers by the time Lewis and Clark arrived. While they were known for hunting game, as well as for gathering local berries, fruits, and roots, their real competitive advantage was in utilization and preservation of fish and shellfish. It is generally considered that much of the Lower Columbia habitat and areas around the estuary were densely covered with evergreen forests; however, reinterpretation of some historic accounts may indicate that the Chinooks had a sophisticated and selective use of fire as a tool for creating forest clearing to increase productivity of deer and elk for hunting and gathering (Botkin 2004).

The immediate objective of European contact was to obtain furs from Indian hunters. Primary occupation was along the rivers and in sheltered harbors. Settlement of the boundary with Canada sharply increased interest in settlement in Washington and Oregon. The first claim for the area containing Fort Clatsop was made in 1849 but it was not settled until 1850. In 1852, a timber mill was built on the site of the Lewis and Clark Expedition canoe landing and the surround area was logged between 1852 and 1854; this lumber was sent to market in San Francisco. The extensive land clearing permitted the establishment of orchards, small gardens, and land for animal grazing. The canoe landing on the Lewis and Clark River proved to be a useful site for operations of the U.S. Revenue Service in the early 1860s and served the needs of the Oregon Steam and Navigation Company with regular steamship service between Portland and Fort Clatsop during the summertime. Around 1900, other transportation routes and a railroad supplanted steam navigation. Clay of suitable quality for pottery was available on the Fort Clatsop site and extraction occurred between 1887 until about 1920 (Cannon 1995).

The activity on the Fort Clatsop site was indicative of the settlement of the estuary region. Small farms and orchards were hewn from the forests, and fishing developed in ports such as Ilwaco, WA, and Astoria, OR, especially for salmon. The estuary lowland environments were rapidly transformed into cultural landscapes. In the present day, these farms and grazing areas are becoming uneconomical and are being subdivided for use as retirement and recreation property. Some larger dairy farms have developed and much of the landscape is reverting to intensively managed forests. Coastal and historic tourism is increasing, especially as a result of interest in the Lewis and Clark Bicentennial. Salmon fishing has vastly diminished as a part of the economy due to downturns in the abundance of Columbia River salmon (e.g. Cone 1995; Taylor 1999; Blumm 2002). In addition, the Columbia River serves as a major international shipping route.

A.2. Hydrology

A.2.a. Oceanographic Setting

Hickey and Banas (2003) describe major large scale oceanographic features of the Pacific Northwest, including the Pacific Coast and estuary region. The Columbia River empties into the Pacific Ocean in an oceanographic region that is dominated by features associated with the North Pacific Gyre, a circular flow formed by the California, Alaska, and Davidson currents. These currents can vary significantly on interannual, seasonal, and multi-day timescales, creating complex eddy fields, as well as upwelling and downwelling patterns.

The California Current is a south-flowing offshore current apparent from the surface to 500 meters depth. It is balanced in part by the north-flowing California Undercurrent, which is narrower and faster, and generally occurs at intermediate depths, between 100 and 400 meters. Both the California Current and Undercurrent are generally stronger in summer than in winter. The Davidson Current also flows north, but is primarily a fall/winter feature. Topographic features such as submarine canyons also influence circulation. Turbidity currents have formed a major submarine canyon (Astoria Canyon) offshore of the mouth of the Columbia.

Winds along the coast are the primary determinants of surface flow. In the winter, winds are primarily from the south, generating onshore currents that lead to downwelling along the coast. In the spring (April or May), winds begin to shift north, and by summer, the predominant coastal winds blow from the north. This leads to offshore flow and strong upwelling from depths of around 200 meters close to the coast. Upwelling contributes to higher productivity and cooler water along the coastal margin (Hickey and Banas 2003). The conversion from winter to summer conditions is known as the Spring Transition. Sea level may drop 10 centimeters or more along much of the coast during this transition, and currents can reverse within just a few days (Strub *et al.* 1987).

Columbia River Plume

The current and eddy patterns are further complicated by the significant and seasonal flow of the Columbia River. Where the river flows into the Pacific Ocean, it forms the Columbia River Plume (CRP), a coherent tongue of low salinity water. The CRP is a dominant and dynamic feature in regional oceanography, reaching as far south as 38°N and as far north as 49°N, and seaward as far as 600 kilometers (Barnes *et al.* 1972; Thomas and Weatherbee 2006).

The CRP varies in strength and directionality from year to year and season to season, primarily as a result of differences in wind, rain, and snowmelt (Thomas and Weatherbee 2006). Mean surface speeds are 12 cm/sec in summer and 17 cm/sec in winter. Flow is much slower along the bottom, averaging 1-2 kilometers/day. Although a common view of the CRP is that it flows north in winter and south in summer, following seasonal wind patterns, Hickey *et al.* (2005) suggest that such a view is misleading. They found that the CRP is often bidirectional and that even with strong southward summer winds, plume water may travel as much as 150 kilometers north of the river mouth. Further, they found that plume water was commonly present over the Washington shelf during the summer months. The CRP can respond within hours to changes in wind speed and direction, and the southward branch can disappear completely with strong downwelling winds (Hickey *et al.* 1998, 2005; Figure 3 below).

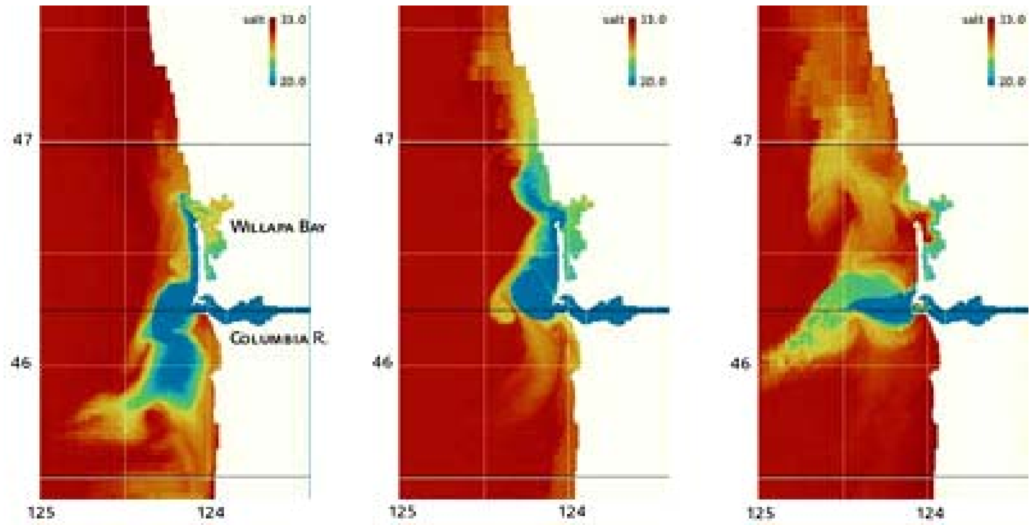

Figure 3. Changes in surface salinity over a one-week period in July 2004. On the left, weak winds cause a bidirectional plume. The center graph shows that during strong downwelling periods, the plume extends north. The right graph shows that with upwelling, the plume moves far offshore. The salinity ranges from <20 psu (blue) to ~32 psu (red) (Banas and MacCready 2007).

During the summer, the CRP tends to be farther offshore than in winter. The plume core generally flows perpendicular to shore for tens of kilometers, and may extend up to 50 or 60 kilometers off the coast. In winter, the core is rarely more than 30 kilometers from the coast. The CRP itself may extend as far as 800 kilometers southwest of the river mouth in summer (Barnes *et al.* 1972), and may flow into the California Current (Thomas and Weatherbee 2006). The CRP has variable thickness, and is between five and 15 meters in depth if offshore, thicker (10-40 meters) if it hugs the coast (Hickey *et al.* 1998).

The discharge rate of the Columbia River typically varies between 2,500 cubic meters/sec in late summer and 17,000 cubic meters/sec in spring. During times of maximum river flow, the discharge rate can be as high as 30,000 cubic meters/sec (Hickey and Banas 2003), and can extend to depths of 40 meters during times of heavy river flow (Barnes *et al.* 1972). The mixing of shelf water by and into the plume can resuspend bottom sediment, bringing iron and other nutrients up into the water column and therefore increasing primary productivity. The tidal plume front generates significant mixing and downwelling, and can generate transitory bottom currents as fast as one meter/sec, down to 65 meters. The leading edge of the CRP also generates high-energy internal waves that may contribute to mixing as well (Nash and Moum 2005).

A.2.b. Hydrologic Setting

LEWI exists within a temperate coastal setting characterized by mild, wet winters and dry summers. In Astoria, OR, the average annual air temperature from 1971-2000 was 51°F, with average monthly mean temperatures ranging between 60.8°F in July and 42.4°F in January. The maximum and minimum temperatures recorded during the same period were 96°F and 6°F. The average annual precipitation in Astoria from 1971-2000 was 67.13 inches while in Seaside (on the Oregon coast), it was 75.74 inches. In both locations, July and August were the driest months, averaging less than two inches of rain, while November and December were the wettest months, averaging close to 10.5 inches each in Astoria and 11.3 inches each in Seaside.

The Columbia River dominates the hydrologic environment in which LEWI is situated. It is the second-largest river in the conterminous United States, crossing two major mountain ranges and draining a basin of approximately 665,000 square kilometers (Thomas and Weatherbee 2006). The drainage basin is divided into two primary subbasins. The upper basin lies east of the Cascades, and the lower coastal basin lies west of the Cascades. Flow through the upper basin historically was controlled by snowmelt, while flow through the lower basin was controlled by rainfall.

Flow in the Columbia River is manipulated by dams. Bonneville Dam, completed in 1938, is one of 18 dams on the Columbia and Snake Rivers. Its location now defines the upstream boundary of the Lower Columbia River. Below Bonneville Dam, the Columbia River extends 146 miles to the mouth. Currently, river flow in the Lower Columbia is regulated largely by releases from Bonneville Dam and by inputs from the Willamette River. This river is the largest tributary entering the lower river; like the Columbia, the Willamette is also heavily dammed. While the coastal basin represents just eight percent of the total drainage areas of the Columbia River, it drains approximately 46,000 square kilometers of the watershed (Systma *et al.* 2004) and contributes 24% of the total river flow (Simenstad *et al.* 1984a).

Flows in the Lower Columbia average 273,000 cubic feet per second (cfs) at the river mouth, with peak flows occurring during winter storm events (LCRE Subbasin Summary 2002). Discharge varies seasonally according to runoff, snowmelt, and hydropower demands. Spring freshets once were a source of flooding along the lower river, but dams now regulate freshets. Discharges in May and June have been reduced by more than 50% since impoundment for water storage, hydropower generation, and irrigation diversion in the middle and upper basins (Systma *et al.* 2004). Late summer and fall flows now are higher and slower than prior to damming, and water temperatures are warmer by a few degrees (LCRE Subbasin Summary 2002).

Columbia River Estuary

The estuary comprises tidally influenced portions of the Lower Columbia River from river mile 34 to the seaward edge of the CRP (LCRE Subbasin Summary 2002). Sites within LEWI are located along the LCRE and its tributaries, or in coastal areas influenced by the CRP. Consequently, hydrological characteristics of the LCRE profoundly influence aquatic areas within LEWI.

The LCRE is a river-dominated drowned river valley estuary. It is partitioned into three distinct sections based on the degree of mixing of salty and fresh water: the fluvial, or freshwater, portion from Bonneville Dam downstream to the maximum upstream extent of saltwater intrusion (approximately river mile 34); the brackish region, where salinity varies as a function of river flow and tidal energy, from river mile 19 to river mile 34; and the marine region, which is heavily influenced by coastal processes, from the mouth to river mile 19. The LCRE contains main, distributary, and dendritic tidal channels, as well as shoals, wetlands, and mudflats. Nearly 71% of the LCRE is less than six meters deep relative to mean lower low water (MLLW). The estuary contains four large, shallow bays (Grays, Baker, Youngs, and Cathlamet), two of which

(Baker and Youngs) are in the vicinity of LEWI. Silt and clay sediments predominate in peripheral bays, while sandy sediments dominate elsewhere (Bottom *et al.* 2001, and references therein). At the river mouth, the estuary is about five miles wide.

Mixing in the estuary results from tidal action, wind, turbulent flow, and velocity shear between the salt wedge and freshwater outflow. Maximum tidal range is around three meters in the estuary (Thomas and Weatherbee 2006). When river flow is high, the effluent salinity is around 20 parts per thousand (ppt); when flow is low, effluent salinity is about 28-30 ppt.

Watersheds

The U.S. Geological Survey (USGS) delineates watersheds using a nationwide system based on surface hydrologic features. This system divides the country into 21 regions, 222 subregions, 352 accounting units, and 2,262 cataloging units. A hierarchical hydrologic unit code (HUC) consisting of two digits for each level in the hydrologic unit system is used to identify any hydrologic area. The six digit accounting units and the eight digit cataloging units are generally referred to as basin and subbasin, respectively. HUC is defined as the Federal Information Processing Standard (FIPS) and generally serves as the backbone for the country's hydrologic delineation.

The parks that comprise LEWI fall into the Lower Columbia/Youngs Bay Subbasin (HUC 17080006, in the Lower Columbia Basin) and the Necanicum Subbasin (HUC 17100201, in the Northern Oregon Coastal Basin). Water resources in this area include lakes, ponds, seeps, seasonal streams, small upland streams, and several rivers. In the region covered by this report, two major rivers drain into the Columbia from the south (the Lewis and Clark and Youngs Rivers), and one from the north (the Chinook River).

Youngs Bay

Youngs Bay, on the south side of the river, is two miles wide where it meets the Columbia River between Astoria and Warrenton (Figure 4), and has been the subject of much research; therefore much of the information in this assessment focuses on this region.

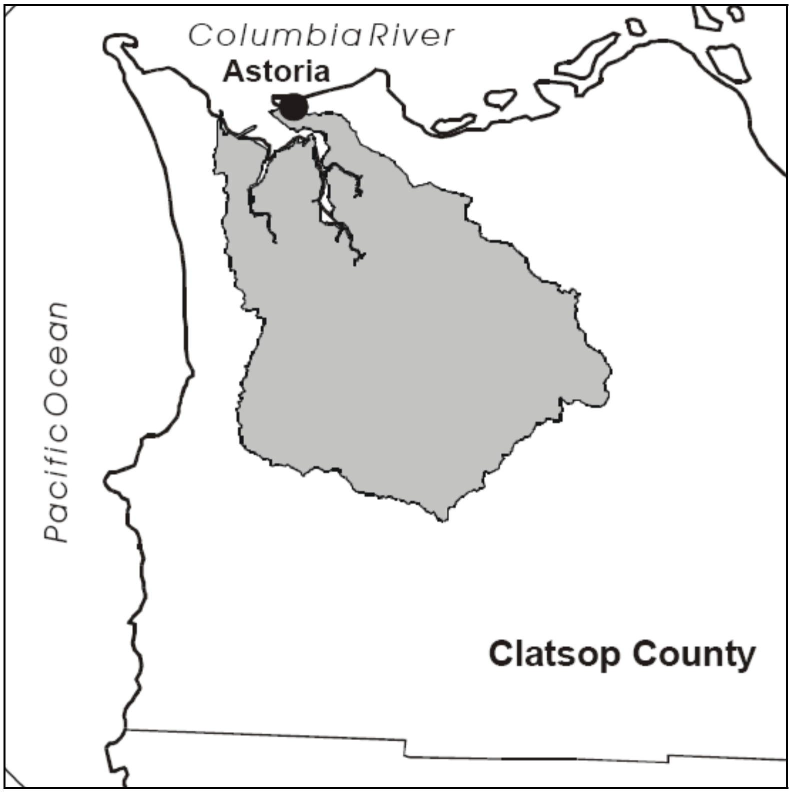

Figure 4. Youngs Bay Watershed (Bischoff *et al.* 2000)

The area was historically one of the most biologically diverse regions of the estuary (NCWA 2007). The relatively shallow entrance limits the volume of salt water entering the bay. The Youngs Bay watershed consists of more than 250 miles of streams and rivers. The bay itself is fed primarily by four rivers: the Lewis and Clark River (21 miles long), Youngs River (17 miles long), Klaskanine River (16 miles long), and Wallooskee (Walluski) River (6 miles long), which in combination drain approximately 184 square miles of the watershed (Figure 5). All four rivers originate in the Coast Range. Although elevations within the watershed range from sea level to 3,284 feet, the bay itself is characterized by a broad floodplain, much of which has been converted to pasture.

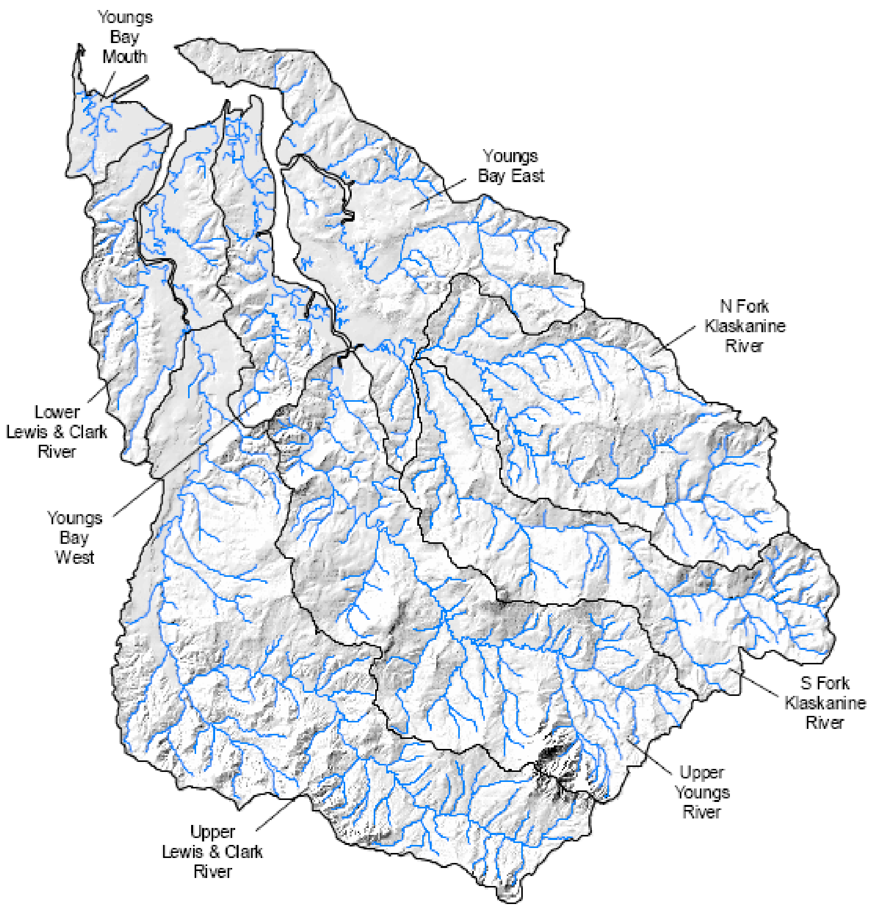

Figure 5. Youngs Bay Subwatersheds (Bischoff *et al.* 2000).

Baker Bay

Baker Bay, on the north side of the river between River Miles 3 and 9, is fed by the salmon-bearing Chinook River. Most of the Chinook River Watershed, with an area of 13.6 square miles, has an elevation of less than 200 feet, although the highest point is 1,400 feet. Prior to dredging and jetty construction, the bay was a high-energy environment, but anthropogenic alterations, combined with the migration of mid-channel islands deeper into the bay, have significantly reduced incoming wave and current energy.

A.3. Aquatic Habitats and Biological Resources

Physical and biological attributes of individual park sites are described by Wetherbee and Hall (2006). Here we expand their characterization by focusing on aquatic habitats in a regional context.

A.3.a. Aquatic Habitats

The LCRE is generally a soft-substrate environment, although sediment grain size is strongly affected by location. In Baker, Trestle, and Youngs Bays, sediment tends to be poorly sorted, ranging from fine sand to coarse silt. Sediment size in estuarine channels tends to be medium-fine sand (Simenstad *et al*. 1984b). Within the estuary, six basic habitat types can be distinguished based on location and biological community: water column, demersal slope, high marsh and swamp, low marsh, tidal flats, channel bottom, and epibenthic layer. Tidal flats, epibenthic communities, and channel bottom habitat dominate the entrance to the estuary. Baker, Trestle, and Youngs Bays contain all but the channel bottom habitat.

Aquatic habitats in the LCRE are influenced by dynamic interactions between fluvial and oceanographic processes, which in turn are modulated by climate and human activities (LCREP 2004 Supp). Human activities in particular have altered natural processes and habitat conditions; chief among these has been the construction and operation of the Columbia River hydropower system. This system along with irrigation withdrawals have resulted in changing both the timing and magnitude of Columbia River flows; in addition maximum flows have been reduced over time, which when combined with diking and dredging activities, has essentially "eliminated overbank flows" in the river (LCREP 2004 Supp). The disappearance of these flows is important because they historically "created a variety of habitats of value to focal species by connecting the river with its floodplain, increasing channel complexity through the deposition of large woody debris, and transporting crucial riverine sediment to the estuary" (LCREP 2004 Supp). Species especially affected include juvenile salmonids such as Chum and fall Chinook, bald eagles, and Columbia white-tailed deer.

The construction of dams has also affected sediment transport and salinity distribution in the estuary. The reduction of spring freshet flow and the construction of reservoirs that trap upstream sediment supply also affect sediment transport (LCREP 2004 Supp). The consequences include the alteration of estuarine habitat, disturbance of turbidity patterns, and a decrease in the amount of sediment that the river can "flush" from its system (LCREP 2004 Supp). Flow has also affected salinity distributions, particularly the "location, size, shape, and salinity gradients of the estuary turbidity maximum zone…[which] can affect seasonal species distributions and the structure of entire fish, epibenthic, and benthic invertebrate prey species assemblages throughout the estuary" (LCREP 2004 Supp).

Land Cover Types

Land cover types within LEWI as designated by the National Wetlands Inventory (NWI) are shown in Figures 6-11. Because the regional NWI coverage is incomplete, reliable acreages are not available by land cover type, but relative proportions of each land cover type can be discerned from the figures.

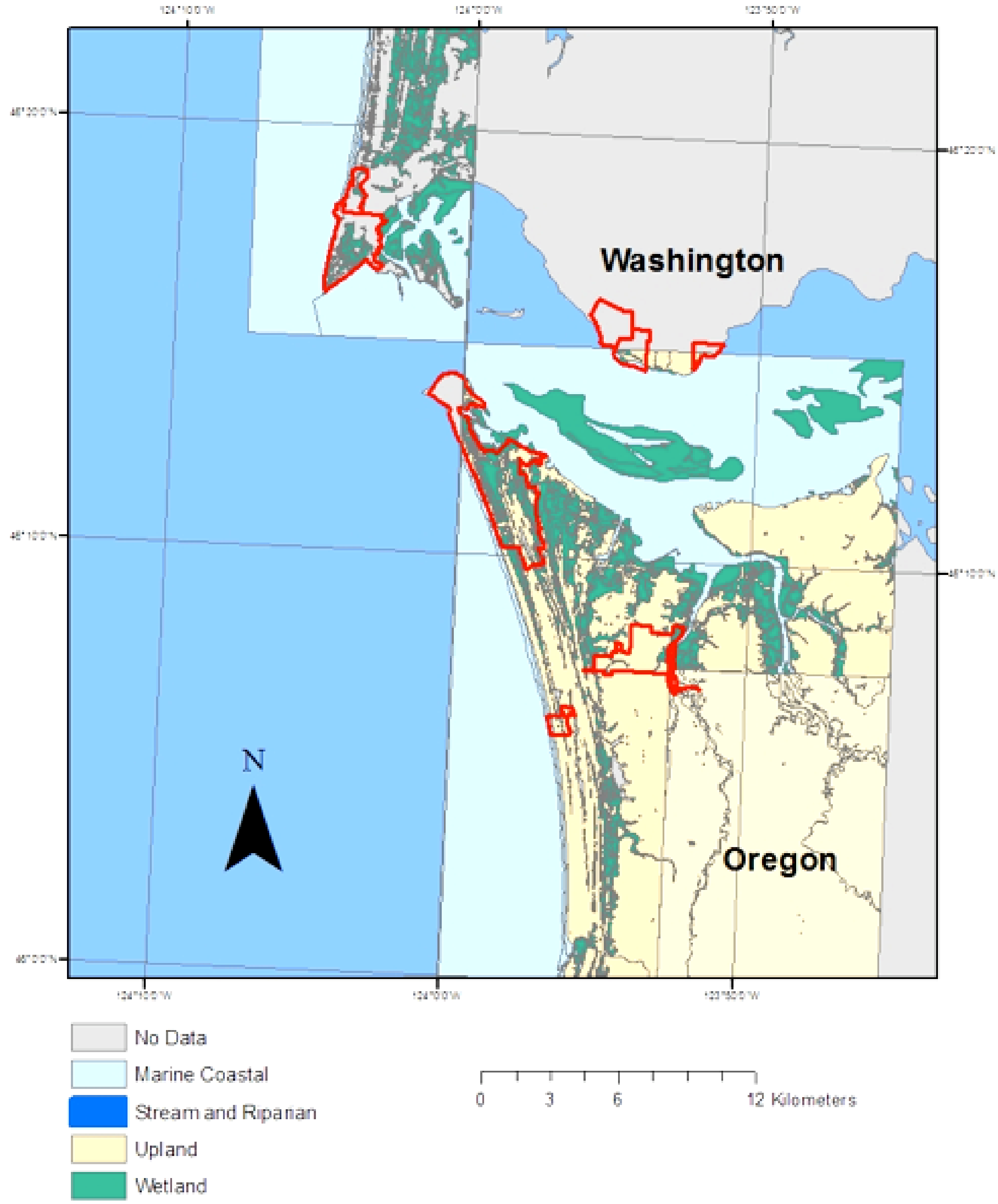

Figure 6. NWI coverage in region of LEWI. Map created by authors from NWI data.

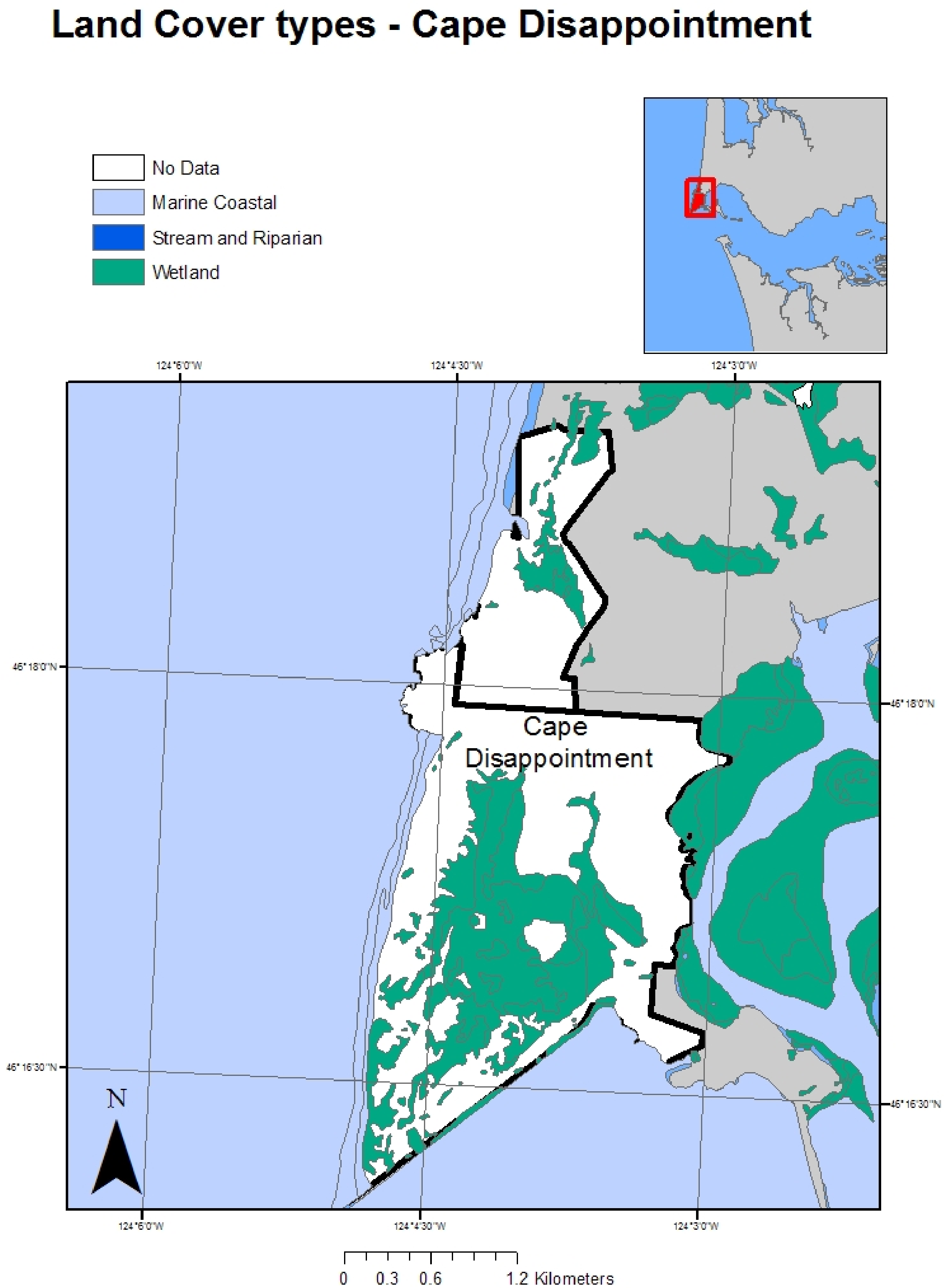

Figure 7. Land cover types within the Cape Disappointment site. Map created by authors from NWI data.

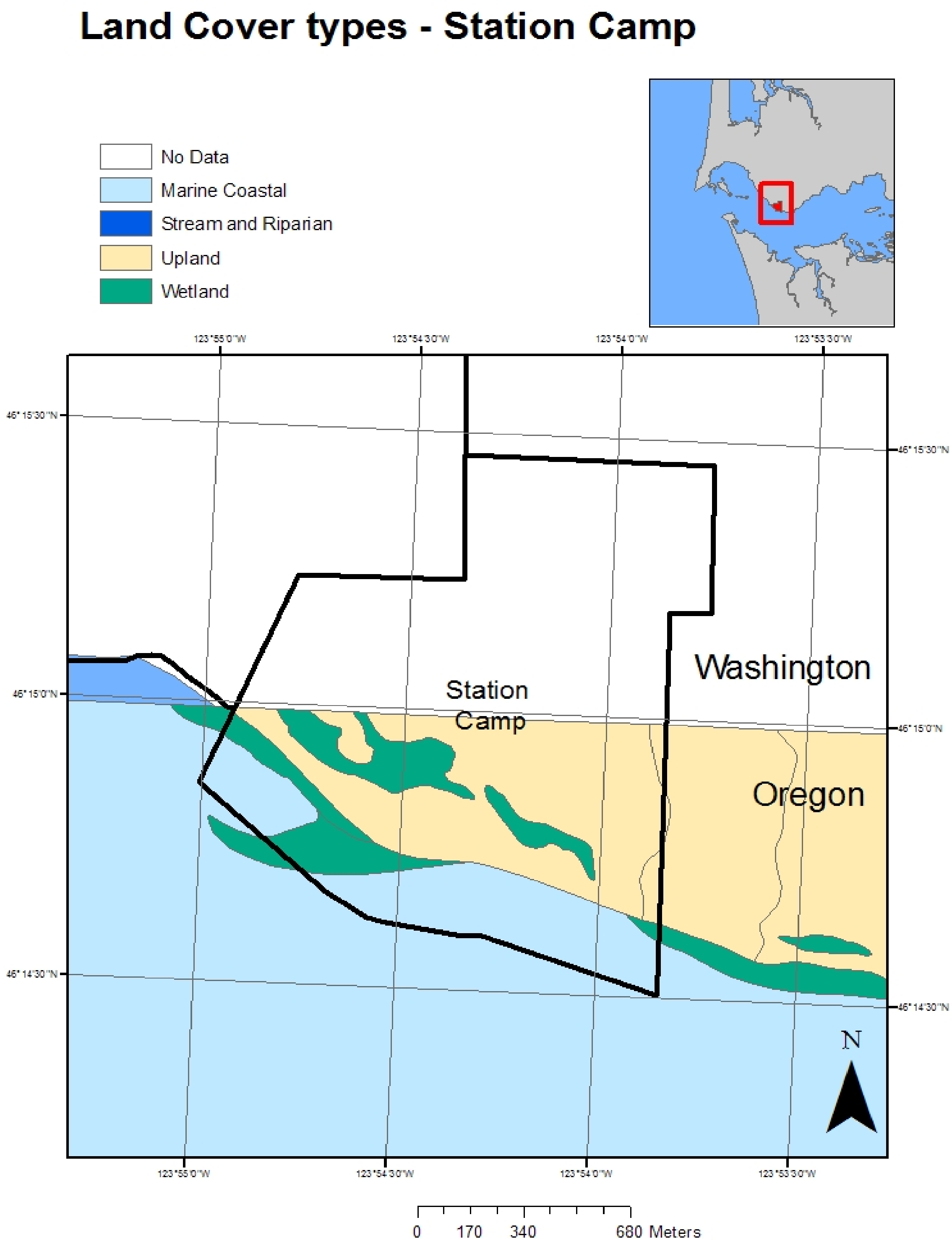

Figure 8. Land cover types within the Station Camp site. Map created by authors from NWI data.

Land Cover types - Dismal Nitch

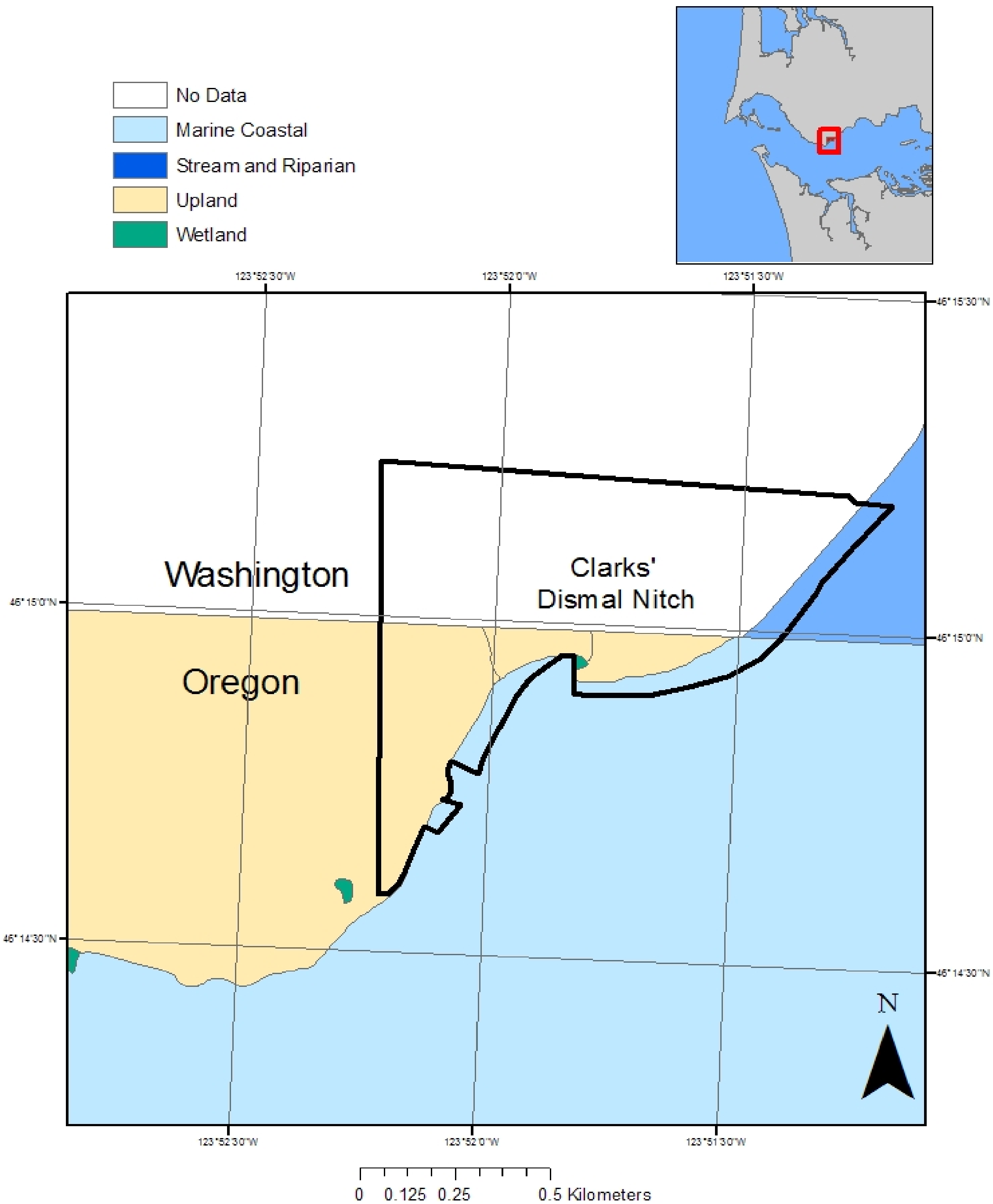

Figure 9. Land cover types within the Dismal Nitch site. Map created by authors from NWI data.

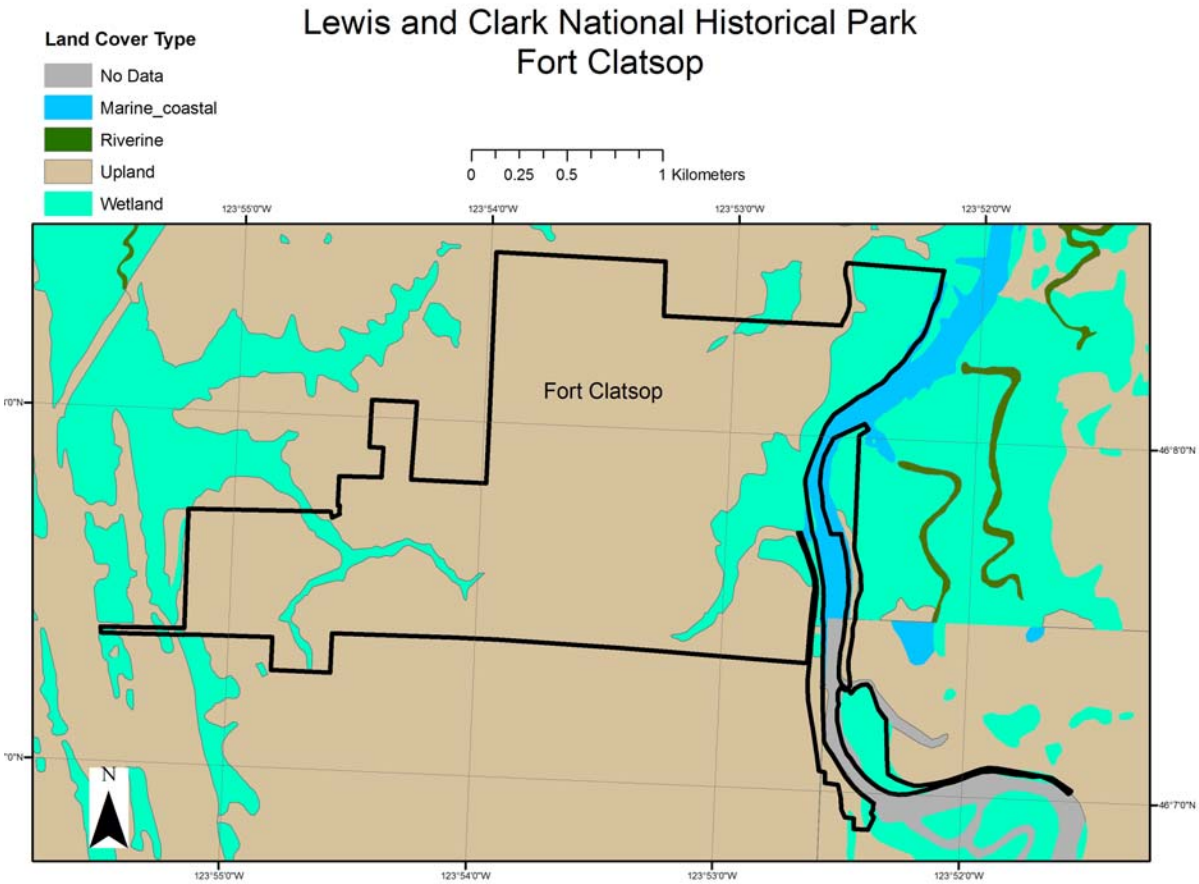

Figure 10. Land cover types within the Fort Clatsop National Memorial site. Map created by authors from NWI data.

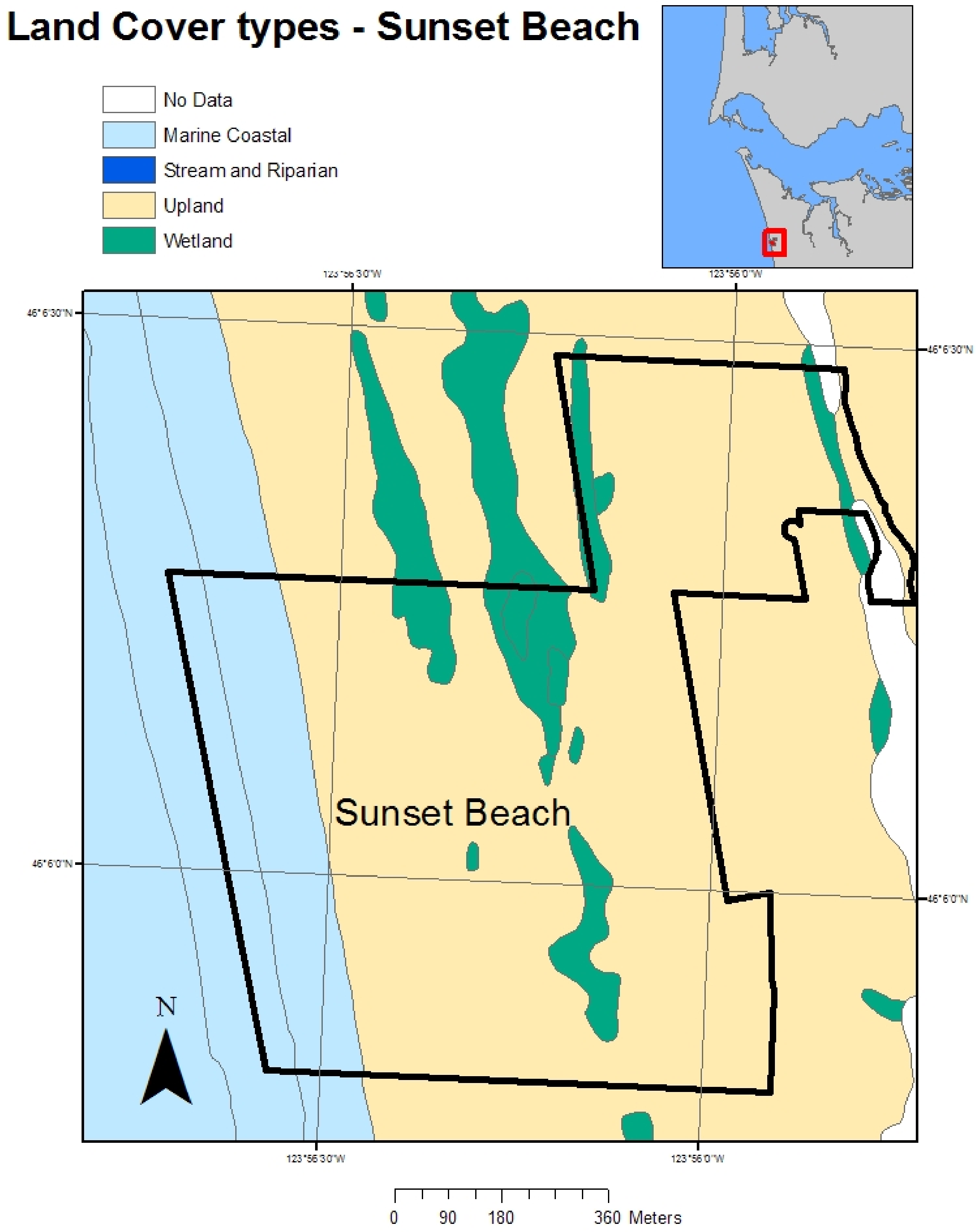

Figure 11. Land cover types within the Sunset Beach site. Map created by authors from NWI data.

A.3.b. Biological Resources

The following section provides a sampling of some of the wildlife species found throughout the LCRE and within reach of LEWI's boundaries.

Fish

The LCRE supports a variety of freshwater and marine fish and invertebrate species, and serves as an important habitat for feeding and breeding. Taxa of economic importance include oysters, clams, mussels, Dungeness crab, sturgeon, and salmon. Salmon especially benefit from this estuarine habitat in various life stages. Chum, Coho, and Chinook salmon are the focal species in the region. Overall, anadromous fish populations are estimated to be at about 10 percent or less of their historic run size; in order to compensate, hatchery programs have become prevalent on the river and now make up about 75 percent of all fish returning to the LCRE (LCREP Subbasin Plan 2002). Critical habitat has been established for Snake River sockeye, spring/summer Chinook, and fall Chinook salmon (WSPRC and COC, LLC 2005). Salmon have been the subject of numerous studies and assessments in order to determine life history, habitat needs, and vulnerabilities. In general, Pacific salmon and steelhead generally exhibit similar characteristics: "*Adult fish migrate upstream into freshwater rivers to spawn. After hatching, juveniles spend a period of time ranging from days to up to 18 months (depending on species and stock) rearing in fresh water before emigrating downstream to the ocean where they live for 1 to 6 years before maturing and returning to fresh water to spawn, thus completing the life cycle. All Pacific salmon die after spawning, though some repeat spawning occurs among steelhead. After emigrating to marine waters, juveniles of all species utilize nearshore areas for rearing and foraging prior to entering the open ocean*" (WSPRC and COC, LLC 2005).

Birds

Approximately 175 species of birds use the LCRE habitat, including gulls, terns, blue herons, bald eagles, peregrine falcons, hawks, ospreys, owls, marbled murrelets, and brown pelicans (LCREP Subbasin Plan 2002). The region is important for migratory birds and in the winter, populations can reach peaks of around 200,000 birds.

Mammals

A variety of marine mammals use the LCRE including Northern and California sea lions. Harbor seals use the jetties and other parts of the lower estuary as haul-out areas. Offshore mammals include northern fur seals, elephant seals, killer whales, gray whales, and harbor porpoise; some of these are occasionally observed in the estuary itself. In addition to these marine species, other mammals in the LCRE include nutria, beavers, muskrats, raccoons, voles, shrews, moles, coyotes, skunks, bats, black bear, black-tailed deer, Roosevelt elks, and Columbia white-tailed deer (LCRE Subbasin 2002).

B. Water Resources Assessment

B.1. Water Quality

We reviewed multiple sources of water quality data for the LCRE region, including information collected by federal and state agencies, non-profit environmental groups, and citizen science groups. We also utilized previous water quality assessments, including the NPS's Fort Clatsop National Memorial Water Resources Scoping Report (1994), the Water Resources Division's Baseline Water Quality Data Inventory and Analysis for Fort Clatsop National Memorial (2000), and the Youngs Bay Watershed Assessment (2000), as references.

B.1.a. Data Sources

The water quality data discussed in this report were extracted from number of sources, including:

- Washington State Department of Health (WDOH)
- Washington State Department of Ecology (WDOE)
- The Environmental Protection Agency's STOrage and RETrieval database (STORET)
- National Park Service's Water Resources Division (NPS WRD)
- The Beach Environmental Assessment, Communication and Health (BEACH) Program, jointly administered by WDOH and WDOE
- The EPA's Beach Advisory and Closing Online Notification (BEACON) Program
- The Surfrider Foundation's Blue Water Task Force (BWTF) and Rashguard.org
- The Oregon Department of Environmental Quality (ODEQ)
- The Lower Columbia River Estuary Partnership (LCREP); and
- Natural Resources Defense Council (NRDC)'s report *Testing the Waters: a Guide to Water Quality at Vacation Beaches.*

B.1.b. Water Quality

In August 2000, the National Park Service's Water Resources Division (NPS WRD) completed a baseline water quality data inventory and analysis report for Fort Clatsop National Memorial (NPS WRD 2000). This was an effort to retrieve, format and describe existing data on surface water quality (both marine and freshwater) collected by various agencies and housed in the EPA national databases, including STORET, River Reach File (RF3), Industrial Facilities Discharge (IFD), Drinking Water Supplies (DRINKS), Water Gages (GAGES), and Water Impoundments (DAMS). The data, covering the years 1901-1998, were then assessed against published EPA water-quality criteria and instantaneous concentration values selected by NPS WRD to identify potential water quality problems within the study area. Eleven parameters exceeded water quality criteria at least once. Dissolved oxygen, pH, and copper exceeded the criteria for both freshwater and marine aquatic life. In addition, chloride exceeded the criteria for freshwater aquatic life, and zinc exceeded the criteria for marine life (NPS WRD 2000). The EPA drinking water criteria were not met with respect to chloride, sulfate, and beryllium (NPS WRD 2000). Total coliform, fecal coliform, *E. coli*, and turbidity "exceeded the WRD screening limits for freshwater and marine bathing, and aquatic life, respectively" (NPS WRD 2000). The report determined that human activities have caused the greatest impact on surrounding surface waters, and identified potential contaminant sources as “municipal and industrial wastewater discharges; stormwater runoff; timber harvesting; agricultural activities; landfill operations; sand and gravel pit activities; recreational use; marine watercraft traffic, and atmospheric deposition” (NPS WRD 2000). These potential sources are discussed throughout this assessment, especially in Section C.

In August 1996, water quality surveys were undertaken by the NPS for the Lewis and Clark River near Fort Clatsop National Memorial. Fecal coliform levels were low, and “river sediment analysis indicated that mean concentrations of several metals (arsenic, beryllium, nickel, and zinc) exceed typical levels in soils, perhaps due to anthropogenic sources. Although no sediment, semi-volatile organic compounds, pesticides, or polychlorinated biphenyls (PCBs) were detected, toxicity equivalency concentrations suggest a source of dioxin/furans upriver from [Fort Clatsop National Memorial]” (Fort Clatsop National Memorial 2001 *in* NPS 2002).

The Lower Columbia River Estuary Partnership (LCREP) maintains a Water Quality Monitoring Program, which is supplemented with information about other water quality programs maintained by the group’s Monitoring Partners. LCREP worked with the U.S. Geological Survey (USGS) throughout 2004 and 2005 to collect data for sites along both the Columbia and Willamette Rivers. In the Lower Columbia River, data were collected near Point Adams, OR (LCREP 2006a; Morace 2006). Morace (2006) found that none of the aquatic life or human health benchmarks based on EPA water quality standards were exceeded at either the Columbia or Willamette River sampling sites. However, no standards have been established for many of compounds measured in the study, so interpretation of some of the data is difficult. In a spatial comparison, concentrations of trace elements in the Columbia River near Point Adams were elevated compared to concentrations further upstream.

CORIE is a continuous environmental observation and monitoring program maintained by the Oregon Graduate Institute for the Columbia River. Its purpose is to “characterize and predict complex circulation and mixing processes in a system encompassing the lower river, the estuary and the near-ocean….[and is] designed to provide objective insights on the spatial and temporal variability of the Lower Columbia River.” Eight stations within the CORIE program are of relevance to LEWI (Figure 12), including Astoria Meglar Bridge South Channel (am169), Astoria Meglar Bridge North Channel (am012), Tansy Point (tansy), Fort Stevens Wharf (red26), Desdemona Sands light (dsdma), Lower Sand Island light (sandi), Chinook River (chnke), and Jetty A (jetta) (CORIE 2006).

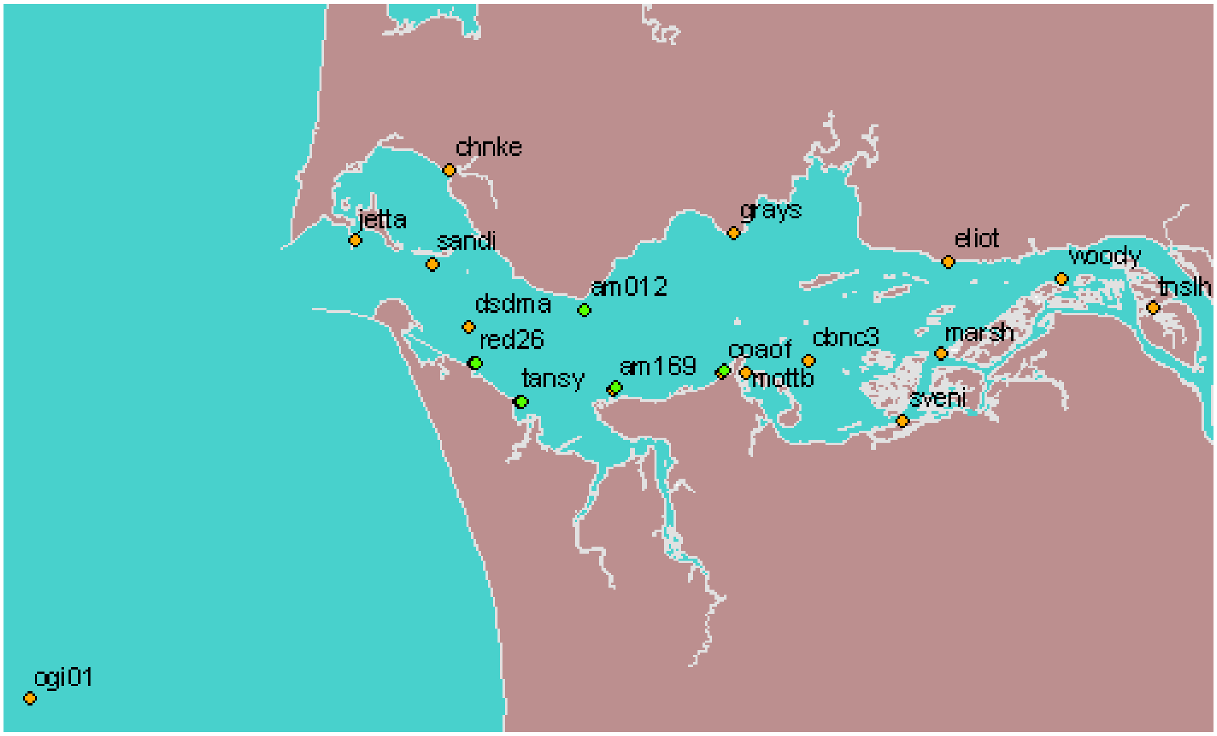

Figure 12. CORIE sampling locations (CORIE 2006).

The CORIE program collects data on environmental parameters (i.e., temperature, salinity, and conductivity) at sites throughout the upper and lower reaches of the river. The majority of the sites of relevance to LEWI either are historical stations or are sites for which no current data are available. The exceptions are Tansy Point and Fort Stevens Wharf, which have reported normal values for both temperature and salinity.

In August 2000, Bischoff *et al.* released the Youngs Bay Watershed Assessment (incorporating data from 1965 to 1999 inclusive), which contains information on Youngs Bay, the Lewis and Clark River, and the Lower Columbia River ecosystem. The assessment used the Oregon Water Quality Index (OWQI), which evaluates measurements of certain water quality parameters (i.e., temperature, dissolved oxygen, pH, fecal coliform) by "a single index value that ranges from 10 (the worst) to 100 (the best)." Based on these criteria, the authors rated the Youngs Bay watershed as "Excellent" with an index value of 92. The Lewis and Clark River at Stavebolt Lane (RM 7.6) is rated "Fair" with a value of 81, and the Klaskanine River at Youngs River Loop Road (RM 1.3) is rated "Very Poor" with a value of 59 (Bischoff *et al.* 2000). Water quality with respect to individual parameters is presented in Table 1, adapted from Bischoff *et al.* (2000). Throughout the entire watershed, nutrients and bacteria were found to be moderately degraded. At both Youngs Bay Mouth and the Lower Lewis and Clark River, temperature was found to be degraded. No data were available for toxics in any subwatershed, and no data exist for dissolved oxygen, nutrients, turbidity, or bacteria in the Lower Lewis and Clark River.

Table 1. Water quality within the Youngs Bay watershed (adapted from Bischoff *et al.* 2000; see text for explanation of individual rankings)

Subwatershed	Temperature	DO	pH	Nutrients	Turbidity	Bacteria	Toxics
Lower Lewis & Clark River		No data		No data	No data	No data	No data
Klaskanine River							No data
Upper Lewis & Clark River							No data
Upper Youngs River							No data
Youngs Bay East							No data
Youngs Bay Mouth							No data
Youngs Bay West							No data

Red = Degraded
Yellow = Moderately Degraded
Green = Not Degraded

The Lewis and Clark River near Fort Clatsop National Memorial has been occasionally monitored by ODEQ since 1969 “at two locations upstream (one-half mile upstream of Peterson Slough and at Stavebolt Lane) and one location downstream (old Highway 101 bridge) of [Fort Clatsop National Memorial].” In general, the data suggest that “water quality within the Lewis and Clark River is usually good and within state standards” (NPS WRD 1994).

Section 303(d) Water Quality Assessment
In order to meet the requirements of Section 303(d) of the Clean Water Act, states are required to submit water quality assessment reports to the EPA. Water bodies are divided into five classification categories, ranging from 1 (water meets tested standards) to 5 (standards violated). Category 4A waters are those “where the data show that a characteristic use is impaired by a pollutant, but a TMDL [Total Maximum Daily Load] addressing that impairment has already been developed and approved” by the EPA (WDOE 2006f). Category 5 waters are those “from which at least one characteristic or designated use is impaired, as evidenced by failure to attain the applicable water quality standard for one or more pollutants” (WDOE 2006f).

Washington State 303(d)
The LCRE borders two Water Resource Inventory Areas (WRIAs) in Southwest Washington, WRIA 24 (Willapa Basin) and WRIA 25 (Grays-Elochoman Basin; WDOE 2006c) (Figure 13). WRIA 24 consists of almost 814,900 acres, and has sixty-seven known Category 5 water bodies. WRIA 25 encompasses nearly 323,097 acres, and has thirty-six known Category 5 water bodies.

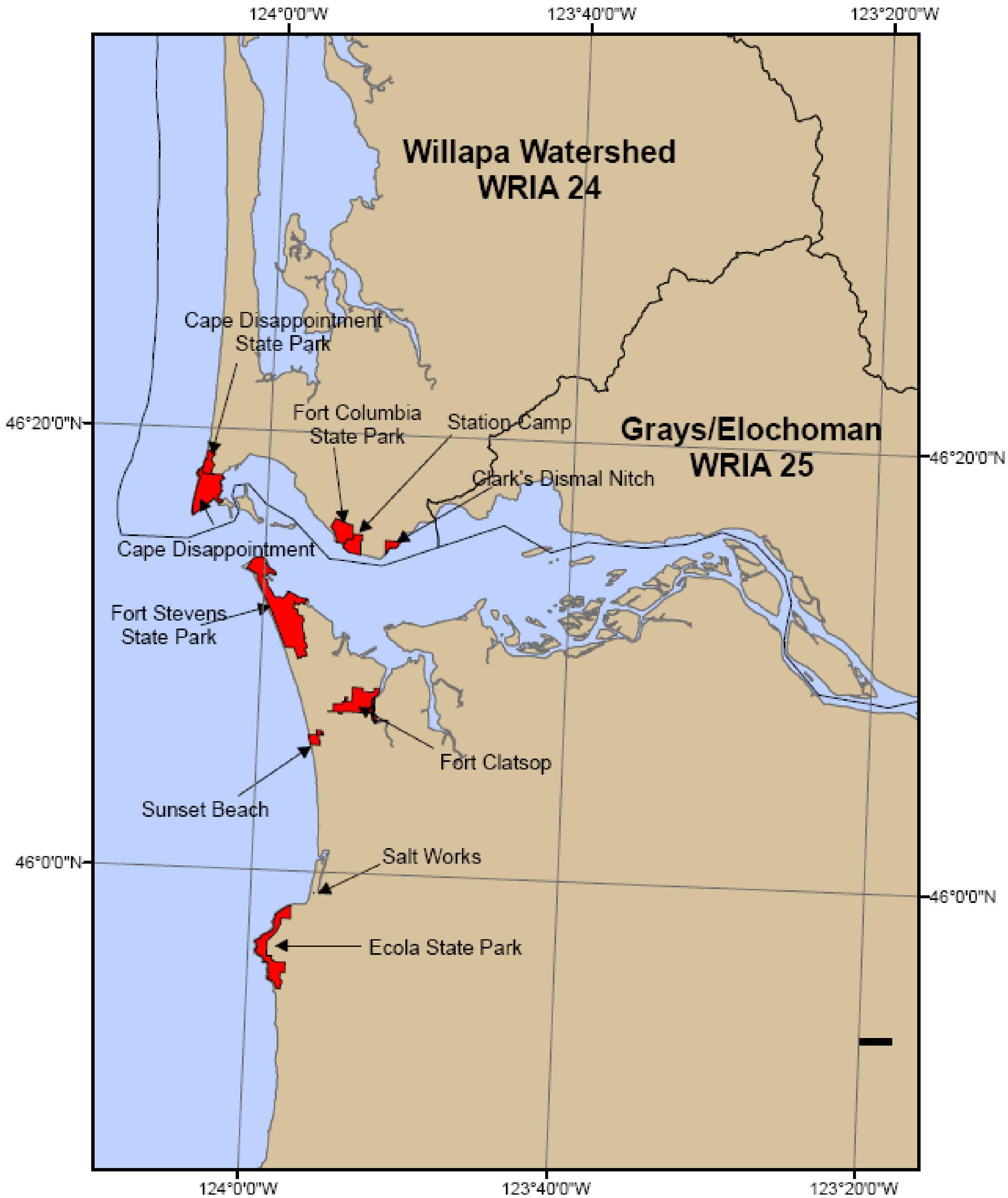

Figure 13. Water Resource Inventory Areas 24 (Willapa Basin) and 25 (Grays-Elochoman Basin). Source: Map created by authors.

The 2004 Category 5 listings for fresh water bodies in WRIA 24 include exceedances of both fecal coliform (water samples) and total PCBs (mussel tissue samples) in the Columbia River (WDOE 2006d). The 2004 Category 5 listings for fresh water bodies in WRIA 25 include a number of temperature exceedances in the Columbia River. Some have attributed temperature exceedances to pulp mill operations throughout the LCRE and its tributaries, but a two year (2002 and 2004) study conducted by Parametrix (and contracted by the Northwest Pulp and Paper Association), concluded that "temperatures higher than the 20°C numeric criteria are a natural condition [in the region]…[and] mills [do] not have a measurable effect on temperatures" (WDOE 2006e).

Category 4A and 5 listings within the Columbia River region of WRIAs 24 and 25 are summarized in Tables 2 and 3 (after WDOE 2006f).

Table 2. Category 5 and 4A 303(d) Listings for the Columbia River (Water Medium)

Category	WRIA	Parameter
5	24	Fecal Coliform
5	25	Fecal Coliform
5	25	Temperature
5	25	Temperature
5	25	Temperature
4A	24	Dioxin
4A	25	Dioxin
4A	25	Dioxin
4A	25	Dioxin
4A	25	Total Dissolved Gas

Table 3. Category 5 303(d) Listings for the Columbia River (Tissue Medium)

Category	WRIA	Parameter
5	24	Total PCBs
5	25	4,4'-DDE
5	25	Dieldrin
5	25	Total PCBs
5	25	Total PCBs
5	25	Total PCBs

Oregon State 303(d)
The 2004 303(d) listings within the Lower Columbia watershed in Oregon include Bear Creek (4A, temperature), Gnat Creek (4A, temperature), Klaskanine River (5, fecal coliform), Skipanon River (5, dissolved oxygen), Youngs River (4A, temperature), and Lewis and Clark River (5, fecal coliform and temperature) (ODEQ 2006a). In all, about 0.359 mi/mi^2 of streams of the Lower Lewis and Clark River are included on the 303(d) list (Pacific Watersheds 2006).

Other Sources
Other water quality information sources examined include the USGS program, the National Stream Water Quality Network (NASQAN), and Columbia Riverkeeper's (CRK) citizen-based group. NASQAN has collected data at Beaver Army Terminal on the Columbia River from

1996-2003; the site is located near Quincy, OR, which is about 40 miles east of Astoria (USGS 2006). CRK monitors for conductivity, pH, dissolved oxygen, and temperature west of Portland (CRK 2006a). Both of these regions are outside of LEWI and therefore not within the scope of this assessment.

Bacterial Contamination

The Washington Beach Environmental Assessment, Communication and Health (BEACH) program was developed in response to the BEACH Act of 2000. This legislation "required states with coastal recreational waters to adopt new or revised water quality standards by April 2004 for pathogens and for pathogen indicators for which the EPA has published criteria under the Clean Water Act" (NRDC 2006). The program is jointly administered by WDOE and WDOH, and monitors high risk beaches for enterococci, bacteria considered to be indicators of water quality. The criteria for acceptable enterococcus levels were established by the EPA in 1986 and have not been changed officially since then. Possible public health action (such as posting warning signs or closing beaches) is recommended if *Enterococcus* levels exceed the EPA criteria of "104 colonies of *Enterococcus* bacteria per 100 milliliters of water for a sample event or a geomean of 35 colonies of *Enterococcus* per 100 milliliters of water for a five-week time period" (BEACH 2006a).

Of all of the sites of relevance to LEWI in Pacific County, WA (i.e., Cape Disappointment, Ilwaco Marina, Chinook County Park, Fort Columbia Historical State Park, Lewis and Clark Campsite State Park), only Cape Disappointment is monitored by BEACH (BEACH 2006b). There were no recorded exceedances in bacterial levels from 2004-2006 (Table 4).

Table 4. BEACH bacterial monitoring results for Cape Disappointment State Park, 2004 – 2006 (BEACH 2006c)

Date	Cape Disappointment State Park # of *Enterococcus* colonies/ 100mL H_20
8/29/06	<10
8/22/06	<10
8/15/06	<10
8/8/2006	<10
8/1/2006	<10
7/25/2006	<10
7/18/2006	19
7/11/2006	<10
7/3/2006	no samples
6/27/2006	<10
6/20/2006	13
6/13/2006	<10
6/6/2006	16
5/30/2006	no samples
5/23/2006	<10
9/21/2005	<10
9/13/2005	<10
8/30/2005	<10
8/8/2005	<10
8/3/2005	<10
7/26/2005	<10
7/19/2005	<10
7/12/2005	<10
7/5/2005	<10
6/28/2005	<10
6/21/2005	<10
6/14/2005	<10
6/8/2005	<10
5/31/2005	<10
10/5/2004	<10
9/27/2004	<10
9/14/2004	<10
9/7/2004	<10
8/31/2004	<10

The same information is displayed for the public on the Earth911 Beach Water Quality website with results by location updated on a Google map (Earth911 2006).

In May 2006 WDOE solicited public comment regarding prioritization of beaches to be monitored weekly for bacteria; there was sufficient state funding to test about 65 out of the 900 or more beaches throughout the entire state, including those located near LCRE and LEWI (WDOE 2006a). Public opinion is one of over 60 parameters that are used to determine which beaches are chosen for testing; others include usage and potential fecal contamination sources. The BEACH program released a proposed list of beaches to be monitored; of relevance to the LCRE is Cape Disappointment State Park (WDOE 2006a).

The Surfrider Foundation, in collaboration with Rashguard.org, also tracks and posts water quality information on their website (Surfrider 2006a). Cape Disappointment State Park is monitored and is listed as "OK," although the last test date was May 19, 2006. Longitudinal water quality data for the park is not listed; instead, daily updates on indications of water pollution are posted (i.e., from polluted runoff in the coastal zone after a rainfall event, sewage spills, or other acute incidents). For example, a polluted runoff warning was posted for Cape Disappointment on August 23, 2006 because of light rain in the region; the warning stated that "higher than normal amounts of polluted runoff in beach waters near river mouths, lagoon openings, storm drain outlets and the like" could be expected (Surfrider 2006a).

Surfrider's Oregon chapter also sponsors water quality testing. The testing is organized through the Blue Water Task Force program (Surfrider BWTF 2006b). Tests are conducted by volunteers who are trained in Colilert and Enterolert methodology, but who are not necessarily water quality professionals. Through this program, tests are performed for the presence of *E. coli* and *Enterococcus sp.* Thirty-six beaches along the Oregon coastal strip are monitored, but none are within the LCRE. Both Fort Stevens and Seaside, OR, located directly outside of the estuary, were found to have low levels of bacteria in 2004.

Contaminants

Among the toxics of concern in the Lower Columbia are pesticides (DDE and DDT), PCBs, dioxin/furans, radionuclides, semi-volatiles, PAHs, and metals (Rosetta and Borys 1996 *in* ODEQ 2000). LCREP worked with the USGS throughout 2004 and 2005 to collect information on water quality data, including contaminants, for sites along both the Columbia and Willamette Rivers. Findings include:

- Concentrations of arsenic, chromium, copper, and lead were present, although at levels below concern with regard to aquatic-life toxicity.
- Of the 173 pesticides and degradation products analyzed, 14 compounds were detected in the Columbia River.
- The known endocrine disruptor, bisphenol A, was detected in both the Columbia and Willamette Rivers.
- Acetaminophen (analgesic) and diphenhydramine (antihistamine) were detected in the Columbia River.
- The antibiotics anhydroerythromycin and trimethoprim were detected at most sites during low-flow conditions, but at only one site during high-flow conditions.
- No organochlorine compounds or PAHs were detected at any of the sites during seasonal samplings of suspended sediment.
- Quantifiable concentrations of the 11 PBDE congeners were detected on suspended sediment near Point Adams.
- 102 PCB congeners were detected at some time on suspended sediment at the sites, usually in trace amounts (Morace 2006).

Johnson *et al*. (2007) sampled tissues and stomach contents of Chinook and coho salmon from the estuary. The contaminants found included PCBs, PAHs, and DDTs, although additional organochlorine pesticides (such as chlordanes, lindane, hexachlorobenzene, dieldrin, aldrin, and mirex) were also detected in lower concentrations. Concentrations of DDTs were especially high in juvenile Chinook salmon from the Lower Columbia River and within the range that could potentially affect fish health and survival (Johnson *et al*. 2007). DDTs and PCBs have been identified as the possible cause of decline of white sturgeon populations in the Columbia River; these contaminants have been found in high levels in the livers, sex organs, and muscle tissue (Feist *et al.* 2005).

Metal contamination has occurred throughout the Columbia River Basin, and some studies have indicated that sources upstream of the Bonneville Dam are the cause. Metals that “exceeded federal and state allowable limits in the water column testing included aluminum, iron, copper, lead, selenium, and silver…[also] fish tissue testing showed the presence of barium, cadmium, chromium, copper, lead, mercury, and zinc” (CRK 2006b). Some estimates from “governmental sources indicate that a possible 281,600 pounds of mercury were dumped into the Columbia from the 1940s to the 1980s” (CRK 2006b).

Concentrations of contaminants “are found throughout the estuary, sometimes near cities and other times in bays and shallows where low-velocity flows allow suspended contaminants to settle. Salmon and steelhead are affected by contaminants through short-term exposure to lethal substances or through longer exposures to chemicals that accumulate over time and magnify through the food chain” (LCREP Module 2006). It is believed that stream-type juvenile salmonids are typically more affected by the short term exposure to pesticides and dissolved metals, while ocean-type juveniles are more susceptible to DDT and PCBs, which can bioaccumulate “during longer estuarine residence times” (Fresh *et al.* 2005 *in* LCREP 2006 Module).

Contaminants can enter the water through surface water runoff and erosion. In the LCRE, PCBs, PAHs, dioxins, and metals have been found in sediments, with the highest concentrations primarily in the Portland, OR and Longview, WA area (Leary 2005).

Marine Biotoxins/Harmful Algal Blooms

WDOH manages a general biotoxin monitoring program in which state, tribal, county, and local agencies, as well as commercial shellfish ventures and federal agencies, collect samples from various bivalve species. Samples are analyzed for the presence of paralytic shellfish poison (PSP) and domoic acid (DA). When the level of PSP in a single sample of a particular shellfish species exceeds the U.S. Food and Drug Administration (FDA) action level of 80 micrograms of PSP toxin in 100 grams of shellfish tissue, WDOH closes commercial and recreational harvest areas for that species. DA closure levels were reassessed by WDOH in September 2000 and established at 20 ppm in sample tissue. Closed areas are reopened only when continued monitoring assures a return to safe conditions (Determan 2003).

Molluscan shellfish tissue samples taken from shellfish growing areas and recreational harvesting areas are monitored for marine biotoxins, specifically saxitoxins (algal compounds responsible for PSP) and DA (WDOH 2006a). Near Cape Disappointment and Fort Canby State

Park, there are marine biotoxin/pollution closures as of March 2007, and the area is closed for clams, geoduck, scallops, mussels, oysters, snails and other invertebrates (WDOH 2006b).

B.1.c. Data Gaps and Information Inconsistencies

Our research has revealed a number of data gaps and information inconsistencies regarding water quality monitoring and data collection in the LCRE region, as illustrated by the following:

- WDOE conducts water quality monitoring on an annual or rotating basis at locations throughout Washington's waters. However, the only locations monitored are in Puget Sound, Grays Harbor, and Willapa Bay. Therefore, no WDOE data are available that describe conditions within or adjacent to LCRE (WDOE 2006g).

- The EPA program BEACON (Beach Advisory and Closing On-line Notification) program provides a public database concerning the status of state beaches. Each beach contains information regarding contact information, monitoring and notification information, general beach characteristics, advisories and closings, and location data (BEACON 2006). The website shows that no water quality or advisory data has been made available for Pacific County, WA beaches along the Lower Columbia River. Clatsop County, OR beaches monitored through the BEACON program are located only along the Pacific coast and not near LEWI boundaries.

- According to *Testing the Waters: A Guide to Water Quality at Vacation Beaches*, a report published by the Natural Resources Defense Council in July 2005, Washington State "regularly monitors less than half of [its] beaches." The report does note that Cape Disappointment State Park was monitored once a week in 2005 for a total of 53 samples, yielding no exceedances (NRDC 2006). In Oregon, no beaches near LCRE are monitored (NRDC 2006).

- While WDOE does have a Marine Sediment Monitoring Program, all of the current sampling locations are within Puget Sound, and none are located near the LCRE region (WDOE 2006b).

B.2. Water Quality Degradation

WDOE's 303(d) water quality assessment for 2004 includes WRIAs 24 and 25. In WRIA 24 (Willapa), approximately sixty-seven Category 5 water bodies are known. The Columbia River is listed for exceedances of both fecal coliform and total PCBs (WDOE 2006d). In WRIA 25 (Grays-Elochoman), approximately thirty-six known Category 5 water bodies are known. The Columbia River is listed for numerous temperature exceedances. There is debate over whether these high temperatures are related to pulp mill operations upstream, or are part of the natural conditions of the ecosystem (WDOE 2006e).

In Oregon, 303(d) listings in 2004 included Bear Creek, Gnat Creek, Klaskanine River, Lewis and Clark River, Skipanon River, and Youngs River (ODEQ 2006a). Approximately 0.359 mi/mi^2 of streams of the Lower Lewis and Clark River are included on the 303(d) list (Pacific Watersheds 2006).

Of the beaches monitored through the BEACH program, only Cape Disappointment State Park is of relevance to the LCRE. There were no recorded bacterial exceedances from 2004 to 2006 at this location (BEACH 2006b and 2006c). These results are supported by the Surfrider Foundation's monitoring program.

The WDOH biotoxin monitoring program monitors levels of PSP and DA in shellfish tissue samples. Areas near Cape Disappointment State Park were closed as of March 2007 for clams, geoduck, scallops, mussels, oysters, snails, and other invertebrates (WDOH 2006b).

In 1994, NPS WRD published the Fort Clatsop National Memorial Water Resources Scoping Report, which addressed some past, present, and future water quality influences on and concerns for the memorial and surrounding areas, including the Lewis and Clark River. The report determined that the majority of water quality influences and concerns were "low-level chronic" and were the result of land-use activities such as logging and agriculture (NPS WRD 1994). Other concerns for water quality in the region were identified as dumps and landfills, farming and dairies, timber harvest and transport, dredging, dikes and levees, and NPS operational activities. These concerns for the pre-expansion region of the memorial are discussed as follows:

- **Unauthorized dumps and landfills:** "*may have a localized effect on the surface and groundwater resources of the Memorial. Specifically, illegal public dumping in a small ravine to the west of the Memorial is suspected of leaking waste oil (and other possible contaminants) into at least one small perennial stream that enters the Memorial. Other more distant landfills could also be affecting the water quality of tributary streams to the Lewis and Clark River.*"
- **Farming and dairies along the Lewis and Clark River:** The pesticides and fertilizers used in farming and agricultural operations could enter the aquatic environment. Also, "dairy operations concentrate livestock, and their waste may also degrade water quality."
- **Timber harvest and transport:** Timber activities have been identified as a possible source of the alteration of flow and degradation of water quality of the Lewis and Clark River. Other potential problems from harvesting include erosion, sedimentation, increased water temperatures, and nutrient loading, all of which could have "profound effects on the diversity and dynamics of the natural flora and fauna of the river system." In addition, "*log booming and log transport on the Lewis & Clark River is the primary means of moving timber to market…as organic debris (primarily bark) decompose from this activity, several water quality parameters may be affected [including] dissolved oxygen concentration, biological oxygen demand (increased due to bark decomposition), chemical oxygen demand (increased due to soluble organic chemicals leaching from logs), and turbidity. Extensive bottom deposits of bark also are suspected to create a physical barrier to the development of a healthy community of benthic organisms.*"

- **Dredging** of the Lewis and Clark River in order to facilitate timber transport "can have a pronounced short term effect on several water quality constituents such as turbidity, as well as a protracted influence on the benthic fauna." The dredged material is then placed outside of Fort Clatsop National Memorial boundaries.
- **Dikes and levees** on the Lewis and Clark River, common throughout the tributaries of the Columbia River estuary, "*were constructed to provide additional farmland within the floodplain, to prevent flooding in settled areas, and as an aid to navigation for boat and commercial traffic…[but] draining and filling has destroyed or greatly altered over 70 percent of the estuarine and riverine wetlands that once occurred within the lowlands along the Lewis and Clark River (Blanchard 1977).*" The remaining wetlands have changed due to alterations in water flows and salinity concentrations. In addition, "flooding potential has increased in recent years because of extensive logging over much of the watershed."
- **National Park Service operations**, including the construction and maintenance of the visitor center and parking lots, have caused "*the alteration of the natural channel in two locations which resulted in the elimination or modification of pristine wetlands. In addition, the parking lot and visitor center roof now drain into this stream, potentially degrading its overall water quality…[and] wastewater systems now in use within the Memorial consist of three separate septic tank/leachfield systems which service the headquarters/visitor center complex and two residences. Wastewater from these systems leaches into the near surface groundwater and may contaminate springs and surface waters within the Memorial*."

The Youngs Bay Watershed Assessment (Bischoff *et al.* 2000) concluded that dredging has a long history in Youngs Bay and along the Lewis and Clark River, mainly in order to "maintain navigability for the Port of Astoria." These activities have "led to losses in aquatic habitats" (Bischoff *et al.* 2000). In addition, diking has occurred extensively throughout the watershed, "extending throughout the south portion of the bay along the entire stretch of the Lewis and Clark River as well as the Youngs River" (Bischoff *et al.* 2000). Diking and draining were identified as having the largest impact on the watershed. These activities were primarily undertaken in order to improve agriculture; however, "disconnecting the floodplain from the rivers has resulted in the loss of flood attenuation that is naturally provided by the floodplains ability to store and impede peak flows which can result in the downcutting of channels and increased flow velocities" (Bischoff *et al.* 2000). The effects of habitat modification are discussed further in Section C.6.

B.3. Sources of Pollutants

Potential sources of pollution in the LCRE include non-point and point sources such as municipal and industrial wastewater discharges, stormwater runoff, timber harvesting, agricultural activities, landfill operations, sand and gravel pit activities, recreational use, marine watercraft traffic, and atmospheric deposition (NPS WRD 2000). All of these sources have the potential to degrade water quality. Bischoff *et al.* (2000) summarized typical watershed issues such as habitat-related and water quality effects by major land uses; their findings are represented in Table 5.

Table 5. Watershed issues by land use category (modified from Bischoff *et al.* 2000)

Land Use Category	**Habitat-Related Effects**	**Water Quality Effects**
Forestry	Channel modification Pool quantity and quality Large wood abundance Shade and canopy Substrate quality Flow alteration Passage barriers	Temperature Turbidity Fine sediments Pesticides and herbicides
Crop-land grazing	Channel modification Pool quantity and quality Large wood abundance Shade and canopy Substrate quality Flow alteration	Temperature Dissolved oxygen Turbidity Fine sediments Suspended sediments Nutrients, bacteria Pesticides and herbicides
Feedlots and dairies	Channel modification	Suspended sediments Nutrients Bacteria Pesticides and herbicides
Urban areas	Channel modification Pool quantity and quality Large wood abundance Shade and canopy Substrate quality Flow alteration	Temperature Dissolved Oxygen Turbidity Suspended Sediments Fine Sediments Nutrients Organic and inorganic toxics Bacteria
Mining	Channel modification Pool quantity and quality Substrate quality	Turbidity Suspended sediments Fine sediments Nutrients Organic and inorganic toxics
Dams and irrigation works	Channel modification Pool quantity and quality Substrate quality Flow alteration Passage barriers	Temperature Dissolved oxygen Fine sediments
Road networks	Channel modification Pool quantity and quality Substrate quality Flow alteration Passage barriers	Turbidity Suspended sediments Fine sediments

Columbia Riverkeeper (CRK) has identified a number of problems that face the river and surrounding ecosystem (CRK 2006b). Paper and pulp mills along the river have been blamed for high levels of dioxins, which have been found in sediment and tissue samples. High water temperatures are believed to be caused by mills, dams, and industrial and municipal discharges. Industrial facilities discharges occur in the vicinity of Fort Clatsop National Memorial (NPS WRD 2000), as summarized in Table 6.

Table 6. Industrial discharges in the vicinity of Fort Clatsop National Memorial and the LCRE (adapted from NPS WRD 2000).

Facility Name	**City**	**Receiving Water**
New England Fish Co	Warrenton	Warrenton Skipanon Ch
American Can Co	Astoria	Columbia R.
Astoria Seafood Co	Astoria	Columbia R.
Clatsop Co School Dist.	Astoria	
Ocean Foods of Astoria	Astoria	Columbia R
Barbey Packing Corp.	Astoria	Columbia R
Astoria Dock Co.	Astoria	
Astoria Fish Factors Inc.	Edmonds	Columbia R
Barbey Packing Corp.	Astoria	Columbia R
Port of Astoria	Astoria	
Alaska Packers Assn.	Hammond	Astoria Tr to Columbia R
City of Warrenton	Warrenton	Columbia R
Sundown Sanitary Dist	Astoria	Youngs R
Union Oil Co	Astoria	
Bumble Bee Seafoods	Astoria	Columbia R
Pacific Hake Fisheries	Astoria	Columbia R
Warrenton Deep Sea, Inc.	Warrenton	Skipanon Ch
Pacific Fabricators Inc.	Warrenton	Skipanon R
Port of Astoria	Astoria	
Bumble Bee Seafoods	Astoria	LW Columbia R

A number of entities and facilities within the Youngs Bay watershed have discharge permits (Table 7).

Table 7. Entities and facilities with permits to discharge into the Youngs Bay watershed (ODEQ 2000) (adapted from Bischoff *et al.* 2000).

Facility Name	Stream
Adamonis, Charles	Youngs River
Astoria, City of	Youngs River
Astoria, City of	Youngs Bay
Brugh, George D.	Youngs River
Chadsey, Betty A. and others DBA	John Day River
Clatsop Economic Development Council	Youngs Bay
Clatsop Transfer and Disposal Co.	Youngs River
Junes, Warren	Lewis and Clark River
Meiners, Darwin L.	Lewis and Clark River
Morisee, Steve	Youngs Bay
Northwest Ready Mix, Inc.	Youngs River
Nygaard, David – DBA	Klaskanine River
Port of Astoria	Youngs Bay
Schock, Donald Duane	Lewis and Clark River
Svensen, Tom	John Day River
Thompson, Barbara L.	Lewis and Clark River
Three D Corp	Youngs River
US Coast Guard	Youngs Bay
Weber, Terry	Lewis and Clark River

The ODEQ Nonpoint Pollution Plan notes that the Youngs Bay watershed has a number of dissolved oxygen problems, and that toxics are of concern in the Lower Columbia region's rivers and tributaries (ODEQ 2000). According to the plan, "87 stream miles in agriculture and rangeland areas are water quality limited. Agriculture and rangeland use is adjacent to approximately 19 percent of the total stream miles. Approximately 59 percent of the water quality limited water bodies that are adjacent to agricultural land use are contained in the Hood watershed. This watershed coincidentally also contains 59 percent of the agricultural lands in the Oregon portion of the combined Southwest Washington and Lower Columbia River ESUs" (ODEQ 2000). Regional land use is summarized in Table 8 and Figure 14.

Table 8. Land use summary in the LCRE (Tetra Tech 1992, Task 2)

	Forest	Agriculture	Urban	Other	Total
Oregon					
Clatsop	454,803	25,821	14,719	19,857	515,200
Columbia	288,000	73,949	23,000	54,731	439,680
Multnomah	142,498	35,011	74,016	19,195	270,720
Washington					
Clark	226,969	94,646	43,699	36,030	401,344
Cowlitz	583,024	37,612	36,816	74,644	732,096
Pacific	530,000	34,870	720	15,510	581,100
Skamania	1,044,016	6,726	2,235	17,295	1,070,272
Wahkiakum	146,346	14,616	1,280	4,606	166,848
TOTAL	3,415,656	323,251	196,485	241,868	4,177,260
	81.8%	7.7%	4.7%	5.8%	100%

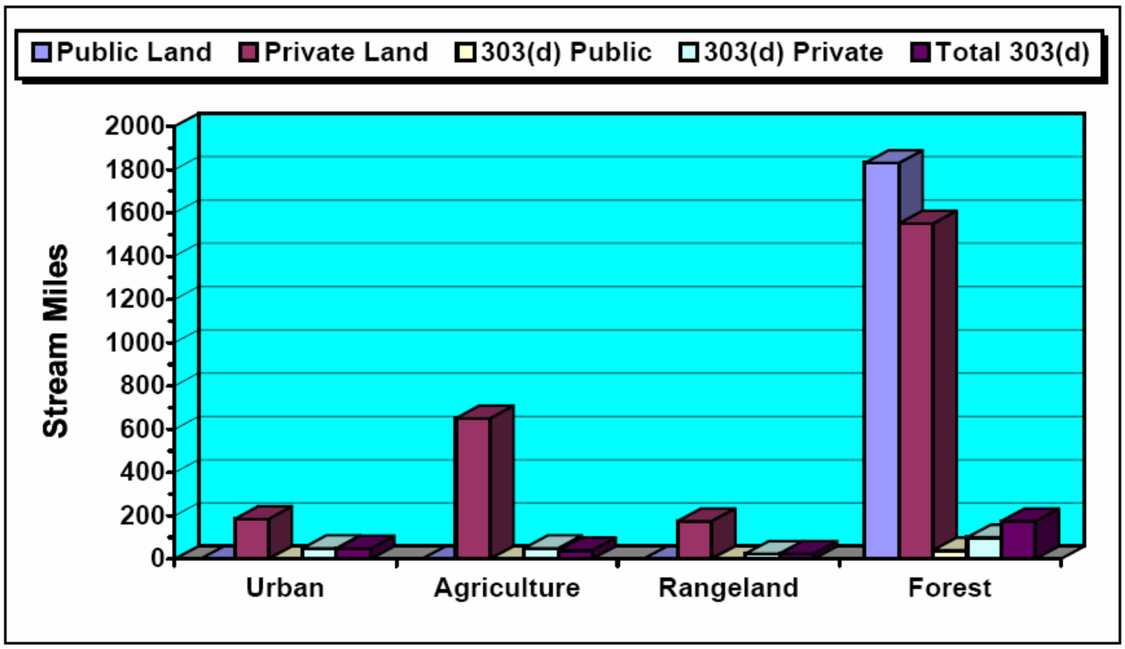

Figure 14. Summary of land use adjacent to streams in Oregon region of LCRE (ODEQ 2000)

The largest cities near the LCRE are Vancouver, WA and Portland, OR. Smaller cities include Longview, WA and Astoria, OR, making the area below Bonneville Dam “the most urbanized section of the river” (LCREP 2006 Module). Sewage treatment plants in Portland, OR and Vancouver, WA were identified as the “largest sources of effluent” to the LCRE by Fresh *et al.* (2004), and Portland Harbor, OR was listed as a Superfund site in December 2000 due to contaminated river sediments (ODEQ 2006c).

C. Other Areas of Concern

In this section we examine other potential threats to water resources within and near the LCRE. The list is not exhaustive but is intended to reflect the nature and range of threats that are known to occur or are anticipated in the region. The concerns listed in subsections C.1 – C.10 differ in their characteristic scales, level of risk, likelihood of occurrence, natural range of variation, and reversibility. They are not equally amenable to local or regional management.

C.1. Harmful Algal Blooms

Harmful algal blooms (HABs) are a potential threat to water quality along the Oregon-Washington coast. HABs are known to cause deaths of both wild and farmed fish and shellfish, illness or death in other marine animals and birds, human illness or death "from toxic seafood or from toxin exposure through inhalation or water contact…and alteration of marine habitats and trophic structure" (Anderson *et al.*, 2002). HABs in the vicinity of the Oregon-Washington coast are most likely to be produced by phytoplankton species that can cause paralytic shellfish poisoning (PSP) or amnesic shellfish poisoning (ASP), also known as domoic acid poisoning (DAP). The alert levels for domoic acid and PSP are 2 ppm and 80 µg/100 g, respectively. Trainer (2002) found the high domoic acid levels (~308 ppm) in razor clams at Clatsop Spit in October 1998; the "highest PSP level (>4367 µg/100 g) was measured in mussels from the south jetty of the Columbia River in late September 1992."

The Oregon Department of Fish and Wildlife (ODFW), Oregon Department of Agriculture (ODA), NOAA, and the National Ocean Service initiated a project in 2005 in order to document and monitor phytoplankton blooms off the coast of Oregon (ODFW 2006). Currently, ODA conducts testing (bi-monthly in winter, weekly in summer) of commercial and recreational shellfish species, including mussels, bay clams, crab, oysters and razor clams (ODA 2006). In July 2006 DA levels in razor clams located on Clatsop Beach (from South Jetty to Tillamook Head) were elevated, but have since declined. The highest levels were recorded the week of July 24 at 31 ppm. One month later, DA levels measured 27 ppm in razor clams. The elevated levels coincided with a seasonal "summer conservation closure," which runs annually from July 15 to September 30 (ODA 2006).

C.2. Non-indigenous and Invasive Species

From the 1880s to the 1970s a new introduced species was found in the lower Columbia River about every five years. Over the past ten years, a new invertebrate species has been discovered about every five months (Figure 15).

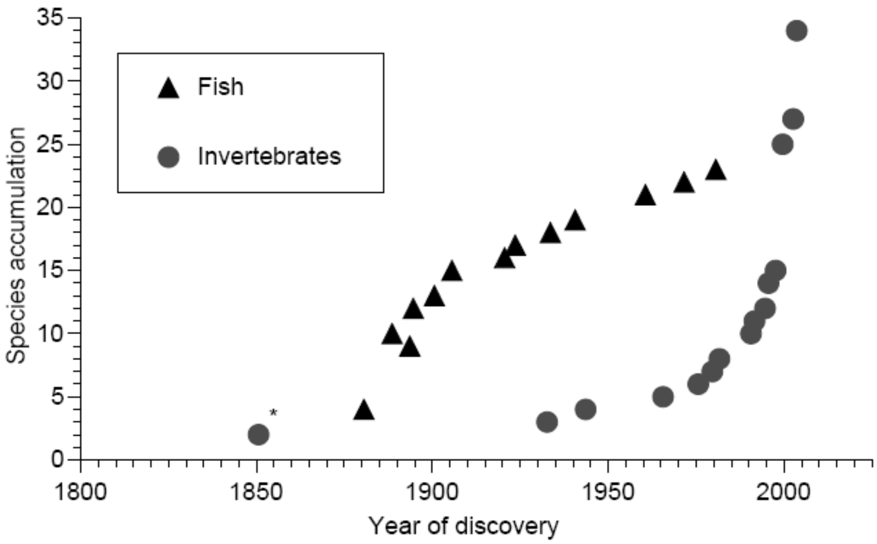

Figure 15. Accumulation of non-indigenous species by year of discovery (Sytsma *et al*. 2004).

This apparent increase in the appearance of non-native species likely reflects both an increase in the frequency of introductions and an increase in detection and reporting. The majority of introduced species originate from North America. Ballast water is believed to be the primary vector responsible for the introduction of nonindigenous invertebrates in the region (Sytsma *et al*. 2004).

One of the most recent aquatic nonnative species found in the lower Columbia River is *Pseudodiaptomus inopinus*, an invasive Asian copepod that became established in abundance in the estuary between 1980 and 1990 (Cordell *et al*. 1992). The species was more recently discovered in the Youngs River. The occurrence of *P. inopinus* appears to be related to temperature and salinity: the species reportedly prefers warmer water temperatures (19.3 ± 1.5ºC) and lower salinities (less than 5 psu – practical salinity units; Cordell and Morrison 1996). Very little is known of the biology and ecology of *P. inopinus* in the invaded habitat; however, its ability to proliferate in high temperature/low salinity environments may have substantial implications as global climate change modifies estuarine environments.

The Lower Columbia River Aquatic Nonindigenous Species Survey (LCRANS) was initiated to provide comprehensive information about the nonindigenous species present in the region and was intended to provide a baseline for evaluating the rate of introduced species. The project included a literature review (2001-2002) and field surveys (2002-2003). From the literature review, it was determined that at least 81 new organisms had been introduced into the lower Columbia River since the mid 1800s. The majority of these species were fish, aquatic plants, and crustacea. Over the course of the field survey, 134 stations were sampled and 269 aquatic species were reported. Of these, 54 species (21%) were introduced, 92 species (34%) were native, and 123 species (45%) were cryptogenic, or of unknown origin. Eight of the 54 introduced species reported were new records for the lower Columbia River. The number of species categorized by minor taxonomic group is shown in Figure 16. The project report is comprehensive and includes an annotated list of native and non-native species (Sytsma *et al*. 2004).

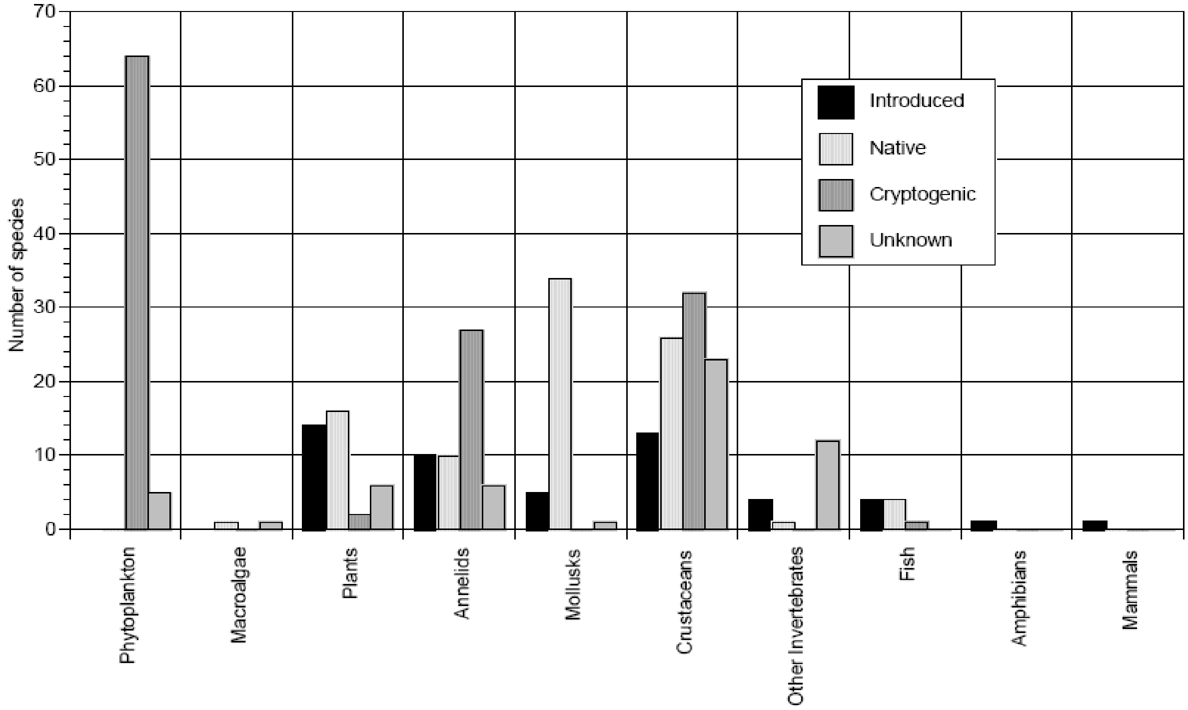

Figure 16. LCRANS field survey species collections by taxonomic group and origin (Sytsma *et al*. 2004).

Specific examples of non-indigenous plant species that have been found in the LCRE include purple loosestrife, Eurasian milfoil, parrot feather, and Brazilian elodea. Introduced plants can out-compete native species, contribute to unhealthy water quality, and "create dense monospecific stands that represent poor habitat for native species (Northwest Power and Conservation Council 2004). In turn, these new plant communities may alter insect and detritus production in and around vegetated wetlands" (LCREP 2006 Module).

C.3. Harvest and Collection of Organisms

LEWI regulations state that "approaching, feeding, hunting or removing wildlife from the park is illegal" [and] a state fishing license is required for fishing within the Lewis and Clark River (NPS 2006). Beyond park boundaries, fishing is permitted in the LCRE and is regulated by the Washington and Oregon Departments of Fish and Wildlife. Although several runs of salmonids are listed as threatened or endangered under the ESA, the sources of these declines are likely attributable to factors other than direct removal within park boundaries.

C.4. Water Withdrawals

In the LCRE, a permit is generally required for water withdrawals from surface and groundwater sources. The primary water source for Warrenton, OR is the Lewis and Clark River, and the largest withdrawals are "for municipal and domestic uses, representing 97 percent of the total" (Bischoff *et al.* 2000; Figure 17 below). Water withdrawals are known to "affect both the magnitude and timing of flows entering the estuary and plume" (LCREP 2006 Module). Withdrawals are often the result of irrigation practices; these withdrawals as well as other water uses are “estimated to have reduced flows of the Columbia River by 7 percent since the latter part of the nineteenth century” (Jay and Kukulka 2002 *in* LCREP 2006 Module). Surface water withdrawals for irrigation purposes account for about 96 percent of total water used, while the remaining four percent are used by municipal sources (National Research Council 2004 *in* LCREP 2006 Module). Groundwater withdrawals for irrigation purposes account for about 75 percent of total water used, while other uses are responsible for the remaining 25 percent (National Research Council 2004 *in* LCREP 2006 Module). Approximately 2,155 acres of land are used during the irrigation season (May 1-September 30, annually) (Tetra Tech 1992).

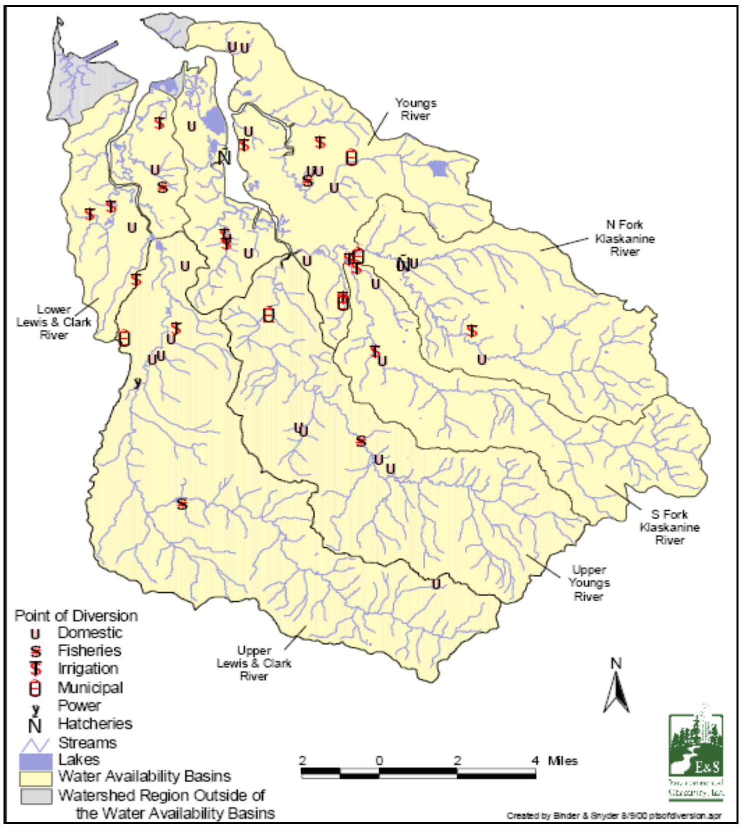

Figure 17. Water withdrawals in the Youngs Bay watershed (Bischoff *et al.* 2000).

C.5. Hydropower and Salmon Recovery

Several federal and non-federal hydropower dam projects exist along the Columbia River (UW CBR 2006). Over 400 dams are located in the Columbia River Basin, including two large federal dams, Bonneville and Grand Coulee. The purpose of these dams is to create "large reservoirs that provide flood control and water for vast irrigation systems on the Columbia Plateau." The Army Corps of Engineers (ACOE) and Bureau of Reclamation (USBR) cooperatively operate the 31 federal hydropower dams on the Columbia and Snake Rivers that make up the Federal Columbia River Power System (FCRPS). Environmental degradation of the river has been attributed to these dams, especially with regard to declines in anadromous fish (by limiting fish passage), decreasing stream flow levels, and destruction of vital fish habitat (NWR 2006; WDOE 2006h). Dams also can cause increased predation of fish in reservoirs (WDOE 2006h).

Pacific salmon stocks have declined substantially since the impoundment of the Snake and Columbia rivers by hydropower dams. Hydropower dams have subjected smolts to delays in migration, injuries and stress associated with dam passage (Kareiva & Marvier 2000), and increased predation by avian predators (Schreck *et al.* 2006). Wilson (2003) reported delayed mortality of juvenile salmon as the result of passage through dams. Salmon spawning and rearing habitat has been reduced by 55% due to the installment of hydroelectric and irrigation diversion dams without providing for fish passage (Bottom *et al.* 2005). Wetlands and floodplain habitats have been eliminated through diking activities, resulting in a reduction of the salmon-rearing capacity of the LCRE (Bottom *et al.* 2005).

These activities and their resultant impacts have led to the listing of twelve Columbia River fish species as either endangered or threatened under the Endangered Species Act. One additional species currently is proposed for listing under the ESA. These include the following (LCREP 2006b):

Endangered
- Snake River Sockeye Salmon ESU (Evolutionarily Significant Unit)
- Upper Columbia River Chinook Salmon Spring-run ESU
- Upper Columbia River Steelhead ESU

Threatened
- Snake River Chinook Salmon Spring/Summer-run ESU
- Snake River Chinook Salmon Fall-run ESU
- Lower Columbia River Chinook Salmon ESU
- Upper Willamette River Chinook Salmon ESU
- Columbia River Chum Salmon ESU
- Snake River Basin Steelhead ESU
- Lower Columbia River Steelhead ESU
- Upper Willamette River Steelhead ESU
- Middle Columbia River Steelhead ESU

Proposed
- Lower Columbia River Coho Salmon ESU

Hatchery programs have been used throughout the region to supplement fish populations. However, hatcheries can contribute to the decline of wild salmon through the spread of disease and through increased competition for food and habitat in streams and in the ocean. They can also interbreed with wild fish, resulting in a loss of genetic diversity (WDOE 2001).

C.6. Habitat Modification

Habitat modification to the LCRE has occurred through the construction of dikes, dams and jetties, dredging activities, and resulting erosion of the banks and river mouth. Many portions of the Youngs Bay watershed have been extensively diked (Figure 18). Most of these dikes were installed between 1917 and 1939 and extend along both the Lewis and Clark and Youngs rivers (Bischoff *et al.* 2000). These structures have caused a 10-12% reduction in the estuary's tidal prism (NOAA Fisheries 2006).

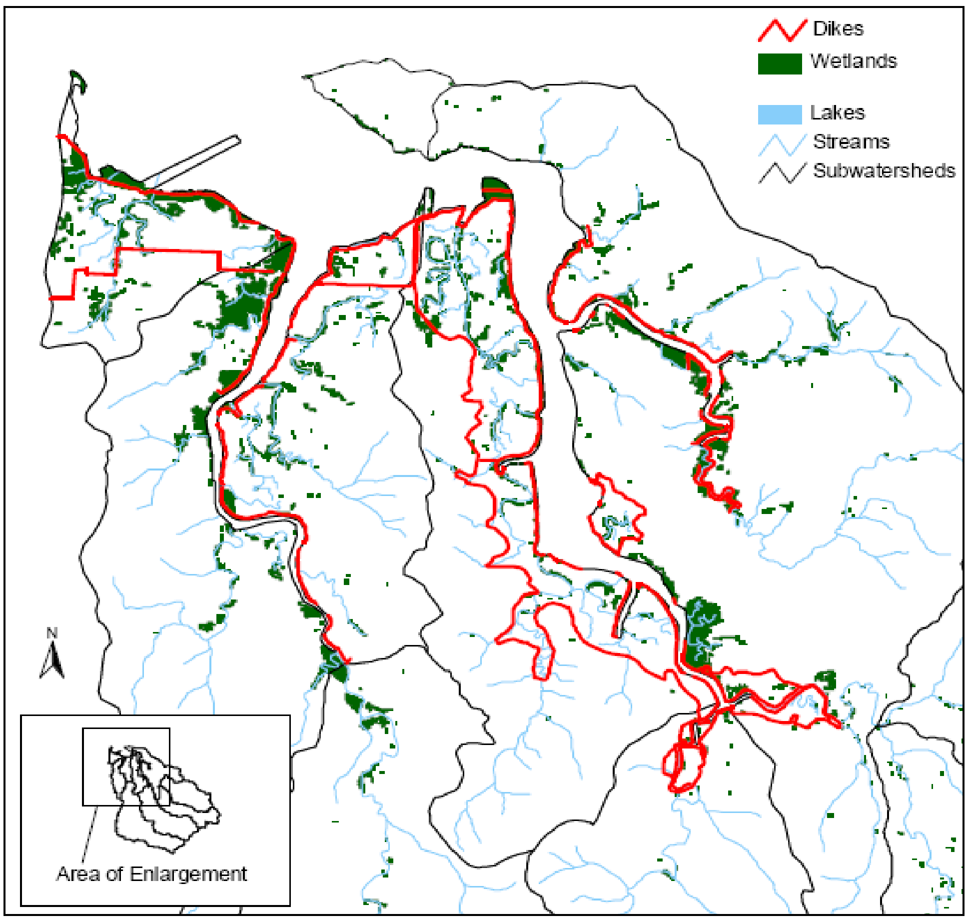

Figure 18. Dikes and wetlands in Youngs Bay Watershed (Bischoff *et al.* 2000).

These alterations have reduced the availability of estuarine habitat to salmonids. In particular "access to and use of floodplain habitats by ocean-type ESUs (salmonids that typically rear for a shorter time in tributaries and a longer time in the estuary) have been severely compromised through alterations in the presence and availability of these critical habitats" (LCREP 2006 Module).

In addition to diking activities, the construction of dams along the Columbia and Snake Rivers (Figure 19) has "significantly restrict[ed] new sand from reaching the ocean" (LCREP 2006 Module).

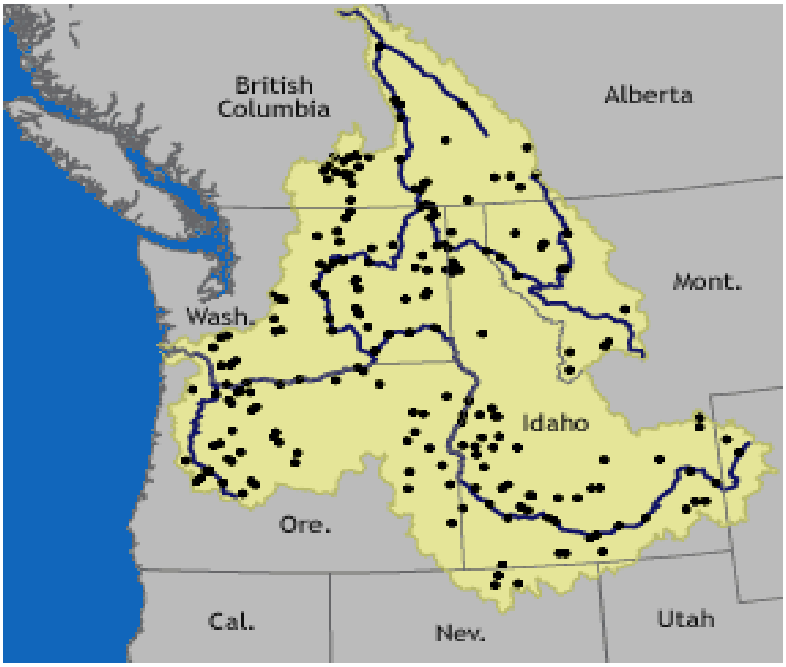

Figure 19. Columbia River Basin dams (www.ecy.wa.gov).

The sediment load in the Columbia River has been reduced by an estimated 24-50% percent from the 1800s. Without sand from the Columbia delta, the coastal shorelines are in the early stages of a long-term erosion phase (WDOE 2001). Erosion along the southwest coast of Washington is affected by jetties, dams, sediment supply, geologic events such as earthquakes, wave action, and weather events like El Niño (WDOE 2006i). The jetties have caused beaches to grow and "possibly erode," and Columbia dams have "reduced the sand supply to coastal beaches by two thirds" (WDOE 2006i).

In the late 1800s, jetties were constructed on both sides of the mouth of the Columbia River (Figure 20).

Figure 20. North and South Jetties at Columbia River Mouth (www.ecy.wa.gov).

The jetties are intended to help accelerate the flow of the river, help maintain the depth and orientation of the navigation channel, and provide protection for ships (both commercial and recreational) entering and leaving the estuary (ACOE 2006a). Portions of the North and South Jetty have become weakened due to wave action, causing concern that the jetties could breach should a large storm event occur along the outer coast. This would allow sand "to be transported and deposited directly into the navigation channel," which would consequently impact both commercial and recreational activities (ACOE 2006a). Some repairs were completed on the North Jetty in 2005, and repairs on the South Jetty are expected to be completed by October 2007.

Jetty construction and dredging have changed the dynamic nature of the estuary entrance in the areas of Clatsop Spit and Trestle Bay. These activities have limited wave action and the marine supply of sediment and have caused the export sand and gravel out of the estuary at a rate three times higher than that at which they enter the estuary (NOAA Fisheries 2006). These activities have also altered currents and wave action in Baker Bay. Mid-channel islands have migrated toward the interior of Baker Bay and as a result, tidal marsh habitat has recently begun to develop in some areas. However, much of the historical tidal marsh and tidal swamp habitat has been lost because of dike construction in the floodplain (NOAA Fisheries 2006).

Dredging has historically occurred throughout the Youngs Bay watershed in order to maintain navigability for the Port of Astoria and the Lewis and Clark River. These alterations have led to loss of aquatic habitat (Bischoff *et al.* 2000). Despite concerns over habitat modifications, some major projects are underway in the LCRE. One is the Columbia River Channel Improvement Project, a collaborative effort between the ACOE and six lower river ports in Oregon and Washington. The overall plan is to deepen the 40-foot channel by three feet in order to improve navigation and the condition of the estuary through various environmental restoration projects (ACOE 2006a). The first phase of the project was completed in February 2006 and the dredged material was deposited at an upland site in Vancouver, WA. This project will allow for increased access to the river by larger container ships and will likely result in increased domestic and international commerce. A White House press release from August 13, 2004 stressed the potential environmental benefits of the project:

- *Migrating juvenile and adult salmon will be helped by tidegate retrofits with fish slides installed along the lower Columbia River, at Grizzly Slough, Tide Creek, and Hall Creek in Oregon, and at Burris Creek and Deep River, Washington;*
- *Juvenile salmon rearing will be helped by connecting channels constructed at the upstream end of Walker-Lord and Hump-Fisher Islands to improve juvenile salmonid access to their embayment-rearing habitats;*
- *Juvenile salmon rearing will be helped by the dredging of Bachelor Slough to improve flow and water quality and restoration of rearing habitat in shallow water/flats and riparian forest habitat;*
- *Restoration and maintenance of native tidal marsh will be helped by implementation of an integrated pest management plan for purple loosestrife control between Columbia River miles 18 and 52;*
- *Migrating juvenile and adult salmon will be helped by implementation of a 3-phase effort to improve water circulation and fisheries ingress and egress at Tenasillahe Island, Columbian white-tailed deer translocation will establish a secure and viable deer population at Cottonwood-Howard Island, and tidal marsh habitat will be restored at Tenasillahe Island via breaching the encircling dike; and*
- *Waterfowl and wading birds will be helped by the restoration of wetland habitat at Shillapoo Lake.*

Despite these potential positive impacts, other studies have shown that dredging activities can resuspend contaminants trapped in bottom sediments. Seelye *et al*. (1982) "demonstrated the potential for uptake of DDE and PCBs by fish as a result of dredging" while Steidl *et al*. (1991) "suggested that the source of DDE and PCBs in ospreys from Delaware Bay was from bottom sediments and dredging activities" (*in* Anthony *et al*. 1993).

C.7. Oil and Fuel Spills

Heavy shipping traffic on the Columbia River renders it vulnerable to oil and fuel spill. The lower estuary region is at additional risk due to the hazards of navigating the lower river and river mouth, and because tides and currents within the lower estuary will cause rapid spread once a spill occurs. In 2005, transport of total domestic tonnage of all commodities exceeded 17 million tons, of which petroleum and petroleum products accounted for more than 6 million tons (USACE Waterborne Commerce Statistics Center 2005).

Oil spill response in the Columbia River System is addressed by the Northwest Area Contingency Plan (NACP 2007). Committee members include Coast Guard Sector Seattle, Coast Guard Sector Portland, Environmental Protection Agency Region Ten, WDOE, ODEQ, Idaho Bureau of Homeland Security, Other federal agencies, Other state agencies, Local government agencies, Tribes, Non-governmental organizations, Industry, and Response Contractors. The US Department of Interior is represented by the Regional Environmental Officer in Portland, OR. The NACP was most recently updated in July 2007. According to that document, Geographic Response Plans (GRPs) exist for many areas within the Columbia River system. Up-to-date GRPs provide a means of improving response in the event of a spill, especially with regard to sensitive areas and those containing wildlife. The Lower Columbia GRP is maintained by WDOE; its status and date of most recent update are unclear.

Recent oil spills in this region have been small but frequent; the cumulative impacts of these spills could degrade water quality and aquatic habitats in the LCRE region. Table 9 shows spills that were reported between October 2005 and June 2007 (ACOE 2006b):

Table 9. Spills in the LCRE Region 2005-2007 (ACOE 2006b)

Date	**Location and Source (if available)**	**Amount of Spill**
October 25, 2005	John Day Dam - Navigation Lock	Less than 3 gallons
November 8, 2005	The Dalles Dam - Spillway Bay 23	Less than 1 pint
February 14, 2006	Lookout Point Dam	About 15 gallons
February 22, 2006	Bonneville	Less than 1 cup
March 27, 2006	Lookout Point - Tailrace	Less than 1 cup
May 10, 2006	The Dalles Lock and Dam - Main Unit 9 scroll case	Less than 50 gallons
May 30, 2006	The Dalles Lock and Dam - Main Unit 18 governor oil pump	Less than 1 pint
June 29, 2006	The Dalles Lock and Dam - Unknown source	Less than 1 pint
July 11, 2006	The Dalles Lock and Dam - Oil/Water separator	Less than 1 quart
July 19, 2006	The Dalles Lock and Dam - Oil/Water separator	Less than 1 gallon
July 28, 2006	Mouth of the Columbia River South Jetty - Komatsu 1250 excavator	Less than 10 gallons on jetty
August 8, 2006	The Dalles Lock and Dam - Tailrace	Less than 1 gallon
August 17, 2006	The Dalles Lock and Dam - A pilot pressure line blew in the governor cabinet of Main Unit 17	Less than 1 gallon made its way to the floor drain
August 25, 2006	Mouth of the Columbia River South Jetty - Komatsu 1250 excavator	Less than 10 gallons on jetty
September 14, 2006	Dexter Dam - from drainage sump in powerhouse	Less than 1 gallon
October 30, 2006	The Dalles Lock and Dam Main Unit 15 blade seals	Less than 1 gallon discharged
November 3, 2006	Dredge Essayons – Columbia River Mile 82, between St. Helens and Kalama, Oregon, Columbia County	11 gallons bow thruster light gear oil, Texaco Meopa 68
November 25, 2006	Dredge Yaquina - from forepeak tank in river at 8010 NW Saint Helens Road, Portland, OR.	About 1 ounce
December 5, 2006	The Dalles Lock and Dam – Main Unit 14	Less than 1 gallon
December 11, 2006	John Day Lock and Dam – Navigation Lock – drainage pump #4	1 quart of Mobil EAL 244H

December 12, 2006	John Day Lock and Dam – Navigation Lock – drainage pump #3	1 quart of Mobil EAL 244H
December 18, 2006	The Dalles Lock and Dam – Tailrace – de-water drainage sump	Sheen
February 14, 2007	The Dalles Lock and Dam – Tailrace – Main Unit 16 blade seals	Less than 1 gallon
April 10, 2007	Bonneville Lock and Dam – Powerhouse 2 head gate system reservoir	314 gallons
May 14, 2007	Lost Creek Reservoir - from privately-owned submerged vehicle	Up to 40 gallons
May 18, 2007	Humboldt Bay, CA - from Corps' dredge Essayons	Approximately 7 gallons released
May 27, 2007	Coos Bay Field Office - released from Corps' dredge Yaquina	Approximately 2 ounces
June 13, 2007	Mouth of the Columbia River, South Jetty - released from contractor's equipment	Approximately 3 gallons hydraulic oil
July 19, 2007	South Jetty construction at Mouth of the Columbia River - spilled from contractor's equipment	5 gallons of hydraulic oil
August 6, 2007	South Coast Clamshell dredging project - from dredging contractor equipment during refueling operations	Up to 15 gallons
August 23, 2007	The Dalles Lock and Dam turbine oil spill	1 gallon reported
September 4, 2007	The Dalles Lock and Dam	Less than 1 pint of oil discharged
September 5, 2007	Willamette Falls Locks -upstream side of gate 1, lock chamber	12 gallons of hydraulic oil
September 20, 2007	Hills Creek Powerhouse	Estimated leak of 1 gallon light turbine oil
September 21, 2007	The Dalles Dam	About .5 gallon of turbine oil

In 1999, approximately 150 gallons of fuel were released near Fort Clatsop National Memorial by Willamette Industries. About 143 tons of potentially contaminated soil were tested for the presence of contaminants, but none were found (Spencer Environmental, Inc. 2000 *in* NPS 2002).

C.8. Land-based and Water-based Recreation

The Fort Clatsop National Memorial Water Scoping Report (NPS WRD 1994) listed restricted access as a barrier to recreational activities, such as boating and fishing, along the Lewis and Clark River. Since 1980, however, Fort Clatsop National Memorial visitation has been steadily increasing. In preparation for the Lewis and Clark Bicentennial (2003-2006), the NPS estimated that approximately 400,000 to 500,000 visitors were expected (NPS 2002).

Fishing and boating are permitted on the Columbia River and Youngs Bay (NPS 2006c). According to some estimates, "more salmon are caught in the Columbia River and its tributaries than any other region in the state" (WDFW 2006). Regulations change annually (and sometimes weekly) to adjust to the status of the salmon runs (WDFW 2006). The mouth of the Columbia is popular for fall Chinook salmon and sturgeon fishing, while Youngs Bay is known for its spring Chinook fishery. The Youngs River is also a popular site for cutthroat trout (Trails.com 2006). In addition to fishing, non-motorized boating is available on the Lower Columbia River Water Trail, which runs from Bonneville Dam to the Pacific Ocean.

C.9. Tsunami Hazards

The potential threat of tsunami impacts on the Oregon-Washington coastal region has been summarized by WDOE (WDOE 2006j). The region is vulnerable to tsunamis generated by earthquakes on the Cascadia Subduction Zone, which is located about 70 miles off of the Pacific coast, as well as from distant sources (Walsh 2005). Recent studies suggest that tsunamis have struck the Oregon coast on a regular basis with wave heights between 20-45 feet at the shoreline (ODGMI 1995). According to some estimates, a tsunami would force the central portion of the Olympic Peninsula in Washington to rise, and coastal areas would be inundated with water, sinking below sea level. Maps developed by the Oregon Department of Geology and Mineral Industries (1995) show tsunami impacts from Clatsop Spit to Astoria as well as complete flooding of Cape Disappointment.

C.10. Climate Change

Climate projections suggest gradual regional warming and higher precipitation, especially in winter. This would likely lead to increased frequency of winter freshets and lower natural spring-freshet flows (Bottom *et al*. 2005). Gradual regional warming makes the accumulation of snowpack less likely and smaller, decreasing spring freshet volume (LCREP Subbasin Summary 2002).

The Climate Impacts Group (CIG) (2004) identified several impacts of warmer temperatures and increased winter precipitation on the Pacific Northwest (PNW) including:

- Increased rain rather than snow during winter months;
- Increased winter streamflow;
- Increased winter flooding in transient basins;
- Reduced amount of water stored as snow;
- Earlier snow melt; and
- Decreased late spring and summer streamflows

Observed and predicted impacts of climate change in the Pacific Northwest (PNW) are summarized in Table 10.

Table 10. Observed and projected impacts of climate change in major climate and hydrologic indicators (CIG 2004)

Indicator	Observed 20th century changes	Projected mid-century changes
Temperature	Region-wide warming of about 1.5°F (1920-2000) Warming has been fairly uniform and widespread, with little difference between warming rates at urban and rural weather monitoring stations. 1990s the warmest decade on record (warmer than any other decade by 0.9ºF) Most warming occurring during winter	2020s: average increase of 2.7°F 2040s: average increase of 4.1°F Temperature changes benchmarked to the decade of the 1990s.
Precipitation	Region-wide increase in precipitation since 1920 Median value: +22% Changes upwards of 60% in northeast Washington and British Columbia)	Uncertain, although most models project wetter winters and drier summers
April 1 snowpack	Substantial declines (>30%) at most monitoring stations below 6,000 feet	Continued decrease in April 1 snowpack in mid- and low-elevation basins. Projected decrease in April 1 snowpack for the Cascades Mountains in Washington and Oregon relative to 20th century climate: 0 - 44% by the decade of the 2020s (based on +3°F average temp change) 0 - 58% by the decade of the 2040s (based on +4.5°F average temp change)
Timing of peak spring runoff	Advanced 10-30 days earlier into the spring season during the last 50 years	Greatest trends occurred in the PNW Earlier peak spring runoff expected on the order of 4-6 weeks
Summer streamflow	Declining in sensitive PNW basins May-September inflows into Chester Morse Lake (WA) in the Cedar River watershed as a fraction of annual flows have decreased 34% since 1946 Losses in June-Sept flows at Dworshak Dam (ID) on the order of 10% in 82 years	Continued and more wide-spread declines April-September natural streamflow in the Cedar River (WA) projected to decrease 35% by the 2040s (based on a 2.5°F increase in average temp) July-October streamflows in the Tualatin Basin (OR) projected to decrease 10-20% by the 2040s; total average annual runoff projected to be less than the historic average

Increased winter flooding, decreased summer streamflows, and elevated estuary temperatures will degrade estuarine salmon habitat. These changes will likely exacerbate stresses on salmon stocks from presently degraded freshwater and estuarine habitat (CIG 2004).

Global climate change is projected to intensify many hazards and stresses currently present in the coastal zone including erosion, shoreline retreat, bluff landsliding, and flooding (CIG 2004). Coastal erosion, shoreline retreat and landslides are predicted to increase as a result of sea level rise and increased precipitation in winter. Some coastal areas may experience accretion, others, erosion.

Sea level rise will depend on circulation changes in the Northeast Pacific and on local vertical land movements. Land subsidence along the northern Oregon coast is predicted to exacerbate sea level rise (CIG 2004).

The potential impacts of climate change on the PNW are predicted to have adverse effects on both hydrologic and biological components. The potential management implications for mitigating these changes are discussed in Table 11.

Table 11. Potential management implications associated with projected climate change impacts on water resources in the Pacific Northwest (CIG 2004).

Projected Hydrologic Impact	**Potential Management Implications**
Increased winter streamflow	- Increases the risk for more winter flooding in low (rain dominant) and midelevation (rain/snow mix) basins, possibly requiring more active management of floods and floodplains - Increases the potential for more streambed scouring events (affecting salmon redds), possibly impacting salmon recovery and management activities - Increases the potential for more winter hydropower production, possibly increasing revenues
Reduced snowpack	- Reduces the amount of water available for spring reservoir refill and summer streamflows, potentially requiring operations adjustments to meet summer water demands (with implications for summer hydropower production and salmon) - Reduces the risk for spring flooding in large snowmelt dominant basins - Likely to increase competition for summer water uses
Earlier snowmelt and earlier peak runoff	- Increases length of the summer low flow season, potentially increasing competition for summer water - May have implications for salmon management and recovery where there is a mismatch between salmon migration patterns and peak flows
Reduced summer streamflow	- Increases frequency of significant low flow events and potential for drought, potentially increasing competition for water and stressing abilities to meet water quality parameters and instream flow requirements (re: warmer water temperatures)

D. Recommendations

D.1. Condition Overview

We summarize the condition of water resources in LEWI in Tables 12-16 based on our review of available data and our best professional judgment. Our recommendations draw upon those previously offered by others. We incorporate uncertainty associated with the limited data available for assessing water resources in LEWI, especially with regard to the newly acquired park sites, for which water resource data are severely limited.

We find that the greatest threats and stressors to water resources within LEWI emanate from outside sources, for example, hydropower, land use (agriculture, forestry, development), and habitat modification (diking, dredging, and biological invasion). Furthermore, the potential for unpredictable catastrophic events such as a major oil spill, tsunami, or contamination from nuclear wastes stored upstream must be recognized.

The combination of anthropogenic changes, successional processes, and climate change requires that park managers determine ecosystem goals for LEWI that are both desirable and feasible, and nest these goals within the broader regional management goals. Assessment of potential changes associated with the cumulative effects of growth, development, and change impacts, and evaluation of management strategies will require a more comprehensive, quantitative basis from which to determine change.

Table 12. Condition of water resources in and around LEWI.

Stressor/ Environmental Indicator	Lower Columbia River Estuary	Youngs Bay Watershed	Wetlands, Lakes, Streams	Outer Coastal Waters
WATER QUALITY INDICATOR				
Nutrients	**ID**	**EP**	**ID**	**OK**
Dissolved Oxygen	**EP**	**EP**	**ID**	**ID**
Fecal Bacteria	**EP**	**EP**	**ID**	**OK**
Toxic Compounds	**EP**	**EP**	**ID**	**OK**
LAND-USE RELATED STRESSORS				
Septic / Wastewater	**IP**	**IP**	**EP**	**OK**
Stormwater Runoff	**IP**	**IP**	**EP**	**OK**
Agricultural Runoff	**IP**	**IP**	**EP**	**OK**
HABITAT MODIFICATION				
Upland Habitat Modification	**EP**	**EP**	**EP**	**OK**
Shoreline/Aquatic Habitat Modification	**EP**	**EP**	**EP**	**EP**
Erosion	**EP**	**EP**	**EP**	**EP**
RECREATIONAL USAGE				
Harvest/Collection of Organisms	**OK**	**OK**	**OK**	**OK**
OTHER STRESSORS/ INDICATORS				
Non-Native Invasive Species	**EP**	**EP**	**EP**	**OK**
Harmful Algal Blooms	**ID**	**ID**	**ID**	**ID**
Fuel / Oil Spills	**PP**	**PP**	**OK**	**PP**

Legend:
EP= existing problem

PP= potential problem

IP= intermittent problem

OK= no detectable problem

ID= insufficient data to evaluate

Table 13. Condition of water resources in the Lower Columbia River Estuary.

Stressor/ Environmental Indicator	Lower Columbia River Estuary	Explanation
WATER QUALITY INDICATOR		
Nutrients	**ID**	Insufficient data to determine. No specific information on nutrients in the estuary or LEWI region (pg. 31)
Dissolved Oxygen	**EP**	Exceedances reported, although interpretation of data is difficult as many standards have not been established for measured parameters (Morace 2006) (pg. 23)
Fecal Bacteria	**EP**	Exceedances reported as Category 5 303(d) listings in WRIA 24 in Southwest Washington and in the Lower Columbia watershed in Oregon (Klaskanine and Lewis and Clark Rivers) (pg. 26). No reported exceedances for Cape Disappointment.
Toxic Compounds	**EP**	PCBs, dioxins, other compounds detected as Category 5 and 4A 303(d) listings in WRIAs 24 and 25 in Southwest Washington (pg. 26). Sources of contaminants believed to include sources upstream of Bonneville Dam, surface water runoff, and erosion, and have been found in salmon tissue and sediments (Feist *et al.* 2005; CRK 2006b; Morace 2006; Johnson *et al.* 2007)
LAND-USE RELATED STRESSORS		
Septic / Wastewater	**IP**	Intermittent releases reported. Discharges from mills, dams, and industrial and municipal facilities blamed as sources (CRK 2006b) (pg. 34, 39).
Stormwater Runoff	**IP**	Seasonal runoff causes intermittent problems
Agricultural Runoff	**IP**	Intermittent releases reported

Legend:
EP= existing problem

PP= potential problem

IP= intermittent problem

OK= no detectable problem

ID= insufficient data to evaluate

HABITAT MODIFICATION		
Upland Habitat Modification	**EP**	Agriculture, forestry, and urban/suburban development have modified habitat. Irrigation practices and dam projects have reduced flow (pg. 43-44)
Shoreline/Aquatic Habitat Modification	**EP**	Diking and dredging have substantially modified habitat. Alterations can reduce availability of estuarine habitat for salmonids (pg. 45, 47). Dikes have caused a 10-12% reduction in the estuary's tidal prism (NOAA Fisheries 2006) (pg. 45).
Erosion	**EP**	Natural processes disturbed by dredging and diking, which have reduced sediment load in the river by about 24-50% since the 1800s (WDOE 2001).
RECREATIONAL USAGE		
Harvest/Collection of Organisms	**OK**	No indication that decline of salmon runs is related to direct removal (pg. 42).
OTHER STRESSORS/ INDICATORS		
Non-Native Invasive Species	**EP**	Invasive species present; some problematic. At least 81 new organisms have been introduced since the mid-1800s (Systma *et al*. 2004).
Harmful Algal Blooms	**ID**	No data available on HABs specific to estuary.
Fuel / Oil Spills	**PP**	Small but chronic spills could have cumulative impacts (see Table 9). Shipping traffic on the river makes the region susceptible to future problems, especially navigation around the river mouth (pg. 48).

Table 14. Condition of water resources in the Youngs Bay Watershed.

Stressor/ Environmental Indicator	Youngs Bay Watershed	Explanation
WATER QUALITY INDICATOR		
Nutrients	**EP**	Exceedances reported near Fort Clatsop (NPS WRD 2000), low levels near Lewis and Clark River in 1996 (NPS 2002), and throughout watershed (Table 1, pg. 25).
Dissolved Oxygen	**EP**	Exceedances reported near Fort Clatsop (NPS WRD 2000).
Fecal Bacteria	**EP**	Exceedances reported throughout watershed except for Lower Lewis and Clark River (Table 1, pg. 25).
Toxic Compounds	**EP**	PCBs, dioxins, other compounds detected in Lewis and Clark River near Fort Clatsop (NPS 2002) in soils believed to be caused by sources upstream (pg. 23).
LAND-USE RELATED STRESSORS		
Septic / Wastewater	**IP**	Intermittent releases reported from Fort Clatsop in the 1990s from three septic tank/leachfield systems (NPS WRD 1994) (pg. 33) and other discharges (NPS WRD 2000) (pg. 36) and (Bischoff *et al.* 2000) (pg. 37).
Stormwater Runoff	**IP**	Seasonal runoff causes intermittent problems. National Park Service operations at Fort Clatsop found to be a source (NPS WRD 1994) (pg. 33).
Agricultural Runoff	**IP**	Intermittent releases reported near Fort Clatsop (NPS WRD 1994) (pg. 33, 37).
HABITAT MODIFICATION		
Upland Habitat Modification	**EP**	Agriculture, forestry, and urban/suburban development have modified habitat (pg. 32, pg. 35, 37).

Legend:
EP= existing problem

PP= potential problem

IP= intermittent problem

OK= no detectable problem

ID= insufficient data to evaluate

Shoreline/Aquatic Habitat Modification	**EP**	Diking and dredging have substantially modified habitat. Dikes along the Lewis and Clark River has destroyed or altered almost 70% of the wetlands, and dredging of the Lewis and Clark River to facilitate navigation and timber transport has influenced the habitat (NPS WRD 1994; Bischoff *et al.* 2000) (pg. 33).
Erosion	**EP**	Natural processes disturbed by dredging and diking
RECREATIONAL USAGE		
Harvest/Collection of Organisms	OK	No indication that decline of salmon runs is related to direct removal (pg. 42).
OTHER STRESSORS/ INDICATORS		
Non-Native Invasive Species	**EP**	Invasive species present; some problematic. At least 81 new organisms have been introduced since the mid-1800s (Systma et al. 2004).
Harmful Algal Blooms	**ID**	No data available on HABs specific to the Youngs Bay watershed.
Fuel / Oil Spills	**PP**	Small but chronic spills could have cumulative impacts. Most in the Columbia River itself (ACOE 2006b), but potential exists in the Youngs Bay watershed. In 1999, about 150 gallons of fuel was released near Fort Clatsop although no contaminants were found in the soil (NPS 2002) (pg. 50).

Table 15. Condition of water resources in freshwater wetlands, lakes, and streams.

Stressor/ Environmental Indicator	Wetlands, Lakes, Streams	Explanation
WATER QUALITY INDICATOR		
Nutrients	**ID**	No data available specific to freshwater bodies.
Dissolved Oxygen	**ID**	No data available specific to freshwater bodies.
Fecal Bacteria	**ID**	No data available specific to freshwater bodies.
Toxic Compounds	**ID**	No data available specific to freshwater bodies.
LAND-USE RELATED STRESSORS		
Septic / Wastewater	**EP**	Intermittent releases reported
Stormwater Runoff	**EP**	Seasonal runoff causes intermittent problems; National Park Service operations at Fort Clatsop found to be a source (NPS WRD 1994) (pg. 33).
Agricultural Runoff	**EP**	Intermittent releases reported near Fort Clatsop (NPS WRD 1994) (pg. 33, 37).
HABITAT MODIFICATION		
Upland Habitat Modification	**EP**	Agriculture, forestry, and urban/suburban development have modified habitat (pg. 32, pg. 35, 37). Irrigation practices and water withdrawals (pg. 43).
Shoreline/Aquatic Habitat Modification	**EP**	Diking and channel modification have substantially altered habitat. See Figure 18 for locations of dikes along wetlands, lakes, and streams.
Erosion	**EP**	Natural processes modified by diking and channel modification.

Legend:
EP= existing problem

PP= potential problem

IP= intermittent problem

OK= no detectable problem

ID= insufficient data to evaluate

RECREATIONAL USAGE		
Harvest/Collection of Organisms	**OK**	No indication that decline of salmon runs is related to direct removal (pg. 42).
OTHER STRESSORS/ INDICATORS		
Non-Native Invasive Species	**EP**	Invasive species present; some problematic. At least 81 new organisms have been introduced since the mid-1800s (Systma *et al*. 2004), which could spread through freshwater system.
Harmful Algal Blooms	**ID**	No data available specific to freshwater bodies.
Fuel / Oil Spills	**OK**	No indication of problems in freshwater system.

Table 16. Condition of water resources in outer coastal areas.

Stressor/ Environmental Indicator	Outer Coastal Waters	Explanation
WATER QUALITY INDICATOR		
Nutrients	**OK**	No indication of problems specific to outer coastal areas.
Dissolved Oxygen	**ID**	No data available specific to outer coastal areas.
Fecal Bacteria	**OK**	Only low levels of bacteria found at Fort Stevens and Seaside, Oregon outside of the estuary in 2004.
Toxic Compounds	**OK**	No indication of problems specific to outer coastal areas.
LAND-USE RELATED STRESSORS		
Septic / Wastewater	**OK**	No indication of problems specific to outer coastal areas.
Stormwater Runoff	**OK**	No indication of problems specific to outer coastal areas.
Agricultural Runoff	**OK**	No indication of problems specific to outer coastal areas.
HABITAT MODIFICATION		
Upland Habitat Modification	**OK**	No indication of problems specific to outer coastal areas.
Shoreline/Aquatic Habitat Modification	**EP**	Mouth of Columbia River modified by jetties. Portions have been weakened by wave action, causing concern that jetties could breach as a result of a large storm event, which could transport sand directly into the navigation channel (ACOE 2006a).
Erosion	**EP**	Natural processes modified by jetties. Wave action and marine supply of sediment has been limited, sand and gravel has been exported out of the estuary at a rate three times higher than that at which they enter (NOAA Fisheries 2006). Currents and wave action have also been altered in Baker Bay, causing migration of mid-channel islands and the creation of tidal marsh habitat in some areas (pg. 47).

RECREATIONAL USAGE		
Harvest/Collection of Organisms	**OK**	No indication that decline of salmon runs is related to direct removal (pg. 42).
OTHER STRESSORS/ INDICATORS		
Non-Native Invasive Species	**OK**	No indication of problems specific to outer coastal areas.
Harmful Algal Blooms	**ID**	Limited data specific to outer coastal areas despite projects to monitor phytoplankton blooms (ODFW 2006). Elevated domoic acid levels in razor clams at Clatsop Spit found by Trainer (2002) and ODA (2006) (pg. 40).
Fuel / Oil Spills	**PP**	Area vulnerable to oil spills because of location of shipping lanes along the coast (pg. 48).

D.2 Recommendations

D.2.a. Context and General Recommendations

The water resource management environment within which LEWI exists is complex and dynamic at several scales. Multiple park sites are distributed around the Lower Columbia River Estuary and along outer coastal shores across two states. Human activities that influence the quality of water resources (e.g., shoreline and upland habitat modification, agriculture, forestry, urban and suburban development, hydropower operations, commercial shipping) occur across multiple spatial scales and vary in intensity through time. Consequently, we consider multiple scales and make recommendations for water resource management within LEWI at 1) the regional scale, in the context of the Lower Columbia River Estuary; 2) the watershed scale, in the context of the Youngs Bay Watershed; and 3) the scale of the park itself. Achieving integration across all three scales presents a substantial challenge that can be met only through partnering with other agencies and entities.

Regional Scale: Lower Columbia River Estuary

LCREP (2004) articulated five action-oriented strategies for the Lower Columbia subbasin:

1) Reduce the effects of the Columbia River hydropower system
2) Protect and restore habitat
3) Address toxic contaminants
4) Slow introductions of non-native species
5) Reduce predation on focal species

Based on our review of water resources within LEWI, these five strategies address several of the most prominent threats to regional water resources. Consequently, we recommend that LEWI retain these as priority strategies, track their implementation by LCREP, and contribute expertise and support for such implementation where appropriate, recognizing that full implementation will require far more capacity than exists within LEWI alone.

Within the LCREP framework, LEWI has the opportunity to participate in the design of the LCREP monitoring program to ensure that it meets NPS water resource needs. In addition, LEWI might reasonably expand its own water resource monitoring program to include newly acquired sites within the park in a design that simultaneously serves its own needs and is integrated with a larger LCREP monitoring program. Priority sites could include Fort Clatsop National Memorial, Station Camp, and estuarine habitat(s) within Cape Disappointment.

USFWS and NOAA are engaged in recovery planning processes under the US ESA for the marbled murrelet and several species of salmon that utilize the Lower Columbia River Estuary during some portion of their life history. These recovery planning processes are consonant with LEWI's interest in restoring the ecosystem to conditions encountered by Lewis and Clark in 1805-1806. Currently, as many as 30 tribes, federal and state agencies, and NGOs are engaged in salmonid recovery. LEWI can leverage these activities by actively participating in recovery planning processes, particularly those with relevance to habitats within or adjacent to park sites.

Watershed Scale: Youngs Bay Watershed

Bischoff *et al.* (2000) made the following recommendations with regard to managing coastal habitats in the Youngs Bay watershed:

> 1) Prioritize areas that salmonids are known to use for spawning and rearing, especially those with sufficient water quality (low temperature, low turbidity) and "good stream channel characteristics (responsive channel habitat type, good geomorphologic conditions, good riparian shade and recruitment potential)."
>
> 2) Create a strategy to collect "continuous discharge data in the primary rivers that flow into Youngs Bay….Discharge data are essential to evaluate current low flow and peak flow conditions in the watershed."
>
> 3) "Develop or expand the continuous temperature monitoring network with monitors at strategically located points such as the mouths of tributary streams, locations of known spawning beds, at the interface between major land use types, or downstream of activities with the potential to influence water temperature."
>
> 4) "Locate and map potential sources of nitrogen, phosphorus, and bacteria in the watershed."

While these four recommendations focus primarily on salmon habitat, they are consistent with monitoring water quality parameters that are essential to maintaining healthy estuarine habitats. LEWI should encourage the development of a sustained monitoring program and participate in such monitoring activities where feasible. In particular, LEWI can contribute site-specific water quality data to regional databases in order to increase the power to detect regional trends.

Watershed-level impacts to LEWI's resources that originate outside the park must be identified and, where possible, minimized or mitigated. This requires that the park keep apprised of land-use activities within the watershed and engage in partnerships to address the impacts of such activities where feasible. Where outside funds are available for activities such as restoration, LEWI can partner with local entities and agencies to plan and implement projects that would benefit water resources within the park.

Park-wide Scale

The recent expansion of LEWI from the original Fort Clatsop National Memorial site to a larger park encompassing several disjunct sites requires that management of water resources be extended to the new park sites. Prior water resource data collection and management for these sites is largely lacking. Although a park-wide system of water resource management is desirable, differences in site history, use, location, and ecology will require the development of site-specific strategies that are compatible with park-wide goals and objectives.

LEWI has maintained a water resource monitoring program at the Fort Clatsop National Memorial site since 1998. Consistent with both a watershed and parkwide approach, this monitoring program could be expanded to include newly acquired park sites and to address new or emerging threats to water quality. Monitoring sediments for toxins and pollutants would add information that could be essential to restoration activities. Monitoring storm-water runoff from roads and parking lots within the park would add valuable information and could help guide remedial action. Rare freshwater resources should be included in any expansion of the monitoring program. Resources for monitoring could be leveraged by partnering with local entities, state agencies, and academic institutions.

LEWI has demonstrated a commitment to wetland restoration. Restoration is an important tool to address habitat loss and modification due to diking, shoreline hardening, forest practices, and biological invasion. In many park areas, restoration will be required to return wetlands to conditions approximating those encountered by Lewis and Clark. Consequently, wetland restoration will be important to meeting park management goals and should remain a priority activity within LEWI. Candidate restoration sites from across all park sites should be prioritized by level of threat, feasibility of restoration, and likelihood of restoring ecological function. As partnerships and funds allow, sites can be selected from such a list.

Elsewhere in coastal Oregon, the US Forest Service has pioneered the ‘Suislaw Process’ as a means of catalyzing wetland restoration programs on lands under the agency’s ownership. The process is led by a multidisciplinary graduate student team working closely with an advisory board and project manager over a short period (weeks to months) to develop a detailed plan for a restoration site (Chase 2006). The benefits of the process as implemented by the USFS are 1) low cost; 2) stakeholder participation and support for the process; 3) leveraged resources and expertise. The process has been used successfully to design a restoration plan for the Lower Drift Creek Estuary in the Alsea watershed and has been extended to the Salmon River estuary. Given the importance of wetland restoration within and around LEWI and the current limitations on funding and personnel, the park could consider implementing a program similar to the Suislaw Process at priority restoration sites.

High volumes of shipping traffic coupled with habitat modification and upland land use render the Lower Columbia River Estuary particularly vulnerable to invasion by non-native species. Control of invasive species is especially appropriate at small scales, for example, site-specific removals in sensitive areas with the park. The park can continue to remove invasive species on a case-by-case basis (as has been done in the past), and can become proactive by developing an invasive species management plan that includes aspects of prevention, detection, control, and eradication in a systematic framework that allows rapid response, sustained activity, and prioritization by species and anticipated threat to habitats. Invasive species management should be coupled with restoration activities to 1) prevent invasion of restored habitats and 2) to restore invaded habitats.

D.2.b. Specific Recommendations

Based on recommendations reported in Section D.2.a. and on our review and assessment of water resource condition and stressors in and around LEWI, we offer the following specific recommendations (Table 17). The order in which the recommendations are presented does not reflect relative importance or urgency. In offering these recommendations, we acknowledge that moderate uncertainty exists in our evaluation of several aspects of water resource condition. This uncertainty reflects the limitations of the data. Consequently, our recommendations include suggestions for closing data gaps, especially those pertaining to water resources that could become degraded in the near-to-mid-term.

Table 17. Specific Recommendations

- Maintain and expand the current water quality monitoring program to include new park sites.
- Integrate the water quality monitoring program with regional programs (e.g., LCREP monitoring program).
- Determine feasibility of restoring aquatic habitats within LEWI to the approximate conditions encountered by Lewis and Clark; prioritize habitats by feasibility, and modify management goals for aquatic habitats deemed not feasible for restoration.
- Where feasible, partner with local groups and tribes to restore degraded freshwater and estuarine habitats, especially those that provide essential fish habitat.
- Develop a plan for managing non-indigenous marine, estuarine, and freshwater species.
- Work with other agencies and entities to reduce the impacts of hydropower and land use on water resources within LEWI.
- Encourage NACP to update the Oil Spill Geographic Response Plans for the Lower Columbia River Estuary and outer coastal regions. Consider whether the definition of sensitive areas under existing Oil Spill Contingency Plan rules could be expanded to include sensitive areas within LEWI.
- Measure stormwater runoff and manage to reduce impacts to estuarine environments.
- Measure the amounts of toxins and contaminants introduced to coastal streams and rivers and to beach areas by surface water flow from primary and secondary roadways and parking areas. Determine whether toxins and contaminants from roadway sources impair water resources in LEWI.
- Plan for impacts due to climate change, including impacts to restoration sites.

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Appendix A. Water Quality Standards

Table A1. EPA Water Quality Standards for Marine Waters

EPA Water Quality Standards for Marine waters		Source
Dissolved Oxygen (DO)	Criteria evaluated for freshwater levels only. Coldwater values were used because the EPA identifies the presence of salmonid species to be indicative of coldwater areas. The acute lethal limit for salmonids is at 3 mg/L, but the coldwater minimum has been established at 4 mg/L due to more sensitive insect populations. Because the criteria are generalized, it is required that states evaluate the species in their own waters to establish appropriate minimum levels of dissolved oxygen.	U.S. EPA. 1986. Ambient Water Quality Criteria for Dissolved Oxygen. EPA 440/5-86-003; EPA Gold Book
Temperature	For marine aquatic life, the maximum increase in the weekly average temperature due to artificial causes is 1°C (1.8°F) during all seasons of the year, and daily temperature cycles of a body of water are not to be altered, neither in amplitude nor frequency.	EPA Gold Book
pH	Shall fall between the range of 6.5-8.5	EPA Gold Book
Turbidity		
Toxic Substances		
Primary Contact Recreation		Source
Fecal Coliforms	The median value for a fecal coliform standard is 15 per 100mL and the 90th percentile should not exceed 43 for a 5-tube, 3-dilution method.	EPA Gold Book

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Natural Resource Program Center

Natural Resources Program Center
Water Resources Division
1201 Oakridge Drive, Suite 250
Fort Collins, CO 80525

www.nature.nps.gov/water

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