CHAPTER TWO
STUDY AREA DESCRIPTION

2. STUDY AREA DESCRIPTION

2.1. Existing Project Description

The Columbia and lower Willamette Rivers navigation project was first authorized in 1878, and the channel has been deepened at intervals since that time. The project authorization, as modified by Congress in 1962, covers 11.6 miles of Willamette River below Portland, Oregon, and 103.5 miles of Columbia River below Vancouver, Washington (figure 1). Work on the authorized 40-foot deep channel from Portland and Vancouver to the sea was complete in 1976. The Willamette River channel, from the Broadway Bridge (WRM 11.6) to the mouth (WRM 0), varies in width from 600 to 1,900 feet. On the Columbia River, the project provides for a channel 35 feet deep and 500 feet wide from the Interstate 5 bridge to the Burlington Northern Railroad bridge (CRM 106.5 to 105.5). The Columbia River channel for the four miles between the mouth of the Willamette River and the railroad bridge at Vancouver is being maintained to a 500-foot width until the need for a wider channel is demonstrated. The rest of the Columbia River navigation channel from the railroad bridge to near the river's mouth (CRM 3) is 40 feet deep and 600 feet wide. Turning basins on the Columbia River are provided at Vancouver, Kalama, and Longview in Washington, and at Astoria in Oregon. The project also includes 30- and 24-foot deep auxiliary channels from the Columbia River channel at St. Helens (CRM 87) and Rainier (CRM 68), respectively.

At Portland, there are six Port of Portland terminals consisting of 43 berths equipped to handle general cargo, bulk cargo, lumber, automobiles, lift-on-lift-off and roll-on-roll-off containers, and bulkhead vessels. The Port of Portland owns and operates a major ship repair yard, which is the west coast's largest, and the world's third largest floating dry dock. Available in the harbor area are privately operated facilities for receiving, storing, and out-loading petroleum, wood chips, grain, logs, sand and gravel, cement, and steel products.

At Vancouver, there are municipal facilities capable of berthing five ships simultaneously. Each berth is completely outfitted with mechanical and lift facilities for receiving and handling all types of cargo. The port has a low dock to handle roll-on-roll-off and side-port discharging vessels. The grain terminal has a total capacity of 5,000,000 bushels.

The Port of Kalama has two berthing areas, one port-owned and one private. The Port of Longview has a public terminal on the Columbia River and a privately owned grain elevator with a capacity of 6,400,000 bushels. This port also has a heavy lift facility with a capacity of 600 tons. At Astoria, there is a terminal with facilities for receiving and handling all types of general cargo. At other locations between Portland and the Columbia River entrance, there are sufficient private facilities to accommodate river vessels and fishing craft.

Deep-draft commerce through the project in 1996 was 32,000,000 short tons. The average annual traffic for the 5-year period from 1992 to 1996 was 32,400,000 short tons.

2.2. Historic Channel Development

The Columbia and lower Willamette Rivers navigation project was originally authorized in 1878 with a 20-foot minimum depth. The navigation depth was increased to 25 feet in 1899 and to 30 feet deep by 300 feet wide in 1912. Between 1930 and 1935, the navigation channel was again increased to 35 feet deep by 500 feet wide. The current channel, which was authorized in 1962 and completed in 1976, is 40 feet deep and 600 feet wide. Figure 2-1 shows a timeline for development of the Columbia River channel. The channel has been maintained using a combination of dredging and hydraulic control works, such as pile dikes. While non-federal dredging and mining occurs in the study area, this discussion focuses on dredging performed by the Corps. Figure 2-2 shows the amount of annual dredging needed to construct and maintain the navigation channel from 1906 through 1996.

Prior to construction of the 30-foot channel in 1912, dredging was limited to a few very shallow reaches of the river where the natural controlling depths were in the 12- to 15-foot range. From 1912 to 1935, the channel was deepened to 35 feet by 500 feet wide and realigned at many reaches. It was also during this time that many hydraulic control structures were built and dredging became necessary to maintain the authorized channel. From 1936 to 1957, channel alignment adjustments were made that added to the dredging requirements. During this period, dredging averaged 6.7 million cubic yards (mcy) per year. By 1958, the channel alignment had stabilized but dredging was augmented to increase the depth of advance maintenance dredging from 2 to 5 feet to allow the channel to shoal for a year and still provide full project dimensions (Corps of Engineers, 1961).

The current channel was constructed in stages between 1964 and 1976. It generally follows the river's thalweg (the deepest part of the river channel). Most of the channel is naturally deeper than the required 40 feet. Shoals tend to form in channel reaches where natural depth was less than 40 feet. Since 1976, dredging has averaged approximately 5.5 mcy per year, after making adjustments for emergency dredging related to the 1980 eruption of Mount St. Helens.

Each channel deepening may be viewed as low intensity disturbances that impact long reaches of the river. The riverbed slowly adjusted its side-slopes adjacent to each new dredge cut. It took several years for the side-slopes to approach equilibrium with the deeper channel. Maintenance dredging increased throughout the river during these adjustment periods.

In addition to deepening the channel, development actions have included constrictions, realignments and in-water fills. Channel constrictions, realignments, and fills are high intensity, localized disturbances in the river. These practices cause immediate changes in flow patterns that can result in local erosion. Although the impacts are generally limited to a short reach of the river, it may be years before equilibrium conditions become reestablished. There have been significant increases in local maintenance dredging as a result of these practices.

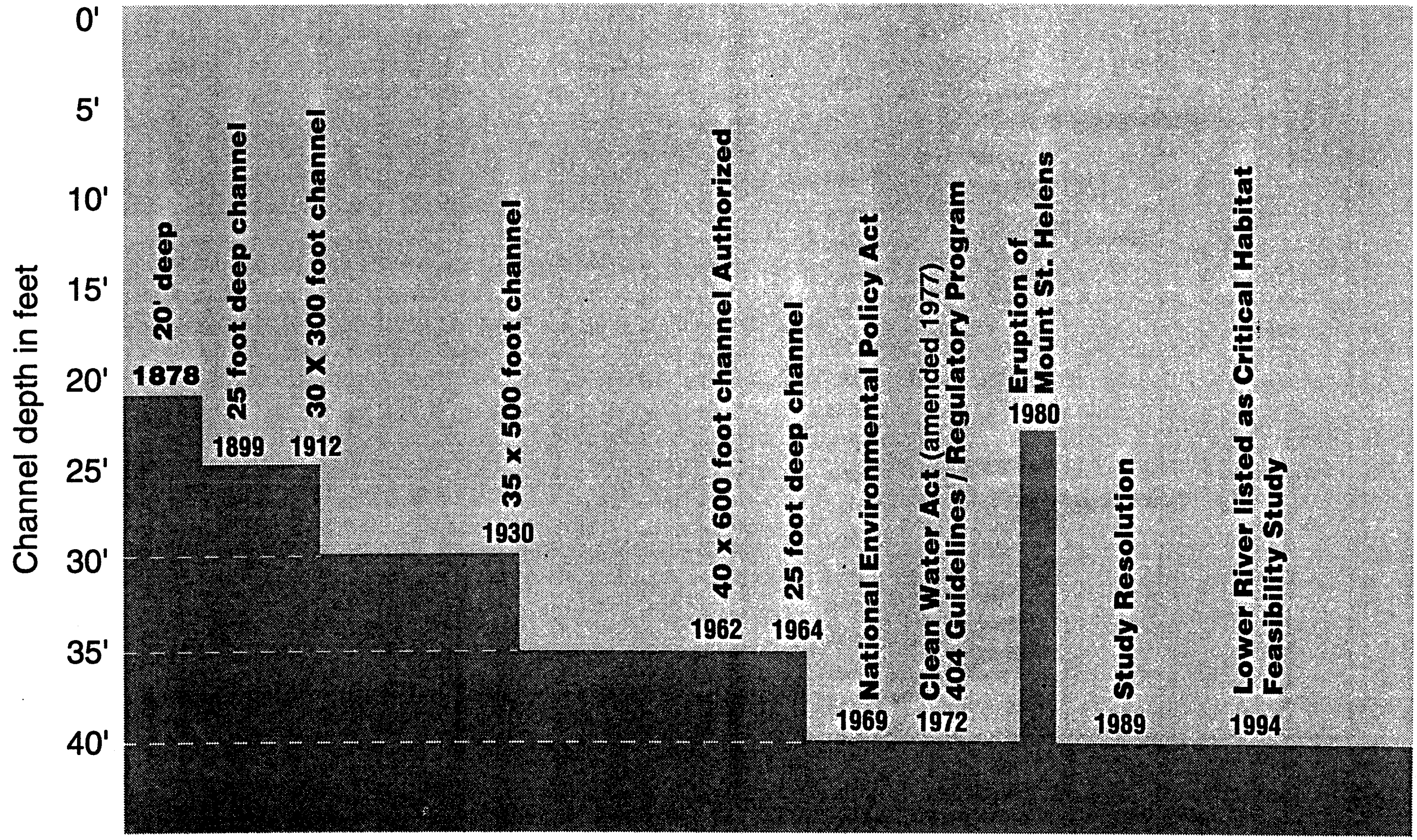
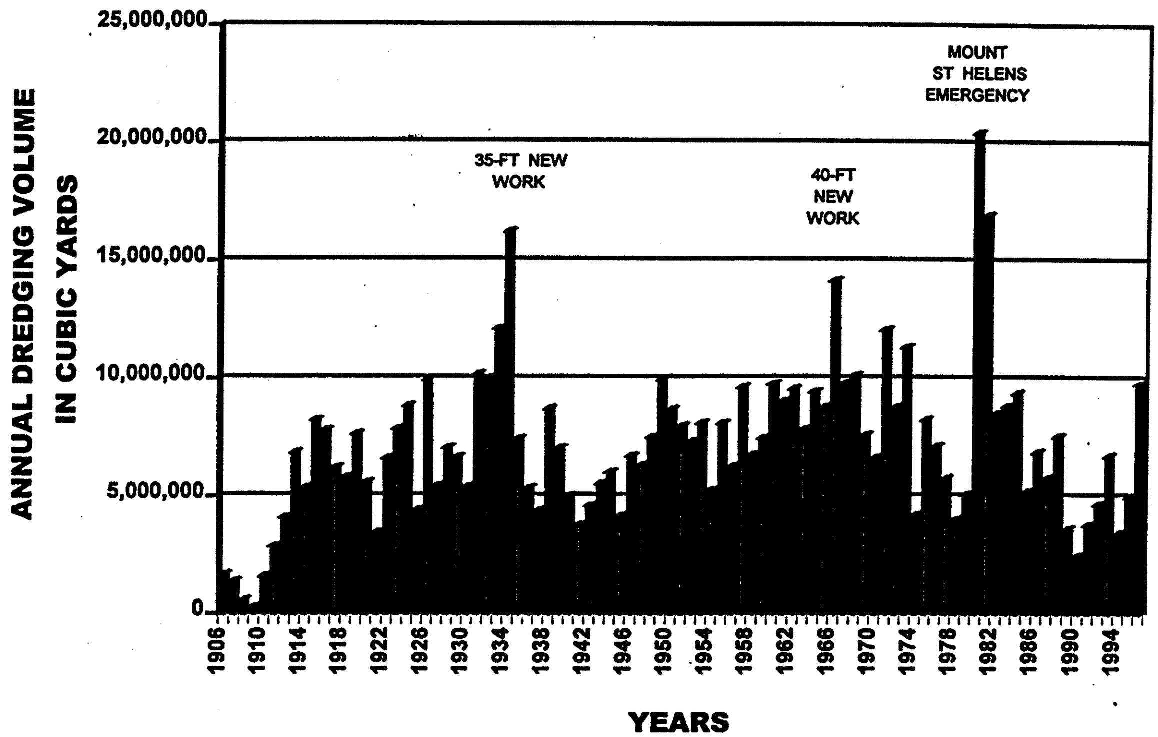


Figure 2-1 Comunbia River Channel Development TimeTable

Figure 2-2. Annual Dredging Volumes, 1906 to 1996



A period of riverbed adjustment has followed each navigation channel development action. The amount of dredging required to maintain the navigation channel during these adjustment periods has depended on the magnitude of the disturbances to the pre-existing riverbed. Because of the frequency and variation of channel development actions, there is not a clear correlation between channel depth and maintenance dredging volumes. Despite large variations in annual dredging volumes, the average annual maintenance dredging for the 30-, 35-, and 40-foot channels all fall between 5.5 and 6.7 mcy per year.

2.3. Navigation Practices

Navigation practices of deep-draft vessels on the Columbia River influence the channel design and potential benefits of any channel improvement project. Especially important are the practices of the outbound container ships and bulk grain carriers that could take advantage of a deeper channel. The size, speed and scheduling of those vessels, the operating requirements of the pilot groups, and the policies of the shippers and government regulators dictate many of the channel design parameters.

To define the navigation practices of container ships and bulk grain carriers on the Columbia River, a detailed study was made of outbound transits that occurred in 1991 through 1993. The study analyzed the number of transits, vessel drafts, departure times, and underkeel clearances. Observed river stages and channel depths were combined with transit times to estimate the depth of water and underkeel clearance experienced during transits. Additional data from 1994 and 1995 was used to supplement the analysis.

Although there are exceptions, the standard navigation practices for outbound ships on the Columbia River are described below. The term "draft" is used to refer to the depth to which a ship is immersed when carrying a load in the fresh water of the Columbia River navigation channel. For ships with drafts from 36 to 40 feet in depth, the fresh water draft is about one foot deeper than the salt-water draft. The design drafts discussed below were obtained from the Lloyd's Registry and relate to specific sea conditions for each ship. No adjustments were made to design drafts to account for fresh water in the navigation channel.

2.3.1. Traffic Volume

Around 2,000 commercial deep-draft vessels transit the Columbia River each year. As shown in table 2-1, these vessels included bulk grain carriers, container ships, vehicle carriers, tankers, and other bulk carriers. Bulk grain carriers make up the largest category of vessels calling on the Columbia River, about 25 percent of the total transits. Container ships are a growing share of the traffic, increasing from 170 (8 percent of the total) in 1991 to 283 (13 percent) in 1995.

Table 2-1. Columbia River Transits from 1991 through 1993

Type of Vessel	Number of Transits
Bulk grain carriers	1,684
Container ships	616
Vehicle carriers	425
Tankers	395
Other vessels	3,161
Total Transits	6,281

The outbound bulk grain carriers and container ships are the ships that operate with the deepest drafts in the river. Panamax-class carriers (a type of deep-draft bulk carrier), with design drafts of up to 44 feet, frequently load corn at the Port of Kalama. From 1991 through 1995, 184 grain ships sailed from Kalama drawing 40 feet or more, including 10 ships that drew 41 feet or more. During the same five years, there were 49 grain ships drawing 40 feet or more that sailed from Portland/Vancouver, with seven of those drawing 41 feet or more. The majority of the container fleet had design drafts around 38 feet, however there are some with design drafts in the 41- to 42-foot range. Container ships typically sail with drafts of less than 36 feet, but drafts above that are becoming more frequent. Few of the other types of ships that call on the Columbia River have design drafts of over 36 feet.

2.3.2. Sailing Schedules

Sailing schedules determine how different ships and ports can use the navigation channel. On the Columbia River, departure times are influenced by vessel type and draft, ocean tides, river discharge, channel depths, and the operating practices of the river and bar pilots. For ships to sail in the 36-foot to 40-foot draft range, departure times must be flexible so the pilot can optimize the above factors. Ships drawing less than 36 feet can depart at essentially anytime during the tidal cycle.

The ocean tides affect water surface elevations up the Columbia River to Bonneville Dam and in the Willamette River to Willamette Falls. Upstream of CRM 40 (near Puget Island), water surface elevations rise and fall with the tide and river discharge. Downstream of CRM 40, ocean tides control water surface elevations and river discharges have little effect on water surface elevations. Outbound vessels departing from Kalama or Longview must pass through at least one low tide water surface at some point during the five-hour transit. Ships departing from Portland/Vancouver have a 7 to 8 hour transit and will commonly pass through two low tides along the way.

Channel depths vary with both location and time in the Columbia River. The controlling depth in the navigation channel is generally the design depth of 40 feet. However, during the winter and spring, shoals develop at several locations along the channel and can reduce the controlling depth to 37 or 38 feet. Immediately after maintenance dredging, the dredged reach may have a channel depth of 45 feet.

To maximize draft and still insure a safe transit, river pilots schedule departure times so that ships do not encounter low tide at a location with minimum controlling depth. The river pilot also schedules the departure so the transit will meet the timing requirements of the bar pilots. Ships with drafts over 36 feet must generally cross the bar within two hours of high tide.

Grain ships are often on the river for 7 to 10 days to load cargo and load as much grain as possible. Bulk grain carriers with design drafts over 36 feet tend to delay their departure in order to wait for optimum tide conditions that would allow maximization of cargo tonnage and draft. For these ships, the decision on sailing draft can be made within a few hours of their departure time, allowing them to take full advantage of river conditions. This has been especially true for the panamax bulk carriers that load corn at the Peavy grain elevator at Kalama.

Container ships may only be in the river for a day or two, and need to sail at a predetermined time to fit into an overall route schedule. Most container ships plan weeks in advance to load to no more than a 36-foot draft. This prevents the container ships from loading additional cargo even when the river conditions would allow extra draft. However, during 1994 and 1995, one container line did regularly load a group of panamax ships with 38- to 40-foot drafts. Those vessels were willing to absorb some delay time in order to wait for favorable tide conditions.

2.3.3. Underkeel Clearance

Underkeel clearance, which is the distance between the ship hull and river bottom, is often the limiting factor in determining the departure draft of the largest container ships and bulk carriers transiting the Columbia River. The Columbia River pilots prefer to have at least 2 to 3 feet of underkeel clearance for all ships at all times. Most of the container lines attempt to have at least 4.5 feet of underkeel clearance. Many of the container ships that call on the Port of Portland have design drafts of 38 feet or more, but routinely sail drawing 36 feet or less because of the underkeel clearance requirements. There are also numerous panamax bulk grain carriers, especially corn ships that sail less than fully loaded.

Underkeel clearance changes constantly as a ship moves through the river because of the changing river stage and bed elevations. Ocean tides may cause the river stages to fluctuate by up to 8 feet during an outbound transit. At the same time, the riverbed elevation changes as ships move over 5- to 12-foot high sand waves and channel shoals. The amount of squat (sinkage of the stern caused by the movement of the ship) a ship has as it moves through the channel also influences the underkeel clearance. Squat can be in the range of 1.5 feet for bulk carriers and 2.5 feet for the faster container ships.

On outbound transits, minimum underkeel clearance generally occurs within a short distance from the point of minimum river stage. With the river stage near minimum, a sand wave or shoal with a crest elevation approaching project depth is likely to cause the minimum underkeel clearance for the transit. Underkeel clearance will quickly increase as the ship moves past the sand wave or shoal, and as the river stage rises. The limited duration of occurrence contributes to minimum underkeel clearances being quite small in the Columbia River. Shown below are two examples of how the underkeel clearance would be affected by these different parameters.

	Example 1	**Example 2**
Channel Depth[1]	40.0 feet	41.0 feet
River Stage[1]	3.0 feet	0.5 feet
Total Available Depth[1]	43.0 feet	41.5 feet
Vessel Draft	38.0 feet	36.0 feet
Vessel Squat	1.5 feet	2.5 feet
Total Vessel Depth	39.5 feet	38.5 feet
Underkeel Clearance[2]	3.5 feet	3.0 feet

[1] Channel depth is referenced to the Columbia River Datum (CRD). The CRD was established in the 1930s and is based on observed water surface elevations during low discharge/low water conditions. The channel elevation is normally stated relative to the CRD as a negative value, for example, -40 feet CRD. However, for this underkeel clearance example, channel depth is stated as a positive value and added to the river stage to determine the total available depth.

[2] Underkeel clearance is calculated by subtracting the total vessel depth (vessel draft + vessel squat) from the total available depth (channel depth + river stage).

The underkeel clearance analysis focused on those outbound container ships and bulk carriers that generally exceeded the standard operating guidelines for departure draft. The goal was to determine what minimum underkeel clearance was actually acceptable in the Columbia River. The study found that in 1991 to 1993, a quarter of the 67 container ships with drafts over 35 feet had minimum underkeel clearances of 2 feet or less. The same analysis found that there were 240 bulk grain carriers that had a draft over 38 feet. Of those bulk carriers, over half had minimum underkeel clearances of one-foot or less and over 25 percent had minimum underkeel clearances near zero.

2.3.4. River Stage Forecasting System

For many years, shippers and the Columbia River pilots have taken advantage of high river stages to move deep-draft ships through the channel. Prior to 1984, the pilots relied solely on their own experience with the river to guide them in selecting safe drafts. In 1984, the Port of Portland, Corps, National Weather Service, and National Ocean Service determined a need to develop an hourly river stage forecast and a real-time river stage monitoring network for the Columbia River to provide better information for pilots to use in scheduling transits. A network of six stage recording stations was established to provide real-time river stage data over the length of the channel. The Northwest River Forecast Center created an interactive dynamic wave computer model capable of providing a three-day, hourly stage forecast for each of the six stations. In 1988, Forecast Center extended the forecast to six days. This system is commonly referred to as *Loadmax.*

The river pilot can use the stage forecast and the expected ship speed and departure time to estimate where the ship would encounter low tide and what the river stage would be at that point. By comparing the forecast river stage and channel depth to the ship's draft, the pilot can determine if it would be a safe transit. If the transit conditions are unacceptable, adjustments can be made to departure time and/or draft until a safe condition is found.

The river stage forecast system allows pilots and shippers to safely increase outbound drafts on the river. This system is especially beneficial to the bulk grain carriers that can make last minute decisions to add more cargo. The system does not give container ships the same benefits because of the pressure to meet route schedules and the practice of scheduling cargo weeks in advance. However, the 1994 and 1995 transit data shows more container ships sailing with drafts of 36 to 38 feet. Only one container line has regularly taken advantage of the forecasting system to schedule departure times that allow drafts of 38 to 40 feet.

2.3.5. Columbia River Entrance

The navigation practices at the Columbia River entrance influence how ships transit the entire river channel. The Columbia River Bar Pilots control the movement of ships through this reach of the channel. The bar pilots have two factors related to physical conditions in the estuary and entrance that limit transits. The primary factor is the underkeel clearance ships have in the river channel between CRM 6 and 13. The second factor is the wave conditions in the entrance channel.

2.3.5.1. Underkeel Clearance

The minimum underkeel clearance in the river channel downstream of Astoria (CRM 3 to 13) is normally the controlling factor for time of departure from upriver ports. The bar pilot's standard practice is to require 4 feet of underkeel clearance on a falling tide or 3 feet on a rising tide at Astoria (CRM 12). These safety clearances are the same for container ships and bulk carriers. Underkeel clearances do not relate to any specific draft limitation because they are a combination of a ship's draft and squat, controlling channel depths, and tide stage.

Ships with 36 feet or less of draft can meet the underkeel requirements anytime. Ships with drafts over 36 feet must schedule departures from upstream ports so arrival at Astoria coincides with the required tide conditions. About half of the 40-foot draft ships must delay their departures to achieve suitable tide stages in the estuary. Ships can not stop and anchor in the estuary to wait for favorable tide conditions in order to transit the entrance.

2.3.5.2. Wave Conditions

The entrance channel is a tiered channel, with the north side 55 feet deep by 2,000 feet wide and the south side 48 feet deep by 640 feet wide. The north side was constructed in 1984 and intended to optimize the 40-foot river channel. The entrance channel design criteria was for a 36-foot draft ship to be able to transit the entrance 95 percent of the time during "safe" wave conditions without exceeding the design excursion. Safe wave conditions were defined as waves less than 10 feet high, a condition that occurred 95 percent of the time according to the wave forecast used in the design. According to the design, the entrance could be closed to 36- and 40-foot draft ships for an average of 960 and 4,900 hours each year, respectively.

It is standard practice for the individual bar pilot to decide if the wave conditions are unsafe for either the pilot boat or the deep-draft ship. The entrance is generally closed when there are breaking waves present. For less severe wave conditions, the bar pilot must decide on the safety of the transit based on the characteristics of the ship and the waves.

Since the 1960s, the amount of time the bar has been closed has varied widely from year to year. However, there has been a persistent decline in the average annual time of closure from about 300 hours in 1971, to 150 hours in 1981, and to 50 hours in 1991. During 1991 through 1995, the bar was closed due to wave conditions for an average of 52 hours per year. The most closure time occurred in 1994, when the bar was closed for a total of 84 hours. The longest closure was 37 hours and also occurred in 1994. Based on wave height frequency data, it appears that the bar is generally closed only when wave heights exceed 18 to 19 feet.

When deciding on the safety of a transit, the bar pilots do not decide based solely on a ship's draft. A ship's ride and steerage characteristics are also important factors in deciding the level of risk. Draft, length, beam, type and location of cargo, and hull design can influence a ship's ride and steerage. The bar pilots report that the large bulk carriers and container ships (over 700 feet in length) handle high waves on the bar better than smaller ships.

2.3.6. Regulatory Environment

The Oregon Board of Maritime Pilots (OBMP) regulates both the river and bar pilots on the Columbia River. Neither the OBMP nor the U.S. Coast Guard has specific rules that govern vessel drafts on the river. However, the regulatory environment at the OBMP does influence the maximum drafts observed on the river. The OBMP tends to hold pilots at fault for any incident with a ship drawing over 40 feet, regardless of the circumstances. Given the potential risk of losing their license, bar and river pilots are hesitant to pilot a ship over 40 feet in draft, even when sufficient water depths are available.

The number of ships drawing over 40 feet has declined from 46 in 1991 to 12 in 1995. This decline occurred despite the fact that most ships drawing over 40 feet were carrying corn and corn exports increased from 4.5 million tons in 1991 to 8.0 million tons in 1995.

2.3.7. Channel Safety

Serious accidents involving deep-draft ships are very rare in the Columbia River navigation channel. Since 1988, there have been eight groundings and one collision involving ships underway in the channel. This equates to an accident rate of about 0.5 accidents per 1,000 ship calls. This rate compares very favorably with average rates for 1988 through 1995, derived from the work of Jebsen and Papakonstantinou (MIT, 1997) for Boston (0.8), Houston (2.0), New York (0.5), San Francisco (0.7), and Tampa (1.5). Those ports have higher volumes of ship traffic, but much shorter channels.

Most grounding in the Columbia River involved ships grounding on sandy shoals along the channel boundaries or on sand waves in the channel. These ships are generally refloated in a few hours with little or no damage to the ship. Since 1988, the most serious grounding on the river occurred in 1995 when an inbound bulk carrier veered across the channel after completing a pass of an outbound ship near CRM 32. The inbound ship suffered bow damage when it grounded on the Washington shore. The outbound ship was not adversely affected by the actions of the inbound ship.

2.3.8. Operating Drafts

The navigation practices in the Columbia River determine the draft at which various ships operate. There is pressure from shippers to load as deep as possible because an extra foot or two of draft means carrying more cargo, which can be economically beneficial. The pilots are responsible for the safety of shipping on the river and must limit drafts to maintain underkeel clearance. The maximum draft at which the different types of ships operate influences what class of ship will call on the river.

It was concluded from the navigation analysis and confirmed in discussions with user groups that the normal navigation practices on the Columbia River should target the values shown in table 2-2.

Table 2-2. Columbia River Navigation Practices

Navigation Practice	Container Ships	Bulk Carriers	
		Portland	Kalama
Target draft (feet)	36.0	39.0	40.0
Average squat (feet)	2.5	1.5	1.5
Minimum underkeel clearance (feet)	2.0	0	0
Minimum river stage (feet CRD)	0.5	1.5	2.0
Maximum channel elevation (feet CRD)	40.0	39.0	39.5
Minimum water depth available (feet)	40.5	40.5	41.5

Table 2-2 shows the clear difference in minimum underkeel clearance and departure draft between container ships and bulk carriers. It also shows the advantage a bulk carrier has when departing from Kalama and only encountering one low tide. Ships departing from Kalama can wait for the "holdup" or high-low tide of the day, providing them with additional river stage. Ships from Portland/Vancouver must schedule around two low tides during a transit and must be very selective to get additional river stage. Because of the longer travel distance from Portland/Vancouver, bulk carriers from these ports experience slightly more channel shoaling than do vessels departing from Kalama.

Maximizing draft is not as important to the container ships. The container ships do not normally delay their departures to take advantage of the additional river stage that might be available during a transit. Additionally, they will only load to the 36-foot target draft if the channel is clear to 40 feet. The river stage and channel elevation targeted by container ships reflects their emphasis on schedule and a conservative approach to risk.

2.4. Channel Maintenance Practices

2.4.1. Maintenance Dredging

Hopper, pipeline, and clamshell dredges are used on the Columbia River. Hopper dredges are used for in-water disposal, clamshell dredges are used for in-water and ocean disposal, and pipeline dredges are used for mostly shoreline disposal with some in-water and upland disposal. Additionally, clamshell dredging of Willamette River material is disposed in-water in the Columbia River. The type of dredge used on a shoal depends on several factors, including dredge availability, size and location of the shoal, and available disposal sites. Currently, all dredging of the channel is considered maintenance dredging.

2.4.1.1. Hopper Dredging

Hopper dredges currently remove about 3 mcy per year of material from the navigation channel. Material from hopper dredges is disposed of in deep areas in and adjacent to the channel, which is called flowlane disposal. Most of this dredging is done by the Corps' hopper dredge *Essayons*. Hopper dredges provide flexibility for dredging operations because they can operate anywhere and are mobile. Hopper dredges are most often used on small volume, sand wave shoals in the river and on larger shoals in the estuary. The

Essayons may spend several weeks in the early spring and fall dredging small shoals in the Columbia River upstream of CRM 25 (Miller Sands Island). During the summer, the estuary work is done as backup work for the dredging at the mouth of the river. When the entrance becomes too rough or foggy for hopper dredges to work, they will move to one of the estuary shoals to dredge. Flowlane disposal is used for hopper operations upstream of CRM 25. In the estuary, hopper disposal has been in the flowlane, at a large disposal site (Area D) located away from the navigation channel near CRM 6 (near Clatsop Spit) and in a sump near CRM 21 (Harrington Sump). Material placed on Harrington Sump is periodically rehandled to a disposal site on Rice Island.

2.4.1.2. Pipeline Dredging

Pipeline dredges are used for the large cutline shoals and areas with multiple sand wave shoals. About 2 mcy of material per year are dredged by pipeline dredges, nearly all by the Port of Portland's 30-inch dredge *Oregon.* Pipeline dredging is done during the summer. In a typical season, the *Oregon* begins dredging river maintenance at shoals in the lower river and progresses upstream. Shoreline disposal is the most common disposal practice for pipeline dredges. However, many shoreline sites are actively eroding sand back into the navigation channel shoals. Although upland disposal sites would erode less, there are limited upland sites available. Occasionally, pipeline dredged material has been disposed in-water adjacent to the navigation channel, but this has not been a common practice.

2.4.1.3. Clamshell Dredging

Clamshell dredging is done using a bucket operated from a crane or derrick that is mounted on a barge or operated from shore. Sediment removed by the bucket is usually placed on a barge for disposal to an upland or in-water site. Since bucket dredges are not self-propelled, they are not typically used in high traffic areas. They are often used in tight quarters, such as around docks and piers. Also, because they are usually on a barge, they can be used in shallow areas where draft restrictions limit other choices. Dredged material comes up virtually *in situ,* so clamshell dredges are particularly good in silts or contaminated material, where water entrainment is a problem. Clamshell dredges are used for side channel projects in the Columbia and Willamette Rivers navigation channel.

2.4.2. Advance Maintenance Dredging

Dredging a channel deeper and wider than authorized is a practice referred to as Advance Maintenance Dredging (AMD). The objective of AMD is to reduce the number of times the channel has to be dredged while maintaining navigation year-round. To achieve this objective on the Columbia River, the channel is dredged up to 5 feet deeper than its 40-foot depth and up to 100 feet wider than its 600-foot width to account for natural sediment movement. For the Willamette River, the channel is dredged up to 2 feet deeper than its 40-foot depth. The amount of AMD varies with the type of shoal and dredge. A review of AMD practices (Corps of Engineers, 1988) found a 5-foot AMD to be sufficient on the Columbia River to minimize sand wave shoaling problems. However, this is not well suited for the cutline shoals. Based on the recommendations from this review, AMD recently has been done up to 100 feet outside the channel width on the Columbia to intercept material moving toward the large cutline shoals.

2.4.3. Disposal of Dredged Material

Material dredged from the existing navigation channel is placed in a combination of shoreline, upland and in-water disposal sites.

2.4.3.1. Shoreline Disposal

Shoreline disposal is done primarily with pipeline dredges. Material dredged from the main navigation channel is pumped onto shallow water and beach areas along the river. The combination of river flows, waves, and tidal effects will cause some of this material to erode from the beaches. Replacement of eroded material on a regular basis is known as beach nourishment, and all recent shoreline disposal has been for this purpose. The Corps disposes an average of one mcy of material on beach nourishment sites each year.

The shoreline disposal process involves pumping dredged material through a floating discharge pipe from the pipeline dredge to an existing beach. The dredge first pumps a landing on the beach to establish a point from which further material placement occurs. Dredged material is pumped in a sand and water slurry (about 20 percent sand) and as it exits the shore pipe, the sand settles out on the beach while the water returns to the river. Settling rates of Columbia River sands are very quick and turbidity from the operation is minimal. After sufficient sand has settled out and begins to increase in height, it is moved by bulldozers to match the elevation of the existing beach at approximately the high water line. A typical beach nourishment operation lasts from 5 to 15 days and the beach created is approximately 100 to 150 feet wide. The process continues by adding length to the shore pipe and proceeding longitudinally along the beach. The length of beach replaced is dependent on the quantity of material to be dredged from the shoal in the channel. After disposal the slope of the beach is groomed to a minimum steepness of 9 percent to prevent the possibility of creating areas where fish could be stranded on the new beach.

The 1975 EIS identified more than 80 shoreline sites. Sixty-two shoreline sites were used for dredged material disposal between 1975 and 1995. The 1994 EA identified 77 shoreline sites as under consideration for future use. However, due to the Endangered Species Act (ESA) listing of Snake River salmonids, only 14 shoreline sites were proposed and subsequently approved by the National Marine Fisheries Service (NMFS) in their 1993 biological opinion for the maintenance dredging program.

These sites were selected because they are highly erosive and not considered valuable juvenile salmonid rearing habitat. In 1994-1995, the Corps evaluated 10 additional sites to determine their acceptability for disposal. The recommended plan for the DMMP (Corps of Engineers, 1998) proposes the use of one shoreline site over the next 20 years. Implementation of the DMMP would take several years, with continued use of 14 beach nourishment sites in 1999 and transitioning to 1 beach nourishment site by 2003.

2.4.3.2. Upland Disposal

Upland disposal can be accomplished with use of either clamshell or pipeline dredges. Clamshell dredged material deposited onto a barge can later be off-loaded at a transfer point to be taken to an upland site. Pipeline dredges pump dredged material in a water slurry directly to a diked upland site near the dredging area. Discharge of water from upland sites into the river is controlled by the use of weirs. Water discharged from the site must meet state water quality discharge guidelines. Not every site is used on an annual basis. The average annual total quantity of dredged material placed upland in recent years is approximately 750,000 cubic yards. This material is completely removed from the river system and does not reenter it.

2.4.3.3. In-Water Disposal

Most in-water disposal occurs in the flowlane (within or adjacent to the channel) by hopper, pipeline, and clamshell dredges. The average annual quantity of material disposed in the flowlane is 3.5 mcy. This type of dredged material disposal is done throughout the Columbia River navigation channel where depths range from 35 to 65 feet, but are typically below 45 feet. These are not designated sites, but rather vary depending on the condition of the channel each year. As flowlane areas fill, new deep areas are formed elsewhere as a result of natural river processes.

Hopper dredges collect dredged material in the "hopper" of the vessel until it is near capacity. When filled, the vessel moves to a flowlane site. As the dredge is moving, the hopper doors open and the material is discharged at varying rates depending upon how far the hopper doors are opened. Some hopper dredges are "split hull" type, which instead of a series of doors opening to discharge material as described above, the entire hull is opened to discharge. The rate of material discharge can be varied by how far the hull is split open.

Flowlane discharge from pipeline dredges differs from hoppers in that material is continuously discharged during dredging operations. Placement of material at flowlane sites is done using a down pipe with a diffuser plate at the end. This down pipe extends 20 feet below the water surface to avoid impacts to migrating juvenile salmonids. During placement of dredged material, the down pipe will continually be moved so that mounding on the bottom does not occur.

2.4.3.4. Ocean Disposal

Currently, there are four EPA-designated ocean dredged material disposal sites at the mouth of the Columbia River. Because of concerns due to mounding at some sites, the sites were expanded in 1993 and 1997. Nearly all of the material placed in these sites, which has averaged about 4.5 mcy per year (1992 to 1996), has been from the MCR project.

For the proposed Columbia River channel improvement alternatives, ocean disposal would be considered as an option for material dredged from the estuary, downstream of CRM 30.

Estuarine sites have become limited in site capacity and would be more environmentally sensitive than open ocean sites. *The Long Term Management Strategy for Dredged Material Disposal in the Columbia River Estuary* (Corps of Engineers, 1990) recognized the need for future ocean disposal of estuarine sediments. As disposal capacity becomes limited in the estuary, transportation of material to the ocean would be a potential disposal solution. Dredged material could only be placed at EPA-designated or Section 103 selected ocean disposal sites. Ocean disposal is now accomplished by hopper or clamshell dredges. The Corps and EPA have evaluated the management of dredged material to be disposed of in the ocean as part of this study. Further detailed information is provided in Appendix H, *Columbia River Ocean Dredged Material Disposal Sites*.

2.4.4. River Control Structures

Pile dikes are the most common hydraulic control structure used by the Corps in the river. Pile dike fields consist of a series of timber pile dikes, spaced about 1,200 to 1,500 feet apart. Pile dikes generally run perpendicular to the direction of flow beginning at the shore. A piling refers to a single pile whereas a pile dike refers to a line of pilings. A typical pile dike contains hundreds of pilings and averages about 400 to 500 feet in length. Pile dikes are used to control channel alignment for navigation, reduce cross-sectional area, focus flow in navigation channel, provide bank protection, reduce erosion, and provide areas for disposal. Although the Corps initiated pile dike construction in 1885, the bulk of the pile dike system was built between 1917 and 1939. The last significant additions to the system were built during construction of the 40-foot channel to further constrict flow and reduce erosion at dredged material disposal sites. The Corps currently maintains a total of 236 pile dikes within the study area. The pile dike fields protect many millions of cubic yards of disposal material from erosion. Many sites have been filled with dredged sand to beyond the limits of erosion protection and are actively eroding.

In-water fills constructed with dredged material have also been used extensively to reduce channel cross-section and control channel alignment. Most fill has been placed along the shoreline to constrict flow. Upstream of CRM 20, nearly half the shoreline along the main channel is composed of dredged material fill. Dredged material has also been used to create several islands to control channel alignment, such as Coffeepot, Lord, Sandy, Goat, Sand, and Miller Sands Spit. Pile dike fields protect most of these dredged material fill sites from erosion.

2.5. Summary of Environmental Conditions

2.5.1. Water and Sediment Quality

Columbia River water quality has recently been addressed in two regional studies conducted under the Lower Columbia River Bi-State Program (Tetra Tech, 1995 and Tetra-Tech, 1996). The conclusion of those studies relative to the "health" of the river characterized them as "marginally healthy" based on levels of dissolved oxygen, toxins, habitat conditions, etc. The primary unregulated sources of pollutants are described as nonpoint sources such as urban and agricultural runoff.

Sediment quality was evaluated for sediments associated with the navigation channel. Sediment samples were collected and subjected to physical and chemical analyses. No biological analyses were conducted. The sediment program objectives and constraints were to (1) characterize sediments to confirm or establish area rankings in accordance with the *Dredged Material Evaluation Framework, Lower Columbia River Management Area*; (2) provide information needed to develop a baseline cost estimate relative to proper disposal of dredged material, and (3) provide information for the EIS to describe the material to be potentially dredged.

Material to be dredged in the Columbia River navigation channel has been determined to be suitable for unconfined open water disposal. The bed material of the Columbia River navigation channel is over 95 percent fine and medium sand. Sediment evaluations of potential maintenance dredging material conducted since the 1970's have consistently found the material to be suitable for unconfined in-water disposal. Sediment samples from outside the navigation channel were tested as part of the lower Columbia River Bi-State program. A total of 69 stations were sampled; only two stations were within the project area. The results of this study indicate that only four samples (all from outside the navigation channel) exceeded chemical screening levels for unconfined in-water disposal. DDT was the only contaminant in the four samples that exceeded screening levels.

The lower Willamette River does have areas of sediment contamination. Maintenance dredging is required every 2 to 5 years to remove a fined grained shoal that develops between WRMs 8 and 10. Willamette River material from this recurring shoal has been tested for contaminants five times since 1986, and found to be suitable for unconfined in-water disposal. Other areas not routinely dredged have contamination that would require additional testing (biological) prior to determination of suitability for undefined in-water disposal. Any dredged material not suitable for aquatic disposal would have to be confined if dredged.

2.5.2. Aquatic Resources

Primary production is the basis of the aquatic food chain in the Columbia River. The organisms that are the primary producers include phytoplankton (plant species that occur in the water column), benthic microalgae (plant species attached to rocks and other substrates at the substrate-water interface), and vegetation in marshes and on land. Invertebrate populations in the river and estuary utilize the nutrients provided by the primary producers. They are also important food sources for higher food chain species, particularly for those species that are of value to human populations. Zooplankton are microscopic organisms that live in the water. For the Columbia River, zooplankton can be divided into marine, brackish, and freshwater groups.

Benthic invertebrate populations consist of organisms that live both on the bottom (benthic) and on the surface of the bottom (epibenthic). Distribution and abundance of these organisms is directly related to sediment grain size, stability of the bottom habitat, and food supply. In general benthic invertebrate productivity is higher in areas that are more stable and have finer grain sediment than in less stable coarser grain areas. A species of particular importance in the estuary and the river is the amphipod, *Corophium salmonis*. It is a microscopic organism and important as a prey item for juvenile and adult salmonids and other species fish. Epibenthic species (larger invertebrates) in the river and estuary are crayfish (*Pacifastacus trowbridgii*), Dungeness crab (*Cancer magister*), and sand shrimp (*Crangon* spp.).

The Columbia River, the estuary, and the Pacific Ocean immediately offshore provide habitat for a variety of anadromous and resident fish species. Anadromous fish are present in the river almost year-round either as adults migrating upstream to spawn, or as juveniles migrating downstream to the ocean. Anadromous species include the following salmonid species: spring, summer, and fall chinook; coho; sockeye, chum and pink salmon; winter and summer run steelhead; and sea run cutthroat trout. Other anadromous species include green and white sturgeon, Columbia River smelt, shad and lamprey.

Resident species consists of both cold water and warm water species. Cold water species include rainbow and cutthroat trout and mountain whitefish. Warm water species include northern pike minnow, small and large mouth bass, yellow perch, chub and crappie. Resident species remain in the river and estuary year around during all phases of their life history.

Marine fish are present both in the ocean and the estuary. Larval and juvenile marine fish comprise a significant portion of the offshore planktonic communities. Smelt, tomcod, right-eye flounder, and anchovy are commonly found in the offshore communities during the winter and spring. Fish most often found in the deeper channels of the estuary are white sturgeon, Pacific herring, shad, and surf smelt. White sturgeon populations in the lower Columbia River are the largest in the species range, because of access to marine areas, abundant food resources and consistently favorable hydrologic conditions during the spawning period. The estuary also serves as a nursery and rearing area for some species of marine fish including Pacific tomcod, surfperch, rockfish, sanddabs, smelt, and flounder.

Prior to 1999, the listed stocks of salmonids in the Columbia River included the Snake River fall and spring/summer runs of chinook salmon (*Oncorhynchus tshawyscha),* Snake River run of sockeye salmon (*O. nerka*), and the upper and lower Columbia and Snake River runs of steelhead (*O. mykiss).* In March 1999, the NMFS also listed chinook salmon as threatened in the lower Columbia River and upper Willamette River, and the spring run as endangered in the upper Columbia River. Columbia River chum salmon (*O. keta*) was listed as threatened. Middle Columbia and upper Willamette steelhead were listed as threatened. Proposed stocks include lower Columbia coho salmon (*O. kisutch)* and Columbia coastal cutthroat trout (*O. clarki clarki*). Additional information on the aquatic resources and threatened and endangered species in the study area is located in Chapter 5.

2.5.3. Wildlife Resources

Riparian habitat represents some of the most important habitat along the lower Columbia River. The Oregon Department of Fish and Wildlife (ODFW) stated in 1998 that riparian areas support more species than any other habitat type in Oregon, including 56 percent of all neotropical migrant birds. Riparian forests provide cover, shelter and nesting habitat for numerous wildlife species, particularly neotropical migrant birds. Birds of prey, including bald eagles, songbirds, reptiles and amphibians, small mammals, including bats, and other species use riparian habitat to an extent disproportionate to other habitats present in a given area. Snags with cavities, large woody debris, leaf litter, and structural diversity (herbaceous, shrub, sub-canopy and canopy layers, tree and shrub density, tree diameter and height) features provide the habitat requirements for these species.

Riparian habitat within 300 feet of the Columbia River has been identified as critical habitat for federally listed stocks of Snake River salmon. Detrital export, invertebrate fauna, shade, cover and other features provided by riparian forest are important to salmonids, resident fish and wildlife. Riparian forested habitats along the lower river have exhibited a substantial decline in acreage from historic (circa 1880s) levels (table 2-3). Cottonwood and ash forests have declined by 13,800 acres to about 14 percent of their historic acreage. Forested swamp habitats have decreased by 27,000 acres to about 29 percent of historic levels. Urban and agricultural lands have been developed in their place.

Table 2-3. Habitat Changes Along the Lower Columbia River, 1880s and 1991

1880s Habitats	Acres (1880s)	1991 Habitats	Acres (1991)	Acreage Increase or Decrease
Sand Bank, Unvegetated	45	Barren Land	3,128	+3,084
Floodplain Lake, Deep and Shallow Water	119,713	Open Water	138,589	+18,876
Prairie & Pasture, Upland	17,992	Grassland	61	-17,930
Emergent Marsh (non-tidal), Flats and Shallows, Tidal Marsh	74,178	Wetland/Marsh	22,181	-51,997
		Shrub/Scrub	4,575	+4,575
Oak, Fir, Ash, Savanna	202	Savanna-like	135	-66
		Coniferous Forest	416	+416
Cottonwood and Ash Riparian Forest	16,051	Broad Leaf Forest	2,240	-13,811
Oak and Forest	1,332	Mixed Forest	6,972	+5,640
		Agricultural	57,856	+57,856
Urban	81	Urban/Developed	20,447	+20,366
Willow Swamp (non-tidal), Tidal Swamp, Tidal Spruce	37,855	Forested Wetland	10,851	-27,004
Totals	**267,449**		**267,451**	

Sources: Graves et al. (1995) and Corps of Engineers (1996); area from mouth (CRM 3.0) to CRM 105.5. Comparison of habitat categories is relative; similar habitat categories were compared as the authors used different, although similar, habitat categories.

Cottonwood-ash forest is more prevalent in the upstream portions of the study area with Sauvie Island and Deer Island containing large tracts. Tidal, forested swamp habitats are more prevalent lower in the study area where tidal fluctuations are greater than in the upstream portions. Willow swamp (non-tidal) may occur throughout the area.

Wetlands also represent an important habitat along the lower Columbia River. Wetland and marsh habitats, excluding forested wetlands, have been reduced by approximately 52,000 acres along the lower Columbia River from historic levels (table 2-3). The remaining acreage represents approximately 30 percent of the historic total. Wetland habitat has numerous values for wildlife (nesting, foraging, and roosting) plus values such as detrital export, nutrient uptake, and groundwater recharge. Numerous regulations at the local, state and federal levels are in place to protect wetlands. Many wetlands in the study area are not pristine in nature. They are often integrated into or associated with agricultural lands and are typically grazed and/or managed using drainage ditches to allow for cultivation of row crops, grazing, or production of hybrid popular trees. Regardless of their degraded state, they generally continue to provide habitat, although diminished in quantity and quality, for a number of wildlife species. Waterfowl, amphibians, wading birds, shorebirds, furbearers, various songbird species, raptors, and small mammals use wetland habitat to meet many of their life requirements.

Most of the lands in the study area are agricultural lands. Approximately 58,000 acres along the lower Columbia River are presently devoted to agricultural production. These lands support row crops, cereal grains and pasture crops. Hybrid poplar plantations also encompass substantial acreage. Acreage used for row crop, cereal grain or pasture production can provide important habitat to wildlife, particularly for wintering waterfowl species. Wintering Canada geese make substantial use of agricultural lands along the lower Columbia River. The wintering population of Canada geese has significantly increased since the early 1970s and includes subspecies that were formerly absent or present in small numbers. Large concentrations of various duck species are also present in winter and make extensive use of agricultural lands. Use of agricultural lands by other wildlife species is not as intensive generally as that by waterfowl. Extent of use by other wildlife species is dependent upon nature of agricultural practices, both in the long-term and on a seasonal basis. Row crops and heavily grazed pasturelands provide little cover or other habitat features suitable for many species.

The study area encompasses substantial open water habitat from offshore to estuarine to riverine areas. The wildlife resources of open water habitat are typically dominated by various bird species although marine mammals (seals, sea lions, whales and porpoises) are present primarily in the ocean and estuarine zones. Harbor seals and sea lions, however, have been known to occur as far upstream as Portland during fish runs. Birds offshore are primarily pelagic (sea-bird) species, such as shearwaters, gulls, and alcids (murres, puffins, guillemots). The estuary provides nesting and foraging habitat for gulls, cormorants, and terns. During spring and fall migration, large flocks of shorebirds, waterfowl, and many other bird species transit through the estuary, often foraging in open water, marsh, and intertidal mudflat habitats. Caspian terns and various gull species are prevalent in the riverine habitat during summer; loon, grebe, and gull species are plentiful in winter.

Twenty-two federally listed threatened and endangered plant and wildlife species could occur in the study area, as shown below.

Pacific Leatherback Sea Turtle
Loggerhead Sea Turtle
Green Sea Turtle
Pacific Ridley Sea Turtle
Hump-backed Whale
Blue Whale
Finback Whale
Sei Whale
Right Whale
Sperm Whale
Steller (Northern) Sea Lion
Columbian White-tailed Deer
Aleutian Canada Goose
Peregrine Falcon
Bald Eagle
Marbled Murrelet
Western Snowy Plover
Brown Pelican
Oregon Silverspot Butterfly
Howellia
Bradshaw's Lomatium
Nelson's Checkermallow
Golden Paintbrush (Proposed)

Four species are marine turtles that rarely occur off Oregon and Washington. The six whale species included on the list would be infrequent visitors to the offshore waters of the area. Northern sea lions may occur offshore and in the Columbia River estuary. Columbian white-tailed deer occur in the Skamokawa-Clatskanie portion of the study area. Six of the listed species are birds. One listed invertebrate, the Oregon silverspot butterfly, occurs in the general vicinity at the mouth of the Columbia River. Three listed and one proposed threatened plant species occur in the general area. Additional information on the wildlife resources and threatened and endangered species in the study area is located in Chapter 5.