Most subpopulations in this ESU experienced a significant decline in abundance in the mid-1990s, followed by an increase to levels above or near the recovery thresholds in the early 2000s, and have since reached levels intermediate to those of the mid-1990s and early 2000s (NMFS 2008d). The geometric mean abundance of natural-origin fish in this ESU returning to the Wenatchee, Methow, and Entiat Rivers has averaged 226, 205, and 63, respectively, for the most recent 10-year period for which data are available (see Table 4-4) (USACE et al. 2007). The 1994 to 1998 geometric mean abundance for these populations was 190, 129, and 38, respectively; the 1999 to 2003 geometric mean abundance was 467, 324, and 103, respectively. This trend reflected a 38 percent improvement in natural-origin spawner abundance for the ESU over the 1994-1998 period. However, longer-term abundance trends of natural-origin fish indicate declines for both the 1980 to 2003 and the 1990 to 2003 periods (with the exception of the Entiat subpopulation, which showed a slight increase) (USACE et al. 2007). The 2007 jack counts, which are used as an indicator of future adult returns, were at the highest level since 1977 (NMFS 2008d). The long-term (100-year) extinction risk for this ESU has been characterized as high (ICTRT 2007a).

Table 4-4. Summary of Status for UCR Spring-Run Chinook

Population	Abundance Estimate (10-year Geometric Mean [a] of Natural-Origin Spawners, 1994-2003)[b]	Recovery Abundance Threshold[c]	Extinction Risk
	Eastern Cascades		
Wenatchee	222	2,000	High
Entiat	59	2,000	High
Methow	180	500	High
Estimated Total for These Populations	**461**	**4,500**	

Sources: ICTRT 2007a, 2007b.

a The geometric mean indicates the central tendency or typical value of a set of numbers.

b Abundance estimates are based on expanded redd counts.

c ICTRT abundance thresholds are average abundance levels that would be necessary to meet ICTRT viability goals at <5% risk of extinction.

4.2.2 Limiting Factors

The key limiting factors for this ESU include hydropower projects, predation, harvest, hatchery effects, degraded estuary habitat, and degraded tributary habitat. Ocean conditions, which have also affected the status of this ESU, generally have been poor over the last 20 years and have improved only recently (NMFS 2008e).

4.2.3 Designated Critical Habitat

Critical habitat was designated for UCR spring-run Chinook on September 2, 2005 (70 FR 52630), and includes all Columbia River estuarine areas and river reaches upstream to Chief Joseph Dam and several tributary subbasins. The critical habitat designation includes the Columbia River rearing/migration corridor, which connects the ESU to the Pacific Ocean and includes the action area (the Columbia River and North Portland Harbor).

The Columbia River rearing/migration corridor is considered to have a high conservation value for rearing and migrating juveniles and migrating adults. Dams, diversions, roads and railways, agriculture (including livestock grazing), residential development, and forest management continue to threaten the conservation value of critical habitat for this species in some locations in the upper Columbia basin (NMFS 2008e).

The action area contains three PCEs: freshwater migration, freshwater rearing, and estuarine areas.

4.3 SNAKE RIVER FALL-RUN CHINOOK

4.3.1 Status and Biological Context

The SR fall-run Chinook ESU includes all naturally spawned populations of fall-run Chinook in the mainstem Snake River below Hells Canyon Dam, and in the Tucannon River, Grande Ronde River, Imnaha River, Salmon River, and Clearwater River subbasins (see Figure 4-6) (70 FR 37160; June 28, 2005). There are four artificial propagation programs for Chinook in this ESU.

Within the action area, adult and juvenile SR fall-run Chinook use the Columbia River and North Portland Harbor for upstream adult migration and holding, and for juvenile outmigration. Upstream-migrating adults are potentially present in the action area from approximately July to November (CRC 2009; NMFS 2005a). Juveniles outmigrating to the ocean are present in the action area between approximately June and October (CRC 2009).

SR fall-run Chinook are likely to be present in the Columbia River and North Portland Harbor in the action area when in-water work will take place. SR fall-run Chinook do not occur in Burnt Bridge Creek. The extent to which SR fall-run Chinook use the Columbia Slough is unknown; use is assumed to be similar to previously described up-river Chinook ESUs (COP 2009a).

Data for the most recently published 10-year period (1994-2004) for this ESU show an average abundance of 1,273 returning adults; this number is below the 3,000 natural spawner average abundance threshold that has been identified as a minimum for recovery (see Table 4-5) (NMFS 2008e). Total returns to Lower Granite Dam increased steadily from the mid-1990s to the present. Natural returns increased at approximately the same rate as hatchery origin returns through run year 2000, but since then, hatchery returns have increased disproportionately to natural-origin returns. On average, for full brood year returns from 1977 to 2004, the naturally spawned fish population has not replaced itself (NMFS 2008e). The long-term (100-year) extinction risk for this ESU has been characterized as moderate to high (ICTRT 2007a).

Table 4-5. Summary of Status for SR Fall-Run Chinook

Population	Abundance Estimate (10-year Geometric Mean of Natural-Origin Spawners, 1995-2004)[a]	Viable Abundance Goal	Extinction Risk
Lower Mainstem	1,273	3,000	Moderate - High
Estimated Total for These Populations	**1,273**	**3,000**	

Sources: NMFS 2008e; NMFS 2006a.

a Abundance estimates based on passage counts at Lower Granite Dam.

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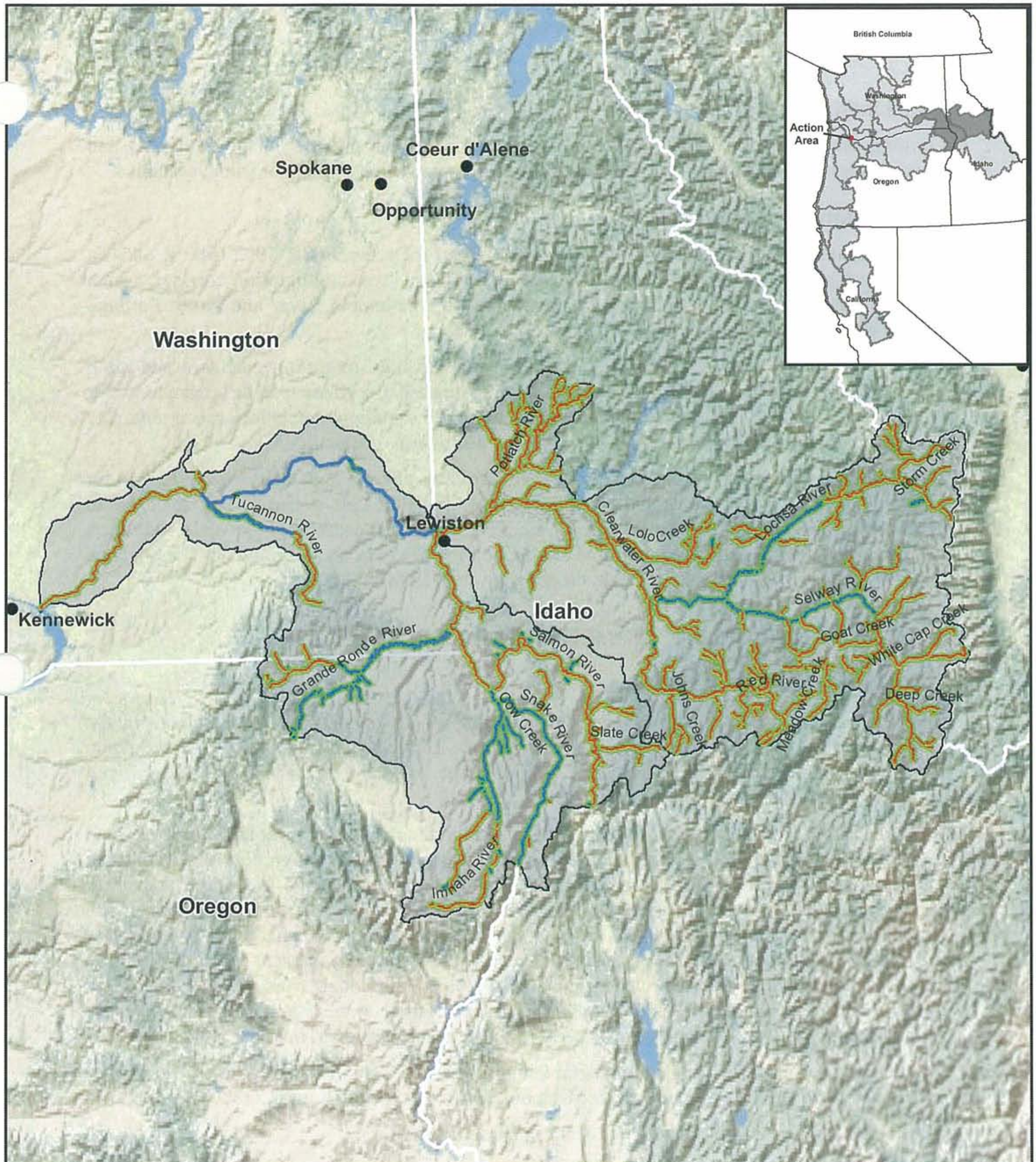


USE TYPE

- Migration only
- Rearing and migration
- Spawning and rearing

- Chinook Salmon ESU
- Action Area

Figure 4-6. General Distribution Map - Snake River Fall-Run Chinook ESU

Map is intended to show distribution of the ESU, and not specific habitat use by life stage within the action area itself.

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: Aug., 2009; Plot Date: File Name: ESUDPS_JL194.mxd

4.3.2 Limiting Factors

Limiting factors for this ESU include mainstem hydroelectric projects in the Columbia and Snake Rivers, predation, harvest, hatchery effects, ocean conditions, and poor tributary habitat.

4.3.3 Designated Critical Habitat

Critical habitat was designated for SR fall-run Chinook on December 28, 1993 (58 FR 68543). The critical habitat designation includes the Columbia River rearing/migration corridor, which connects the ESU to the Pacific Ocean and includes the Columbia River and North Portland Harbor within the action area.

The following PCEs occur within in the action area: juvenile migration corridors and adult migration corridors. Essential features of the juvenile migration corridor include substrate, water quality, water quantity, water velocity, cover/shelter, food, riparian vegetation, space, and safe passage conditions. See Section 5.4.2 for additional discussion of specific PCEs.

The Columbia River migration corridor is considered to have a high conservation value for rearing and migrating juveniles and migrating adults. The PCEs are generally degraded due to hydropower systems on the Snake and Columbia Rivers that cause high juvenile mortality, altered seasonal temperature regimes, and a reduction in spawning and rearing habitat associated with the mainstem lower Snake River hydropower system (NMFS 2008e).

4.4 SNAKE RIVER SPRING/SUMMER-RUN CHINOOK

4.4.1 Status and Biological Context

This ESU includes all naturally spawned populations of spring/summer-run Chinook in the mainstem Snake River and the Tucannon River, Grande Ronde River, Imnaha River, and Salmon River subbasins (70 FR 37160; June 28, 2005) (see Figure 4-7). There are 15 artificial propagation programs for Chinook in this ESU.

Within the action area, adults and juveniles are present in the Columbia River and North Portland Harbor during upstream adult migration and downstream juvenile outmigration (see Table 4-6, Figure 4-1, and Figure 4-2). Adult spring-run Chinook migrate through the action area from approximately mid-February until the first week of June; adults classified as summer-run Chinook migrate through the action area from June through approximately mid-September (NMFS 2005a). Juveniles outmigrating to the ocean are potentially present in the action area between approximately February and August (CRC 2009). Individuals from this ESU are likely to be present in the Columbia River and North Portland Harbor in the action area from February through September and will probably be present during some periods of in-water work.

The extent to which SR spring/summer-run Chinook use the Columbia Slough is unknown; use is assumed to be similar to that of upriver Chinook ESUs, described above (COP 2009a).

SR spring/summer-run Chinook do not occur in Burnt Bridge Creek.

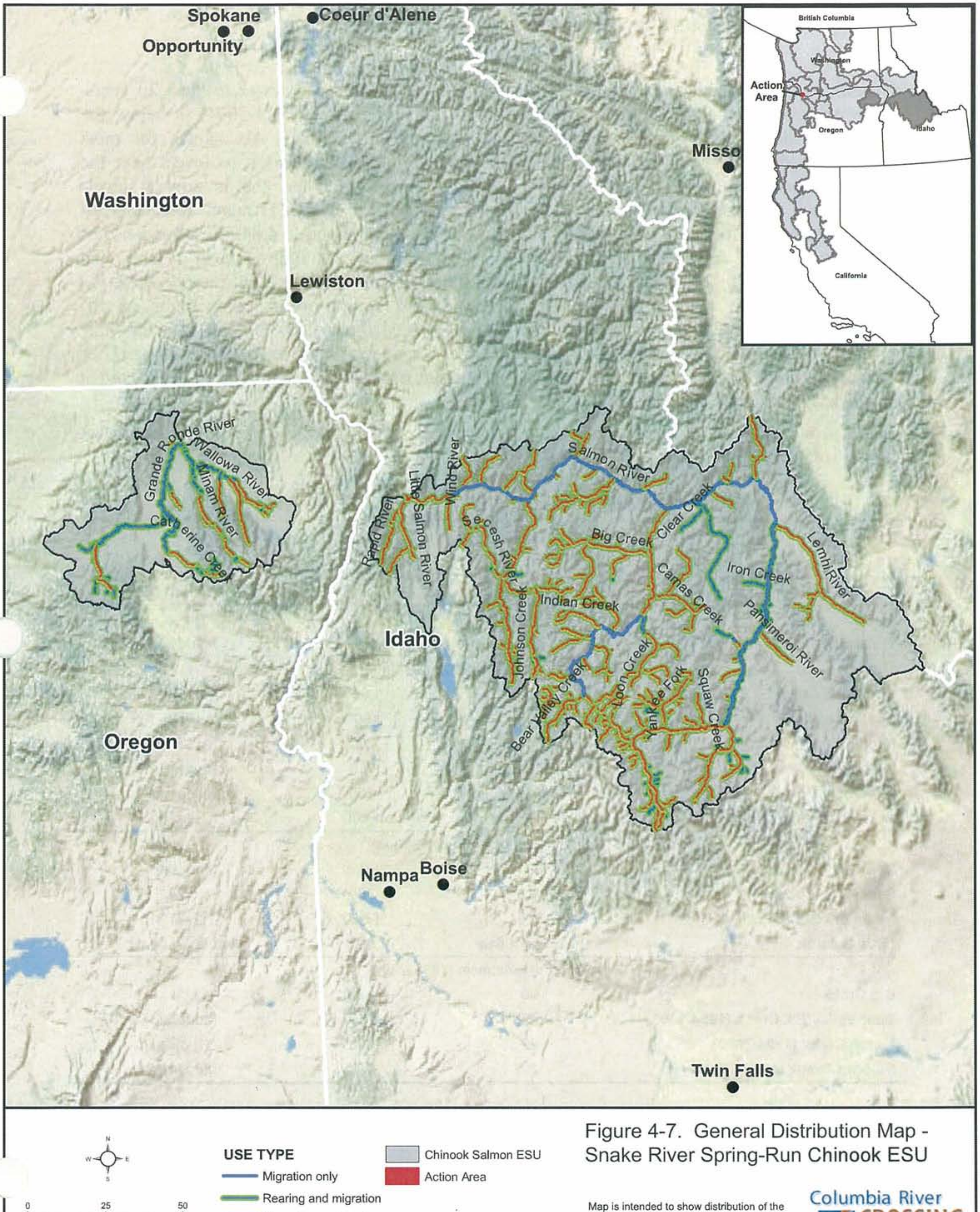


Figure 4-7. General Distribution Map - Snake River Spring-Run Chinook ESU

Map is intended to show distribution of the ESU, and not specific habitat use by life stage within the action area itself.

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: May 20, 2009; Plot Date: May 20, 2009; File Name: ESUDPS_JL194.mxd

Overall, average abundance of this ESU has been stable or increasing over the last 20 years. However, average abundance over the most recent 10-year period (1994-2004) is below the thresholds identified as the minimum for low risk (ICTRT 2007a). Abundance for most populations declined to extremely low levels in the mid-1990s, increased to levels near the recovery abundance thresholds for a few years in the early 2000s, and is now at levels intermediate to those of the mid-1990s and early 2000s. The geometric mean abundance of natural-origin fish for the 2001 to 2005 period was 25,957, compared to 4,840 for abundance of natural-origin fish for the 1996 to 2000 period, a 436 percent improvement (Fisher and Hinrichsen 2006). In 2007, jack counts (a qualitative indicator of future adult returns) were the second highest on record. However, on average, the natural-origin components of SR spring/summer-run Chinook populations have not replaced themselves (NMFS 2008e). Most populations in this ESU were determined to have a moderate long-term (100-year) risk of extinction; however, six populations were ranked at high risk and six populations were ranked at low risk of extinction (ICTRT 2007a).

Table 4-6 summarizes the abundance status and extinction risk for the various SR spring/summer-run Chinook populations.

Table 4-6. Summary of Status for SR Spring/Summer-Run Chinook

Population	Abundance Estimate (10-year Geometric Mean of Natural-Origin Spawners)	Viable Abundance Goal	Extinction Risk
	Lower Snake (1997-2006)		
Tucannon	82	750	Moderate
	Grande Ronde/Imnaha (1996-2005)		
Catherine Creek	107	1,000	Moderate
Lostine/Wallowa	276	1000	High
Minam	337	750	Moderate
Imnaha	380	750	Moderate
Wenaha	376	750	Moderate
Upper Grande Ronde	38	1,000	Moderate
	South Fork Salmon (1994-2003)		
South Fork Mainstem	601	1,000	Moderate
Secesh (1996-2005)	403	750	Low
East Fork South Fork	105	1,000	Low
Little Salmon	Insufficient data	500	Insufficient data
	Middle Fork Salmon (1995-2004)		
Big Creek	90	1,000	Low
Bear Valley/Elk Creek (1994-2003)	182	750	Moderate
Marsh Creek (1994-2003)	42	500	Low
Sulphur Creek (1994-2003)	21	500	Moderate

Population	Abundance Estimate (10-year Geometric Mean of Natural-Origin Spawners)	Viable Abundance Goal	Extinction Risk
Camas Creek	28	500	Moderate
Loon Creek	51	500	Moderate
Chamberlain Creek	Insufficient data	500	Low
Lower Middle Fork Salmon	Insufficient data	500	Moderate
Upper Middle Fork Salmon	Insufficient data	750	Insufficient data
	Upper Salmon (1996-2005)		
Lemhi (1994-2003)	79	2,000	High
Valley Creek (1994-2003)	34	500	Moderate
Yankee Fork (1994-2003)	13	500	High
Upper Salmon	246	1,000	Moderate
North Fork Salmon	Insufficient data	500	Low
Lower Salmon	103	2,000	Low
East Fork Salmon	148	1,000	High
Pahsimeroi	127	1,000	High
Estimated Total for These Populations	**3,869**	**23,250**	

Source: NMFS 2008e.

4.4.2 Limiting Factors

Limiting factors for SR spring/summer-run Chinook include federal and private hydropower projects, predation, harvest, poor passage through the estuary, ocean conditions, and degraded tributary habitat. Although hatchery management is not identified as a limiting factor for the ESU as a whole, hatchery impacts may be a factor for a few individual populations (NMFS 2008e; ICTRT 2007a).

4.4.3 Designated Critical Habitat

Critical habitat was designated for SR spring/summer-run Chinook on October 25, 1999 (64 FR 57399). The critical habitat designation includes the Columbia River rearing/migration corridor, which connects the ESU to the Pacific Ocean and includes the action area (Columbia River and North Portland Harbor).

The following PCEs occur within the action area (in the Columbia River and North Portland Harbor): juvenile migration corridors and adult migration corridors. Essential features of the juvenile migration corridor include substrate, water quality, water quantity, water velocity, cover/shelter, food, riparian vegetation, space, and safe passage conditions. See Section 5.4.2 for additional discussion of specific PCEs.

The migration corridor is considered to have a high conservation value for rearing and migrating juveniles and migrating adults. The PCEs are generally degraded due to mortality in the mainstem hydrosystem, lack of adequate pool and riffle channel structure in tributaries, high summer water temperatures, low flows, poor overwintering conditions due to loss of floodplain connection, and high sediment loads (NMFS 2008e).

4.5 UPPER WILLAMETTE RIVER CHINOOK

4.5.1 Status and Biological Context

This ESU includes all naturally spawned populations of spring-run Chinook in the Clackamas River and in the Willamette River, and its tributaries, above Willamette Falls, Oregon, as well as seven artificial propagation programs (see Figure 4-8) (70 FR 37160; June 28, 2005). All naturally spawned spring-run populations of Chinook (and their progeny) residing in these waterways are included in this ESU. Fall-run Chinook above Willamette Falls were introduced and are not considered part of this ESU (Myers et al. 1998).

The ESU is made up of seven historical populations: Clackamas, Molalla/Pudding, Calapooia, North Santiam, South Santiam, McKenzie, and the Middle Fork Willamette; Table 4-7 summarizes the status of each of these populations. Of these, significant natural production now occurs only in the Clackamas and McKenzie subbasins; the other naturally spawning populations are small and are dominated by hatchery-origin fish (NMFS 2008e).

UWR Chinook differ from other Columbia basin Chinook in both genetic composition and life history strategy (Schreck et al. 1986; Utter et al. 1989; Myers et al. 1998). Adult Chinook in this ESU are present in the action area from approximately late February through early May (Myers et al. 1998).

Table 4-7. Summary of Status for UWR Chinook

Population	Legacy[a,d]	Core[b,d]	Abundance Estimate (Natural-Origin Spawners, 1990–2006[e])	Viable Abundance Goal[c,e]	Extinction Risk[e]
			Upper Willamette		
Clackamas	No	Yes	500–6,000	2,900	Low
Molalla	No	No	<50	1,000–1,400	Very High
North Fork Santiam	No	Yes	<50	1,400–2,000	Very High
South Fork Santiam	No	No	<50	2,000–2,600	Very High
Calapooia	No	No	<50	1,000–1,400	Very High
McKenzie	Yes	Yes	900–5,800	3,100	Moderate
Middle Fork Willamette	No	Yes	<50	1,400–2,000	Very High
Estimated Total for These Populations			**1,400–11,800[f]**	**12,800–15,400**	

a Genetic Legacy designation by the Technical Recovery Team. Genetic legacy populations represent unique life histories or are relatively unchanged by hatchery influences.

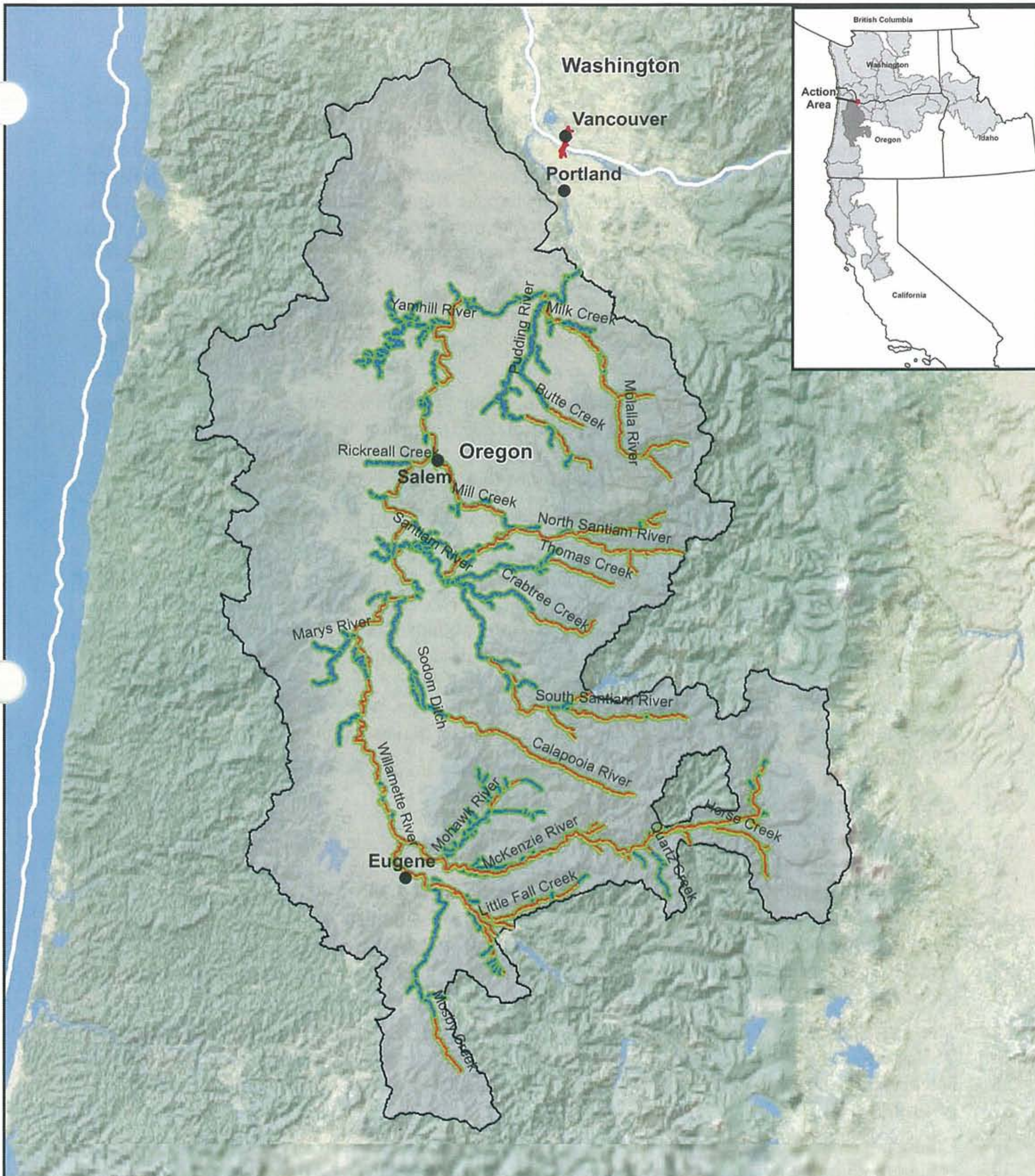
b Core population designation by Technical Recovery Team. Core populations were the largest historical populations and were key to metapopulation processes.

c The delisting goals for abundance are the average number of wild spawners expected for a population whose probability of declining below the critical risk threshold during a 100-year period is 5% or less (i.e., low extinction risk) (ODFW 2007b). NOTE: These abundance goals are Draft and may be revised when the newer version of the draft recovery plan is released in early 2010.

d Source: WLCTRT 2003.

e Source: ODFW 2007b.

f Lower bound does not include populations <50. Upper bound assumed to be unaffected by potential production from populations <50.



N W E S

0 9 18
Miles

USE TYPE
- Migration only
- Rearing and migration
- Spawning and rearing

- Chinook Salmon ESU
- Action Area

Figure 4-8. General Distribution Map
Upper Willamette River
Chinook Salmon ESU

Map is intended to show distribution of the ESU, and not specific habitat use by life stage within the action area itself.

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: Aug., 2009; Plot Date: File Name: ESUDPS_JL194.mxd

Juveniles exhibit a diverse migratory life history in the lower Willamette River, with separate spring and fall emigration periods. Spring juvenile emigrants move through the action area from February through April (ODFW 2007a; Teel et al. 2009). Fall juvenile emigrants move into the lower Willamette mainstem in summer, rear through summer in the lower Willamette River, Columbia Slough, or lower reaches of other Willamette tributaries, and then emigrate in the fall, winter, or spring (ODFW 2007a). Juveniles may be present in the action area (Columbia Slough and Kelley Point area) at any time of year. They may use the action area to rest, forage, and find refuge from high flows in the Columbia.

UWR Chinook are documented in the action area year round, and may be present in the action area during in-water work. These Chinook use the action area as a rearing and migration corridor.

UWR Chinook also use seasonally wet areas of the Columbia Slough for juvenile rearing, foraging, and refuge from high flows (Teel et al. 2009). Habitat use and timing are similar to those for other Chinook ESUs, as described earlier (i.e., juveniles are not present during summer months when water temperatures exceed tolerance thresholds) (COP 2009a).

UWR Chinook do not occur in North Portland Harbor or Burnt Bridge Creek (see Figure 4-8) (70 FR 37160).

Abundance of UWR spring-run Chinook is extremely depressed (McElhany et al. 2007). Historically, this run may have exceeded 275,000 fish (Myers et al. 1998). Most of the natural-origin populations in this ESU have very low current abundances (less than a few hundred fish), and many have been largely replaced by hatchery production. The current abundance of naturally produced fish is less than 10,000 fish, and only the McKenzie and Clackamas River populations contribute significantly to this estimate (NMFS 2008e). Long- and short-term abundance trends are negative (NMFS 2008e). This ESU has been characterized as having a high risk of extinction (McElhany et al. 2007).

4.5.2 Limiting Factors

Limiting factors for UWR Chinook include habitat loss and degradation, hatchery effects, fishery management and harvest decisions, and predation (NMFS 2008e). Dams and other barriers within the river influence sedimentation, flows, temperatures, and water quality. Native spring-run Chinook above Willamette Falls declined in abundance and distribution after construction of the numerous Willamette Valley dams; development of dams on the McKenzie, Santiam, and Middle Fork Willamette Rivers resulted in a loss of approximately 50 percent of historic Chinook habitat (WRI 2004).

The introduction of fall-run Chinook into the basin and the construction of fish ladders at Willamette Falls increased the potential for genetic introgression between wild spring-run and hatchery fall-run Chinook. However, there is no direct evidence of hybridization between these two runs (WRI 2004).

Chinook harvest levels also constitute a limiting factor for species recovery. Harvest on this ESU is high, both in the ocean and in freshwater (NOAA Fisheries 2003).

4.5.3 Designated Critical Habitat

Critical habitat was designated for UWR Chinook on September 2, 2005 (70 FR 52630), and is present in the action area in the Columbia River near its confluence with the Willamette River at Kelley Point.

The action area contains three PCEs: freshwater migration, freshwater rearing, and estuarine areas.

The migration corridor is considered to have a high conservation value for rearing and migrating juveniles and migrating adults. The PCEs are generally degraded due to mortality in the mainstem hydrosystem, lack of adequate pool and riffle channel structure in tributaries, high summer water temperatures, low flows, poor overwintering conditions due to loss of floodplain connection, and high sediment loads (NMFS 2008e).

4.6 LOWER COLUMBIA RIVER STEELHEAD

4.6.1 Status and Biological Context

This DPS includes all naturally spawned anadromous steelhead populations below natural and manmade impassable barriers in tributaries to the Columbia River between (and including) the Cowlitz and Wind Rivers in Washington, and the Willamette and Hood Rivers in Oregon (71 FR 834, January 5, 2006) (see Figure 4-9). There are 10 artificial propagation programs for steelhead in this DPS.

In the lower Columbia River basin, migrating adult steelhead can occur in the action area year-round. Steelhead can be classified into summer and winter runs. Of the 25 extant populations in this DPS, 6 are summer runs and 19 are winter runs. Returning adults of both runs are 4–6 years of age. Summer-run steelhead return to the Columbia River between May and October, and require several months in fresh water to reach sexual maturity and spawn. Spawning typically occurs between January and June (NMFS 2005a; CRC 2009). Winter-run steelhead return to the Columbia River between November and May as sexually mature individuals that spawn shortly after returning to fresh water (NMFS 2005a; CRC 2009).

In river systems that contain both summer- and winter-run fish, those with summer-run life history strategies usually spawn higher in the watershed than those of winter runs. In rivers where both winter and summer runs occur, they may be separated by a seasonal hydrologic barrier (e.g., a waterfall). Coastal streams are typically occupied by winter-run steelhead, and interior subbasins are typically occupied by summer-run steelhead. Historically, winter-run steelhead may have been excluded from interior Columbia River subbasins by Celilo Falls (NMFS 2005a).

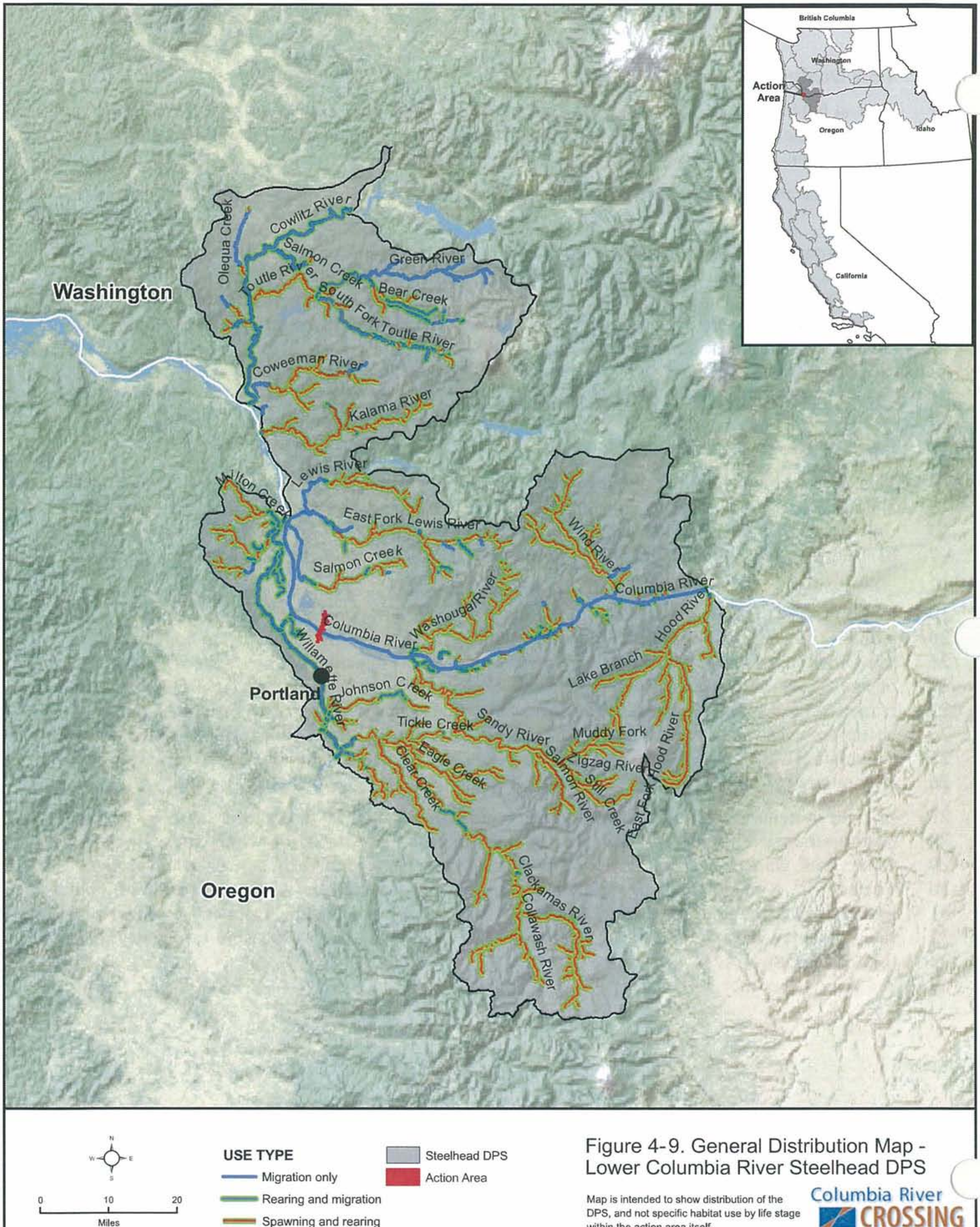


Figure 4-9. General Distribution Map - Lower Columbia River Steelhead DPS

Map is intended to show distribution of the DPS, and not specific habitat use by life stage within the action area itself.

Analysis by J. Koloszar; Analysis Date: May 20, 2009; Plot Date: May 20, 2009; File Name: ESUDPS_JL194.mxd

LCR steelhead use the Columbia River within the action area for migration, holding, and rearing. Steelhead typically rear in freshwater tributaries for 1 to 4 years prior to outmigration, and spend limited time rearing in the lower mainstem Columbia River (Quinn 2005, as cited in Carter et al. 2009). Rearing winter-run steelhead use the lower Columbia River year-round (CRC 2009). Rearing habitat is limited in the action area, but is present in off-channel areas downstream of the existing I-5 bridge (e.g., accessible areas of small tributaries, backwater areas, and other low-velocity refugia).

Outmigrating juvenile winter-run steelhead are present in the action area from mid-February through November; outmigrating juvenile summer-run steelhead are present in the action area from March to September (CRC 2009). Juvenile steelhead abundance in the Columbia River estuary peaks between late May and mid-June (Carter et al. 2009). Outmigrating kelts (adults that have spawned and are returning to the ocean) pass through the action area in March and April, and are primarily summer-run steelhead (Boggs et al. 2008.). Given that LCR steelhead are documented in the Columbia River and North Portland Harbor year-round, they are likely to be present during in-water work.

Some evidence suggests that steelhead occur within the Burnt Bridge Creek portion of the action area. Surveys conducted in April and May 2003 documented juvenile steelhead within or immediately upstream and downstream of the action area: eight juvenile steelhead were observed between the mouth of Burnt Bridge Creek and Nicholson Road (a stream reach of approximately 3.5 miles, extending about 1.5 miles upstream of I-5), three at Leverich Park (within the action area), and one at the Second Avenue bridge (less than 0.50 mile downstream of I-5) (PSMFC 2003). Some suitable spawning habitat is present in the action area in Burnt Bridge Creek, and steelhead may use the creek for spawning and migration. Rearing steelhead may be present in the action area year-round. However, the water temperature during the summer months is often above the range tolerated by steelhead, and seasonal barriers may limit access to the action area in certain flows (see discussion on passage barriers in Section 4.1.1) (WDFW 2007a).

LCR steelhead are known to use the Columbia Slough up to NE 18th Avenue, including the action area. LCR steelhead use the Columbia Slough for rearing, holding, and migration only, as spawning habitat is absent from the Slough (COP 2009a). Timing in the Slough is similar to that previously described for Chinook ESUs (i.e., juveniles are not present during summer months when water temperatures exceed tolerance thresholds) (COP 2009a).

There are four major population groups in this DPS: Cascade summer, Gorge summer, Cascade winter, and Gorge winter. These are further divided into subpopulations (see Table 4-8), all of which migrate through the action area. Wild steelhead in the lower Columbia basin, although depressed from historical levels, are generally thought to occur in most of their historical range (McElhany et al. 2007). However, many of the populations in this DPS are small, and many of the long- and short-term trends in abundance of individual populations are negative to severely negative (see Table 4-8). Many of the populations also have a significant component of hatchery-origin spawners. Exceptions include several populations which have few hatchery fish spawning in natural spawning areas; however, these populations have relatively low recent abundance estimates (NMFS 2008e). Most populations of LCR steelhead have a high risk of extinction (McElhany et al. 2007) (see Figure 4-10).

Table 4-8. Summary of Status for LCR Steelhead in the CRC Project Area (Subpopulations Occurring Within or Above the Action Area Only)

Subpopulation	Legacy[a,c]	Core[b,c]	Abundance Estimate (4-year Average of Natural-Origin Spawners)		Viable Abundance Goal[d]	Current Viability[d]	Extinction Risk[d]
			LCFRB 2004	NMFS 2008e			
Cascade Winter							
Washougal	No	No	421	323	600	Low	High
Clackamas	No	Yes	277	1,168	1,000	Low	Moderate
Sandy	No	Yes	589	1,040	1,800	Low	High
Gorge Winter							
Lower Gorge Tributaries (Hardy)	No	No	Not available		200	Low	High
Upper Gorge Tributaries (Wind)	No	No	Not available		100	Low	Moderate-High
Hood	Yes	Yes	436	756	1,400	Low	Moderate-High
Cascade Summer							
Washougal	Yes	Yes	136	264	500	Low	High
Gorge Summer							
Wind	No	Yes	391	472	1,200	Med	Moderate
Hood	No	No	154	195	600	Low	High-Very High
Estimated Total for These Populations			**2,404**	**4,218**	**7,400**		

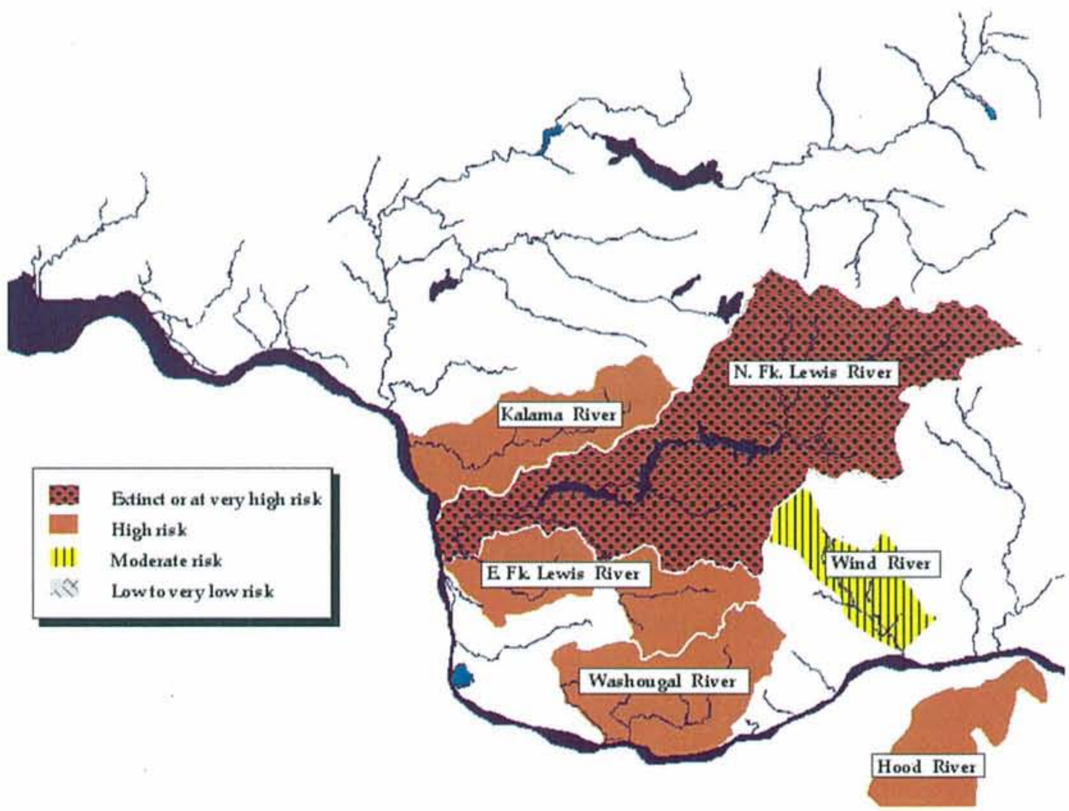
a Genetic Legacy designation by the Technical Recovery Team. Genetic legacy populations represent unique life histories or are relatively unchanged by hatchery influences.

b Core population designation by Technical Recovery Team. Core populations were the largest historical populations and were key to metapopulation processes.

c Source: WLCTRT 2003.

d Source: LCFRB 2004.

e Source: McElhany et al. 2007.



SOURCE: Lower Columbia River Fish Recovery Board 2004.
Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan

Figure 4-10.
Extinction Risk - Lower Columbia River Steelhead DPS

Columbia River CROSSING

4.6.2 Limiting Factors

Limiting factors for this DPS include habitat degradation (including tributary hydropower development), hatchery effects, fishery management and harvest decisions, and ecological factors, including predation. Tributary habitat has been degraded by extensive development and other effects of changing land use. This has adversely affected stream temperatures and reduced the habitat diversity needed for steelhead spawning, incubation, and rearing. All populations are affected by habitat degradation in the Columbia River mainstem and estuary (NMFS 2008e).

4.6.3 Designated Critical Habitat

Critical habitat was designated for LCR Steelhead on September 2, 2005 (70 FR 52630) and is present in the action area in the Columbia River and North Portland Harbor. Designated critical habitat also occurs in the Columbia Slough, but ends roughly 3.4 miles downstream of I-5 and is therefore outside of the action area.

The action area contains the following PCEs: freshwater rearing, freshwater migration, and estuarine areas.

The critical habitat designation includes the Columbia River rearing/migration corridor, which is considered to have a high conservation value. This corridor connects the DPS with the ocean and is used by rearing and migrating juveniles and migrating adults. The Columbia River estuary is an essential area for juveniles and adults making the physiological transition between life in freshwater and marine habitats (NMFS 2005a). The PCEs within the action area are of generally poor quality due to altered channel morphology and stability, lost and/or degraded floodplain connectivity, loss of habitat diversity, excessive sediment, degraded water quality, increased stream temperatures, reduced stream flow, and reduced access to spawning and rearing areas.

4.7 MIDDLE COLUMBIA RIVER STEELHEAD

4.7.1 Status and Biological Context

This DPS includes all naturally spawned anadromous steelhead populations below natural and manmade impassable barriers in tributaries from above the Wind River, Washington, and the Hood River, Oregon, upstream to (and including) the Yakima River, Washington (see Figure 4-11) (71 FR 834; January 5, 2006). (Steelhead from the Snake River basin and the Wind and Hood Rivers are not considered part of this DPS.) There are seven artificial propagation programs for steelhead in this DPS.

Middle Columbia River (MCR) steelhead are predominantly summer-run fish, and use the Columbia River within the action area for migration and holding. Returning adults in this DPS are present in the action area from May through October (see Figure 4-1). Outmigrating juveniles are present in the action area from approximately March to June (see Figure 4-2) (CRC 2009). Outmigrating kelts pass through the action area in March and April, and are primarily summer-run steelhead (Boggs et al. 2008).

MCR steelhead are likely to be present in the Columbia River and North Portland Harbor during the time that in-water work will take place.

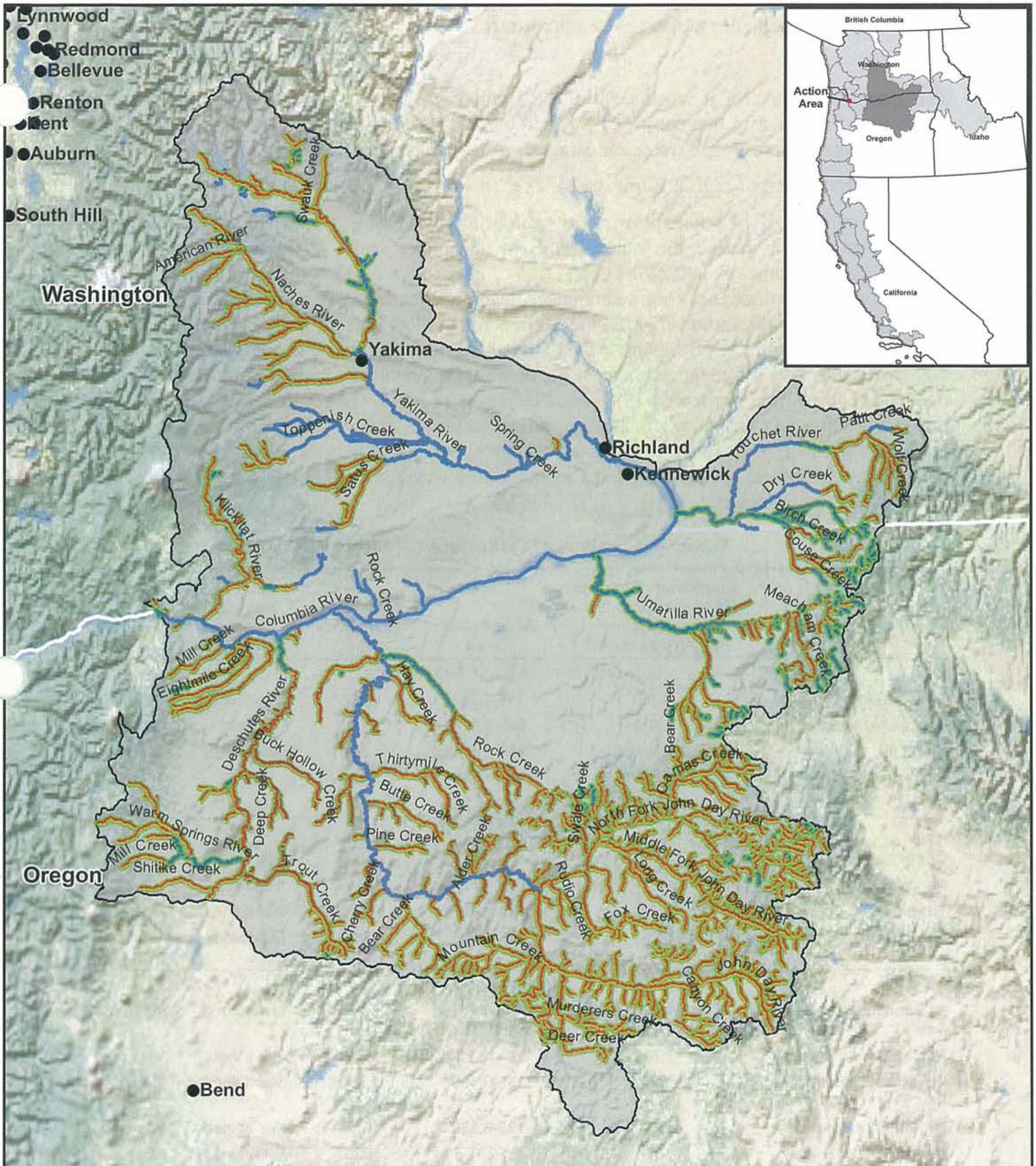


Figure 4-11. General Distribution Map - Middle Columbia River Basin Steelhead DPS

Map is intended to show distribution of the DPS, and not specific habitat use by life stage within the action area itself.

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: May 20, 2009; Plot Date: May 20, 2009; File Name: ESUDPS_JL194.mxd

The extent to which MCR steelhead use the Columbia Slough is unknown; however, use is assumed to be similar to that described for LCR steelhead (i.e., juveniles may be present, except during summer months when water temperatures exceed tolerance thresholds) (COP 2009a).

MCR steelhead do not occur in Burnt Bridge Creek.

The DPS consists of 14 populations, all of which migrate through the action area. During the most recent 10-year period for which trends in abundance could be estimated, trends were positive for approximately half of the populations and negative for the remainder. For 3 of the 14 populations with estimates of recent abundance, average abundance over the most recent 10-year period is above the thresholds identified as a minimum for low risk (ICTRT 2007a). The Interior Columbia Technical Recovery Team (ICTRT) considers the remaining 11 populations to be low risk (see Table 4-9). Abundance for most populations was relatively high during the late 1980s, declined to low levels in the mid-1990s, and increased to levels similar to the late 1980s during the early 2000s. On average, when only natural production is considered, most of the populations in this DPS have replaced themselves (NMFS 2008e). Most populations in this DPS have a low or moderate long-term (100-year) risk of extinction; however, one population has very low risk and five populations have high risk (ICTRT 2007a).

Table 4-9. Summary of Status for MCR Steelhead

Population	Abundance Estimate (10-year Geometric Mean of Natural-Origin Spawners)	Abundance Range	Viable Abundance Goal	Current Viability	Extinction Risk
	Cascade Eastern Slope Tributaries				
Deschutes R. West	456	108-1,283	1,000	High Risk	High
Deschutes R. East	1,599	299-8,274	1,000	Viable	Medium
Klickitat	Insufficient data	Insufficient data	1,000	Maintained	Moderate
Fifteenmile Creek	703	231-1,922	500	Viable	Low
Rock Creek	Insufficient data	Insufficient data	500	High Risk	High
	Yakima River				
Upper Yakima	85	34-283	1,500	High Risk	High
Naches	472	142-1,454	1,500	High Risk	High
Toppenish	322	44-1,252	500	Maintained	Moderate
Satus Creek (Tributary Only)	379	138-1,000	1,000	Maintained	Moderate
	John Day River				
Lower Mainstem John Day	1,800	563-6,257	2,250	Maintained	Moderate
North Fork John Day	1,740	369-10,235	1,500	Highly Viable	Very Low
Upper Mainstem John Day	524	185-5,169	1,000	Maintained	Moderate
Middle Fork John Day	756	195-3,538	1,000	Maintained	Moderate
South Fork John Day	259	76-2,729	500	Maintained	Moderate

9018

Population	Abundance Estimate (10-year Geometric Mean of Natural-Origin Spawners)	Abundance Range	Viable Abundance Goal	Current Viability	Extinction Risk
		Umatilla/Walla Walla			
Umatilla	1,472	592-3,542	1,500	Maintained	Moderate
Walla Walla Mainstem	650	270-1,746	1,000	Maintained	Moderate
Touchet	Insufficient data	Insufficient data	1,000	High Risk	High
Estimated Total for These Populations	**11,217**	**3,246-48,684**	**22,000**		

Source: NMFS 2009a.

4.7.2 Limiting Factors

Limiting factors for MCR steelhead include mainstem hydropower projects, degradation and loss of tributary habitat, water storage projects, predation, hatchery effects, harvest, and ocean and estuary conditions.

4.7.3 Designated Critical Habitat

Critical habitat was designated for MCR steelhead on September 2, 2005 (70 FR 52630), and is present in the action area in the Columbia River and North Portland Harbor.

PCEs present in the action area include: freshwater migration and estuarine areas.

The critical habitat designation includes the Columbia River migration corridor, which connects the DPS with the ocean. The corridor is considered to have a high conservation value for rearing and migrating juveniles and migrating adults. PCEs in the action area are limited by degradation of tributary habitat conditions, dams, water diversions, roads and railways, agriculture (including livestock grazing), residential development, and forest management in some locations in the upper Columbia basin (NMFS 2008e).

4.8 UCR STEELHEAD

4.8.1 Status and Biological Context

This DPS includes all naturally spawned anadromous steelhead populations below natural and manmade impassable barriers in tributaries in the Columbia River Basin upstream from the Yakima River, Washington, to the Canadian border (NMFS 2008a) (see Figure 4-12). There are six artificial propagation programs for steelhead in this DPS.

9019

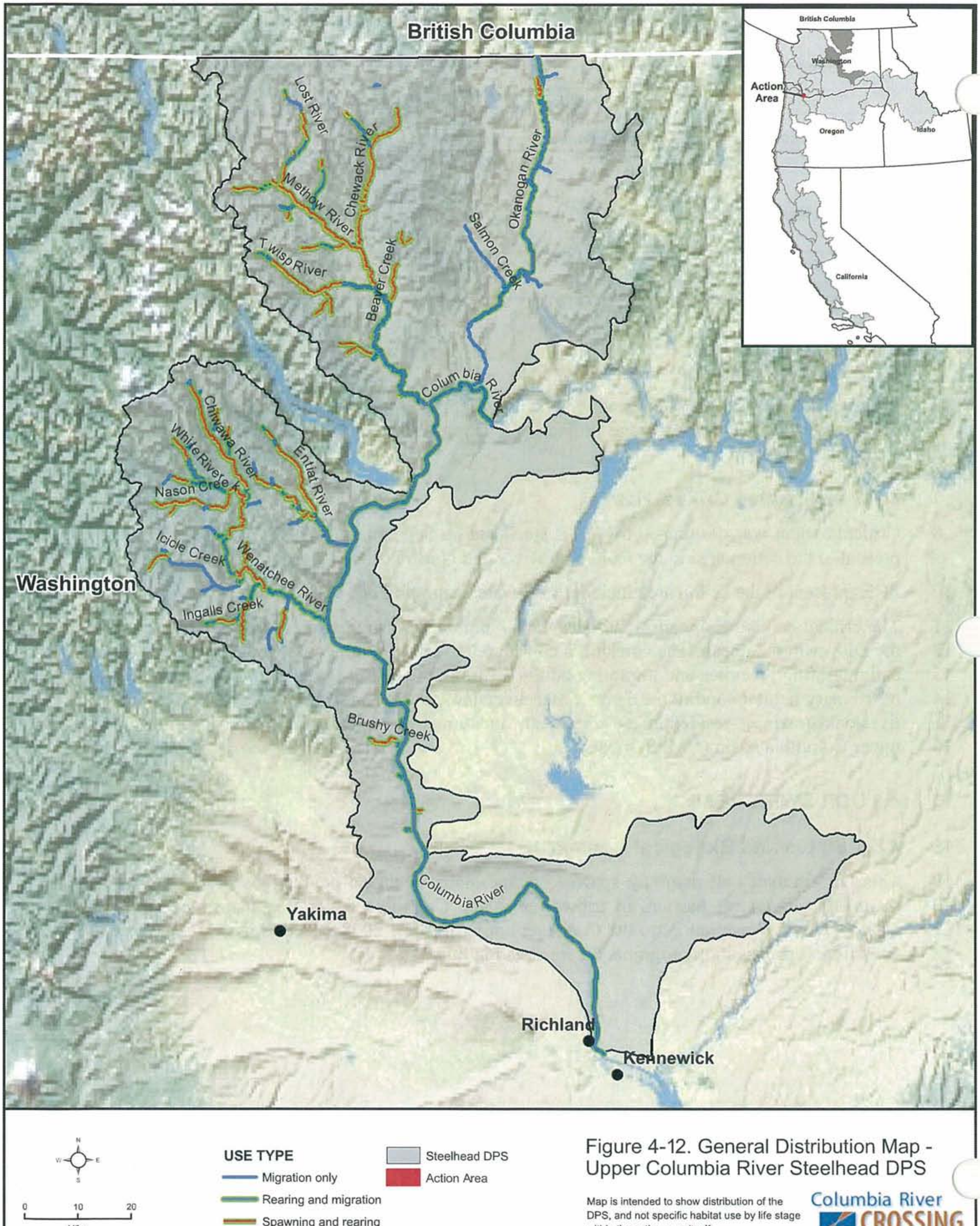


Figure 4-12. General Distribution Map - Upper Columbia River Steelhead DPS

Map is intended to show distribution of the DPS, and not specific habitat use by life stage within the action area itself.

Analysis by J. Koloszar; Analysis Date: May 20, 2009; Plot Date: May 20, 2009; File Name: ESUDPS_JL194.mxd

UCR steelhead are entirely summer-run fish, and use the Columbia River within the action area for migration and holding (see Figure 4-1 and Figure 4-2). Returning adults are present in the action area from May through October. Juveniles tend to rear higher in the watershed than steelhead juveniles from the Lower and Middle Columbia River DPSs (NMFS 2005a). Outmigrating juveniles are present in the action area from approximately March to late June (CRC 2009). Outmigrating kelts pass through the action area in March and April, and are primarily summer-run steelhead (Boggs et al. 2008.). Overall, UCR steelhead are likely to be present in the action area (Columbia River and North Portland Harbor) from March to October and are likely to be present during in-water work.

The extent to which UCR steelhead use the Columbia Slough is unknown; use is assumed to be similar to that described for previous steelhead DPSs.

UCR steelhead may also use the Willamette River en route to seasonally wet areas of the Slough.

UCR steelhead do not occur in Burnt Bridge Creek.

This DPS includes four populations, all of which migrate through the action area. For all populations, abundance over the most recent 10-year period is below the minimum threshold for recovery (ICTRT 2007a) (see Table 4-10). Abundance for most populations declined to extremely low levels in the mid-1990s, increased to levels above or near the recovery abundance thresholds (all populations except the Okanogan) in a few years in the early 2000s, and is now at levels intermediate to those of the mid-1990s and early 2000s. Abundance since 2001 has substantially increased for the DPS as a whole. All populations in this DPS were determined to have a high long-term (100-year) risk of extinction (ICTRT 2007a).

Table 4-10. Summary of Status for UCR Steelhead

Population	Abundance Estimate (10-year Geometric Mean of Natural-Origin Spawners, 1997-2006)	Viable Abundance Goal	Extinction Risk
	Eastern Cascades		
Wenatchee	900	1,000	High
Methow	281	1,000	High
Entiat	94	500	High
Okanogan	104	1,000	High
Estimated Total for These Populations	**1,379**	**3,500**	

Source: NMFS 2008e

4.8.2 Limiting Factors

The key limiting factors and threats for this DPS include hydropower projects, predation, harvest, hatchery effects, degraded tributary habitat, ocean conditions, and degraded estuary habitat.

4.8.3 Designated Critical Habitat

Critical habitat was designated for UCR steelhead on September 2, 2005 (70 FR 52630). The critical habitat designation includes the Columbia River rearing/migration corridor, which connects the DPS to the Pacific Ocean and includes the action area (Columbia River and North Portland Harbor). The action area contains the following PCEs: freshwater migration and estuarine areas.

The Columbia River rearing/migration corridor is considered to have a high conservation value for rearing and migrating juveniles and migrating adults. The Columbia River estuary is an essential area for juveniles and adults making the physiological transition between life in freshwater and marine habitats (NMFS 2005a). Factors such as dams, diversions, roads and railways, agriculture (including livestock grazing), residential development, and forest management threaten the conservation value of the PCEs in the action area (NMFS 2008e).

4.9 SR STEELHEAD

4.9.1 Status and Biological Context

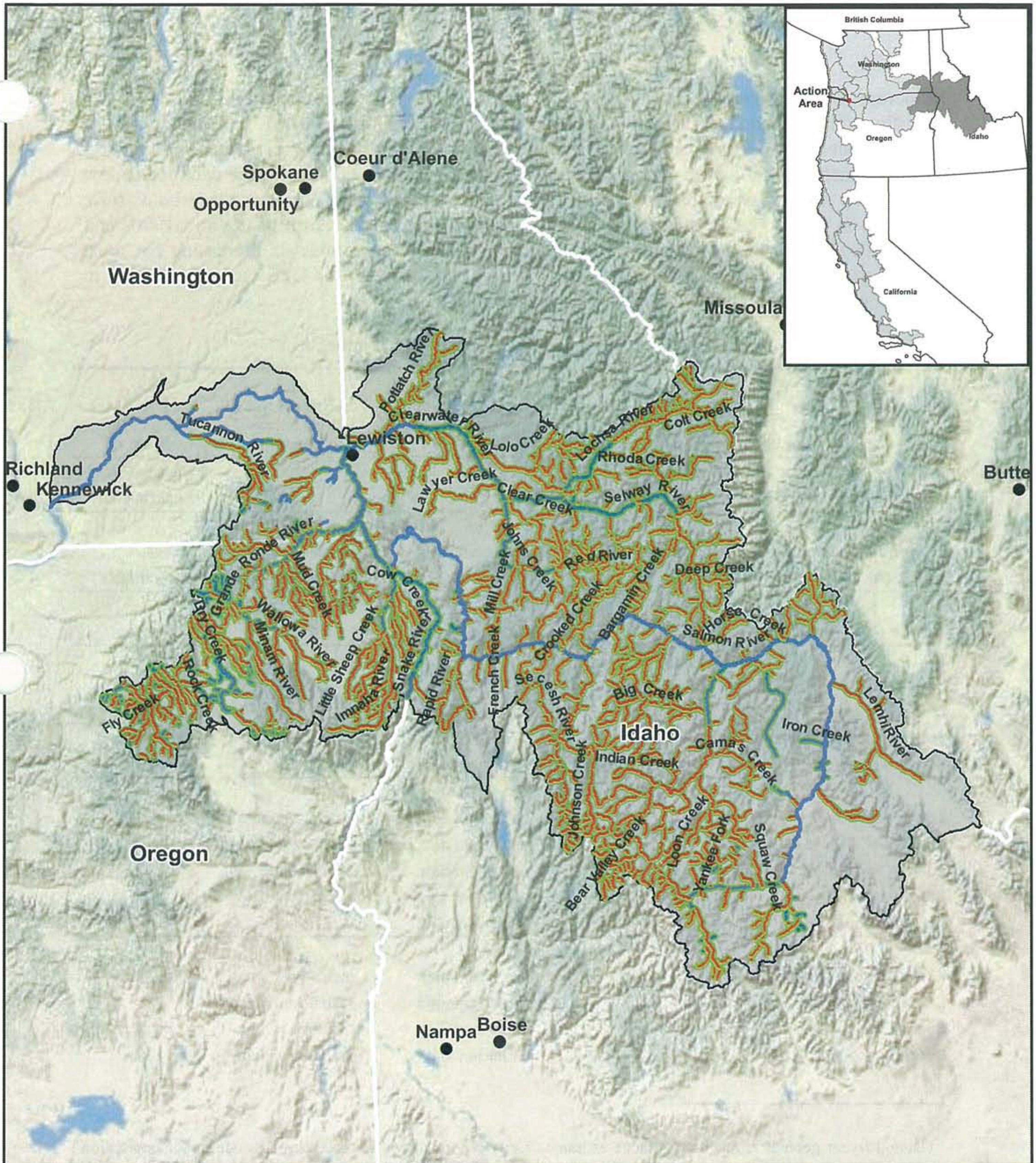
This DPS includes all naturally spawned anadromous steelhead populations below natural and manmade impassable barriers in tributaries in the Snake River basin of southeast Washington, northeast Oregon, and Idaho (71 FR 834; January 5, 2006) (see Figure 4-13). There are six artificial propagation programs for steelhead in this DPS.

SR steelhead are generally classified as summer-run, based on their adult run timing patterns. Adults use the Columbia River within the action area for migration and holding, and are present between June and October (see Figure 4-1 and Figure 4-2). Juveniles of this DPS tend to rear higher in the watershed than steelhead that occupy lower tributaries of the Columbia River. Outmigrating juveniles are present in the action area from March to late June (CRC 2009). Outmigrating kelts pass through the action area in March and April, and are primarily summer-run steelhead (Boggs et al. 2008.).

The extent to which SR steelhead use the Columbia Slough is unknown. Use is assumed to be similar to that described for other steelhead DPSs in the action area.

SR steelhead may also use the Willamette River en route to seasonally wet areas of the Slough.

SR steelhead do not occur in Burnt Bridge Creek.



USE TYPE

- Migration only
- Rearing and migration
- Spawning and rearing
- Steelhead DPS
- Action Area

N S E W

0 20 40
Miles

Figure 4-13. General Distribution Map - Snake River Steelhead DPS

Map is intended to show distribution of the DPS, and not specific habitat use by life stage within the action area itself.

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: May 20, 2009; Plot Date: May 20, 2009; File Name: ESUDPS_JL194.mxd

Numerous SR steelhead subpopulations migrate through the action area (see Table 4-11). Specific adult abundance estimates are generally not available for SR steelhead due to difficulties conducting surveys in much of their range. Population-specific estimates for this DPS are supplemented with Lower Granite Dam counts (see Table 4-11). Abundance declined to low levels in the mid-1990s, increased to levels at or above the recovery abundance thresholds for a few years in the early 2000s, and are now at levels intermediate to those of the mid-1990s and early 2000s.[1] Overall, the abundance of SR steelhead has been stable or increasing for most populations during the last 20 brood cycles. Most populations in this DPS were determined to have a high long-term (100-year) risk of extinction (ICTRT 2007a).

Table 4-11. Summary of Status for SR Steelhead

Population	Abundance Estimate (10-year Geometric Mean of Natural-Origin Spawners)[a]	Recovery Abundance Threshold[b]	Extinction Risk[c]
Average "A-Run" Populations (1995–2004)	456	1,000	Insufficient data
Average "B-Run" Populations (1995–2004)	272	1,000	Insufficient data
	Lower Snake		
Tucannon (A, but below Lower Granite)	Insufficient data	Insufficient data	Moderate
Asotin (A)	Insufficient data	Insufficient data	Moderate
	Imnaha		
Imnaha (A)	Insufficient data	1,000	Moderate
	Grande Ronde		
Upper Mainstem (1997–2006) (A)	1,226	1,500	Moderate
Lower Mainstem (A)	Insufficient data	1,000	Insufficient data
Joseph Creek (1996–2005) (A)	2,132	500	Low
Wallowa River (A)	Insufficient data	1,000	Moderate
	Clearwater River		
Lower Mainstem (A)	Insufficient data	Insufficient data	High
Lolo Creek (A and B)	Insufficient data	Insufficient data	High
Lochsa River (B)	Insufficient data	Insufficient data	High
Selway River (B)	Insufficient data	Insufficient data	High
South Fork (B)	Insufficient data	Insufficient data	High
	Salmon River		
Little Salmon/Rapid (A)	Insufficient data	Insufficient data	Moderate
Chamberlain Creek (A)	Insufficient data	Insufficient data	High
Secesh River (A)	Insufficient data	Insufficient data	High
South Fork Salmon (B)	Insufficient data	Insufficient data	High

[1] Using 10-year geometric mean abundance estimates for two populations in the Grande Ronde major population group (MPG), average abundance can be used as an indicator for the other populations. MPGs were defined as sets of populations that share genetic, geographic (hydrographic), and habitat characteristics within the ESU (ICTRT 2007a). For the two Grande Ronde MPG populations, one recent average abundance estimate exceeds the abundance threshold and the second is below the threshold. Both are below the average abundance thresholds identified as a minimum for low risk.

Population	Abundance Estimate (10-year Geometric Mean of Natural-Origin Spawners)[a]	Recovery Abundance Threshold[b]	Extinction Risk[c]
Panther Creek (A)	Insufficient data	Insufficient data	High
Lower Middle Fork Tributaries (B)	Insufficient data	Insufficient data	High
Upper Middle Fork Tributaries (B)	Insufficient data	Insufficient data	High
North Fork (A)	Insufficient data	Insufficient data	Moderate
Lemhi River (A)	Insufficient data	Insufficient data	Moderate
Pahsimeroi River (A)	Insufficient data	Insufficient data	Moderate
East Fork Salmon (A)	Insufficient data	Insufficient data	Moderate
Upper Mainstem (A)	Insufficient data	Insufficient data	Moderate
Estimated Total for These Populations	**Insufficient data**	**Insufficient data**	

a Source: NMFS 2008e.

b Source: NMFS 2008e; ICTRT abundance thresholds are average abundance levels that would be necessary to meet ICTRT viability goals at <5% risk of extinction.

c Source: NMFS 2006c.

4.9.2 Limiting Factors

Historically, the key limiting factors for SR steelhead include hydropower projects, predation, harvest, hatchery effects, ocean conditions, and tributary habitat.

4.9.3 Designated Critical Habitat

Critical habitat was designated for SR steelhead on September 2, 2005 (70 FR 52630). The critical habitat designation includes the Columbia River rearing/migration corridor, which connects the DPS to the Pacific Ocean and includes the action area (the Columbia River and North Portland Harbor).

The action area contains the following PCEs: freshwater migration, and estuarine areas.

The Columbia River rearing/migration corridor is considered to have a high conservation value for rearing and migrating juveniles and migrating adults. The Columbia River estuary is an essential area for juveniles and adults making the physiological transition between life in freshwater and marine habitats (NMFS 2005a). The PCEs are generally degraded due to mortality from the mainstem dams, lack of adequate pool and riffle channel structure in tributaries, high summer water temperatures, low flows, poor overwintering conditions due to loss of floodplain connection, and high sediment loads (NMFS 2008e).

4.10 UWR STEELHEAD

4.10.1 Status and Biological Context

This DPS includes all naturally spawned winter-run steelhead populations below natural and manmade barriers in the Willamette River and its tributaries from Willamette Falls upstream to the Calapooia River (inclusive) (see Figure 4-14). NMFS originally listed this DPS as threatened on March 25, 1999, and reaffirmed its status on January 5, 2006 (71 FR 834). There are four subpopulations of the UWR steelhead: the Molalla, North Santiam, South Santiam, and Calapooia—all use the action area. Table 4-12 summarizes the status of these populations.

Within the action area, UWR steelhead are likely to be present in the Columbia River and Columbia Slough. They are likely to use the action area only when they are migrating into or out of the mouth of the Willamette River (approximately late February to early June for adults, April through June for juveniles).

UWR steelhead do not use North Portland Harbor or Burnt Bridge Creek (70 FR 37160) (see Figure 4-14).

Steelhead of this DPS are late-migrating winter-run steelhead, entering fresh water primarily in March and April (Howell et al. 1985, as cited in 63 FR 11797) and entering the mouth of the Willamette River from March through May (Busby et al. 1996). Winter-run steelhead historically occurred above Willamette Falls, while summer-run steelhead did not. Juvenile outmigration past Willamette Falls occurs between early April and early June (Howell et al. 1985), with migration peaking in early to mid-May. Steelhead juveniles generally migrate away from the shoreline and enter the Columbia via Multnomah Channel rather than the mouth of the Willamette. Most spend 2 years in the ocean before re-entering fresh water to spawn (Busby et al. 1996). Steelhead in this DPS generally spawn once or twice. Repeat spawners are predominantly female and generally account for less than 10 percent of the total run size (Busby et al. 1996).

Population counts of this DPS have been reduced from historical levels, due in part to the alteration and reduction of spawning and rearing habitat associated with hydropower development. Willamette Falls (at RM 26.5/RKm 42.7) is a known migration barrier. All populations migrate through and rear in the Willamette River and are relatively small, with the recent mean abundance of the entire DPS at less than 6,000 (Good et al. 2005). Based on recent analyses of the population criteria, the species risk of extinction is moderate, with the highest risk category being genetic diversity (McElhany et al. 2007).

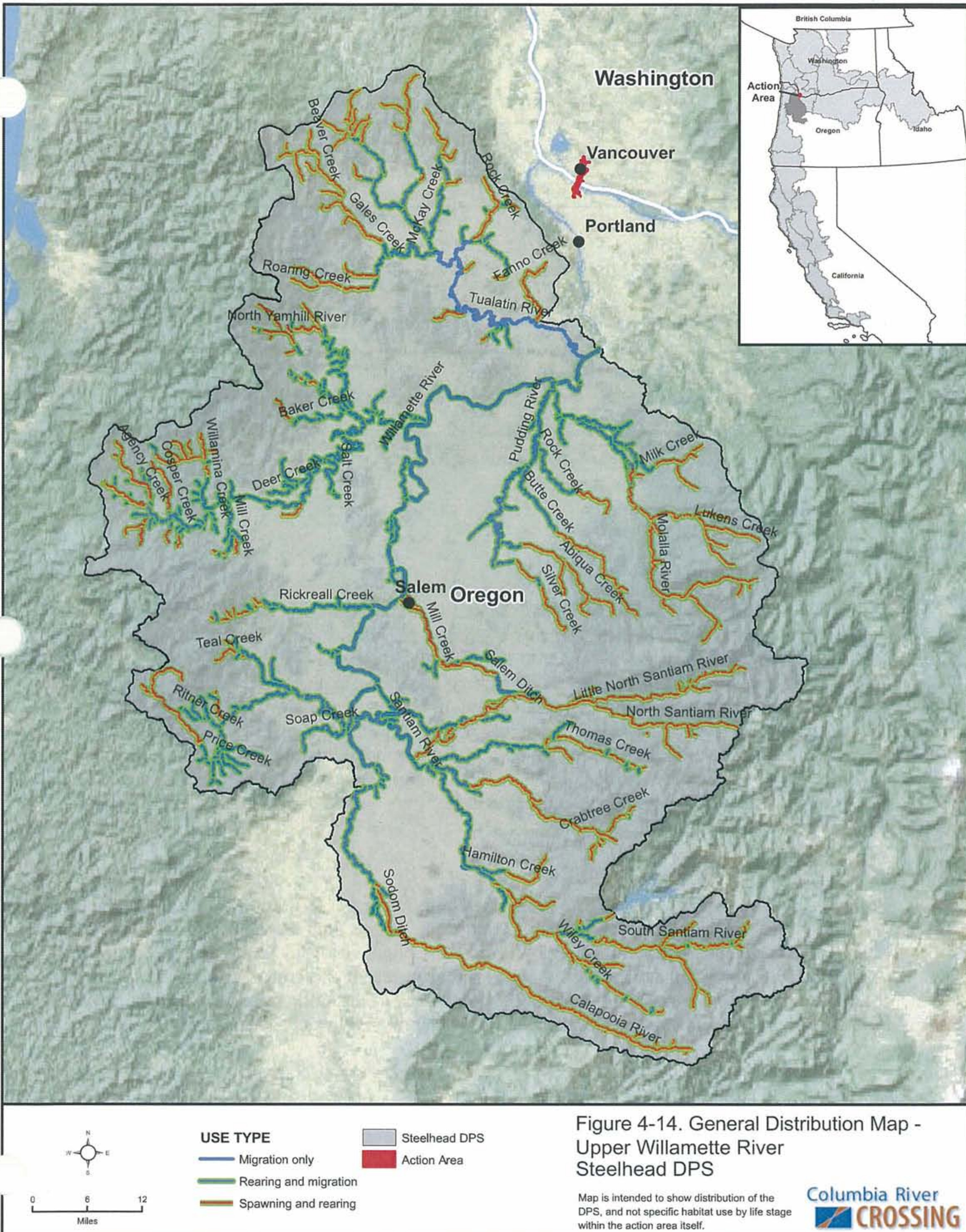


Figure 4-14. General Distribution Map - Upper Willamette River Steelhead DPS

Map is intended to show distribution of the DPS, and not specific habitat use by life stage within the action area itself.

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: Aug., 2009; Plot Date: File Name: ESUDPS_JL194.mxd

Table 4-12. Summary of Status for UWR Steelhead

Population	Legacy[a,d]	Core[b,d]	Abundance Estimate of Natural-Origin Spawners, 1990-2006, as available	Viable Abundance Goal[c,e]	Extinction Risk[f]
Molalla	No	No	350–2,900	1,400	Moderate
North Santiam	Yes	Yes	550–7,400	2,150	Moderate
South Santiam	Yes	Yes	1,000–4,950	2,150	Moderate
Calapooia	No	No	50–1,400	1,000	Moderate
Estimated Total for These Populations			**1,950–16,650**	**6,700**	

a Genetic Legacy designation by the Technical Recovery Team. Genetic legacy populations represent unique life histories or are relatively unchanged by hatchery influences.

b Core population designation by Technical Recovery Team. Core populations were the largest historical populations and were key to metapopulation processes.

c The delisting goals for abundance are the average number of wild spawners expected for a population whose probability of declining below the critical risk threshold during a 100-year period is 5% or less (i.e., low extinction risk) (ODFW 2007b). NOTE: These abundance goals are Draft and may be revised when the newer version of the draft recovery plan is released in early 2010.

d Source: WLCTRT 2003.

e Source: ODFW 2007b.

f Source: McElhany et al. 2007.

4.10.2 Limiting Factors

Limiting factors for UWR steelhead include habitat loss and degradation, tributary hydropower development, hatchery effects, fishery management and harvest decisions, and predation. Detroit and Big Cliff Dams have blocked access to spawning and rearing habitat in the North Santiam River. There are no winter-run steelhead hatchery programs in the upper Willamette basin; however, the potential exists for genetic introgression with the non-native summer-run steelhead hatchery program. Habitat has been particularly degraded in the lower reaches of tributaries to the Willamette, for example, by the reduction of channel complexity associated with the removal of large wood to improve navigability (NMFS 2009b). Based on recent analyses of the population criteria, the species risk of extinction is moderate, with the highest risk category being genetic diversity (McElhany et al. 2007).

4.10.3 Designated Critical Habitat

Critical habitat was designated for UWR Steelhead on September 2, 2005 (70 FR 52630). The designation includes a rearing and migration corridor, connecting the DPS with the Pacific Ocean. The corridor extends from the mouth of the Columbia to the Willamette River at its confluence with the Clackamas River. Only a small portion of the critical habitat unit occurs within the action area, near Kelley Point at the confluence of the Willamette with the Columbia River. PCEs present in the action area include freshwater migration and estuarine areas.

4.11 SR SOCKEYE SALMON

4.11.1 Status and Biological Context

This ESU includes all anadromous and residual sockeye salmon from the Snake River basin, Idaho, as well as artificially propagated sockeye from the Redfish Lake captive propagation program (70 FR 37160) (see Figure 4-15).

Within the action area, adult SR sockeye are present in the Columbia River and North Portland Harbor during upstream migration in June and July. Sockeye juveniles rear in freshwater lakes for 1 to 3 years prior to migrating to the ocean, and primarily use the lower Columbia River as a migration corridor (Burgner 1991 and Gustafson et al. 1997, as cited in Carter et al. 2009). Juvenile outmigration occurs from April to mid-September (CRC 2009); the limited information available indicates that sockeye outmigration through the action area peaks in May (Carter et al. 2009). There is some evidence that juvenile migration typically occurs between sunset and sunrise (Burgner 1991 and Gustafson et al. 1997, as cited in Carter et al. 2009). SR sockeye of both life stages likely spend some time holding and resting in the action area. SR sockeye are likely to be present in the Columbia River and North Portland Harbor during the time that in-water work will take place.

The extent to which SR sockeye use the Columbia Slough is unknown. Use is assumed to be similar to that previously described for Chinook ESUs and steelhead DPSs. SR sockeye may also use the Willamette River en route to seasonally wet areas of the Slough. SR sockeye do not use Burnt Bridge Creek.

Historic returns for SR sockeye were estimated to be between 25,000 and 35,000 returning adults. Returns for this ESU were limited to 16 sockeye during the 1990s. Between 1991 and 1998, all 16 of the natural origin adult sockeye salmon that returned to the weir at Redfish Lake were incorporated into the captive broodstock program. The program has used multiple rearing sites to minimize chances of catastrophic loss of broodstock and has produced several hundred thousand eggs and juveniles, as well as several hundred adults, for release into the wild. Between 1999 and 2007, more than 355 adults returned from the ocean from captive broodstock releases—almost 20 times the number of wild fish that returned in the 1990s (see Table 4-13). The program has been successful in its goals of preserving important lineages of Redfish Lake sockeye salmon for genetic variability and in preventing extinction in the near-term. In 2008, Lower Granite Dam sockeye counts were 902 fish; the second-highest count was 299 sockeye in 2000. Most of the returning fish are the product of large juvenile releases from the captive broodstock program. This ESU has a very high risk of extinction (NMFS 2008e).

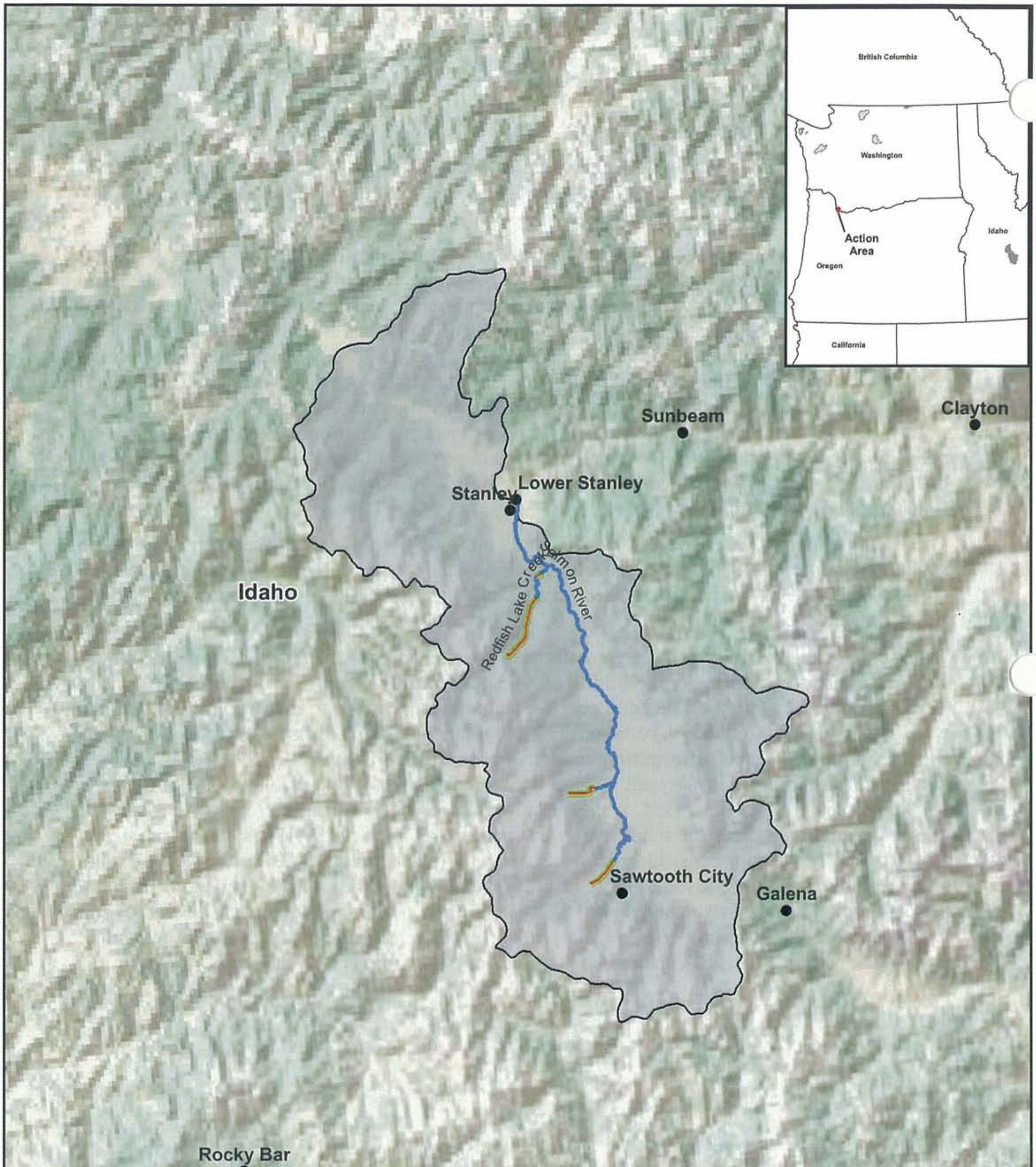


Figure 4-15. General Distribution Map - Snake River Sockeye ESU

Map is intended to show distribution of the ESU, and not specific habitat use by life stage within the action area itself.

Analysis by J. Kolaszar; Analysis Date: May 20, 2009; Plot Date: May 20, 2009; File Name: ESUDPS_JL194.mxd

Table 4-13. Summary of Status for SR Sockeye

Population	Abundance Estimate of Natural-Origin Spawners, 1999-2007	Viable Abundance Goal	Extinction Risk
Stanley Basin[a] (Redfish Lake)	355	2,000	Very High

Source: NMFS 2008e, NMFS 2006b.

a This ESU is characterized as a single population. No other extant populations or spawning groups have been identified.

4.11.2 Limiting Factors

At the time of listing in 1991, SR sockeye had declined to the point that there was no longer a self-sustaining, naturally spawning anadromous population. This has been the largest factor limiting the recovery of this ESU, important in terms of both risks due to catastrophic loss and potentially to genetic diversity. It is not yet clear whether the existing population retains sufficient genetic diversity to successfully adapt to variable conditions that occur within its natural habitat. However, genetic data indicate that the captive broodstock has levels of haplotype diversity similar to other sockeye populations in the Pacific Northwest, and that the program has been able to maintain rare alleles in the population over time. The broodstock program reduces the risk of domestication by using a spread-the-risk strategy, outplanting pre-spawning adults and fertilized eyed eggs as well as juveniles raised in the hatchery. The progeny of adults that spawn in the lakes and juveniles that hatch successfully from the eyed eggs are likely to have adapted to the lake environment rather than become "domesticated" to hatchery rearing conditions (NMFS 2008e).

4.11.3 Designated Critical Habitat

Critical habitat was designated for SR sockeye on December 12, 1993 (58 FR 68543), and is present in the action area in the Columbia River and North Portland Harbor. The designation includes the Columbia River rearing/migration corridor, which connects the ESU with the ocean and intersects the action area (Columbia River and North Portland Harbor).

The following PCEs occur within the action area: juvenile migration corridors and adult migration corridors. Essential features of the juvenile migration corridors include substrate, water quality, water quantity, water velocity, cover/shelter, food, riparian vegetation, space, and safe passage conditions.

The Columbia River migration corridor is considered to have a high conservation value. This corridor is used by rearing and migrating juveniles and migrating adults. The Columbia River estuary is an essential area for juveniles and adults making the physiological transition between life in freshwater and marine habitats (NMFS 2005a). The PCEs are generally limited by passage barriers (especially during periods of high summer temperatures) in the mainstem lower Snake and Salmon Rivers, passage mortality at the mainstem dams, and high sediment loads in the upper reaches of the mainstem Salmon River (NMFS 2008e).

4.12 LOWER COLUMBIA RIVER COHO

4.12.1 Status and Biological Context

The ESU includes all naturally spawned populations of coho salmon in the Columbia River and its tributaries in Washington and Oregon from the mouth of the Columbia River upstream to and including the Big White Salmon and Hood Rivers. This ESU also includes naturally spawned populations of coho in the Willamette River up to Willamette Falls, Oregon (70 FR 37160; June 28, 2005). The ESU includes 3 major population groups and 24 historical populations (see Figure 4-16). There are 25 artificial propagation programs for coho in this ESU.

LCR coho use the Columbia River within the action area for migration, holding, and rearing. Upstream migrating adults are present in the action area from approximately mid-August to mid-February (NMFS 2005a; CRC 2009). Rearing habitat is limited in the action area, but is present in off-channel areas downstream of the existing I-5 bridge (e.g., accessible areas of small tributaries, backwater areas, and other low-velocity refugia). Spawning habitat is not documented within the action area in the Columbia River. However, coho spawn upstream of the action area in the lower Columbia River near Ives Island and Hamilton Creek, at RM 143 (RKm 230), 3 miles downstream from Bonneville Dam (FPC 2008). Spawning occurs approximately from December to February (ODFW and WDFW 2008a). Rearing juveniles of this ESU are present in the action area year-round (Carter et al. 2009; CRC 2009). Outmigrating juveniles are present in the action area from mid-February to mid-September (CRC 2009), with peak juvenile outmigration occurring between April and June (Carter et al. 2009). Given that coho could be present in the action area year round, they will likely be present during in-water work.

Coho are known to use the Columbia Slough up to NE 18th Avenue, including the action area. Coho use the Columbia Slough for rearing and migration, as spawning habitat is absent from the Slough (COP 2009a). Coho are likely to be present in the Slough from fall through spring. As discussed previously, water temperatures during the summer (approximately June through September) often exceed tolerance thresholds for juvenile salmonids.

There is the potential for juvenile LCR coho presence in Burnt Bridge Creek at any time of year. The water temperature during the summer months is often above the range tolerated by coho (Sandercock 1991; Ecology 2008), and, as discussed in Section 4.1.1, numerous barriers limit access to the action area (WDFW 2007a). Nevertheless, coho spawning is documented within Burnt Bridge Creek. Spawning surveys conducted in November and December 2002 documented four coho redds in Burnt Bridge Creek, three redds between I-205 and the mouth of Burnt Bridge Creek, and one redd between the headwaters and the mouth of Burnt Bridge Creek (PSMFC 2003). One adult coho was observed during the spawning survey. This study did not specify exact locations of documented redds; therefore, it cannot be stated where they were located relative to the action area for this project. However, presence of these redds indicate that coho have access to, and successfully spawn in, portions of the creek adjacent to, if not within, the action area. Upstream of the action area, WDFW also documented two coho redds in Burnt Bridge Creek in November and December 2002, one between St. Johns Boulevard and NE 41st Circle and one between St. Johns Boulevard and Fourth Plain Boulevard (WDFW unpublished data).

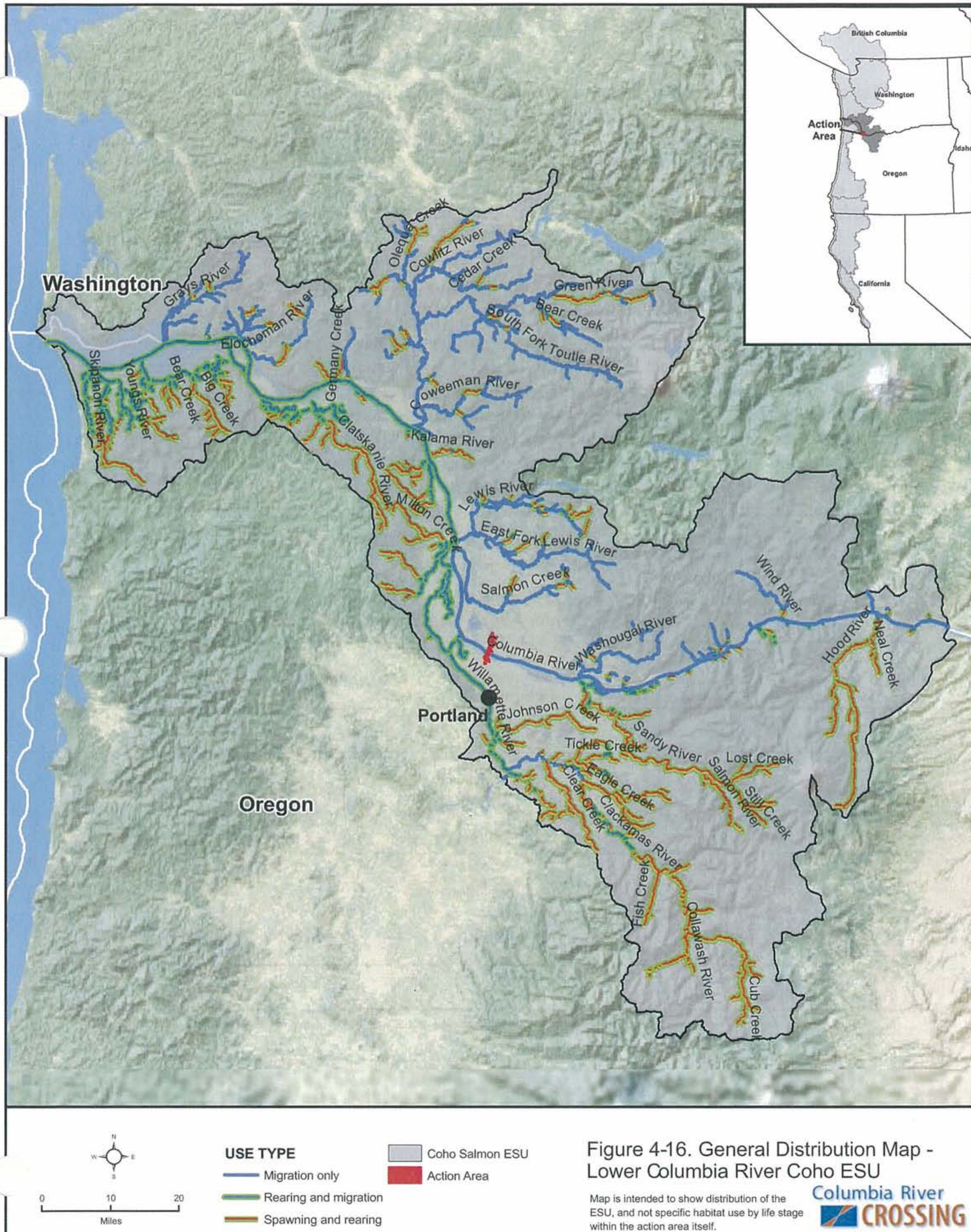


Figure 4-16. General Distribution Map - Lower Columbia River Coho ESU

Map is intended to show distribution of the ESU, and not specific habitat use by life stage within the action area itself.

Columbia River CROSSING

Analysis by J. Koloszar. Analysis Date: May 20, 2009; Plot Date: May 20, 2009; File Name: ESUDPS_JL194.mxd

Wild coho in the lower Columbia River have been in decline for the last 75 years. Returns of wild coho have fallen from historical highs of 600,000 or more fish (Chapman 1986) to as low as 400 fish in 1996 (Chilcote 1999). The abundance and distribution of wild coho has been significantly reduced throughout the basin, and all coho populations upstream of Hood River were extirpated nearly 50 years ago (McElhany et al. 2007). Coho production is likely reproductively dependent on the spawning of stray hatchery fish, with the exception of wild coho in the Clackamas and Sandy Rivers, where there has been an increase in the abundance of wild coho since 2002. Other wild coho populations showing a limited increase in abundance are those in the Scappoose and Clatskanie basins, although these populations were largely absent from those basins during a 10-year period in the 1990s.

Data on the status of natural-origin LCR coho are very limited. Most populations have low or very low numbers, and most natural runs largely have been replaced by hatchery production (NMFS 2008e). Several subpopulations migrate through the action area, but population-specific abundance estimates are available for only five populations, and trend estimates are available for only the Clackamas and Sandy populations (see Table 4-14). These two systems represent the only subbasins with appreciable numbers of wild coho remaining, and therefore are not representative of other LCR coho salmon populations (LCFRB 2004). The status of Washington populations is still under assessment; however, there is no evidence that self-sustaining populations of wild coho survived the poor marine survival period of the 1990s. This ESU has a high risk of extinction (McElhany et al. 2007) (see Figure 4-17).

Table 4-14. Summary of Status for LCR Coho in the CRC Project Area (Subpopulations Occurring Within or Above the Action Area Only)

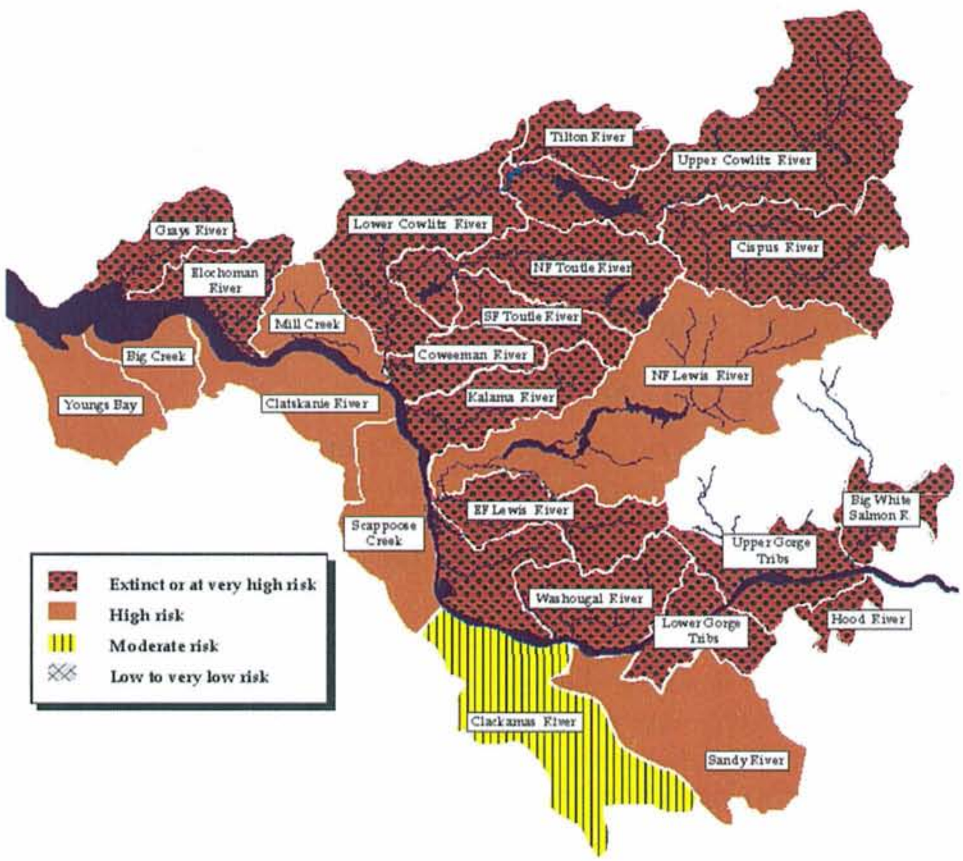
Subpopulation	Legacy[a,c]	Core[b,c]	Abundance Estimate of Natural-Origin Spawners		Viable Abundance Goal[c]	Current Viability[c]	Extinction Risk[d]
			McElhany et al. 2007	NMFS 2008e			
Cascade							
Clackamas	Yes	No	1693	482	1,200	Moderate	Moderate
Sandy	Yes	No	647	482	1,200	Low	High
Washougal	Yes	No	Insufficient Data		4,200	Very Low	Very High
Gorge							
Lower Gorge and Big White Salmon	No	No	Insufficient Data		2,400	Very Low	Very High
Upper Gorge and Hood River	No	No	Insufficient Data	1,317	2,300	Very Low	Very High
Estimated Total for These Populations			**2,340**	**2,281**	**11,300**		

a Genetic Legacy designation by the Technical Recovery Team. Genetic legacy populations represent unique life histories or are relatively unchanged by hatchery influences.

b Core population designation by Technical Recovery Team. Core populations were the largest historical populations and were key to metapopulation processes.

c Source: LCFRB 2004.

d Source: McElhany et al. 2007.



SOURCE: Lower Columbia River Fish Recovery Board 2004.
Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan

Figure 4-17.
Extinction Risk - Lower Columbia River Coho ESU

Columbia River CROSSING

4.12.2 Limiting Factors

Limiting factors for LCR coho include habitat degradation (including tributary hydropower development), hatchery effects, fishery management and harvest decisions, and predation. Populations above Bonneville Dam are affected by upstream and downstream passage and, for Oregon populations, by inundation of some historical habitat by the Bonneville Pool. For populations originating in tributaries below Bonneville, migration and habitat conditions in the mainstem and estuary have been affected by hydropower flow operations. Tributary habitat degradation is pervasive due to development and other land uses, and Federal Energy Regulatory Commission (FERC)-licensed hydroelectric projects have blocked some spawning areas. Coho populations in the lower Columbia River have been heavily influenced by extensive hatchery releases. While those releases represent a threat to the genetic, ecological, and behavioral diversity of the ESU, some of the hatchery stocks at present also protect a significant portion of the ESU's remaining genetic resources (NMFS 2008e).

4.12.3 Designated Critical Habitat

Critical habitat has not been designated for LCR coho, but this issue is currently under review by NMFS.

4.13 COLUMBIA RIVER CHUM

4.13.1 Status and Biological Context

This ESU includes all naturally spawned populations of chum salmon in the Columbia River and its tributaries in Washington and Oregon (70 FR 37160; June 28, 2005) (see Figure 4-18). There are 16 historical populations in 3 major population groups in Oregon and Washington between the mouth of the Columbia River and the Cascade crest. There are three artificial propagation programs for chum in this ESU.

Columbia River (CR) chum in Washington occur primarily in Grays River, in areas immediately below Bonneville Dam, and in a more limited distribution just upstream of the I-205 bridge near Vancouver (McElhany 2005). All of the historical populations in Oregon are considered extirpated or nearly so. CR chum use the Columbia River within the action area for migration, holding, rearing, and spawning. Upstream migrating adults are present in the action area from approximately mid-October through mid-January (NMFS 2005a; ODFW and WDFW 2008a; CRC 2009).

Spawning occurs between approximately early November and mid-January (ODFW and WDFW 2008a). Historically, chum primarily spawned in the Columbia River mainstem and lower tributary reaches, exhibiting a preference for microhabitats with hyporheic flow (Rawding personal communication, as cited in McElhany et al. 2007). The vast majority of 2002 chum spawning occurred in the Grays River (downstream of the action area) and Lower Gorge tributaries (upstream of the action area), and in the mainstem Columbia between the I-205 Bridge and Bonneville Dam. Notable spawning also occurred in the Washougal River basin. Currently, the majority of spawning occurs on the Washington side of the Columbia. The only documented spawning locations in Oregon are occurrences of redds in the mainstem Columbia near McCord Creek and Multnomah Falls (McElhany 2005).

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Figure 4-18. General Distribution Map - Columbia River Chum ESU

Map is intended to show distribution of the ESU, and not specific habitat use by life stage within the action area itself.

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: Aug., 2009; Plot Date: File Name: ESUDPS_JL194.mxd

Surveys of chum spawning areas conducted in 2006 in the Pierce and Ives Islands Complex below Bonneville indicated that juvenile chum emergence began on February 13, peaked on April 5, and ended on April 27 (Tomaro et al. 2007).

Within the action area, chum spawn in the mainstem Columbia River at approximately 7 RM (11 RKm), upstream of the I-5 bridge near the I-205 bridge at RM 113 (RKm 182) (FPC 2008).

Chum fry spend very little time in fresh water, and begin their migration soon after emerging (Tomaro et al. 2007); emergence typically occurs at night (Salo 1991). What rearing is done in the lower Columbia River occurs from December through mid-March in off-channel areas (e.g., accessible areas of small tributaries, backwater areas, and other low-velocity refugia). Such rearing habitat is present to very limited extent in the action area at the western end of Government Island, in North Portland Harbor, and in small backwater areas along the mainstem channel. Outmigrating fry are present from February through May (NMFS 2005a; CRC 2009), peaking from mid-April through mid-May (Carter et al. 2009).

CR chum are likely to be present in the Columbia River and North Portland Harbor during the time that in-water work will take place. Chum do not use Burnt Bridge Creek, and the extent to which chum use the Columbia Slough is unknown. However, the potential presence of adult and juvenile chum cannot be wholly discounted because: (1) there are no physical barriers to the Slough; and (2) other upriver ESUs have been documented using the area. In the absence of definitive data to indicate otherwise, potential presence of migrating adults, and rearing and migrating juveniles, is assumed for the Columbia Slough.

Historical returns of CR chum are estimated to be over a million fish in some years (McElhany 2005). In recent years, returns have been limited to a few hundred to a few thousand, returning mainly to the Washington side of the Columbia River (McElhany 2005). Significant spawning now occurs for only two of the 16 historical populations, indicating that 88 percent of the historical populations are extirpated or nearly so (NMFS 2008e).

Several subpopulations of chum use the action area (see Table 4-15). Estimates of abundance and trends for naturally spawning populations occurring within the action area are available only for the Lower Gorge populations; geometric mean for the years 1996–2000 is 425m (NMFS 2008e). Abundances for these populations were low, but trends were relatively stable in the 1990s. They subsequently increased for several years before declining in 2005 (Keller 2006, as cited in NMFS 2008e). The risk of extinction is high or very high for all populations. All four of the populations on the Oregon side of the river are extirpated or nearly so, and those that remain are at very high risk of extinction (McElhany et al. 2007) (see Figure 4-19).

Table 4-15. Summary of Status for CR Chum in the CRC Project Area (Subpopulations Occurring Within or Above the Action Area Only)

Subpopulation	Legacy[a,c]	Core[b,c]	Abundance Estimate of Natural-Origin Spawners		Viable Abundance Goal[d]	Current Viability[d]	Extinction Risk[d,e]
			LCFRB 2004	NMFS 2008e			
			Cascade				
Clackamas	No	Yes	<150	Insufficient data	1,100	Very low	Very high
Sandy	No	No	<150	Insufficient data	1,100	Very low	Very high
Washougal	No	No	<150	Insufficient data	1,100	Low	High
			Gorge				
Upper Gorge	No	No	<100	Insufficient data	1,100	Very low	Very high
Lower Gorge	Yes	Yes	542	425	2,600	Medium	Moderate
Estimated Total for These Populations			**1,092**	**425**	**7,000**		

a Genetic Legacy designation by the Technical Recovery Team. Genetic legacy populations represent unique life histories or are relatively unchanged by hatchery influences.

b Core population designation by Technical Recovery Team. Core populations were the largest historical populations and were key to metapopulation processes.

c Source: WLCTRT 2003

d Source: LCFRB 2004

e Source: McElhany et al. 2007

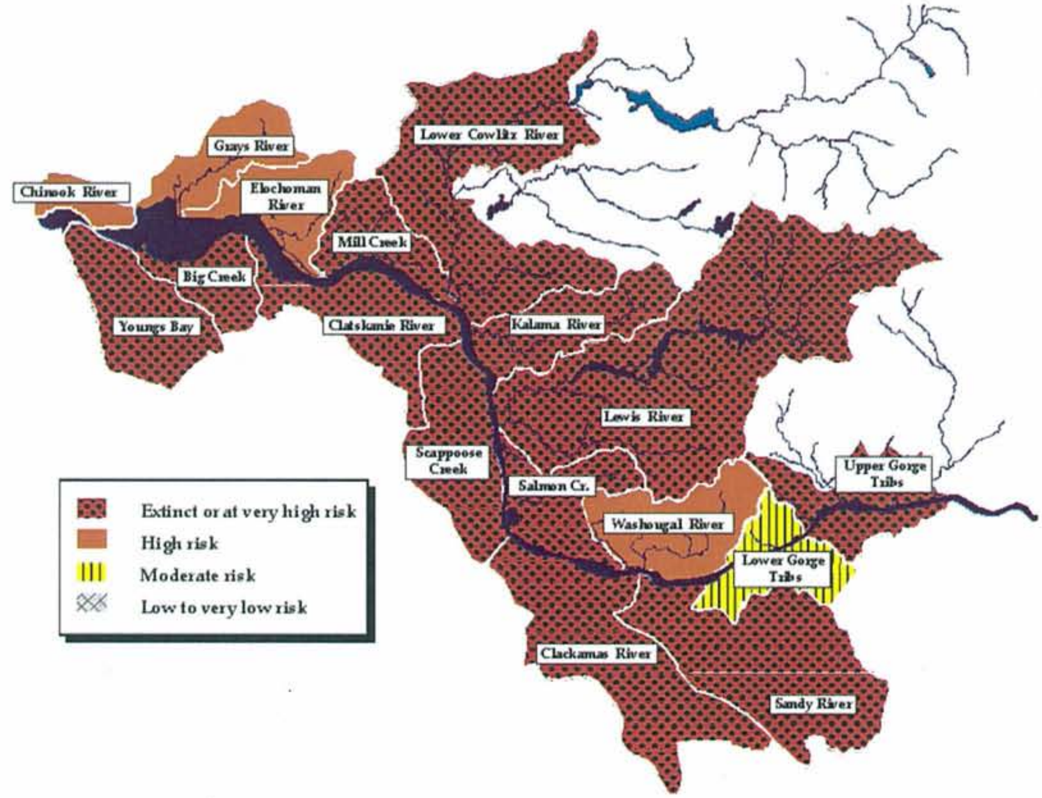
4.13.2 Limiting Factors

Limiting factors for CR chum include mainstem and tributary hydropower development (e.g., loss of historical spawning habitat; availability of spawning habitat for the mainstem population; adult and juvenile access to/from Hardy and Hamilton Creeks), migration and habitat conditions in the lower Columbia River and the estuary, and degradation of tributary habitat.

4.13.3 Designated Critical Habitat

Critical habitat was designated for CR chum on September 2, 2005 (70 FR 52630), and is present in the action area in the Columbia River and North Portland Harbor.

PCEs present in the action area include freshwater spawning, freshwater migration, freshwater rearing, and estuarine areas. In the lower Columbia River and its tributaries, major factors affecting PCEs are altered channel morphology and stability, lost and/or degraded floodplain connectivity, loss of habitat diversity, excessive sediment, degraded water quality, increased stream temperatures, reduced stream flow, and reduced access to spawning and rearing areas (NMFS 2008e).



SOURCE: Lower Columbia River Fish Recovery Board 2004.
Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan

Figure 4-19.
Extinction Risk - Columbia River Chum ESU

Columbia River CROSSING

4.14 TRANSIT TIME AND BEHAVIOR OF LISTED SALMON, STEELHEAD, AND EULACHON IN THE LOWER COLUMBIA RIVER

4.14.1 Transit Timing

Migration rates of anadromous salmonid juveniles through the lower Columbia River are variable and are influenced by river flow, species, and run type (e.g., stream or ocean type); distance from the ocean; time of year; time of day; and fish size (see Table 4-17). Most anadromous salmonid juveniles migrate quickly through the lower Columbia River, and juvenile passage rates there tend to be faster during high flows and faster later in their respective migration seasons. Larger juveniles generally move more rapidly than their smaller cohorts (Carter et al. 2009).

Studies on juvenile Chinook survival in the lower Columbia River and estuary indicate that travel time for subyearling and yearling Chinook from Bonneville Dam to the estuary is approximately 4.1 days, meaning that the fish average approximately 32-36 miles per day (McComas et al. 2008). Data collected beginning in 2007 indicate that yearling and subyearling Chinook and steelhead travel more slowly in the final 30 miles of the Columbia River than in the previous 120 miles, then substantially increase their travel rates as they exit the river and enter the Pacific Ocean, usually on an ebb tide (Carter et al. 2009).

Juvenile travel times and migration rates can be estimated from PIT-tagged juveniles detected at Bonneville Dam and downstream at the annual trawl surveys in the Columbia River estuary (FPAC 2009). Table 4-16 presents average travel time (duration) and rates from Bonneville Dam to the CRC project area along with instantaneous velocity (m/s). Average velocity ranged from 0.39 to 1.15 m/s for LCR spring-run Chinook and SR sockeye, respectively.

Table 4-16. Travel Time and Migration Rates for Select Populations of Chinook, Sockeye, and Steelhead Juveniles

Species	ESU/DPS and Population	Mean Travel Time (days)[a]	Mean Migration Rate (distance/day)	Mean Migration Rate (m/s)[a]	Period of Record
Chinook	LCR Spring-Run (Hatchery)	4.1 (1.92– 4.52)	20.9 mi 33.7 km	0.39 (0.28–0.51)	1999–2008
	SR Spring/ Summer-Run	0.58 (0.35-0.82)	56.9 mi 91.6 km	1.06 (0.85–1.19)	1999–2008
	SR Fall-Run	0.75 (0.67-0.86)	50.4 mi 81.2 km	0.94 (0.81–1.03)	1999–2008
Sockeye	SR	0.67	61.7 mi 99.4 km	1.15 (1.41–0.63)	1999–2008
Steelhead	LCR Summer-Run	0.77 (0.56-0.96)	50.4 mi 81.2 km	0.94 (0.81–1.03)	1999–2008
	LCR Winter-Run	1.37 (0.63-2.57)	47.8 mi 76.9 km	0.89 (0.60–1.13)	2005–2008
	MCR Summer-Run	0.66 (0.56–0.88)	57.4 mi 92.5 km	1.07 (0.79–1.25)	1999–2008

Species	ESU/DPS and Population	Mean Travel Time (days)[a]	Mean Migration Rate (distance/day)	Mean Migration Rate (m/s)[a]	Period of Record
	UCR Summer-Run	0.64 (0.54–0.80)	59.0 mi 95.0 km	1.10 (0.87–1.29)	1999–2008
	SR Summer-Run	0.85 (0.6–2.60)	58.0 mi 93.3 km	1.08 (0.88–1.19)	1999–2008

Source: FPAC 2009.

Note: Statistics are based on PIT tag detections at Bonneville Dam and in the Columbia River estuary.

a Data range.

Coho juveniles are thought to migrate through the action area (Columbia River and North Portland Harbor) at rates varying from approximately 2 to 15 miles per day (Dawley et al. 1986, as cited in Carter et al. 2009). Coho move passively downstream in strong currents and hold in low-velocity habitats; therefore, their movement is influenced by river flow (Bottom et al. 2005, as cited in Carter et al. 2009).

Transit times of eulachon are not well studied. It is expected that larval eulachon have poor swimming ability and travel at the rate of the current (LCFRB 2004), which has been conservatively estimated to be 0.6 m/s under general conditions (CRC 2008). Observations suggest that transit times vary widely and are dependent on river flow, water temperature, tides, and other environmental conditions (Carter et al. 2009). Large groups of adult eulachon have been observed holding low in the estuary for extended periods before promptly migrating to the Cowlitz River in 2 days (Langness 2009 personal communication).

Table 4-17. Transit Times of Chinook, Steelhead, and Coho Juveniles in the Lower Columbia River

Species	River Miles	Mean Travel Time (days)	Migration Rate (m/d)	Migration Rate (km/day)	Migration Rate (m/s)	Reference
Chinook	Bonneville 138–5	4.1	32.46	54.1	0.6	McComas et al. 2008
Steelhead	140–45	1.91–2.78	34.2–49.8	57–83	0.7–1.0	Ledgerwood et al. 2004
Coho	140–45	5.99–45.23	2.1–15.84	3.5–26.4	0.0–0.3	Dawley et al. 1986

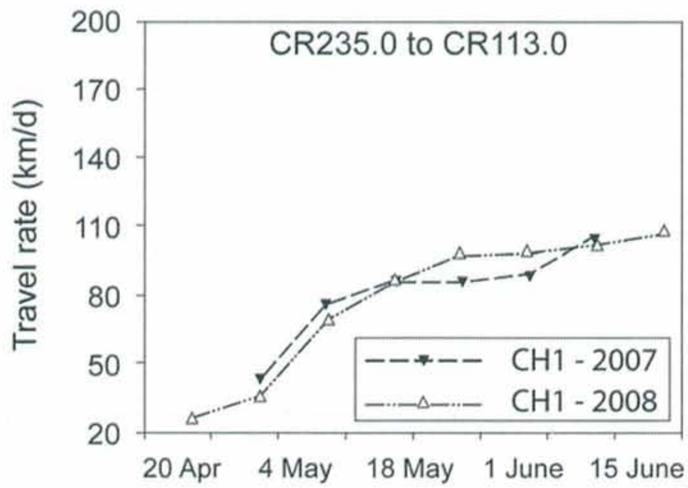
In a 4-year study of acoustic-tagged juveniles migrating in the Columbia River estuary, Carter et al. (2009) observed that juveniles travel faster in the upper reaches of the estuary than in the lower (see Table 4-18). Yearling Chinook traveled at a rate of approximately 50 miles (80 km)/day from Bonneville Dam to Vancouver, Washington, and then slowed to a rate of approximately 37 miles (60 km) per day from Vancouver to just before the mouth of the Columbia River (RM 5.2/RKm 8.4). Other juveniles exhibited a similar pattern. Extrapolating from these results, and assuming comparable flows, water temperatures, season timing, and other environmental variables, we estimate that steelhead and Chinook juveniles may travel at an average rate of 0.5 to 1.1 m/s through the action area (see Table 4-18). The data are inconclusive regarding diel travel patterns and the number of hours per day that fish travel. Therefore, this estimate assumes 24-hour per day travel and does not attempt to calculate differential migration rates by time of day.

Table 4-18. Migration Rates for Chinook and Steelhead Juveniles Traveling Downstream of Bonneville Dam

		Bonneville Dam to Vancouver			Vancouver to RM 5.2/RKm 8.4		
Species	Year	Mean (km/d)	Median (km/d)	Mean Migration Rate (m/s)	Mean (km/d)	Median (km/d)	Mean Migration Rate (m/s)
Subyearling Chinook	2007	64.3	65.3	0.7	40.8	42.0	0.5
Yearling Chinook	2007	76.1	82.1	0.9	57.6	60.5	0.7
Yearling Chinook	2008	79.9	82.1	0.9	60.7	63.6	0.7
Steelhead	2008	97.0	97.9	1.1	76.8	76.6	0.9

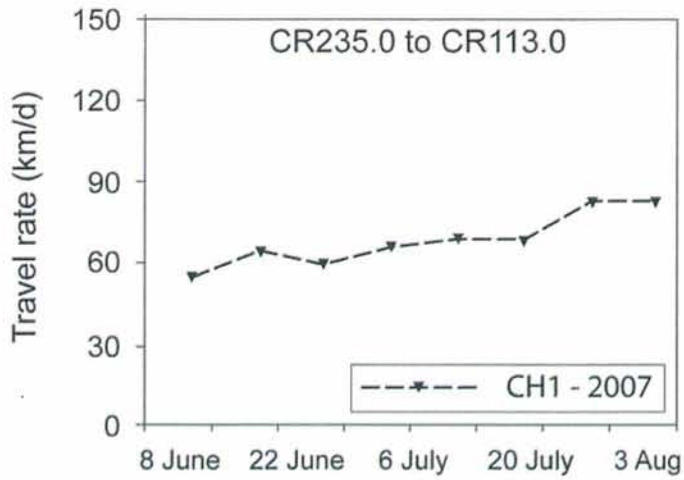
Source: Carter et al. 2009.

Carter et al. (2009) also found that outmigrating yearling Chinook, subyearling Chinook, and steelhead consistently traveled more quickly in the late spring than in the early spring (see Figure 4-20 to Figure 4-22). For example, in April 2008, yearling Chinook traveled between Bonneville Dam (RM 146/RKm 235) and Cottonwood Island (RM 70.2/RKm 113) at an average rate of approximately 20 km/day. By mid-June of the same year, yearling Chinook traveled the same distance at a rate of approximately 100 km/day.



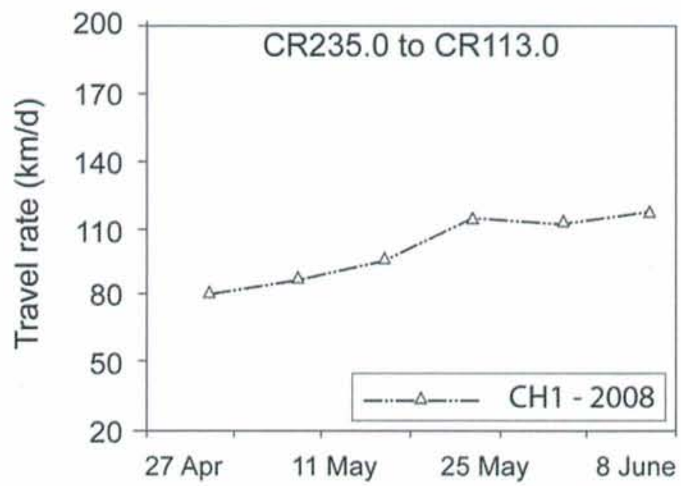
Source: Carter et al. 2009.

Figure 4-20. Weekly Median Travel Rates for Yearling Chinook Between Bonneville Dam and Cottonwood Island, 2007–2008



Source: Carter et al. 2009.

Figure 4-21. Weekly Median Travel Rates for Subyearling Chinook Between Bonneville Dam and Cottonwood Island, 2007



Source: Carter et al. 2009.

Figure 4-22: Weekly Median Travel Rates for Steelhead Between Bonneville Dam and Cottonwood Island, 2008

Extrapolating from these data, we estimate that yearling Chinook may travel through the action area at an average rate of 0.5 to 1.16 m/s, subyearling Chinook at a rate of 0.64 to 0.98 m/s, and steelhead at a rate of 0.93 to 1.30 m/s (see Table 4-19 to Table 4-21). As with other travel rate estimates, a 24-hour-travel day is assumed.

Table 4-19. Weekly Median Travel Rates for Yearling Chinook Between Bonneville Dam and Cottonwood Island, 2007–2008

Year	Day	Km/day	Feet/s	m/s
2007	2-May	45	1.71	0.52
	9-May	78	2.96	0.90
	16-May	80	3.04	0.93
	23-May	79	3.00	0.91
	30-May	80	3.04	0.93
	6-Jun	100	3.80	1.16
2008	25-Apr	25	0.95	0.29
	2-May	40	1.52	0.46
	9-May	70	2.66	0.81
	16-May	80	3.04	0.93
	23-May	85	3.23	0.98
	30-May	85	3.23	0.98
	6-Jun	97	3.68	1.12
	13-Jun	100	3.80	1.16

Source: Carter et al. 2009.

Table 4-20. Weekly Median Travel Rates for Subyearling Chinook Between Bonneville Dam and Cottonwood Island, 2007

Date	Km/day	Feet/s	m/s
13-Jun	55	2.09	0.64
20-Jun	62	2.35	0.72
27-Jun	60	2.28	0.69
4-Jun	63	2.39	0.73
11-Jun	64	2.43	0.74
18-Jul	63	2.39	0.73
25-Jul	85	3.23	0.98
1-Aug	85	3.23	0.98
13-Jun	55	2.09	0.64

Source: Carter et al. 2009.

Table 4-21. Weekly Median Travel Rates for Juvenile Steelhead Between Bonneville Dam and Cottonwood Island, 2008

Date	Km/day	Feet/s	m/s
2-May	80	3.04	0.93
9-May	85	3.23	0.98
16-May	90	3.42	1.04
23-May	112	4.25	1.30
30-May	110	4.18	1.27
6-Jun	112	4.25	1.30
2-May	80	3.04	0.93
9-May	85	3.23	0.98
16-May	90	3.42	1.04

Source: Carter et al. 2009.

In summary, migration rates for juvenile salmonids are reasonably well understood. However, rates vary between species and populations and also by time of year. While it would be inappropriate to calculate an overall average juvenile velocity across species and studies, it can be observed from the preceding data that a general tendency for downstream migrant salmonids may be in the range of 0.8–0.9 m/s.

4.14.1.1 Adult Migration

From 2003 to 2009, Columbia Basin Research counted PIT-tagged adult salmon and steelhead on return migrations at selected dams in the Columbia Basin, posting yearly results through interactive, online Data Analysis in Real Time (DART) reports (CBR 2009). Their counts include an estimate of mean travel time between dams. The dams nearest the project area at which CRB made counts are between Bonneville Dam (RM 146/ RKm 235) and McNary Dam (RM 293/RKm 471), a distance of 236 km. These dams do not occur in the action area, but, nevertheless, these data represent the best estimates available for adult transit time in the lower Columbia. Table 4-22 shows DART report estimates of mean travel time for migratory salmonids from Bonneville Dam to McNary Dam. Extrapolating from their data, we estimate transit time in meters per second and assume 24-hour-per-day travel. Because currents are stronger in the action area than they are between Bonneville and McNary Dams (CRC 2008; CEG 2008), it is reasonable to expect adult salmon and steelhead transit rates to be slower than in the action area.

Table 4-22. Historical Mean Travel Time Estimates for Adult Salmon and Steelhead from Bonneville Dam to McNary Dam

	2002	2003	2004	2005	2006	2007	2008	2009	Mean Rate (m/s)
SR Sockeye									
Mean travel time (days)	***	4.96	***	***	4.47	4.42	5.05	5.98	
Rate (m/s)	***	0.55	***	***	0.61	0.62	0.54	0.46	0.56
UCR Spring/Summer-Run Chinook									
Mean travel time (days)	8.11	8.68	6.54	6.91	7.88	8.49	7.91	6.47	
Rate (m/s)	0.34	0.31	0.42	0.40	0.35	0.32	0.35	0.42	0.36
UCR Spring-Run Chinook									
Mean travel time (days)	9.25	***	5.34	6.26	6.73	5.78	6.93	6.32	
Rate (m/s)	0.30	***	0.51	0.44	0.41	0.47	0.39	0.43	0.42
SR Fall-Run Chinook									
Mean travel time (days)	5.34	6.17	8.49	5.48	6.46	6.06	6.87	6.84	
Rate (m/s)	0.51	0.44	0.32	0.50	0.42	0.45	0.40	0.40	0.43
SR Steelhead									
Mean travel time (days)	27.83	37.29	31.47	28.65	38.25	34.48	31.66	14.49	
Rate (m/s)	0.10	0.07	0.09	0.10	0.07	0.08	0.09	0.19	0.10

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	2002	2003	2004	2005	2006	2007	2008	2009	Mean Rate (m/s)
MCR Steelhead									
Mean travel time (days)	47.04	54.09	54.20	38.71	54.94	38.68	45.80	17.31	
Rate (m/s)	0.06	0.05	0.05	0.07	0.05	0.07	0.06	0.16	0.07
UCR Steelhead									
Mean travel time (days)	15.87	30.09	19.41	17.54	***	***	15.17	13.47	
Rate (m/s)	0.17	0.09	0.14	0.16	***	***	0.18	0.20	0.16

Source: CBR 2009.

4.14.2 Habitat Use and Behavior

In general, larger (yearling) juvenile salmonids occur in the deeper, offshore channel areas of the lower Columbia River. Numerous studies have documented smaller fish (subyearling Chinook) utilizing nearshore habitats (Johnsen and Sims 1973; Dawley et al. 1986; McCabe et al. 1986; Ledgerwood et al. 1991, as cited in Carter et al. 2009), frequently at depths of 3 meters or less (Carlson et al. 2001, as cited in Carter et al. 2009). Data indicate that most active outmigration occurs in or near the navigation channel, although off-channel migration routes are also utilized (Carter et al. 2009).

There are limited data regarding the depths at which the different types of juvenile salmonids travel through the lower Columbia River and the estuary. Sampling efforts between RM 47 (RKm 76) and the mouth of the river suggested that 95 percent of juvenile fall-run Chinook were within 3 meters of the surface (Dawley et al. 1986, as cited in Carter et al. 2009).

There are studies indicating that juvenile Chinook less than 50–60 mm in length typically occupy shallow water (<1 meter), fish 60–100 mm in length occupy slightly deeper habitats (shoals, channels), and fish greater than 100 mm in length occupy both deep and shallow water habitats (Carlson et al. 2001; Bottom et al. 2005, as cited in Carter et al. 2009). Most coho salmon juveniles are found near shore in the mid-morning to late afternoon, and are found in mid-river areas at dawn and dusk (Pearson et al. 2005, as cited in Carter et al. 2009). Data indicate that juvenile chum less than 50–60 mm in length typically occupy shallow water (e.g., <1 meter), fish 60–100 mm in length occupy slightly deeper habitats (shoals, channels), and fish greater than 100 mm in length occupy both deep and shallow water habitats (Carlson et al. 2001; Bottom et al. 2005, as cited in Carter et al. 2009).

Another study found that juvenile salmonids were significantly higher in the water column during the day than during the evening and night; the same study found that most juvenile salmonids close to shore were detected within 2 meters of the bottom during both day and night (Carlson et al. 2001, as cited in Carter et al. 2009). Laboratory and field studies have shown that juvenile salmonids prefer to occupy surface waters, but will move up or down in the water column in response to changes in conditions, including temperature and oxygen levels (Birtwell and Kruzynksi 1989, as cited in Carter et al. 2009). NMFS states that salmonid use of the water column greater than 20 feet deep is rare (NMFS 2002).

Juvenile salmonids tend to move through the lower Columbia River throughout the day, with more movement during daylight hours (Dawley et al. 1986; Ledgerwood et al. 1991; Carlson et al. 2001, as cited in Carter et al. 2009; McComas et al. 2008). Yearling and subyearling Chinook are most likely to be moving between sunrise and early afternoon (Ledgerwood et al. 1991). Nearshore and mid-river catches of coho indicated a fairly uniform migration throughout the day (Ledgerwood et al. 1991, as cited in Carter et al. 2009). Using beach and purse seines, most coho were captured during the day between 0600 and 2000 hours (Dawley et al. 1986, as cited in Carter et al. 2009). One study showed steelhead moving mainly between noon and early evening (Ledgerwood et al. 1991).

Habitat preferences of eulachon within the Columbia River are not well understood. With the exception of preferred spawning habitat (which is typically coarse sand or pea-sized gravel substrate), observational data suggest that migrating eulachon exhibit little preference for habitat type, and may utilize deep, shallow, brightly lit, and/or shaded portions of the river. Out-migrants may occur anywhere along the river's transect, and at all depths (Langness 2009 personal communication). Larval eulachon have been found in some studies at greater densities at the bottom of the water column, compared to mid-level or near the surface, and may occur in greater densities outside the navigation channel than within the channel (Howell et al. 2001). However, because they are relatively weak swimmers, larval eulachon distribution and use of the water column is thought to be determined by local hydraulic conditions rather than by depth at a particular site (Langness 2009 personal communication; Howell et al. 2001).

Typical or optimal water velocities for eulachon migration or spawning are not known (Langness 2009 personal communication).

4.15 COLUMBIA RIVER BULL TROUT

4.15.1 Status and Biological Context

The CR bull trout DPS includes the entire Columbia River basin within the United States, with the exception of the Jarbidge River in Nevada. The Columbia River distribution includes all tributaries in Oregon and Washington downstream of the Snake River confluence near the town of Pasco, Washington (64 FR 58909; November 1, 1999) (see Figure 4-23).

Bull trout in the lower Columbia River below Bonneville Dam primarily inhabit tributary systems, including the Lewis, Klickitat, and Hood Rivers. Within the Lewis River system, local populations of bull trout occur in Cougar, Pine, and Rush Creeks. These populations are restricted to portions of the Lewis River upstream of Merwin Dam. Anecdotal reports of bull trout below Merwin Dam suggest that bull trout may occasionally be flushed below the dam; however, the dam does not allow fish passage, and any bull trout below the dam would not have access to upstream habitat (USFWS 2002). One local population is known in the West Fork of the Klickitat River (USFWS 2002).

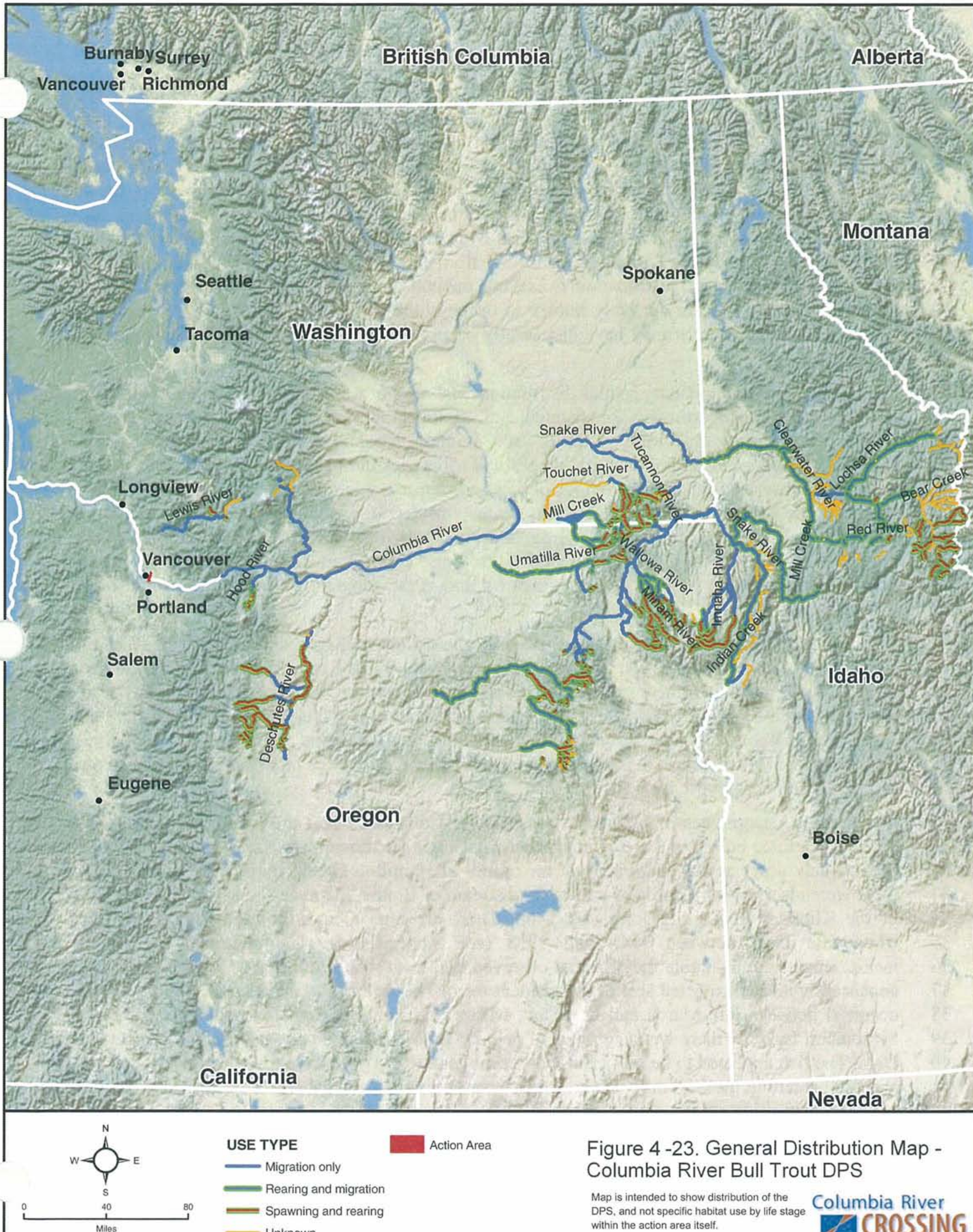

Figure 4 -23. General Distribution Map - Columbia River Bull Trout DPS

Map is intended to show distribution of the DPS, and not specific habitat use by life stage within the action area itself.

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: Sept. 2009; File Name: ESUDPS_JL194.mxd

The Hood River and its tributaries contain two local populations: Clear Branch and Hood River. The Clear Branch local population occupies the Clear Branch Hood River, Laurance Lake, and Pinnacle Creek; the Hood River local population occupies Bear Creek, Coe Branch, Compass Creek, Eliot Branch, the mainstem Hood River, and Tony Creek. Bull trout have also been sighted in East Fork Hood River tributaries and in the West Fork of Hood River; however, these populations are not well defined. Within the Hood River system, bull trout spawn in the headwater creeks (e.g., Pinnacle Creek, the Coe Branch of the Middle Fork Hood River) and use the mainstem Hood River for migration to and from the mainstem Columbia River (USFWS 2002) (see Figure 4-23). Information is lacking on bull trout presence and use of the Sandy River. No populations are currently known to occur in the White Salmon, Cowlitz, or Kalama Rivers, although bull trout may have historically occupied these rivers and suitable habitat may be present.

Current bull trout abundance, spatial distribution, and temporal use of the mainstem Columbia River have not been thoroughly documented. Bull trout exhibit both anadromous and resident (or fluvial) life histories; bull trout in the lower Columbia River basin are thought to be of the resident life history form, remaining in creeks and tributaries throughout their life cycle. Current knowledge does not support anadromous populations occurring in the mainstem Columbia River; however, the Lower Columbia Recovery Team considers the mainstem Columbia River to contain core habitat for foraging, migrating, and overwintering, which may be important for full species recovery to occur (USFWS 2002). Bull trout use of the mainstem Columbia River in the lower Columbia River basin is largely unknown and is the subject of ongoing research efforts (USFWS 2002).

Bull trout populations were historically linked by the Columbia River, and in higher reaches of the Columbia River watershed (e.g., Wenatchee and Walla Walla Rivers) bull trout are known to migrate seasonally to some extent from tributaries downstream into the Columbia River to overwinter and feed (USFWS 2002). The extent to which this occurs in the lower Columbia River (below Bonneville Dam) is not well documented, although populations in some tributaries (bull trout from Hood River, in particular) are known to migrate to the mainstem Columbia River as part of their normal life history strategy.

Documented occurrences of bull trout in the lower Columbia River are listed in Appendix J. Since 2000, three bull trout have been incidentally caught and documented at Bonneville Dam or immediately downstream of the dam at the mouth of Hamilton Creek; during this time period, there were also several records of bull trout upstream of Bonneville near Drano Lake, the mouth of the Klickitat River, and John Day Dam. There are nine records of bull trout at or near Bonneville Dam between 1941 and 1998 (see Appendix J). The sightings for which measurements are available indicate that observed bull trout were from 9 to 15 inches in length, consistent with the expected size of the resident form. The majority of sightings since 1941 have occurred between late March and late May, with a few sightings between mid-June and early September. In 2009, there were sightings of one fish on May 30 and two on June 2 at Bonneville Dam. The fish appeared to be bull trout, but recent genetic analyses have revealed that arctic char are also present in the Columbia River. Arctic char are indistinguishable from bull trout by sight, so the identification could not be confirmed.

Based on current knowledge, non-anadromous subadult and adult bull trout may be present at low levels in the lower Columbia River within the action area. If present, they would be expected to occur in the action area between late March and early September.

Based on historical data collected since 1941, bull trout could potentially be present in the Columbia River and North Portland Harbor over the time period when in-water work will take place. However, based on the locations and numbers of bull trout documented in the lower Columbia River, the number of bull trout that may occur would likely be very limited.

Bull trout do not use Burnt Bridge Creek, the Willamette River, or the Columbia Slough (63 FR 31647).

4.15.2 Limiting Factors

Limiting factors for bull trout include habitat degradation and fragmentation, migratory barriers, degraded water quality, angler harvest and poaching, entrainment into diversion channels and dams, and introduced non-native species. Land and water management activities impacting bull trout populations and habitat include dams and other diversion structures, forest management practices, livestock grazing, agriculture, road construction and maintenance, mining, and urban and rural development. Some threats to bull trout are the continuing effects of past land management activities (USFWS 2002).

4.15.3 Proposed Critical Habitat

Critical habitat was designated for CR bull trout on September 26, 2005 (70 FR 56211), but is not present in the action area. The nearest designated critical habitat is in the Hood River, approximately 64 RM (103 RKm) upstream of the action area.

A revised designation of critical habitat was proposed on January 14, 2010. Under this proposal, the lower Columbia River within the action area would be included in critical habitat (75 FR 2269). The following PCEs of proposed critical habitat are present within the action area: migratory habitats; an abundant food base; complex river environments and processes; suitable water temperatures; suitable river flows; and sufficient water quality and quantity such that normal growth and survival are not inhibited.

4.16 NORTHERN (STELLER) SEA LION – EASTERN DPS

4.16.1 Status and Biological Context

The Eastern DPS of Steller sea lions extends from California to Alaska, including the Gulf of Alaska, to 144° W longitude (a line near Cape Suckling, Alaska) (62 FR 24345; May 5, 1997).

As shown on Figure 4-24, the Steller sea lion range follows the coastline from southern California, north to Alaska, west through the Aleutian Islands and eastern Russia, and south to the northern Japan islands. In the Pacific Northwest, they occur primarily in coastal habitats in Oregon and Washington, but are present year-round in the lower Columbia River, usually downstream of the confluence of the Columbia and Cowlitz Rivers (RM 70/RKm 113) (ODFW 2008b). However, in recent years, adult and subadult male Steller sea lions have been observed at Bonneville Dam, where they prey primarily on white sturgeon (*Acipenser transmontanus*) and some Chinook that congregate below the dam.

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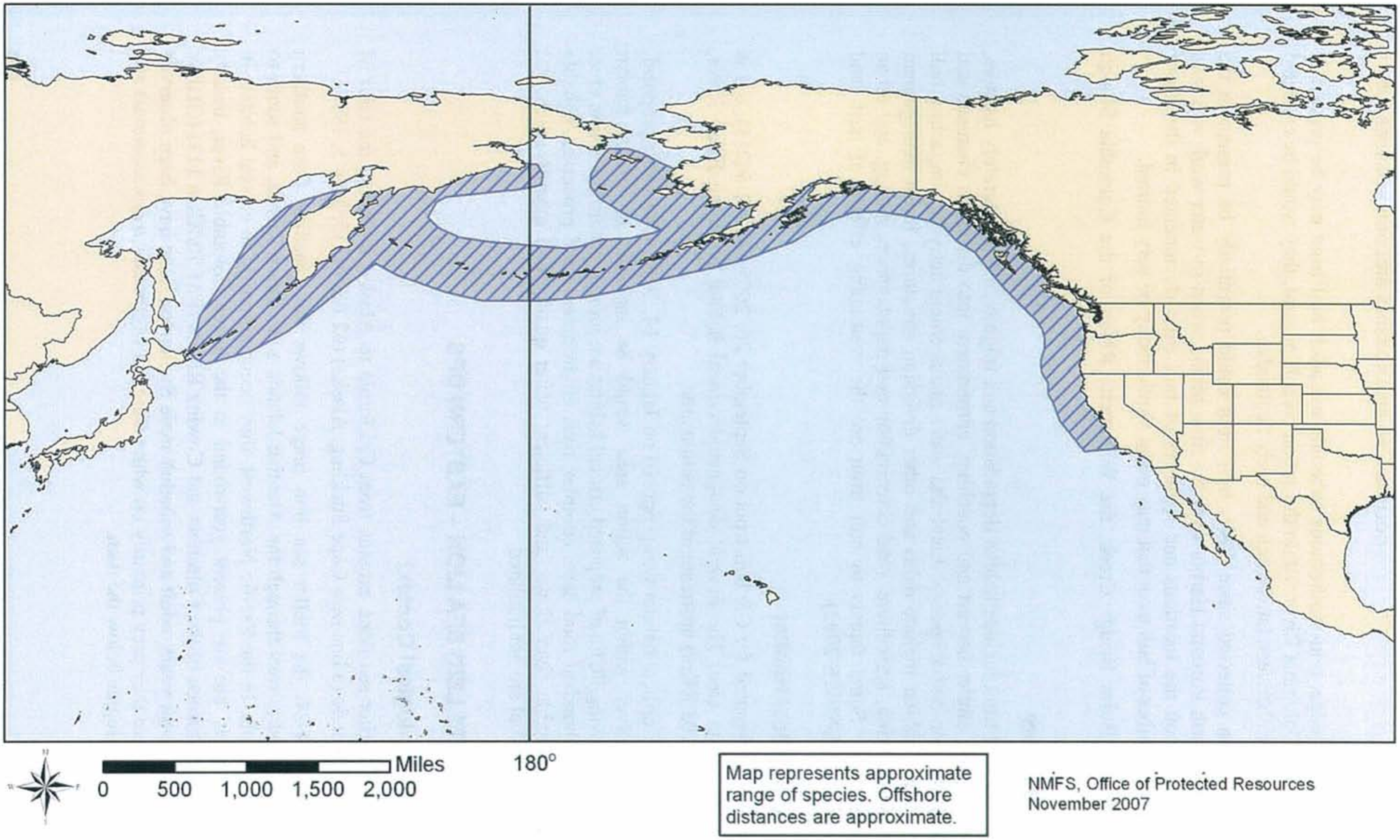

Figure 4-24. Steller Sea Lion Range

Columbia River CROSSING

In 2002, USACE began monitoring seasonal presence, abundance, and predation activities of marine mammals in the Bonneville Dam tailrace (Tackley et al. 2008). Steller sea lions have been documented every year since 2003; the lowest abundance was two Steller sea lions in 2004, and the highest was 26 in 2009 (Stansell et al. 2009).

Steller sea lions arrive at the dam in late fall (November), although occasionally individuals are sighted near Bonneville Dam as early as October (Stansell et al. 2009). Steller sea lions are present at the dam through May, and can travel between the dam and the mouth of the Columbia River several times during these months (Tackley et al. 2008). It is assumed that Steller sea lions could be present in the action area any time during the November–May window as they transit between the mouth of the river and Bonneville Dam.

Steller sea lions use the Columbia River for travel, foraging, and resting as they move between haul-out sites and the dam. There are no documented haul-out sites within the action area. The nearest known haul-out in the Columbia River is a rock formation (Phoca Rock) approximately 8 miles downstream of Bonneville Dam (approximately 32 miles upstream of the action area) (Tennis 2009a personal communication). Up to 40 Steller sea lions were observed hauled out at Phoca Rock in November and December 2009 (Stansell 2010 personal communication). Steller sea lions are also known to haul out on the south jetty at the mouth of the Columbia River, near Astoria, Oregon. There are no rookeries located in or near the action area. The nearest Steller sea lion rookery is on the northern Oregon coast at Three Arch Rocks near Oceanside (ODFW 2010a), more than 150 miles from the action area.

No tagged Steller sea lions have been observed at Bonneville Dam to date (Tennis 2009 personal communication); therefore, transit times between the south jetty and Bonneville Dam are not available for this species. However, PSFMC leads a tagging and tracking program for California sea lions, observing that transit time for California sea lions between Astoria and Bonneville Dam is 30-36 hours (upstream), and 15 hours from Bonneville Dam to Astoria (downstream) (Tennis 2009b personal communication). CRC assumes similar transit times for Steller sea lions, using California sea lions as the closest available proxy.

Steller sea lions are likely to be transiting in the Columbia River and North Portland Harbor during the time that in-water work will take place.

The abundance of the Eastern DPS of Steller sea lions is increasing throughout the northern portion of its range (Southeast Alaska and British Columbia), and stable or increasing slowly in the central portion (Oregon through central California). In the southern end of its range (Channel Islands in southern California), it has declined significantly since the late 1930s, and several rookeries and haul-outs have been abandoned. Changes in ocean conditions (e.g., warmer temperatures) may be contributing to habitat changes that favor California sea lions over Steller sea lions in the southern portion of the Steller range (NMFS 2007). The overall annual rate of increase for the Eastern DPS is 3.1 percent throughout most of the range (Oregon to southeastern Alaska) (Angliss and Allen 2007). The total population of the Eastern DPS of Steller sea lions is estimated to be approximately 45,095 to 55,832 (Angliss and Allen 2007). The most recent minimum count for Steller sea lions in Oregon and Washington was 5,813 in 2002. Trend counts in Oregon were relatively stable in the 1980s, with uncorrected counts between 2,000 and 3,000 sea lions (NMFS 1992). Counts in Oregon have shown a gradual increase from 1,486 in 1976 to 4,169 in 2002 (NMFS 2007).

4.16.2 Limiting Factors

Limiting factors for recovery of Steller sea lions include reduced food availability, possibly resulting from competition with commercial fisheries; incidental take and intentional kills during commercial fish harvests; subsistence take; entanglement in marine debris; disease; pollution; and harassment.

The change in food availability, associated with lowered nutritional status of females and consequent reduced juvenile recruitment, may be the primary cause of the decline (60 FR 51968). Declines of this species in the early 1980s were associated with exceedingly low juvenile survivorship, whereas declines in the 1990s were associated with disproportionately low fecundity (Holmes and York 2003). Steller sea lions are also sensitive to disturbance at rookeries during pupping and breeding and at haul-out sites.

4.16.3 Designated Critical Habitat

Critical habitat was designated for Steller sea lions on August 27, 1993 (58 FR 45269), but is not present within the action area. The nearest designated critical habitat is on the southern Oregon coast at Orford Reef, approximately 5 miles northwest of Port Orford and more than 200 miles from the project area (NMFS 2008h).

4.17 GREEN STURGEON (SOUTHERN DPS)

4.17.1 Status and Biological Context

The Southern DPS of green sturgeon includes coastal and Central Valley populations south of the Eel River in California, with the only known spawning population in the Sacramento River (71 FR 17757, April 7, 2006). Adults and subadults from this DPS migrate up the coast and use coastal estuaries, including the lower Columbia River, for resting and feeding during the summer (see Figure 4-25).

Green sturgeon occur in the Columbia River up to Bonneville Dam (RM 146/RKm 235), but are predominantly distributed below RM 37 (RKm 60) (68 FR 4433). Adult green sturgeon enter the Columbia River estuary when water temperatures reach 15°C (59°F) in June and spend the warm summer months resting, in general preferring the salt water portions of the lower estuary. There is also evidence of feeding use of the estuary during the summer months (Langness 2008 personal communication). Adult and subadult green sturgeon in the Columbia River estuary feed on crangonid shrimp, burrowing thalassinidean shrimp (primarily the burrowing ghost shrimp *Neotrypaea californiensis*), amphipods, clams, juvenile Dungeness crab (*Cancer magister*), anchovies, sand lances (*Ammodytes hexapterus*), lingcod (*Ophiodon elongatus*), and other, unidentified fish species (NMFS 2008c). Studies indicate that green sturgeon utilizing the lower Columbia River are subadults and adults (13 years and older and at least 90 cm fork length) (Langness 2009 personal communication). Green sturgeon usually leave the estuary by September to return to winter habitat in the southern portions of their range.

Green sturgeon are potentially present in the Columbia River and North Portland Harbor portions of the action area from mid-May until September (CRC 2009), including the time that in-water work will take place. However, suitable habitat (i.e., estuarine areas with higher salinity and an abundance of preferred prey species) for this species is extremely limited within the action area.

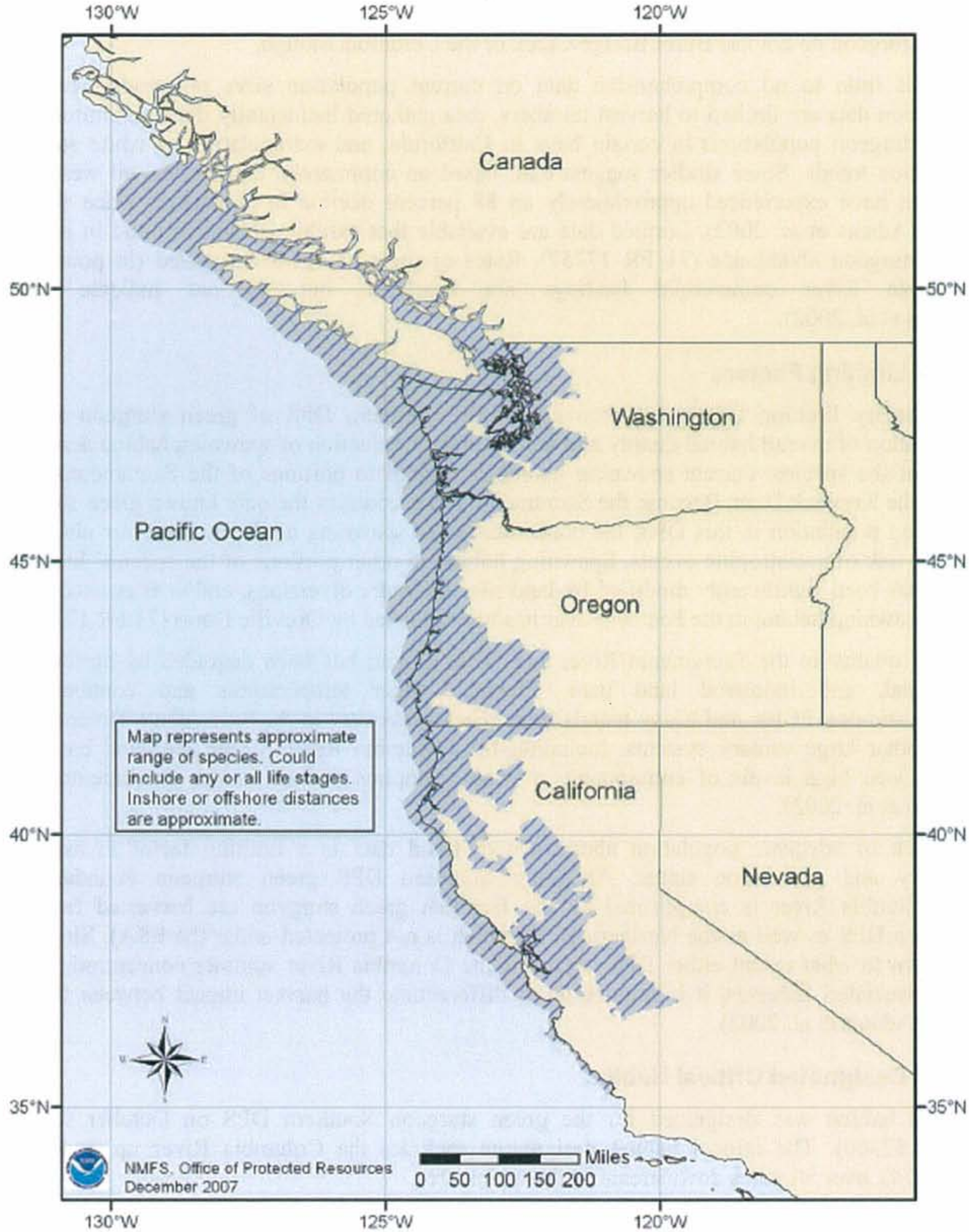

Figure 4-25. Green Sturgeon Range

Map is intended to show distribution of the species, and not specific habitat use by life stage within the action area itself. The southern DPS includes coastal and Central Valley populations south of the Eel River in California. Adults and subadults from this DPS use coastal estuaries, including the Lower Columbia River, during the summer.

Columbia River CROSSING

Analysis by J. Koloszar Analysis Date: May 20 2009; Plot Date: May 20, 2009; File Name: ESUDPS_JL194.mxd

Green sturgeon do not use Burnt Bridge Creek or the Columbia Slough.

There is little to no comprehensive data on current population sizes or trends. Available population data are limited to harvest numbers, data gathered incidentally during monitoring of white sturgeon populations in certain bays in California, and extrapolation of white sturgeon population trends. Some studies suggest that, based on commercial catch rates, all west coast sturgeon have experienced approximately an 88 percent decline in abundance since the late 1800s (Adams et al. 2002). Limited data are available that exhibit a negative trend in juvenile green sturgeon abundance (71 FR 17757). Rates of green sturgeon harvested (in pounds) in Columbia River commercial landings are available, but do not indicate trends (Adams et al. 2002).

4.17.2 Limiting Factors

The primary limiting factors for recovery of the Southern DPS of green sturgeon are the degradation of overall habitat quality and the significant reduction of spawning habitat across the range of the species: current spawning habitat is limited to portions of the Sacramento River below the Keswick Dam. Because the Sacramento River contains the only known green sturgeon spawning population in this DPS, the concentration of spawning adults in one river places the DPS at risk of catastrophic events. Spawning habitat in other portions of the species' historical range has been significantly modified by land use and water diversions, and/or is not accessible (e.g., spawning habitat in the Feather River has been blocked by Oroville Dam) (71 FR 17757).

Habitat quality in the Sacramento River and Delta system has been degraded by agricultural, municipal, and industrial land uses. Elevated water temperatures and contamination from pesticides, PCBs, and heavy metals limit species recovery in the Sacramento River as well as in other large estuary systems, including the Columbia River. Green sturgeon have also experienced high levels of entrainment at water pumping stations in the Sacramento Delta (Adams et al. 2002).

The lack of adequate population abundance or trend data is a limiting factor in assessing recovery and population status. Assessing Southern DPS green sturgeon abundance in the Columbia River is complicated by the fact that green sturgeon are harvested from the Southern DPS as well as the Northern DPS (which is not protected under the ESA). Since it is unknown to what extent either DPS is part of the Columbia River summer concentrations and their associated fisheries, it is impossible to differentiate the harvest impact between the two DPSs (Adams et al. 2002).

4.17.3 Designated Critical Habitat

Critical habitat was designated for the green sturgeon Southern DPS on October 9, 2009 (74 FR 52300). The critical habitat designation includes the Columbia River up to RM 46 (RKm 74), over 50 miles downstream of the action area.

4.18 SOUTHERN RESIDENT DPS KILLER WHALE

4.18.1 Status and Biological Context

As shown on Figure 4-26, the distribution of the Southern Resident Killer Whale DPS includes the inland waterways of Puget Sound, Strait of Juan de Fuca, and Southern Georgia Strait during the spring, summer, and fall. They are known to occur in the coastal Pacific Ocean off of Oregon, Washington, Vancouver Island, and more recently, off the coast of central California in the south and off the Queen Charlotte Islands to the north. They do not occur in the freshwater action area water bodies described in this BA. Little is known about the winter movements and range of the Southern Resident stock. Southern Residents are not known to associate with other resident whales, and genetic data suggest that Southern Residents interbreed with other killer whale populations rarely if at all (70 FR 69903). The Southern Resident Killer Whale DPS consists of three pods, identified as J, K, and L pods. Although the entire Southern Resident DPS has the potential to occur in the coastal waters at any time during the year, occurrence is more likely from November through April. For additional information about the Southern Resident Killer Whale DPS, see Appendix H.

Southern Residents spend the majority of their time from late spring to early autumn in inland waterways of Washington State and British Columbia (Strait of Georgia, Strait of Juan de Fuca, and Puget Sound) (Bigg 1982; Ford et al. 2000; Krahn et al. 2002). Typically, J, K and L pods arrive in May or June and spend most of their time in the core area of Georgia Basin and Puget Sound until departing in October. K and L pods also make frequent trips to the outer coasts of Washington and southern Vancouver Island during this time; these trips generally last a few days (Ford et al. 2000).

The Southern Residents were formerly thought to range southward along the coast to about Grays Harbor (Bigg et al. 1990) or the mouth of the Columbia River (Ford et al. 2005). However, recent sightings of members of K and L pods in Oregon (in 1999 and 2000) and California (in 2000, 2003, 2005, 2006 and 2008) have considerably extended the southern limit of their known range (NMFS 2008b). There have been 40 verified sightings or strandings of J, K, or L pods along the outer coast from 1975 to the present, with most made from January to May. These include 16 records off Vancouver Island and the Queen Charlottes, 11 off Washington, 4 off Oregon, and 9 off central California. Most records have occurred since 1996, but this is more likely because of increased viewing effort along the coast during this time period.

Although there is little information available regarding the historical abundance of Southern Resident killer whales, two methods have been used to estimate a historical population size of 140 to 200. The minimum estimate (~140) is the number of whales killed or removed for public display in the 1960s and 1970s added to the remaining population at the time of the captures. The maximum estimate (~200) is based on a recent genetic analysis of microsatellite DNA (NMFS 2003).

Figure 4-26. Southern Resident Killer Whale DPS Distribution

Biological Assessment Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: Nov. 2009; File Name: KillerWhaleDist_JL194.mxd

At present, the Southern Resident population has declined to essentially the same size as estimated during the early 1960s, when it was considered as likely depleted (Olesiuk et al. 1990). Since censuses began in 1974, J and K pods have steadily increased their numbers. However, the DPS population suffered approximately a 20 percent decline from 1996–2001, largely driven by declines in L pod. There have been recent increases in the population from 2002–2006, indicating that L pod's decline may have ended; however, such a conclusion is premature. The 2007 census counted 87 Southern Resident killer whales, 25 in J pod, 19 in K pod, and 43 in L pod. As of November 2009, the Southern Resident population totaled 87 individuals: 27 in J pod, 19 in K pod, and 41 in L pod (Balcomb 2009 personal communication).

4.18.2 Limiting Factors

Limiting factors for Southern Resident killer whales include quantity and quality of prey, toxic chemicals which accumulate in top predators, and disturbances from sound and vessel traffic. Recent studies have documented high concentrations of polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT), and polybrominated diphenylethers (PBDEs) in killer whales (Ross et al. 2000; Ylitalo et al. 2001; Reijnders and Aguilar 2002; Krahn et al. 2004). As top predators, when killer whales consume contaminated prey they accumulate the contaminants in their blubber. When prey is scarce, killer whales metabolize their blubber and the contaminants are mobilized (Krahn et al. 2002). Nursing females transmit large quantities of contaminants to their offspring. The mobilized contaminants can reduce the whales' resistance to disease and can affect reproduction.

Several studies in the inland waters of Washington State and British Columbia have observed changes in killer whale behavior in the presence of vessels (Kruse 1991; Williams et al. 2002a,b; Foote et al. 2004; Bain et al. 2006). These behavioral changes can affect the whales' foraging efficiency and the amount of energy they expend in migrating, foraging, and other activities. Sound from vessels can also interfere with communication and prey location.

Oil spills have also been identified as a potential risk factor for this DPS. In marine mammals, acute exposure to petroleum products can cause changes in behavior and reduced activity, inflammation of the mucous membranes, lung congestion, pneumonia, liver disorders, and neurological damage (Geraci 1990; Wursig 1990). In addition, oil spills have the potential to adversely impact habitat and prey populations, and, therefore, may adversely affect Southern Residents by reducing food availability.

4.18.3 Designated Critical Habitat

Critical habitat was designated for Southern Resident killer whales on November 29, 2006 (71 FR 69054). Designated critical habitat includes the summer core area of Puget Sound, the Strait of San Juan de Fuca, and Haro Strait. Critical habitat is not present within the action area.

4.19 EULACHON – SOUTHERN DPS

4.19.1 Status and Biological Context

Figure 4-27 illustrates the eulachon range. The Southern DPS of this species has been determined to be threatened under the ESA; the final ruling will become effective on May 17, 2010 (75 FR 13012). The Southern DPS of eulachon consists of populations that spawn in rivers south of the Nass River in British Columbia, up to and including the Mad River in California. Within the range of the Southern DPS, major production areas or ''core populations'' for this species include the Columbia River (74 FR 10857).

The majority of the eulachon production south of the U.S./Canadian border is in the Columbia River basin; the largest and most consistent spawning runs in the basin occur in tributaries of the Columbia River from RM 25 (RKm 40) to RM 146 (RKm 235), directly downstream of Bonneville Dam, and in the Cowlitz River (73 FR 13187). The timing of adult entry into the Columbia system is highly variable. This is particularly evident for the Sandy River that provides the last significant spawning area for eulachon upstream of the CRC area, although some mainstem and tributary spawning occurs and is known locally (Langness 2009 personal communication). The annual catch record shows eulachon to be absent from the Sandy River in one or more consecutive years (JCRMS 2007; NOAA 2008). The ODFW typically investigates first reports of eulachon presence in the Sandy River and maintains records of first arrival (North 2009 personal communication). Eulachon runs have been recorded 31 of 81 years (1929–2009), with sustained absences in 1958–1970 and 1989–2000. January 23 and April 20 were the earliest and latest landings, respectively. March timing for first entry is most common; the median entry date for the Sandy River was March 24. Note that first entry is not the peak abundance of the run which occurs some time later, potentially into the early summer.

Spawning occurs in fresh water in the lower Columbia basin soon after entry (January through May), at water temperatures between 4 and 10°C (40°F and 50°F). Preferred spawning habitat consists of coarse sand or pea-sized gravel substrates (Smith and Saalfeld 1955; Romano et al. 2002). Spawning depth generally ranges from 8 to 20 feet, with a preference for calm water near a shoreline (Langness 2009 personal communication; LCFRB 2004). Eggs are demersal and adhesive and develop over a period of 30-40 days depending on water temperature, and then immediately begin non-volitional drift downstream to tidal estuarine habitats. Larvae are 4 to 8 mm in length at hatching (WDFW and ODFW 2001). Adults are semelparous (die soon after spawning).

Outmigration (larval drift) in the lower Columbia River generally occurs between February and mid-June, peaking in February and March (73 FR 13187; WDFW and ODFW 2001; ODFW and WDFW 2008b; LCFRB 2004). However, larval presence in the CRC project area can be expected to be as variable by month and year as the adult returns indicate for the Sandy River. Larval drift beyond June and into peak summer water temperatures is uncertain and potentially dependent on peak water temperatures.

After entering the lower Columbia River system, eulachon adults are observed to occupy and utilize mainstem and tributary habitats progressively upstream, with the Sandy River being the latest (Langness 2009 personal communication). Therefore, while eulachon enter the river beginning in December or January, they would be expected to arrive in the Columbia River and North Portland Harbor portions of the action area from late January through the end of August. However, adult presence may be limited by sustained water temperatures exceeding 10–11°C, the temperature range at which adult movements (net migration) markedly decrease (Langness 2009 personal communication). Larval eulachon may be present in the action area from mid-April into the summer months, assuming that in most years unknown temperature/survival thresholds are not reached. Thus, they are likely to be present during in-water work. Eulachon do not use Burnt Bridge Creek or the Columbia Slough (74 FR 10857).

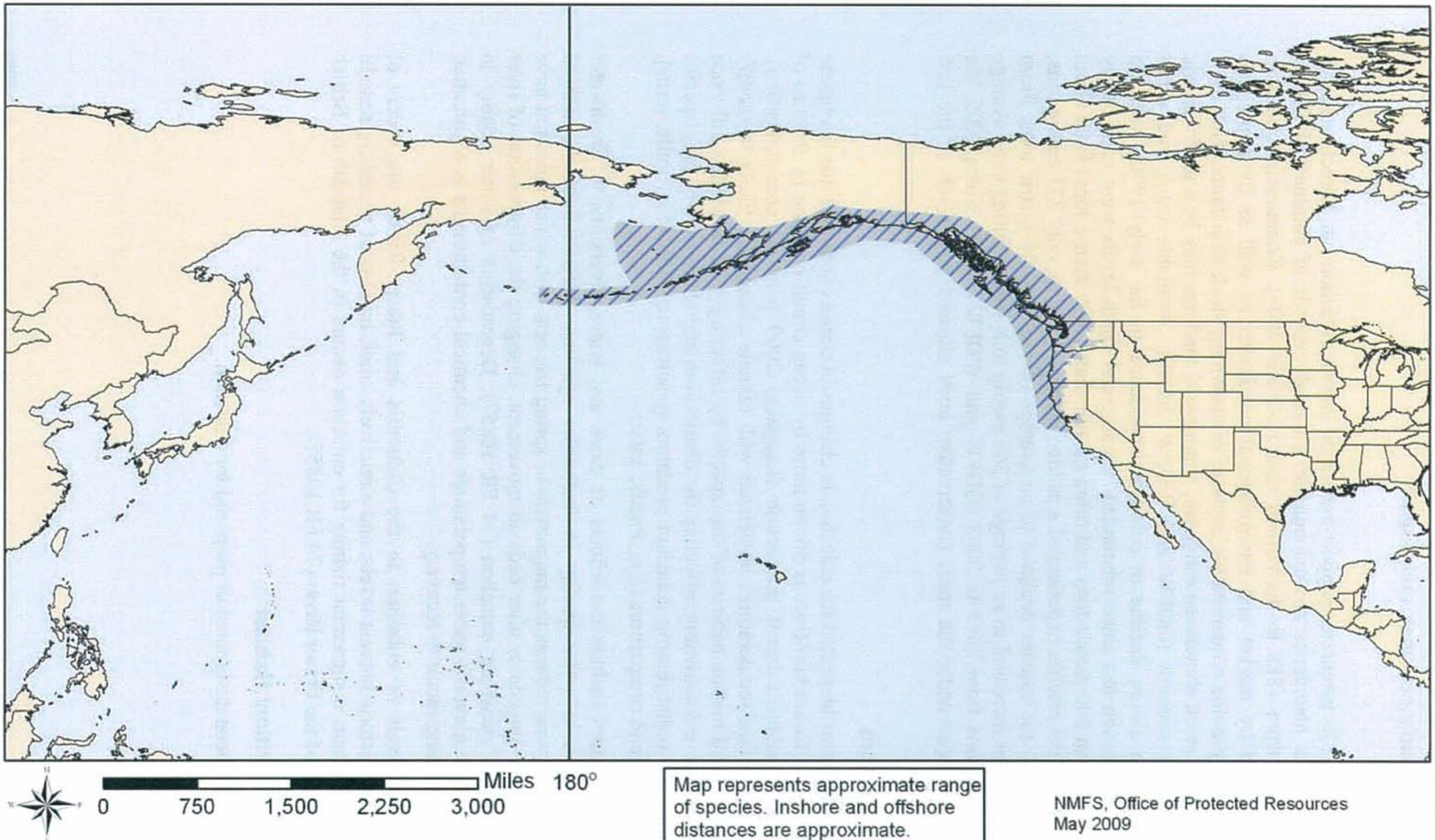

Figure 4-27. Eulachon Range

Columbia River CROSSING

The Columbia River and its tributaries support the largest known eulachon run. Direct estimates of adult spawning stock abundance are unavailable, although records of commercial fishery landings are available from 1888 to the current time (LCFRB 2004). Commercial eulachon landings are influenced by market and environmental conditions as well as by population abundance, and do not provide a quantitative measure of spawning stock abundance. However, in the absence of direct stock abundance estimates, commercial landings may be a useful metric of relative annual run strength (ODFW and WDFW 2008b). Available catch and effort information indicate an abrupt decline in eulachon abundance in the early 1990s, with no evidence that the population has since rebounded. Commercial catch levels were consistently high (usually greater than 500 metric tons and often greater than 1,000 metric tons) from about 1915 to 1992. In 1993, the catches experienced a sudden decline, yielding only 233 metric tons; between 1994 and 2000 the catches declined to an average of less than 40 metric tons. From 2001 to 2004, the catches increased to an average of 266 metric tons before falling to an average of less than 5 metric tons from 2005 to 2008 (ODFW and WDFW 2008b). Since 2005, the fishery has been managed under the most conservative level allowed as a result of the low returns (74 FR 10857).

4.19.2 Limiting Factors

The primary limiting factor identified for eulachon is changes in ocean conditions due to climate change. Run size in the Columbia River is driven more by ocean conditions than by the size of the parent run or subsequent larval production (Langness 2009 personal communication). Changes in air and surface temperatures associated with climate change are likely to modify freshwater, estuarine, and marine habitats of this species by affecting peak flows that influence freshwater temperatures and spawning, affecting the distribution and abundance of prey species (e.g., zooplankton) and redistributing eulachon predators (piscivorous birds [e.g., gulls, terns], sea lions, and sturgeon) and competitors (e.g., Pacific hake).

Additional limiting factors include the effects of dams and water diversions on freshwater systems, and reductions in water quality in freshwater systems. Alteration of the natural hydrograph of river systems reduces the magnitude of spring freshets with which eulachon have evolved. Dams can also impede or alter bedload movement, changing the composition of river substrates important to spawning eulachon (74 FR 10857). Degradation of water quality in spawning habitat due to elevated water temperatures and chemical contaminants is a potential, yet undocumented, limiting factor to recovery.

Commercial harvest levels of eulachon in the Columbia and Fraser Rivers are orders of magnitude lower than historic harvest levels, and a relatively small number of vessels operate in this fishery. No significant commercial fishing for eulachon occurs in the Klamath or British Columbia Rivers north of the Fraser River (74 FR 10857).

4.19.3 Designated Critical Habitat

Critical habitat has not been designated or proposed for eulachon.

Section 5

Section 5

SECTION 5

What does this section present?

Section 5 presents an analysis of the effects of past and ongoing human and natural factors leading to the current condition of listed species and their habitat within the action area. This section discusses historical and present conditions of both terrestrial and aquatic habitats. The discussion of aquatic habitat focuses on surface water bodies that are affected by the project: the Columbia River, North Portland Harbor, Columbia Slough, and Burnt Bridge Creek.

This section also presents the baseline condition of critical habitat units present in the action area. By identifying the current baseline, the BA can determine whether the project restores, maintains, or degrades suitable habitat for listed species.

5. ENVIRONMENTAL BASELINE

This section presents an analysis of the effects of past and ongoing human and natural factors leading to the current status of listed species and their habitat (including designated critical habitat) within the action area.

The action area is located within the Lower Columbia River subbasin. The Columbia River and its tributaries are the dominant aquatic system in the Pacific Northwest. The Columbia River originates on the west slope of the Rocky Mountains in Canada and flows approximately 1,200 miles to the Pacific Ocean, draining an area of approximately 219,000 square miles in Washington, Oregon, Idaho, Montana, Wyoming, Nevada, and Utah. Within the U.S., there are 11 major dams along the main reach of the river. In addition, there are 162 smaller dams that form reservoirs with capacities greater than 5,000 acre-feet in the Canadian and United States' portions of the basin (Fuhrer et al. 1996). Saltwater intrusion from the Pacific Ocean extends approximately 23 miles upstream from the river mouth at Astoria. Coastal tides influence the flow rate and river level up to Bonneville Dam at RM 146.1 (RKm 235) (USACE 1989).

5.1 HISTORICAL CONDITIONS

Within the Lower Columbia River subbasin, including the action area, flooding was historically a frequent occurrence, contributing to habitat diversity via flow to side channels and deposition of woody debris. The Lower Columbia River estuary is estimated to have once had 75 percent more tidal swamps than the current estuary because tidal waters could reach floodplain areas that are now diked. These areas provided feeding and resting habitat for juvenile salmonids in the form of low-velocity marshland and tidal channel habitats (Bottom et al. 2005).

Dams built on the river between the 1930s and 1970s significantly altered the timing and velocity of hydrologic flow and reduced peak season discharges. Availability of aquatic habitat for native fish, particularly those that rely heavily on low-velocity side channel habitat for holding, feeding, and rearing, has declined as a result of these changes to habitat-forming processes. Aquatic habitat components that have been affected by these changes include the amount and distribution of woody debris (e.g., controlled flows and navigation management discourage free transport of large wood), rates of sand and sediment transport, variations in temperature patterns, the complexity and species composition of the food web, the distribution and abundance of salmonid predators, the complexity and extent of tidal marsh vegetation, and seasonal patterns of salinity.

The Columbia River estuary historically received annual spring freshet flows that averaged 75–100 percent higher than current freshet flows. In addition, historical winter flows (October through March) were approximately 35–50 percent lower than current flows. The greater historical peak and variable flows encouraged greater sediment transport and more flooding of wetlands, contributing to a more complex ecosystem than exists today (ISAB 2000).

Historically, terrestrial habitat in the action area was characterized by closed upland forest/woodland, with patches of grassland savannah and prairie in lowland areas near water (Hulse et al. 2002). Forest types in the region included old-growth conifers such as Douglas-fir (*Pseudotsuga menziesii*), spruce (*Picea* sp.), and hemlock (*Tsuga* sp.); remnant hardwoods (e.g., Oregon oak [*Quercus garryana*] woodlands); and riparian, wetland, and aquatic systems (Omernik 1987). Most upland habitat in the action area has been converted to commercial and residential developed uses. The action area is located within the Pacific Flyway, the major north-south route for migratory birds that extends from Patagonia to Alaska. Migratory birds use the area for resting, feeding, and breeding.

5.2 EXISTING BASELINE CONDITIONS

5.2.1 Terrestrial Habitats

Starting in the mid-1800s, European settlement and development of urban areas gradually displaced native plant and wildlife habitats. Current urbanized conditions preclude the persistence of most large mammals and many native amphibians, reptiles, birds, and other wildlife that were once common in the action area. Terrestrial vegetation and habitats currently are limited to urban landscapes and relatively small habitat patches protected by city and/or county regulations or programs (e.g., wetlands, forested park areas, open spaces, and riparian buffers), and currently support species with relatively small home ranges and restricted habitat requirements (e.g., turtles). Portions of the region adjacent to the action area (e.g., Forest Park and the western end of Hayden Island) retain forested and wetland habitats capable of supporting native wildlife.

Throughout the region and within the action area, most natural habitat for native plants has been lost or highly degraded through land use conversion from natural to urban use. Remaining habitat for botanical resources (insofar as it exists within the action area), particularly for rare plants, is restricted to open space, wetlands, riparian buffers, and park lands managed under protective mandate. These habitats tend to be relatively small and isolated from each other, limiting the distribution of native plants. Non-native and noxious weeds are ubiquitous in the action area and further limit the ability of native plants to persist in most of the remaining suitable habitat.

5.2.2 Aquatic Habitats

The action area contains portions of the following water bodies: the lower Columbia River, North Portland Harbor, Columbia Slough, and Burnt Bridge Creek. These are described individually in more detail below.

Because of potential impacts to the diet of the Southern Resident DPS of killer whales, the action area also includes that portion of the Pacific Ocean within 50 km of the coast from southern Oregon to the Queen Charlotte Islands. A description of the environmental baseline for this portion of the action area appears in Appendix H.

5.2.2.1 Columbia River and North Portland Harbor

The Columbia River and North Portland Harbor portions of the action areas are part of the Columbia River estuary. The Columbia River estuary is the portion of the Columbia River from the mouth upstream to all tidally influenced areas (that is, to Bonneville Dam). The I-5 bridges are located at RM 106 (RKm 171) of the Columbia River. The portion of the action area that occurs within the Columbia River extends from RM 101 to 118 (RKm 163 to 190). This area is highly altered by human disturbance, and urbanization extends up to the shoreline. There has been extensive removal of streamside forests and wetlands throughout this portion of the action area. Riparian areas have been further degraded by the construction of dikes and levees and the placement of streambank armoring. For several decades, industrial, residential, and upstream agricultural sources have contributed to water quality degradation in the river. Additionally, existing levels of disturbance are high due to heavy barge traffic.

The North Portland Harbor is a large side channel of the Columbia River that flows between the south side of Hayden Island and the Oregon mainland. The channel branches off the Columbia River approximately 2 RMs upstream (east) of the existing bridge site, and flows approximately 5 RMs downstream (west) before rejoining the mainstem Columbia River.

The existing I-5 crossing consists of two separate bridges. Each bridge is approximately 3,500 feet long by 45 feet wide with approximately 284,000 sq. ft. of total deck area located directly above the water surface. The bottom of each deck ranges from 25 to 60 feet above the water surface. Together, these bridges have 11 pairs of bridge piers, nine of which are located below the ordinary high water line (OHW) of the Columbia River. Two pairs (piers 10 and 11) are located in shallow-water (that is, less than 20 feet deep). Each pier measures approximately 32 feet wide by 50 feet long at the footing. In total, the in-water piers occupy approximately 27,800 sq. ft. of substrate and represent approximately 44,000 cubic yards of fill below OHW. At the existing structures, maximum water depth is about 40 to 45 feet. At present, all stormwater runoff drains directly from the bridge deck through scuppers into the Columbia River without undergoing water quality treatment. Together, these structures convey approximately 135,000 vehicles per day.

The existing North Portland Harbor bridge conveys I-5 from Hayden Island to the mainland. The structure is approximately 1,325 feet long by 150 feet wide with approximately 144,000 sq. ft. of total deck area located directly above the water surface. The bottom of the deck ranges from 25 to 30 feet above the water surface. This bridge has a total of 10 bents, six of which occur below OHW. Each bent consists of three piers, each measuring approximately 24 by 24 feet at the mudline. In total, the piers occupy 10,368 sq. ft. of substrate below OHW. Water depths at the crossing range from 0 to 20 feet, meaning that all of the piers occur in shallow water. At present, all stormwater runoff drains directly from the bridge deck through scuppers into North Portland Harbor without undergoing water quality treatment. This bridge conveys approximately 137,950 trips per day.

Hydrology

The 12 major dams located in the Columbia Basin are the primary factors affecting flow conditions in the action area. Consequently, the Columbia River, including the action area, is a highly managed waterbody that resembles a series of slack-water lakes rather than its original free-flowing state. Development of the hydropower system on the Columbia River has significantly influenced peak seasonal discharges and the velocity and timing of flows in the river. The Columbia River estuary historically received annual spring freshet flows that were on average 75 to 100 percent higher than current flows (ISAB 2000). Historical winter flows (October through March) also were approximately 35 to 50 percent lower than current flows (ISAB 2000). The second major contributor to stream flow conditions in the action area is tidal influence from the Pacific Ocean. Although the saltwater wedge does not extend into the action area, high-tide events affect flow and stage in the Columbia up to Bonneville Dam.

Hydrology in the action area has been profoundly altered from historical conditions. In the action area, natural landforms and constructed landforms (e.g., dikes and levees) are the dominant floodplain constrictions, while bridge footings are the subdominant floodplain constrictions.

Nine bridge pier pairs are located below OHW in the mainstem Columbia River, and one bridge pier is located below OHW in North Portland Harbor. A flood control levee runs along the south bank of North Portland Harbor, forming a boundary between the adjacent neighborhoods and the harbor. Numerous upstream dams, levees located along shorelines, and channel modifications (e.g., armoring, reshaping) have restricted habitat-forming processes such as sediment transport and deposition, erosion, and natural flooding. Therefore, habitat complexity is significantly reduced from historic conditions. Shoreline erosion rates are likely slower than they were historically due to flow regulation. The river channel is deeper and narrower than under historical conditions (Bottom et al. 2005).

Reduced flow poses particularly high risks for juvenile anadromous fish. Dramatic reductions in flow compared to the historical spring freshet have increased the travel time of juvenile outmigrants. This increases potential exposure to predation, elevated temperatures, disease, and other environmental stressors (NMFS 2008e, Bottom et al. 2005).

Water Quality

The Columbia River and North Portland Harbor are on the DEQ 303(d) list for the following parameters: temperature, polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs), dichlorodiphenyltrichloroethane (DDT) metabolites (e.g., dichlorodiphenyldichloroethylene [DDE]), and arsenic (DEQ 2007a). The Columbia River is on the Washington State 303(d) list for temperature, PCBs, and dissolved oxygen (Ecology 2009b). The U.S. Environmental Protection Agency (EPA) has approved TMDLs for dioxin and total dissolved gas in the Columbia River (DEQ 1991, 2002). In addition to the contaminants listed above, dissolved copper, a neurotoxicant that damages the olfactory abilities of fish, is also known to be present above naturally occurring levels in the Columbia River. Studies indicate that dissolved copper in the action area may occur at levels known to injure salmonids (WSDOT 2005; Ecology 2006; DEQ 2009).

Current studies indicate that there are high levels of chemical contaminants in the salmonid food chain in the Columbia River estuary (NMFS 2004). During several studies at Sand Island in the lower estuary, NMFS NWFSC Environmental Conservation Division consistently found elevated levels of DDT and PCBs in the stomach contents of juvenile salmonids (NWFSC Environmental Conservation Division 2001, cited in NMFS 2004). The PCB concentrations were of particular concern because levels exceeded threshold tissue concentrations believed to cause adverse effects to salmonids. The high levels of these contaminants in stomach contents indicated that exposure occurred while the juvenile salmonids were present in the estuary (NMFS 2004). Other data suggest that PAH concentrations are increasing in the lower estuary. In 1998, PAH concentrations found in the stomach contents of juvenile Chinook and PAH concentrations found in fish bile of collected near Sand Island were very low. However, by 2000, concentrations of PAH in both stomach contents and in fish file substantially higher (NMFS 2004).

Pesticides and heavy metal contaminants have been detected in Columbia River sediments (DEQ 2007b, as cited in NMFS 2008e), potentially resulting in immunosuppression, and reduced growth rates in juvenile fish during their residence in the estuary (Arkoosh et al. 1991, 1994, 1998; Varanasi et al. 1993; Casillas et al. 1995a, 1995b, and 1998a, all cited in NMFS 2008e).

Terrestrial portions of the action area that drain to the Columbia River and North Portland Harbor are highly urbanized, containing a complex system of roadways, including I-5, state highways, local access roads, residential streets, parking lots, and other impervious surfaces. The high area of impervious surface has implications for water quality in the Columbia River and North Portland Harbor. At present, the action area contains approximately 153 acres of pollution-generating impervious surface (PGIS) that drains to these water bodies. Of these, nearly 150 acres drain into the water without first undergoing water quality treatment. Typical pollutants found in stormwater runoff include total suspended solids, nutrients, oil and grease, other fluids associated with automobiles, PAHs, agricultural chemicals used in highway maintenance, total zinc, dissolved zinc, total copper, dissolved copper, and other metals (NMFS 2008j). These pollutants are known to be toxic to fish (Everhart et al. 1953; Hecht et al. 2007; Johnson et al. 2009; Sandahl et al. 2007; Sprague 1968) and have potential adverse effects on salmon and steelhead even at ambient levels (Loge et al. 2006; Hecht et al. 2007; Johnson et al. 2007; Sandahl et al. 2007; Spromberg and Meador 2006, all cited in NMFS 2008j). Stormwater outfalls have not been sampled for pollutant concentrations in the Columbia River and North Portland Harbor portions of project area. However, it is likely that the large amount of untreated runoff in the watershed contributes to the high levels of pollutant loading in the Columbia River and North Portland Harbor.

The Columbia River portion of the action area is on the 303(d) list due to excessively high water temperatures (DEQ 2007a). Columbia River water temperatures at Washougal, Washington, range from approximately 6 degrees (°) Celsius (C) (43° Fahrenheit [F]) in early spring to approximately 22°C (72°F) in late summer (USGS 2007). Temperatures in the action area are assumed to be comparable. For at least part of the year, water temperatures exceed maximum levels for spawning (60°F) and for migration and rearing (64°F). No Total Maximum Daily Load (TMDL) for temperature has been proposed at this time (DEQ 2009).

These high water temperatures represent a degradation of the environmental baseline in that they may increase the risk of risk of disease, delay adult migration, increase the foraging rate of predators, and decrease the survival rate of smolts (NMFS 2008e).

Turbidity in the action area is very low compared to historical conditions (Bottom et al. 2005). Although high turbidity levels are typically associated with negative impacts to fish and their habitat, there are also beneficial effects, especially when considering natural stream processes. Decreased spring flows and sediment discharges have reduced turbidity levels throughout the lower Columbia River (NMFS 2004). The hydropower system traps approximately 12 million cubic yards of debris and sediment that would otherwise flow uninhibited through the lower Columbia River (NMFS 2008j). Total sediment discharge in the lower Columbia River mainstem is about one third of levels measured in the 1800s (NMFS 2008e). From October 2002 to September 2007, Ecology conducted water quality sampling in the action area approximately 3 miles upstream of the I-5 bridges (Ecology 2009a). Of 36 samples, all were 12 nephelometric turbidity units (NTU) or under and 28 were 5 NTUs or under; this is extremely low turbidity. Accordingly, the reduction in sediments has reduced the extent, speed, and depth of the turbidity plume extending into the Pacific Ocean (Cudaback and Jay 1996; Hickey et al. 1997, both cited in NMFS 2008e) and has led to reduced sediment inputs into lower Columbia River shorelines and tidal marshes (NMFS 2008j: Bottom et al. 2005).

Throughout the estuary, lowered turbidity levels pose a risk to fish and fish habitat. The sediment supply is an important source of the organic material that was historically the basis the food web. Floodplain inundation continually replenished organic material and recharged primary production. With the loss of overland flow and this source organic detritus, the food web is currently driven by phytoplankton. This has decreased the food supply for salmonids, although no study has quantified to what extent (Bottom et al. 2005). Within the action area, overland flow occurs only very occasionally, turbidity levels are extremely low, and sediment accumulating landforms (such as marshes, wetland forests, or beds of emergent vegetation) are rare. Thus, food sources for fish are expected to be much lower than historical levels.

Lowered turbidity levels may also pose a risk to individual fish. Decreased turbidity may lower visual cover for juvenile salmonids, making them more vulnerable to predation by birds and other fish. Low turbidity combined with reduced spring freshets pose particularly high risks to outmigrating juvenile salmonids (Bottom et al. 2005).

Substrate

In the Columbia River and North Portland Harbor, substrate consists mainly of sand with relatively small percentages of fine sediments and organic material (NMFS 2002; DEA 2006). Little to no gravel or cobble is present in the substrate within the action area. A bathymetric study completed in 2006 found significant scouring on the upstream side of each Columbia River bridge pier and scour channels on the downstream side (DEA 2006). The scouring ranged from approximately 10 to 15 feet deep. Bedload transport patterns were evident in the form of sand waves, a continuously shifting natural feature of the river bottom that indicates the influence of the currents. The sand waves observed in this study were especially distinct on the downstream side of the Columbia River bridges. The sand waves in the middle of the river were regular, while the sand waves on the northern downstream side were larger and more irregular. The northern upstream side of the bridge was relatively smooth and had few to no sand waves, while the southern upstream side had irregular sand waves. Average river depth was approximately 27 feet. Shallow-water habitat (defined as 20 feet deep or less) is present along both banks of the Columbia River, but is more abundant along the Oregon bank.

The substrate in North Portland Harbor within the project area is predominantly composed of sand with relatively small percentages of fine sediments and organic material. A bathymetric study completed in 2006 found deep scouring near the ends of the downstream piers of the existing North Portland Harbor bridge on the north bank, with scour holes approximately 8 to 10 feet deep (DEA 2006). Scouring around the upstream piers was approximately 3 to 7 feet deep. Scouring was more pronounced around the northern piers than the southern piers. A particularly deep area (approximately 21 feet deep) on the south side of the channel downstream of the existing bridge is indicative of a fast-moving current through the harbor. The average depth of the harbor was approximately 14 feet. Shallow-water habitat (defined as 20 feet deep or less) is present throughout the project area in North Portland Harbor.

Dredging and sand and gravel mining regulated by DSL occur in some areas of the Columbia River portion of the action area. For example, the Rose City Yacht Club (approximately 3 miles upstream of the existing I-5 bridges) holds a DSL permit for maintenance dredging of their marina, with subsequent sale of the dredged sand. This work is done in relatively shallow water (less than 20 feet in depth) and therefore may temporarily degrade on-site habitat for migrating salmonids. Columbia River Sand and Gravel and Northwest Aggregates each hold permits for dredging within the navigation channel within the action area between RM 102–106 (RKm 164–171) and RM 117–118 (RKm 188–190), respectively. Such in-channel activity is likely to temporarily and locally elevate turbidity and suspended sediment.

Physical Habitat Features

Since the 1800s, USACE has performed dredging throughout the Columbia River estuary in order to maintain the navigation channel (NMFS 2004). Once maintained at a depth of 20 feet, the channel is now dredged to an average depth of 43 feet (NMFS 2008j). USACE has also realigned the navigation channel and installed hydraulic control structures, such as in-water fills, channel constrictions, and pile dikes (NMFS 2004). As a result, benthic habitat is highly degraded throughout the lower Columbia River system (NMFS 2008j). Navigation channel maintenance over the past century has closed river side channels, realigned river banks, inhibited natural channel migration, and removed many habitat features that promote the survival of listed fish within the estuary.

Within the action area, the Columbia River and North Portland Harbor contain few to no backwaters, ponds, oxbows, and other low-energy off-channel areas. Historic off-channel areas have been filled, rechanneled, diverted, and otherwise developed over the past 150 years. As a result, there is a severe reduction in connectivity between the Columbia River and North Portland Harbor and their historic floodplains. Overbank flows occur only very occasionally. Wetland extent is drastically reduced, and the succession of riparian vegetation has been significantly altered. As a result, the action area provides few refugia for salmonids. North Portland Harbor may provide some of the only off-channel habitat functions (lower energy flows relative to the Columbia River).

The remaining tidal marsh and wetland habitats in the estuary are restricted to a narrow band along the Columbia River and its lower tributaries (NMFS 2004). Some high-quality backwater and side channel habitats have persisted along the lower Columbia River banks and near undeveloped islands (USACE 2001) downstream of the action area, and to some extent, within the action area at Government Island. These habitats contain high-quality wetlands and riparian vegetation, such as emergent plants and low herbaceous shrubs.

The riparian area within the action area is relatively degraded. Tree canopy is generally absent or sparse. As a result, shallow-water habitat has only sparse vegetative cover (see site photos in Appendix B for examples of existing riparian conditions). Because riparian areas are limited in size and are unlikely to expand in this urban setting, there is little potential for future large wood recruitment. Fish cover elements are generally sparse to absent in the action area, although some boulders and artificial structures (for example, docks and pilings) are present.

Shallow-water and nearshore habitat is present in the action area on both the Oregon and Washington sides of the river and is influenced by flow and sediment input from tributaries and the mainstem river that eventually settles to form shoals and shallow flats. This shallow-water habitat is used extensively by juvenile and adult salmonids for migrating, feeding, and holding. Phytoplankton, microdetritus, and macroinvertebrates are present in shallow areas and serve as the prey base for salmonids (USACE 2001). Overall, shallow-water habitat has been greatly reduced from historical levels throughout the estuary and in the project area. As river stage has declined with the operation of the hydropower system, shallow-water habitat has decreased concurrently (Bottom et al. 2005). Dredging, diking, armoring, and other shoreline alterations have exacerbated the problem, such that shallow-water habitat is rare in the project area. What little shallow-water and nearshore habitat that remains is of low quality. Shoreline armoring has reduced the quality of shallow-water habitat areas by providing habitat for predaceous fish, increasing water temperatures, removing resting and holding areas for juvenile fish, and reducing primary productivity. Numerous overwater structures in shallow-water habitat areas likely provide habitat for predaceous fish and birds and may cause interference with juvenile migration. North Portland Harbor, in particular, contains a high density of permanently moored floating homes and docks.

5.2.2.2 Columbia Slough

The Columbia Slough (also known as the Slough) is a slow-moving, low-gradient drainage canal running nearly 19 miles from Fairview Lake in the east to the Willamette River in the west (see site photos in Appendix B). Running roughly parallel to the Columbia River, the Slough is a remnant of the historic system of lakes, wetlands, and channels that dominated the south floodplain of the mainstem Columbia.

The Columbia Slough has undergone profound hydrologic alteration from its original condition. Originally, the Slough was a side channel of the Columbia River. Today, the original inlet is blocked at the upstream end, and it no longer receives flows from the Columbia. The Slough is now intensively managed to provide drainage and flood control with dikes, pumps, weirs, and levees (CH2M Hill 2005). The Columbia Slough Watershed drains approximately 37,741 acres of land in portions of Portland, Troutdale, Fairview, Gresham, Maywood Park, Wood Village, and unincorporated Multnomah County. The Slough and surrounding area were historically used by Native Americans for fishing, hunting, and gathering food (BES 2006).

The Slough is divided into upper, middle, and lower reaches. The Upper and Middle Sloughs receive water inputs from Fairview Lake, as well as groundwater and stormwater from PDX and other industrial, commercial, and residential sites in the surrounding area. Water levels in the Upper and Middle Sloughs are managed to provide adequate flows for pollution reduction (PDX de-icing) and surface water withdrawals, flood control, and recreation (COP 2009b).

The project area crosses the Lower Slough at Slough RM 6.5 (RKm 10.5) (CH2M Hill 2005). The Lower Slough extends from the Peninsula Drainage Canal to the Willamette River, less than 1 mile south of its confluence with the Columbia River. It experiences from 1 to 3 feet of tidal fluctuation in its water surface daily. Water levels are generally unmanaged, but are affected by the management of the dams on the Columbia and Willamette Rivers. The Lower Slough ranges from 2.0 to 4.5 feet NGVD and is generally between 100 and 200 feet wide. The Lower Slough receives water inputs from combined sewer overflows, stormwater, Smith and Bybee Lakes, leachate from the St John's Landfill, and the Upper Columbia Slough (COP 2009a).

I-5 crosses the Slough at RM 6.5 (RKm 10.5) in a highly urbanized area. The predominant land use around the Slough in the project vicinity is light industrial, with some residential. The Slough connects to the Willamette River approximately 6.5 miles west of the project area, within 1 mile of the confluence of the Columbia and Willamette Rivers (COP 2009b).

Anadromous fish can access the Lower Columbia Slough up to an impassable levee located near NE 18th Avenue (RM 8.3 [RKm 13.3]). At Smith and Bybee Lakes, a water control structure allows fish passage.

The water column in the Slough is characterized by algal and aquatic macrophyte growth, especially in summer months when flow is low and temperatures are high. The Slough is a lentic (still water) system with low dissolved oxygen levels. However, it provides habitat for many fish and wildlife species. As of 2004, 26 species, including juvenile salmonids, other fish species, freshwater shrimp, and crawfish, have been identified in the Lower Slough, which provides some of the only remaining off-channel and refugia habitat in the lower Willamette River area (COP 2009b).

The Columbia Slough does not exceed 303(d) list standards for turbidity. However, according to the National Pollutant Discharge Elimination System (NPDES) 1200-COLS permit regulating industrial discharges to the Columbia Slough, the in-stream target for total suspended solids (TSS) is 25 mg/L in the Columbia Slough (COP 2009a). Downstream of the project area, near Portland International Raceway, less than 50 percent of City of Portland samples met the target. Generally, though, water clarity improves in the Columbia Slough with distance upstream from the confluence with the Willamette River. Upstream of the project area, near the Vancouver Avenue crossing of the Columbia Slough, greater than 90 percent of the samples met the target.

Columbia Slough is on the 303(d) list for exceedance of temperature standards (DEQ 2007a). The 303(d) list notes temperatures greater than 17.8°C (64°F) from RM 0 to 8.5 (RKm 0.0 to 13.8), including the action area. These temperatures exceed levels considered suitable for salmonid spawning (60°F) and salmonid rearing (64°F). A draft TMDL is being prepared.

The Columbia Slough is on the 1994/1996 DEQ 303(d) list of water quality-impaired streams for the following parameters: lead, PCBs, DDE/DDT, dieldrin, and 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), pH, dissolved oxygen, phosphorous, chlorophyll a, bacteria, and temperature (COP 2009a). TMDLs have been established for all of these parameters except temperature (DEQ 1998).

Benthic habitat in the Lower Slough is dominated by sand, is extremely low in dissolved oxygen, and contains toxic pollutants. Generally, the benthic community, including 36 taxa, increases in abundance from the Lower to the Upper Slough. This increase in species abundance is correlated to an increase in silt dominance, which increases with the distance upstream in the Slough. Most of the species are adapted to low dissolved oxygen levels and still water conditions. The benthic community in the Slough appears to be similar in species richness and density to similar aquatic habitats in the region (COP 2009b).

Riparian habitat along the Slough has been largely replaced by buildings and pavement. Remaining areas of vegetation generally occur in a narrow band along Slough banks and are dominated by black cottonwood (*Populus trichocarpa*), Oregon ash (*Fraxinus latifolia*), willows (*Salix* spp.), red osier dogwood (*Cornus stolonifera*), Himalayan blackberry (*Rubus discolor*), common snowberry (*Symphoricarpos albus*), and reed canarygrass (*Phalaris arundinacea*). Both Himalayan blackberry and reed canarygrass are aggressive non-native species. The Slough's riparian area functions are highly impaired; these functions include microclimate and shade, bank stabilization and sediment control, pollution control, stream flow moderation, organic matter input, large woody debris, and contiguous wildlife travel corridors.

Habitat elements that typically support the life stages of listed fish are generally lacking in Columbia Slough. Large woody debris is scarce and because the riparian area is largely devoid of trees, the potential for future large woody debris recruitment is limited. Because the Slough has been intensely managed through dredging and channelization, habitat complexity is limited and habitat structures such as boulders and undercut banks are largely absent. Overbank flow occurs very infrequently and the stream is severed from its original floodplain. Likewise, low-energy off-channel areas (such as backwaters, ponds, and oxbows) are also scarce. However, remnant wetlands and restored wetlands do exist in the Slough watershed and provide habitat for wildlife, thermoregulation, nutrient removal, and other important ecosystem functions. Smith and

Bybee Lakes, a 2,000-acre complex of wetlands, are the dominant wetland features of the Lower Slough. This wetland complex borders the Lower Slough and connects to the Lower Slough via the North Slough, a mile-long channel running between the St John's Landfill and the south side of Bybee Lake (COP 2009b).

Several restoration efforts are ongoing in the Columbia Slough area. The City of Portland's Watershed Revegetation Program and its community partners are conducting non-native species removal and native plantings in many areas along the Slough. MCDD now uses in-channel equipment to perform repairs and maintenance of channel and bank areas. Formerly, MCDD cleared vegetation to access these areas from the shore. Both vegetation enhancement and MCDD's alteration of maintenance practices have resulted in an increase in native plant diversity and cover in the Slough watershed. The City of Portland Bureau of Environmental Services has been involved in revegetation efforts in the Slough watershed since 1996 and has successfully re-established native vegetation along many parts of the Slough (COP 2009b).

DEQ has listed irrigation, domestic and industrial water supply, livestock watering, anadromous fish passage, salmonid fish rearing, salmonid fish spawning, resident fish and aquatic life, wildlife and hunting, fishing, boating, water contact recreation, aesthetic quality, and hydropower as beneficial uses of the Columbia Slough (COP 2009b).

5.2.2.3 Burnt Bridge Creek

Burnt Bridge Creek is a small perennial tributary to the lower Columbia River. It originates near the Mill Plain suburb located east of Vancouver, Washington, and flows west (roughly paralleling SR 500 for approximately 5 miles) to its outlet at Vancouver Lake. The lake then drains into the lower Columbia River via Lake River. Burnt Bridge Creek crosses I-5 at approximately RM 2 (RKm 3.2). For the majority of its course, the stream passes through a valley constrained by surrounding land uses (primarily residential development). Stream slope is between 0 and 2 percent, but approximately 80 percent of the stream has a gradient of less than 0.1 percent (PBS 2003). Habitat in the majority of the upper reaches of the creek is degraded by urban development, non-native vegetation, channelization, and bank armoring, and provides little habitat for salmonids.

Hydrology in Burnt Bridge Creek has been highly altered compared to its original state. The overall watershed is heavily urbanized, and numerous stormwater outfalls discharge to the creek. Additionally, the creek was lengthened several miles through the draining and channelization in the early 1900s of a large marsh located at its original headwaters near Falk Road. Its current headwaters are located in east Vancouver near NE 162nd Avenue. All of these factors have increased peak flows, reduced base flows, and altered flow timing in comparison to historical conditions (PBS 2003).

Upstream of the action area, between Fourth Plain Boulevard and I-5, there are mature trees providing high canopy cover, with abundant beaver activity and pond habitat. Good rearing and spawning habitat is present in portions where the stream flows through a greenbelt with protected riparian areas (e.g., Leverich and Arnold Parks) (WDFW 2007a).

Burnt Bridge Creek enters the action area in Leverich Park, northeast of the SR-500/I-5 interchange. In the park area, the creek has substantial overhead cover from large-diameter trees and shrubs in some areas, and sparse cover by widely spaced large-diameter trees in areas maintained by park staff. In the more open areas within the park, the banks are highly eroded by regular visitor usage and mowing of herbaceous vegetation in the vicinity of the channel. Substrate within the park consists of fine sediments and gravels. Both riffles and pools are present within the park channel (WDFW/MHCC 1999).

From Leverich Park, the Burnt Bridge Creek channel passes under Leverich Park Way through a cement culvert and onto City property adjacent to I-5. The channel is armored for approximately 100 feet, after which it continues north, parallel to I-5 and Leverich Park Way, through a silt-dominated channel. The vegetation surrounding this portion of the channel is dominated by reed canarygrass with some overhanging blackberry and dogwood (*Cornus* sp.). Site observations indicate that the channel banks are undercut due to the growth habit of reed canarygrass and eroded due to the presence of nutria (*Myocastor coypus*).

Approximately 500 feet north of the cement culvert, Leverich Park Way bends to the west and the Burnt Bridge Creek channel passes under the roadway through a large corrugated metal pipe culvert. Upstream of the second culvert under Leverich Park Way, the channel is dominated by fine sediments (PBS 2003), and has moderate to dense overhanging vegetation consisting of deciduous and coniferous tree and shrub species. The channel continues north through a densely vegetated, privately owned area for about 200 feet. No permission to enter this area was granted during field visits to assess habitat and site characteristics. The channel then crosses under I-5, continuing north alongside a WSDOT wetland mitigation site to the west and Bonneville Power Administration (BPA) property and private land to the east.

Within the action area, habitat in the creek between I-5 and Vancouver Lake is characterized by low-gradient pool and marsh habitat with moderate canopy cover, and was described in a 2007 WDFW survey as good salmonid rearing habitat (WDFW 2007a).

There are no complete passage barriers in Burnt Bridge Creek, although seasonal velocity and flow barriers exist. A 2007 WDFW fish passage inventory of the creek documented several culverts within the action area that function as partial barriers, including the I-5 culvert at MP 3.07 (RM 1.9). This structure is an undersized box culvert with less than 1 percent slope, which results in high velocities through the culvert at certain flows (WDFW 2007a). Yearly stream flows vary, and the frequency with which the culvert is impassable is unknown; however, the presence of coho redds above the culvert in November and December 2002 indicates that access to spawning habitat is possible (WDFW unpublished data).

Within the action area, a temperature gauge at Leverich Park (gauge BBC 2.6) indicated that from mid-May through late September 2008, the highest annual running 7-day average of maximum temperatures exceeded 17.5°C (63.5°F) 92 times (Ecology 2008). These measurements indicate that temperatures in Burnt Bridge Creek exceed standards for salmonid spawning (60°F) and salmonid migration and rearing for at least part of the year (NMFS 1996). The 303(d) list includes Burnt Bridge Creek as a stream that exceeds standards for temperature (Ecology 2008).

In general, turbidity is not considered to be a parameter of concern in Burnt Bridge Creek (Ecology 2009a). Burnt Bridge Creek does not appear on the 303(d) list for streams impaired by turbidity (Ecology 2008).

The 303(d) list shows 16 segments of Burnt Bridge Creek that exceed standards for fecal coliform bacteria, dissolved oxygen, and temperature (Ecology 2009b). The 2008 303(d) list also shows 12 segments of Burnt Bridge Creek with pH impairments (Ecology 2009a). Naturally occurring concentrations of phosphorus in the groundwater, coupled with nutrient inputs from urban and agricultural runoff, has supported nuisance growths of algae and has further degraded aquatic habitat (COV 2007). Of nine samples taken between July and August 2008 at a gauge near Leverich Park, bacteria were above water quality standards in six of the samples, and pH was above standards in one sample (Ecology 2009a). Upper reaches of the stream pass through farmland, where the use of chemical fertilizers and pesticides likely contribute chemical contamination and nutrients to the stream.

Burnt Bridge Creek does not appear on the 303(d) list as having water quality issues related to chemical contaminants. Most stormwater runoff from the project area is discharged into the ground through buried infiltration facilities. However, there are three stormwater outfalls from I-5 that discharge runoff into Burnt Bridge Creek. These outlets likely discharge chemical contaminants to the creek.

5.3 CRITICAL HABITAT: FUNCTIONAL CONDITION OF PRIMARY CONSTITUENT ELEMENTS

Critical habitat is present in the action area in the Columbia River and North Portland Harbor for all ESUs and DPSs of salmonids shown in Table 1-3. Critical habitat is defined under the ESA as: (1) specific areas within the geographical area occupied by the species at the time of listing, on which are found those physical or biological features that are essential to the conservation of the listed species and that may require special management considerations or protection, and (2) specific areas outside the geographical area occupied by the species at the time of listing that are essential for the conservation of a listed species (70 FR 52630).

Critical habitat for Chinook, sockeye, and chum salmon and steelhead within the action area falls under two separate designations. The first designation occurred in 1993 (58 FR 68543) and covers critical habitat for SR sockeye, SR spring/summer-run Chinook, and SR fall-run Chinook. The second designation occurred in 2005 (70 FR 52630) and covers 12 ESUs/DPSs, nine of which occur in the action area. Critical habitat was designated for the Columbia River DPS of bull trout in 2005 (70 FR 56211), but does not include any portion of the action area within the Columbia River; a revised designation was proposed on January 14, 2010, and includes the Columbia River portion of the action area (75 FR 2269).

No designated or proposed critical habitat is present in Burnt Bridge Creek or portions of the Columbia Slough that occur within the action area.

Critical habitat units are described by their primary constituent elements (PCEs). PCEs are the physical and biological features of critical habitat essential to the conservation of listed species, including, but not limited to (1) space for individual and population growth and for normal behavior; (2) food, water, air, light, minerals, or other nutritional or physiological requirements; (3) cover or shelter; (4) sites for breeding, reproduction, rearing of offspring, germination, or seed dispersal; and (5) habitats that are protected from disturbance or are representative of the historic geographic and ecological distributions of a species (USFWS and NMFS 1998). The sections below identify the PCEs for each critical habitat designation and describe the current functional condition of the each PCE occurring in the action area.

5.3.1 2005 Salmonid Critical Habitat Designation

Of the critical habitat units that occur in the action area, the 2005 designation addresses LCR Chinook, UWR Chinook, UCR Chinook, CR chum, UCR steelhead, SR steelhead, MCR steelhead, LCR steelhead, and UWR steelhead. This designation consists of six PCEs, three of which occur in the action area.

PCE: Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation, and larval development.

Spawning habitat is extremely limited in the action area, and is present for only three species. CR chum spawn in shallow habitat on the Washington shore of the Columbia River near Government Island, approximately RM 7 (RKm 11) upstream of the I-5 bridges. LCR steelhead spawn in Burnt Bridge Creek and LCR Chinook may spawn in the lowest reaches of Burnt Bridge Creek near Vancouver Lake. Otherwise, the rest of the action area appears to lack suitable spawning habitat (e.g., gravel substrate influenced by groundwater seeps). Although there is suitable chum spawning habitat in the action area, redds may be at risk if river levels drop and expose eggs. Due to residential development in upland areas adjacent to spawning habitat, groundwater seeps that support hyporheic flow may be at risk.

PCE: Freshwater rearing sites with: (i) water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; (ii) water quality and forage supporting juvenile development; and (iii) natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.

This PCE is functioning in the action area but is highly degraded. Based on site visits and the interpretation of aerial photographs, floodplain connectivity with associated off-channel refugia is limited or absent. Dikes, levees, and streambank armoring are abundant alongside critical habitat within the action area. Urban development extends up to the streambank in numerous locations. Water quality in the action area is 303(d)-listed for temperature, PCBs, PAHs, DDT metabolites (DDE), and arsenic; EPA has approved TMDLs for dioxin and total dissolved gas (DEQ 2007a). Dissolved copper and dissolved zinc are commonly detected in highway stormwater runoff, and are likely to be present in the action area. Natural cover elements are limited or absent due to the highly altered and managed nature of the river channel. Given the volumes of water conveyed in the mainstem Columbia River, water quantity is not necessarily limited. However, flow control at Bonneville Dam affects river levels, and juvenile strandings and entrapments are possible (FPC 2008). Forage for juvenile salmonids is not documented as limited in the action area. However, lack of complex habitat structure and cover likely reduces the abundance and diversity of forage species.

PCE: Freshwater migration corridors free of obstruction and excessive predation with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival.

The action area functions as a migration corridor for salmonids, but this PCE is highly degraded. There are no known physical barriers to fish passage between the action area and the Pacific Ocean. However, water quality is impaired, and natural cover is limited or absent within the action area. Water quantity is not a limiting factor, with the exception of the risk of strandings and entrapments as discussed above.

PCE: Estuarine areas free of obstruction with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh-and saltwater; natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation.

Although the Columbia River estuary is generally defined as the portion of the Columbia River extending from the mouth to all tidally influenced areas (that is, to Bonneville Dam), this PCE is more applicable to those portions of the estuary with salinity conditions conducive to physiological changes required for juveniles to transition between freshwater and the saltwater marine environment. The intrusion of saltwater into the lower Columbia River is generally limited to Harrington Point at RM 23 (RKm 37); however, at lower daily flows saltwater intrusion can extend past Pillar Rock at RM 28(RKm 45) (LCREP 2007). This reach is approximately 78 miles downstream of the I-5 bridge. Therefore, this PCE is not present in the action area.

PCE: Nearshore marine areas free of obstruction with water quality and quantity conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation; and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels.

This PCE refers to marine areas in the Pacific Ocean. As discussed in section 3, the action area portion of the Pacific Ocean (i.e., the marine environment within 50 km of the Pacific coast from southern Oregon north to the Queen Charlotte Islands) is related to the overlap of the distribution of Southern Resident killer whales and Chinook salmon. This portion of the action area is specifically addressed only for killer whales. Effects to this PCE for salmon will not occur and are not addressed in this document.

PCE: Offshore marine areas with water quality conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation.

This PCE refers to marine areas in the Pacific Ocean and does not occur in the action area.

5.3.2 1993 Salmonid Critical Habitat Designation

Of the critical habitat units that occur in the action area, the 1993 designation addresses SR spring/summer-run Chinook, SR fall-run Chinook, and SR sockeye. Critical habitat for these species includes the bottom and water of the designated waterways and the adjacent riparian zone (areas within 300 feet of the OHW of the designated water body) (58 FR 68543). This designation consists of four "Habitat Components" two of which occur in the action area.

Habitat Component: Spawning and Juvenile Rearing

This PCE is not present in the action area. According to the critical habitat designation, spawning and rearing for these ESUs occurs several hundred miles upstream of the project area, in the Snake River and its tributaries (58 FR 68544).

Habitat Component: Juvenile Migration Corridors

Juvenile migration corridors for these ESUs include the Columbia River to the Pacific Ocean, including the action area (in the Columbia River and North Portland Harbor). This habitat component consists of ten "essential habitat features:" (1) substrate, (2) water quality, (3) water quantity, (4) water temperature, (5) water velocity, (6) cover/shelter, (7) food, (8) riparian vegetation, (9) space, and (10) safe passage conditions.

This habitat component is degraded but functioning, as evidenced by successful migration of individuals from these ESUs through the action area. Substrate in the action area is predominantly sand. Although dredging and flow management associated with upstream dams have altered substrate transport and deposition patterns to some extent, substrate composition is fairly consistent with historical conditions and is functioning for juvenile migration. Water quantity and velocity are not compromised in the mainstem Columbia River within the action area, and provide sufficient flow to allow juveniles to migrate. Cover and shelter in the action area are limited, but are present in low-velocity shoreline habitat at Government Island, Hayden Island, and in North Portland Harbor. Food (e.g., aquatic macroinvertebrates) is not known to be a limiting factor for migrating juveniles within the action area. Space is not limited in the action area, as migrating juveniles have full access to the width and depth of the water column in the Columbia River and North Portland Harbor. Passage conditions for migrating juveniles are generally safe, although predators (e.g., piscivorous fish such as pikeminnow; piscivorous birds) are likely to be seasonally present within the action area. There are no passage barriers for these ESUs within the action area.

Water quality, water temperature, and riparian vegetation are the most degraded of the essential habitat features. The Washington State 303(d) list includes records in the action area for water temperatures of greater than 68°F, well above standards for salmonid survival (Ecology 2009b). High levels of chemical contaminants (PCBs, PAHs, DDT, arsenic) and low levels of dissolved oxygen occur on the 303(d) list for reaches of the Columbia River that occur within the action area. Riparian areas have experienced particularly high levels of disturbance due to urbanization and streambank armoring. Riparian vegetation therefore offers less function in terms of cooling water temperatures and providing shoreline habitat complexity, relative to historical conditions.

Habitat Component: Areas for Growth and Development to Adulthood

This habitat component refers to marine areas in the Pacific Ocean and does not occur in the action area.

Habitat Component: Adult Migration Corridors

This habitat component consists of the same ten essential habitat features as juvenile migration corridors. This habitat component is present in the action area but is highly degraded as described for juvenile migration corridors above.

5.3.3 2010 Bull Trout Proposed Critical Habitat

This proposed designation consists of nine PCEs, six of which occur in Columbia River portion of the action area.

PCE: Springs, seeps, groundwater sources, and subsurface water connectivity (hyporehic flows) to contribute to water quality and quantity and provide thermal refugia.

These habitat characteristics are applicable to spawning and rearing habitat, and are not present within the action area.

PCE: Migratory habitats with minimal physical, biological, or water quality impediments between spawning, rearing, overwintering, and freshwater and marine foraging habitats, including but not limited to permanent, partial, intermittent, or seasonal barriers.

The action area functions as a migration corridor for bull trout, but this PCE is degraded, particularly with respect to water quality (see Section 5.3.1). The Washington State 303(d) list includes records in the action area for water temperatures of greater than 68°F, well above standards for salmonid survival (Ecology 2009b). Water temperatures within the action area are likely to seasonally limit bull trout presence. Water temperatures above 15°C (59°F) may limit bull trout distribution (Fraley and Shepard 1989; Rieman and McIntyre 1995). Columbia River water temperatures at Washougal, Washington, range from approximately 6°C (43°F) in early spring (mid-March) to approximately 22°C (72°F) in late summer (late July/early August) (USGS 2009); temperatures in the action area are assumed to be comparable. Depending on the year, water temperatures in the action area may exceed the bull trout tolerance threshold of 15°C (59°F) between May and October.

There are no known physical barriers to fish passage in the action area.

PCE: An abundant food base, including terrestrial organisms of riparian origin, aquatic macroinvertebrates, and forage fish.

This PCE is present within the action area. Because the riparian areas within the action area are highly degraded and little intact riparian vegetation is present, terrestrial organisms of riparian origin are very limited. However, aquatic macroinvertebrates (e.g., sand shrimp, mysids) are present (NMFS 2005c). Forage fish species for bull trout include sculpins (*Cottus* spp.), minnows (*Cyprinidae*), whitefish (*Prosopium* spp.), and juvenile salmonids (Rieman and McIntyre 1993), all of which are present in the Columbia River and North Portland Harbor within the action area.

PCE: Complex river, stream, lake, reservoir, and marine shoreline aquatic environments and processes with features such as large wood, side channels, pools, undercut banks and substrates, to provide a variety of depths, gradients, velocities, and structure.

As discussed in Section 5.2.2.1, the complexity of riverine habitat in the action area has been reduced relative to historical conditions. Numerous upstream dams, levees located along shorelines, and channel modification (e.g., armoring, reshaping) have restricted habitat-forming processes such as sediment transport and deposition, erosion, and natural flooding. Shoreline erosion rates are likely slower than they were historically due to flow regulation. Connection to historical floodplains and side channels has been altered or lost. The river channel is deeper and narrower than historical conditions. Therefore, this PCE is present, but degraded, in the action area. Lake, reservoir, and marine shoreline habitats are not present in the action area.

PCE: Water temperatures ranging from 2 to 15°C (36 to 59°F), with adequate thermal refugia available for temperatures at the upper end of this range. Specific temperatures within this range will vary depending on bull trout life-history stage and form; geography; elevation; diurnal and seasonal variation; shade, such as that provided by riparian habitat; and local groundwater influence.

This PCE is degraded in the action area, as water temperatures exceed the tolerance threshold for bull trout for significant portions of the year. Compared to other salmonids, bull trout have a more narrow tolerance for habitat quality parameters, and require particularly cold, clean water. As discussed above, water temperatures above 15°C (59°F) likely limit bull trout distribution

(Fraley and Shepard 1989; Rieman and McIntyre 1995). Depending on the year, water temperatures in the action area may exceed the bull trout tolerance threshold of 15°C (59°F) between May and October. During these months, adequate thermal refugia are likely to be scarce in the action area. Water temperatures between November and April, however, are suitable for bull trout.

Within the action area, the Columbia River does not meet DEQ standards for temperature and is 303(d) listed (DEQ 2007a). No TMDL for temperature has been proposed at this time (DEQ 2009).

PCE: Substrates of sufficient amount, size, and composition to ensure success of egg and embryo overwinter survival, fry emergence, and young-of-the-year and juvenile survival. A minimal amount (e.g., less than 12 percent) of fine substrate less than 0.85 mm (0.03 in) in diameter and minimal embeddedness of these fines in larger substrates are characteristic of these conditions.

This PCE is specific to bull trout spawning and rearing habitat, and is not present in the action area.

PCE: A natural hydrograph, including peak, high, low, and base flows within historic and seasonal ranges or, if flows are controlled, they minimize departures from a natural hydrograph.

This PCE is present but is degraded from historical conditions. Development of the hydropower system on the Columbia River has significantly influenced peak seasonal discharges and the velocity and timing of flows in the river. The Columbia River estuary historically received annual spring freshet flows that were 75–100 percent higher on average than current freshet flows. Historical winter flows (October through March) also were approximately 35–50 percent lower than current flows (ISAB 2000). Although current conditions represent a departure from the natural hydrograph, base flows in the action area have not been disrupted to the extent that foraging, migration, and overwintering behavior are significantly impaired for bull trout.

PCE: Sufficient water quality and quantity such that normal reproduction, growth, and survival are not inhibited.

As discussed above, water quality is impaired within the action area, and flows are altered from historical conditions. However, water quality and quantity are suitable to the extent that foraging, migration, and overwintering behavior of bull trout is possible. Spawning and rearing habitat is not present, although growth and survival of bull trout are not precluded by current conditions (as evidenced by a limited number of documented sightings in the lower Columbia River; see Appendix J).

PCE: Few or no non-native predatory (e.g., lake trout, walleye, northern pike, smallmouth bass); inbreeding (e.g., brook trout); or competitive (e.g., brown trout) species present.

Non-native fish species are present in the action area. Given the paucity of data on bull trout distribution and habitat use in the lower Columbia River, the extent to which non-native fish affect bull trout in the action area is unknown. Because any bull trout occurring in the action area are expected to be subadults or adults (see discussion in Section 4.15.1), they are likely to be less susceptible to predation than juveniles. Therefore, non-native predatory fish are unlikely to have a significant impact on bull trout in the action area. Bull trout do not breed in the action area, and would not be affected by the potential for inbreeding with non-native species.

Non-native competitive species may be present in the action area. Brown trout, for example, are more likely to be present in tributaries to the Columbia River (including associated lakes and reservoirs) because they are stocked for recreational harvest; however, it is possible that brown trout could stray to the mainstem river and survive there. The extent to which this actually occurs is unknown; however, the potential for such non-native species to be present in the mainstem cannot be ruled out.

Therefore, this PCE is not expected to be present in the action area because the potential exists for non-native competitive fish species to be present.

Section 6

SECTION 6

What does this section present?

Section 6 analyzes the effects of the project on listed and proposed species, designated and proposed critical habitat, and the environmental baseline with respect to habitat for listed species.

What kind of effects are discussed?

The effects are categorized by direct effects to fish, indirect effects to fish, effects to fish habitat, effects to Steller sea lions, cumulative effects, and effects due to interrelated and interdependent actions.

What direct effects will the project have on listed fish and their habitat?

Direct effects are all immediate impacts that are caused by the project and occur during or very close to the time of the project. The majority of direct effects to ESA-listed fish occur during construction and include:

- Impact pile driving, vibratory pile driving, and other in-water construction activities that are likely to increase noise levels in the Columbia River and North Portland Harbor, potentially causing disturbance or injury to fish.
- Fish salvage from cofferdams installed for in-water construction posing the risk of injury or mortality to fish.
- Temporary overwater structures likely increasing the amount of shade in the project area, potentially resulting in visual disorientation, migration delays, and increased predation on juvenile fish.
- Illumination from temporary overwater structures potentially increase light levels at the water surface at night, potentially causing visual disorientation, migration delays, and increased predation on juvenile fish.
- During in-water construction turbidity could potentially create temporary, localized impacts to water quality that may result in disturbance to fish.
- In-water and overwater temporary structures potentially attracting avian predators that may increase predation on juvenile fish.

All of these impacts are likely to temporarily adversely affect listed salmon, steelhead, and eulachon as these species will be present in the project area during the construction period. The impacts are not likely to adversely affect bull trout and green sturgeon as their presence in the project area during the construction period is considered discountable.

Summary of Major Project Effects, Stressors, and Listed Fish Responses

Project Element with Effect	Stressor	Potential Response	Anticipated Effect of Exposure to Each Stressor	
			Salmon and Steelhead	Bull Trout and Green Sturgeon*
Permanent				
Change in In-Water Area – Columbia River	Loss of shallow and deep water habitat, change in over-water coverage, shading	Limited loss of foraging, migration, holding habitat, increased or potential decrease in predation, insignificant disorientation, migration delay or augmentation due to removal of barrier and increase in habitat.	LAA	NLAA
Change in In-Water Area – North Portland Harbor	Loss of shallow water habitat, change in over-water coverage, shading	Limited loss of foraging, migration, holding habitat, increased predation, insignificant disorientation, migration delay.	LAA	NLAA
Increase in PGIS from direct and indirect effects	Impacts to water quality and quantity	Potential improvement to environmental baseline; limited to no or beneficial response.	NLAA	NLAA
Riparian and shoreline changes from direct project effects and indirect effects from land use changes	Productivity, Shading, Habitat Complexity	Limited due to minimization measures, minimization of sprawl, and anticipated decrease in traffic congestions.	NLAA	NLAA
Temporary				
Pile Installation – Impact	Elevated noise	Range from startling, disruption in feeding, avoidance, impaired ability to avoid predators, brief migration delay to mortality, injury, temporary or permanent hearing los, interference with movement and predator avoidance.	LAA	NLAA
Pile Installation – Vibratory	Elevated noise	Avoidance	LAA	NLAA

Project Element with Effect	Stressor	Potential Response	Anticipated Effect of Exposure to Each Stressor	
			Salmon and Steelhead	Bull Trout and Green Sturgeon*
General Construction Activities – Drilling Shafts, Barge Traffic, etc.	Elevated noise and potential disturbance	Avoidance	NLAA	NLAA
	Chemical Contamination	Limited potential exposure due to implementation of BMPs.	NLAA	NLAA
	Turbidity	Gill damage, physiological stress, migration delay, interference with foraging, avoidance, spawning (eulachon only).	LAA	NLAA
	Contaminated Sediments	Exposure will not occur or will be extremely limited due to use of BMPs.	NLAA	NLAA
Fish Salvage	Harassment, handling	Avoidance, injury, mortality.	LAA	NLAA
Presence of Temporary Structures – Cofferdams, Work Platforms, Bridges, Support Structures, and Barges	Shading/Light-Dark Interface, Artificial Lighting, Avian Predation, Loss of Shallow and Deep Water Habitat	Increased predation, disorientation, migration delay, minor change in primary productivity, insignificant loss of foraging, migration, holding habitat.	LAA	NLAA
Installation of New PGIS and Stormwater Treatment Facilities	Stormwater runoff impacts to water quality or quantity	Potential improvement to environmental baseline; limited to no or beneficial response.	NLAA	NLAA

*Presence of bull trout or green sturgeon is considered discountable.

How long will effects to fish resources last?

Potential impacts to fish from turbidity, increased predation pressure, nearshore habitat disturbance, and hydroacoustic effects from pile driving will only occur during in-water construction. The timing of fish resources through the project area has been evaluated on a listed entity basis (ESU/DPS) to avoid and minimize impacts to endangered and threatened species that spawn in the middle and upper Columbia River. The species that spawn in the lower Columbia River tend to be present in the established in-water work window. CRC worked with state and federal fish managers to identify the timing of these species in the project area. Therefore, impacts to these species have been evaluated based on the best science available.

Why is impact pile driving potentially harmful to fish?

In-water impact pile driving produces high levels of noise that are pressure waves in the water column. Elevated noise levels may result in delayed migration, disturbance, injury, or mortality to fish.

How is the project measuring in-water noise effects from impact pile driving?

The project has modeled how much exposure will be produced in any construction week when impact pile driving will occur. We have labeled this the "exposure factor." The exposure factor accounts for the number of pile strikes, the noise emanating from the pile strikes, and how many days pile driving occurs within a week in any given construction year. We will implement a monitoring plan that, based on a representative number of piles, will record and determine actual noise levels that impact driving of piles will produce. We will be able to compare real exposure factors with those we estimated.

What is the project doing to minimize the effects of impact pile driving on fish?

The project includes a number of actions designed to minimize the effects of impact pile driving on fish, including:

- Minimizing the number of in-water piers.
- The project is installing drilled shafts for permanent pier piles, rather than impact driving 8-foot diameter piles. In-water impact pile driving will be restricted to a 31-week work window coinciding with the period of time when fish abundance in the project area is at its lowest.
- Reduced pile strikes by 90 percent by using vibratory installation to the point of refusal.
- All non-load bearing piles will be installed by non-impact means.
- The project will use a noise attenuation device (such as a bubble curtain) to reduce the amount and the extent of in-water noise.
- The project will conduct underwater noise monitoring to ensure that noise levels and durations do not exceed performance standards.
- Biological monitors will be employed during impact pile driving to ensure any incidental take allocated for the project by the NMFS will not be exceeded.

What indirect effects will the project have on listed fish?

Indirect effects are those that are caused by the proposed action and that occur later in time, but are still reasonably certain to occur. The indirect effects of the project include:

- The City of Vancouver has adopted plans for redevelopment of downtown Vancouver and the City of Portland has adopted plans for redevelopment of Hayden Island. Both Cities planned redevelopment in conjunction with the CRC project. The CRC project will promote transit-oriented development (a compact design that limits the need for private automobile usage). New developments or redevelopments that occur within the cities' plans will meet current standards for environmental protection, including upgrading of stormwater treatment and protection of critical areas or environmental zones, such as shorelines. Redevelopment will result in long-term beneficial effects to listed fish due to increased stormwater treatment, reduced automobile usage, and adherence to current development standards.

What effects will the project have on the environmental baseline and fish habitat?

The project will result in a permanent loss of 0.08 acre of shallow water habitat (North Portland Harbor) and 1.50 acres of deep-water habitat (Columbia River), temporary increase in the amount of shade in shallow-water and deep-water habitat through work platforms, work bridges, and barges, and increase potential juvenile salmon predator holding areas through hydraulic shadowing from temporary piles and work structures and permanent piers. These activities are likely to adversely affect listed salmon, steelhead, and eulachon. None are likely to adversely affect bull trout or green sturgeon. In addition, temporary activities such as the small removal of riparian habitat, debris removal, and vessel noise are not likely adversely affect listed species.

What are the effects of the project on critical habitat?

The following project impacts are likely to adversely affect critical habitat for salmon and steelhead: underwater noise, turbidity, and overwater structures. Other project impacts (stormwater runoff treatment and future land-use and traffic changes) are not likely to adversely affect critical habitat for salmon and steelhead. None of these impacts are likely to adversely affect critical habitat for bull trout.

What effects will the project have on Steller sea lions?

Effects will be limited to brief, temporary during certain construction activities, incidental harassment primarily from underwater pile driving noise of adult and subadult Steller sea lions as they go through the project area to and from the tail race at Bonneville Dam to forage during several months of each construction year. The project will avoid injury to Steller sea lions by curtailing impact pile driving when individuals occur in close vicinity to this activity. No long-term effects to Steller sea lions from the project will occur.

What beneficial effects will the project have on listed fish and fish habitat?

- The project will provide water quality treatment for the 18 acres of net new pavement and 168 acres of existing, currently untreated pavement. The project will treat over nine times the net new pavement resulting in a reduction in pollutants discharged to action area waterbodies.
- The project will also include two compensatory mitigation sites to address requirements under state and federal Clean Water Act regulations: one in the lower Hood River and one in the lower Lewis River. These sites will, at minimum, meet required mitigation standards. CRC expects the benefits from proposed mitigation actions to greatly outweigh the habitat impacts being mitigated. The project will permanently impact a total of 1.58 acres of aquatic habitat. The two compensatory mitigation sites combined will provide over 30 acres of restored and enhanced aquatic habitat. These mitigation activities are anticipated to enhance survival and production of listed salmonids and eulachon that use the lower Columbia River.
- The project would more than double the number of transit passenger trips over the I-5 crossing. For weekdays, there would be 20,600 bridge crossings on transit, compared to 10,200 trips under the 2030 No-Build Alternative. Of the transit passengers crossing the Columbia River, 18,700 are estimated to be on light rail transit (91 percent) and 1,900 are

estimated to be on buses (9 percent). Decreased use of motor vehicles will decrease the amount of pollutants that could enter the aquatic ecosystem.

What cumulative effects will the project contribute to?

Cumulative effects are state, local, tribal, and private activities that are reasonably certain to occur within the action area and are likely to affect listed species. Project cumulative effects include state and local land use planning and permitting, roadside, and commercial development, recreational and commercial fisheries, restoration projects, and long-term climate change. Generally, cumulative effects are expected to have adverse impacts on listed species in the action area.

What are the interrelated and interdependent actions that may affect listed fish?

Compensatory[1] mitigation activities are expected to beneficially affect fish. Mitigation activities will occur in the Lewis River and lower Hood River near the lower mainstem Columbia River in the Lewis River. These activities will restore side channel habitat which will salmon and steelhead by creating off-channel rearing habitat, creating spawning habitat, and improving foraging and holding habitat. Benefits from these two restoration projects to listed fish will remain in perpetuity.

The project will cause displacement of floating homes in North Portland Harbor. Activities associated with displacement and relocation of floating homes may adversely affect listed species due to shading.

How will the project affect killer whales?

Chinook represent a substantial portion of the killer whale prey base in the northern Pacific Ocean. The project will adversely affect a small percentage of the Columbia River Chinook population, which represents a negligible portion of the killer whale prey base. This loss of prey will have only insignificant effects on the killer whale prey base.

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[1] Compensatory mitigation is required to fulfill permit requirements determined by USACE and DSL in Oregon and the USACE, WDFW, and Ecology in Washington.

6. ANALYSIS OF EFFECTS OF THE ACTION

This section analyzes direct, indirect, and cumulative effects to listed species, habitat for listed species, and critical habitat for listed species. This section also analyzes the effects of interrelated and interdependent actions on listed species and critical habitat (USFWS and NMFS 1998). Direct effects include all immediate impacts that are caused by the project (such as construction and demolition) and that are directly related to actions that occur at or very close to the time of the project. Indirect effects are impacts that are caused by the project, but that occur later in time or are farther removed in distance from the project area and are still reasonably certain to occur. Cumulative effects are future state, tribal, local, and private activities that are reasonably certain to occur within the action area and are likely to affect the species considered in this BA. An interrelated action is one that is part of a larger action and depends on the larger action for its justification. An interdependent action is one that has no independent utility apart from the proposed action.

Analysis of the effects due to stormwater runoff appears in Section 6.2.1. Although stormwater impacts may be considered both direct and indirect effects of the action, the analysis appears only in the indirect effects section because most of the effects occur well after project completion and, in some cases, distant from the action. In addition, this format avoids the redundancy of placing the stormwater information in two locations.

Appendix I, the Exposure Matrix, provides a tabular summary of each element of the project that is likely to affect listed species in the action area. It also provides the timing and duration of each project element as well as summarizes the overall effect that each element will have on listed species.

Section 8.0 summarizes the overall effect determination for each listed species and critical habitat that occurs in the action area.

Appendix H provides an assessment of the effects of the project to the killer whale. This information appears in a separate appendix at the request of NMFS liaison Devin Simmons. This format facilitates review by the Office of Protected Resources, a division of NMFS that will review this section separately from the rest of the Biological Assessment.

6.1 DIRECT EFFECTS TO FISH

Direct effects to listed species will only occur during proposed in-water work in the Columbia River and North Portland Harbor. No in-water work will occur in Burnt Bridge Creek or Columbia Slough. Specific elements of the project that may cause direct effects to fish include following:

- In-water pile driving is likely to create elevated noise levels in the Columbia River and North Portland Harbor, potentially causing disturbance, injury, or mortality to listed fish.
- Fish may become entrained in work-area isolation devices in the Columbia River, where they may experience injury or mortality. Additionally, fish salvage operations occurring inside of work-area isolation devices may also pose a risk of injury or mortality.

- Overwater structures in the Columbia River and North Portland Harbor will likely increase shading above ambient levels. This may cause visual disorientation and increased predation pressure on juvenile fish.
- Illumination on overwater structures in the Columbia River and North Portland Harbor may increase light levels at the water surface in the nighttime. Both of these may cause visual disorientation and increased predation pressure on juvenile fish.
- In-water construction may create temporary, localized turbidity above ambient levels, potentially resulting in disturbance to fish.
- In-water and overwater structures may attract avian predators, potentially increasing predation on juvenile fish.

Sections 6.1.1 through 6.1.6 provide more detail on the pathways by which each of these project elements is likely to affect listed species.

6.1.1 Hydroacoustic Impacts

Direct injury, mortality, or behavioral disturbance to fish species may result from sound levels produced by impact pile driving, vibratory pile driving, and other in-water construction techniques used for the installation of temporary and permanent in-water structures in the Columbia River and North Portland Harbor. Impacts associated with impact pile driving may include physical injury (particularly to air-filled spaces such as swim bladders), auditory tissue damage, temporary or permanent hearing loss, behavioral effects, and immediate and delayed mortality. The amount of energy and the resulting sound pressure from impact pile driving depend on the size and type of pile, type of hammer, energy of the hammer, depth of the water column, and substrate. Impacts to individual fish depend on sound pressure levels, fish species, fish size, fish condition, and depth of the water column (Popper et al. 2006). Use of bubble curtains or other noise attenuation devices during impact pile driving may reduce the level of noise impacts to fish (Caltrans 2009).

Sound, measured in dB, is a relative measure and is referenced in the context of underwater sound pressure to 1 micropascal (μPa) ("dB re: 1 μPa"). One pascal is the pressure resulting from a force of 1 newton exerted over an area of 1 square meter. For purposes of this analysis, underwater sound is referenced in units of decibels re: 1 μPa when referring to sound pressure levels (SPLs) or 1 μPa^2-second when referring to SELs, and will be denoted as dB.

Root mean square (RMS) is the quadratic mean sound pressure over the duration of an impulse. This measurement is often used in the context of discussing behavioral effects to fish, in part because behavioral effects, which often result from auditory cues, and effects on hearing may be better expressed through averaged units rather than by peak pressures.

When discussing the effects of explosions on animals, authors often use impulse as the acoustic parameter, as in Yelverton et al. (1973) discussed below. Positive impulse is the integral of pressure over time, from arrival of the leading edge of the pulse until the pressure becomes negative. Impulse is measured in pascal-seconds (Pa-s). As sound propagates away from a source, several factors change its amplitude. These factors include the spreading of the sound over a wider area (spreading loss), losses to friction (absorption), scattering and reflections from objects in the sound's path, and interference with one or more reflections of the sound off the surface of the streambed (in the case of underwater sound).

The sum of all propagation and loss effects on a signal is referred to as the transmission loss. A major component of transmission loss is spreading loss. From a point source in a uniform medium (water or air), sound spreads outward in spherical waves. Sound transmission in shallow water is highly variable and site specific. Refraction can result in either reduced or enhanced sound transmission in shallow water (Richardson et al. 1995). Ambient noise is the background noise. In water, sources of ambient noise include wind, waves, organisms, shipping traffic, and rain.

6.1.1.1 Hydroacoustic Effects to Fish from Impact Pile Driving

Hydroacoustic injury and disturbance thresholds for marine fish species have been identified by NMFS and USFWS for impulse noises, such as impact pile driving (Table 6-1) (Popper et al. 2006; Southall et al. 2007; NMFS 2008f). Some of the thresholds are dependent on whether the fish are greater than or equal to 2 grams (g) in size. Fish potentially occurring in the action area include adult salmonids, adult and subadult green sturgeon, and adult eulachon migrating upriver, steelhead kelts migrating downriver, outmigrating juvenile salmonids, and larval eulachon. All of these species fall into the greater than 2 g size class, except for juvenile chum and larval eulachon, as described in Appendix K.

Table 6-1 lists the injury thresholds and disturbance guidance for noise impacts to fish.

Table 6-1. Hydroacoustic Injury Thresholds and Disturbance Guidance for Fish

Underwater Sound Criteria		
Size Class	**Injury Threshold**	**Disturbance Guidance**
Fish over 2 g	206 dB Peak; 187 SEL_{cum}	150 dB RMS
Fish under 2 g	206 dB Peak; 183 SEL_{cum}	150 dB RMS

Notes: Cumulative SEL (SEL_{cum}) is calculated as: SEL (single strike at ~10 meters from the pile) + 10 log x (number of strikes).

Impact pile driving will occur during installation of temporary in-water work structures in the Columbia River and North Portland Harbor as described in Section 3. As described in Section 3.5, temporary piles used in these structures are expected to fall into two size classes: 18 to 24 inches and 36 to 48 inches in diameter.

Approximately 1,500 temporary steel piles will be installed and removed during the multi-year construction of the Columbia River and North Portland Harbor bridges. The need for piles will be staged over the construction and demolition periods so that between 100 and 400 piles may be in the water at any given time.

Temporary structures that are not load-bearing, such as mooring piles and cofferdams, will be installed with a vibratory driver only. Drilled shaft casings may also be vibrated into position. These vibratory driving activities are proposed to occur year-round and without the use of an attenuation device. Section 6.1.1.2 provides more detail about the effects of vibratory pile driving on listed fish.

Structures requiring load-bearing piles include temporary work bridges, work platforms, tower cranes, and oscillator support platforms. These piles will be installed first with a vibratory driver to refusal and then proofed with an impact hammer.

Each pier complex of the Columbia River bridge will require approximately 132 load-bearing piles for support of work platforms/bridges and an additional eight load-bearing piles for a tower crane several months later (see Table 3-7), for a total of approximately 840 impact driven piles. An average of six temporary, load-bearing piles could be installed per day using one or two impact drivers. The project is anticipating that temporary piles for each of the six work bridges/work platforms will be installed in one 22-day period. Temporary piles for each of the six tower cranes will be installed in one day. Figure 6-14 shows the sequencing of pile-driving activities in the Columbia River based on an impact driving start date of September 2013. Impact pile driving in the Columbia River will occur on approximately 138 days over the approximately 4-year construction period.

Each of the 31 oscillator support platforms in North Portland Harbor will require four load-bearing piles (124 piles). In addition, the nine temporary work bridges will each require approximately 25 load-bearing piles (225 piles) (Table 3-13). There will be a total of approximately 349 impact-driven piles in North Portland Harbor. Only one impact driver will operate at a given time in North Portland Harbor. Figure 6-15 shows the sequencing of pile-driving activities in North Portland Harbor. Impact pile driving in North Portland Harbor will occur on approximately 134 days over the approximately 4-year construction period.

In-water noise attenuation measures will be employed during impact driving activities for the majority of pile strikes. The CRC project assumes that an at-source noise reduction of approximately 10 dB is achievable through use of a noise attenuation device. (Appendix K details the rationale behind this assumption.) Unattenuated pile driving may occur as part of the hydroacoustic monitoring program for this project or incidentally during attenuation equipment failures. In the Columbia River, unattenuated pile driving may occur for up to 7.5 minutes per week. In North Portland Harbor, unattenuated pile driving may occur on average for up to 5 minutes per week.

Based on NMFS models, calculation of distances to injury thresholds and disturbance guidance is related to noise from a single pile strike. For accumulated SEL, the variables include: single-strike dB SEL, the number of pile strikes over a time period, the time period, the distance from pile, and fish movement. Refer to Appendix K for further discussion on attenuation, noise metrics, and impact calculations.

During construction of the Columbia River bridge, up to two impact pile drivers may operate simultaneously in close proximity to one another, although it is not anticipated to produce additional noise levels due to multiple drivers. Pile strikes from both drivers would need to be synchronous (within 0.0 and approximately 0.1 seconds apart) in order to produce higher noise levels than a single pile driver operating alone. Because two pile drivers operating with exactly synchronous pile strikes is highly unlikely, the CRC team assumed for analysis purposes that two pile drivers will not generate noise levels greater than that of a single pile driver.

For construction of the Columbia River bridges, an average of 300 impact blows per pile are estimated to be needed. Project designers estimate that up to 1,800 attenuated pile strikes will occur per day of pile driving. For construction of the North Portland Harbor bridges, a total of 1,800 attenuated pile strikes per day of driving were also assumed. The actual number of pile strikes will vary depending on the type of hammer, the hammer energy and substrate composition. However, these pile strikes will not be spread evenly throughout the work day. It is likely that day-to-day pile driving activities will vary. This hour-to-hour and day-to-day variation, coupled with timing of fish runs and fish speed through the area, creates a complex scenario for analyzing effects.

To accommodate this complex scenario of pile sizes, initial sound levels, pile strike numbers, timing and duration of pile driving, etc., the CRC team developed an analytical tool to determine the extent to which fish are exposed to potentially injurious accumulated sound levels within the project area. The CRC project has called this extent of exposure the "exposure factor." The exposure factor uses the variables for calculating the accummulated SEL through the moving fish model (size of pile [initial sound levels], daily pile strikes, timing and duration of pile strikes, fish speed, and fish mass) and combines that with variables, such as days of pile driving within a week, to estimate the potential exposure to fish that are within or pass through the project area. Different combinations of any of these elements (such as pile strikes, duration or timing of pile strikes, and initial sound levels) will yield different exposure factors.[1] During construction, the contractor will calculate the weekly, maximum yearly, average yearly, and total project exposure factor to ensure that they do not exceed levels specified in Section 7 of this document.

Exposure factors were calculated for impact pile driving activities in both the Columbia River and North Portland Harbor.

The Services have accepted the use of a revised moving fish model based on this project's specific conditions, as described in Appendix K, to determine exposure factors and to quantify effects to listed fish. This model uses the mass and the measured or assumed rate of travel for juvenile and adult fish through the project area. Juvenile chum and larval eulachon were assumed to be under 2 g in mass and travel with the current at 0.6 m/s. Other juvenile fish were assumed to be over 2 g in mass and travel a little faster than the current of 0.8 m/s. All adult fish were assumed to be over 2 g in mass and travel at 0.1 m/s through the project area. These assumptions are discussed further in Section 4 of this document and Section 4 of Appendix K.

It is important to correctly assume the rate of travel and mass for the moving fish model. The faster a fish moves through an area, the less time it has to become exposed to accumulated levels of potentially injurious sound energy. The effect of speed on the area of effect is more noticeable at higher fish movement speeds (nearing 1.0 m/s), whereas the area of effect for fish moving 0.1 m/s are substantially the same as the area of effect calculated using the stationary fish model. For example, an attenuated 36- to 48-inch-diameter pile struck 300 times would result in a pile driving time of approximately 7.5 minutes. A fish (over 2 g) moving at a speed of 0.8 m/s would travel approximately 360 m in a 7.5-minute period. If that fish passed within approximately 47 m of the driven pile, it could receive enough sound energy for injury to occur. If the fish were traveling at only 0.6 m/s, then it could experience enough sound energy for injury to occur within approximately 58 m from the pile. If the fish were traveling at 0.1 m/s or was stationary, then it could experience enough sound energy for injury to occur within approximately 83 m from the pile. If the fish passed inside of the threshold distance for its given speed, injury would be more likely.

[1] As a simple example, a higher number of pile strikes on a small pile with a low initial SPL over a given time period may result in the same exposure factor as a lower number of pile strikes conducted on a large pile that has higher initial sound levels. Section 3 of Appendix K provides detailed information on how typical and maximum exposure factors were calculated, and provides details on how exposure factors can be calculated during construction activities.

In order to analyze potential impacts to listed fish, the CRC project team calculated the proportion of a listed fish run that may be impacted within the Columbia River and North Portland Harbor through potential injury due to increased sound pressure levels from the impact driving of temporary piles. Calculating exposures to fish requires multiplying the proportion of a fish run likely present in the project area in a given week by the weekly exposure factor for that week. The CRC project used 13 full Columbia River Bridge construction scenarios to estimate potential and maximum exposure factors. Details of these analyses, including calculations of estimated impacts for each run, are presented in Appendix K.

Due to the numerous variables in determining exposure factors, the CRC project used representative numbers of pile strikes, such as those in Table 6-2 and Table 6-3, to estimate exposure factors for the project. The numbers in Table 6-2 and Table 6-3 are also used in this section of the BA to illustrate the extent of underwater noise exceeding the injury thresholds and disturbance guidance.

Table 6-2. Pile-Strike Summary for Columbia River Bridge Construction

Pile Size	Strikes per Day	Days per Week[a]	Strike Interval[b]
Without Attenuation Device			
Single pile driver: 18- to 24-inch pile	150	1	1.5
Single pile driver: 36- to 48-inch pile	150	1	1.5
With Attenuation Device			
Single pile driver: 18- to 24-inch pile	400	5	1.5
Single pile driver: 36- to 48-inch pile	800	5	1.5
Two pile drivers: each with 18- to 24-inch pile	200	5	0.75
Two pile drivers: one 18- to 24-inch pile and one 36- to 48-inch pile, or two 36- to 48-inch piles	400	5	0.75

a Days per week during active driving only.
b Measured in seconds between strikes.

Table 6-3. Pile-Strike Summary for North Portland Harbor Bridge Construction

Pile Size	Strikes per Day	Days per Week[a]	Strike Interval[b]
Without Attenuation Device			
Single pile driver: 18- to 24-inch pile	75	1	1.5
Single pile driver: 36- to 48-inch pile	75	1	1.5
With Attenuation Device			
Single pile driver: 18- to 24-inch pile	900	3 to 5	1.5
Single pile driver: 36- to 48-inch pile	900	2	1.5

a Days per week during active driving only.
b Measured in seconds between strikes.

Estimated Extent, Timing, and Duration of Effect

Table 6-4 through Table 6-8 summarize the distances within which noise exceeds the injury thresholds and disturbance guidance in the Columbia River and North Portland Harbor during impact pile driving. These distances are presented for impact pile driving occurring both with and without the use of an attenuation device for comparison. Note that the upstream extent of pile-driving noise may differ from the downstream extent. These values indicate the distance at which noise encounters a landform (such as an island or streambank) that completely blocks the spread of in-water noise. The calculations assume that the noise attenuation device will achieve 10 dB of noise reduction at the source.

Table 6-4, Figure 6-1, and Figure 6-2 show the distances within which noise exceeds peak injury thresholds.

Table 6-4. Distances at Which Underwater Noise Exceeds 206 dB Peak Injury Threshold Levels for Peak Noise in the Columbia River and North Portland Harbor

Pile Size	Distance (m)	
	Without Attenuation Device	With Attenuation Device
18- to 24-inch pile	25	5
36- to 48-inch pile	34	7

Table 6-5 and Figure 6-3 through Figure 6-5 show the distances within which noise is estimated to exceed the 187 dB SEL injury thresholds for fish over 2 g and moving at 0.1 m/s for a single pile driver and for two pile drivers operating simultaneously, as calculated in the moving fish model.

Table 6-5. Distances at Which Underwater Noise Exceeds 187 dB SEL Injury Threshold for Adult Fish Over 2 g at 0.1 m/s in the Columbia River and North Portland Harbor

Pile Size	Distance (m)	
	Without Attenuation Device	With Attenuation Device
18- to 24-inch pile	113	50
36- to 48-inch pile	243	156
Two 18- to 24-inch piles	N/A	59[a]
Two 36- to 48-inch piles OR One 18- to 24-inch and one 36- to 48-inch pile	N/A	130[a]

Note: Includes adult salmon, steelhead, and eulachon.

a Applies to Columbia River only.

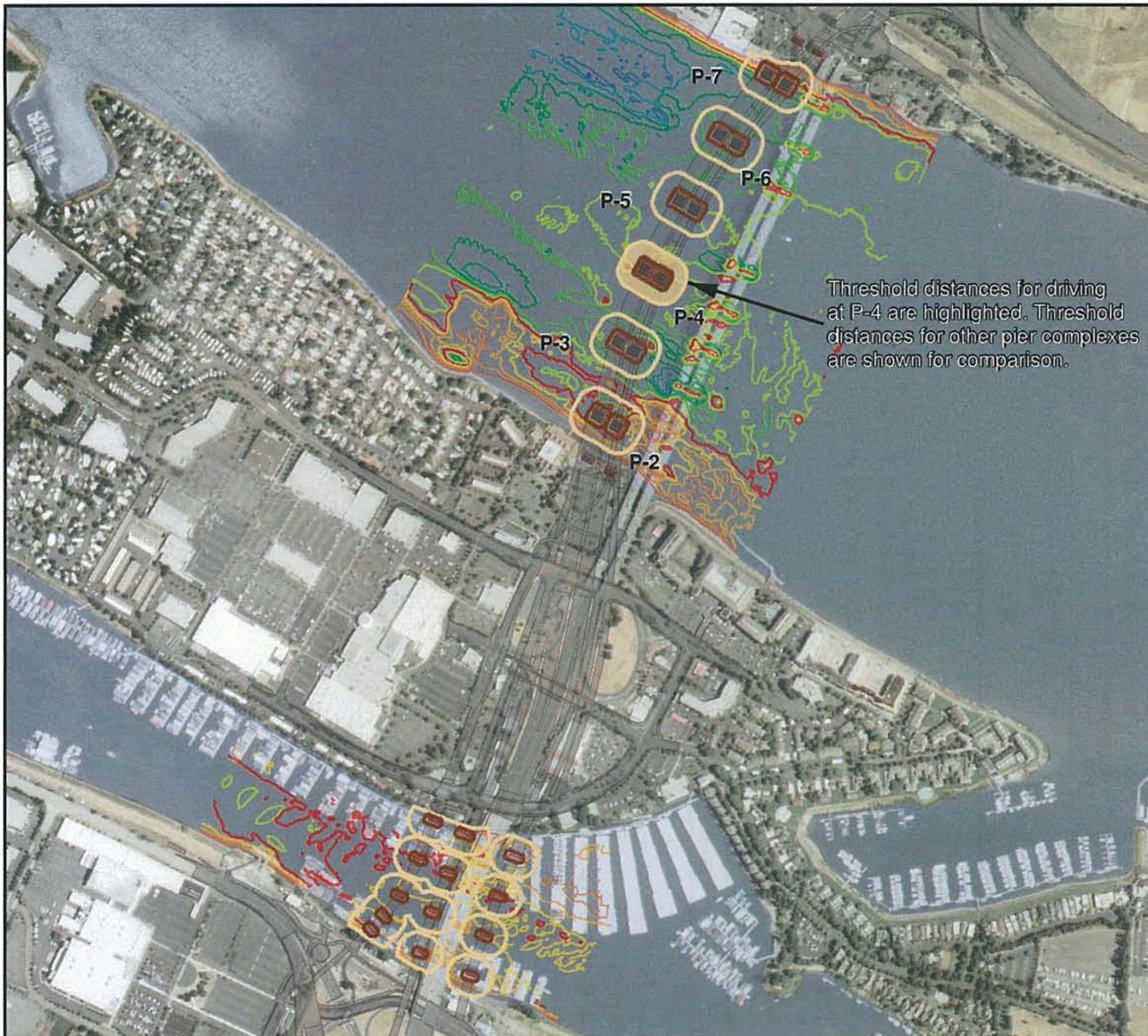


Figure 6-1. Extent of underwater impact pile-driving noise exceeding 206 dB peak injury threshold for fish, 36 to 48-inch pile.

Distance to Exceedance of Threshold

- 7 meters with attenuation device
- 34 meters without attenuation device

Area of affect for single pile drivers at a single pier using P4 as an example

- 7 meters with attenuation device
- 34 meters without attenuation device

Depth (CRD, ft.)

- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55

Design Shapes

- Project Bridge Piers
- Project Footprint

N
W E
S

0 475 950
Feet

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Impact pile driving will not take place simultaneously at all piers.

Columbia River CROSSING

Analysis: ...oloszar: Analysis Date: Feb. 11, 2010; File Name: HydroSound_MG246_2.mxd

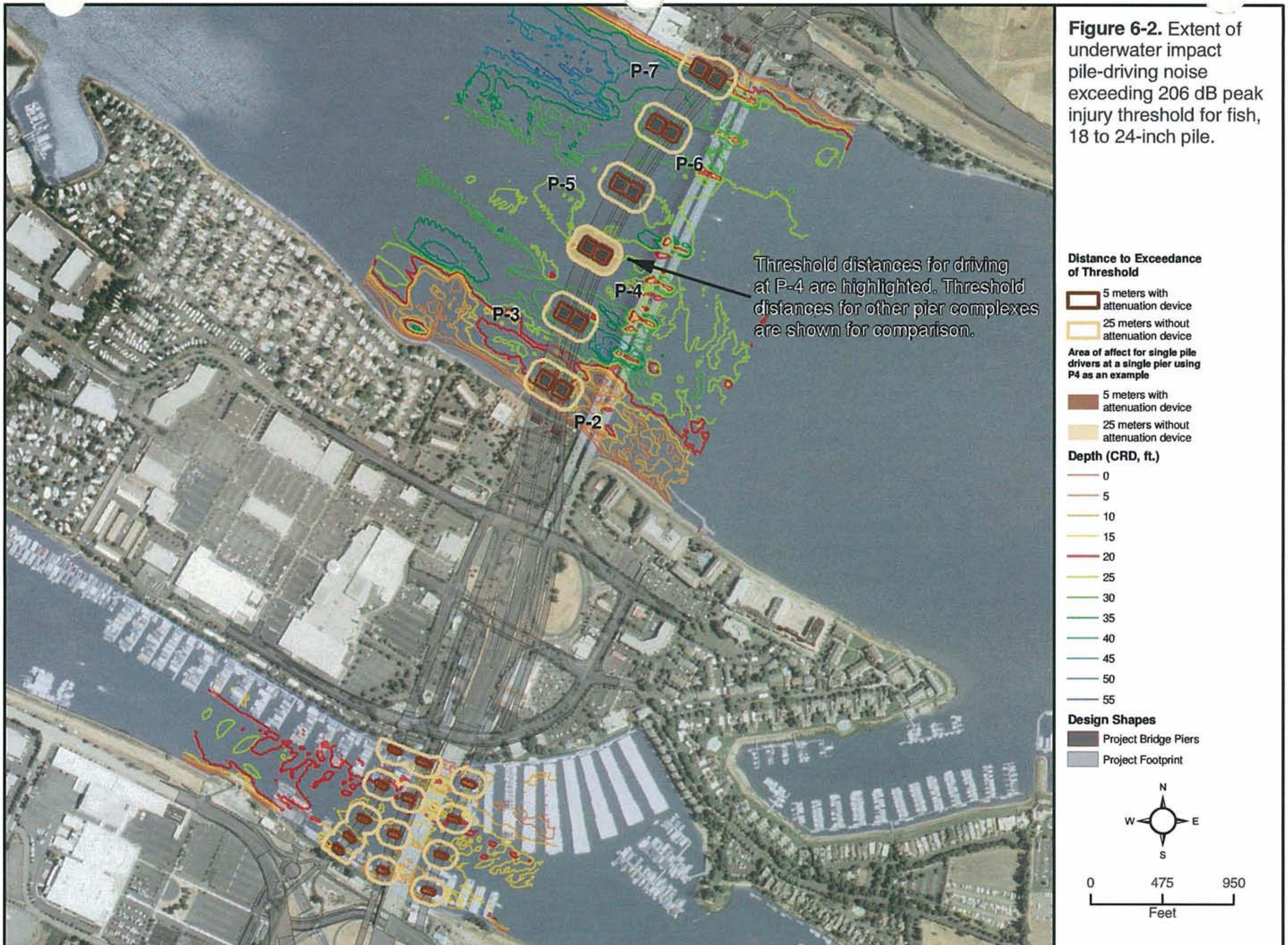


Figure 6-2. Extent of underwater impact pile-driving noise exceeding 206 dB peak injury threshold for fish, 18 to 24-inch pile.

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Impact pile driving will not take place simultaneously at all piers.

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: Feb. 11, 2010; File Name: HydroSound_MG245_2.mxd

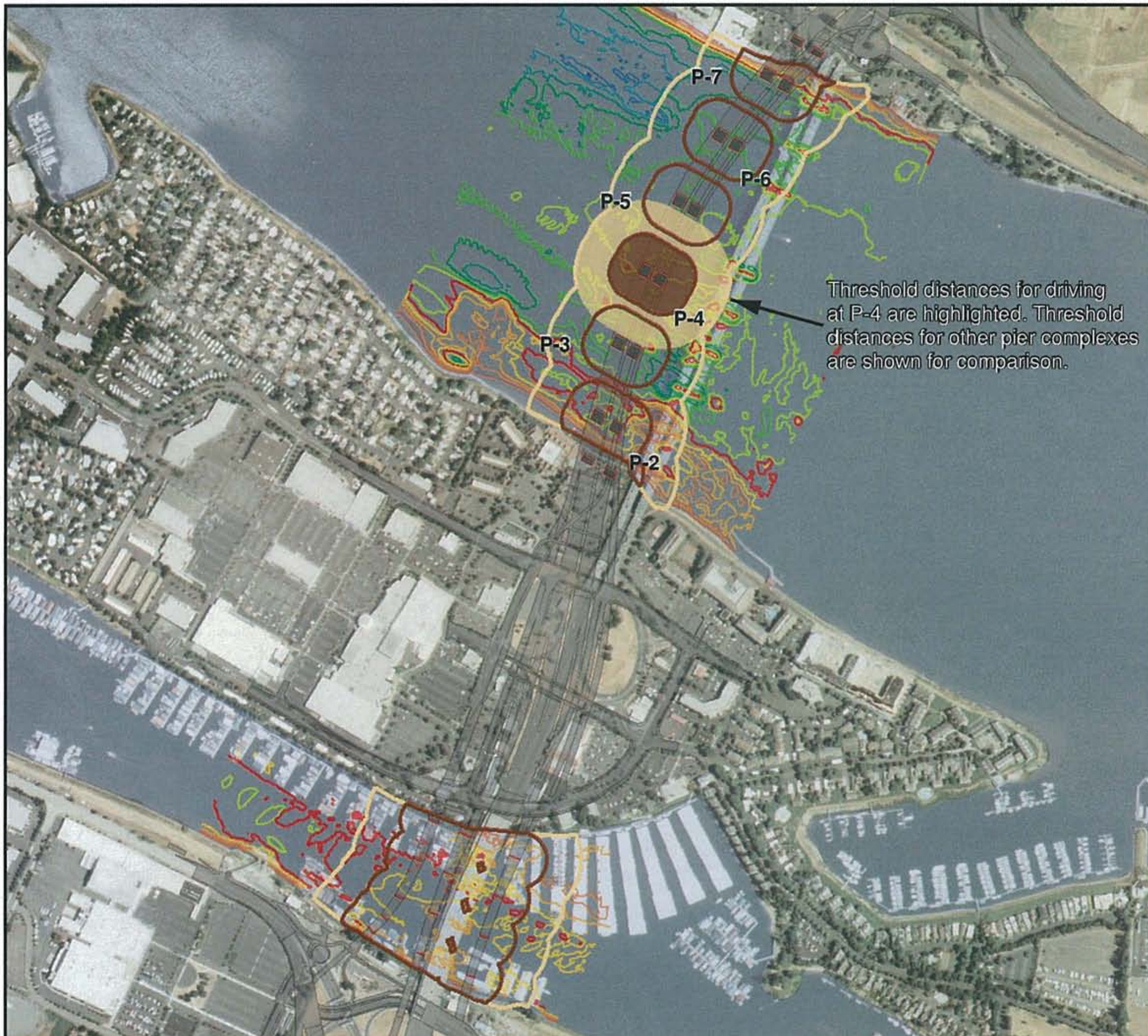


Figure 6-3. Extent of underwater impact pile-driving noise exceeding 187 dB SEL injury threshold for fish over 2 grams, 18 to 24-inch pile, single pile driver.

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Impact pile driving will not take place simultaneously at all piers.

Columbia River CROSSING

Analysis: Koloszar; Analysis Date: Feb. 11, 2010; File Name: HydroSound_MG246_2.mxd

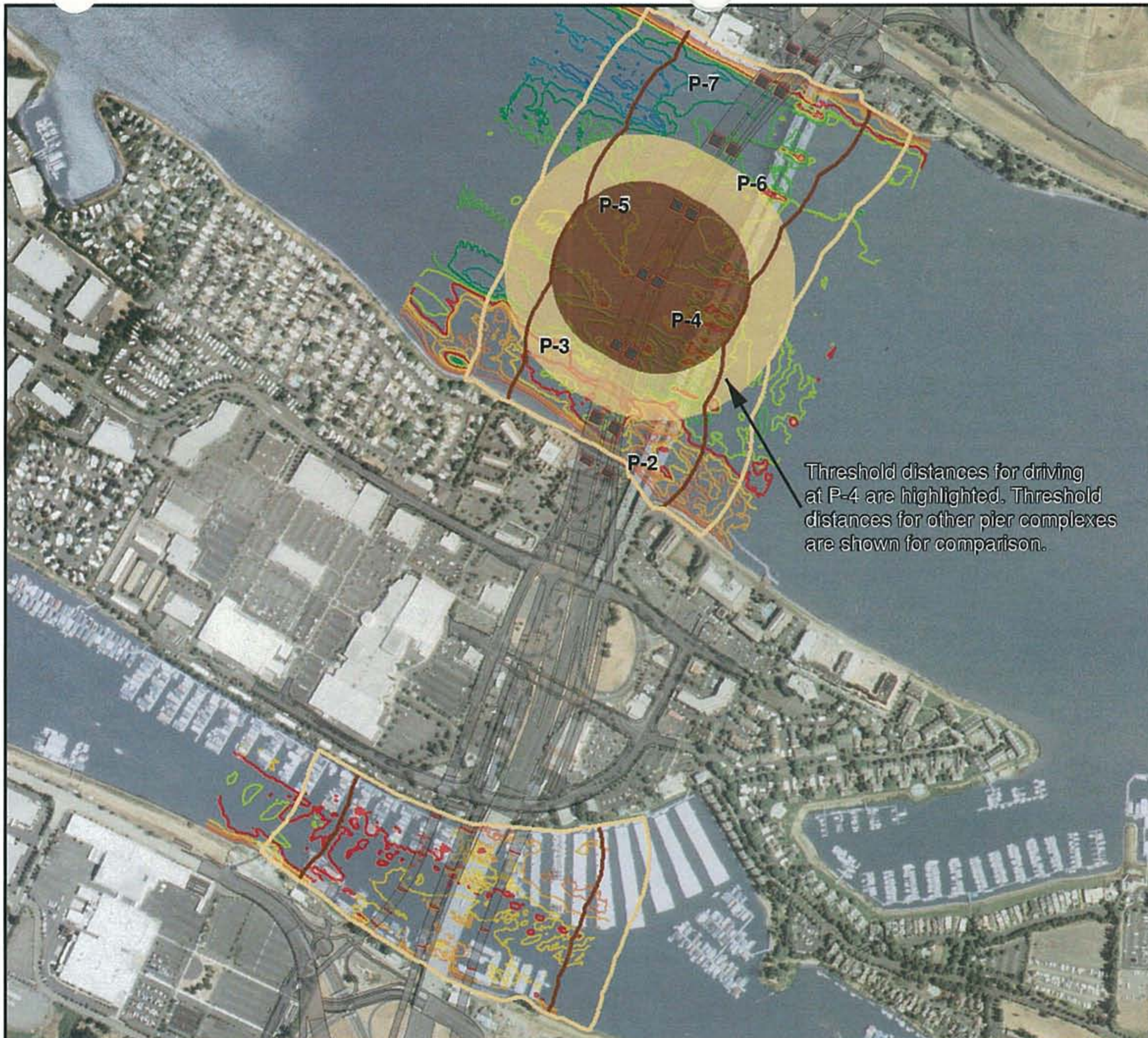


Figure 6-4. Extent of underwater impact pile-driving noise exceeding 187 dB SEL injury threshold for fish over 2 grams, 36 to 48-inch pile, single pile driver.

Fish speed 0.1 m/s

Distance to Exceedance of Threshold

- 156 meters with attenuation device
- 243 meters without attenuation device

Area of affect for single pile drivers at a single pier using P4 as an example

- 156 meters with attenuation device
- 243 meters without attenuation device

Depth (CRD, ft.)

0
5
10
15
20
25
30
35
40
45
50
55

- Project Bridge Piers
- Project Footprint

N W E S

0 510 1,020
Feet

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Impact pile driving will not take place simultaneously at all piers.

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: May 20, 2010; File Name: HydroSound_MG246_2.mxd

Figure 6-5. Extent of underwater impact pile-driving noise exceeding 187 dB SEL injury threshold for fish over 2 grams, multiple pile drivers.

Fish speed 0.1 m/s

Distance to Exceedance of Threshold

- 59 meters, two 18 to 24-inch piles
- 130 meters, two 36 to 48-inch piles or one 18- to 24-inch plus one 26- to 48-inch pile

Area of affect for multiple pile drivers at a single pier using P4 as an example

- 59 meters, two 18 to 24-inch piles
- 130 meters, two 36 to 48-inch piles or one 18- to 24-inch plus one 26- to 48-inch pile

Depth (CRD, ft.)

- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55
- Project Bridge Piers
- Project Footprint

N
W E
S

0 510 1,020
Feet

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Multiple pile drivers will operate simultaneously at a single pier complex for a large majority of impact pile driving. Only rarely (about one day out of every 142 in-water work days) will multiple pile drivers operate at seperate pier complexes.

Columbia River CROSSING

Analysis by ... Koloszar; Analysis Date: May 20, 2010; File Name: HydroSound_MG245_2.mxd

Table 6-6 and Figure 6-6 through Figure 6-8 present the results of calculations showing distances within which noise is estimated to exceed the 183 dB SEL injury thresholds for fish under 2 g and moving at 0.6 m/s for a single pile driver and for two pile drivers operating simultaneously.

Table 6-6. Distances at Which Underwater Noise Exceeds 183 dB SEL Injury Threshold for Moving Fish Under 2 g at 0.6 m/s in the Columbia River and North Portland Harbor

Pile Size	Distance (m)	
	Without Attenuation Device	With Attenuation Device
18- to 24-inch pile	200	50
36- to 48-inch pile	446	235
Two 18- to 24-inch piles	N/A	79[a]
Two 36- to 48-inch piles OR One 18- to 24-inch and one 36- to 48-inch pile	N/A	209[a]

Note: Includes juvenile chum and larval eulachon.
a Applies to Columbia River only.

Table 6-7 and Figure 6-9 through Figure 6-11 show the distances within which noise is estimated to exceed the 187 dB SEL injury thresholds for fish over 2 g and moving 0.8 m/s for a single pile driver and for two pile drivers operating simultaneously.

Table 6-7. Distances at Which Underwater Noise Exceeds 187 dB SEL Injury Threshold for Fish Over 2 g at 0.8 m/s in the Columbia River and North Portland Harbor

Pile Size	Distance (m)	
	Without Attenuation Device	With Attenuation Device
18- to 24-inch pile	102	9
36- to 48-inch pile	237	67
Two 18- to 24-inch piles	N/A	48[a]
Two 36- to 48-inch piles OR One 18- to 24-inch and one 36- to 48-inch pile	N/A	111[a]

Note: Includes juvenile salmonids except for chum.
a Applies to Columbia River only.

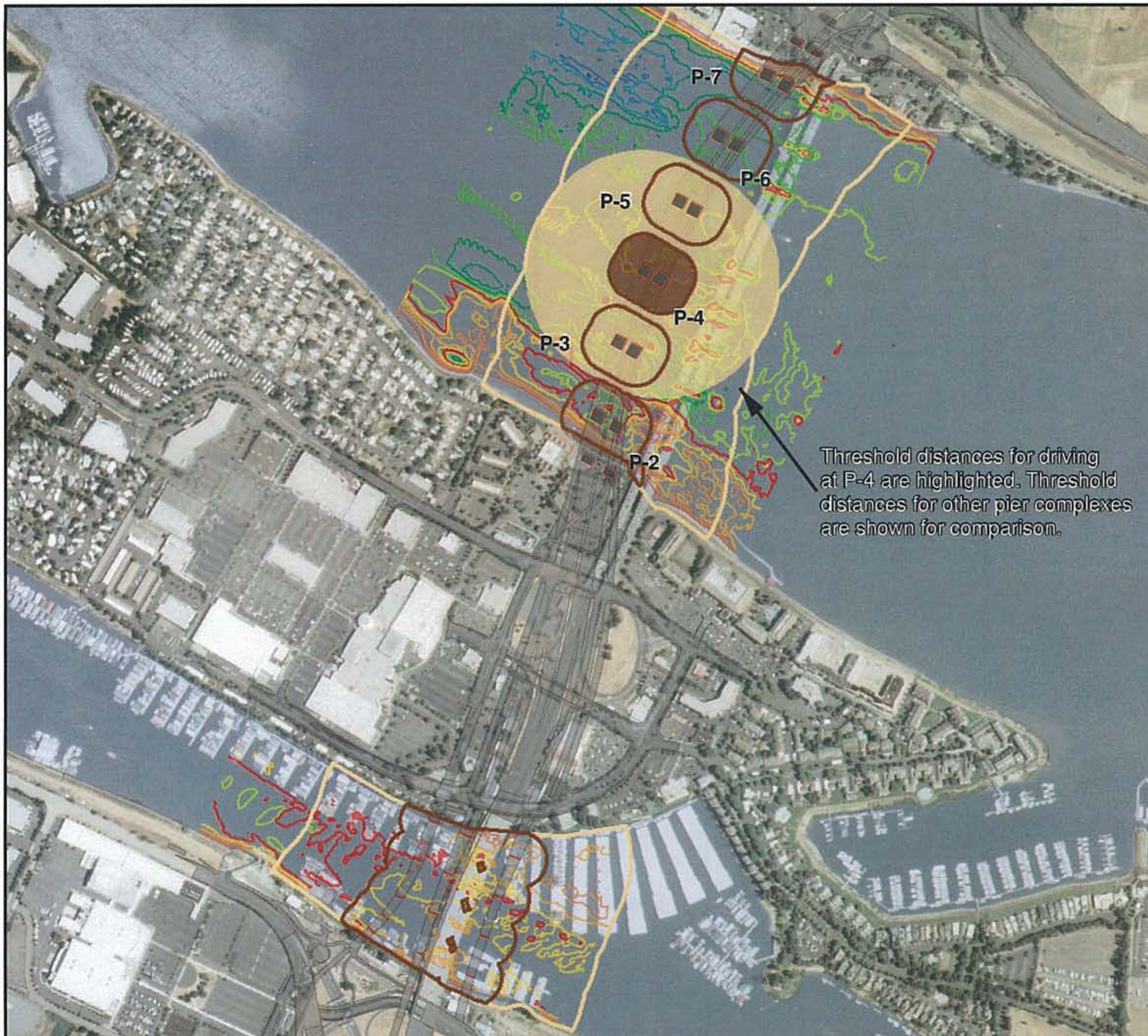


Figure 6-6. Extent of underwater impact pile-driving noise exceeding 183 dB SEL injury threshold for fish under 2 grams, 18 to 24-inch pile, single pile driver.

Fish speed 0.6 m/s

Distance to Exceedance of Threshold

- 50 meters with attenuation device
- 205 meters without attenuation device

Area of affect for single pile drivers at a single pier using P4 as an example

- 50 meters with attenuation device
- 205 meters without attenuation device

Depth (CRD, ft.)

0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55

Design Shapes

- Project Bridge Piers
- Project Footprint

N, E, S, W

0 475 950
Feet

Columbia River CROSSING

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Impact pile driving will not take place simultaneously at all piers.

Analysis by [illegible]oloszar. Analysis Date: Feb. 11, 2010; File Name: HydroSound_MG245_2.mxd

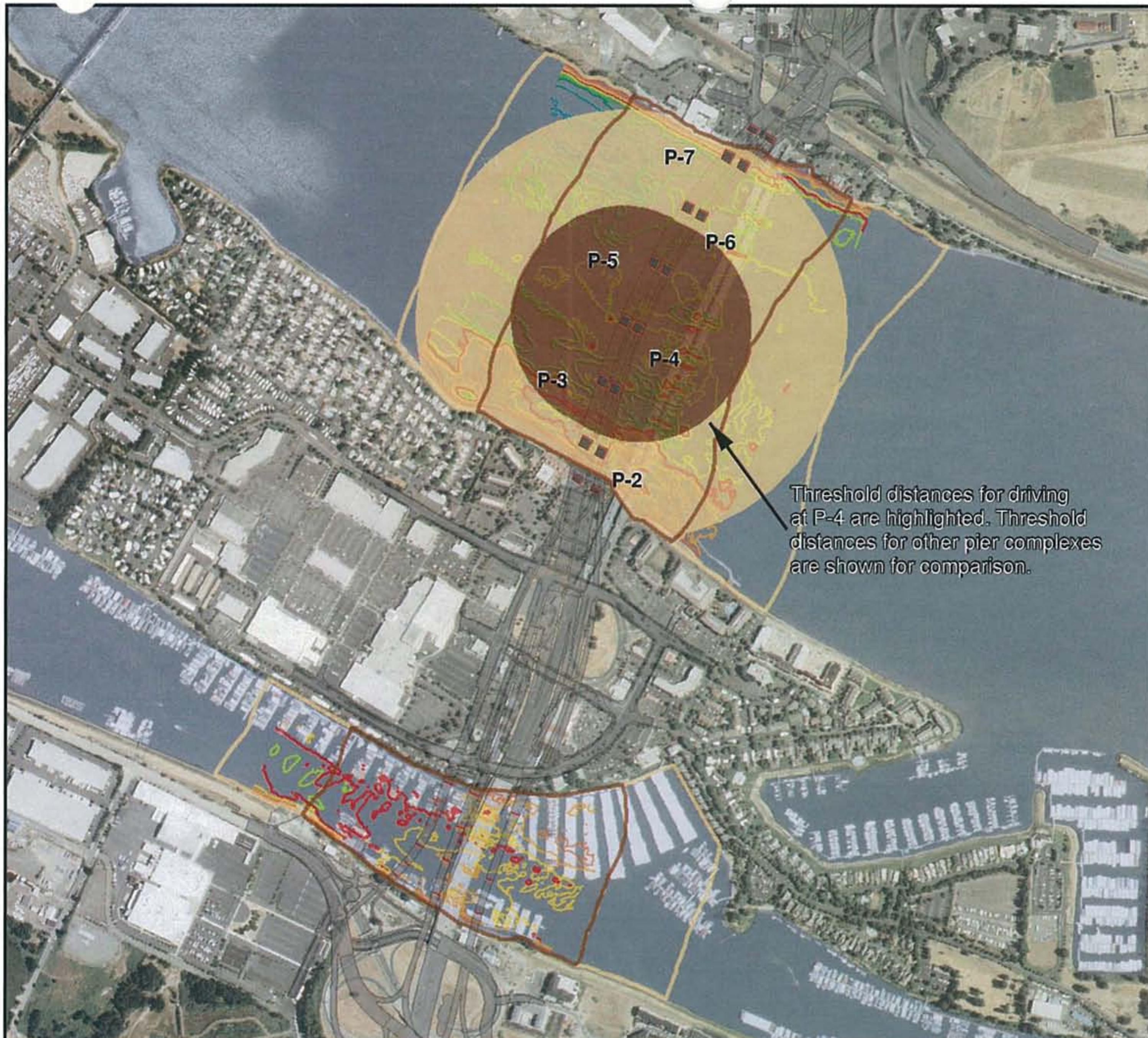


Figure 6-7. Extent of underwater impact pile-driving noise exceeding 183 dB SEL injury threshold for fish under 2 grams, 36 to 48-inch pile, single pile driver.

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Impact pile driving will not take place simultaneously at all piers.

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: May 20, 2010; File Name: HydroSound_MG246_2.mxd

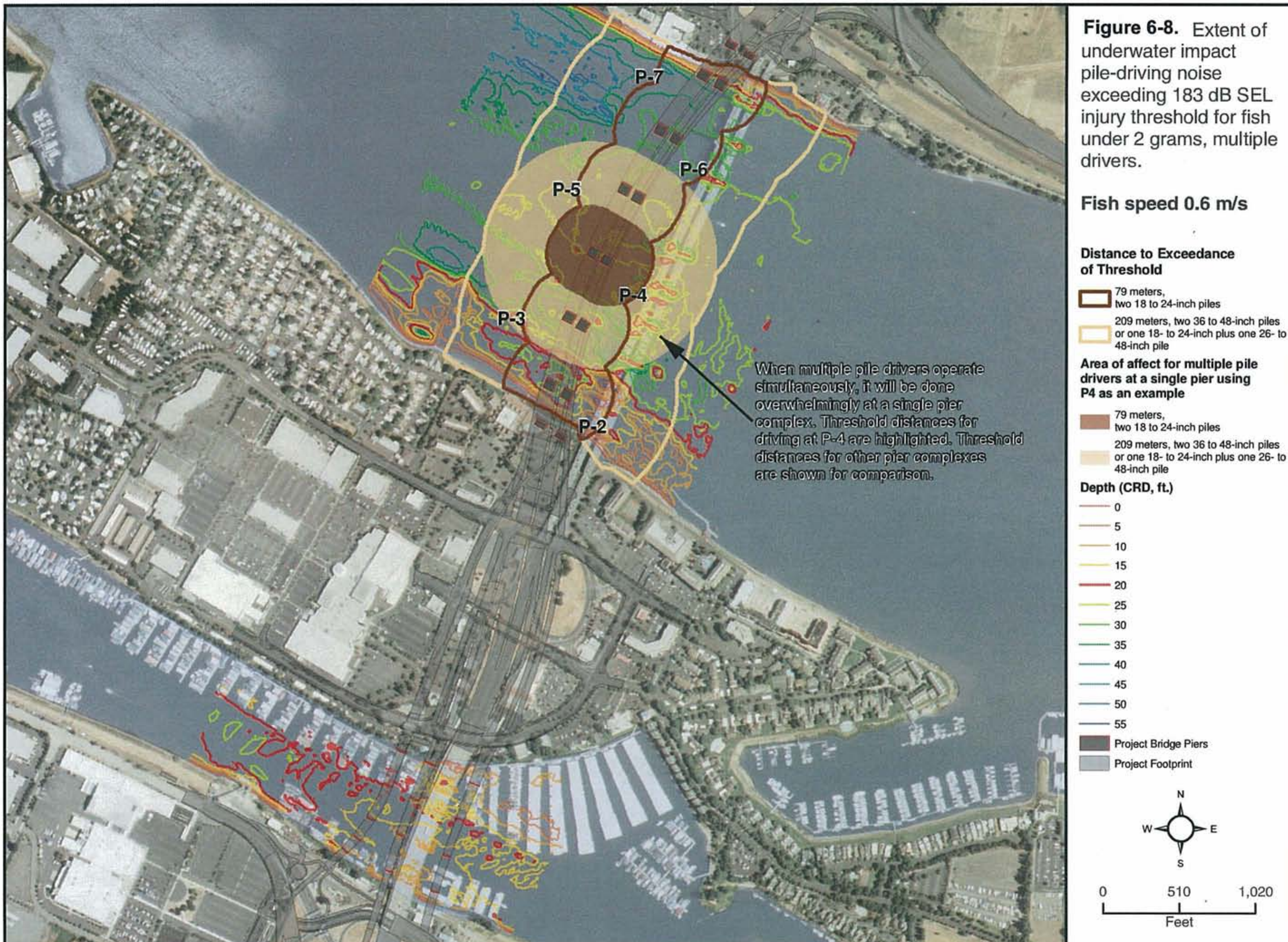


Figure 6-8. Extent of underwater impact pile-driving noise exceeding 183 dB SEL injury threshold for fish under 2 grams, multiple drivers.

Fish speed 0.6 m/s

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Multiple pile drivers will operate simultaneously at a single pier complex for a large majority of impact pile driving. Only rarely (about one day out of every 142 in-water work days) will multiple pile drivers operate at seperate pier complexes.

Columbia River CROSSING

Analysis by Koloszar; Analysis Date: May 20, 2010; File Name: HydroSound_MG246_2.mxd

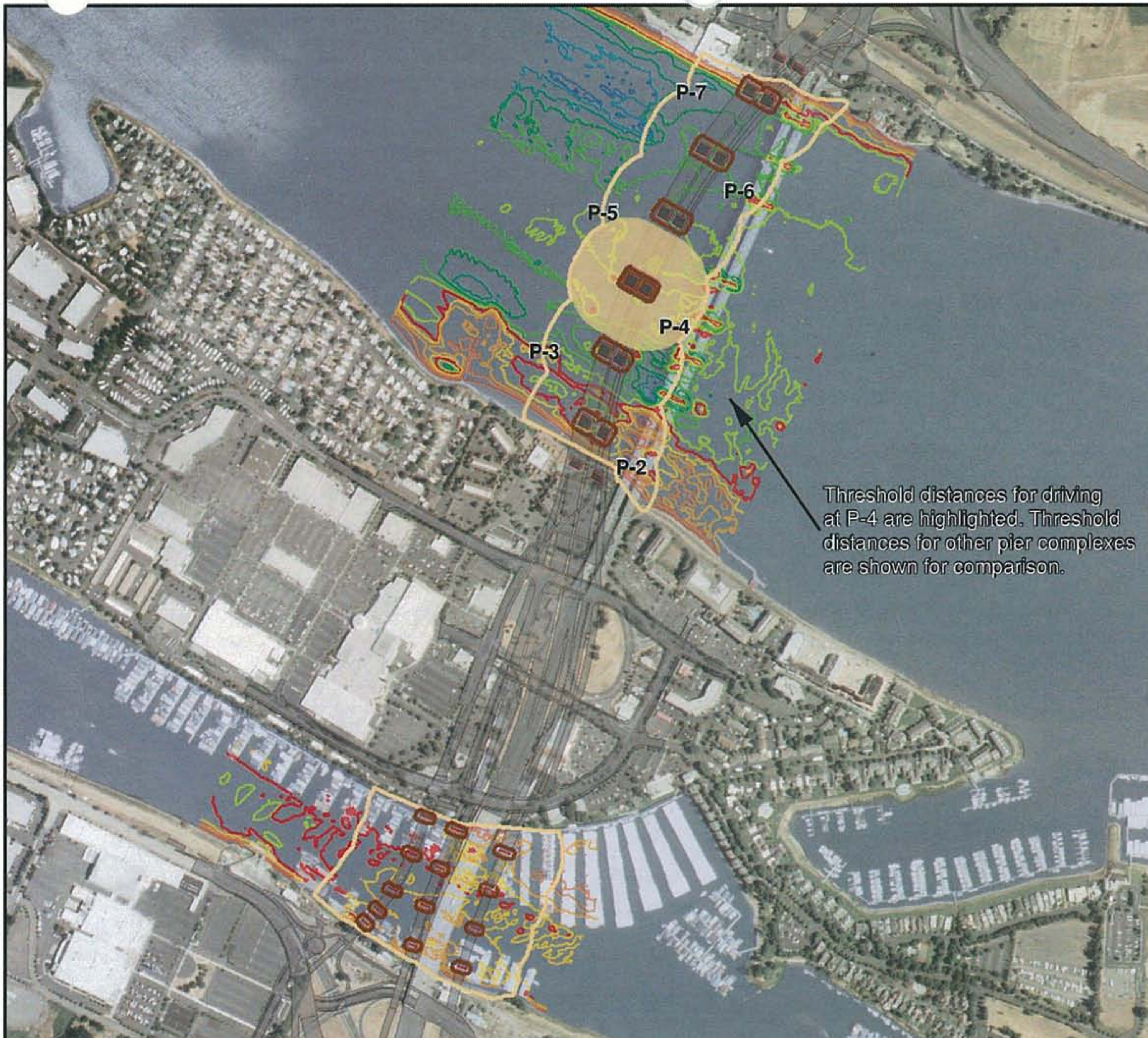


Figure 6-9. Extent of underwater impact pile-driving noise exceeding 187 dB SEL injury threshold for fish over 2 grams, 18 to 24-inch pile, single pile driver.

Fish speed 0.8 m/s

Distance to Exceedance of Threshold

- 9 meters with attenuation device
- 102 meters without attenuation device

Area of affect for single pile drivers at a single pier using P4 as an example

- 9 meters with attenuation device
- 102 meters without attenuation device

Depth (CRD, ft.)

- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55
- Project Bridge Piers
- Project Footprint

N
W E
S

0 520 1,040
Feet

Columbia River CROSSING

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Impact pile driving will not take place simultaneously at all piers.

Analysis by J. Koloszar; Analysis Date: May 20, 2010; File Name: HydroSound_MG246_2.mxd

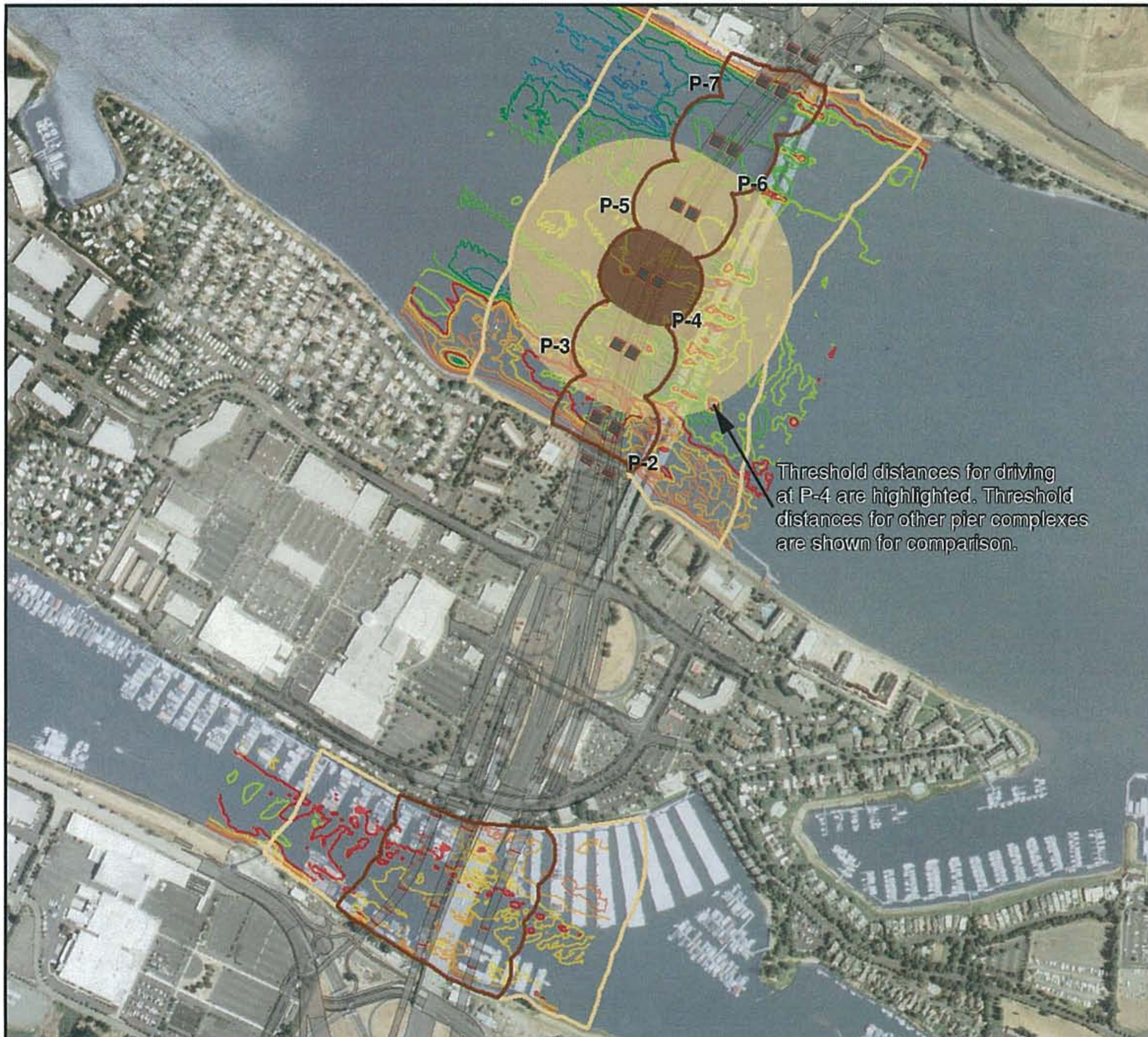


Figure 6-10. Extent of underwater impact pile-driving noise exceeding 187 dB SEL injury threshold for fish over 2 grams, 36 to 48-inch pile, single pile driver.

Fish speed 0.8 m/s

Distance to Exceedance of Threshold

- 67 meters, with attenuation device
- 237 meters, without attenuation device

Area of affect for single pile drivers at a single pier using P4 as an example

- 67 meters, with attenuation device
- 237 meters, without attenuation device

Depth (CRD, ft.)

0
5
10
15
20
25
30
35
40
45
50
55

Project Bridge Piers
Project Footprint

N
W E
S

0 510 1,020
Feet

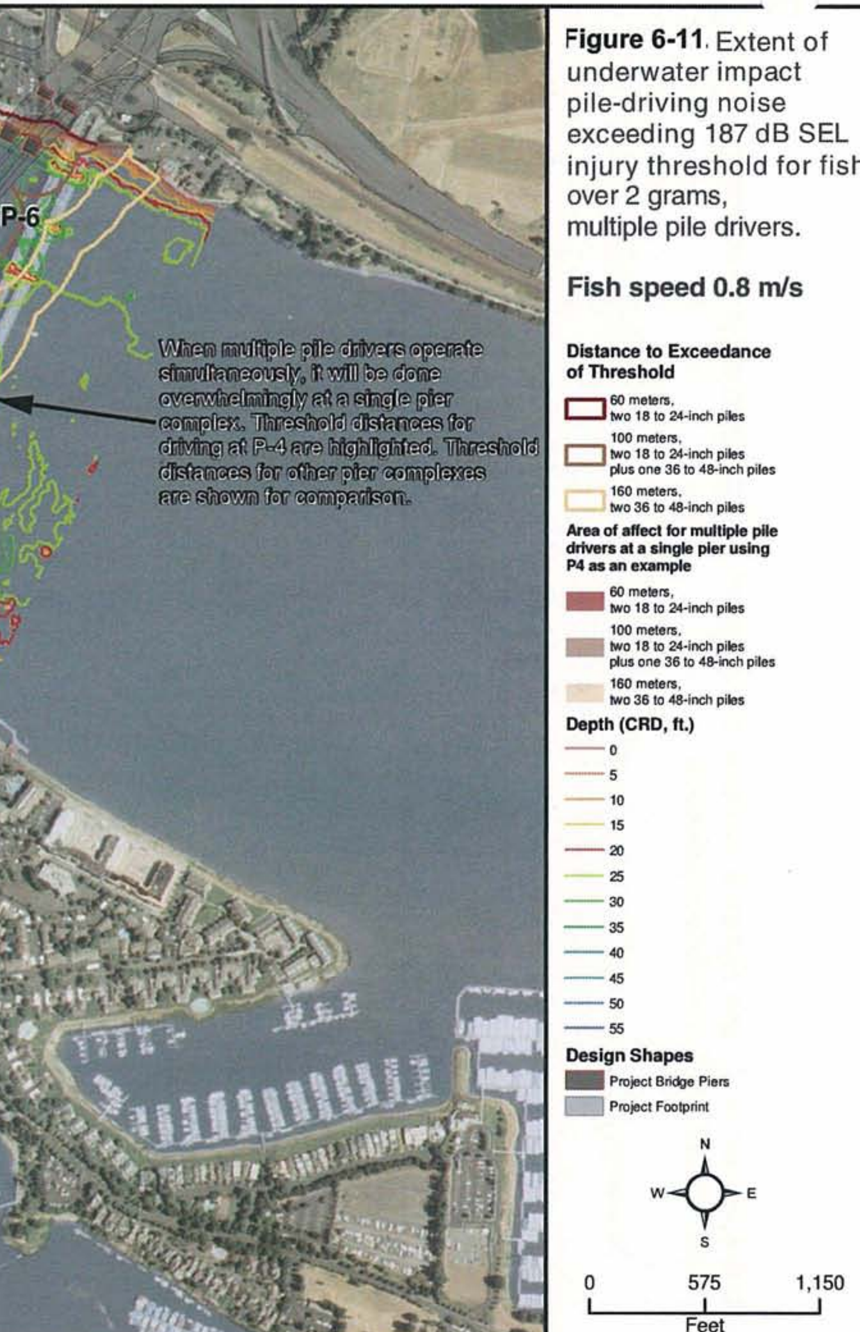
Columbia River CROSSING

This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Impact pile driving will not take place simultaneously at all piers.

Analysis Koloszar; Analysis Date: May 20, 2010; File Name: HydroSound_MG246_2.mxd

Figure 6-11. Extent of underwater impact pile-driving noise exceeding 187 dB SEL injury threshold for fish over 2 grams, multiple pile drivers.

Fish speed 0.8 m/s



This is a conceptual diagram only. Threshold distances are not exact, as precise locations of pile drivers are likely to vary within the footprint of each pier complex or bent. Multiple pile drivers will operate simultaneously at a single pier complex for a large majority of impact pile driving. Only rarely (about one day out of every 142 in-water work days) will multiple pile drivers operate at separate pier complexes.

Columbia River CROSSING

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Table 6-8, Figure 6-12, and Figure 6-13 show the distances within which noise is estimated to exceed the 150 dB RMS disturbance guidance.

Table 6-8. Distances at Which Underwater Noise Exceeds 150 dB RMS Disturbance Guidance in the Columbia River and North Portland Harbor

	Columbia River		North Portland Harbor	
Impact Pile Driving	**Distance Upstream (m)**	**Distance Downstream (m)**	**Distance Upstream (m)**	**Distance Downstream (m)**
Without Attenuation Device				
18- to 24-inch pile	3,981	3,981	3,058	3,981
36- to 48-inch pile	20,166	8,851	3,058	5,632
With Attenuation Device				
18- to 24-inch pile	858	858	858	858
36- to 48-inch pile	5,412	5,412	3,058	5,412

Figure 6-12. Extent of underwater impact pile-driving noise exceeding 150 dB RMS disturbance guidance for fish, 36 to 48-inch pile.

Distance to Exceedance of Guidance

- 5,412 meters with attenuation device
- 20,166 meters without attenuation device

Design Shapes

- Project Bridge Piers
- Project Footprint

N
W E
S

0 6,600 13,200
Feet

Columbia River CROSSING

Analysis by J. Koloszar; Analysis Date: Feb. 11, 2010; File Name: HydroSound_MG246_2.mxd

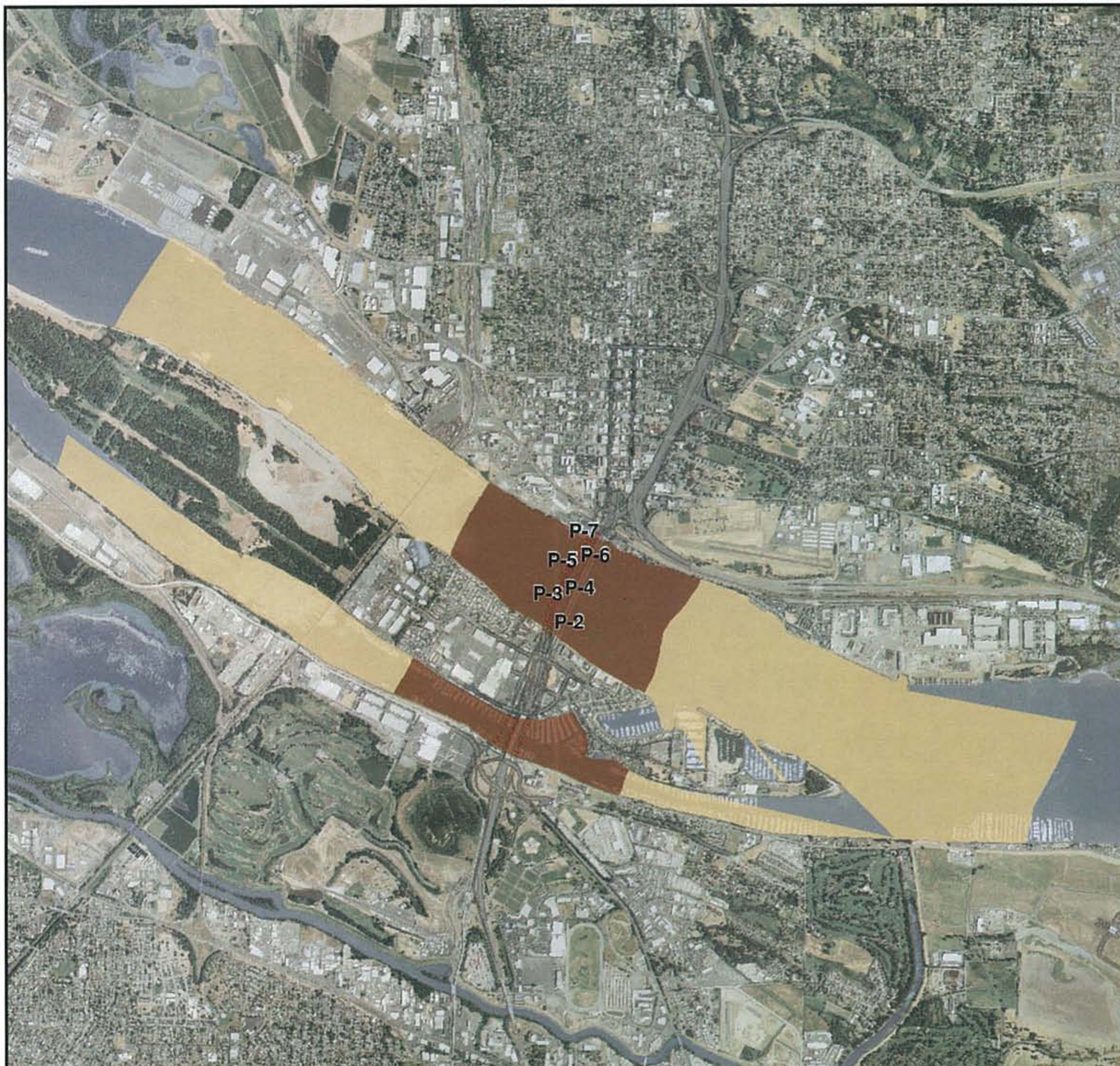


Figure 6-13. Extent of underwater impact pile-driving noise exceeding 150 dB RMS disturbance guidance for fish, 18 to 24-inch pile.

Distance to Exceedance of Guidance

- 858 meters with attenuation device
- 3,981 meters without attenuation device

Design Shapes

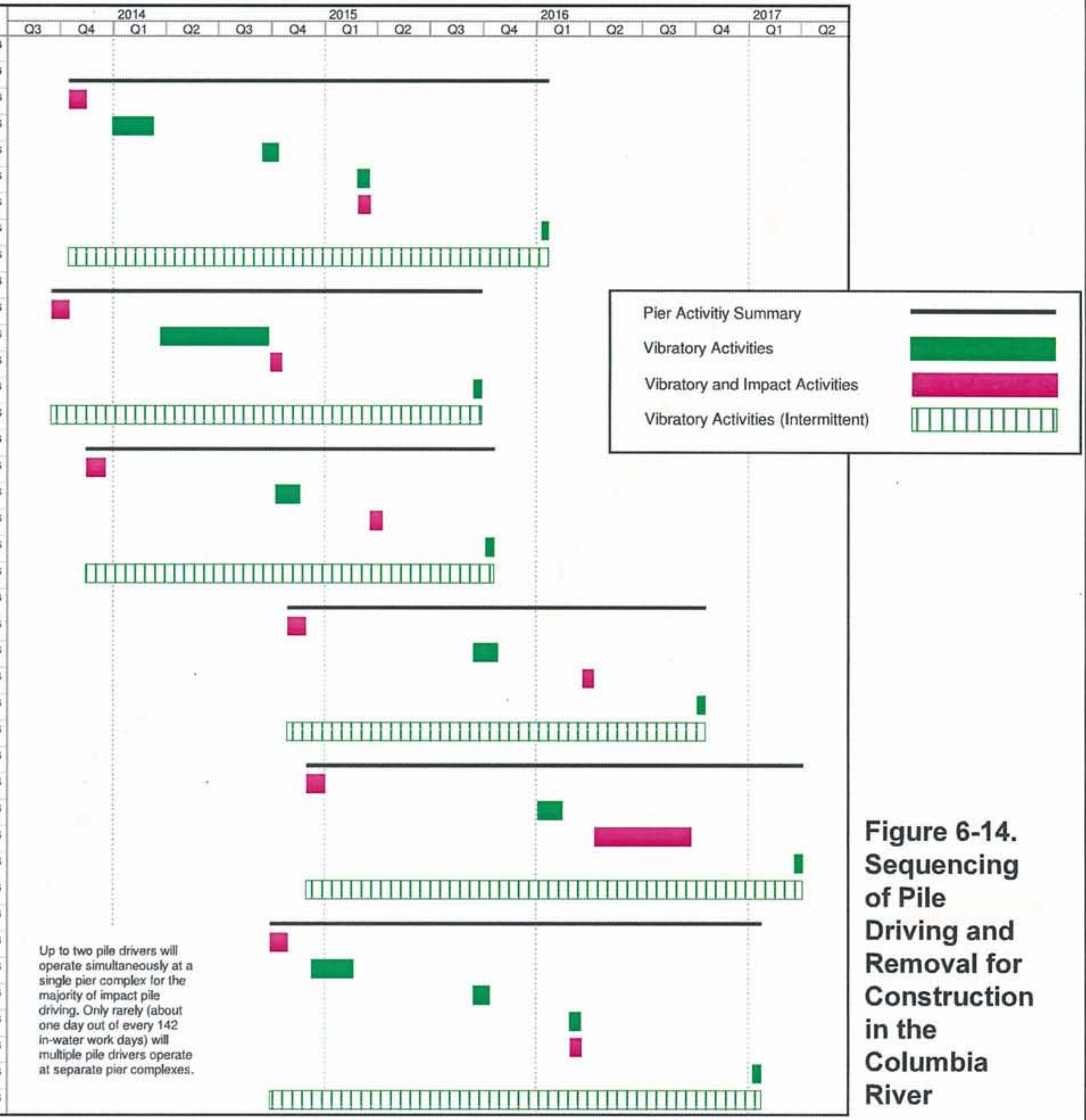
- Project Bridge Piers
- Project Footprint

N
W E
S

0 2,000 4,000
Feet

Columbia River CROSSING

Task Name	Start	Finish	Duration
Bridge Construction Scenario 2/5/13	**9/16/13**	**4/5/17**	**928 days**
Pier 2	**10/16/13**	**1/22/16**	**593 days**
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	10/16/13	11/14/13	22 days
Install Cofferdam (Vibratory Installation)	12/31/13	3/11/14	51 days
Remove Work Bridge & Piles (Vibratory Removal)	9/16/14	10/13/14	20 days
Remove Cofferdam (Vibratory Removal)	2/27/15	3/19/15	15 days
Erect Tower Crane (Vibratory & Impact Pile Driving)	2/27/15	3/19/15	15 days
Remove Tower Crane (Vibratory Removal)	1/11/16	1/22/16	10 days
Barge Moorings (Vibratory Installation & Removal)	10/16/13	1/22/16	593 days
Pier 3	**9/16/13**	**9/29/15**	**532 days**
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	9/16/13	10/15/13	22 days
Remove Work Platform & Piles (Vibratory Removal)	3/24/14	9/26/14	135 days
Erect Tower Crane (Vibratory & Impact Pile Driving)	9/29/14	10/17/14	15 days
Remove Tower Crane (Vibratory Removal)	9/16/15	9/29/15	10 days
Barge Moorings (Vibratory Installation & Removal)	9/16/13	9/29/15	532 days
Pier 4	**11/15/13**	**10/20/15**	**503 days**
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	11/15/13	12/17/13	23 days
Remove Work Platform & Piles (Vibratory Removal)	10/9/14	11/19/14	30 days
Erect Tower Crane (Vibratory & Impact Pile Driving)	3/20/15	4/9/15	15 days
Remove Tower Crane (Vibratory Removal)	10/7/15	10/20/15	10 days
Barge Moorings (Vibratory Installation & Removal)	11/15/13	10/20/15	503 days
Pier 5	**10/29/14**	**10/19/16**	**516 days**
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	10/29/14	11/28/14	23 days
Remove Work Platform & Piles (Vibratory Removal)	9/16/15	10/27/15	30 days
Erect Tower Crane (Vibratory & Impact Pile Driving)	3/21/16	4/8/16	15 days
Remove Tower Crane (Vibratory Removal)	10/6/16	10/19/16	10 days
Barge Moorings (Vibratory Installation & Removal)	10/29/14	10/19/16	516 days
Pier 6	**12/1/14**	**4/5/17**	**613 days**
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	12/1/14	12/31/14	23 days
Remove Work Platform & Piles (Vibratory Removal)	1/5/16	2/15/16	30 days
Erect Tower Crane (Vibratory & Impact Pile Driving)	4/11/16	9/23/16	120 days
Remove Tower Crane (Vibratory Removal)	3/23/17	4/5/17	10 days
Barge Moorings (Vibratory Installation & Removal)	12/1/14	4/5/17	613 days
Pier 7	**9/29/14**	**1/23/17**	**606 days**
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	9/29/14	10/28/14	22 days
Install Cofferdam (Vibratory Installation)	12/11/14	2/20/15	52 days
Remove Work Bridge & Piles (Vibratory Removal)	9/16/15	10/13/15	20 days
Remove Cofferdam (Vibratory Removal)	2/29/16	3/18/16	15 days
Erect Tower Crane (Vibratory & Impact Pile Driving)	2/29/16	3/18/16	15 days
Remove Tower Crane (Vibratory Removal)	1/10/17	1/23/17	10 days
Barge Moorings (Vibratory Installation & Removal)	9/29/14	1/23/17	606 days



Conceptual Schedule Only, April 2010
Note: This is a proposed schedule, so activity dates are likely to change.

Figure 6-14. Sequencing of Pile Driving and Removal for Construction in the Columbia River

Columbia River CROSSING

9116

Task Name	Duration	Start	Finish
Widening of Existing Bridge	**111 days**	**9/15/13**	**1/30/14**
Bent 4	**20 days**	**9/15/13**	**10/8/13**
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	8 days	9/15/13	9/22/13
Remove Work Bridge and Piles (Vibratory Removal)	1 day	10/8/13	10/8/13
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	9/23/13	9/24/13
Remove Oscillator Support Piles (Vibratory Removal)	1 day	10/8/13	10/8/13
Bent 5	**10 days**	**10/11/13**	**10/24/13**
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	10/11/13	10/14/13
Remove Oscillator Support Piles (Vibratory Removal)	1 day	10/24/13	10/24/13
Bent 6	**10 days**	**10/27/13**	**11/7/13**
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	10/27/13	10/28/13
Remove Oscillator Support Piles (Vibratory Removal)	1 day	11/7/13	11/7/13
Bent 7	**10 days**	**11/10/13**	**11/21/13**
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	11/10/13	11/11/13
Remove Oscillator Support Piles (Vibratory Removal)	1 day	11/21/13	11/21/13
Bent 8	**22 days**	**11/24/13**	**12/19/13**
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	11/24/13	11/25/13
Remove Oscillator Support Piles (Vibratory Removal)	1 day	12/19/13	12/19/13
Bent 9	**42 days**	**12/12/13**	**1/30/14**
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	8 days	12/12/13	12/19/13
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	8 days	1/1/14	1/8/14
Remove Work Bridge and Piles (Vibratory Removal)	1 day	1/30/14	1/30/14
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	12/22/13	12/23/13
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	1/9/14	1/10/14
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	1/18/14	1/20/14
Remove Oscillator Support Piles (Vibratory Removal)	1 day	1/30/14	1/30/14
Barge Moorings - All Bents (Vibratory Installation & Removal)	111 days	9/15/13	1/30/14
Light Rail Transit/Multi-Use Plan Bridge	**142 days**	**9/15/14**	**3/12/15**
Bent 2	**30 days**	**9/15/14**	**10/22/14**
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	8 days	9/15/14	9/22/14
Remove Work Bridge and Piles (Vibratory Removal)	1 day	10/22/14	10/22/14
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	9/22/14	9/23/14
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	10/2/14	10/3/14
Remove Oscillator Support Piles (Vibratory Removal)	1 day	10/22/14	10/22/14
Bent 3	**21 days**	**10/25/14**	**11/20/14**
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	10/25/14	10/26/14
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	11/4/14	11/5/14
Remove Oscillator Support Piles (Vibratory Removal)	1 day	11/20/14	11/20/14
Bent 4	**20 days**	**11/23/14**	**12/18/14**
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	11/23/14	11/24/14
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	12/3/14	12/4/14
Remove Oscillator Support Piles (Vibratory Removal)	1 day	12/18/14	12/18/14
Bent 5	**34 days**	**12/21/14**	**1/29/15**
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	12/21/14	12/22/14
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	12/31/14	1/1/15
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	7 days	1/10/15	1/17/15
Remove Oscillator Support Piles (Vibratory Removal)	1 day	1/29/15	1/29/15
Bent 6	**41 days**	**1/22/15**	**3/12/15**
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	8 days	1/22/15	1/29/15
Remove Work Bridge and Piles (Vibratory Removal)	1 day	3/12/15	3/12/15
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	2/1/15	2/2/15
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	2/11/15	2/12/15
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	2/21/15	2/22/15
Remove Oscillator Support Piles (Vibratory Removal)	1 day	3/12/15	3/12/15
Barge Moorings - All Bents (Vibratory Installation & Removal)	142 days	9/15/14	3/12/15

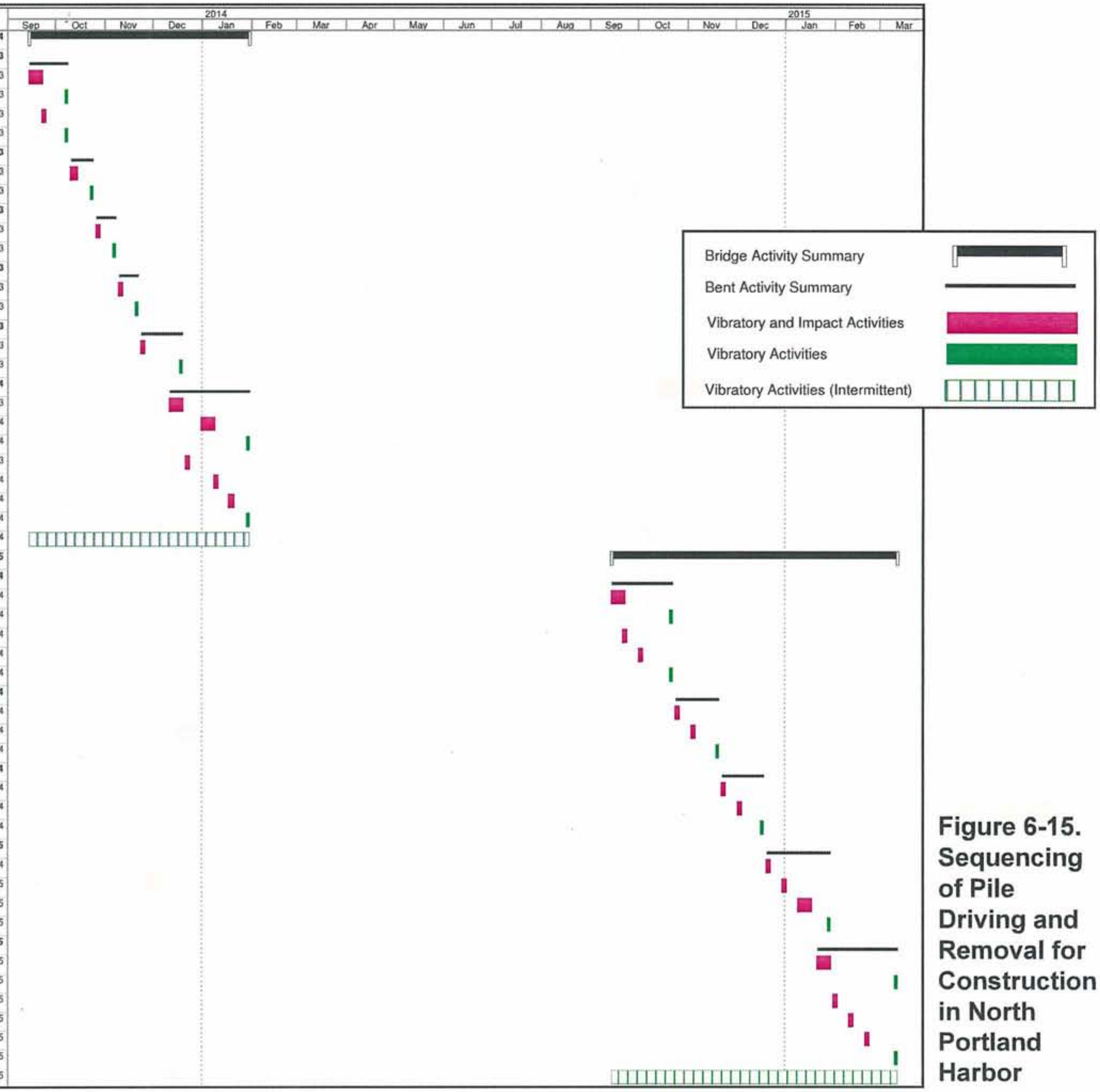
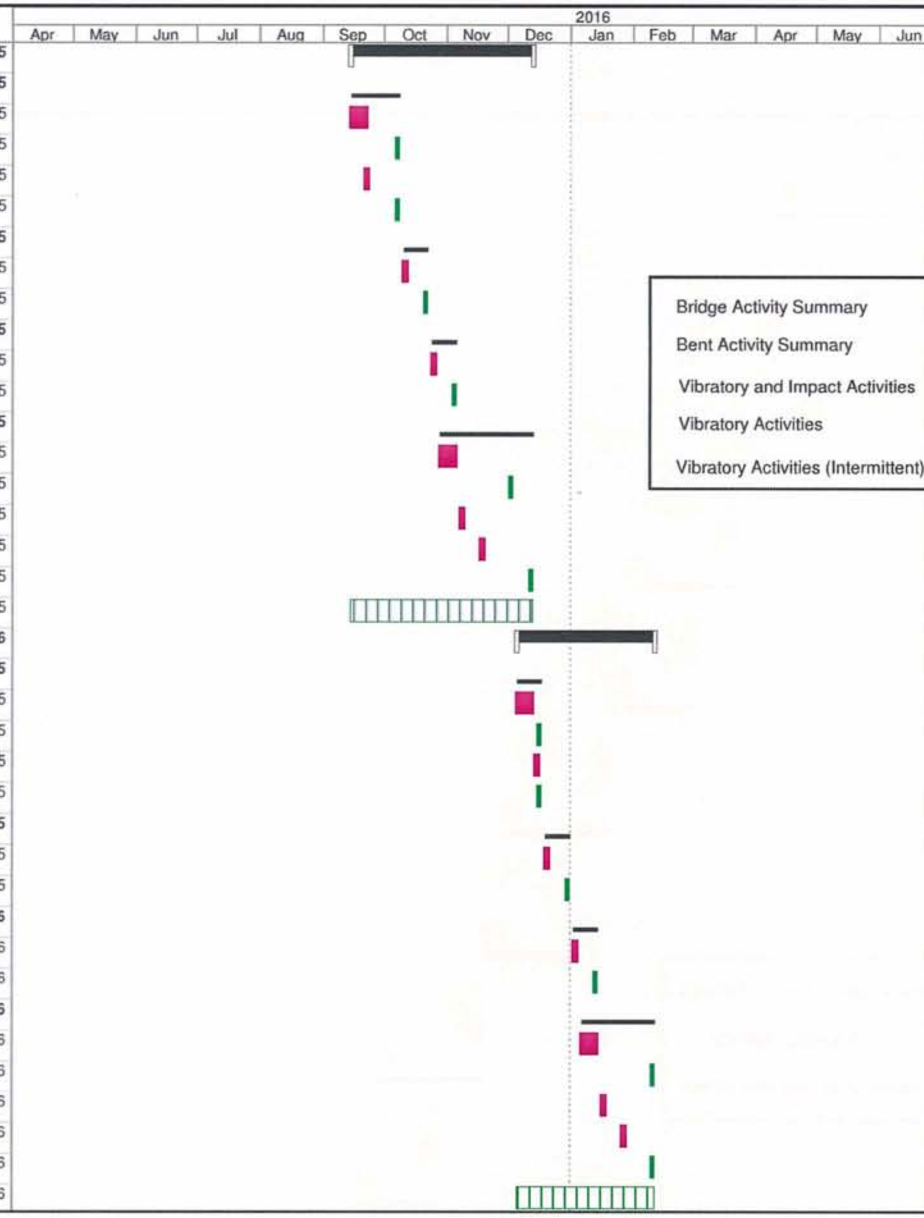


Figure 6-15. Sequencing of Pile Driving and Removal for Construction in North Portland Harbor

Conceptual Schedule Only, April 2010
Note: This is a proposed schedule, so activity dates are likely to change.

Columbia River CROSSING

Task Name	Duration	Start	Finish
Northbound Collector Distributor Ramp	**74 days**	**9/15/15**	**12/13/15**
Bent 6	**20 days**	**9/15/15**	**10/8/15**
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	8 days	9/15/15	9/22/15
Remove Work Bridge and Piles (Vibratory Removal)	1 day	10/8/15	10/8/15
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	9/22/15	9/23/15
Remove Oscillator Support Piles (Vibratory Removal)	1 day	10/8/15	10/8/15
Bent 7	**10 days**	**10/11/15**	**10/22/15**
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	10/11/15	10/12/15
Remove Oscillator Support Piles (Vibratory Removal)	1 day	10/22/15	10/22/15
Bent 8	**12 days**	**10/25/15**	**11/5/15**
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	10/25/15	10/26/15
Remove Oscillator Support Piles (Vibratory Removal)	1 day	11/5/15	11/5/15
Bent 9	**38 days**	**10/29/15**	**12/13/15**
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	8 days	10/29/15	11/5/15
Remove Work Bridge and Piles (Vibratory Removal)	1 day	12/3/15	12/3/15
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	11/8/15	11/9/15
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	11/18/15	11/19/15
Remove Oscillator Support Piles (Vibratory Removal)	1 day	12/13/15	12/13/15
Barge Moorings - All Bents (Vibratory Installation & Removal)	74 days	9/15/15	12/13/15
Southbound Collector Distributor Ramp	**57 days**	**12/6/15**	**2/11/16**
Bent 2	**12 days**	**12/6/15**	**12/17/15**
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	8 days	12/6/15	12/13/15
Remove Work Bridge and Piles (Vibratory Removal)	1 day	12/17/15	12/17/15
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	12/15/15	12/16/15
Remove Oscillator Support Piles (Vibratory Removal)	1 day	12/17/15	12/17/15
Bent 3	**10 days**	**12/20/15**	**12/31/15**
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	12/20/15	12/21/15
Remove Oscillator Support Piles (Vibratory Removal)	1 day	12/31/15	12/31/15
Bent 4	**12 days**	**1/3/16**	**1/14/16**
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	1/3/16	1/4/16
Remove Oscillator Support Piles (Vibratory Removal)	1 day	1/14/16	1/14/16
Bent 5	**29 days**	**1/7/16**	**2/11/16**
Install Work Bridge Piles (Vibratory & Impact Pile Driving)	8 days	1/7/16	1/14/16
Remove Work Bridge and Piles (Vibratory Removal)	1 day	2/11/16	2/11/16
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	1/17/16	1/18/16
Install Oscillator Support Piles (Vibratory & Impact Pile Driving)	2 days	1/27/16	1/28/16
Remove Oscillator Support Piles (Vibratory Removal)	1 day	2/11/16	2/11/16
Barge Moorings - All Bents (Vibratory Installation & Removal)	57 days	12/6/15	2/11/16

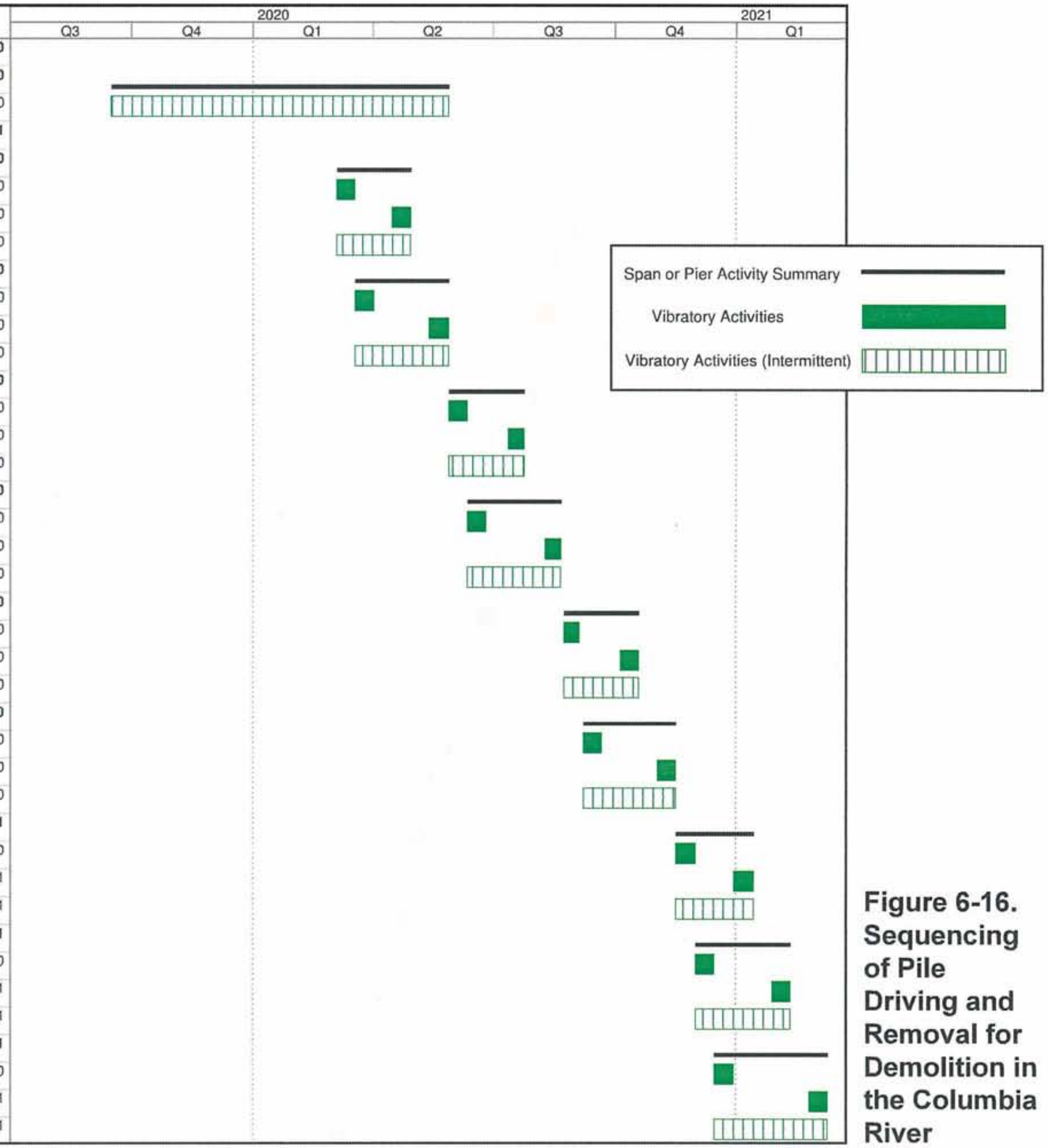


Conceptual Schedule Only, April 2010
Note: This is a proposed schedule, so activity dates are likely to change.

Figure 6-15 (Continued). Sequencing of Pile Driving and Removal for Construction in North Portland Harbor

Columbia River CROSSING

Task Name	Duration	Start	Finish
Superstructure Demolition	**184 days**	**9/16/19**	**5/28/20**
Spans 1-10	**184 days**	**9/16/19**	**5/28/20**
Install and Remove Barge Moorings (Vibratory)	184 days	9/16/19	5/28/20
Substructure Demolition	**266 days**	**3/5/20**	**3/11/21**
Pier 2	**40 days**	**3/5/20**	**4/29/20**
Install Cofferdam (Vibratory Installation)	10 days	3/5/20	3/18/20
Remove Cofferdam (Vibratory Removal)	10 days	4/16/20	4/29/20
Install and Remove Barge Moorings (Vibratory)	40 days	3/5/20	4/29/20
Pier 3	**51 days**	**3/19/20**	**5/28/20**
Install Cofferdam (Vibratory Installation)	10 days	3/19/20	4/1/20
Remove Cofferdam (Vibratory Removal)	11 days	5/14/20	5/28/20
Install and Remove Barge Moorings (Vibratory)	51 days	3/19/20	5/28/20
Pier 4	**41 days**	**5/29/20**	**7/24/20**
Install Cofferdam (Vibratory Installation)	10 days	5/29/20	6/11/20
Remove Cofferdam (Vibratory Removal)	10 days	7/13/20	7/24/20
Install and Remove Barge Moorings (Vibratory)	41 days	5/29/20	7/24/20
Pier 6	**51 days**	**6/12/20**	**8/21/20**
Install Cofferdam (Vibratory Installation)	10 days	6/12/20	6/25/20
Remove Cofferdam (Vibratory Removal)	10 days	8/10/20	8/21/20
Install and Remove Barge Moorings (Vibratory)	51 days	6/12/20	8/21/20
Pier 7	**41 days**	**8/24/20**	**10/19/20**
Install Cofferdam (Vibratory Installation)	10 days	8/24/20	9/4/20
Remove Cofferdam (Vibratory Removal)	10 days	10/6/20	10/19/20
Install and Remove Barge Moorings (Vibratory)	41 days	8/24/20	10/19/20
Pier 8	**50 days**	**9/8/20**	**11/16/20**
Install Cofferdam (Vibratory Installation)	10 days	9/8/20	9/21/20
Remove Cofferdam (Vibratory Removal)	10 days	11/3/20	11/16/20
Install and Remove Barge Moorings (Vibratory)	50 days	9/8/20	11/16/20
Pier 9	**43 days**	**11/17/20**	**1/14/21**
Install Cofferdam (Vibratory Installation)	11 days	11/17/20	12/1/20
Remove Cofferdam (Vibratory Removal)	11 days	12/31/20	1/14/21
Install and Remove Barge Moorings (Vibratory)	43 days	11/17/20	1/14/21
Pier 10	**52 days**	**12/2/20**	**2/11/21**
Install Cofferdam (Vibratory Installation)	10 days	12/2/20	12/15/20
Remove Cofferdam (Vibratory Removal)	10 days	1/29/21	2/11/21
Install and Remove Barge Moorings (Vibratory)	52 days	12/2/20	2/11/21
Pier 11	**62 days**	**12/16/20**	**3/11/21**
Install Cofferdam (Vibratory Installation)	11 days	12/16/20	12/30/20
Remove Cofferdam (Vibratory Removal)	10 days	2/26/21	3/11/21
Install and Remove Barge Moorings (Vibratory)	62 days	12/16/20	3/11/21



Conceptual Schedule Only, April 2010
Note: This is a proposed schedule, so activity dates are likely to change.

Figure 6-16. Sequencing of Pile Driving and Removal for Demolition in the Columbia River

Columbia River CROSSING

Note that in most instances, use of an attenuation device decreases the area of effect appreciably. For example, when comparing scenarios in which a single pile driver is operating:

- The radius of the 206 dB Peak injury zone decreases by about 80 percent.
- In the Columbia River, the radius of the disturbance zone decreases by about 80 percent for smaller piles and by 40 to 70 percent for larger piles, depending on the direction (upstream or downstream).
- In North Portland Harbor, radius of the disturbance zone decreases for smaller piles by about 75 percent. For the larger piles, use of a noise attenuation device does not shrink the disturbance zone because noise encounters landforms at fairly short distances from the source (3,058 m upstream and 5,412 m downstream).
- Similar reductions in distances to accumulated SEL threshold levels will occur with attenuation devices, but details are not presented here due to the numerous variables associated with calculating accumulated SEL in the moving fish model.

Table 6-9 and Table 6-10 summarize these results, showing the extent and duration of noise levels exceeding the injury thresholds and disturbance guidance.

Figure 6-14 and Figure 6-15 further describe the timing and duration of these effects, showing the sequencing of all pile-driving activities.

Table 6-9. Exposure of Fish to Threshold/Guidance Levels of Underwater Noise in the Columbia River

		Without Attenuation Device[a]			With Attenuation Device (assumes 10 dB of attenuation)		
Size Class	Threshold or Guidance	Distance (m)	Duration	Number of Days	Distance (m)	Duration	Number of Days
≥ 2 grams	Injury: 206 dB Peak	25 - 34	7.5 min/ week	38	5 - 7	0.66 hr / day	138
	Injury:[b] 187 SEL_{cum}						
	0.1 m/sec	113 - 243			50 - 156		
	0.8 m/sec	102 - 237			9 - 111		
	Disturbance:[c] 150 dB RMS						
	Upstream	3,981-20,166			858-5,412		
	Downstream	3,981-8,851			858-5,412		
< 2 grams	Injury: 206 dB Peak	25 - 34	7.5 min/ week	38	5 - 7	0.66 hr / day	138
	Injury:[b] 183 SEL_{cum}	205 - 446			50 - 235		
	Disturbance:[c] 150 dB RMS						
	Upstream	3,981-20,166			858-5,412		
	Downstream	3,981-8,851			858-5,412		

a As part of the hydroacoustic monitoring program and to account for equipment failure, up to 7.5 minutes one day per week of pile driving is assumed to occur for purposes of estimating impacts

b Accumulated SEL (injury) threshold distances are calculated based on the construction scenario presented in Table 6-2.

c. Distances show extent of calculated values or where noise stops at landforms.

Table 6-10. Exposure of Fish to Threshold/Guidance Levels of Underwater Noise in North Portland Harbor

		Without Attenuation Device[a]			With Attenuation Device (assumes 10 dB of attenuation)		
Size Class	**Threshold/Guidance**	**Distance (m)**	**Duration**	**Number of Days**	**Distance (m)**	**Duration**	**Number of Days**
≥ 2 grams	Injury: 206 dB Peak	25 -34	2–5 min/ week	18 - 31	5 - 7	0.66 hr / day	134
	Injury:[b] 187 SEL_{cum}						
	0.1 m/sec	113 - 243			50 - 156		
	0.8 m/sec	102 - 237			9 - 111		
	Disturbance:[c] 150 dB RMS						
	Upstream	3,058			858-3,058		
	Downstream	3,981-5,632			858-5,412		
< 2 grams	Injury: 206 dB Peak	25 - 34	2–5 min/ week	18 - 31	5 - 7	0.66 hr / day	134
	Injury:[b] 183 SEL_{cum}	205 - 446			50 - 235		
	Disturbance:[c] 150 dB RMS						
	Upstream	3,058			858-3,058		
	Downstream	3,981-5,632			858-5,412		

a As part of the hydroacoustic monitoring program and to account for equipment failure, up to 3.75 minutes one day per week of pile driving is assumed to occur for purposes of estimating impacts

b Accumulated SEL (injury) threshold distances are calculated based on the construction scenario presented in Table 6-3.

c. Distances show extent of calculated values or where noise stops at landforms.

Exposure factors were calculated using the information presented in the above tables for the 13 different construction scenarios for the Columbia River and the one scenario for North Portland Harbor. Table 6-11 shows representative weekly exposure factors for adult fish (over 2 g, speed of 0.1 m/s) calculated from the in-water impact pile-driving scenario based on a construction contract awarded on February 5, 2013. Weekly exposure factors are presented for both Columbia River and North Portland, in addition to the total weekly exposure factor. When no pile driving is anticipated to occur, the weekly exposure factor is zero. While this representative table shows the weekly exposure factors for adult fish in one scenario, they were also calculated for juvenile fish (over 2 g, moving at 0.8 m/s, and under 2g, moving at 0.6 m/s) and those for the other scenarios 12 scenarios.

Table 6-11. Pile-Strike Summary for Construction in North Portland Harbor

Pile Size	Estimated Piles Installed per Day	Estimated Strikes per Pile	Estimated Maximum Strikes per Day	Hours of Pile Driving/12-hr Daily Pile Driving Work Period
Temporary Work Bridge				
18"– 24"	3	300	900	0.165
Oscillator Support Platforms				
36" – 48"	3	300	900	0.165

For purposes of estimating impacts and performance measure thresholds, exposure factors were calculated for all construction scenarios using the moving fish model, based on a fish of over 2 grams with a movement rate of 0.1 m/s. The following exposure factor results were found during these calculations:

- The maximum weekly exposure factor (based on one calendar week) for all scenarios was 0.18649 (the minimum was zero, when no impact pile driving was scheduled to occur).
- The maximum yearly total exposure factor (the sum of all weekly exposure factors in one calendar year) was 0.20218.
- The average maximum yearly exposure factor (the mean value of all yearly total exposure factors) was 0.12009 per calendar year of construction.
- The maximum total exposure factor (the sum of all weekly exposure factors throughout the project) was 0.48036.

Effects of Impact Pile Driving on Listed Fish

Impact pile driving will result in effects to fish that may range from behavioral disturbance to immediate death, depending on size of the fish, duration of exposure to sound pressure, proximity to the strike site, size of the pile, and number of strikes in a given time frame (e.g., per 12-hour period).

Actual exposure to noise above the injury thresholds and disturbance guidance will be fairly limited, restricted to the periods when impact pile driving is occurring: 138 days in the Columbia River and 134 days in North Portland Harbor interspersed over the entire four-year in-water construction period from roughly mid-September through mid-April of each year (Figure 6-14 and Figure 6-15). Within this time period, exposure will be further restricted to no more than approximately 40 minutes per 12-hour work day.

Project-generated noise above the injury threshold may cause a range of lethal and sublethal injuries to fish, as outlined in Appendix K. Effects may include damage to non-auditory tissues, including rupture of air-filled organs, such as the swim bladder. Damage to the swim bladder may lead to loss of control over vertical movement or may result in mortality. Loud noise may cause damage to the skin, nerves, and eyes of fish. Elevated sound levels may also result in the formation of gas bubbles in tissue, causing inflammation, cellular damage, and blockage or rupture of blood vessels. These injuires may lead to immediate or delayed mortality.

Intense sound may lead to hearing loss in fish. Such hearing loss may be temporary and reversible, known as temporary threshold shift (TTS). TTS and represents fatigue of the hair cells in the inner ear and is not considered tissue damage (Carlson et al. 2007). Intense sound may also reach levels that cause permanent threshold shift (PTS): permanent hearing loss resulting from the irreversible death of sensory hair cells in the inner ear. Such auditory damage may result in a general decrease in fitness, foraging success, ability to avoid predators, and ability to communicate. Thus, even if intense noises do not directly result in death, auditory damage could result in delayed mortality to fish.

Project-generated noise above the disturbance guidance may cause behavioral effects to fish (as described in more detail in Appendix K). Literature related to the effect of pile driving on fish behavior is extremely limited and somewhat conflicting. Effects could be relatively minor, limited to startling, disruption in feeding, or avoidance of the action area (WSDOT 2008). Other effects could be more significant, with consequences for survival and reproduction. For example, while exposure to noise levels above 150 dB RMS is not likely to directly cause mortality or injury, it could result in an impaired ability to avoid predators, indirectly resulting in death (WSDOT 2008). Additionally, avoidance of the action area could presumably cause delays in migration. Migration delays, in turn, may present a variety of risks for fish including: depletion of energy reserves; delayed or reduced spawning; increased exposure to predation, disease, and thermal stress; disruption of arrival timing to the estuary (which may desynchronize arrival with prey availability); and an increase in residualism in some steelhead and Chinook (NMFS 2008a).

Overall, this element of the project is likely to adversely affect individuals of all listed salmon, steelhead, and eulachon present in the areas exposed to noise above the injury threshold and disturbance guidance during impact pile driving activities. Table 6-12 summarizes the species and life stages of listed fish likely to be exposed to this effect. Section 5 of Appendix K presents detailed results of modeling exposure factors and run timing on impacts to these fish at the ESU/DPS and life stage scale.

Due to the extremely limited numbers of green sturgeon and bull trout present in the action area, risk of exposure is discountable. Thus, this element of the project is not likely to adversely affect green sturgeon and bull trout.

Table 6-12. Species and Life Stages Expected to be Present in the Action Area During Pile Driving

	Life Stage				
Species	**Spawning**	**Incubation**	**Rearing**	**Outmigrating Juveniles**	**Migrating/ Holding Adults**
Chinook					
LCR ESU			X	X	X
UCR Spring-Run ESU			X	X	X
UWR ESU			X	X	X
SR Fall-Run ESU				X	X
SR Spring/Summer-Run ESU				X	X
Steelhead					
LCR DPS			X	X	X
MCR DPS				X	X
UWR DPS				X	X
UCR DPS				X	X
SR DPS				X	X
Sockeye					
SR ESU				X	X
Coho					
LCR ESU			X	X	X
Chum					
CR ESU	X	X	X	X	X

	Life Stage				
Species	**Spawning**	**Incubation**	**Rearing**	**Outmigrating Juveniles**	**Migrating/ Holding Adults**
Bull Trout					
CR DPS					X[a]
Green Sturgeon					
Southern DPS					X[a]
Eulachon					X
Southern DPS	X	X		X	X

a Includes subadults.

6.1.1.2 Hydroacoustic Impacts to Fish from Vibratory Pile Driving and Removal

Vibratory pile driving will be used to install cofferdams and temporary piles throughout the in-water project area in the Columbia River and North Portland Harbor. Load-bearing piles (used for temporary work platforms, work bridges, tower cranes, and oscillator platforms) will be vibrated into place before being proofed with an impact hammer. Piles that are not load bearing (mooring piles) will be installed using vibration only.

Vibratory pile driving produces lower peak noise levels than impact pile driving of the same sized pile, and this generally results in fewer injuries to fish (USFWS 2009), as described in greater detail in Appendix K. Rise time is also much slower during vibratory pile driving, decreasing the potential for injury (Carlson et al. 2004, Nedwell and Edwards 2002, as cited in USFWS 2009). USFWS states that there are no documented kills attributed to the use of a vibratory hammer (USFWS 2004a, as cited in WSF 2009).

Currently there are no established thresholds for noise levels generated by vibratory pile driving that are likely to cause injury or behavioral disturbance to fish. Additionally, there are no established threshold distances at which vibratory noise is likely to harm fish. However, NMFS offers the guidance that vibratory pile driving noise at 150 dB RMS may cause behavioral disturbance to fish.

Vibratory pile driving on the CRC project is likely to create noise above 150 dB RMS. Table 6-13 outlines a range of typical noise levels produced by vibratory pile driving as measured by Caltrans during hydroacoustic monitoring of several construction projects (Caltrans 2009). The monitoring showed that vibratory driving of pipe pile (up to 72-inches in diameter) generated initial sound levels of up to 180 dB RMS, and vibratory driving of sheet pile generated initial sound levels of 160 to 165 dB RMS.

Table 6-13. Summary of Unattenuated Underwater Sound Pressures for Vibratory Pile Driving

Pile Type and Approximate Size	Water Depth (meters)	SPLs (dB RMS)[a]
0.30-meter (12-inch) steel H-type	<5	150
0.30-meter (12-inch) steel pipe pile	<5	155
0.6-meter (24-inch) AZ steel sheet – typical	~15	160
0.6-meter (24-inch) AZ steel sheet – loudest	~15	165
1.0-meter (36-inch) steel pipe pile – typical	~5	170
1.0-meter (36-inch) steel pipe pile – loudest	~5	175
1.8-meter (72-inch) steel pipe pile – typical	~5	170
1.8-meter (72-inch) steel pipe pile – loudest	~5	180

Source: Caltrans 2009, Appendix I.

a Impulse level (35 millisecond average).

On the CRC project, vibratory pile driving is likely to occur frequently during installation of temporary structures throughout the four-year in-water construction period and the 18-month in-water demolition period. Figure 6-14, Figure 6-15, and Figure 6-16 show the locations and duration of vibratory pile driving for temporary structures in the project area. Vibratory pile driving for installation of temporary structures will likely take place up to approximately 5 hours per day during the in-water construction period and may occur during any hour of day.

Vibration may also be used to install the 10-foot-diameter steel casings for the drilled shafts of the permanent structures in the Columbia River and North Portland Harbor. No data were available regarding the initial SPLs generated by steel casings of this size. Therefore, it is currently not possible to calculate the extent of noise generated from vibratory installation of 10-foot-diameter casings. However, the assumption is that vibration of the 10-foot steel casings will produce at least as many initial SPLs as 72-inch steel pipe pile (180 dB RMS at 5 m), and therefore, noise from 10-foot-diameter casings will extend at least as far as that from 72-inch-diameter steel pipe pile. The design team estimates that vibratory installation of the drilled shaft casings will take approximately 90 days in the Columbia River and 31 days in North Portland Harbor. Vibratory installation is not restricted to the in-water work window and therefore may take place any time during the four-year in-water construction period.

All of the species and life stages of salmon, steelhead, and eulachon shown in Table 6-12 could be exposed to this effect when they are present in this portion of the action area (Figure 4-1 and Figure 4-2). However, because fish kills attributed to the use of a vibratory hammer have never been documented, this activity is unlikely to injure fish and is not expected to significantly interfere with behaviors such as migration, rearing, or foraging. Thus, vibratory pile driving is not likely to adversely affect any of these species.

Due to the extremely limited numbers of green sturgeon and bull trout present in this portion of the action area, risk of exposure is discountable. Thus, this element of the project is not likely to adversely affect green sturgeon or bull trout.

6.1.1.3 Noise Impacts to Fish from Excavating Drilled Shaft Casings

After the casings are installed, the project will excavate the material from inside of the permanent shafts. Hydroacoustic impacts from drilling and excavating inside of casings have not been well documented but will be far less than impacts from impact pile driving. Drilling shafts will likely elevate in-water noise levels, causing disturbance to fish, but the extent of this disturbance cannot be calculated. Lethal effects from drilling of shafts have not been documented on other projects and are not likely to occur. Shafts will be excavated year-round during the in-water construction period (roughly, January 2014 to August 2017 in the Columbia River and September 2013 to February 2016 in North Portland Harbor). Effects to listed fish are expected to be insignificant.

6.1.2 Work-Area Isolation and Fish Salvage

The project will use cofferdams to isolate the in-water work area from active flow during construction in the Columbia River. Cofferdams will be used during demolition of the existing bridge in the Columbia River if a wire saw is not used to cut the existing piers into pieces. The purpose of the cofferdams is to avoid contaminating the Columbia River with work materials or wastes, to contain re-suspended sediments, and to minimize disturbance and injury to fish. Cofferdams will be installed in a manner that minimizes fish entrapment. Sheet piles will be installed from upstream to downstream and lowered slowly until contact with the substrate.

Tables 3-5, 3-6, 3-19, and 3-20 provide a summary of the size of the cofferdams and their timing and duration in the Columbia River. Up to 11 cofferdams are anticipated. The two cofferdams used during construction of Piers 2 and 7 in the Columbia River will cover a combined area of approximately 15,750 sq. ft. The nine cofferdams used during demolition of the existing in-water Columbia River bridge piers 2 through 10 will each encompass an area of 7,500 sq. ft. (for a total area of 67,500 sq. ft.). Cofferdams will likely be installed and removed at any time of year, pending approval from USFWS and NMFS. ODFW and WDFW have both agreed that performing this activity outside of the standard work window will not cause significant harm to fish. Installation will use low-impact methods such as vibrating or pressing into place.

Cofferdams used for construction will each require 10 days to install, be in place for approximately 330 to 470 calendar days apiece, and will require 15 days for removal. Figure 6-14 shows the timing and duration of cofferdam installation and removal during construction in the Columbia River.

Each cofferdam used for demolition will require 10 days to install, be in place for approximately 20 additional work days apiece, and require approximately 10 work days to remove. Figure 6-16 shows the timing and duration of cofferdam installation and removal during demolition in the Columbia River.

Installation of the cofferdams is likely to generate low-level noise and visual disturbance. For this reason, fish are likely to actively avoid the work area during the construction of cofferdams. Nevertheless, due to the large size of the cofferdams, it is impossible to guarantee that no fish will become trapped inside. To minimize impacts to fish, the project will perform measures to remove fish from the work area during and after the installation of the cofferdams. Fish salvage will be conducted by qualified biologists in compliance with protocols outlined in Section 7 and Appendix E. Methods may include seining, electrofishing, trapping, and encouraging volitional movement of fish away from the work area. Captured fish will be released outside of the work area. To avoid entrainment of fish, pump intakes will be screened according to ODFW and WDFW standards and ODOT and WSDOT protocols outlined in Section 7.

The salvage operation involves capture, direct handling, and transporting of fish; therefore, there is a reasonable risk that the operation may harass, injure, or kill fish. If fish remain trapped in a cofferdam during construction, mortality is likely.

Because the fish salvage operations may take place at any time of year, individuals from any of the fish species using the project area in the Columbia River and North Portland Harbor may be exposed to this effect. Table 6-14 shows the species and life stages of fish that may potentially be present during work-area isolation.

Table 6-14. Species and Life Stages of Fish Expected to be Present in the Action Area During Work-Area Isolation

	Life Stage				
Species	**Spawning**	**Incubation**	**Rearing**	**Outmigrating Juveniles**	**Migrating/ Holding Adults**
Chinook					
LCR ESU			X	X	X
UCR Spring-Run ESU			X	X	X
SR Fall-Run ESU				X	X
SR Spring/Summer-Run ESU				X	X
Steelhead					
LCR DPS			X	X	X
MCR DPS				X	X
UCR DPS				X	X
SR DPS				X	X
Sockeye					
SR ESU				X	X
Coho					
LCR ESU			X	X	X
Chum					
CR ESU			X	X	X
Bull Trout					
CR DPS					X[a]
Green Sturgeon					
Southern DPS					X[a]
Eulachon					
Southern DPS	X	X		X	X

a Includes subadults.

The species of salmon, steelhead, and eulachon shown in Table 6-14 are likely to be present in the action area at the time of the fish salvage and work area isolation. Thus, these species are likely to be adversely affected by this element of the project.

Due to the extremely limited numbers of green sturgeon and bull trout present in the action area, these species are not likely to be present while this activity is taking place. The risk of exposure is therefore discountable. Thus, this element of the project is not likely to adversely affect green sturgeon or bull trout.

6.1.3 Shading

The project will create several temporary and permanent sources of new overwater coverage in the Columbia River and North Portland Harbor and will increase the overall shade footprint in the action area. Temporary overwater structures include work platforms, work bridges, tower cranes, oscillator support platforms, and barges. Permanent overwater structures include the shaft caps of the new Columbia River bridges and the new spans of the Columbia River and North Portland Harbor bridges (Table 6-15).

Studies have shown that fish communities under overwater structures differ from those in adjacent areas, in part due to the effect of shading (Southard et al. 2006). In general, shade may affect listed fish by increasing habitat for predators, causing visual disorientation, and decreasing primary productivity.

6.1.3.1 General Effects of Shading on Fish

Overwater coverage increases the amount of shade in the water column. Fish rely on visual cues when performing life functions such as foraging, schooling, avoiding predators, and migration. The literature shows that changes in light conditions can alter fish behavior (Simenstad et al. 1999; Nightingale and Simenstad 2001). Overwater structures that alter the existing light regime may limit the ability of fish to perform essential life functions (Southard et al. 2006). Shade may also affect the productivity of underwater plants, the basis of the food web for many juvenile fish (Nightingale and Simenstad 1999). Finally, shade may affect fish by providing cover for predators (Carrasquero 2001).

Predation

Shade attracts and provides cover for many species of predatory fish, including northern pikeminnow, smallmouth bass, and largemouth bass (Pribyl et al. 2004; Celedonia et al. 2008). The literature does not draw a clear, consistent relationship between an increase in predation and an increase in shade; predation rates have been shown to both increase and decrease with increasing light (Carrasquero 2001). In a review of the available literature, researchers concluded that the effect of shading on predation is "inconclusive" (WSF 2009). However, a literature review conducted by Carrasquero (2001) shows that largemouth and smallmouth bass have a strong affinity for piers and overwater structures, potentially using the cover of darkness to ambush fish. In a study in the Columbia River, Beamesderfer and Riemen (1991, as cited in Celedonia et al. 2008) noted that northern pikeminnow selected low-velocity microhabitats created by in-water structures, where juvenile salmonids were congregating. In a study conducted in the lower Columbia River, Zimmerman (1999) found that smallmouth bass consumed salmonids averaging 119 mm in length, and pikeminnow consumed salmonids averaging 167 mm in length. Relatively few salmonids consumed by pikeminnow were greater than 250 mm in length (Zimmerman 1999). This indicates that predation risks are greater for juvenile salmonids.

Migration and Orientation

The literature provides empirical evidence that juvenile salmonids may become disoriented beneath overwater structures or other shaded areas with sharp contrast between light and dark. Heiser and Finn (1970), Weitkamp (1982), and Pentec (1997) reported that fish were reluctant to enter shadow zones under docks and or other sources of intense shade. Pentec (1997), Taylor and Willey (1997), Simenstad et al. (1999), Williams et al. (2003), and Toft et al. (2004) reported observing fish movement along the shadow zone boundary without penetration into the shadow. Shreffler and Moursund (1999) found that juvenile Chinook ceased directional movement at the shadow line rather than immediately continuing under an overwater structure. Juvenile salmon consistently swam from the shadow line into the light, then immediately darted down and back into the light-dark transition area again.

Other literature suggests that a sharp light/dark interface caused by overwater structures may interfere with migration in juvenile salmonids. Response of fish to overwater structures is complex, as some fish will readily pass under structures, and others will not. Schools may either disband upon encountering an overwater structure, or they may pause and proceed as a group (Southard et al. 2006). A study conducted by Pacific Northwest National Laboratory (PNNL) (Williams et al. 2003) concluded that overwater structures are likely to be impediments to juvenile migration, depending on numerous factors such as light levels, angle of the sun, cloud cover, current velocity and direction, and tidal stage. For example, the study indicated that effects of shading were reduced during low tide when more light can dissipate beneath overwater structures. The same study also observed that juvenile chum would not cross into shade when the decrease in light level was 85 percent over a horizontal distance of approximately 5 m. Acoustic tagging at Port Townsend revealed that juvenile Chinook and coho passed under overwater structures more quickly in the evening when the light-dark interface is indistinct (Southard et al. 2006). On the other hand, Weitkamp (1982) found that juvenile salmonids will readily swim under overwater structures. Williams et al. (2003) found that salmon fry were not inhibited by the 33-foot-wide shadow cast by an overwater structure at the Mukilteo Ferry Terminal, even though light levels under the structure were 97 percent lower than ambient levels.

Thus, although the literature is not in agreement regarding the effects of a shade on orientation, there appears to be some evidence that a shadow line under overwater structures could interfere with the migration of salmonid juveniles during some daylight hours. Studies have suggested that this may prompt fish to enter deeper water, where they could presumably be exposed to predation from birds, mammals, and other fish (WSF 2009). Additionally, juveniles may congregate at the edge of the shadow line, making them more vulnerable to predation (Southard et al. 2006).

Primary Productivity

Shading may result in decreased productivity of underwater vegetation. Macrophytes, benthic algae, and phytoplankton contribute to aquatic habitat complexity and form the basis of the food web for many species of fish. Carrasquero (2001) notes that lowered light levels may reduce or eliminate macrophyte beds, algae, and other aquatic vegetation beneath overwater structures. This may, in turn limit the amount of prey available to fish (Simenstad and Nightingale 2001). Epibenthic crustaceans are of most concern because they are typically associated with nearshore plants (Simenstad et al. 1999). Loss of underwater vegetation may also reduce cover for juvenile fish, potentially increasing exposure to predation (Carrasquero 2001). Furthermore, shading underneath overwater structures may reduce primary production in phytoplankton. However, this relationship is complex and poorly understood (Carrasquero 2001). For example, there is evidence that primary productivity of phytoplankton may be greater at the edge of overwater structures than in areas outside of the structure (White 1975, as cited in Carrasquero 2001). On the other hand, Mulvihill et al. (1980, as cited in Carrasquero 2001) report that pilings and piers beneath overwater structures may provide substrate for algal growth where bottom depths are below the photic zone or where bottom substrates are unstable. The increase in algal growth may potentially compensate for loss of phytoplankton primary productivity.

6.1.3.2 Sources of Shade on the CRC Project

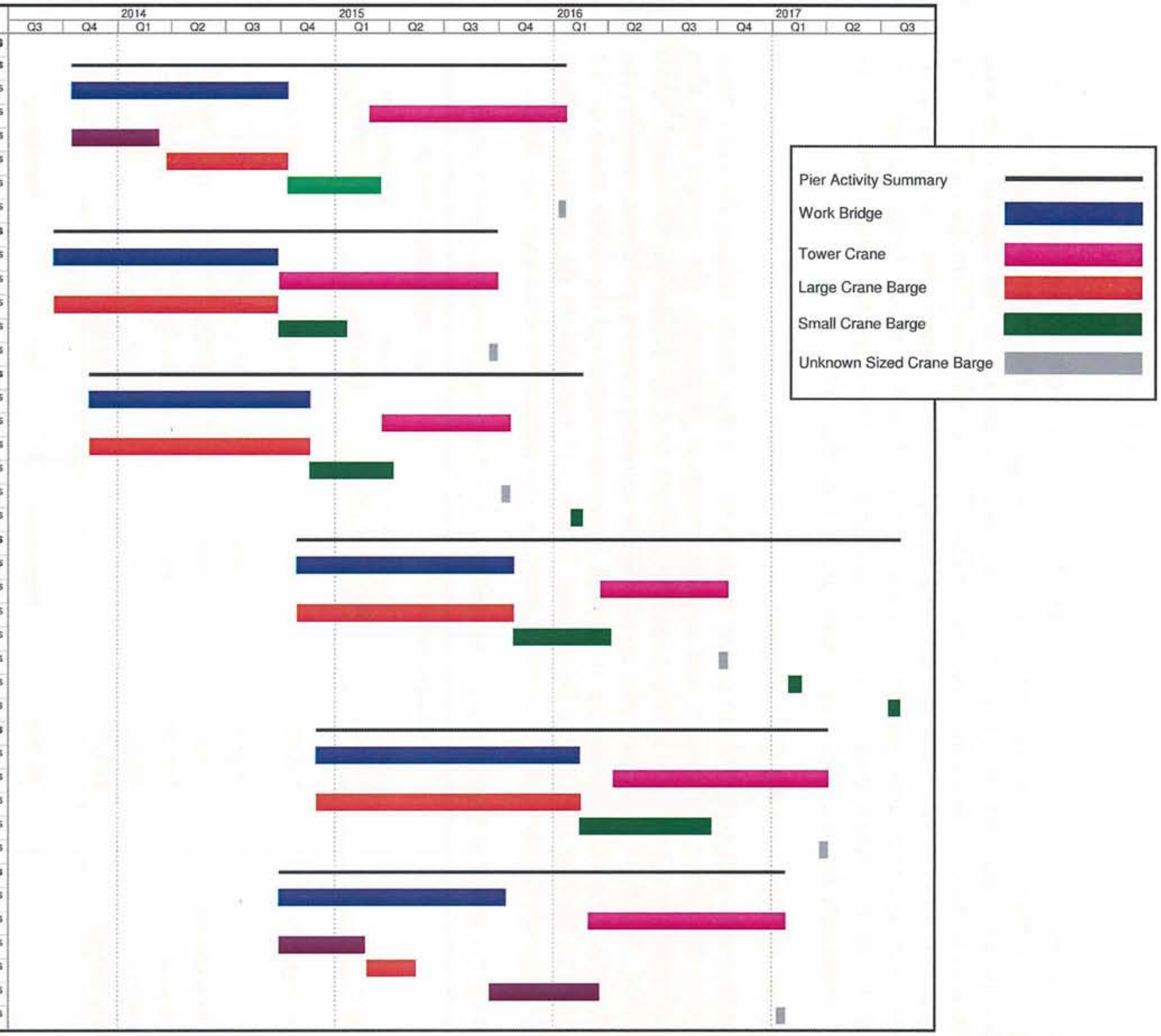
The CRC project will create several temporary sources of in-water shade: barges, in-water work platforms, work bridges, tower cranes, and oscillator support platforms. The project will also introduce permanent new shade by creating the new bridges over the Columbia River and North Portland Harbor. Finally, the project will remove some existing sources of shade, namely, the existing Columbia River bridge, and an overwater structure located on the north shore of the Columbia River at the Red Lion at the Quay hotel. Table 6-15 summarizes the sources of shade produced by this project. There will be a net increase in both permanent and temporary shade.

Table 6-15. Summary of Shade Sources in the Columbia River and North Portland Harbor

	Columbia River		North Portland Harbor	
Type	Area (sq. ft.)	Duration in Water (days)	Area (sq. ft.)	Duration in Water (days)
Temporary				
Work platforms/bridges for drilling shafts	148,000	120	29,640.	up to 42
Tower cranes	2,400.	600	N/A	N/A
Oscillator support platforms	N/A	N/A	27,900	Up to 33
Barges for construction	106,432	Varies	1,085,000	up to 42
Barges for demolition	42,000.	~1	N/A	N/A
Total Temporary Impact	**256,432**	---	**1,142,540**	---
Permanent				
Shaft caps	58,200	Permanent	N/A	Permanent
New bridge spans	676,000.	Permanent	310,000–416,000	Permanent
Existing spans - to be removed	-284,000	N/A	N/A	N/A
Overwater structure at the Quay - to be removed	-12,647–35,120	N/A	N/A	N/A
Total Permanent Impact	**415,080–437,553**		**310,000–416,000**	

The shade sources shown in Table 6-15 will not all be present in the action area at the same time. Figure 6-17, Figure 6-18, and Figure 6-19 show the anticipated sequencing of the temporary overwater structures in the action area. Appendix A, Figures 1-11 provide preliminary plan sheets for Columbia River construction sequencing.

Task Name	Start	Finish	Duration
Bridge Construction Scenario 2/5/13	**9/16/13**	**8/4/17**	**1015 days**
Pier 2	**10/16/13**	**1/22/16**	**593 days**
Work Bridge (17,500 s.f.)	10/16/13	10/13/14	259 days
Tower Crane (400 s.f.)	2/27/15	1/22/16	236 days
Medium Crane Barge (10,500 s.f.)	10/16/13	3/11/14	104 days
Large Crane Barge (30,000 s.f.)	3/24/14	10/13/14	145 days
Medium and Small Crane Barges (16,500 s.f.)	10/14/14	3/19/15	112 days
Unknown Sized Crane Barge	1/11/16	1/22/16	9 days
Pier 3	**9/16/13**	**9/29/15**	**532 days**
Work Bridge (29,000 s.f.)	9/16/13	9/26/14	270 days
Tower Crane (400 s.f.)	9/29/14	9/29/15	262 days
Large Crane Barge (30,000 s.f.)	9/16/13	9/26/14	269 days
Small Crane Barge (6,000 s.f.)	9/29/14	1/21/15	82 days
Unknown Sized Crane Barge	9/16/15	9/29/15	10 days
Pier 4	**11/15/13**	**2/19/16**	**591 days**
Work Bridge (29,000 s.f.)	11/15/13	11/19/14	264 days
Tower Crane (400 s.f.)	3/20/15	10/20/15	153 days
Large Crane Barge (30,000 s.f.)	11/15/13	11/19/14	263 days
Small Crane Barge (6,000 s.f.)	11/20/14	4/9/15	100 days
Unknown Sized Crane Barge	10/7/15	10/20/15	10 days
Small Crane Barge (6,000 s.f.)	2/1/16	2/19/16	15 days
Pier 5	**10/29/14**	**8/4/17**	**723 days**
Work Bridge (29,000 s.f.)	10/29/14	10/27/15	260 days
Tower Crane (400 s.f.)	3/21/16	10/19/16	153 days
Large Crane Barge (30,000 s.f.)	10/29/14	10/27/15	259 days
Small Crane Barge (6,000 s.f.)	10/28/15	4/8/16	117 days
Unknown Sized Crane Barge	10/6/16	10/19/16	10 days
Small Crane Barge (6,000 s.f.)	1/31/17	2/20/17	15 days
Small Crane Barge (6,000 s.f.)	7/17/17	8/4/17	15 days
Pier 6	**12/1/14**	**4/5/17**	**613 days**
Work Bridge (29,000 s.f.)	12/1/14	2/15/16	315 days
Tower Crane (400 s.f.)	4/11/16	4/5/17	258 days
Large Crane Barge (30,000 s.f.)	12/1/14	2/15/16	316 days
Small Crane Barge (6,000 s.f.)	2/16/16	9/23/16	158 days
Unknown Sized Crane Barge	3/23/17	4/5/17	10 days
Pier 7	**9/29/14**	**1/23/17**	**606 days**
Work Bridge (18,500 s.f.)	9/29/14	10/13/15	272 days
Tower Crane (400 s.f.)	2/29/16	1/23/17	236 days
Medium Crane Barge (10,500 s.f.)	9/29/14	2/20/15	104 days
Large Crane Barge (30,000 s.f.)	2/23/15	5/15/15	60 days
Medium Crane Barge (10,500 s.f.)	9/16/15	3/18/16	132 days
Unknown Sized Crane Barge	1/10/17	1/23/17	10 days

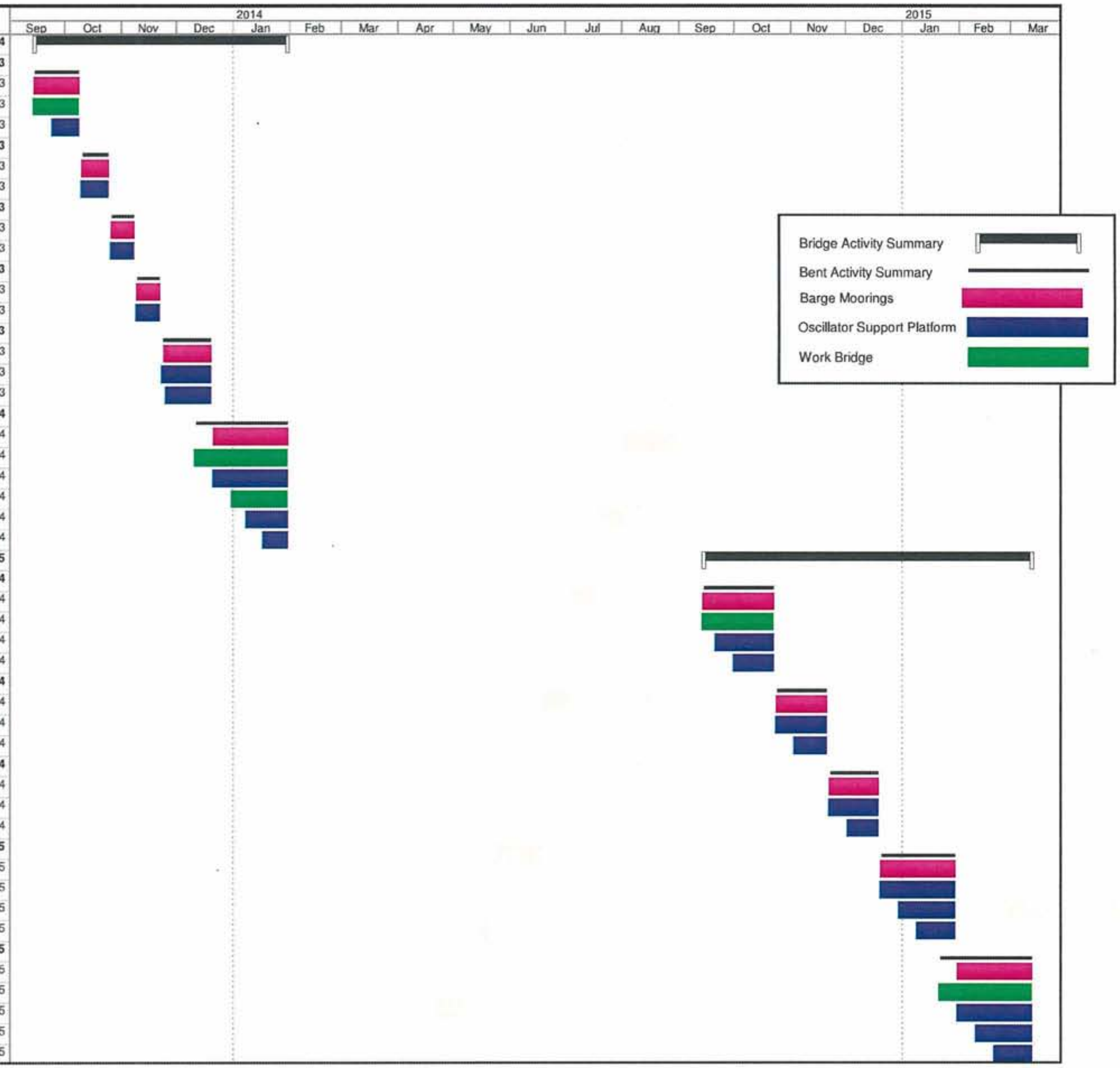


Conceptual Schedule Only, March 2010
Note: This is a proposed schedule, so activity start and finish dates are likely to change.

Figure 6-17. Sequencing of Temporary Over-Water Structures for Construction in the Columbia River

Columbia River CROSSING

Task Name	Duration	Start	Finish
Widening of Existing Bridge	**111 days**	**9/15/13**	**1/30/14**
Bent 4	**20 days**	**9/15/13**	**10/8/13**
Two Medium Crane Barges (35,000 s.f.)	20 days	9/15/13	10/8/13
Work Bridge (3,360 s.f.)	20 days	9/15/13	10/8/13
Oscillator Support Platform (900 s.f.)	10 days	9/25/13	10/8/13
Bent 5	**10 days**	**10/11/13**	**10/24/13**
Two Medium Crane Barges (35,000 s.f.)	10 days	10/11/13	10/24/13
Oscillator Support Platform (900 s.f.)	10 days	10/11/13	10/24/13
Bent 6	**10 days**	**10/27/13**	**11/7/13**
Two Medium Crane Barges (35,000 s.f.)	10 days	10/27/13	11/7/13
Oscillator Support Platform (900 s.f.)	10 days	10/27/13	11/7/13
Bent 7	**10 days**	**11/10/13**	**11/21/13**
Two Medium Crane Barges (35,000 s.f.)	10 days	11/10/13	11/21/13
Oscillator Support Platform (900 s.f.)	10 days	11/10/13	11/21/13
Bent 8	**22 days**	**11/24/13**	**12/19/13**
Four Medium Crane Barges (70,000 s.f.)	22 days	11/24/13	12/19/13
Oscillator Support Platform 1 (900 s.f.)	22 days	11/24/13	12/19/13
Oscillator Support Platform 2 (900 s.f.)	20 days	11/26/13	12/19/13
Bent 9	**42 days**	**12/12/13**	**1/30/14**
Six Medium Crane Barges (105,000 s.f.)	33 days	12/22/13	1/30/14
Work Bridge 1 (2,240 s.f.)	42 days	12/12/13	1/30/14
Oscillator Support Platform 1 (900 s.f.)	33 days	12/22/13	1/30/14
Work Bridge 2 (2,240 s.f.)	25 days	1/1/14	1/30/14
Oscillator Support Platform 2 (900 s.f.)	17 days	1/9/14	1/30/14
Oscillator Support Platform 3 (900 s.f.)	10 days	1/18/14	1/30/14
Light Rail Transit/Multi-Use Plan Bridge	**142 days**	**9/15/14**	**3/12/15**
Bent 2	**30 days**	**9/15/14**	**10/22/14**
Four Medium Crane Barges (70,000 s.f.)	30 days	9/15/14	10/22/14
Work Bridge (2,960 s.f.)	30 days	9/15/14	10/22/14
Oscillator Support Platform 1 (900 s.f.)	23 days	9/22/14	10/22/14
Oscillator Support Platform 2 (900 s.f.)	15 days	10/2/14	10/22/14
Bent 3	**21 days**	**10/25/14**	**11/20/14**
Four Medium Crane Barges (70,000 s.f.)	21 days	10/25/14	11/20/14
Oscillator Support Platform 1 (900 s.f.)	21 days	10/25/14	11/20/14
Oscillator Support Platform 2 (900 s.f.)	13 days	11/4/14	11/20/14
Bent 4	**20 days**	**11/23/14**	**12/18/14**
Four Medium Crane Barges (70,000 s.f.)	20 days	11/23/14	12/18/14
Oscillator Support Platform 1 (900 s.f.)	20 days	11/23/14	12/18/14
Oscillator Support Platform 2 (900 s.f.)	12 days	12/3/14	12/18/14
Bent 5	**34 days**	**12/21/14**	**1/29/15**
Six Medium Crane Barges (105,000 s.f.)	34 days	12/21/14	1/29/15
Oscillator Support Platform 1 (900 s.f.)	34 days	12/21/14	1/29/15
Oscillator Support Platform 2 (900 s.f.)	26 days	12/31/14	1/29/15
Oscillator Support Platform 3 (900 s.f.)	18 days	1/10/15	1/29/15
Bent 6	**41 days**	**1/22/15**	**3/12/15**
Six Medium Crane Barges (105,000 s.f.)	32 days	2/1/15	3/12/15
Work Bridge (1,520 s.f.)	41 days	1/22/15	3/12/15
Oscillator Support Platform 1 (900 s.f.)	32 days	2/1/15	3/12/15
Oscillator Support Platform 2 (900 s.f.)	24 days	2/11/15	3/12/15
Oscillator Support Platform 3 (900 s.f.)	16 days	2/21/15	3/12/15

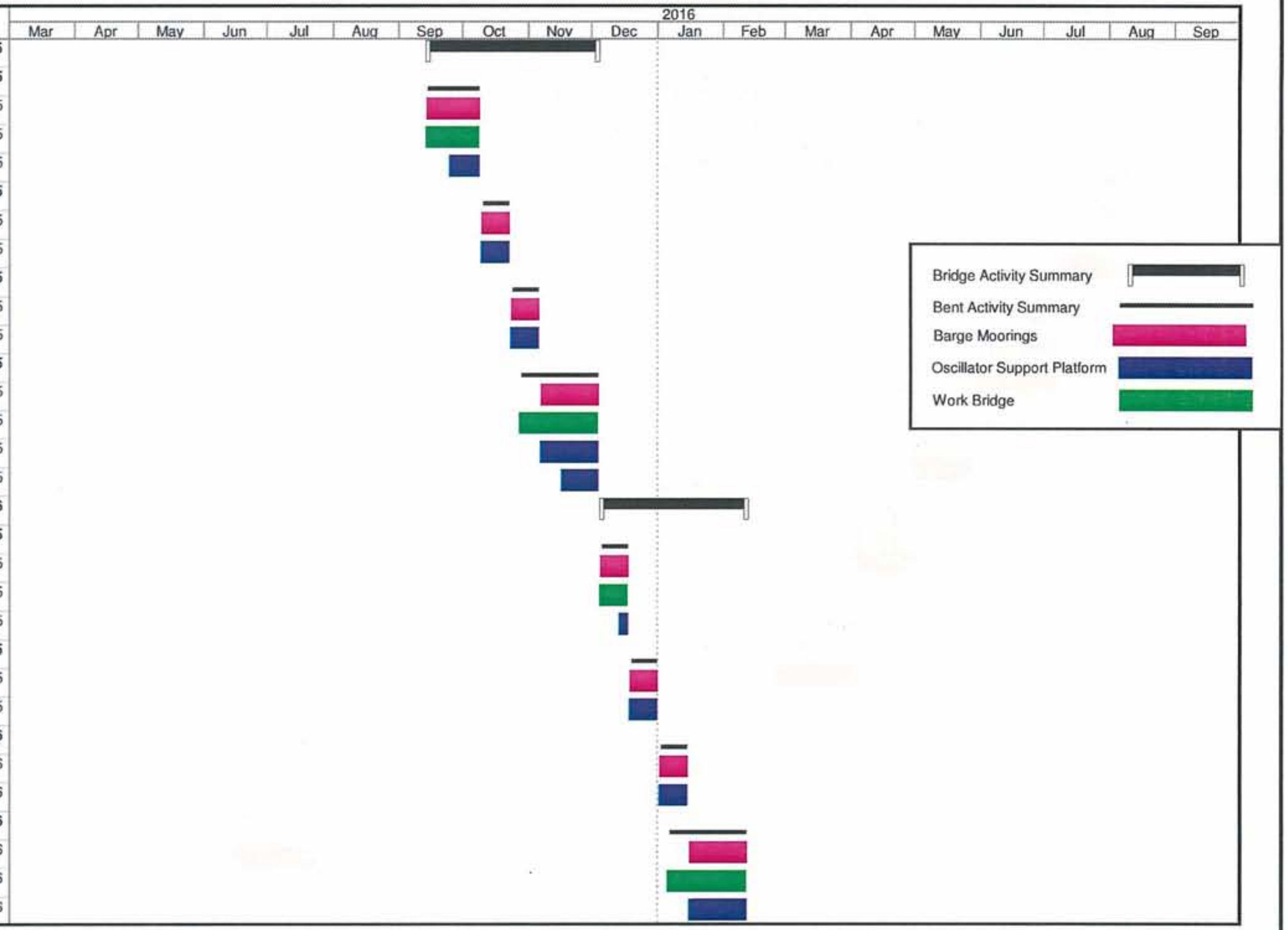


Conceptual Schedule Only, April 2010
Note: This is a proposed schedule, so activity dates are likely to change.

Figure 6-18. Sequencing of Temporary Overwater Structures for Construction in North Portland Harbor

Columbia River CROSSING

Task Name	Duration	Start	Finish
Northbound Collector Distributor Ramp	**66 days**	**9/15/15**	**12/3/15**
Bent 6	**21 days**	**9/15/15**	**10/8/15**
Two Medium Crane Barges (35,000 s.f.)	21 days	9/15/15	10/8/15
Work Bridge (4,080 s.f.)	21 days	9/15/15	10/8/15
Oscillator Support Platform (900 s.f.)	10 days	9/26/15	10/8/15
Bent 7	**10 days**	**10/11/15**	**10/22/15**
Two Medium Crane Barges (35,000 s.f.)	10 days	10/11/15	10/22/15
Oscillator Support Platform (900 s.f.)	10 days	10/11/15	10/22/15
Bent 8	**12 days**	**10/25/15**	**11/5/15**
Two Medium Crane Barges (35,000 s.f.)	12 days	10/25/15	11/5/15
Oscillator Support Platform (900 s.f.)	12 days	10/25/15	11/5/15
Bent 9	**29 days**	**10/29/15**	**12/3/15**
Four Medium Crane Barges (70,000 s.f.)	20 days	11/8/15	12/3/15
Work Bridge 1 (2,240 s.f.)	29 days	10/29/15	12/3/15
Oscillator Support Platform 1 (900 s.f.)	20 days	11/8/15	12/3/15
Oscillator Support Platform 2 (900 s.f.)	12 days	11/18/15	12/3/15
Southbound Collector Distributor Ramp	**57 days**	**12/6/15**	**2/11/16**
Bent 2	**12 days**	**12/6/15**	**12/17/15**
Two Medium Crane Barges (35,000 s.f.)	12 days	12/6/15	12/17/15
Work Bridge (4,880 s.f.)	12 days	12/6/15	12/17/15
Oscillator Support Platform (900 s.f.)	3 days	12/15/15	12/17/15
Bent 3	**10 days**	**12/20/15**	**12/31/15**
Two Medium Crane Barges (35,000 s.f.)	10 days	12/20/15	12/31/15
Oscillator Support Platform (900 s.f.)	10 days	12/20/15	12/31/15
Bent 4	**12 days**	**1/3/16**	**1/14/16**
Two Medium Crane Barges (35,000 s.f.)	12 days	1/3/16	1/14/16
Oscillator Support Platform (900 s.f.)	12 days	1/3/16	1/14/16
Bent 5	**29 days**	**1/7/16**	**2/11/16**
Four Medium Crane Barges (70,000 s.f.)	20 days	1/17/16	2/11/16
Work Bridge (2,280 s.f.)	29 days	1/7/16	2/11/16
Oscillator Support Platform (900 s.f.)	20 days	1/17/16	2/11/16



Conceptual Schedule Only, April 2010
Note: This is a proposed schedule, so activity dates are likely to change.

Figure 6-18 (Continued). Sequencing of Temporary Overwater Structures for Construction in North Portland Harbor

Columbia River CROSSING

Construction Barges

Barges will be anchored in the Columbia River and North Portland Harbor to serve as in-water work platforms during construction of in-water and overwater bridge elements. Stationary barges will be used at each of the in-water piers or bents. The shade footprint of moving barges (such as materials and spoils barges) was not included in this analysis. These barges move more or less constantly and on an unpredictable schedule, so it is impossible to quantify the extent or duration of shade cast by these sources.

Although the project will use numerous barges, there will be a limited number of barges in place at any one time. During construction in the Columbia River, there will likely be one to four stationary barges operating in the Columbia River at one time (Figure 6-17), casting no more than 120,000 sq. ft. of shade at once. In North Portland Harbor, there will likely be no more than six crane barges operating at one time, creating a maximum of approximately 105,000 sq. ft. of shade at one time (Figure 6-18).

In-Water Structures

The project will use temporary in-water work platforms, work bridges, tower cranes, and oscillator support platforms to support the equipment used to drill shafts in the Columbia River and North Portland Harbor.

In the Columbia River, there will be six temporary work platforms/bridges, one at each of the in-water pier complexes. At pier complexes 2 and 7, the work bridges will be L-shaped, approximately 17,500 sq. ft. and 18,500 sq. ft. in size, respectively. At pier complexes 3 through Pier 6, each work platform will cover an area of approximately 29,000 sq. ft. (Table 6-15). Up to four platforms will be in place at one time (Figure 6-17). Once drilled shafts are completed, the platforms will be removed. Six temporary tower cranes will be installed, one for each in-water pier complex. Each will shade an area of approximately 400 sq. ft. (Figure 6-17). Including the work platforms, work bridges, and the tower cranes, roughly 125,000 sq. ft. will be shaded at one time in the Columbia River.

In North Portland Harbor, the project will use nine work bridges of different sizes to build the nine bents nearest the shorelines (Figure 6-18). Only one or two work bridges will be in place at any given time. Additionally, the project will use 31 oscillator support platforms (900 sq. ft.), one for each in-water shaft in North Portland Harbor (Figure 6-18). Only one to three oscillator support platforms will be in place at once. At any one time, in-water structures in North Portland Harbor will shade no more than 7,180 sq. ft altogether.

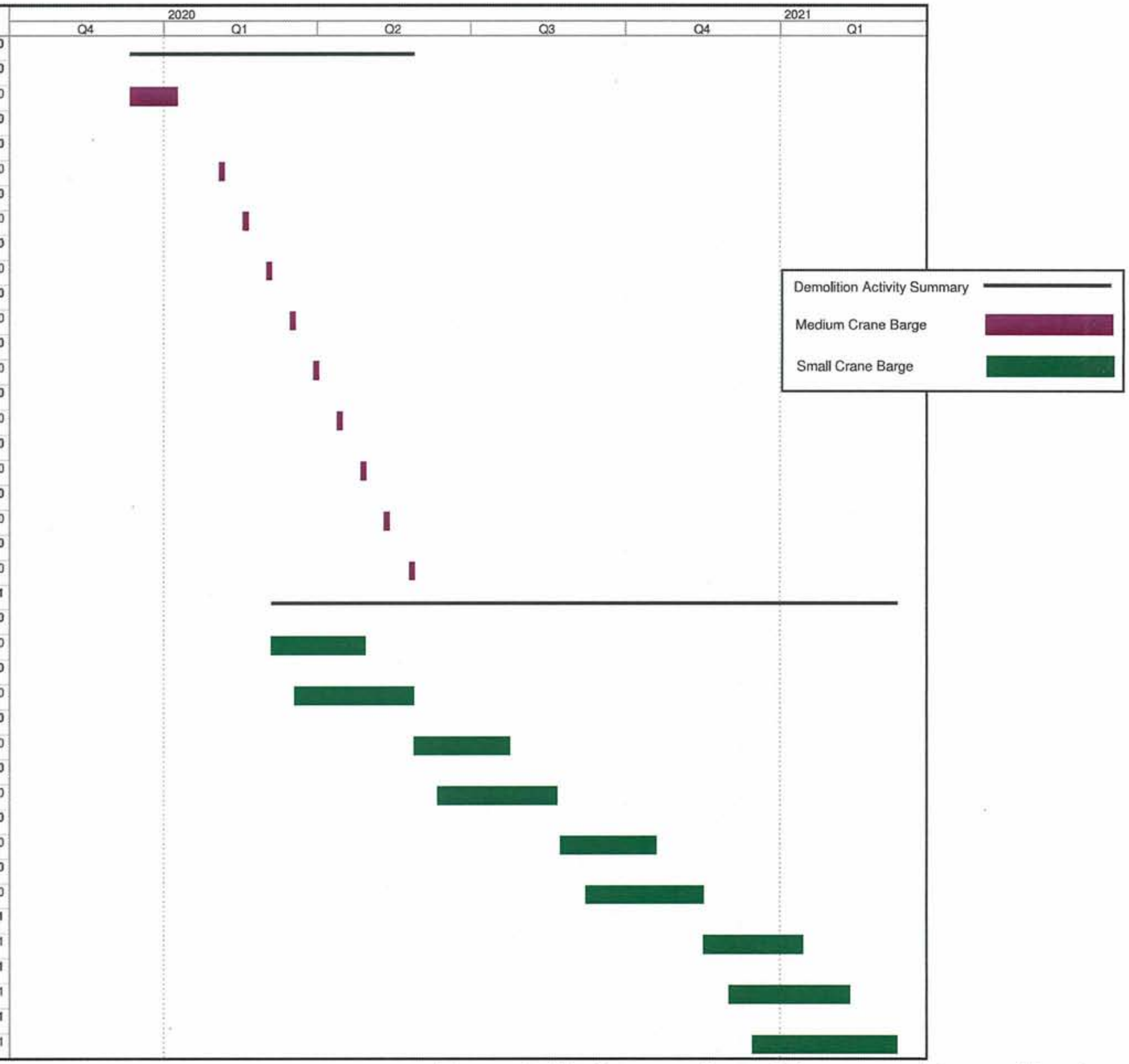
Demolition in the Columbia River will not require shade-producing in-water structures.

Demolition Barges

Demolition of the existing structures in the Columbia River will require one to three stationary barges at any one time, with a maximum shade footprint of approximately 21,000 sq. ft. at once. Figure 6-19 shows the sequencing of stationary barges for demolition in the Columbia River.

There will be no demolition or demolition barges in North Portland Harbor.

Task Name	Duration	Start	Finish
Superstructure Demolition	**121 days**	**12/12/19**	**5/28/20**
Demolish Lift Span Towers	**20 days**	**12/12/19**	**1/8/20**
Two Medium Crane Barges (21,000 s.f.)	20 days	12/12/19	1/8/20
Remove Spans	**83 days**	**2/4/20**	**5/28/20**
Span 2	**2 days**	**2/4/20**	**2/5/20**
Medium Crane Barge (10,500 s.f.)	2 days	2/4/20	2/5/20
Span 3	**2 days**	**2/18/20**	**2/19/20**
Medium Crane Barge (10,500 s.f.)	2 days	2/18/20	2/19/20
Span 4	**2 days**	**3/3/20**	**3/4/20**
Medium Crane Barge (10,500 s.f.)	2 days	3/3/20	3/4/20
Span 5	**2 days**	**3/17/20**	**3/18/20**
Medium Crane Barge (10,500 s.f.)	2 days	3/17/20	3/18/20
Span 6	**2 days**	**3/31/20**	**4/1/20**
Medium Crane Barge (10,500 s.f.)	2 days	3/31/20	4/1/20
Span 7	**2 days**	**4/14/20**	**4/15/20**
Medium Crane Barge (10,500 s.f.)	2 days	4/14/20	4/15/20
Span 8	**2 days**	**4/28/20**	**4/29/20**
Medium Crane Barge (10,500 s.f.)	2 days	4/28/20	4/29/20
Span 9	**2 days**	**5/12/20**	**5/13/20**
Medium Crane Barge (10,500 s.f.)	2 days	5/12/20	5/13/20
Span 10	**2 days**	**5/27/20**	**5/28/20**
Medium Crane Barge (10,500 s.f.)	2 days	5/27/20	5/28/20
Substructure Demolition	**266 days**	**3/5/20**	**3/11/21**
Pier 2	**40 days**	**3/5/20**	**4/29/20**
Small Crane Barge (6,000 s.f.)	40 days	3/5/20	4/29/20
Pier 3	**51 days**	**3/19/20**	**5/28/20**
Small Crane Barge (6,000 s.f.)	51 days	3/19/20	5/28/20
Pier 4	**41 days**	**5/29/20**	**7/24/20**
Small Crane Barge (6,000 s.f.)	41 days	5/29/20	7/24/20
Pier 6	**51 days**	**6/12/20**	**8/21/20**
Small Crane Barge (6,000 s.f.)	51 days	6/12/20	8/21/20
Pier 7	**41 days**	**8/24/20**	**10/19/20**
Small Crane Barge (6,000 s.f.)	41 days	8/24/20	10/19/20
Pier 8	**50 days**	**9/8/20**	**11/16/20**
Small Crane Barge (6,000 s.f.)	50 days	9/8/20	11/16/20
Pier 9	**43 days**	**11/17/20**	**1/14/21**
Small Crane Barge (6,000 s.f.)	43 days	11/17/20	1/14/21
Pier 10	**52 days**	**12/2/20**	**2/11/21**
Small Crane Barge (6,000 s.f.)	52 days	12/2/20	2/11/21
Pier 11	**62 days**	**12/16/20**	**3/11/21**
Small Crane Barge (6,000 s.f.)	62 days	12/16/20	3/11/21



Conceptual Schedule Only, April 2010
Note: This is a proposed schedule, so activity dates are likely to change.

Figure 6-19. Sequencing of Temporary Barges Used During Demolition in the Columbia River

Columbia River CROSSING

Permanent Shade Sources

The permanent new bridges over the Columbia River and North Portland Harbor will create new sources of shade, as shown in Table 6-15. After the new bridges are completed, the project will demolish the existing Columbia River bridges, removing 284,000 sq. ft. of overwater shade.

The project will also permanently remove at least part of the overwater structure at the Red Lion at the Quay. At the very least, portions of the structure within 50 feet of the bridge will be removed (12,647 sq. ft. over water).

Project wide, there will be a permanent net gain of approximately 725,080 to 853,553 sq. ft. of shade (Table 6-15) in the Columbia River and North Portland Harbor.

The project will also remove floating homes from North Portland Harbor, resulting in the elimination of approximately 155,810 sq. ft. of shade from the project area. Floating homes will likely be moved from their current location to elsewhere in North Portland Harbor, the Willamette River, or the lower Columbia River. It is not possible to predict where each floating home will be placed, but it is likely that many will remain in the Lower Columbia system and move to existing floating home communities. Because it is not known whether the floating homes will be relocated outside of the project area in the long term, it is also unknown whether relocation of the homes will result in a net loss of shade. Section 6.7.5 outlines in greater detail the effects of floating home relocation.

6.1.3.3 Potential Effects of Shading on Fish in the CRC Action Area

Although there is a net gain of overall permanent shade in the project area, not all shade sources are likely to have negative effects on juvenile fish. The new bridge spans will permanently shade the action area, but are not likely to result in shading effects on any of the listed fish that use the project area (Table 6-14). The North Portland Harbor spans will be approximately 35 feet above OHW (similar to the existing spans, which are approximately 30 feet above OHW), and the Columbia River spans will range from 50 to 90 feet above OHW (compared to the existing spans which range from 40 to 80 feet above OHW). At these heights, light can readily dissipate beneath the structures and the spans are not likely to create the type of intense shade that attracts predators or causes visual disorientation to fish.

The bottoms of the shaft caps of the Columbia River structures will be located just below the water line and are likely to create the type of intense light-dark contrast that could potentially attract predators or cause visual disorientation to fish. This effect would be permanent, adding 52,800 sq. ft. of dense shade to the project area. (The current structure does not generate this type of dense shade. Thus, the shaft caps represent a new permanent, dense shade source.) Removal of the overwater structure at the Quay will permanently eliminate approximately 12,647 sq. ft. of dense shade. Compared to the 58,500 sq. ft. of intense shade created by the shaft caps, this represents a net gain of roughly 45,000 sq. ft. of permanent, intense shade. This could potentially degrade habitat for juvenile fish, increasing the probability of predation and interference with migration.

Temporary overwater structures, including the barges, work platforms, work bridges, oscillator support platforms, and tower cranes, are also located at the water line and therefore could create new, high-intensity shade in the Columbia River and North Portland Harbor. This impact will be temporary, limited to the time that these structures are in the water (Figure 6-17, Figure 6-18, and Figure 6-19).

Temporary shading will not be uniform over all of the in-water construction years (Figure 6-17). In the Columbia River, shading will be limited to the first three pier complexes during the first year, expand to all six in the second, and taper off to three or fewer during the last two years. In North Portland Harbor, temporary shade will be distributed more or less evenly over the first two years of the in-water construction periods with more shade-producing activities concentrated in the last in-water construction year (Figure 6-18). Temporary shading will be evenly dispersed over the in-water demolition period (Figure 6-19).

Effects to Predation

The existing Columbia River and North Portland Harbor bridges likely attract predators, such as largemouth bass, smallmouth bass, and northern pikeminnow. The project increases the amount of shade in the action area compared to existing levels, but chiefly on a temporary basis. Permanent increases in dense shade are limited to the net new 23,000 to 45,000 sq. ft. created by the shaft caps in the Columbia River. It is impossible to quantify the extent to which increased shade may affect predation rates on juveniles. However, it is probable that an increase in predator habitat will increase predation pressure on juvenile salmonids and larval eulachon in the action area during daylight hours. Project-related sources of shade likely to attract predators (barges, temporary overwater structures, and shaft caps) are located in juvenile migration routes, creating an opportunity for predators to forage on juveniles during migration. Additionally, rearing juvenile salmonids are present in the action area and could experience increased predation pressure as a result of increased shade. Figure 4-2 shows the timing of juvenile fish presence in the Columbia River and North Portland Harbor, indicating the time periods when they could be exposed to this effect. Green sturgeon and bull trout are unlikely to be subjected to increased predation pressure, because only adult and subadults may use the action area and the risk of predation is extremely low for fish of this size (Zimmerman 1999). Likewise, adult salmonids are unlikely to be exposed, for the same reason.

The increase in shade along the nearshore may have particularly adverse effects on certain life stages of juvenile salmonids. In general smaller, rearing and subyearling-migrant salmonids are highly dependent on the nearshore. Overwater structures that create a shadow line completely blocking the nearshore may force these runs into deeper water where they could be subjected to higher levels of predation. (It should be noted that the literature does not show widespread agreement on this effect, and therefore this result is not certain to occur.) This scenario could occur in several locations: at the temporary work bridges at Columbia River pier complexes 2 and 7, the permanent new shaft cap at pier complex 7 in the Columbia River, and at all of the temporary work bridges in the North Portland Harbor. While all runs of juvenile salmonids could be exposed to increased predation, species that rear in this portion of the action area (LCR Chinook, UCR spring-run Chinook, UWR Chinook, LCR coho, and LCR steelhead) and species that migrate as subyearling through this portion of the action area (CR chum and a portion of the LCR Chinook run) are generally more vulnerable to this effect both because they are dependent on the nearshore and because they are of a small size more easily captured by predators. It is not possible to quantify how many of these individuals will be exposed to increased predation in shallow water. However it is possible to estimate the physical extent, timing and duration of the effect. Exposure is presented as the overlap of when structures are present in shallow water (Table 6-33, Table 6-34, Figure 6-32, and Figure 6-33) with the timing of juvenile fish presence in this portion of the action area (Figure 4-2).

Effects to Orientation and Migration

As stated earlier, the literature is not in agreement as to whether the light-dark interface definitively causes visual disorientation or interference with migration in juvenile salmonids. This analysis assumes a worst-case scenario, that is, that all new intense shade sources in the action area may result in visual disorientation during the day time. Assuming this is true, juvenile salmonids could be exposed to this effect during daylight hours when they are present in the Columbia River and North Portland Harbor portions of the action area (Figure 4-2). It is impossible to quantify the magnitude of the effect on fish, but it is possible to estimate the duration and physical extent of the effect. Permanent effects would be limited to the net new 45,000 sq. ft. of intense shade (the shaft caps minus the existing pier at the Quay) (Table 6-15). The timing, duration, and areal extent of the temporary effects are illustrated in Figure 6-17, Figure 6-18, and Figure 6-19. These values represent the size of the shadow when the sun is directly overhead. At other times of day, the shadow will likely be larger.

For juvenile salmonids, visual disorientation could presumably lead to delayed migration and increased vulnerability to predation. The literature indicates that these effects are not certain to occur, and in any case, it is impossible to quantify the magnitude of these effects. The project will not create a swath of dense shade that completely spans either the Columbia River or North Portland Harbor stream channel. Therefore, even if the light-dark interface does prompt avoidance of the shadow zone, it is not likely to completely block migration. Nighttime migration would be unaffected.

Eulachon larvae do not have volitional movement (Langness personal communication 2009) and are therefore not subject to disorientation.

Green sturgeon are bottom feeders (NMFS 2008c) that inhabit portions of the stream channel with low light levels. Shade effects (particularly, a sharp light-dark interface) are not likely to extend to the depths that green sturgeon inhabit. In addition, their presence in the action area is extremely limited. Therefore, green sturgeon are not likely to experience visual disorientation as a result of increased shade in the action area.

Because bull trout abundance is extremely low in the action area and because the proportion of the action area likely to be exposed to increased shade is very limited, the risk of exposure to this effect is discountable. Additionally, only adult and subadult bull trout could potentially occur in this portion of the action area, and these age classes are not subject to visual disorientation from shade.

The increase of shade in shallow-water habitat may have particularly adverse effects to species that are highly dependent on the nearshore for migration: CR chum and the portion of the LCR run that migrates as subyearlings. Shade may completely overlap shallow-water habitat at the temporary work bridges at Columbia River pier complexes 2 and 7, at the permanent new shaft cap at pier complex 7 in the Columbia River, and at all of the temporary work bridges in the North Portland Harbor, potentially prompting these salmonids to swim into deeper water to circumvent the shadow line. It is not possible to quantify how many individuals may experience delayed migration due to the presence of shade in the nearshore. However it is possible to estimate the physical extent, timing, and duration of the effect. Exposure is presented as the overlap of when structures are present in shallow water (Table 6-33, Table 6-34, Figure 6-32, and Figure 6-33) with the timing of juvenile fish presence in this portion of the action area (see Figure 4-2).

Effects to Primary Productivity

The project is not expected to cause significant impacts to primary productivity or the food web for any of the fish species using the action area. The project may reduce the productivity of plants, algae, and phytoplankton occurring both within the photic zone and beneath overwater structures. However, shade will be limited to localized, discrete areas, measuring no more than several hundred to several thousand square feet. Permanent effects to primary production will be limited to shaded areas adjacent to the shaft caps in the Columbia River, estimated at 58,500 sq. ft. Other sources of shade, (barges, work platforms, tower cranes, and oscillator support platforms) will be temporary. The extent and duration of this effect are shown in Figure 6-17, Figure 6-18, and Figure 6-19.

Although the project may result in loss of primary production in the shadow zone, this loss is not likely to significantly impact the food web. The project area does not contain habitats that are known to support high primary and secondary productivity for fish. In northwest estuaries, such habitats include areas that produce and retain high levels of detritus: floodplains, vegetated riparian areas with overhanging vegetation, shallow marshes, tidal creeks, dendritic channel networks, low intertidal and subtidal eelgrass beds, emergent vegetation in tidal wetlands, and macroalgal beds (such as mudflats and sandflats). In the Columbia River estuary, detritus is concentrated in low-velocity peripheral bay habitats (Bottom et al. 2005). These habitats are completely lacking in the project area, which is dominated by high-velocity open water that is severed from the historical floodplain and lacks emergent vegetation, structural complexity, and riparian areas with overhanging vegetation. In areas of the upper estuary that lack these habitat features, there has been a shift from detritus-based primary production to production dominated by phytoplankton. This has led to widespread loss of food webs supporting epibenthic feeders such as juvenile salmonids (Bottom et al. 2005). This type of food web also favors production of a microdetrital food web dominated by simple-celled plants and organic particles (NMFS 2005c), as well as calanoid copepods and other organisms that are not consumed by juvenile salmon (Bottom et al. 2005). Because of the shift in the food web, the suspension/deposit feeder *Corophium salmonisis* is now the most abundant prey item of juvenile salmonids in the estuary. This species is a poor food source because it is low in protein and high in chitin (NMFS 2005c). Because the project area lacks detritus-rich habitat types and harbors a microdetrital food web, it provides only limited, low-quality foraging habitat and food web support for salmonids.

In shallow-water areas of the lower Columbia River, the large majority of primary productivity is driven by benthic algae, with some contribution from filamentous algae and flowering grasses. Within the water column, primary productivity is driven by phytoplankton (NMFS 2005c). Because shallow-water habitat is limited in the project area, the majority of primary productivity is likely driven by phytoplankton. Sections 6.3.1 and 6.3.2 discuss this in further detail.

There have been no known surveys of underwater vegetation or periphyton in the project area. However, in the lower Columbia, small diatoms (*Achnanthes*, *Cocconeis*, and some filamentous blue greens) are expected to be present. Other grazing-resistant algae are expected to be present on the riprap along shorelines and on bridge piers, together with filamentous green algae (such as *Cladophora*) and its associated epiphyton (for example, *Rhoicosphenia*, *Cocconeis*, and *Epithemia*). Red algae are also probably very common (Carpenter personal communication 2010).

Typical macrophytes in the lower Columbia River include *Potomogeton crispus*, *Elodea* (*cascadensis*, *nuttallii*, and others), *Ceratophyllum*, and possibly *Hetheranthera dubia*. However, macrophytes are likely not present or are very limited in the project area, as they typically occur in backwater areas (Carpenter personal communication 2010). Because underwater portions of the project area are characterized by high current velocity and an armored streambank, backwater areas are generally lacking, and thus, macrophytes are limited. Additionally, substrate is unstable sand, and the underwater topography slopes off steeply, reducing the size of the photic zone.

Because the project area lacks high-productivity, detritus-based plant communities and is dominated by plankton and periphyton, shading will not impact habitats of particularly high quality. Additionally, outside of the areas potentially influenced by shading, the surrounding area contains dozens of square miles of water available for primary production both upstream and downstream. Shading will only impact a tiny fraction of the remaining area available for primary production, such that there is no measureable reduction in baseline levels of production. All of the listed species that forage in the action area are highly mobile and can readily move to these nearby areas in response to localized impacts to vegetation or the food web. Because the impact is small relative to the amount of habitat present in the surrounding area, this effect will be insignificant.

The new bridge piers in the Columbia River and North Portland Harbor may also provide additional substrate for algae. This is a potential benefit to fish habitat, although the magnitude of this effect is likely very small, and its impact on fish is impossible to quantify.

Beneficial Effects of Shade

Shade may also confer benefits to salmonids using the action area. Salmonids require cool water to perform life history functions. Temperatures of 50 to 57°F are considered adequate to support spawning, migration, and rearing (Bjornn and Reiser 1991). The 303(d) listings for the Columbia River portion of the project area indicate that temperature exceeds standards for spawning, migrating, and rearing salmonids during summer months in the Columbia River and North Portland Harbor (DEQ 2009), with measured temperatures ranging as high as 72°F (USGS 2007). Overwater structures may create shade, resulting in localized areas of cooler water. The temporary overwater structures and the permanent shaft caps will create new areas of dense shade that could potentially provide an increase in summertime cool-water refugia compared to the current condition. These increases in shade may confer a benefit to migrating and rearing salmon, although it is impossible to quantify to what extent.

6.1.4 Artificial Lighting over Water

The project will require several new sources of overwater artificial lighting to be used during nighttime construction. The following sections outline the general effects of lighting on fish and provide an analysis of the likely effects on fish in the CRC action area.

6.1.4.1 General Effects of Artificial Lighting on Fish

Artificial light sources associated with overwater structures or construction activities may attract fish. Because salmon rely on vision for capturing prey, the artificial lights may improve both prey detection and predator avoidance (Tabor et al. 1998, as cited in Carrasquero 2001). During a study of the Columbia River at Bonneville Pool, Collis et al. (1995) observed that juvenile salmon were attracted to work lights directed at the water surface. In Lake Washington, juvenile Chinook have been observed congregating at night near streetlights on the SR 520 bridge (Celedonia et al. 2008). Tabor et al. (2004) observed sockeye fry in the Cedar River, noting that they were significantly more abundant under city street lights than at nearby sites that were not illuminated. Light levels as low as 0.22 lux (0.020 foot candle) appeared to influence fry behavior. In one location, turning off the streetlights resulted in a significant decrease in the number of sockeye fry present.

Artificial lights can create sharp boundaries between dark and light areas under water. This, in turn, may cause juvenile fish to become disoriented or avoid crossing the light-dark interface, as outlined in detail in Section 6.1.3.1. Williams and Thom (2001) noted that artificial lighting on docks may change nighttime movement patterns in juvenile salmon. Numerous other studies (Fields 1966, Prinslow et al. 1979, Weitkamp 1982, Ratte and Salo 1985, Pentec 1997, Taylor and Willey 1997, and Johnson et al. 1998; as cited in Southard et al. 2007) corroborate these findings, noting behavioral changes in juvenile salmon in response to artificial lighting. McDonald (1960, as cited in Tabor et al. 2004) found that sockeye fry will stop swimming downstream upon encountering artificial lighting, and was able to completely stop nightly migration of sockeye salmon fry with artificial lighting kept on all night at 30 lux (2.8 foot candles). A USFWS (1998) literature review noted that sockeye fry moved through experimental streams more quickly in complete darkness than under bright lights (Tabor et al. 1998). Increased light appeared to inhibit migration of sockeye fry, with significant effects to migration when light levels reached 2.0 lumens/ft^2 (2.0 foot candles). A later study (Tabor et al. 2004) corroborated the finding that fewer sockeye moved through illuminated artificial streams than in darkness, and those that did move, moved more slowly. In this study, light intensity levels from 1.08 to 5.40 lux (0.1 to 0.5 foot candle) appeared to inhibit migration. The same study noted that the delay in outmigration in sockeye fry increased their vulnerability to predation.

Another USFWS study (Tabor and Piaskowski 2001) observed juvenile Chinook in nearshore habitat in Lake Washington, noting that individuals became active when light levels reached 0.08 to 0.21 foot candle and were scarce in the study area when light levels were between 2.2 to 6.5 foot candles. A review of the impact of ferry terminals on juvenile migration in Puget Sound (Simenstad and Nightingale 1999) cites Ali (1958, 1960, and 1962) as stating that light is tremendously important for numerous life functions of chum, coho, sockeye, and pink salmon, noting that feeding, minimum prey capture, and schooling are dependent on light levels lower than 10^{-4} foot candles (similar to a clear, moonless night) and that maximum prey capture for chum and pink fry occurs when the light level is 1.0 foot candle (similar to light levels at dawn and dusk).

Artificial light sources may provide an advantage to predators such as smallmouth bass, largemouth bass, northern pikeminnow, and salmonids. Rainbow trout predation on sockeye fry in artificial streams increased with increased lighting at levels of less than 1.1 lux (Ginetz and Larkin 1976, as cited in Tabor et al. 2004). Northern pikeminnow are attracted to areas where juvenile salmonids congregate, such as hatchery release sites and dams (Collis et al. 1995;

Beamesderfer and Rieman 1991). If light sources attract congregations of juvenile salmonids, this could cause an increase in predation by northern pikeminnow. Celedonia et al. (2008) found that smallmouth bass may feed at night in the vicinity of artificial light or under moonlight. Largemouth bass have been shown to forage efficiently at light levels ranging from low-intensity daylight to full moonlight, with less foraging at light levels equivalent to a starlit, moonless night (McMahon and Holanov 1995).

Tabor et al. (2004) observed the effect of light intensity on cottid predation of sockeye fry in artificial streams, noting that cottids consumed 45 percent of the fry under intense illumination (5.4 lux or 0.50 foot candle), 28 percent under dim light (0.22 lux or 0.020 foot candle), and 5 percent in complete darkness (0 lux or 0 foot candle). The study also observed that fewer fry emigrated in illuminated streams and did so at a faster rate when predators were present than in lighted streams where predators were not present, indicating that the presence of predators may inhibit migration in some individuals. In a field study in the Cedar River, Washington, Tabor et al. (2004) further noted that the number of shoreline fry and rates of predation by cottids increased with an increase in light levels. At one site, shielding the lights to levels of 0.1 to 0.32 lux (0.013 to 0.030 foot candle) substantially reduced predation.

The literature is not in complete agreement about light levels that are likely to impede migration or increase predation on juvenile fish. However, data from Tabor et al. (2004) may present a worst-case scenario. That is, light levels as low as 0.22 lux (0.20 foot candle) may delay migration or increase predation on juvenile salmonids.

6.1.4.2 Effects of Lighting on Fish in the CRC Action Area

The project will install both temporary and permanent lighting.

Temporary Lighting

Temporary overwater lighting sources will include the cofferdams, barges, work platforms/bridges, oscillator platforms, and tower cranes. Figure 6-17, Figure 6-18, and Figure 6-19 show the locations and sequencing of temporary structures requiring artificial lighting in the work area. Temporary lighting will not be uniform over all of the in-water construction years. During the Columbia River in-water construction period, temporary lighting will be limited to the first three pier complexes during the first year, expand to all six in the second, and taper off to three or fewer during the last 2 years (Figure 6-17). In North Portland Harbor, temporary lighting will be distributed more or less evenly over the first 2 years of the in-water construction periods with illumination-producing structures concentrated in the last in-water construction year (Figure 6-18). Temporary lighting will be distributed evenly across the Columbia River in-water demolition period (Figure 6-19).

The barges and temporary in-water structures will cast light at the water surface during construction and demolition in the Columbia River and North Portland Harbor. At this stage in the project design, the intensity of light likely to be cast on the water surface is not known. However, to the extent practicable, the project will implement conservation measures that minimize the effects of lighting on fish. Measures may include using directional lighting with shielded luminaries to control glare and to direct light onto work areas instead of surface waters.

Although it is impossible to quantify how many fish will be exposed to increased lighting, it is possible to estimate the locations, timing, and duration of this effect (Figure 6-17, Figure 6-18, and Figure 6-19). All of the juvenile fish that use the action area could be exposed to this effect when they are rearing in or migrating through the project area (see Figure 4-2). The exposure to this effect is the overlap of: (1) juvenile salmonid presence (see Figure 4-2) with, (2) the timing of temporary lighting in the project area, and (3) the areas exposed to elevated levels of temporary lighting (Figure 6-17, Figure 6-18, and Figure 6-19).

It is possible that the increase in lighting in the action area could cause some interference with juvenile salmonid migration. Overwater structures will be limited to discrete locations measuring from several hundred to several thousand square feet and will only span a fraction of the entire channel. While lighting may prompt juvenile fish to avoid the illuminated area, it will not constitute a complete barrier to migrating juvenile fish.

It is also possible that rearing and migrating juvenile salmonids could congregate under light sources, potentially becoming exposed to an increased risk of predation than they are currently. As with effects to migration, it is impossible to quantify the extent to which predation will increase. However, it seems likely that an increase in the conditions that confer an advantage to visual predators could increase levels of predation. Rearing juveniles (LCR Chinook, coho, and steelhead) are present in the area for a relatively long proportion of the year, and therefore could be especially vulnerable to this effect.

Illumination in shallow water may place subyearling migrants (LCR Chinook and CR chum) at particular risk, as these individuals are highly dependent on nearshore areas. This effect is discussed in greater detail in Section 6.1.3.3.

Permanent Lighting

The permanent lighting on the bridges has not yet been designed. USCG will require bridge lighting to be brighter than the background lighting. While there is likely to be a large amount of illumination on the bridge spans high above the water, permanent lighting at the water surface will likely be minimal, limited to navigation lights, which are typically small, dim, and not cast directly on the water surface. Although it is not known at this point whether permanent lighting on the bridge will represent an increase in overall lighting in the project area, any increases are likely to be small.

The project will implement measures that minimize the effects of lighting on fish. Measures may include using directional lighting with shielded luminaries to control glare and to direct light onto work areas, instead of surface waters. Therefore, permanent lighting is not expected to cause significant adverse effects to listed fish.

6.1.5 Temporary Effects to Water Quality

The project will implement BMPs during in-water and upland construction activities to avoid and minimize impacts to water quality. Without implementation of BMPs, water quality could be impacted in a number of ways. Chemical contamination could potentially occur through the accidental release of construction materials or wastes. Upland excavation could lead to erosion, causing turbidity in adjacent water bodies. In-water work (such as pile driving, demolition, debris removal, barge use, and installation of bridge piers) could generate turbidity directly in waterways. The implementation of BMPs will help ensure that these effects will be localized and temporary, limited to the duration of the project, and will result in minimal impacts to water quality.

This section describes the sources of effects to water quality, outlines the BMPs that will be used to contain them, and analyses the potential effects to listed fish.

6.1.5.1 Chemical Contamination

There are numerous potential sources of chemical contamination associated with in-water work in the Columbia River and North Portland Harbor.

- Equipment located in or over the water (such as barges or equipment operating on barges, temporary work platforms, the existing structures, or the new structures) are potential sources of contamination.
- Uncured concrete will be present in numerous locations, both in and over the water, for the construction of the shaft caps, piers, and superstructure for the new bridges.
- Construction of the superstructure will involve the use of numerous other potential contaminants, including various petroleum products, adhesives, metal solder, concrete and metal dust, asphalt, and others.
- Bridge demolition will occur both in and over the water and may release contaminants such as concrete debris, concrete dust created by saw cutting, and lead paint.
- There are a total of approximately 1,800 timber piles at the nine existing Columbia River bridge piers. It is assumed that these piles have been chemically treated, based on their age and intended purpose. Contaminants from the piles could be mobilized during demolition of the piers.

Although there are several sources of chemical contaminants, there is a low risk that chemicals will actually enter the Columbia River and North Portland Harbor. A SPCC plan will be implemented to completely contain sources of chemical contamination such as equipment leaks, uncured concrete, and other pollutants.

During construction of the drilled shafts, uncured concrete will be poured into water-filled steel casings, creating a mix of concrete and water. As the concrete is poured into the casing, it will displace this highly alkaline mixture. The project will implement BMPs to contain the mixture and ensure that it does not enter any surface water body. Once contained, the water will be treated to meet state water quality standards and either released to a wastewater treatment facility or discharged to a surface water body.

In-water bridge demolition will take place only in the Columbia River. All demolition activities will be completely contained within cofferdams. The contractor is required to prepare a demolition plan according to ODOT and WSDOT standard specifications. The plan will be submitted to ODOT and WSDOT and will not be implemented without being approved and stamped by a registered professional engineer. The demolition plan will specify containment methods to ensure that bridge elements and wastes do not enter the Columbia River. Breaking up the concrete piers with an excavator or saw cutter could potentially introduce concrete dust into the water; however, because of the containment proposed, there is minimal risk that dust or debris will enter the Columbia River during demolition. Any concrete wastes will be allowed to settle in the cofferdams before the cofferdams are disassembled. During removal of the cofferdams, released water will meet state water quality standards.

Removal of the timber piles that are deemed navigational hazards and located beneath the existing Columbia River piers will be contained within cofferdams during the demolition of the rest of the piers. There may be, however, some piles that must be removed and are located outside of the cofferdam footprint. These will likely be cut off at or below the mudline. No containment is proposed for the removal of these pilings. However, given the high flow in the Columbia River, dilution of contamination is likely to be high, and the extent of the contamination is expected to be minimal.

The project will obtain several regulatory permits that include terms and conditions for controlling and containing chemical releases to surface water bodies. These permits include: Ecology's 401 Water Quality Certification, WDFW HPA, DEQ's 401 Water Quality Certification, DSL's Removal/Fill Permit, and USACE's 404 Removal/Fill Permit. The project will adhere to the terms and conditions of all of these permits, further minimizing risks to water quality in the Columbia River and North Portland Harbor.

In general, construction equipment operating on land poses a low risk of releasing chemical contaminants (such as petroleum fuel or other fluids) that could enter surface water bodies by way of stormwater inlets, ditches, or other forms of conveyance. Implementation of a Pollution Control Plan will minimize the risk of landward contaminants entering water, to ensure that the risk of contaminant release is discountable. These measures are outlined in greater detail in Section 7. Overall, this aspect of the project is not likely to adversely affect any listed fish.

6.1.5.2 Temporary Turbidity and Suspended Sediment

The project is likely to generate temporary, localized turbidity during the in-water work in the Columbia River and North Portland Harbor. Table 6-16 lists the activities that could potentially generate turbidity downstream of each activity and summarizes the effect to the environmental baseline in the Columbia River and North Portland Harbor.

Table 6-16. Potential Sources of Turbidity

Activity	Timing[a]	Location[b]	Likely Extent of Downstream Turbidity	Duration of Effect (hr/day)	Number of Workdays
Install temporary piles, impact methods	9/15 – 4/15	Adjacent to P2 – P7 in CR Adjacent to new NPH shafts	~25 feet	0.66	138 in CR 134 in NPH
Install temporary piles and cofferdams, vibratory methods	Year-round	Adjacent to P2 – P7 in CR Adjacent to new NPH shafts	~25 feet	Up to 24	Continually over ~1015 days in CR ~334 in NPH
Remove temporary piles and cofferdams, direct pull or vibratory	Year-round	Adjacent to P2 – P7 in CR Adjacent to new NPH shafts	Minimal	Up to 24	Continually over ~1015 days in CR ~334 days in NPH

Activity	Timing[a]	Location[b]	Likely Extent of Downstream Turbidity	Duration of Effect (hr/day)	Number of Workdays
Install steel casings to drill permanent shafts – vibratory hammer, oscillator, or rotator	Year-round	P2 – P7 in CR New NPH shafts	~25 feet	8 – 10	250 / CR pier <1 / NPH shaft
Drill and excavate permanent shafts	Year-round	P2 – P7 in CR New NPH shafts	Minimal (contained)	n/a	100 / CR pier ≤8 / NPH shaft
Operate stationary and moving barges in shallow water	Year-round	P2 – P7 in CR new NPH shafts	<300 feet	Varies	Continually over ~1015 days (CR) ~640 in NPH
Debris removal (clamshell)	11/1 – 02/28	Potentially at 31 locations in NPH.	~300 feet (or as prescribed by permits)	4-6 hr/day, ≤ 4x/day	Less than 7 days
Demolish existing Columbia River bridge piers (includes installation of cofferdams)	Year-round	Existing Piers 2 - 11 in CR	Minimal	8 – 10	~266

a All activities likely to take place within the 4-year in-water construction period.

b CR = Columbia River; NPH = North Portland Harbor, P = pier complex.

Potential Effects to the Environmental Baseline

The project will employ numerous BMPs to minimize the extent and duration of turbidity. These BMPs may include (but will not be limited to) a Spill Prevention/Pollution Control Plan, an Erosion Control Plan, and others as outlined in Section 7. The exact BMPs have not yet been determined. However, these BMPs will ensure that the amount and extent of turbidity will meet the terms and conditions of the two Section 401 Water Quality Certifications that will be obtained from DEQ and Ecology. The certifications will specify a mixing zone for turbidity: that is, a specified distance beyond which turbidity may not exceed ambient levels downstream of the source. We anticipate that the permits will specify a mixing zone of 300 feet downstream of turbidity-generating activities, as this is typical for water bodies the size of the Columbia River and North Portland Harbor (that is, with flows of 300 cubic feet per second [cfs] or greater). Typically, these permits allow exceedance of ambient levels of turbidity for a period of 4 hours within the mixing zone and 2 hours outside of the mixing zone, after which the applicant must stop work until the turbidity dissipates to ambient levels. The project will implement regular water quality monitoring in accordance with the permits to ensure that the project adheres to the permit conditions, with cessation of work if conditions are not met.

In actuality, many of the activities listed in Table 6-16 are not expected to generate large amounts of turbidity. The following activities are expected to generate turbidity at far shorter distance than the anticipated 300-foot mixing zone: installation of piles and cofferdams using impact or vibratory methods, removal of piles and cofferdams using direct pull or vibratory methods, installation of large diameter steel casings using an oscillator, rotator, or vibratory hammer, and demolition activities contained within a cofferdam. These activities do not involve in-water excavation and disturb relatively small amounts of material; therefore, the potential for generating turbidity is greatly reduced.

EPA advises that turbidity extends no more than 25 feet from the source during impact or vibratory pile installation (WSF 2009). Assuming that this is an average value observed over a range of substrate types and flow levels, we expect this threshold distance to be achievable on the CRC project. The Columbia River and North Portland Harbor are large water bodies, providing very high levels of dilution, and reducing size of the potential mixing zone. Additionally, substrates in these water bodies are coarse sand, which settles in relatively short distances compared to finer sediments. Given these mitigating circumstances, we expect that turbidity levels in the CRC action area will be similar to average conditions in other streams, or at least not exceed them. Therefore, we expect that the turbidity will extend to no more than 25 feet from installation of piles, cofferdams, and the steel casings for drilled shafts.

Few studies document the magnitude or extent of turbidity resulting from pile removal. Roni and Weitkamp (1996) reported that pile removal in Manchester, Washington, generated turbidity at less than 1 Nephelometric Turbidity Unit (NTU) above background levels. Washington State Ferries (WSF) performed water quality monitoring during pile removal at Friday Harbor Ferry Terminal; they reported that turbidity levels did not exceed 1 NTU above background levels and were less than 0.5 NTU above background for most of the samples. WSF also performed water quality monitoring during pile removal at Eagle Harbor Maintenance Facility in 2005, reporting that removal of steel and creosote pile resulted in turbidity levels of no more than 0.2 NTU. These values represent extremely small increases above background turbidity levels. Given that the Columbia River and North Portland Harbor have very high dilution capacity and given that substrate in the project area is coarse sediment that settles readily, it is expected that turbidity generated by removal of piles and cofferdams will dissipate within a minimal distance Specifically, it is assumed that this distance will be less than that for pile installation (25 feet), as pile removal displaces less sediment than pile installation.

Drilling and cleaning the permanent shafts will introduce only minimal amounts of sediment into the water. All of the drilling and excavation will occur within the closed steel casings. To the extent practicable, excavated materials will not be allowed to enter the water, but will be stored in contained areas on the barges or work platforms and transported to a permitted upland disposal site.

Debris removal is the only aspect of in-water work likely to generate significant amounts of turbidity. Debris removal could potentially occur at discrete locations in North Portland Harbor. While debris removal is not certain to occur, this information is presented as a worst-case analysis.

There are anecdotal reports that remnant pieces of the original North Portland Harbor bridge (including riprap used as scour protection), still remain on the stream floor. The exact location of the material is not known, but the design team believes that it occurs in several scattered locations, potentially within the footprint of any of the new North Portland Harbor bridge shafts. If this is the case, the material must be removed before drilled shafts can be installed in these locations. Before debris removal begins, divers will pinpoint the locations of the material. Debris removal will be performed only in the precise locations where the material occurs within the footprint of the new bents, greatly minimizing the areal extent of the activity. As stated previously, the amount of material in this location is not known. Assuming a worst-case scenario, that the area of the material is the same as the footprint of the drilled shafts, the project would remove debris at each of the 31 new bridge shafts (encompassing an area of roughly

2,433 sq. ft., total). The design team estimates that no more than 90 cubic yards of material will be removed.

Due to the large size of the North Portland Harbor, the design team anticipates that it will not be possible to install physical BMPs to contain turbidity during debris removal in these locations. Regardless, the project will comply with the terms of all permits related to in-water turbidity, and turbidity will not exceed the levels, distance, or duration specified by the permits. Depending on the permit specifications, the turbidity plumes are expected to reach no more than 300 feet downstream of the source for a duration of no more than 4 to 6 hours. In all cases, debris removal will be performed using a clamshell and at a slow, controlled pace to minimize turbidity.

Barges operating in shallow water have the potential to produce turbidity at Pier Complexes 2 and 7 in the Columbia River and at all of the new North Portland Harbor bents. Barges will have a draft depth of about 13 feet and will operate in water as shallow as 20 feet deep. Therefore, barge propellers may produce turbulence that causes sediments to become suspended. Additionally, tug boats that position barges may also have propellers that generate suspended sediment. Tug boats will operate only during discrete time periods to (1) position the work barges at each of the shallow-water piers (Pier Complex 7 in the Columbia River and all North Portland Harbor bents) and (2) to remove them when work is completed. These barges will remain stationary for the duration of the work, and therefore have little potential to produce turbidity. Additionally, there will be one or two barges at each of the shallow-water piers used to store and move materials and dredge spoils. These barges will make numerous trips, as needed, operating on a sporadic schedule. Because the schedule is unknown, it is not possible to predict the timing and duration of the turbidity plumes. In any case, the size of the plumes is expected to be much smaller than the typical plume created by dredging (estimated to be no more than 300 feet). Given that sediment in this portion of the action area consists mainly of coarse material with only minor amounts of fines, suspended sediment is expected to settle quickly, further restricting the size of the potential turbidity plume. Additionally, compared with the existing energy generated by high-velocity flow in this portion of the action area, disturbance of sediment by tug and work boat propellers is expected to be minimal. Because little aquatic vegetation is present in this portion of the action area, turbidity generated by barges and tug boats is not expected to have a significant impact on underwater vegetation. In any case, turbidity will not exceed the levels, distance, or duration specified by the permits. Construction barges will not be grounded.

Demolition will involve cutting, breaking, and removing the nine existing Columbia River bridge piers. Exact demolition methods are unknown at this time and will be determined by the contractor at a later date. However, the CRC team anticipates that all demolition work will be performed from barges and will be completely contained inside of enclosed cofferdams. Installation and removal of the cofferdams is the only aspect of bridge demolition likely to cause turbidity. Turbidity is likely to extend only a minimal distance from the source (Table 6-16) and could potentially be present for the duration of the time it takes to install or remove each cofferdam. Installation of the cofferdam, demolition of the pier, and removal of the cofferdam is expected to take 40 days throughout the 18-month in-water demolition period (Figure 6-16). In any case, turbidity will not exceed the levels, distance, or duration specified by the permits.

In general, upland excavation has the potential to cause erosion, which in turn may introduce suspended sediments into water bodies by way of stormwater inlets, ditches, or other forms of conveyance. However, it is not likely that upland construction will cause turbidity in the CRC action area water bodies. To prevent the introduction of sediments into waterways from upland excavation, the project will adhere to an erosion control plan that specifies the type and placement of BMPs, mandates frequent inspections, and outlines contingency plans in the event of failure. Additionally, in many cases, there will likely be numerous other barriers between the potential sources and the action area water bodies. Therefore, there is only a discountable risk that upland excavation will generate turbidity in action area water bodies. Erosion control specifications are outlined in further detail in Section 7.

General Effects of Turbidity on Fish

Turbidity is a naturally occurring phenomenon; however, turbidity above background levels may harm fish. Several factors contribute to turbidity levels in water, including suspended sediments, dissolved particles, finely divided organic and inorganic matter, chemicals, plankton, and other microscopic organisms. Not all of these materials are necessarily harmful, meaning that turbidity levels alone may not accurately indicate the effect on fish. TSS, a direct measure of particles transported in the water column, may be a more useful indicator of the effect to fish. However, due to the ease of taking turbidity measurements, turbidity is in widespread use throughout the literature as an indicator of the effect of suspended sediments on fish (Bash et al. 2001).

The response of fish to turbidity is complex. High levels of turbidity may be fatal to salmonids, but salmonids may also be affected by turbidity at relatively low levels (Lloyd 1987). Juvenile salmonids have been observed in naturally turbid estuaries and highly turbid glacial streams, which indicates that that salmon are able to cope with elevated turbidity during certain life stages (Gregory and Northcote 1993, as cited in Bash et al. 2001). In contrast, salmonids not normally exposed to elevated turbidity levels may be adversely affected at relatively low levels (Gregory 1992, as cited in Bash et al. 2001). The severity of effect depends on a variety of factors, such as the turbidity level, extent of the turbidity plume, the duration and frequency of exposure, the toxicity and angularity of the particles, life stage of the fish, and access to "turbidity refugia" (Bash et al. 2001). Depending on the amount of exposure, turbidity above background levels may prompt the following effects: direct mortality, gill tissue damage, physiological stress, and behavioral effects.

Numerous studies document that direct mortality for juvenile salmonids occurs at a 96-hour median sediment concentration of 6,000 mg/L (Stober et al. 1981 as cited in Bash et al. 2001; Salo et al. 1980; LeGore and DesVoigne 1973 as cited in WSF 2009).

Suspended sediments have been shown to damage gill structure (Noggle 1978). When the filaments of salmonid gills are clogged with sediment, fish attempt to expunge the sediment by opening and closing their gills excessively, in a physiological process known as "coughing." In response to the irritation, the gills may secrete a protective layer of mucus. Although this may interfere with respiration, it is not a lethal effect (Berg 1982, as cited in Bash et al. 2001). Servizi and Martens (1992) noted a significant increase in coughing in subyearling coho when turbidity measured 30 NTU. Berg (1982, as cited in Bash et al. 1991) observed a significant increase in coughing in juvenile coho at 60 NTU, with a decline or return to pre-exposure levels of coughing at 10 NTU. This indicates that turbidity somewhere between 10 and 30 NTUs may cause onset of coughing. Servizi and Martens (1987) found that gill trauma occurred in subyearling sockeye at suspended sediment concentrations of 3,148 mg/L.

The literature indicates that exposure to suspended sediments may cause stress response in both adult and juvenile salmonids. Physiological stress generally manifests itself as elevated blood sugar, plasma glucose, and plasma cortisol (Bash et al. 2001). Redding et al. (1987) observed physiological stress in subyearling coho after exposure to sediment concentrations of 2,000 mg/L for 7 to 8 days. Servizi and Martens (1987) observed elevated blood glucose levels in adult and juvenile sockeye after contact with fine sediment. In adults, this response occurred at concentrations of 500 to 1,500 mg/L after exposure for 2 to 8 days. At levels of 150 to 200 mg/L, no stress response was observed (Redding et al. 1987; Servizi and Martens 1987). At the individual level, stress may reduce growth, increase the likelihood of disease, inhibit the development from parr to smolt, disrupt osmotic balance, impair migration, and reduce survival (Wedermeyer and McLeay 1981, as cited in Bash et al. 2001). At the population level, stress may reduce spawning success, increase larval mortality, and decrease overall population abundance (Bash et al. 2001).

Turbidity may also prompt behavioral responses in fish, including avoidance, migration delays, and changes in foraging and predation. Numerous studies document salmonids avoiding suspended sediments and migrating to less turbid areas (Berg 1982; Sigler et al. 1984). Lloyd et al. (1987) showed that juvenile salmonids avoid streams that are chronically turbid unless they cannot avoid these areas on their migration path. Cederholm and Salo (1979) showed that the upstream migration of salmonids in the lower Columbia River may be delayed when water clarity is reduced. On the other hand, adult male Chinook experienced no disruption in migration to spawning grounds after exposure to sediment concentrations of 650 mg/L over 7 days.

The literature is not in complete agreement as to whether or not turbidity increases the rate of prey capture in salmonids. Some studies reveal that fish have decreased foraging success in response to increased turbidity (Berg 1982; Berg and Northcote 1985; Redding et al. 1987; Gardner 1981 as cited in Bash et al. 2001; Boehlert and Morgan 1985 as cited in Bash et al. 2001; Vogel and Beauchamp 1999 as cited in Bash et al. 2001). One study showed decreased foraging at levels as low as 20 NTU (Berg 1982). In contrast, other studies show that juvenile coho, steelhead, and Chinook have increased foraging success in "slightly to moderately turbid" water (Sigler at al. 1984; Gregory and Levings 1998). There is also evidence that suspended sediments may offer cover from predators (Gregory 1993; Gregory and Levings 1996; Davies-Colley and Smith 2001), which may both enhance survival and increase foraging success.

Turbidity and concurrent sedimentation may negatively affect survival of eggs and emergence of fry or larvae. After being deposited in spawning areas, high levels of fines may become embedded in the substrate, reducing the permeation of oxygen into eggs, potentially resulting in mortality. Additionally, deposition of sediment may physically block the emergence of fry or larval fish (Cederholm and Salo 1979).

Effects on Fish in the CRC Action Area

There are few water quality monitoring studies that cite turbidity levels encountered during installation and removal of piles, cofferdams, and steel casings. Due to the lack of data, the analysis of the effects of turbidity on fish is based on turbidity levels observed during dredging, for which there are numerous monitoring studies. Havis (1988, as cited in WSF 2009)), Salo et al. (1979, as cited in WSF 2009), and Palermo et al. (1990, as cited in WSF 2009) note that typical samples collected within 150 feet of dredging contain sediment concentrations between 50 and 150 mg/L. LaSalle (1988, as cited in WSF 2009) concluded that maximum sediment concentrations resulting from dredging range between 700 and 1,100 mg/L at a distance of approximately 300 feet from the source, based on monitoring data from seven clamshell dredging operations. These levels would be expected for dredging of fine sediments such as silt or clay. Much lower concentrations, 50 to 150 mg/L, would be expected for dredging in coarser substrates (LaSalle 1988). The CRC in-water project area contains a mixture of coarser sediments and silty sand. Therefore, the amount of turbidity encountered during debris removal is likely to be more than 50 to 150 mg/L but is not expected to exceed 700 to 1,100 mg/L. Turbidity levels for the other activities listed in Table 6-16 (installation and removal of piles and cofferdams, installing large steel casings, barge use, and drilling shafts) are expected to be much lower than levels resulting from dredging.

Turbidity levels on the CRC project are not expected to reach levels that cause mortality in fish. The highest sediment concentrations expected to occur (1,100 mg/L) will be well below levels known to kill fish (6,000 mg/L). Likewise, turbidity levels on the CRC project are not likely to cause gill trauma, as gill trauma occurs at roughly 3,000 mg/L, well above the highest levels of turbidity expected on the project. However, turbidity will likely reach levels that could cause "coughing." Coughing may occur at 30 NTU, a value roughly estimated to be greater than 100 mg/L (Lloyd 1987). Actual exposure to these levels is expected to be minimal, however. Regulatory permits will require restricting the size of the plumes (about 300 feet from the source) and their duration (about 4 to 6 hours). Additionally, because of the large size and the high dilution capacity of the Columbia River and North Portland Harbor, there are abundant turbidity refugia, and listed fish should not become trapped in turbid water. The turbidity will be localized in areas downstream of specific activities (Table 6-16) and will not extend across the entire width of the Columbia River or North Portland Harbor. Therefore, it will not cause a complete barrier to movement. Thus, while turbidity levels are theoretically high enough to prompt coughing in fish, it is unlikely that the duration and extent of exposure will be great enough to cause gill damage.

The project may produce turbidity at levels that could cause physiological stress in fish. Of the studies available, the data indicate that stress may occur at a minimum level of 500 mg/L after several days of exposure. The project may generate a maximum of 1,100 mg/L of sediment concentration, but more typically in the range of 50 to 150 mg/L. On the CRC project, the actual duration of exposure to elevated turbidity is likely to be quite low, as regulatory permits will restrict the size and duration of the turbidity plumes, about 300 feet and to about 4 to 6 hours at a time. Additionally, because of the large size and the high dilution capacity of the Columbia River and North Portland Harbor, listed fish will be able to avoid the turbidity plumes and not become trapped in turbid water. The turbidity will not cause a complete migration barrier. Thus, while turbidity levels are theoretically high enough to prompt stress in fish, it is unlikely that the duration and extent of exposure will be great enough to cause stress.

It is highly likely that turbidity generated by the project will cause both adult and juvenile fish to avoid discrete portions of the work area (Table 6-16), as avoidance has been documented at very low turbidity levels. Figures 4-1 and 4-2 show when listed fish may be present in portions of the action area where they could be exposed to this effect. Turbidity-generating activities will be ongoing for the duration of the 4-year in-water construction period, and, therefore, these activities are likely to intersect up to four migration periods of juvenile salmon and steelhead.

The exception is debris removal, which will likely intersect only about 7 days of one juvenile migrational period. Fish will likely circumvent the turbidity plumes and swim into less turbid areas. Whether this avoidance will result in a biologically significant effect is less clear. Although the literature shows that juvenile salmonids may delay migration in response to high turbidity, this may not necessarily be true in the CRC action area for two reasons. First, due to the large size of the Columbia River and North Portland Harbor, turbidity refugia will be abundant, and juvenile fish will probably circumvent the plumes with no significant delay to migration. Second, larger sediment plumes (anticipated to be no more than 300 feet) will occur in the action area for no more than roughly 4 to 6 hours at a time. Therefore, there is ample time for juveniles to migrate between sediment pulses, and even if there were a delay, it would only be for a matter of hours. Adults have not been shown to delay migration even after many days of exposure to high turbidity. Because the CRC project will cause only low exposure (due to the abundance of turbidity refugia) over a limited spatial extent and over short durations, delays to adult migration are not probable.

Turbidity will likely reach levels that have been shown both to enhance and impede foraging abilities in fish. Therefore, we can expect that turbidity generated by the project will cause listed fish in the action area to increase foraging in some circumstances and decrease foraging in others. There is also evidence that turbidity may provide cover from predators, creating a benefit to juvenile fish. However, due to the uncertainly in the literature, and due to the wide variations in the levels of turbidity shown to cause either of these outcomes, it is impossible to quantify this effect.

Turbidity and resulting sedimentation may affect spawning eulachon in the action area. (Other listed fish will not be exposed to this effect because none spawn in portions of the action area downstream of activities likely to generate turbidity.) High levels of turbidity have the potential to smother eggs and block the emergence of larvae (Langness 2009 personal communication). There are no known eulachon spawning concentrations in portions of the action area likely to be exposed to elevated turbidity and sedimentation (see Section 4). Given the lack of precise spawning locations, it is assumed that spawning could potentially occur anywhere in the portions of the Columbia River and North Portland Harbor with water depths of 8 to 20 feet, and if spawning occurs in this area, it would likely be exposed to elevated turbidity. In other words, exposure could result from turbidity-generating activities at Pier 7 in the Columbia River and throughout North Portland Harbor. Actual exposure is expected to be quite low, as high levels of turbidity will be limited to approximately 300 feet downstream of the discrete areas where debris removal will occur and will be restricted to a much smaller area for other in-water activities (Table 6-16). This represents a minuscule proportion of the channel and an insignificant fraction of the total available spawning habitat immediately surrounding the affected area for many miles upstream and downstream.

Exposure to eulachon eggs or larvae would be limited to the overlap of (1) the incubation and emergence period, approximately from January through June, with (2) the 4-year in-water construction period. Table 6-17 summarizes the effect of turbidity and sedimentation on various life functions of fish.

Table 6-17. Summary of Effect of Turbidity and Sedimentation on Life Functions of Listed Fish

Activity/ Timing[a]	Mortality[b]	Gill Damage[c]	Stress[c]	Avoidance	Migration Delay[c]	Foraging/ Predation[d]	Spawning[e]
Debris Removal 11/1 – 2/28	No	Not likely	Not likely	Likely (~300 ft, 4-6 hrs, ~4x/day)	Not likely	Likely	Likely (~300 feet)
Impact installation 9/15 – 4/15	No	Not likely	Not likely	Likely (25 ft, ~1 hr/day)	Not likely	Likely	Likely (~25 feet)
Vibratory installation year-round	No	Not likely	Not likely	Likely (25 ft, ≤24 hr/day)	Not likely	Likely	Likely (~25 feet)
Pile/cofferdam removal year-round	No	Not likely	Not likely	Likely (minimal, ≤24 hr/day)	Not likely	Likely	Likely (minimal)
Drilled shafts year-round	No	Not likely	Not likely	Not likely (contained)	Not likely	Likely	Not likely (contained)
Demolition year-round	No	Not likely	Not likely	Likely (minimal, ~8-10 hr/day)	Not likely	Likely	Likely (minimal)
Barges, shallow water year-round	No	Not likely	Not likely	Likely <300 feet	Not likely	Likely	Likely (<300 feet)

a All activities to occur within 4-year in-water constriction period.
b Turbidity will not reach levels known to cause mortality.
c Exposure unlikely due to avoidance, dilution, turbidity refugia, and limited extent and duration of effect.
d Effect likely but not quantifiable.
e Applies to eulachon only.

Table 6-18 summarizes the species and life stages of fish that could potentially be exposed to turbidity and sedimentation in the Columbia River and North Portland Harbor.

Table 6-18. Fish Species Potentially Exposed to Project-Generated Turbidity in the Columbia River and North Portland Harbor

	Life Stage				
Species	**Spawning**	**Incubation**	**Rearing**	**Juvenile Outmigration**	**Migrating/ Holding Adults**
Chinook					
LCR ESU			X	X	X
UCR Spring-Run ESU			X	X	X
UWR ESU				X	X
SR Fall-Run ESU				X	X
SR Spring/Summer-Run ESU				X	X
Steelhead					
LCR DPS			X	X	X
MCR DPS				X	X
UWR DPS				X	X
UCR DPS				X	X
SR DPS				X	X

Species	Spawning	Incubation	Rearing	Juvenile Outmigration	Migrating/ Holding Adults
	Life Stage				
Sockeye					
SR ESU				X	X
Coho					
LCR ESU			X	X	X
Chum					
CR ESU			X	X	X
Bull Trout *(exposure is discountable due to extremely low numbers in action area)*					
CR DPS					X[a]
Green Sturgeon *(exposure is discountable due to extremely low numbers in action area)*					
Southern DPS					X[a]
Eulachon					
Southern DPS	X	X		X	X

a Includes subadults.

Figure 4-1 and Figure 4-2 show when these species are likely to be present in the portions of Columbia River and North Portland Harbor likely to be exposed to elevated turbidity.

Summary of Effects to Listed Species

Bull trout and green sturgeon could potentially be exposed to turbidity effects, but due to extremely low numbers of these species in the very limited areas subject to elevated turbidity, exposure is discountable.

Adult and juvenile salmon and steelhead (Table 6-18) are likely to be exposed to elevated turbidity, but not at levels likely to cause mortality, gill damage, stress, or migratory delay. Turbidity may reach levels that could cause temporary avoidance of the areas within the discrete mixing zones and timelines outlined in Table 6-16 and Table 6-17. This is likely an adverse effect.

Adult and larval eulachon are likely to be exposed to elevated turbidity in the same manner as described for salmon and steelhead. Additionally, turbidity and sedimentation may have adverse effects on spawning and potential spawning habitat, but these effects will be limited to discrete areas, representing a miniscule proportion of available spawning habitat. Turbidity is not expected to interfere with migration of larval eulachon, which do not have volitional movement.

6.1.5.3 Contaminated Sediments

State and federal databases have identified upland sites in the project area or immediate vicinity that are known or suspected to contain contaminated media (Parcel Insight 2009). Parcel Insight (2009) compiled information from all of the regulatory databases related to chemical contamination in the project area, including: the federal Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) database, Oregon State Environmental Cleanup Site Information (ECSI) database, Oregon and Washington State Leaking Underground Storage Tank (LUST) database, and Oregon State Hazardous Materials (HAZMAT) database. DEQ suspects that four sites in the project area may contain contaminated sediments due to their proximity to the contaminated upland sites and due to available information about past activities on the sites (Parcel Insight 2009).

- Schooner Boat Works Pier 99 is a marine repair facility located on the south bank of North Portland Harbor, east of I-5. The facility appears in the ECSI and CERCLIS databases. Metals and petroleum products were detected in on-site soils. Groundwater and sediment at the site have not yet been analyzed. Considering the types of activities conducted at the site and the length of time that these activities occurred, other potential site contaminants may include: organotoxins, toxic metals (such as arsenic, lead, cadmium, chromium, mercury, and zinc), volatile organic compounds, semi-volatile organic compounds, and PCBs. Additionally, regulatory agencies have received complaints about this site releasing materials into the water (Parcel Insight 2009).
- Diversified Marine is a second marine repair facility located on the south bank of North Portland Harbor, west of the I-5 bridge. This facility also appears in the Oregon State HAZMAT and ESCI databases and in the federal CERCLIS database. As for Pier 99, regulatory agencies have received complaints about the Diversified Marine site releasing materials into the water. The record of Pollution Complaints and Spill Reports suggests that on-site activities could have contaminated the site soils and nearby sediments with any of a variety of contaminants used in boat building, maintenance, and repair. These contaminants may include paint chips, toxic metals (such as copper oxide, organotins, lead, cadmium, chromium, mercury, and zinc), petroleum constituents (such as benzene, toluene, ethylbenzene, and polycyclic aromatic hydrocarbons [PAHs]), and organic contaminants such as phthalates, pentachlorophenol, chlorinated solvents, and PCBs (Parcel Insight 2009).
- The site of a former landfill is located on Hayden Island near the Columbia River shoreline and to the west of I-5 at the current location of the Thunderbird Hotel. This unregulated landfill was located in a seasonal lake basin and probably operated between 1950 and 1970, after which it was covered with a 7- to 8-foot layer of clean fill. In 1989, an ARCO gas station that later opened on the eastern edge of the former landfill initiated a study and detected gasoline contamination in the groundwater. Borings also revealed a layer of landfill debris beneath clean fill. The DEQ LUST program (file #26-89-0149) requested a Corrective Action Plan from ARCO, leading to pump-and-treat remediation that began operating in August 1990. Groundwater samples from eight monitoring wells contained dissolved metals, which are most likely a result of leachate percolating through unknown solid wastes in the unsaturated zone (Parcel Insight 2009). Because there is a high connectivity between the groundwater and the Columbia River in this location, it is suspected that metals could be present in the river sediments immediately adjacent to the site.
- The former site of the Boise-Cascade Lumber Mill is located in Vancouver on the north shore of the Columbia River, about 1,500 feet to the west of the I-5 bridge and to the west of the Red Lion Hotel. Based on the industrial history and type of activities conducted on the site, it is possible that these contaminants may have impacted nearby sediments in the Columbia River. However, the USACE performed in-water sediment sampling near the site, but did not detect contaminated sediments (USACE 2008b, 2009).

The project will implement several measures to prevent the mobilization of contaminated sediments in the project area. First, the project will complete a Phase I Environmental Site Assessment or each acquired property that could reasonably contain contaminated materials. The Phase I Environmental Site Assessment may identify possible contamination based on the site history, a visual inspection of the site, and a search of federal and state databases of known or suspected contamination sites. If there is evidence of contamination, a Phase II Environmental Site Assessment may be performed to pinpoint the location of the contaminated sediments as well as to measure the extent and concentration of the contaminants. The Phase II Environmental Site Assessment will also identify the specific areas recommended for remedial action.

The project will implement BMPs to ensure that the project either: 1) avoids areas of contaminated sediment or 2) enables responsible parties to initiate cleanup activities for contaminated sediments occurring within the project construction areas. The exact BMPs are not yet determined, but the contractor will be required to develop mitigation and remediation measures in accordance with ODOT and WSDOT standard specifications and all state and federal regulations. The plan will also comply with all regulatory criteria related to contaminated sediments. There will be coordination with regulatory agencies such as DEQ and Ecology on the assessment of site conditions and the cleanup of contaminated sediments. If contaminated sediments are removed from the site, they will be disposed of at a permitted upland disposal site.

Because the project will identify the locations of contaminated sediments and use BMPs to ensure that they do not become mobilized, there is little risk that listed species will be exposed to contaminated sediments. This aspect of the project is not likely to adversely affect any listed species.

6.1.6 Avian Predation

Project-related in-water and overwater structures may have an effect on avian predation in the CRC action area. Such structures may include the temporary work platforms/bridges, tower cranes, oscillator support platforms, barges, and cofferdams, as well as the permanent new bridge spans.

Avian predation is known to be a factor that limits salmon recovery in the Columbia River basin (NMFS 2008e). Throughout the basin, birds congregate near man-made structures and eat large numbers of migrating juvenile salmonids (Ruggerone 1986, Roby et al. 2003, and Collis et al. 2002 cited in NMFS 2008e). Basin wide, avian predation is high enough to constitute a substantial portion of the mortality rate of several runs of salmon and steelhead (Roby et al. 2003 cited in NMFS 2008e). Predation rates are particularly high in impoundments upstream of dams, dam bypass systems, and dredge spoil islands (NMFS 2008e). Additionally, local environmental factors may exacerbate avian predation. In particular, mainstem dams in the lower Columbia detain suspended sediments, a condition that has increased water clarity, potentially enhancing the foraging success of predaceous birds (NMFS 2008e).

The effects of overwater structures on interactions between salmonids and avian predators are widely recognized but have not been the subject of extensive study (Carrasquero 2001). In a 2001 literature review Carrasquero (2001) determined that there is no quantitative or qualitative evidence that docks, piers, boathouses, or floats either increase or decrease predation on juvenile salmonids. Additionally, the review found no studies related to predator-caused mortality specifically associated with overwater structures. Caspian terns, double-crested cormorants, and various gull species are the principal avian predators in the Columbia River basin (NMFS 2000b cited in NMFS 2008e). Populations in the basin have increased as a result of nesting and feeding habitats caused by the creation of dredge spoil islands, reservoir impoundments, and tailrace bypass outfalls (Roby et al. 2003). However, no studies have demonstrated the use of overwater structures by predaceous birds (Carrasquero 2005).

The overwater structures in the CRC action area are not likely to attract large concentrations of avian predators as do such features as nesting islands, impoundments, or tailraces. Nevertheless, because avian predators are known to congregate on overwater structures and because the project will increase the number of available perches, it is possible that the avian predation rates could increase to some extent within the project area. Specifically, the new bridges could create a permanent increase in the number of perches available. Additionally, the work platforms/bridges, tower cranes, oscillator support platforms, and barges will temporarily increase the number of perches available in the Columbia River and North Portland Harbor. Presumably, avian predation may occur during the overlap of: 1) when overwater structures are present in the project area (Figure 6-17, Figure 6-18, and Figure 6-19) and 2) when juvenile fish are present in the project area (see Figure 4-2); however, it is impossible to quantify how many individual fish will be affected.

6.2 INDIRECT EFFECTS TO FISH

Indirect effects are those that are caused by the proposed action and are later in time, but are still reasonably certain to occur. Two elements of the CRC project are likely to result in indirect effects. Increased area of PGIS and consequent increase in stormwater runoff will cause ongoing effects to the action area water bodies. Increased capacity of the highway system and LRT network could potentially lead to changes in land use or traffic patterns for years to come.

6.2.1 Stormwater Effects on Water Quality and Water Quantity

The project area currently contains 217 acres of PGIS and will add a net 21 acres, resulting in a post-project net total of 238 acres. This section discusses the effect of project-related PGIS and stormwater runoff on all of the action area water bodies: Columbia River, North Portland Harbor, Columbia Slough, and Burnt Bridge Creek.

The CRC project occurs within several different state and local jurisdictions, each of which has different stormwater treatment standards. The CRC project team agreed to incorporate the most restrictive water quality requirements of all these standards, as embodied in the ODOT stormwater BMP selection tool (ODOT 2008). The selection tool requires that the project incorporate the highest practicable levels of stormwater treatment and outlines a process for selecting the BMPs that fulfill this requirement. Stormwater treatment facilities must also adhere to design standards. The ODOT standards require water quality treatment for 50 percent of the 2-year 24-hour event. Flow control standards require that the project does not result in an increase in sediment-transporting flows in the receiving water body between a lower and an upper endpoint. In western Oregon, the lower endpoint is 42 percent of the 2-year event. The upper endpoint is either the channel-topping event for streams that are not incised or only slightly incised or the 10-year flow event for streams that are moderately or severely incised (ODOT 2009).

The BMP selection tool was developed as a collaborative effort between ODOT, FHWA, NMFS, and other resource agencies. The final selection of the design storms and elements of the BMP selection tool were consensus decisions among these agencies. Incorporation of the tool meets NMFS requirements for ESA consultations related to stormwater (ODOT 2009). Once the team selected the BMPs, they compared the design standards with state and municipal agency stormwater criteria to ensure that the BMPs incorporated the most restrictive requirements. Table 6-19 outlines the jurisdictional stormwater treatment standards used on this project. The sizing and detailed design of individual water quality facilities will meet or exceed the specific requirements of the state or local agency that has jurisdiction over that facility. For example, treatment facilities within the WSDOT right-of-way will be sized and designed in accordance with the WSDOT Highway Runoff Manual.

Table 6-19. Jurisdictional Stormwater Treatment Requirements

Jurisdiction	Water Quality Design Criteria	Flow Design Criteria
ODOT	Treat 85% of the cumulative runoff.	Not applicable. Flow control not required for receiving water bodies in this portion of the action area.
Ecology (applies to WSDOT right-of-way and City of Vancouver)	Treat 91% of the runoff volume over the period of simulation.	Columbia River – Not applicable. Flow control not required this water body. Burnt Bridge Creek - discharge must be reduced to pre-development (forested) flow rates from 50% of the 2-year to the 50-year peak flow.
City of Portland	Treat 90% of the average annual runoff.	Not applicable. Flow control not required for receiving water bodies in this portion of the action area.

The majority of the water quality facilities proposed for the CRC project use infiltration as the primary mechanism for water quality treatment and flow control. Depending on the infiltration rates available at a particular site, these facilities may be able to provide an even higher level of stormwater treatment than what is required.

6.2.1.1 General Effects of Stormwater on Fish

In general, addition of impervious surface to a watershed has the potential to affect listed fish by altering water quality in the receiving water bodies. Stormwater runoff flows over the roadway, picking up contaminants from impervious surfaces and delivering them to the roadside drainage system and eventually to surface water bodies (Pacific EcoRisk 2007). Sources of these contaminants include vehicles, atmospheric deposition, roadway maintenance, and pavement wear (Pacific EcoRisk 2007).

The addition of PGIS increases the level of vehicle-generated pollutants deposited on the roadway and delivered to surface waters. Common pollutants present in stormwater runoff include total suspended solids, nutrients, oil and grease, other fluids associated with automobiles, PAHs, agricultural chemicals used in highway maintenance, total zinc, dissolved zinc, total copper, dissolved copper, and other metals (NMFS 2008j). These pollutants are known to be toxic to fish (Everhart et al. 1953; Sprague 1968; Hecht et al. 2007; Sandahl et al. 2007; Johnson et al. 2009) and have potential adverse effects on salmon and steelhead, even at ambient levels

(Loge et al. 2006, Hecht et al. 2007, Johnson et al. 2007, Sandahl et al. 2007, Spromberg and Meador 2006, all cited in NMFS 2008j). These contaminants are persistent in the aquatic environment, traveling long distances in solution or adsorbed onto suspended sediments. Alternatively, they may also persist in streambed substrates, mobilizing during high-flow events (Anderson et al. 1996, Alpers et al. 2000a, 2000b, all cited in NMFS 2008j). Some of these pollutants may also persist in the tissues of juvenile salmonids, resulting in long-term interference with important life functions such as olfaction, immune response, growth, smoltification, hormonal regulation, reproduction, cellular function, and physical development (Fresh et al. 2005, Hecht et al. 2007, LCREP 2007b all cited in NMFS 2008j). The addition of PGIS may also increase the levels of contamination in surface waters, degrading water quality and causing further harm to fish.

The following sections provide more detail about the types of contaminants found in stormwater runoff and their likely effects on fish.

Contaminant Levels and Effects on Fish

There have been no comprehensive studies performed about the types and concentrations of pollutants found in stormwater runoff emanating from the project area. However, Herrera (2007) prepared a white paper on the types and concentrations of contaminants found in untreated runoff in western Washington, an area with climate and traffic volumes comparable to the action area. No such study exists in Oregon, and therefore, this study represents the most comprehensive review of the characteristics of stormwater runoff applicable to the CRC project area. The study reported that typical contaminants found in stormwater runoff included TSS, metals, nutrients, and organic compounds. Additionally, stormwater runoff had levels of oxygen demand corresponding to detectable levels of these pollutants.

Geosyntec (2008) performed a comprehensive study of contaminant concentrations in treated stormwater runoff in western Washington. The results of both studies are presented in the subsections below in order to characterize the likely pollutant levels in stormwater runoff in the CRC project area and the risk that listed fish are exposed to toxic levels of contaminants in the CRC action area.

Total Suspended Solids

TSS has the potential to harm fish by causing gill tissue damage, physiological stress, altered behavior, and degradation of aquatic habitat (Pacific EcoRisk 2007). The level of effect generally depends on the characteristics of the particles, with hard angular particles causing more damage than softer, smoother ones. Given the short-term duration of most precipitation events, exposure of individual fish to such effects is likely to be limited in space and time (Pacific EcoRisk 2007). However, chronically high levels of TSS may cause long-term degradation of habitat (such as spawning redds) or may reduce the productivity of the benthic communities that make up the food web of numerous fish species.

Herrera (2007) reported mean TSS concentration levels of 93 mg/L in untreated runoff in western Washington, with maximum concentrations of 900 mg/L. Stormwater treatment BMPs reduced TSS levels significantly such that post-treatment median concentration ranged from 6 to 20.5 mg/L (Geosyntec 2008).

There are several criteria for levels of TSS likely to harm aquatic organisms or habitats. Neither Oregon nor Washington offer numeric guidance for TSS. However, EPA guidance classifies impairment to aquatic habitat or organisms as follows:

- < 10 mg/L – Impairment is improbable
- < 100 mg/L – Potential impairment
- > 100 mg/L – Impairment probable.

The National Academy of Sciences (NAS) (1973) offers the following:

- < 25 mg/L – High level of protection to aquatic community
- 25–80 mg/L – Moderate level of protection
- 80–400 mg/L – Low level of protection
- > 400 mg/L – Very low level of protection

In the absence of site-specific data about ambient turbidity levels in the receiving water body, the timing and duration of TSS concentrations, and the characteristics of the suspended particles, it is difficult to draw a clear line between TSS concentrations and harm to fish. However, the data show that stormwater treatment facilities significantly reduce TSS concentrations, and, in comparison to the NAS standard, potentially to levels that offer a high level of protection to the aquatic community. In comparison to the EPA threshold, stormwater runoff treatment may reduce TSS concentrations to the low end of the potential impairment standard (Pacific EcoRisk 2007).

Section 6.1.5.2 provides a more detailed review of the effects of suspended sediment on fish.

Metals

The main sources of metals in stormwater runoff include friction in engine and suspension systems, attrition of brake pads and tires, and rust and corrosion of automobile body parts. Other sources include guardrail plating, vehicle emissions, impurities in de-icing compounds, and atmospheric deposition (Herrera 2007). Metals may occur as particulates or dissolved ions (Pacific EcoRisk 2007). Metals in highway runoff are often correlated with levels of suspended sediments because they either occur as particulates or are bound to the surfaces of other solids. Zinc, copper, and chromium show a particularly high correlation with TSS concentrations (Herrera 2007). In general, factors that affect levels of solids in the water column will also affect the levels of metals; however, due to the varied behavior of metals under different environmental conditions, this relationship is very complex (Pacific EcoRisk 2007).

Herrera (2007) reported the following metals in untreated stormwater runoff: antimony, arsenic, barium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, vanadium, and zinc. About half of these (arsenic, antimony, barium, cobalt, molybdenum, nickel, and vanadium) occurred at levels well below any known thresholds for toxicity to aquatic organisms, and therefore, the authors deemed that these metals were not pollutants of concern for listed fish. Thus, only cadmium, chromium, copper, lead, mercury, and zinc will be addressed further in this discussion.

Cadmium: Herrera (2007) reported median concentrations of 1.2 µg/L in untreated stormwater runoff, with maximum concentrations of 2.80 µg/L. Treated stormwater runoff contained much lower concentrations, with median concentrations ranging from 0.05 to 0.20 µg/L (Geosyntec 2008). Median cadmium levels in treated stormwater were well below freshwater acute criteria. They were also below chronic water quality criteria and EPA Genus Mean Acute Values (GMAVs), that is, values specific to fish genera *Oncorhynchus* and *Salvelinus.* However, some of the upper 95th percentile values for treated stormwater exceeded freshwater acute and chronic criteria, indicating that, despite undergoing treatment, stormwater runoff may still contain cadmium at levels that could potentially harm listed fish (Pacific EcoRisk 2007).

Studies have indicated that chronic levels of cadmium at 0.5 µg/L for 30 days may have sublethal effects on bull trout, including interference with prey selection and prey capture efficiency (Riddell et al. 2005, cited in Pacific EcoRisk 2007). However, this concentration would not likely persist in highway runoff for such an extended period of time (Pacific EcoRisk 2007).

Chromium: Herrera (2007) reported median concentrations of 12.7 µg/L of total chromium in untreated highway runoff, with maximum concentrations of 17.9 µg/L. No data were presented for treated highway runoff (Geosyntec 2008). These values were well below the GMAV Cr (III) and Cr (IV) values for *Oncorhynchus* and *Salvelinus*, which ranged from 9,669 to 69,000 µg/L. The values were also well below the chronic and acute freshwater criteria for Cr (III) (64.4 to 628.6 µg/L), indicating that stormwater runoff does not contain Cr (III) at levels likely to harm listed fish (Pacific EcoRisk 2007).

Measured maximum values of total chromium did, however, exceed the freshwater acute (15 µg/L) and chronic criteria (10 µg/L) for Cr (IV). The measured median concentration is within the acute criterion, but exceeds the chronic criterion. This indicates that while typical chromium levels in untreated stormwater effluent may not cause direct injury or mortality to listed fish, there may be toxic effects on food chain organisms (Pacific EcoRisk 2007).

There were no direct data measuring chromium concentrations in treated runoff. However, it is presumed that levels in treated runoff would be much less than for untreated runoff. While it is reasonable to assume that chromium concentrations in treated runoff will be below levels likely to directly harm listed fish, it is uncertain as to whether concentrations are toxic to food chain organisms (Pacific EcoRisk 2007).

Copper: Herrera (2007) reported median concentrations of 5.18 µg/L for dissolved copper and 24.4 µg/L for total copper in untreated stormwater runoff in western Washington. Median concentrations of dissolved copper in treated effluent ranged from 4.4 to 10 µg/L (Geosyntec 2008). Regardless of whether the samples originated from treated or untreated stormwater, concentrations were in exceedance of freshwater acute criteria, but were below GMAVs for salmon and bull trout (Pacific EcoRisk 2007).

Although dissolved copper concentrations in stormwater runoff may not typically occur at levels likely to cause lethal toxicity to salmonids, sub-lethal toxicity is of great concern. Salmonids may avoid waters with copper concentrations at 2.3 µg/L (Sprague 1964). Dissolved copper is known to interfere with olfaction in fish, even at very low levels. Reduced olfactory ability interferes with important life functions, such as prey location, predator avoidance, mate recognition, contaminant avoidance, and migration. Baldwin et al. (2003) observed that an increase of 2.3 µg/L above background levels reduced olfactory response in salmonids by 25%. Sandahl et al. (2007) observed 50% reduction in olfactory response and 40% reduction in predator avoidance when dissolved copper levels were 2.0 µg/L above background levels of 0.3 µg/L.

The above data indicate that stormwater runoff contains dissolved copper at levels that may cause sublethal effects in salmonids. However, it is important to note that site-specific conditions, such as the presence of dissolved organic carbon, can reduce the bioavailability of dissolved copper and mitigate for the negative effect on olfaction (Pacific EcoRisk 2007). Therefore, even though a given highway system may discharge dissolved copper at these levels, it is not possible to definitively conclude that this causes harm to fish in every setting (Pacific EcoRisk 2007).

Lead: Herrera (2007) reported median and maximum dissolved lead concentrations at 3.2 µg/L in untreated runoff. BMPs markedly reduced dissolved lead concentrations; median post-treatment concentrations ranged from 0.1 to 2.2 µg/L. Regardless of treatment, dissolved lead levels in runoff were well below acute criteria (16.3 µg/L), indicating that stormwater runoff does not contain dissolved lead at levels likely to kill listed fish or prey organisms. In some cases, median concentrations for treated runoff exceeded chronic freshwater criteria (0.64 µg/L). However, the authors note that exposure to chronic levels of dissolved lead is unlikely due to the short duration of most runoff events (Pacific EcoRisk 2007).

Lead is also under investigation as a potential endocrine disruptor in fish. Isidori et al. (2007, cited in Pacific EcoRisk 2007) found potential estrogen receptor sensitivity at lead concentrations as low as 0.0004 µg/L. There are no data, however, that provide a direct evidence of actual endocrine disruption in fish at such low levels. The issue warrants more study (Pacific EcoRisk 2007).

Mercury: Herrera (2007) reported median concentrations of 0.02 µg/L for total mercury in untreated stormwater runoff in western Washington. There were no data for mercury concentrations typically found in treated stormwater (Pacific EcoRisk 2007). Total mercury concentrations were well below acute criteria and GMAVs for Hg(II) and were also below acute criteria for total mercury. These values indicate that mercury concentrations in stormwater runoff do not pose a risk to listed fish or their prey (Pacific EcoRisk 2007). Total mercury did, however, exceed chronic criteria, but Pacific EcoRisk (2007) concludes that chronic exposure to elevated levels of mercury is unlikely.

Organic mercury is of particular concern to listed fish due to its propensity to bioaccumulate in the aquatic environment. Pacific EcoRisk (2007) caution that it is impossible to extrapolate organic mercury levels or bioaccumulation rates from existing highway runoff sampling data. Nevertheless, the authors note that organic mercury is still an issue for listed fish, in particular where runoff flows into lentic systems that accumulate organic mercury.

Zinc: Herrera (2007) reported median dissolved zinc concentrations of 39 µg/L in untreated stormwater (with maximum concentrations of 394 µg/L). In the same study, median total zinc concentrations in untreated stormwater measured 116 µg/L (with maximum concentrations of 394 µg/L). Treated stormwater showed somewhat reduced levels of dissolved zinc, with median concentrations ranging from 7.5 to 41 µg/L (Geosyntec 2008). All of the dissolved zinc levels, whether for treated or untreated stormwater, were well below GMAVs for salmon and steelhead (931.3 µg/L) and bull trout (2,100 µg/L). However, some dissolved zinc concentrations exceeded acute freshwater quality criteria (40 µg/L) and chronic freshwater criteria (36.5 µg/L), indicating that direct lethal effects to listed fish and their prey species may occur after exposure to stormwater runoff, even after it has undergone water quality treatment (Pacific EcoRisk 2007). As with dissolved copper, it is important to note that site-specific conditions may reduce bioavailability of dissolved zinc and mitigate for its toxicity in fish-bearing waters.

Dissolved zinc may also have sublethal effects on salmonids. Sprague (1968) reported that salmonids may avoid waters with zinc concentrations of 5.6 μg/L above background levels of 3 to 13 μg/L. Geosyntec (2008) reported that dissolved zinc concentrations in both treated and untreated stormwater exceeded these levels.

Nutrients

Nutrients are chemicals that promote growth in organisms. Nutrients are of concern to listed fish in that they may cause excessive algal growth in fish-bearing waters, which may in turn reduce dissolved oxygen available to fish or may outcompete food organisms for space in streambed substrate (Pacific EcoRisk 2007). Nutrient levels are not necessarily correlated with traffic levels and may be more closely tied to other land use practices (Pacific EcoRisk 2007). Chief sources of nutrients in highway runoff include atmospheric deposition, vehicle exhaust, and fertilizer applications on the adjacent right-of-way (Herrera 2007). The nutrients of highest concern include nitrogen (in the form of ammonia and nitrate/nitrite) and phosphorous (in the form of orthophosphate and total phosphorous).

Ammonia: Herrera (2007) reported that untreated runoff contained median ammonia concentrations of 1.84 μg/L, with maximum concentrations of 2.66 μg/L. Geosyntec (2008) reported median ammonia concentrations in treated runoff at significantly lower levels, ranging from 0.03 to 0.08 μg/L. In surface waters, ammonia toxicity is highly variable, depending on ambient pH values; therefore, there is no one numeric acute toxicity criterion for ammonia. Acute toxicity is instead determined by using a complex numeric formula based on ambient pH. Using median highway runoff pH values (Herrera 2007), Pacific EcoRisk (2007) estimates acute toxicity for western Washington waters at 31.26 μg/L. In this case, ammonia found in both treated and untreated runoff is well below the estimated acute toxicity standards, indicating that ammonia levels in highway runoff do not occur at levels likely to kill listed fish.

Stormwater runoff may contain ammonia at levels that could cause sublethal effects to fish. Wicks et al. (2002, as cited in Pacific EcoRisk 2007) found that ammonia at concentrations of 0.02 to 0.08 μg/L may reduce the ability of coho to maintain their highest levels of swimming speed, potentially interfering with upstream migration.

Nitrate/Nitrite: Herrera (2007) reported that untreated runoff contained median nitrate/nitrite concentrations of 1.54 μg/L, with maximum concentrations of 2.99 μg/L. In the Geosyntec (2008) study, median concentrations of nitrate/nitrite in treated stormwater ranged from 0.20 to 0.70 μg/L. Both treated and untreated stormwater runoff has concentrations well below the 96-hour acute toxicity standard of nitrate to salmonids (ranging from 994 to 2342 mg/L). Additionally, levels were well below the 96-hour acute toxicity standard for nitrite (ranging from 110 to 1,700 mg/L). These data indicate that stormwater runoff is not a significant source of nitrate/nitrite in surface water bodies, at least not at levels that are likely to harm listed fish.

Phosphorus: Herrera (2007) reported that untreated runoff contained median orthophosphate concentrations of 0.10 mg/L, with maximum concentrations of 0.42 mg/L. The same study reported median total phosphorus levels of 0.19 mg/L, with maximum concentrations of 0.57 mg/L. The Geosyntec (2008) study noted that treated stormwater runoff contained median concentrations of 0.04 to 0.26 mg/L. There are no toxicity-based water quality criteria for phosphorus; however a Pacific EcoRisk (2007) review of the scientific literature concluded that 96-hour exposures to 90 to 1,875 mg/L of di-ammonium phosphate may cause acute harm to certain species of fish (including coho, Chinook, and trout). Given that these standards far exceed levels typically found in both treated and untreated runoff, stormwater does not appear to be a significant source of phosphorus to surface water bodies.

Petroleum Hydrocarbons

This category of pollutants includes vehicle emissions from fuels, such as oil and grease, total petroleum hydrocarbons (TPH), and PAHs. Sources of PAHs include asphalt sealing, vehicle emissions, oils, and atmospheric deposition (Herrera 2007). These contaminants correlate closely with traffic volumes. Additionally, these contaminants have a high affinity for particulates, and therefore they are highly correlated with concentrations of suspended solids. PAHs in streambed sediments have been shown to cause adverse impacts to benthic invertebrates, with potential implications to the prey base of listed fish (Pacific EcoRisk 2007).

Petroleum hydrocarbons include a large subset of compounds, generally occurring as mixtures of many different chemicals. Accordingly, petroleum hydrocarbons are evaluated in broad groupings such as oil and grease, total PAHs (the sum of numerous individual PAHs), and TTPH (the sum of individual petroleum hydrocarbons) (Pacific EcoRisk 2007).

Pacific EcoRisk (2007) examined the Herrera (2007) data regarding PAH concentrations in untreated stormwater runoff and concluded that concentrations of individual PAHs were well below freshwater acute values. This indicates that PAHs from stormwater runoff do not occur at levels that are toxic to listed fish or their prey base, even when the runoff is untreated. (No data were presented for treated runoff.) For total PAH, the study concluded that median concentrations were well below freshwater acute values, but maximum concentrations were high enough to warrant concern and continued monitoring.

Other studies demonstrate that PAH may cause toxicity in fish embryo-larval life stages (Incardona et al. 2004; Incardona et al. 2005; Incardona et al. 2006, all cited in Pacific EcoRisk 2007); however, no study presents the concentration levels at which this toxicity may occur. Pacific EcoRisk (2007) posits that this type of toxicity may occur at lower levels than the acute toxicity criteria presented above, and therefore this issue warrants further study.

PCBs

PCB use has been banned in the United States since the 1970s (Herrera 2007). However, these compounds are highly persistent, and PCB residues still occur throughout the aquatic environment. PCBs are of particular concern for their propensity to bioaccumulate in fish (Yonge et al. 2002, as cited in Herrera 2007). Sources include atmospheric deposition, pesticides, and herbicides. Few data are available for PCBs concentrations in stormwater runoff. However, they have not been detected in stormwater runoff in western Washington (Zawlocki 1981 as cited in Herrera 2007). Pacific EcoRisk (2007) posits that PCBs are not believed to be a contaminant of concern in highway runoff in western Washington.

Oxygen Demand

Herrera (2007) reported that biological oxygen demand (BOD) median concentrations in untreated runoff were 40.3 mg/L, with maximum concentrations of 71.0 mg/L. For chemical oxygen demand (COD), median concentrations in untreated runoff were 106 mg/L, with maximum levels of 1,377 mg/L.

The State of Washington water quality standards mandate that if a stream has an ambient DO below the water quality criteria, then anthropogenic oxygen demand cannot lower the dissolved oxygen levels by more than 0.2 mg/L. Additionally, the State of Washington offers dissolved oxygen levels necessary for sustaining various salmonid life stages in freshwater, ranging from 6.5 to 9.5 mg/L. Site-specific conditions, such as water flow, turbulence, and ambient temperature, influence the degree to which stormwater runoff with high BOD or COD would result in reduced dissolved oxygen levels in a given surface water body. It is likely that mixing and turbulence in a stream would mitigate the effect of stormwater discharge with high oxygen demand, such that effects would be limited in spatial extent and duration. Nevertheless, Pacific EcoRisk (2007) posits that levels of BOD and COD found in stormwater runoff have the potential to reduce dissolved oxygen in surface water bodies, particularly in warm or lentic water bodies, although it is not possible to predict to what extent.

Factors Affecting Toxicity of Pollutants in Stormwater Runoff

Although stormwater runoff certainly contains contaminants that are known to be toxic to fish, it is difficult to predict what specific concentration levels are likely to cause harm. Water quality criteria are nearly always based on laboratory studies that used purified water to avoid confounding influences from other waterborne contaminants. Accordingly, these results may not reflect site-specific field conditions. Ambient water quality conditions may influence the bioavailability of contaminants, either increasing or decreasing the ability of the contaminant to enter fish tissues. A contaminant concentration that is toxic in one setting may not be toxic in another, depending on the site-specific factors that determine the bioavailability of the contaminant. Similarly, toxicity levels in actual water bodies may be much less than that encountered in a laboratory setting (Pacific EcoRisk 2007).

Suspended solids may bind to chemical contaminants in the water column, reducing their bioavailability to fish. Suspended clay particles have a high capacity for binding, with particular affinity for metals and polar organics (Li et al. 2004, Roberts et al. 2007; Sheng et al. 2002; all cited in Pacific EcoRisk 2007). Thus, presence of clay in the water column may reduce the toxicity of contaminants to fish. On the other hand, silica-based particles (such as sand) have little affinity for such contaminants, and therefore their presence in the water column is not likely to reduce toxicity of chemicals in the water column (Cary et al. 1987, cited in Pacific EcoRisk 2007).

Dissolved organic carbon may have a similar effect, binding to both metals and organics and reducing the potential toxicity of both to aquatic organisms (Newman and Jagoe 1994, cited in Pacific EcoRisk 2007).

Water hardness (particularly concentrations of calcium and magnesium) has an antagonistic relationship with metals, potentially hindering with the uptake of metals into gill tissue (Hollis et al. 2000, cited in Pacific EcoRisk 2007). Interestingly, water hardness does not appear to significantly limit the uptake of copper into fish olfactory tissues (MacIntyre et al. 2007, cited in

Pacific EcoRisk 2007). On the other hand, water hardness my increase the bioavailability of some PAHs and PCBs (Akkanen and Kukkonen 2001, cited in Pacific EcoRisk 2007).

The pH of water may affect the ionic charge of waterborne contaminants. In general, conditions that promote the ionic form of a contaminant will reduce the contaminant's bioavailability and its toxicity to fish.

Water Quantity

New PGIS also may also alter water quantity in the receiving water body. In general, addition of PGIS to a watershed increases the amount of runoff entering surface waters. This may cause changes in stream dynamics, including higher peak flow, reduced peak-flow duration, and more rapid fluctuations in the stream hydrograph. These changes may in turn lead to scour, potentially resulting in impacts to water quality and degradation of stream bed habitat. Increasing the amount of PGIS also decreases infiltration to groundwater, potentially reducing base flows in streams and decreasing the amount of water available during summer months.

6.2.1.2 General Effects to the Environmental Baseline in the CRC Action Area

The project will install numerous stormwater treatment facilities to provide flow control where required and to sequester pollutants before runoff enters any surface water body. It is important to note that even treated stormwater contains some level of pollutants. Most treatment facilities are not 100 percent efficient, and although they greatly reduce pollutant levels, they do not completely eliminate discharges of pollutants to receiving water bodies. Flow-through facilities, in particular, will discharge pollutants during most events. Certain kinds of infiltration facilities have outfalls that discharge untreated stormwater to surface water bodies during events that exceed their design storm.

The project area currently provides treatment or infiltration for 20 acres of PGIS. The completed project will add 21 acres of net new PGIS, and will provide treatment for almost all of the new PGIS and for 188 acres of existing untreated PGIS. This scenario represents additional treatment of more than 9 times the net new PGIS area. This level of treatment is expected to result in a net benefit to water quality and water quantity in action area water bodies during events that do not exceed the design storm. Although treatment facilities on the CRC project will not completely eliminate pollutants during these events, they will discharge pollutants at much lower levels than currently, due to the high level of treatment provided.

During events that exceed the design storm, stormwater will likely overwhelm treatment facilities, resulting in a release of untreated stormwater into action area water bodies. The CRC team performed a precipitation-time series analysis to estimate the number of events and time of year when there could be precipitation events that exceed the water quality design storm for the treatment facilities in the CRC action area. The methodology chosen to determine this was (1) to compare historic daily rainfall data to threshold stormwater design standards for volume control, and (2) to determine the frequency with which exceedance events occurred for each month of the year. Daily precipitation data for PDX was obtained for a period of 83 years, between September 1926 and September 2009 (NOAA 2009) (Table 6-20). Since this project spans multiple jurisdictions, there are variations in the level of treatment required. Therefore, a precipitation-time series analysis was performed for each jurisdiction's treatment requirements. Table 6-21shows the size of the event that exceeds each of the jurisdictions' design storms.

Table 6-20. Average Daily Storm Event Based on Rain Gauge Data from PDX Weather Station (356751)

Month	Average (inches)
Jan	1.22
Feb	1.21
Mar	1.23
Apr	1.21
May	1.45
Jun	1.36
Jul	NA
Aug	1.29
Sep	1.28
Oct	1.21
Nov	1.21
Dec	1.21

Table 6-21. Events Exceeding Jurisdictional Design Storms

Jurisdiction	Design Volume	Event Exceeding Design Volume
City of Portland	90%	1.66 inches in 24 hours
Ecology	91%	1.45 inches in 24 hours
ODOT	85%	1.25 inches in 24 hours

Figure 6-20 shows the frequency distribution of storm events that exceed the design storm for each of the jurisdictions in the action area. The highest frequencies occurred in the late fall to winter months, between November and February.

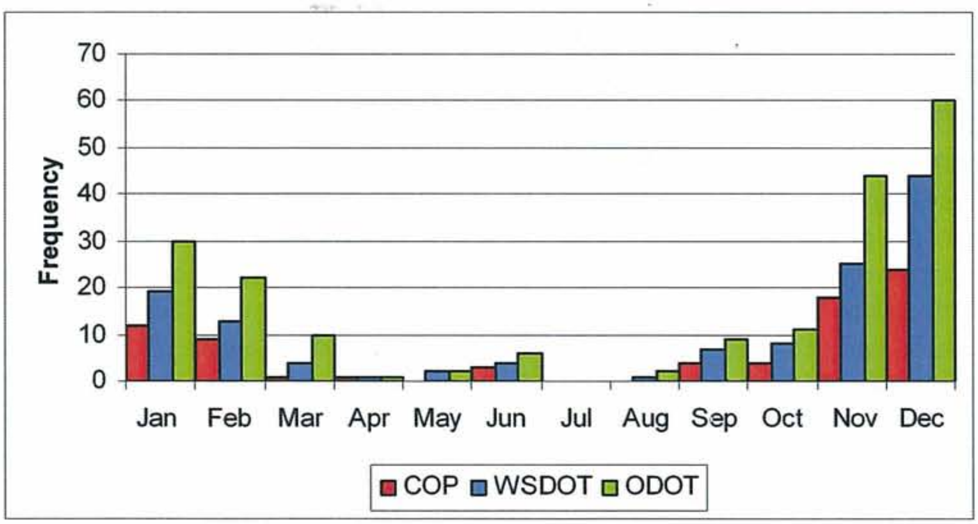


Figure 6-20. Frequency of Design Volume Exceedances by Jurisdiction

This analysis is limited by the assumption that daily precipitation values are representative of 24-hour precipitation events. Realistically, 24-hour storm events can and do occur over the course of two calendar days. If the total daily precipitation is below the threshold exceedance for either of the two days, then the storm event would not qualify as an exceedance event, even though the cumulative 24-hour value may count. Therefore, the frequencies listed in Figure 6-20 are likely lower than the actual number of events that occurred. This assumption, however, is not likely to affect the relative distribution since the timing of storm events during the calendar day is probably not seasonally dependent.

Taking the monthly frequency and dividing it by the number of years of recorded data gives an estimated percent chance that an exceedance event would occur during any given month (Figure 6-21). For example, the table shows that in any given January there is about a 14 percent chance that a storm event will exceed the City of Portland standard, a 23 percent chance of exceeding the Ecology standard, and a 36 percent chance of exceeding the ODOT standard.

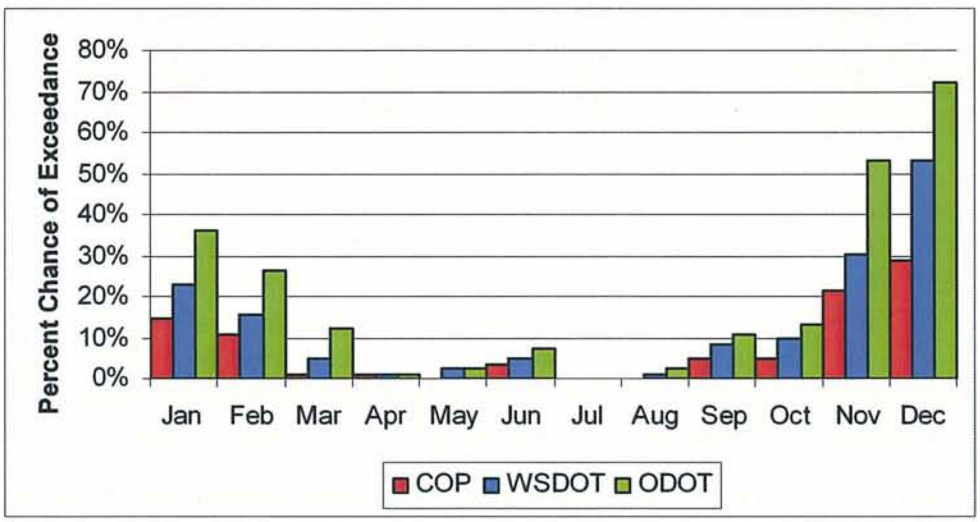


Figure 6-21. Percent Probability of Storm Design Exceedance by Month

During events that exceed the design storm, untreated stormwater may discharge to surface water bodies, potentially degrading water quality in the receiving water bodies. However, the elevated contaminant levels would likely be concentrated around stormwater facility outfalls, and would only occur infrequently following large storm events (Lee et al. 2004). Because these discharges will occur only during larger events, a high level of dilution is expected, reducing the concentration of pollutants. The following sections outline the effects to listed species as they occur in each of the action area receiving water bodies.

6.2.1.3 Stormwater Impacts to the Columbia River and North Portland Harbor

Table 6-22 summarizes the treatment scenario for PGIS that drains to the Columbia River South watershed in Oregon. Overall, there is a net loss of 4.5 acres of PGIS draining to this watershed. Additionally, the project will treat or infiltrate all of the 52.3 acres of new and rebuilt PGIS and significant quantities of the existing retained PGIS, for a net total of 54.6 acres of treated or infiltrated PGIS. Flow control is not required or provided for runoff discharged to the Columbia River or North Portland Harbor. Only one new outfall is proposed.

In order to prevent discharges to the Columbia River and North Portland Harbor, the project will install a sediment debris trap for the LRT guide way. This conservation measure is intended to capture sand used during deicing activities on the guide way.

Table 6-22. Summary of Changes in PGIS – Columbia River South Watershed

	Area (acres)			
	Infiltrated	**Treated**	**Untreated**	**Total**
Existing PGIS	**0.0**	**0.0**	**59.1**	**59.1**
Post-Project PGIS	**0.0**	**54.6**	**0.0**	**54.6**
Existing PGIS retained as-is	0.0	2.3[a]	0.0	2.3
Existing PGIS resurfaced	0.0	0.0	0.0	0.0
Net change in existing PGIS	0.0	2.3	(59.1)	(56.8)
New and rebuilt PGIS	0.0	52.3	0.0	52.3
Net Change in Total PGIS	**0.0**	**54.6**	**(59.1)**	**(4.5)**

a The existing North Portland Harbor Bridge.

Table 6-23 summarizes the treatment scenario for PGIS that drains to the Columbia River North watershed in Washington. Currently, only 2.8 acres of PGIS receives infiltration or treatment. The completed project will add 12.6 acres of net new PGIS to this watershed and will treat or infiltrate 88.4 of the 91.5 acres of new and rebuilt PGIS and significant quantities of the existing resurfaced PGIS, for a net total of 104.3 acres of treated or infiltrated PGIS. This represents additional treatment of more than 800 percent of the net new PGIS. Flow control is not required or provided for runoff discharged to the Columbia River, and no new outfalls are proposed.

Table 6-23. Summary of Changes in PGIS – Columbia River North Watershed

	Area (acres)			
	Infiltrated	**Treated**	**Untreated**	**Total**
Existing PGIS	**2.8**	**0.0**	**97.4**	**100.2**
Post-Project PGIS	**71.6**	**35.5**	**5.7**	**112.8**
Existing PGIS retained as-is	0.0	0.0	0.0	0.0
Existing PGIS resurfaced	13.1	5.6	2.6	21.3
Net change in existing PGIS	10.3	5.6	(94.8)	(78.9)
New and rebuilt PGIS	58.5	29.9	3.1	91.5
Net Change in Total PGIS	**68.8**	**35.5**	**(91.7)**	**12.6**
Existing PGIS not within Footprint[a]	**9.0**	**8.3**	**0.0**	**17.3**

a Areas from which runoff will drain to proposed water quality facilities or "equivalent" areas to compensate for new or rebuilt PGIS from which it may not be feasible to treat runoff.

It is difficult to quantify exactly to what extent the treatment scenario will affect water quality in the Columbia River and North Portland Harbor. But given there will be a net loss of 4.5 acres of PGIS draining to the Columbia River south watershed (Table 6-22), it is likely that the treatment scenario will result in a net benefit to water quality in this area during events that do not exceed the design storm. Additionally, the facilities will treat roughly 800 percent of the net new PGIS in the Columbia River North watershed, potentially resulting in a net benefit to the environmental baseline in the Columbia River during events less than the design storm. During these events, listed fish will continue to be exposed to pollutants, but because the project treats such a large proportion of currently untreated PGIS, the exposure level will likely be lower than currently.

Only during events exceeding the design storm will the project likely discharge untreated runoff into the receiving water bodies, potentially resulting in exposure of fish to waterborne pollutants. The design storms fall under the jurisdiction of the City of Portland, ODOT, and Ecology. For the City of Portland, the design storm is 90 percent of the average annual runoff volume, meaning that, on average, 10 percent of the annual runoff volume will discharge untreated into the receiving water bodies. For ODOT, the design storm is 85 percent of the average annual discharge, meaning that approximately 15 percent of the annual runoff will discharge untreated. In Washington, the design storm is 91 percent of the average annual runoff volume, meaning that 9 percent of the average annual runoff volume will discharge untreated.

Table 6-24 outlines the number of times that a precipitation event typically exceeds the design storms used in areas that drain to the Columbia River and North Portland Harbor. It also illustrates the percent chance that such events will occur in a given month. Events that exceed the design storm are very likely to occur from September through February, but are also possible during other months. Exceedances are unlikely in July and August.

In any case, even during events that exceed the design storm, the project will likely discharge pollutants at a lower rate than currently, due to the high level of treatment relative to the amount of net new PGIS. Additionally, given the large volume of water in the Columbia River and North Portland Harbor, dilution levels are expected to be very high, and pollutant levels will likely dissipate to background levels within a short distance of the outfalls.

Table 6-24. Frequency and Probability of Design Storm Event Exceedance for a Given Month (Columbia River and North Portland Harbor)

	City of Portland		Ecology		ODOT	
Month	No. Events	Probability of Exceedance	No. Events	Probability of Exceedance	No. Events	Probability of Exceedance
Jan	12	14%	19	23%	30	36%
Feb	9	11%	13	16%	22	27%
Mar	1	1%	4	5%	10	12%
Apr	1	1%	1	1%	1	1%
May	0	0%	2	2%	2	2%
Jun	3	4%	4	5%	6	7%
Jul	0	0%	0	0%	0	0%
Aug	0	0%	1	1%	2	2%
Sep	4	5%	7	8%	9	11%
Oct	4	5%	8	10%	11	13%
Nov	18	22%	25	30%	44	53%
Dec	24	29%	44	53%	60	72%

Traffic models projected to 2030 predict that the project will substantially decrease overall traffic congestion on the new bridges and the roadways that contribute runoff to the Columbia River and North Portland Harbor. Idling and brake pad wear, which contribute to the amount of oil, grease, copper, and other pollutants released, are expected to decrease with congestion relief, as will the amount of pollutants transported to the Columbia River and North Portland Harbor. This may further decrease exposure of listed fish to pollutants.

Numerous listed species are present in the Columbia River and North Portland Harbor. The following species may be exposed to water quality effects:

- Adult and juvenile LCR coho; CR chum; SR sockeye; LCR, MCR, UCR, and SR steelhead; and LCR, UCR spring-run, SR fall-run, SR spring/summer-run Chinook.
- Adult and subadult bull trout.
- Adult and subadult green sturgeon.
- All life stages of eulachon.

Figure 4-1 and Figure 4-2 illustrate when these species are present in the Columbia River and North Portland Harbor.

These species could be exposed to untreated stormwater during the overlap of: 1) when the species are present in the action area near stormwater outfalls (see Figure 4-1 and Figure 4-2) and, 2) any event that exceeds the design storm of the treatment facilities (Table 6-24). However, exposure will likely less than it is currently due to the high level of treatment provided.

USFWS and NMFS have both determined that the Columbia River and North Portland Harbor are "flow-control exempt" water bodies. This means that PGIS draining to these water bodies does not require flow control facilities. Increases in PGIS in these watersheds will have no measurable effect on flow.

6.2.1.4 Stormwater Impacts to Columbia Slough

Table 6-25 summarizes the treatment scenario for PGIS that drains to the Columbia Slough watershed. Stormwater outfalls in this watershed discharge directly to Walker Slough and Schmeer Slough. From there, flows are pumped over a levee into the Columbia Slough.

The project will treat or infiltrate 35.1 acres of new and rebuilt PGIS and significant quantities of the existing retained and resurfaced PGIS, for a net total of 40.6 acres of treated or infiltrated PGIS. Flow control is not required for stormwater runoff discharged to Columbia Slough. No new outfalls are proposed in this watershed.

Table 6-25. Summary of Changes in PGIS – Columbia Slough Watershed

	Area (acres)			
	Infiltrated	**Treated**	**Untreated**	**Total**
Existing PGIS	**2.7**	**0.0**	**39.0**	**41.7**
Post-Project PGIS	**1.0**	**42.3**	**8.4**	**51.7**
Existing PGIS retained as-is	0.0	1.9[a]	0.0	1.9
Existing PGIS resurfaced	0.0	6.3	4.7	11.0
Net change in existing PGIS	(2.7)	8.2	(34.3)	(28.8)
New and rebuilt PGIS	1.0	34.1	3.7	38.8
Net Change in Total PGIS	**(1.7)**	**42.3**	**(30.6)**	**10.0**

a The existing North Portland Harbor Bridge. This area is not currently in the watershed.

It is difficult to quantify exactly how the treatment scenario will affect water quality in the Columbia Slough. However, given that the project will treat roughly 350 percent of the net new PGIS in this watershed, it is likely that the treatment will decrease the amount of stormwater pollutants entering the Columbia Slough, resulting in a net benefit to the environmental baseline during the majority of events (i.e., events that do not exceed the design storm). During most events, listed fish will continue to be exposed to pollutants, but due to increased PGIS treatment they are likely exposed to lower pollutant levels than current conditions.

Only during events that exceed the design storm will untreated stormwater be discharged into Walker Slough and Schmeer Slough. Table 6-24 depicts the predicted frequency and probability that untreated runoff will enter these sloughs (note the City of Portland and ODOT frequencies). Such events are very likely to occur from September to March, but are also possible during the other months of the year. These events are very unlikely in July and August.

Upon entering Walker and Schmeer Sloughs, stormwater runoff will become diluted at the outfalls. The water will then travel through several thousand feet of vegetated open conveyance, where it will be further diluted in the water column before discharging to Columbia Slough. The diluted runoff would discharge into the Columbia Slough only during periods when the pump is running. (The pump schedule is unknown. This analysis assumes that the pump is continually running in order to provide a worst-case scenario.) Because discharge to Walker and Schmeer Sloughs is likely to occur only during larger events (that is, events that exceed the design storm), untreated runoff is likely to become highly diluted by the increased volume of water. Given the high levels of dilution and the large distance between the nearest outfall and the Columbia Slough, it is expected that dilution will reduce pollutants to background levels before this runoff enters fish-bearing waters. Therefore, exposure to listed fish in Columbia Slough is unlikely.

Traffic models projected to 2030 predict that the project will substantially decrease overall traffic congestion in the treatment facilities that drain to the Columbia Slough. Idling and brake pad wear, which contribute to the amount of oil, grease, copper, and other pollutants that are released, are expected to decrease with congestion relief, as will the amount of pollutants transported to the Columbia Slough. This may have a net benefit on listed species using this waterway.

With the exception of bull trout, all of the salmonids addressed by this BA could potentially use the Columbia Slough for rearing and migration (as detailed in Section 4). Of these ESUs/DPSs, the following are likely to be present, based on numerous documented detections: LCR Chinook, UWR Chinook, LCR steelhead, UWR steelhead, and LCR coho. Other ESUs/DPSs are not documented but are presumed present, given that recent studies have documented up-river ESUs using the Slough and its adjacent floodplain wetlands (Teel et al. 2009). Because the Columbia Slough portion of the action area is accessible to fish, their presence in this area cannot be discounted.

There are no precise data on the times of year that listed salmonids use Columbia Slough. However, they are likely only present from fall through spring, and may to be exposed to water quality effects at any time during this period when there are events that exceed the design storm (Table 6-24). However, as described earlier, exposure is likely to be minimal due to the high level of stormwater treatment and the high levels of in-stream dilution. Exposure during the summer is possible but not likely, because events that exceed the design storm are relatively rare in summer and because water temperatures often exceed levels in which juvenile salmonids can survive (DEQ 2007).

Addition of PGIS to this stormwater drainage area will have no effect on flows in the Columbia Slough. The Columbia Slough is a flow control-exempt water body, meaning that addition of PGIS in this area is not expected to degrade the flow regime in the Slough, and therefore, the stormwater treatment facilities in this drainage area do not require flow control. Discharges to the Slough are regulated by a Multnomah County Drainage District pump system designed to handle up to the 100-year event. Because the pumps regulate flows between the outfalls and Columbia Slough, additional runoff from these areas will not affect flows in the Slough during the large majority of events, and the inclusion of flow control in treatment facilities would be redundant. Additionally, the tidal influence in Columbia Slough is likely to overwhelm any water quantity impacts occurring during high tides.

Green sturgeon and eulachon are not known to occur in the Columbia Slough. These species are not likely to be exposed to stormwater effects in the Columbia Slough.

6.2.1.5 Stormwater Impacts to Burnt Bridge Creek

Table 6-26 summarizes the treatment scenario for facilities that drain to the Burnt Bridge Creek watershed. At present, nearly all of the PGIS in this watershed is treated. The project will increase the total PGIS in the watershed by 3.1 acres and will treat or infiltrate 16.8 acres of new, rebuilt, and resurfaced PGIS.

According to Ecology standards, discharge to Burnt Bridge Creek between 50 percent of the 2-year event and the 50-year event must be reduced to the pre-development (forested) condition.

Table 6-26. Summary of Changes in PGIS – Burnt Bridge Creek Watershed

	Area (acres)			
	Infiltrated	**Treated**	**Untreated**	**Total**
Existing PGIS	**14.5**	**0.0**	**1.7**	**16.2**
Post-Project PGIS	**16.8**	**0.0**	**2.5**	**19.3**
Existing PGIS retained as-is	0.0	0.0	0.0	0.0
Existing PGIS resurfaced	9.0	0.0	1.2	10.2
Net change in existing PGIS	(5.5)	0.0	(0.5)	(6.0)
New and rebuilt PGIS	7.8	0.0	1.3	9.1
Net Change in Total PGIS	**2.3**	**0.0**	**0.8**	**3.1**
Existing PGIS not within Footprint[a]	**0.9**	**0.0**	**0.0**	**0.9**

a Areas from which runoff will drain to proposed water quality facilities or "equivalent" areas to compensate for new or rebuilt PGIS from which it may not be feasible to treat runoff.

It is difficult to quantify whether the enhanced proportion of infiltration will outweigh the impacts associated with the net new PGIS. (Potential effects are described in earlier subsections of Section 6.2.1) However, given that the project will provide additional treatment or infiltration for roughly 540 percent of the net new PGIS in this watershed, it is possible that the improved treatment scenario will cause a net benefit to the environmental baseline and to listed fish in Burnt Bridge Creek during events that do not exceed the design storm. In any case, the project is not likely to significantly degrade conditions in the creek during events less than the design storm.

During events that exceed the design storm, however, untreated runoff will certainly enter Burnt Bridge Creek. On average, 9 percent of the average annual volume from treatment facilities will discharge untreated into Burnt Bridge Creek. Table 6-27 depicts the estimated frequency and probability of events that will exceed the design storm.

Table 6-27. Frequency and Probability of Design Storm Event Exceedance – Burnt Bridge Creek

	91% Design Volume	
	No. Events	**Probability of Exceedance**
Jan	12	14%
Feb	9	11%
Mar	1	1%
Apr	1	1%
May	0	0%
Jun	3	4%
Jul	0	0%
Aug	0	0%
Sep	4	5%
Oct	4	5%
Nov	18	22%
Dec	24	29%

These types of events are most likely to occur from November through February, but may also occasionally occur during the rest of the year. Discharge during May, July, and August is highly unlikely. However, given the high level of infiltration in this drainage area, actual discharge of untreated stormwater is expected to occur less often than predicted in Table 6-27. Additionally, pollutants will likely be diluted due to the large volume of water that typically is present during these events. Although listed fish may be exposed to untreated stormwater during events that exceed the design storm, exposure will likely be less than it is currently due to the high level of treatment proposed. During events that exceed the design storm, stormwater runoff may also degrade the flow regime in Burnt Bridge Creek. However, due to the high levels of infiltration proposed, impacts are expected to be slight.

All freshwater life stages of coho, Chinook, and steelhead are potentially present in the creek (Weinheimer 2007 personal communication). Therefore, runoff may affect all life stages, as well as spawning, migration, foraging, and rearing habitat. The abundance of these species is thought to be very low in Burnt Bridge Creek (PSMFC 2003). Therefore, it is expected that very few individuals will be exposed to these effects. Steelhead and coho have been detected in Burnt Bridge Creek in proximity to stormwater outfalls, and exposure of these species to stormwater effects is likely. Chinook have been detected in Burnt Bridge Creek within 1 mile of the project-area stormwater outfalls. However, because abundance of Chinook is very low and there is a partial passage barrier between the location of the detection and the nearest project-area outfall, the likelihood of exposure is discountable.

LCR coho, Chinook, and steelhead could be exposed to stormwater runoff during events that exceed the design storm. Exposure is likely from fall through spring, when design storm-exceeding events most frequently occur and when these species have been documented in the stream. Due to the limited data on fish presence, there are no precise dates for when these species occur in Burnt Bridge Creek. There are only two known stream surveys in Burnt Bridge Creek, conducted in November/December 2002 and April 2003 (PSMFC 2003). The results of the surveys indicate that these species are at least present from November through April. They presumably occur there at all times of year except during the warmest summer months.

During summer, exposure is possible, but less likely. Given the lack of data, we cannot discount the possibility that fish occur there during the summer. However, the Washington 303(d) list has documented water temperatures that exceed the range tolerated by salmonids during some summers (Ecology 2009b). Therefore, these species may not be present in Burnt Bridge Creek in the summer, at least not during some years. Additionally, events exceeding the design storm are less likely in the summer, further reducing the likelihood for exposure.

Other salmonid ESUs/DPSs, eulachon, and green sturgeon are not present in Burnt Bridge Creek and will not be affected by stormwater runoff in this stream.

6.2.1.6 Ruby Junction

The CRC project will expand the existing Ruby Junction light rail maintenance facility, resulting in an increase in impervious surface. All of the new, CRC-related PGIS will be routed from the expansion area to a new infiltration facility. Stormwater will be completely infiltrated, with no discharge to any surface water body at any time. During events that exceed the design storm, stormwater will pond in a nearby field adjacent to the treatment facility. Because there is no discharge to any surface water body, this element of the project will have no effect on listed fish.

6.2.1.7 Summary of Stormwater Effects to Listed Fish

The project will provide a high level of treatment for a large proportion of the project-area PGIS, installing treatment not just for new PGIS but also for 188 acres of PGIS that is currently untreated. Project-wide, there will be treatment for over nine times the area of net new PGIS. While the project will not completely eliminate effects to water quality and flow, the high level of treatment is expected to provide an overall benefit to the environmental baseline. Effects to individual listed species are summarized below.

Bull trout adults and subadults could potentially be exposed to degraded water quality in the Columbia River and North Portland Harbor. However, given the very low abundance of bull trout and high levels of dilution in these water bodies, the likelihood of exposure is insignificant and discountable.

Green sturgeon adults and subadults could also be exposed to degraded water quality in the Columbia River and North Portland Harbor. However, given the high levels of dilution, exposure is expected to be insignificant. Due to the rarity of green sturgeon in the areas subjected to diminished water quality, the likelihood of exposure is discountable.

Stormwater effects to listed salmon and steelhead are as follows:

- In the Columbia River and North Portland Harbor, listed salmon and steelhead may potentially be exposed to degraded water quality within a short distance of the outfalls during periods when fish are present (Figure 4-1 and Figure 4-2) and when there is an event that exceeds the design storm (Table 6-27). Exposure will be minimal due to the high dilution capacity of these large water bodies. During events that do not exceed the design storm, the project is expected to discharge runoff that has less pollutant content than the pre-project condition due to the high level of stormwater treatment relative to the net new PGIS. While it is inconclusive whether this constitutes a benefit to these fish, the high level of treatment makes it improbable that the runoff will degrade the baseline or cause higher levels of exposure during these events.
- In the Columbia Slough, there is a minimal chance that listed salmonids will be exposed to degraded water quality. Stormwater outfalls discharge directly into water bodies that do not contain listed fish and travel through several thousand linear feet of a vegetated open conveyance system before entering the Columbia Slough. Given the distance between stormwater outfalls and the nearest locations where listed fish are present, and given the high levels of dilution likely to occur, pollutants will likely dissipate to ambient levels before discharging to fish-bearing waters.
- In Burnt Bridge Creek, LCR coho, steelhead, and Chinook may be exposed to degraded water quality and flow regime during periods when fish are present (fall through spring) and when there is an event that exceeds the design storm (Table 6-27). Due to the low abundance of these species in Burnt Bridge Creek, few individuals will be exposed to these effects. Steelhead and coho are likely to experience exposure to these effects, as they have been detected in proximity to stormwater outfalls associated with this project. For Chinook, exposure is discountable, as they have been detected more than a mile from the nearest outfall and downstream of a partial passage barrier.

6.2.2 Indirect Effects and Land Use Changes Overview

An extensive body of research provides insight into the complex relationship between transportation infrastructure and land use. Different types of transportation system changes can have different types and degrees of indirect effect on land use. For example, some types of roadway projects increase automobile demand which can encourage auto-oriented development, while other roadway projects do not. Conversely, some transit projects lead to increased development density around transit stations, while others do not. Because CRC is a multimodal project, it has the potential to promote auto-oriented and/or transit-oriented development (TOD).

In general, auto-oriented development tends to occur at relatively low densities around the urban periphery; while local and regional land use plans allow some of this type of development, they generally attempt to limit it because it is considered to be an inefficient method of accommodating population and employment growth and results in relatively higher costs, higher environmental impacts, and a greater consumption of land. In contrast, TOD is often higher density, in an already urbanized area, and is typically a more efficient method of accommodating future growth. Concentrating growth can help protect listed species and their habitat from potentially adverse effects of development, such as habitat conversion and contamination from stormwater runoff. However, without proper land use controls and environmental protections, any type of development can degrade habitat and affect listed species.

A review and synthesis of existing research and case studies[2] revealed several factors that influence how a transportation investment such as CRC could influence travel and land use patterns. These factors include proximity to urban boundaries, existing land uses, changes in traffic and transit performance, real estate market characteristics, public perceptions, and land use and growth management regulations.

The following evaluation identifies likely project effects on future travel behavior and land use patterns, and the associated effects on listed species and their habitat. The evaluation applies factors identified in the literature review that influence how transportation projects affect land use. Additionally, it evaluates the results from travel demand modeling and an iterative transportation-land use-real estate model (Metroscope). Current local, state, and federal regulations that manage growth and protect environmental resources within the project vicinity are discussed in terms of potential impact minimization to listed species and their habitat. The review concludes with the anticipated resulting project effects on listed species and their habitat.

6.2.2.1 Will the project create a new facility?

Yes. CRC will extend light rail over Hayden Island and through downtown Vancouver to Clark College. This is the first high capacity transit system in Vancouver and Clark County since the removal of the early streetcar lines in the nearly one hundred years ago. This light rail facility will connect to the existing light rail system that currently ends at the Expo Center in North Portland, allowing riders to travel on light rail between downtown Vancouver to key destinations in the region, such as downtown Portland and Portland International Airport. This light rail extension includes five stations along the alignment and three park and ride facilities SR 14, Mill

[2] See Appendix A of the CRC Land Use Technical Report (CRC 2008c).for a detailed description of this literature review. Available at: http://www.columbiarivercrossing.com/FileLibrary/TechnicalReports/Land_Use_TechnicalReport.pdf.

District, and Clark College. Section 3.10 provides a detailed description of the transit facilities included in this project.

The CRC highway improvements do not represent a new facility. These improvements are to an existing 5-mile segment of an established freeway corridor (I-5). It has been a major auto corridor since the first bridge was constructed in 1917 and has been an Interstate highway for more than 40 years. CRC does not include any new interchanges, but will make improvements to seven interchanges in this 5-mile segment to improve the safety and mobility of motorists. These highway improvements include accommodation of additional auxiliary lanes, full shoulders, separation of conflicting traffic movements (e.g., motorists entering and exiting the freeway) and direct (e.g., non-stop) connections between the intersecting arterials and highways.

Auxiliary lanes are a key component of the CRC highway improvements, but because the highway currently exists they are not considered new facilities. These lanes connect two or more highway interchanges to improve safety and reduce congestion by providing space for motorists to enter and exit the freeway without interacting with through-traffic. Some of the interchanges in the CRC project area are about 0.50 mile apart (the recommended minimum distance is 1 mile), leaving little room for cars entering and exiting the highway to merge with traffic or decelerate and diverge to an off-ramp. Substandard length on- and off-ramps in the project area compound this problem by allowing little time for merging traffic to accelerate to mainline speeds, or for exiting traffic to decelerate on the off-ramps. Auxiliary lanes will increase I-5 capacity within the project area, alleviating congestion occurring at the bottleneck around the river crossing and removing safety problems in this corridor. The existing three through-lanes will be maintained through the project corridor, and the new auxiliary lanes will end north of SR 500 and south of Marine Drive to tie in with the three through-lanes north and south of this project.

CRC provides one change in access between I-5 and intersecting roadways—new direct connections between I-5 and SR 500. Currently, the connections between SR 500 westbound to I-5 northbound and from I-5 southbound to SR 500 eastbound are made indirectly. To make these connections today, traffic exits one highway, travels on 39th Street, then enters the other highway. The project will result in on and off ramps directly connected to SR 500 and I-5 for both of these connections. I-5 southbound traffic will connect to SR 500 via a new ramp underneath I-5. SR 500 westbound traffic will connect to I-5 northbound on a new off-ramp. The 39th Street connections with I-5 to and from the north will be eliminated. Travelers will instead use the connections at Main Street to connect to and from 39th Street. These improvements should make traffic connections between these highways more efficient and reduce congestion on nearby local streets by keeping motorists traveling between SR 500 and I-5 on highways, but do not represent a material change in connections.

6.2.2.2 Will the project improve level of service of an existing facility?

The CRC project will improve transit service and reliability and improve transit travel times. It will also improve the level of service for bicyclists and pedestrians.

The project will also significantly improve the level of service of I-5 as described below. It will decrease the duration of congestion at this bottleneck each day thus reducing the number of cars and highway users caught in congestion. It will also improve safety and remove bridge lifts, thus reducing congestion associated with accidents and eliminating congestion caused by bridge lifts.

Travel demand modeling and traffic simulation estimate that by 2030 CRC will cause the following important transportation performance changes compared to 2030 No-Build conditions (CRC 2008a):

- Increased transit ridership: PM peak period transit ridership is anticipated to increase about 250 percent compared to No-Build, more than doubling the share of travelers during this period that is anticipated to be on transit versus autos.
- More bicyclists and pedestrians: Approximately 5,000 bicyclists and 1,000 pedestrians per day are expected to use the new pathway over the river connecting to paths in North Portland and downtown Vancouver. This compares to only 370 bicyclists and 80 pedestrians currently using the crossing per day.
- Congestion reduction: CRC is anticipated to reduce daily congestion duration from 15 hours under No Build conditions to approximately 5 hours;
- Reduced travel times: Compared to the No Build, CRC is anticipated to provide an average 23 minute travel-time savings for a round trip between 179th in Vancouver and I-84 in Portland during peak periods.[3]
- Greater peak period throughput: CRC will allow 61,800 or more people in 51,800 vehicles to cross the bridge during the 4-hour peak period in the peak direction (southbound in the morning and northbound in the afternoon) versus only 51,300 people in 43,200 vehicles under No-Build conditions. This is largely because the greater congestion with the No-Build alternative does little to curb the number of cars trying to cross the river; it only limits the number of cars that can actually get across in that time frame.
- Minimal traffic diversion to I-205: Though CRC will add a toll on the I-5 crossing, travel demand modeling indicates only a modest 6.5 percent increase in traffic on the I-205 crossing.
- Lower daily traffic: Despite this greater peak-period throughput, CRC is anticipated to lower daily cross-river traffic on the I-5 and I-205 bridges by 3 percent.[4] This is because, even though I-205 traffic volumes go up with a toll on I-5, the combined I-5 and I-205 cross-river traffic go down with LRT and a toll on I-5.

6.2.2.3 Does the project have a causal relationship to land use changes?

CRC's changes to transportation infrastructure and resultant alterations in travel patterns are likely to have an effect on future land use patterns. CRC will facilitate achieving some land use goals in local plans, but perhaps more significantly, this project is expected to concentrate future regional growth within the I-5 corridor. The following evaluation examines how CRC will affect local land use plans and travel patterns. It concludes with a discussion on how CRC can be expected to influence future land use and development patterns.

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[3] AM peak commute period is southbound between 6am–10am; PM peak commute period is northbound between 3pm–7pm.

[4] 184,000 cars will travel over the I-5 bridges under the No Build scenario versus 178,000 with a replacement crossing, a toll on I-5, and light rail.

Effects to Local Land Use Plans

There are no building moratoriums in place that are contingent on CRC, or any plans that include different land use scenarios based on whether this project is constructed (Gillam 2009 personal communication). However, recent planning by the City of Portland for Hayden Island and by the City of Vancouver for its downtown relies on the transportation improvements offered by CRC. The Hayden Island Plan outlines a vision for the future growth and development and redevelopment of the commercial core of Hayden Island. For existing land use and zoning within the geographic extent of this plan, see Figure 6-22 and Figure 6-23. This plan includes the expectation that access to the island will be improved by the new I-5 interchange and light rail extension included by CRC (Figure 6-24). The Hayden Island Plan envisions these access improvements facilitating new, transit-oriented development on the island. For example, the Jantzen Beach shopping center immediately west of the I-5 interchange is expected to redevelop from low-density retail into a medium-density mix of commercial and residential uses with up to 2,000 new housing units centered around the new light rail station (COP 2009b).

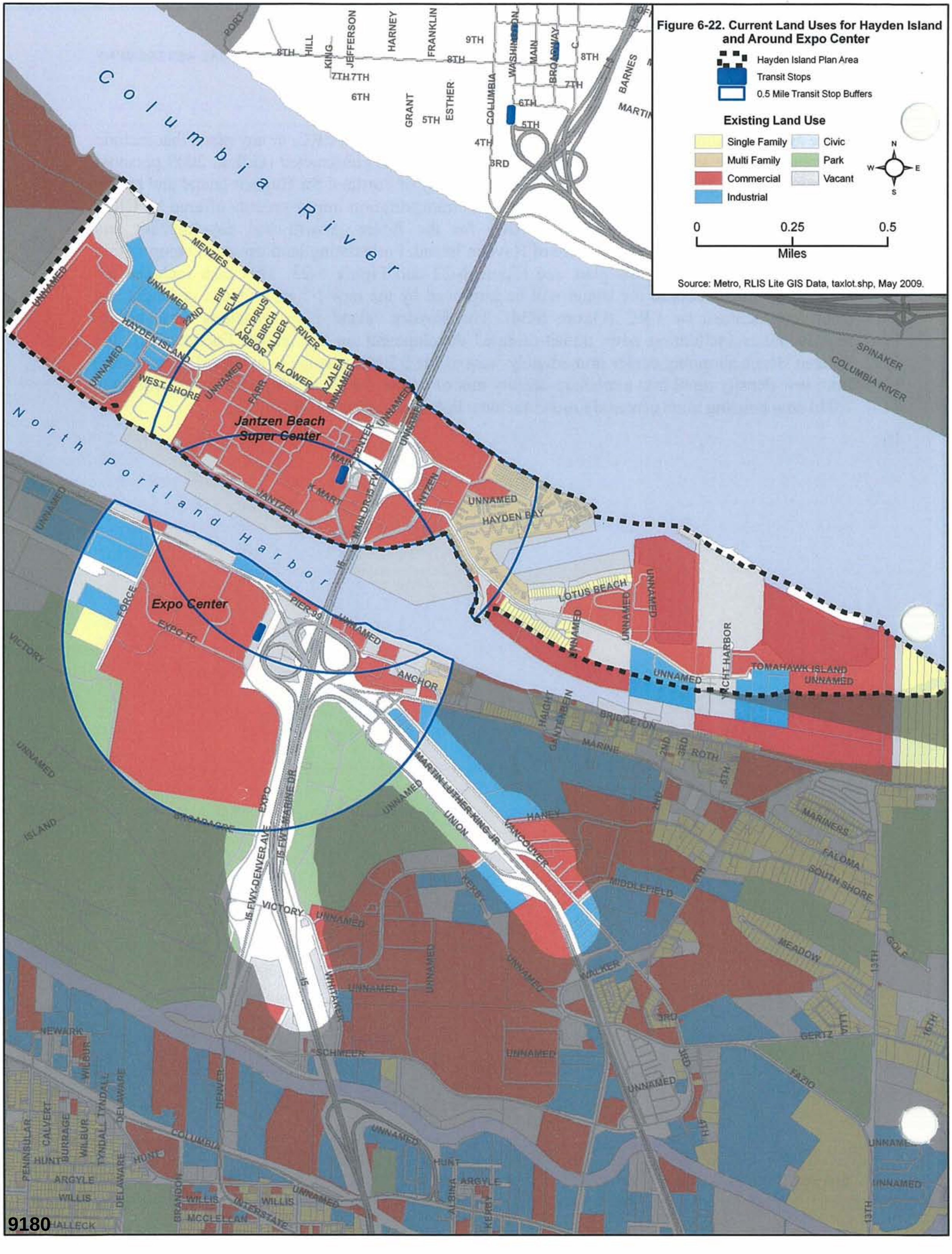

Figure 6-22. Current Land Uses for Hayden Island and Around Expo Center

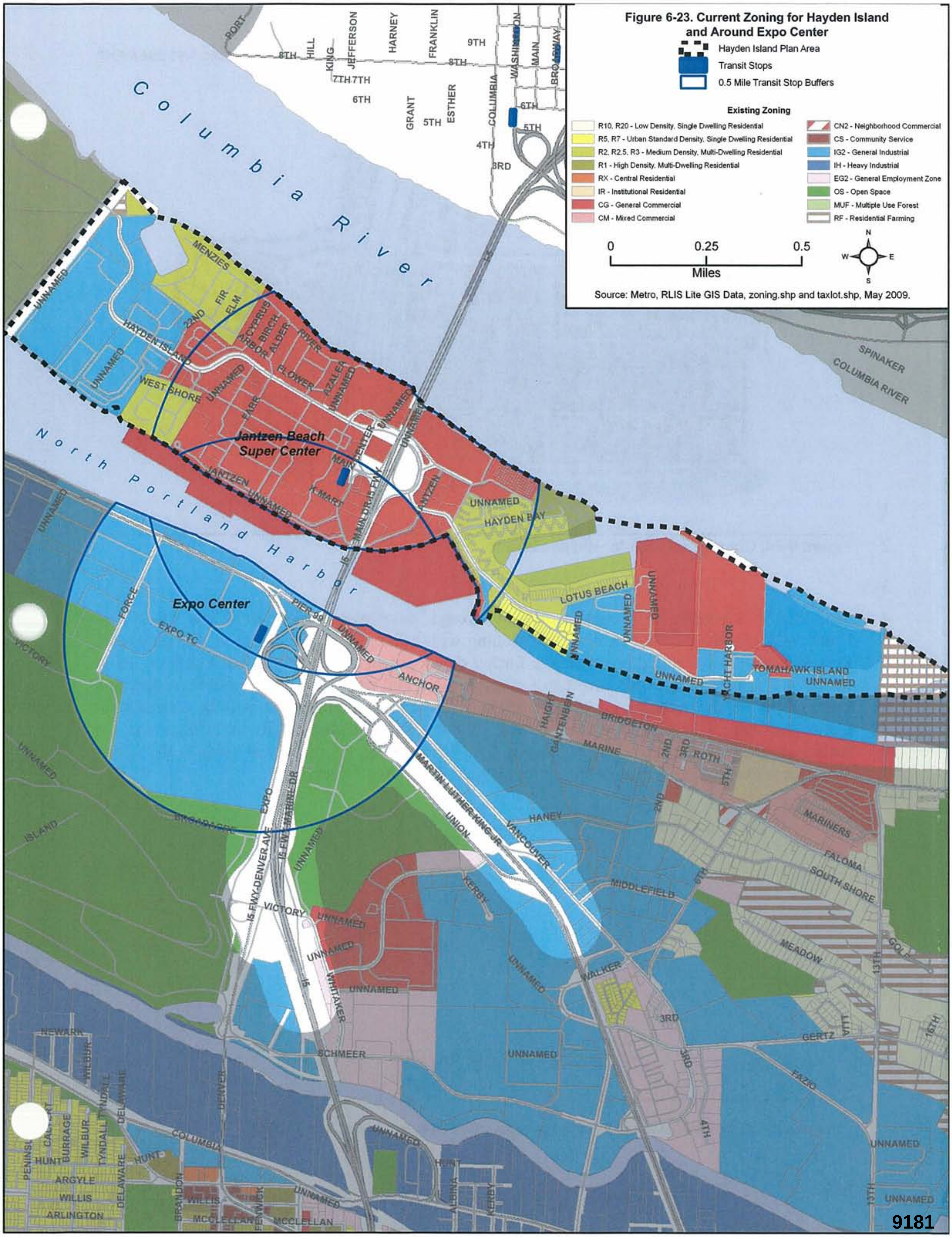

Figure 6-23. Current Zoning for Hayden Island and Around Expo Center

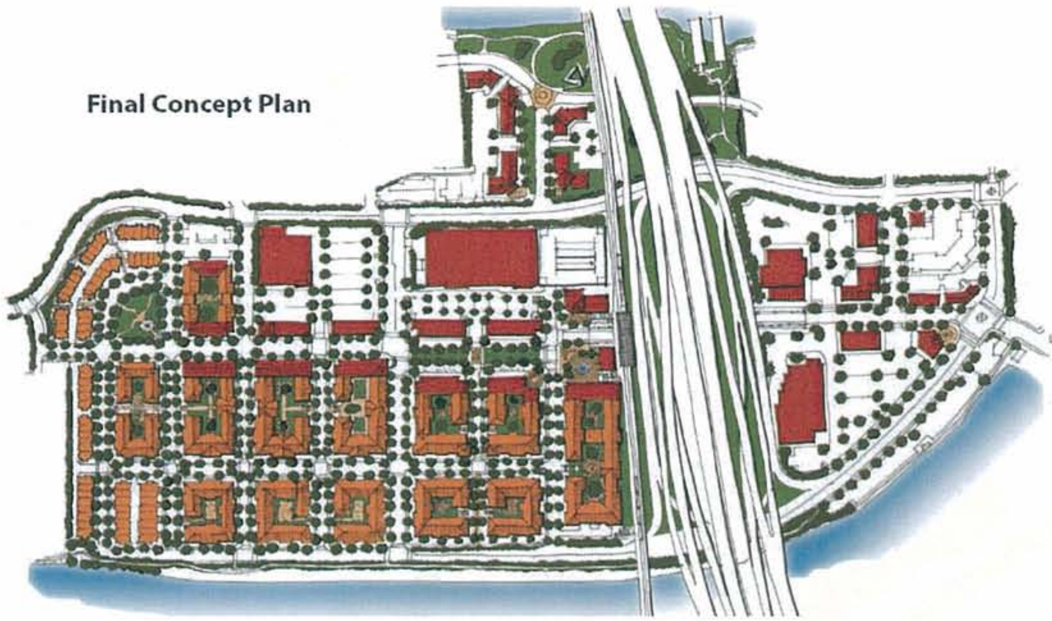

Figure 6-24. Conceptual Plan for Hayden Island

The VCCV[5] identifies high capacity transit through downtown Vancouver (Figure 6-25 and Figure 6-26 for the existing land use and zoning within the geographic extent of this plan) as a key transportation goal and to encourage further development in the downtown. Another goal in the VCCV is extending Main Street to Columbia Way and providing greater public access and connectivity to the waterfront. As part of the CRC project Main Street will be extended to Columbia Way. This is due to the removal of the existing Columbia River bridges and the increased grade of the replacement bridges. The Main Street extension will support the City's vision of providing greater connectivity to the waterfront, an indirect effect.

[5] Vancouver City Center Vision and Subarea Plan, City of Vancouver, adopted June 18, 2007.

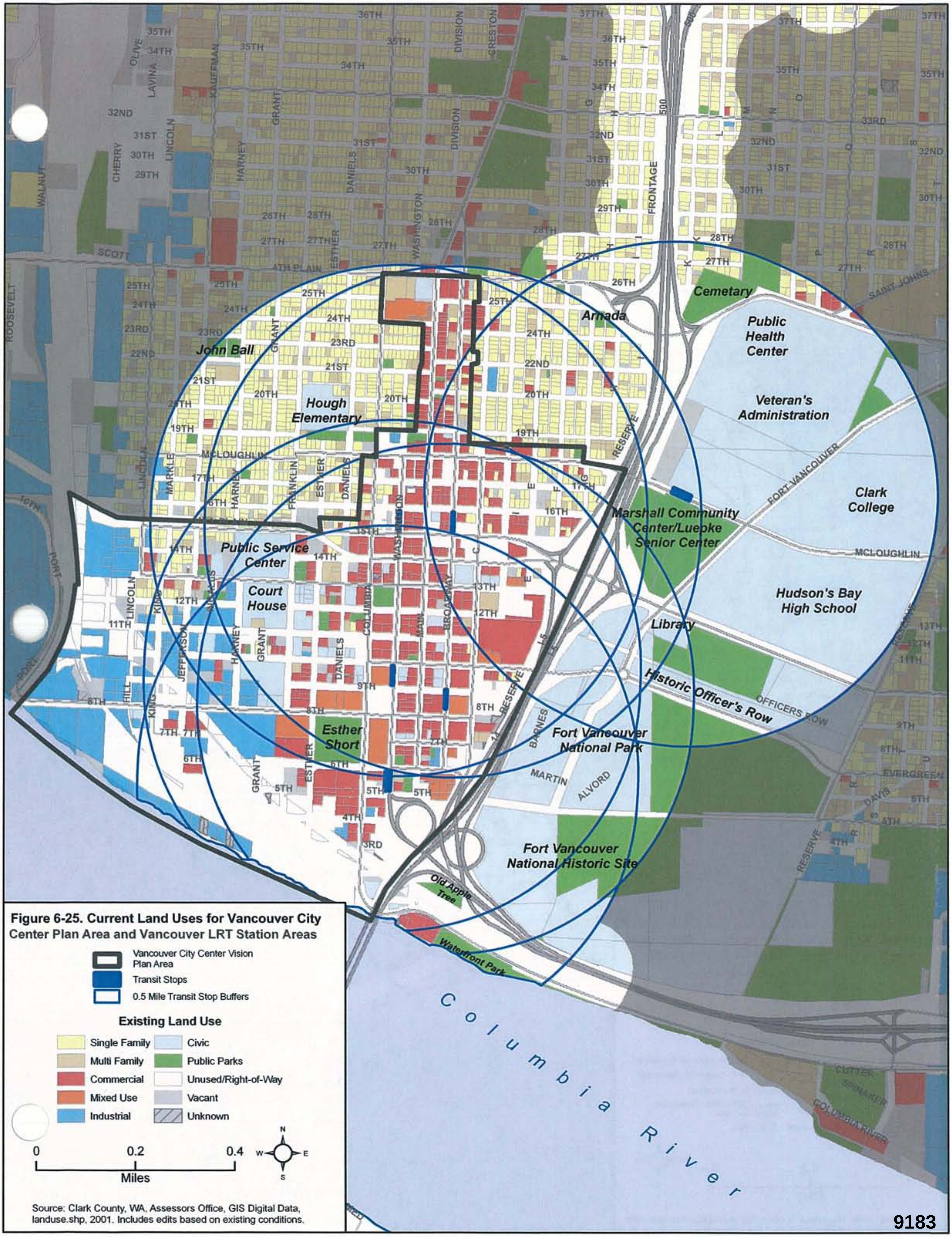

Figure 6-25. Current Land Uses for Vancouver City Center Plan Area and Vancouver LRT Station Areas

Source: Clark County, WA, Assessors Office, GIS Digital Data, landuse.shp, 2001. Includes edits based on existing conditions.

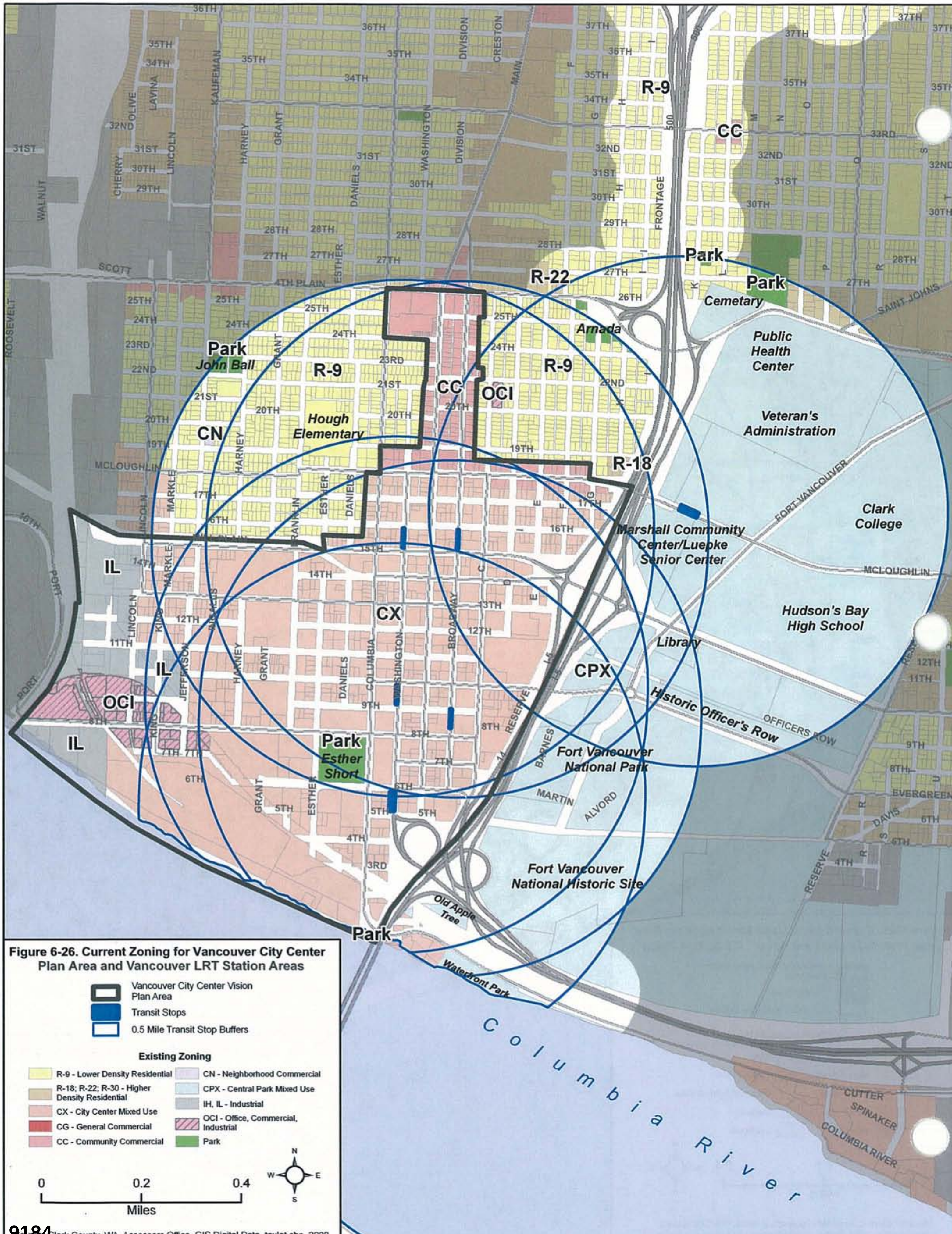

Figure 6-26. Current Zoning for Vancouver City Center Plan Area and Vancouver LRT Station Areas

9184 Clark County, WA, Assessors Office, GIS Digital Data, taxlot.shp, 2008.

The Main Street extension, Columbia Way design, and the completion of the street grid south of the railroad berm will also add additional access to planned redevelopment of 35 acres along the Vancouver waterfront immediately west of I-5. Most of the acreage was formerly occupied by Boise Cascade and used for industrial purposes. Currently, the area is primarily covered in asphalt, has no stormwater treatment, and little riparian vegetation (Figure 6-27). The riverbank currently consists of a combination of riprap, native cottonwoods, and an understory dominated by non-native vegetation. This area has been rezoned and is being redeveloped into a high-density mixed use area with open space and public access along the entire waterfront. The developer's Master Plan for the area was approved by the City of Vancouver Planning Commission on November 10, 2009.[6] The redeveloped area will be accessed first off Columbia Way, near the Red Lion Hotel property's northern entrance, and later by two additional points via tunnels under the BNSF railroad berm at Grant and Esther Streets. The plan does not incorporate redevelopment of the Red Lion Hotel and associated restaurants because it assumes the parcel will be displaced by CRC for staging and construction. Although, the waterfront development is planned and progressing forward separately from CRC, an additional access point from Main Street will potentially increase the rate of the redevelopment.

Figure 6-27. Site of Proposed Redevelopment Project Showing Existing Conditions Along Vancouver Waterfront

[6] Columbia Waterfront, LLC, a group of local investors led by Gramor Development of Tualatin, Oregon., submitted a conceptual pre-application for site development in December 2008. The city commented on the pre-application January 8, 2009. Gramor incorporated city feedback (including feedback on Shorelines and Critical Area Ordinance compliance) into their master plan application.

To achieve the VCCV goal of public use of the shoreline, the area along the shoreline will be dedicated to the City, designed and managed by the City of Vancouver Parks Department, and required by conditions of the Master Plan to be designed in a sustainable manner, as well as be compliant with the Shoreline Management Act (SMA) and Clark County Critical Areas Ordinances (CAO). Preliminary means of complying with the goals for the projects sustainability include: a wide (minimum 200 foot) buffer from the OHW mark, exclusive use of native plants, minimal or no irrigation, limited use of fencing or other appurtenances, and potentially habitat restoration.

Connecting Travel Pattern Changes to Land Use

The CRC project team evaluated the potential for indirect land use changes as a result of altered travel patterns using four analytical methods:

- A survey of national research and case studies on how transportation infrastructure can indirectly impact land use,
- An analysis of growth management in Washington and Oregon,
- Travel demand modeling and traffic operational analysis of CRC, and
- Integrated land use/transportation/real estate modeling that estimates how the CRC project might influence the location of future growth in housing and employment.

Survey of Research and Case Studies

A broad survey of national research and case studies on how transportation infrastructure can indirectly impact land use underpinned the analysis of how this project could induce land use changes. National research and case studies revealed a variety of important factors that influence whether and how transportation investments change travel and land use patterns. In general, some transit projects tended to promote higher density development, particularly around new transit stations, while some projects adding highway capacity increased automobile use and could have the potential to induce low-density, auto-oriented development further from urban centers. At the same time, other transit projects and highway projects did not have these effects. The most relevant findings from the national research were the answers to the following two questions:

- What factors were associated with highway projects that tended to increase auto use and low density development, and
- What factors were associated with high capacity transit projects that tended to increase transit-oriented and higher density development?

Table 6-28 answers the first question regarding factors that increase auto use and auto-oriented development, and identifies the extent to which each factor is or is not included in the CRC project.

Table 6-28. Factors Associated with Highway Projects That Can Lead to Induced Auto Travel and Sprawl

Factors from National Research	Does CRC exhibit these factors?
The project provides new access to areas previously un-served or greatly underserved by highways.	**No.** CRC is entirely within an urbanized area, and I-5 has been an Interstate corridor since 1958. Project adds no new interchanges.
The project provides new highway access to land on the urban edge.	**No.** CRC improvements are located 7 miles inside the Vancouver Urban Growth Area boundary to the north, and over 13 miles inside the Metro Urban Growth Boundary to the south.
The project substantially improves highway travel times.	**Yes.** However, the potential for travel time savings to induce auto use are largely offset by the added toll. Drivers consider both the value of travel time and the cost of the trip, when determining if, when, how, and where to travel. Compared to the No-Build, CRC is anticipated to provide a 23-minute travel time savings for a round trip between 179th and I-84 during peak periods. The cost of the toll is equivalent to a travel time penalty that negates almost 75% of the trip-making effect of this travel time savings. The net effect of these countervailing factors is equivalent to a 6% decrease in travel time; this is not expected to have a material impact on induced demand or access to fringe areas.
The project reduces auto travel costs.	**No.** CRC has the opposite effect by adding a toll on the highway, increasing auto travel costs relative to No Build alternative.
Local and regional land use regulations are ineffective at managing growth.	**No.** Growth management controls backed by state law exist in the I-5 corridor in both Oregon and Washington that require: • the vast majority of future growth to occur within urban growth areas that reduce sprawl and that are sized to meet population and employment forecasts; • comprehensive plans that implement efficient and sustainable urban development within urban growth areas; • minimum densities in urban areas; and, • protections for rural, agricultural, and environmentally sensitive areas.
There are real estate markets supporting low density development.	**Yes, but these areas are small and distant from the project area** The minimum average densities required to be achieved in Vancouver growth management areas is notably higher than that required in Metro's "Inner Neighborhood" designation. In certain locations densities as high as those targeted for Town Centers, Station Areas, and Main Streets are anticipated. The minimum densities required in the urban growth areas of Washougal, Battle Ground, Camas, and Ridgefield are similar to the densities required in Metro's "Outer Neighborhoods." The two urban growth areas that allow low densities are Yacolt (20 miles from Vancouver) and La Center (15 miles from Vancouver). These growth areas are distant and quite small, representing only 0.9% of the County's population in 2004, and 1.7% of the County's projected population in 2024; no material urban sprawl is anticipated in these areas from the CRC Project.

Table 6-29 answers the second question regarding factors that increase transit ridership and encourage higher density development around transit stations, and identifies the extent to which each of these factors is or is not included in the CRC project.

Table 6-29. Factors Associated with High-Capacity Transit Projects That Can Promote Transit-Oriented Development

Factors from National Research	Does CRC exhibit these factors?
The project increase transit ridership.	**Yes**. The portion of travelers over the I-5 crossing on transit is projected to be more than twice as high with the project, compared to the No Build alternative.a
The project provides new access to developable/redevelopable land previously unserved or underserved by transit.	**Yes**. The project area is not currently served by high capacity transit and there is substantial latent demand for cross-river transit service
There are real estate markets supporting such development.	**Yes**. The majority of the recent and planned developments in downtown Vancouver are high density and/or mixed use.
There is positive public perception of transit.	**Yes**. Over 70% of residents polled support extending light rail across the river to Vancouver.[b]
Local and regional land use regulations support transit-oriented development.	**Yes**. Comprehensive plans and implementing regulations, including zoning, exist in Oregon and Washington that (a) require minimum densities in urban areas, (b) encourage compact and mixed-use development, and (c) encourage transit-oriented development.

a PM peak period transit mode split for the I-5 crossing.

b A scientific telephone poll of 504 randomly selected households in Multnomah, Washington, and Clackamas Counties in Oregon, and Clark County in Washington (Riley Research Associates 2008).

Analysis of Washington and Oregon Growth Management

The national research and case studies emphasized the importance of land use regulations for influencing the type and magnitude of effect from transportation improvements. The jurisdictions in Washington and Oregon have strong growth management measures in place that have many similarities.

Both states mandate growth management. Oregon's Senate Bill 100, adopted in 1973, specifies 19 Statewide Planning Goals that are applicable to all 36 counties and 212 cities. When Washington adopted its Growth Management Act (GMA) in 1990, the Act applied to most counties and the cities therein, including Clark County and the City of Vancouver. Both growth management systems require the development and adoption of 20-year comprehensive plans with urban growth boundaries/areas that provide clear distinctions between rural and urban land. Both laws also encourage compact urban forms and multimodal transportation systems, established land use courts, require capital facility planning, allow for the collection of system development charges, and are tied to numerous implementing mechanisms.

The GMA includes 14 goals to guide the development and adoption of comprehensive plans and development regulations. These goals are very similar to the 19 Statewide Planning Goals in Oregon. They discourage sprawling development, encourage focusing growth and development in existing urban areas with adequate public facilities, encourage economic development throughout the state consistent with comprehensive plans, encourage efficient multimodal transportation systems, and require that adequate public facilities and services necessary to support development be available when new development is ready for occupancy.

Metro is a regional government tasked with land use planning in the Portland metropolitan area in Oregon with a long history of effective growth management. The City of Portland has a sophisticated zoning code with provisions for focusing growth where desired and encouraging compact mixed-use development around transit facilities. After 19 years of planning and regulation under the state GMA, the City of Vancouver and Clark County have also developed robust growth management policies and regulations. The Vancouver Comprehensive Plan targets growth in designated urban centers and corridors connecting these centers in an approach comparable to Metro's 2040 Growth Concept that outlined a plan for accommodating regional growth expected in 50 years. Vancouver has a Transit Overlay District allowing for "higher densities and more transit-friendly urban design" than afforded by base zoning. Portland has a similar Light Rail Transit Station Zone that is an overlay zone allowing for "increased densities for the mutual re-enforcement of public investments and private development". Also, in preparation for the construction of the CRC project, the City of Vancouver has recently made changes to the downtown plan (the VCCV) and is implementing regulations that encourage complementary development along the light rail alignment.

Clark County and the City of Vancouver have planned residential densities of approximately 16 and 20 persons per acre. This compares favorably to Metro's "inner neighborhood" and "outer neighborhood" areas that target 14 and 13 persons per acre, respectively. Metro has other significant goals applied throughout its jurisdiction, tied to designations such as Regional, Town Centers and Main Streets with much higher density targets. The City of Vancouver has policy and regulations encouraging higher densities in planned sub-areas, downtown, and along transit corridors that are comparable to the densities targeted in Metro's Town Centers and Main Streets.

Travel Demand Modeling

Travel time and resulting accessibility can influence the demand for land at both the urban fringe and in established urban areas. Significant improvements in travel time from areas along the urban periphery to key destinations such as downtown Portland could increase pressure for suburban residential development in northern Clark County. At the same time, increases in transit ridership could promote higher density development around transit stations in the central Vancouver area. Travel demand modeling and traffic simulation can provide valuable information about how the CRC project might change travel behavior and, in turn influence land use patterns.

Travel demand modeling and traffic simulation indicate that the CRC project has a far greater effect on transit ridership than I-5 travel times. Though CRC is anticipated to substantially reduce congestion within the project area compared to the No Build scenario, travel times are not as dramatically changed because this project improves a relatively small portion of the region's highway system, and because the toll on the I-5 crossing will add a perceived penalty to auto travel. Modeling the toll entailed incurring a 6-minute time penalty (one-way) to simulate drivers' responses to paying this fee as assumed in Metro's demand modeling. This penalty is based on the average value travelers place on their time[7]. Accounting for this 6-minute time-penalty incurred by the toll, the round-trip travel time savings on I-5 between 179th Street north of Vancouver to I-84 near downtown Portland diminishes from a 28-minute savings to just a 16-minute savings.

[7] In October, 2008, the project convened a panel of national experts to review the travel demand model methodology, including this method of simulating the toll's effect. The panel unanimously concluded CRC's methods and conclusions were valid and reasonable.

Because of the toll and the introduction of a reliable and efficient transit alternative, modeling shows that the project is anticipated to actually lower the number of vehicles using the I-5 crossing each day by about 1 percent.[8] In contrast, transit ridership is anticipated to increase over 250 percent during the p.m. peak period.[9] These travel pattern changes suggest the project will not induced automobile demand, and thus should not increase development pressure along the urban periphery. The significant increase in transit ridership also suggests CRC could spur development around the new light rail stations.

Transportation/Land Use/Real-Estate Modeling (Metroscope)

Another method for evaluating this project's potential for inducing land use changes entailed review of a Metroscope model analysis of transportation improvements in the I-5 corridor similar to CRC. Metroscope is an integrated land use and transportation model designed by Metro to predict how changes in transportation infrastructure could influence the future distribution of employment and housing throughout the region.

In 2001, as part of the I-5 Partnership Study, Metro used its Metroscope model to estimate land use changes if I-5 were to increase to four through-lanes between Going Street in Portland and 134th Street in Vancouver, and light rail were extended to Clark College. This scenario had the same transit improvements as CRC, but added capacity to a significantly longer portion of I-5, adding 22 new lane-miles versus 11 lane-miles that will be added with CRC. This 2001 scenario also did not include a toll on the bridge. This scenario had important similarities to CRC, but added more highway capacity and didn't include an important demand management tool (tolling). These differences resulted in greater travel time savings and increased vehicle use compared to CRC. As such, this scenario represents more potential to induce auto demand and auto-oriented development along the urban periphery, and possibly less potential for transit-oriented development.

Under this scenario, Metroscope showed only minimal changes in employment location and housing demand compared to the No-Build scenario. Metroscope estimated a one percent regional redistribution of jobs to the I-5 corridor with 4,000 more in North and Northeast Portland and 1,000 more in Clark County. The model estimated very modest changes in residential values (a proxy for residential demand), with the highest increase in some Clark County and North Portland areas experiencing up to three percent greater values by 2020, equating to about 0.12 percent growth per year. This analysis also concluded the land-use policies in the Metro boundary and in Clark County were far more likely to influence growth patterns than a single project like CRC.

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[8] 184,000 cars will travel over the I-5 bridges under the No Build scenario versus 178,000 with a replacement crossing, a toll on I-5, and light rail.

[9] With a replacement crossing, a toll on the I-5 bridges, and light rail, 7,250 people will ride transit during the PM peak period compared to 2,050 people for the No Build alternative.

Conclusion: Expected Land Use Changes

Though a large project like CRC has the possibility of having far-reaching effects on travel and land use patterns, local plans and an analysis of how this will affect travel patterns suggest it will have the most pronounced effects immediately surrounding the new infrastructure. CRC will not induce automobile demand or development pressure on the urban periphery, but the project is likely to redistribute some future growth in jobs and housing to the I-5 corridor and to promote planned development on Hayden Island and in downtown Vancouver, particularly around new light rail stations.

It is impossible to predict specific land use changes from this project, but the preceding analysis does provide a good indication of the general location and type of development that will be induced by CRC. The most pronounced land use changes as a result of this project will be on Hayden Island and in downtown Vancouver, where the transportation improvements from this project are anticipated in local plans and likely necessary for these areas to fully develop as these plans envision.

Improved multimodal access to Hayden Island should allow for a more cohesive community, with more residences and new locally-focused commercial services replacing the dispersed, auto-oriented regional retail outlets. The anticipated redevelopment of the Jantzen Beach shopping center into a mixed-use community focused on the new light rail station is perhaps the most significant change expected on the island. Figure 6-22 shows existing land uses on Hayden Island and around the Expo Center light rail station, while Figure 6-23 shows the existing zoning in this area that is anticipated to change in the near future. The proposed zoning will allow for higher residential and commercial densities on the island, notably west of the I-5 interchange where the Jantzen Beach Supercenter is currently located.

In downtown Vancouver, planned development and redevelopment may be accelerated and facilitated because of improved connectivity to the existing downtown street grid. Transit oriented development is expected around the LRT stations in downtown Vancouver as well (Figure 6-28). Studies of high-capacity transit projects indicate that areas within walking distance, or approximately a half-mile, of new LRT transit stations can attract new development.[10] Figure 6-25and Figure 6-26 show the existing land uses and zoning in Vancouver around these LRT stations and in the area of the VCCV.

[10] Reconnecting America. 2007., TOD 101: Why Transit-Oriented Development And Why Now? Available at: www.reconnectingamerica.org/public/download/tod101full.

Figure 6-28. LRT Alignment through Downtown Vancouver

The areas around the downtown LRT stations are zoned "City Center Mixed Use," which allows high-density residential and commercial uses. Recent development in downtown Vancouver means that many areas around the new light rail station are already built up, but there are still some vacant and underutilized parcels that offer potential for these stations to spur added density of jobs and housing. The stations between 15th and 16th Streets are probably most likely to spur development as this area has several vacant parcels and generally lower densities, though zoning and height restrictions reflect the intent for this area to serve as a transition from the downtown to northern neighborhoods. Additional new development can be expected in some of the other remaining vacant or underutilized parcels in the project area. Table 6-30 shows the vacant land within 0.50 mile of the light rail stations to be constructed with the CRC project.

Table 6-30. Area of Vacant Land within 0.50 mile of Proposed LRT Stations

Current Zoning	Acres of Vacant Land
0.50 mile from Hayden Island LRT station	
CG – General Commercial	8.74
IG2 – General Industrial	1.05
R2 – Medium Density, Multi-Dwelling Residential	2.06
R3 – Medium Density, Multi-Dwelling Residential	0.00
0.50 mile from Vancouver LRT stations	
CC – Community Commercial	0.01
CPX – Central Park Mixed Use	0.06
CX – City Center Mixed Use	3.72
OCI – Office, Commercial, Industrial	0.43
IH – Industrial	0.02
IL- Industrial	0.46
R-9 – Lower Density Residential	0.03
Total	**16.58**

In addition, the Main Street extension, Columbia Way design, and the completion of the street grid south of the railroad berm will provide an additional access point to the 35 acre waterfront area immediately west of I-5 that is currently in planning for redevelopment. This access, although only one of two other non-project access points, potentially could increase the rate of redevelopment at the site. The details of how the areas along the shoreline would be redeveloped are not yet available. However, the new designs will be required by conditions of the Master Plan to be designed in a sustainable manner and be SMA and CAO compliant.

The Action Area related to land use reflects these potential land use changes by including areas within a half mile of each of the transit stations, including the existing Expo Station, as the project will affect this area by reconfiguring the Marine Drive interchange and by extending light rail north from this station. The areas of the Hayden Island Plan and the VCCV are also included in the action area.

6.2.2.4 What measures are in place to minimize effects from land use changes?

The form of development in the Action Area will be largely dictated by adopted land use plans and policies. In addition to land use plans, listed species and their habitats are also protected at the federal level and any land use change caused by the Project would be required to comply with federal standards as well. This section identifies and outlines the federal, state, regional and local regulations that would minimize effects from land use changes.

Federal

The two primary federal laws protecting listed fish and wildlife and their habitats would apply to development or land use change indirectly caused by the CRC project include the CWA and the ESA, both of which are briefly outlined here.

Clean Water Act

The CWA requires a Section 404 permit from USACE for impacts to jurisdictional wetlands or other waters. For activities that may result in discharge to waters of the U.S., Section 401 of the CWA requires certification that the project will comply with water quality requirements and standards. Dredging, filling, and other activities that alter a waterway require a Section 404 permit and Section 401 certification. The appropriate state agency must also certify that development meets state water quality standards and does not endanger waters of the state or U.S. or wetlands. Water quality certifications are issued by DEQ and Ecology.

Endangered Species Act

The ESA (16 USC 1531-1544, as amended) regulates the take of any federally listed species. Take is defined in the law to include harass and harm; harm is further defined to include any act which actually kills or injures federally listed species, including acts that may modify or degrade habitat in a way that significantly impairs essential behavioral patterns of the species. Under Section 7 of the ESA, any federal agency that permits, funds, carries out, or otherwise authorizes an action is required to ensure that the action will not jeopardize the continued existence of listed species or result in the destruction or adverse modification of designated critical habitat. An incidental take permit, obtained through a formal Section 7 consultation with NMFS and/or USFWS, will be required if there is potential for development to adversely impact federally listed species or their critical habitat. Informal consultations occur for projects that result in a "not likely to adversely affect" determination; formal consultations occur for projects that are "likely to adversely affect" listed species.

State Regulations

Effective growth management controls backed by state law exist in the I-5 corridor on both sides of the Columbia River. Overall, these land use controls require:

- The vast majority of future growth to occur within urban growth areas, reducing sprawl and meeting population and employment forecasts;
- Comprehensive plans that implement efficient and sustainable urban development within urban growth areas;
- Minimum densities in urban areas; and,
- Protections for rural, agricultural, and environmentally sensitive areas.

Oregon

Statewide Land Use Planning

In 1973, the Oregon Legislature enacted Senate Bill 100[11] (SB 100), which established the statewide land use planning program. The primary goals of SB 100 are to protect the state's farm and forest economies and prevent the spread of unplanned urban sprawl. SB 100 requires cities and counties to adopt and implement comprehensive land use plans that comply with 19 statewide goals and guidelines.

[11] ORS 197.175(2)

9194

One of the primary features of Oregon's land use planning system is the requirement that cities, counties, and regional governments draw urban growth boundaries (UGBs) that separate urban land from rural land (Goal 14). These boundaries establish where cities and urbanized areas can and cannot grow. The UGBs work together with planned growth laid out in local adopted Comprehensive Plans.

Another strong land use protection built into the Oregon system is designed to prevent the conversion of farm and forest lands to urban uses (Goals 3 and 4). A zoning designation called "exclusive farm use" limits farm and forest lands to agriculture production or timber harvesting. Farm and forest lands allow only a small range of compatible uses, limiting the amount of housing or infrastructure that can be built.

Statewide Land Use Goal 5, Natural Resources, Scenic and Historic Areas, and Open Spaces is also instrumental to minimizing the effects of land use change. Goal 5 requires cities and counties to inventory these resources and adopt programs to protect them.

Oregon Department of Fish and Wildlife Habitat Mitigation Policy

The Oregon Wildlife Habitat Mitigation Policy is intended to support the Wildlife Policy (ORS 496.012) and the Food Fish Management Policy (ORS 506.109) of the State of Oregon. The policy provides consistent goals and standards to mitigate impacts to fish and wildlife habitat caused by development. Under the policy, ODFW requires or recommends mitigation for losses of fish and wildlife habitat resulting from development actions, depending upon the habitat protection and mitigation opportunities provided by specific statutes. Priority for mitigation actions is given to habitat for native fish and wildlife species. Mitigation actions for non-native fish and wildlife species may not adversely affect habitat for native fish and wildlife.

Washington

Growth Management Act

The GMA was adopted because the Washington State Legislature found that uncoordinated and unplanned growth posed a threat to the environment, sustainable economic development, and the quality of life in Washington. The GMA (Chapter 36.70A RCW) was adopted by the Legislature in 1990. The GMA requires state and local governments to manage Washington's growth by identifying and protecting critical areas and natural resource lands, designating urban growth areas, and preparing comprehensive plans and implementing them through capital investments and development regulations. The GMA goals that will influence land use changes include those that discourage sprawling development, encourage development in urban areas with adequate public facilities, and encourage efficient multimodal transportation systems. The GMA goals are not ranked in any order with one goal having more importance over others. When local governments develop their plans and regulations, they determine how the goals will be carried out. Cities and counties develop their comprehensive plans to be in compliance with the GMA goals and to provide for 20 years of growth and development needs.

Shoreline Management Act

The SMA was enacted in 1972 with the following purpose: *"to prevent the inherent harm in an uncoordinated and piecemeal development of the state's shorelines."* The SMA has three broad policies:

- Encourage water-dependent uses: "uses shall be preferred which are consistent with control of pollution and prevention of damage to the natural environment, or are unique to or dependent upon use of the states' shorelines..."
- Protect shoreline natural resources, including "...the land and its vegetation and wildlife, and the water of the state and their aquatic life..."
- Promote public access: "the public's opportunity to enjoy the physical and aesthetic qualities of natural shorelines of the state shall be preserved to the greatest extent feasible consistent with the overall best interest of the state and the people generally." (Ecology 2009).

Local jurisdictions implement the SMA through individual Shoreline Master Programs that identify shorelines of the state and designate which shoreline protection category each reach of the shoreline falls under. Each designation defines appropriate uses and development standards, and development with shorelines is subject to administrate review with Ecology providing review of permit decisions.

State Environmental Policy Act

The State Environmental Policy Act (SEPA) of Washington (Chapter 43.21C RCW) was enacted in 1971. SEPA applies to decisions by every state and local agency within Washington State, including state agencies, counties, cities, ports, and special districts. These decisions may be related to issuing permits for private projects, constructing public facilities, or adopting regulations, policies, or plans.

It provides the framework for agencies to consider the environmental consequences of a proposal before taking action and also gives agencies the authority to condition or deny a proposal due to identified likely significant adverse impacts. For example, if an Environmental Impact Statement indicates the proposal will damage a wetland, the agency decision-maker may require the applicant to change his proposal so that no construction will be done within one hundred feet of the wetland. SEPA is implemented through the SEPA Rules, Chapter 197-11 WAC (Ecology 2009).

Hydraulic Project Approval

In 1949, the Washington State Legislature passed a state law now known as the "Hydraulic Code" (Chapter 77.55 RCW). The Hydraulic Code has been amended occasionally since it was originally enacted, but the basic authority has been retained. It is intended to ensure that required construction activities are performed in a manner to prevent damage to the state's fish, shellfish, and their habitat. An HPA from WDFW would be required for work occurring within waters of the state (defined as all salt and fresh waters waterward of the OHW line and within the territorial boundary of the state). The major types of activities in freshwater requiring an HPA include, but are not limited to: stream bank protection; construction or repair of bridges, piers, and docks; pile driving; channel change or realignment; conduit (pipeline) crossing; culvert installation; dredging; gravel removal; pond construction; placement of outfall structures; log, log jam, or debris removal; installation or maintenance of water diversions; and mineral prospecting (WDFW 2009).

By complying with the Hydraulic Code, most construction activities can be allowed with little or no adverse impact on fish or shellfish (WDFW 2009). Permits are processed by WDFW and are submitted with a Joint Aquatic Resources Permit Application.

Regional and Local

The Action Area is influenced by several local and regional governments including Metro, City of Portland, City of Vancouver, and Clark County. The regional and local controls most pertinent to protecting fish and wildlife habitat from indirect land use effects are found in density and growth policies, natural resource protection ordinances, and stormwater controls.

Density and Growth

Metro, the regional government in the Portland Metropolitan region, has a long history of effective growth management through the development and implementation of the regional urban growth boundary (UGB), the Metro 2040 Growth Concept and the Urban Growth Management Functional Plan. In 1978, to comply with Statewide Goal 14, Urbanization, Metro adopted the regional UGB for the Portland metropolitan area. The UGB defines the area within the three Oregon metro counties where urban-level zoning, infrastructure, and development may occur. Local jurisdiction comprehensive plans and implementing ordinances must provide urban services necessary to achieve the urban level of development envisioned in the UGB assumptions.

During the first 20 years of the plan, the UGB has expanded by about 1.5 percent. By comparison, population within the three-county Portland metropolitan region has increased by approximately 60 percent (1978-1996), and employment has increased by approximately 73 percent (1978-1996). In 2002, Metro expanded the UGB by approximately 18,000 acres. The UGB has profoundly affected the land use and development patterns in the Oregon by promoting infill and redevelopment rather than expansion (CRC 2008). This deliberate pattern of development provides protection for resources outside of the UGB.

Metro's 2040 Growth Concept and Urban Growth Management Functional Plan were both adopted in 1997. The 2040 Growth Concept defines development in the metropolitan region through the year 2040 and guides how the UGB is managed. It encourages efficient land use, directing most development to existing urban centers and along existing major transportation corridors and promotes a balanced transportation system within the region that accommodates a variety of transportation options such as bicycling, walking, driving and public transit (Metro 1997). The plan designates regional and town centers and calls for growth to be concentrated in these centers—as well as main streets, station communities and corridors—in order to use urban land most efficiently (Metro 1997). The Urban Growth Management Functional Plan establishes requirements and tools to implement the goals of the 2040 Growth Concept including Title 6, defining density and development standards for areas designated as Central City, Regional Center, Town Center or Station Community (Metro Code 3.07.610–3.07.650: Title 6, Functional Plan). Title 6 requires cities to plan for increased densities in these areas, effectively focusing future growth within the core of developed areas, and away from the fringes.

Local comprehensive plans must be in alignment with Metro's 2040 Growth Concept and Functional Plan, and are based on the regional transportation policy set in 1976. At that time, the policy shifted from emphasizing automobile accommodation to a broader approach aimed at the efficient use of land and integration with the transportation system. A 1973 Governor's task force on transportation concluded that fiscal and environmental realities made it impractical to rely on new radial highways to meet future travel demand, and that most of the new commuter growth into the central city needed to be accommodated with mass transit. As a result, for over 20 years land use and transportation plans have been based on the policy that no new radial highway capacity would be built in the region. Instead, future capacity and level-of-service to and from the central city would depend primarily on high-capacity transit.

Within the City of Portland, zoning controls the allowed maximum densities for new developments and zones allowing higher densities are all focused around the Metro-designated Regional Centers, Town Centers, and Station areas.

In 1990, the Washington GMA established requirements for counties to plan for and manage growth (RCW 36.70A.070(6)). The GMA requires local governments to identify and protect critical and natural resource lands, designate urban growth areas, and prepare comprehensive plans to be implemented through capital investments and development regulations. The land use regulations in the City of Vancouver (Chapter 20, Vancouver Municipal Code [VMC]) and Clark County (Title 40, Clark County Unified Development Code) have robust growth management policies and regulations that comply with the GMA requirements. The Vancouver Comprehensive Plan targets growth in designated urban centers and corridors connecting these centers in a growth management approach comparable to Metro's 2040 Growth Concept. Vancouver also has a Transit Overlay District (VMC 20.550) allowing for "higher densities and more transit-friendly urban design" than afforded by base zoning. This overlay zone is similar to Portland's Light Rail Transit Station Zone that is an overlay zone allowing for "increased densities for the mutual re-enforcement of public investments and private development" (CPC 33.450).

Clark County and the City of Vancouver have planned residential densities of approximately 16 and 20 persons per acre. This compares favorably to Metro's "inner neighborhood" and "outer neighborhood" areas that target 14 and 13 persons per acre, respectively. The City of Vancouver has policies and regulations encouraging higher densities in planned sub-areas, downtown, and along transit corridors that are comparable to the densities anticipated in Metro's Town Centers and Main Streets (VMC, Chapter 20).

Natural Resource Protection

The City of Portland, Metro, the City of Vancouver, and Clark County all have extensive environmental protections in place that minimize impacts to wetlands, riparian areas, and sensitive habitat areas.

City of Portland

Any indirect impacts to fish and wildlife that could result from land use changes within the City of Portland would be required to meet the standards for protecting fish, wildlife, and their habitat found in the Environmental Overlay Zones and the Tree Cutting regulations in the City of Portland Code.

The environmental zones provide for fish habitat protection through the designation of environmental protection or conservation zones. These zones were developed to comply with Metro's Title 3 and Goal 5 of the Statewide Planning goals and are based on an inventory and Economic Social, Environmental, and Energy analysis of important natural resources within the city. Development or disturbances within these zones must be at least 50 feet from the boundary of any wetland and include a 25-foot transition area buffer from the edge of all identified conservation or protection resource areas. The protected resource areas are identified within Natural Resource Management Plans and the official City of Portland Zoning Maps and are not based on a system wide buffer measurement. Applicants must conduct an alternatives analysis and determine that their proposal has the least detrimental effects to the protected resources. Proposals are required to demonstrate how they have avoided and minimized impacts before being allowed to create an adverse impact. Unavoidable impacts must be mitigated. Mitigation must meet strict vegetation replacement standards and include ongoing maintenance and monitoring to ensure success (1994. CPC 33.430, as amended).

The City of Portland also protects trees that are not within an Environmental Overlay zone. Permits administered by City of Portland Urban Forestry department are required to cut trees on private or public property. The City also regulates the cutting and planting of trees on public property, including street trees located on the public right-of-way. Permits are required to plant, prune, remove, or cut the roots of any tree located on public property (2002. CPC 20.42).

City of Vancouver and Clark County

In Washington, Vancouver and Clark County environmentally sensitive areas are protected under the GMA through the local jurisdiction Critical Areas Ordinances, the SMA through Shoreline Master Programs, SEPA implementing regulations, and tree protections.

Critical Areas Protection Ordinances

The Fish and Wildlife Habitat Conservation Area and Wetlands ordinances under the Vancouver and CAO applies to habitat for any life stage of state or federally designated endangered, threatened, or sensitive fish or wildlife species, priority habitats and habitats of local importance, riparian management areas and riparian buffers, and water bodies. CAOs also regulate development in the floodplain, erosion hazard areas, and critical aquifer recharge areas. Any development within fish and wildlife habitat areas, wetlands or buffers would be required to obtain a Critical Areas Permit. A Critical Areas Report would be required as part of the submittal for a Critical Areas Permit. Similar to the City of Portland Environmental Review process, the Critical Areas permit requires applicants to demonstrate they have first avoided impacts, then minimized those that are unavoidable, and finally provides appropriate mitigation. A Critical Areas Report for a riparian management area or riparian buffer must include an evaluation of habitat functions using the Clark County Habitat Conservation Ordinance Riparian Habitat Field Rating Form or another habitat evaluation tool approved by the WDFW.

The Fish and Wildlife Habitat Conservation Area chapter (VMC 20.740.110) uses Riparian Management Areas and Riparian Buffers to protect habitat. The regulated areas extend from the ordinary high water mark of protected waters to a specified distance as measured horizontally in each direction. The Riparian Management Area is adjacent to the lake, stream, or river, and the Riparian Buffer is adjacent to the Riparian Management Area. The specified distances vary considerably as determined by the resource type and quality and the proposed land use change. The Riparian Management Area distance is either 25 feet for a non-fish bearing, perennial/seasonal, small stream that is not connected to any other surface water, or 100 feet from the ordinary high water mark of all other applicable water resources. Outside of the Riparian Management Area, the Riparian Buffer extends from the edge of the Riparian

Management Area and ranges from 25 feet to 75 feet. Functions and resources within the buffer and management areas are protected by standards requiring findings of no net loss. Permitted development uses within the Riparian Management Area are limited to three general types: water oriented, infrastructure oriented, or approved mitigation oriented. Applicants proposing these types of uses must demonstrate findings of no net loss through impact avoidance, minimization techniques and mitigation.

The Wetlands chapter (VMC 20.740.140) establishes protections for wetlands and buffers based on a wetland rating system and the proposed land use intensity. Buffers range from 25 feet for a Category IV wetland with a low land use intensity activity proposed to 300 feet for a Category I wetland with a high land use intensity activity proposed. Permitted activity types are limited by category of wetland. For instance, only necessary infrastructure that cannot be located elsewhere or low impact trails and wildlife viewing structures are allowed within Category I wetlands, and applicants must demonstrate no net loss of wetland functions. (Critical Areas Protection Ordinance. 2005. City of Vancouver – Vancouver Municipal Code (VMC) 20.740; Fish and Wildlife Habitat Conservation Areas. 2005. VMC 20.740.110. Vancouver, WA. Critical Areas and Shorelines. 2005. Clark County Code. Title 40.4. Vancouver, WA.)

Shoreline Master Programs

The local Shoreline Management Master Programs at the City of Vancouver and Clark County implement the Washington Shoreline Management Act and provide protection to fish and wildlife habitat. A Substantial Development Permit would be required for development activities occurring within areas regulated by the Shoreline Management Master Program. Within the City of Vancouver, Shorelines of the state include the Columbia River, Vancouver Lake, Lake River, Salmon Creek, Mill Creek, Burnt Bridge Creek (From I-205 to its mouth), and Glenwood (a.k.a. Curtain Creek). The Columbia River and Vancouver Lake are also classified as shorelines of statewide significance due to their size, flow rates and general significance. The regulations of the City of Vancouver Shoreline Management Master Program apply to shorelands extending landward for two hundred feet in all directions measured on a horizontal plane from the ordinary high water mark or the landward extend of the 100-year floodplain; floodways and areas landward two hundred feet from such floodways; whichever is farther landward, and all associated wetlands. Reaches of the shoreline are designated with one of several Environment Designations and various standards apply within each designation. Generally, development on lands within Shoreline jurisdiction must balance the multiple uses and needs along shorelines, including protecting natural resources and habitats, or mitigating impacts (Shoreline Management Area. 2005. VMC 20.760. Vancouver, WA and Critical Areas and Shorelines. 2005. Clark County Code. Title 40.4. Vancouver, WA).

The cities of Battle Ground, Camas, Clark County, La Center, Ridgefield, Vancouver, Washougal, and Yacolt are collaborating in a two- to three- year effort to update their respective SMPs. These SMP updates are funded by a Department of Ecology grant administered through the City of Vancouver on behalf of the eight jurisdictions. In early 2010, they will be working to develop a shoreline inventory and characterization report with the help of a Technical Advisory Committee. The report will document existing conditions for areas including those discussed herein. In the spring of 2010 they will begin to review and update goals and policies with the help of the community and a Shoreline Stakeholder Advisory Committee.

SEPA

Vancouver and Clark County implement SEPA through local ordinances that review individual projects and submit threshold determinations to the Department of Ecology (SEPA Regulations. 2004. VMC 20.790 and SEPA. 2009. Clark County Code 40.570).

Street Trees

Street Trees and Tree Conservation municipal codes require permits if development would result in the cutting of trees on public or private property. There are two kinds of permits required for trees in the City of Vancouver: one for street trees and one for private trees. If the tree is in the public right-of-way, a street tree permit is required (Street Trees. VMC 12.04; and Tree Conservation. VMC 20.770)

Stormwater Controls

Indirect land use changes that could potentially be a result of the project may create additional impervious surfaces. Increased impervious surface increases stormwater runoff which can adversely affect fish habitat. The City of Portland implements stormwater management under a permit issued by the DEQ under the CWA. The Phase I NPDES Municipal Separate Storm Sewer System (MS4) Permit requires municipalities with populations of 100,000 or more to support CWA goals by reducing pollutants in stormwater discharges from their MS4s to the maximum extent practicable. The CWA goals include restoring and maintaining the chemical, physical, and biological integrity of our waters (rivers, streams, lakes, wetlands, and marine waters) (Portland Stormwater Management Manual, 2008).

Within Portland, the Bureau of Environmental Services requires stormwater treatment for any increase in impervious surface greater than 500 sq. ft. There are many treatment options available for on site quality and quantity treatment (City of Portland Stormwater Management Manual 2008). Treatment options include vegetated swales, grassy swales, vegetated filters, and vegetated infiltration basins.

Vancouver's Surface Water Management Program administers activities required by the CWA and the city's Phase II NPDES Permit issued by the Washington Department of Ecology. The City is currently reviewing the stormwater program to bring it into compliance with Phase II standards. The City relies on the 2005 Stormwater Management Manual for Western Washington for technical requirements that must be met by development with stormwater impacts (VMC 14.24-26). Treatment options include vegetated swales, grassy swales, vegetated filters, and vegetated infiltration basins, in addition to other Department of Ecology-approved methods.

6.2.2.5 What are the potential impacts to species and habitat from land use changes?

As noted above population and employment growth is anticipated to occur with or without the CRC project, and land uses will change to accommodate more people and jobs. More people and jobs will also mean greater demands for transportation. Potential impacts to species and habitats could occur from changes in traffic patterns, development, and redevelopment resulting in impacts to water quality and water quantity, and a decrease in natural habitats. In addition, development may result in changes to riparian and nearshore areas, including changes in vegetation and overwater structures. Listed species may be affected through the addition of impervious surface (particularly pollutant generating surfaces), unsuccessful treatment of stormwater from pollutant generating surfaces, and a decrease in riparian and aquatic habitat.

With respect to traffic changes, without the CRC project, the number of vehicles crossing the bridge is anticipated to be slightly higher than with the CRC project, and would move more slowly and less efficiently (i.e., congestion for up to 15 hours per day). Current stormwater treatment within the action area is limited (see Section 3.12 of the BA). With the construction of the CRC project, including the addition of light rail to Clark College and a toll on the I-5 crossing, growth in automobile traffic is anticipated to be slightly reduced and would move more efficiently through the corridor. This reduction in average daily traffic (ADT) and congestion, coupled with the integration of stormwater treatment meeting current regulatory standards for new and redeveloped impervious surfaces, will likely result in improved water quality within the action area.

New development or redevelopment near the project area is anticipated to occur in response to local plans that encourage medium- and high-density development on Hayden Island and through downtown Vancouver. The CRC project is expected to facilitate the land use visions in these plans by providing or accommodating the anticipated transportation facilities that would support the new development. Furthermore, the introduction of light rail through these areas is anticipated to spur higher density development as local zoning code and plans encourage transit-oriented development around high-capacity transit.

New development or redevelopment of existing infrastructure would comply with applicable land use codes, in particular the need to upgrade to existing stormwater treatment regulations. Redevelopment associated with the project is anticipated to occur in downtown Vancouver and northeastward to Clark College as shown on Figure 6-28 Redevelopment will also occur on Hayden Island as shown on Figure 6-24, and potentially in north and northeast Portland along Marine Drive and MLK. No listed terrestrial species are located at these sites, but runoff from stormwater could indirectly impact habitat associated with the fish species addressed in this BA. Development and redevelopment, including removal or renovation of existing in-water structures such as docks, piers, and floating homes and near-shore development, would comply with the relevant laws, regulations, policies, and code in force at the time of the action. As noted above, these regulatory approvals range from street tree removal, to stormwater treatment, to environmental zone and critical areas protections, to more complicated processes for larger developments.

With the integration of local and state land use requirements discussed in Section 4 of this document, negative impacts to listed species and their habitats from development and redevelopment would be limited. Local regulations require the avoidance or minimization of impacts to protected resources. These resources include shorelines, wetlands, streambanks, and their buffers, that are often most important to juvenile salmonids and their habitat. For upland development activities, state laws and local implementation of those laws, such as Washington's SMA and CAO, dictate what type of development is allowed within 200 feet of the shoreline and the type and quantity of vegetation that must be retained or planted in the area. For upland development activities in Oregon, the City of Portland's environmental zone provides for similar requirements, but only within 35 to 50 feet of the top of bank.

For fill within the Columbia River and North Portland Harbor, federal laws such as Section 404 of the Clean Water Act and consultation under Section 7 of the ESA will require analysis and approval by federal agencies to ensure that impacts are avoided, minimized, or offset if necessary. Likewise, for work within waters, WDFW's hydraulic project approval and ODFW's habitat mitigation policy require avoidance, minimization, and offsets of negative impacts. Each agency's process mandates that resources be protected or mitigated for.

With implementation of laws and regulations described above negative impacts to existing aquatic and terrestrial resources would likely result in a net benefit in the long term.

Further away from the immediate project alignment, development and redevelopment are not projected to occur as a result of this project. If land use changes did occur, the regulations, policies, and restrictions discussed above would minimize adverse effects to listed species and their habitats.

In summary, the CRC project is expected to encourage more compact development within existing urban areas that should accommodate future growth more efficiently, reducing potential loss of habitat and impervious surface throughout the region. By concentrating future regional population and employment growth in North Portland and downtown Vancouver, the CRC project should reduce development pressure in outlying areas that is more likely to result in loss of previously undisturbed habitat and incur a greater development footprint to accommodate this growth. Redevelopment and development within the project area will need to comply with stringent natural resource laws, regulations, and codes. Proper enforcement of these requirements should result in better treatment of stormwater runoff and incorporation of upland, riparian, and in-water habitat elements that are conducive to salmon recovery.

6.3 EFFECTS TO FISH HABITAT

6.3.1 Shallow-Water Habitat

The project will have both temporary and permanent impacts on shallow-water habitat (water less than 20 feet deep) in the Columbia River and North Portland Harbor. Temporary impacts to shallow water include: in-water and overwater structures (work platforms, work barges, tower cranes, oscillator support piles, cofferdams, and barges), turbidity, and elevated underwater noise. Permanent impacts include the addition of in-water and overwater bridge elements and the removal of existing in-water and overwater structures.

This section outlines the role of shallow-water habitat in the life history of fish and provides an analysis of the project's likely effects on fish in shallow-water habitat in the CRC action area.

6.3.1.1 Fish Distribution in Shallow-Water Habitat

Shallow water is of particular importance in the life history of fish for migration, feeding, holding, rearing, and predator avoidance (Everhart et al. 1953; Simenstad et al. 1982; Spence et al. 1996 as cited in Bottom et al. 2005). LCR Chinook and CR chum migrate as subyearlings and are particularly dependent on nearshore, shallow-water areas during outmigration (Levy and Northcote 1982, Myers and Horton 1982, Simenstad et al. 1982, and Levings et al. 1986 as cited in Bottom et al. 2005). Typically, these fish are less than less than 50 to 60 mm fork length and primarily use water that is less than 1 m deep (Bottom et al. 2005). Numerous studies have documented smaller fish (subyearling Chinook) utilizing nearshore habitats (Johnsen and Sims

1973; Dawley et al. 1986; McCabe et al. 1986; Ledgerwood et al. 1991, as cited in Carter et al. 2009), frequently at depths of 3 m or less (Carlson et al. 2001, as cited in Carter et al. 2009). However, LCR Chinook and CR chum can and do occupy other parts of the channel (Bottom et al. 2005; NMFS 2005c). While these fish are highly dependent on shallow water and are most likely to occur there, they do not occur exclusively in the nearshore and may potentially be present across the entire cross-section of the channel (Bottom et al. 2005).

Other juvenile salmonids outmigrate after they reach the yearling stage or older. These species include all of the salmonid runs addressed by this BA except for chum. (Note that LCR Chinook may emigrate as either subyearlings or as yearlings.) In general, cross-sectional distribution of these larger juveniles in the stream channel appears to be correlated with size. Fish measuring 60 to 100 mm fork length use deeper water, such as shoals and distributary channels. Fish greater than 100 mm in length are found in both deep and shallow water habitats, indicating that these individuals do not show preferential use of a particular water depth (Bottom et al. 2005), although they may seek out these areas for resting or as flow refugia during high-velocity events. Fish that migrate as yearlings or older tend to move quickly and occupy deeper-water habitats, but it is well documented that all use the nearshore to some extent during their outmigration (Bottom et al. 2005; NMFS 2005c; Celedonia et al. 2008; Friesen 2005; Southard et al. 2006; Carter et al. 2009). These juveniles may alternate active migration in deeper water interspersed with periods of holding and resting in shallow water and/or low-velocity areas (Bottom et al. 2005; Celedonia et al. 2008). Thus, while these older juveniles are less dependent on the nearshore than their subyearling migrant counterparts, they are likely to be present across the entire cross-section of the channel (Bottom et al. 2005; Southard et al. 2006).

Rearing juveniles are largely dependent on shallow water habitats (Bottom et al. 2005; Southard et al. 2006; NMFS 2006). ESUs that rear in the action area include LCR Chinook, UCR spring-run Chinook, UWR Chinook, CR chum, LCR coho, and LCR steelhead.

Adult salmonids generally migrate at mid-channel, but may occupy depths of 1 to 50 feet (NMFS 2006). While they may occur in shallow-water habitat, they are not particularly dependent on it, although they may seek out these areas for resting or as flow refugia during upstream migration (Bottom et al. 2005).

None of the life stages of eulachon or green sturgeon occurring in the action area are particularly dependent on shallow water, as described in Section 4.

6.3.1.2 Effects to Shallow-Water Habitat in the CRC Action Area

In the case of the CRC project, shallow-water impacts include physical loss of habitat, increase in the area of overwater structures, temporary turbidity, and underwater noise.

The following habitats, species, and life stages of fish could be exposed to these effects:

- Holding, feeding, and migration habitat for juveniles and holding and migration habitat for adults in several ESUs/DPSs: LCR coho; CR chum; SR sockeye; LCR, MCR, UCR, and SR steelhead; and LCR, UCR spring-run, SR fall-run, and SR spring/summer-run Chinook.
- Rearing habitat for juvenile Chinook (LCR, UCR spring-run, and UWR), LCR coho, CR chum, and LCR steelhead.

- Adult bull trout migration and holding habitat. Because of the extremely low numbers of bull trout in this portion of the action area, risk of exposure to this effect is discountable.
- Adult and subadult green sturgeon feeding and migration habitat. Because of the extremely low numbers of green sturgeon in this portion of the action area, risk of exposure to this effect is discountable.
- Adult and larval eulachon spawning and migration habitat.

Figures 4-1 and 4-2 show when these species are likely to be present in the action area and could be exposed to activities occurring in shallow water. Since shallow-water impacts will occur continually throughout the 4-year in-water construction period, as many as four migration cycles of salmon, steelhead, and eulachon could be exposed to these effects.

All of these species and life stages may use shallow-water habitat at some point during their presence in the action area. Of these life stages, rearing juvenile salmonids and subyearling migrant salmonids (CR chum and LCR Chinook) are the most closely dependent on shallow-water habitat, and therefore are the most vulnerable to these effects.

Physical Loss of Shallow-Water Habitat

The project will lead to temporary physical loss of approximately 20,700 sq. ft. of shallow-water habitat. Project elements responsible for temporary physical loss include the footprint of the numerous temporary piles associated with in-water work platforms, work bridges, tower cranes, oscillator support piles, cofferdams, and barge moorings in the Columbia River and North Portland Harbor. Table 6-31 and Table 6-32 quantify the temporary physical loss of shallow-water habitat.

The in-water portions of the new structures will result in the permanent physical loss of approximately 250 sq. ft. of shallow-water habitat at pier complex 7 in the Columbia River. Demolition of the existing Columbia River structures will permanently restore about 6,000 sq. ft. of shallow-water habitat, and removal of a large overwater structure at the Quay will permanently restore about 600 sq. ft. of shallow-water habitat. Overall, there will be a net permanent gain of about 5,345 sq. ft. of shallow-water habitat in the Columbia River (Table 6-31). At North Portland Harbor, there will be a permanent net loss of about 2,435 sq. ft. of shallow-water habitat at all of the new in-water bridge bents (Table 6-32). Note that all North Portland Harbor impacts are in shallow water.

Table 6-31. Physical Impacts to Shallow-Water Habitat in the Columbia River

Structure	Columbia River	
	Area	Time in Water
Temporary		
Work Platforms – Construction (P2 & 7) (portions are in shallow water)	728 sq. ft.	150–300 days each
Barge Moorings – Construction (P7)	25 sq. ft.	120 days each
Cofferdams –Construction (P7) (about a quarter is in shallow water)	2,000 sq. ft.	240 days each
Barge Moorings – Demolition (existing Pier 10, 11)	200 sq. ft.	30 days each
Cofferdams – Demolition (existing Pier 10, 11)	15,000 sq. ft.	40 days each
Total Temporary Impact	**17,753 sq. ft.**	---

	Columbia River	
Permanent		
New Bridge Shafts (2 Drilled Shafts at P7)	236 sq. ft.	Permanent
Existing Bridge Piers to be Removed (Existing Pier 10, 11)	- 6,181 sq. ft.	Permanent
Existing Piers to be Removed – Red Lion at the Quay	- ~600 sq. ft.	Permanent
Total Permanent Impact	**- 5,345 sq. ft.**	---

Table 6-32 Physical Impacts to Shallow-Water Habitat in North Portland Harbor

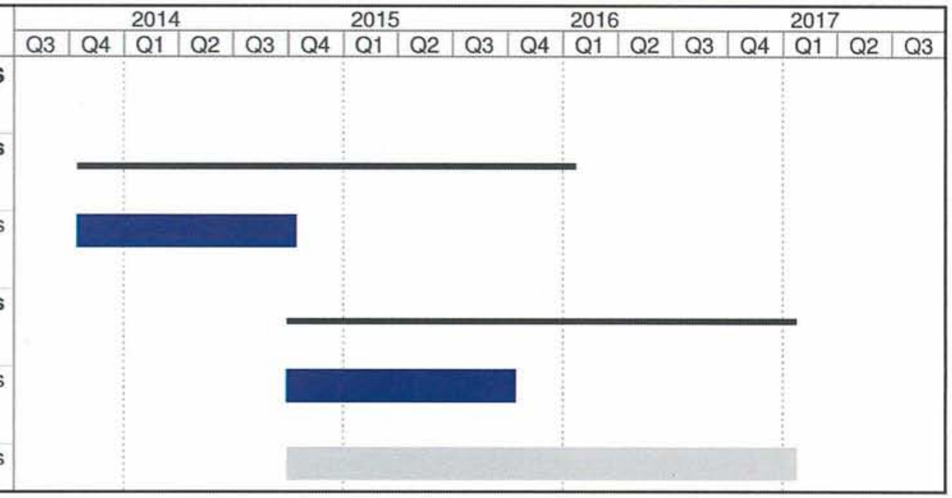
Structure	North Portland Harbor Area	North Portland Harbor Time in Water
Temporary		
Work Bridges – Construction (9 locations)	400–710 sq. ft.	Up to 42 days each
Oscillator Platforms (31 locations)	1,200–1,560 sq. ft.	Up to 34 days each
Barge Moorings – Construction (31 locations)	318–678 sq. ft.	Up to 34 days each
Total Temporary Impact	**1,970–2,940 sq. ft.**	---
Permanent		
New Bridge Shafts (31 columns)	2,435 sq. ft.	Permanent
Total Permanent Impact	**2,435 sq. ft.**	---

The structures listed in Table 6-31 and Table 6-32 will not all occur in the action area at the same time. Figure 6-29 shows the sequencing of in-water structures in shallow-water habitat.

Physical loss of shallow-water habitat is of particular concern for rearing or subyearling migrant salmonids. In general, in-water structures that completely block the nearshore may force these juveniles swim into deeper-water habitats to circumvent them. Deep-water areas generally represent lower quality habitat because predation rates may be higher there. Numerous studies show that predators such as walleye and northern pikeminnow occur in deepwater habitat for at least part of the year (Johnson 1969; Ager 1976; Paragamian 1989; Wahl 1995; Pribyl et al. 2004). In the case of the CRC project, in-water portions of the structures will not pose a complete blockage to nearshore movement anywhere in the action area. Although these structures will cover potential rearing and nearshore migration areas, the habitat is not rare and is not of particularly high quality. These juveniles will still be able to use the abundant shallow-water habitat available for miles in either direction.

Neither the permanent nor the temporary structures will force these juveniles into deeper water, and therefore pose no added risk of predation. Additionally, northern pikeminnow and walleye tend to avoid high-velocity areas during the spring juvenile salmonid outmigration (NMFS 2000b; Gray and Rondorf 1986; Pribyl et al. 2004). The high velocities present in deep-water portions of the CRC project area may limit the potential for actual predation in deep-water areas.

Task Name	Start	Finish	Duration
Bridge Construction Scenario 2/5/13	**9/16/13**	**4/5/17**	**928 days**
Pier 2	**10/16/13**	**1/22/16**	**593 days**
Work Bridge (Approx. 350 s.f.)	10/16/13	10/13/14	259 days
Pier 7	**9/29/14**	**1/23/17**	**606 days**
Work Bridge (Approx. 350 s.f.)	9/29/14	10/13/15	272 days
Barge Moorings (Approx. 200 s.f.)	9/29/14	1/23/17	606 days



Conceptual Schedule Only, March 2010
Note: This is a proposed schedule, so activity start and finish dates are likely to change.

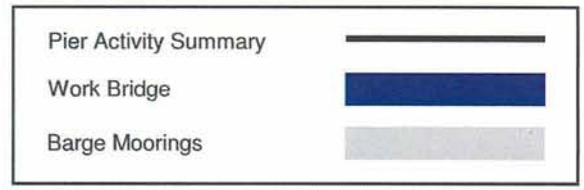
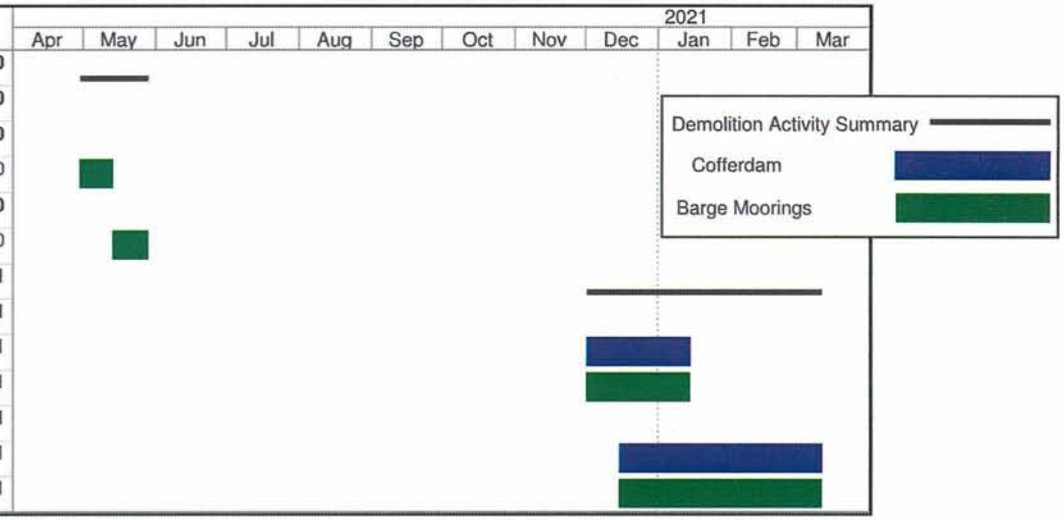


Figure 6-29. Sequencing of Temporary In-Water Structures for Construction in Shallow Water in the Columbia River

Columbia River CROSSING

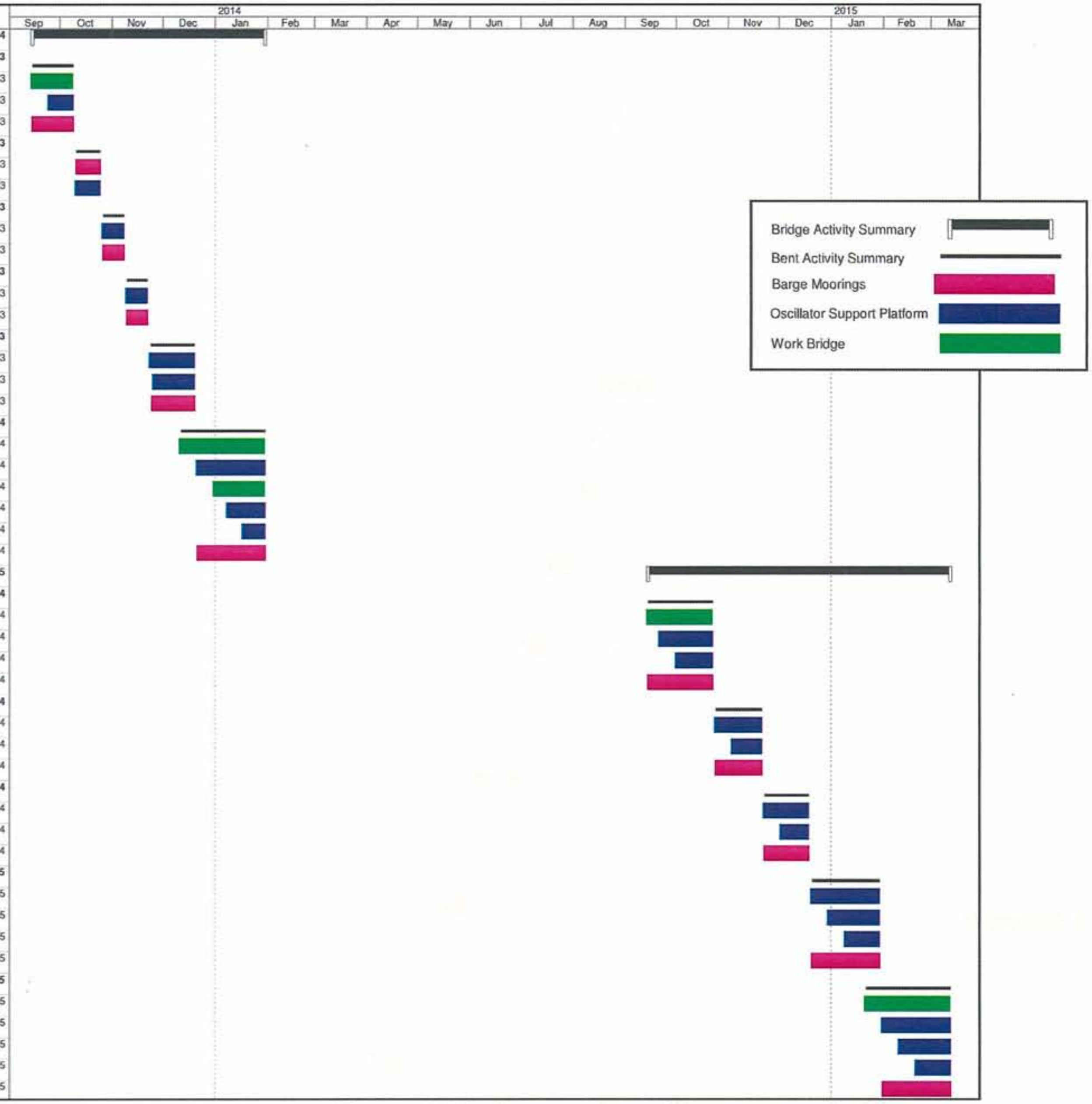
Task Name	Duration	Start	Finish
Superstructure Demolition	**21 days**	**4/30/20**	**5/28/20**
Remove Spans	**21 days**	**4/30/20**	**5/28/20**
Span 9	**10 days**	**4/30/20**	**5/13/20**
Barge Moorings (~56 s.f.)	10 days	4/30/20	5/13/20
Span 10	**11 days**	**5/14/20**	**5/28/20**
Barge Moorings (~56 s.f.)	11 days	5/14/20	5/28/20
Substructure Demolition	**72 days**	**12/2/20**	**3/11/21**
Pier 10	**32 days**	**12/2/20**	**1/14/21**
Cofferdam (7,500 s.f.)	32 days	12/2/20	1/14/21
Barge Moorings (50 s.f.)	32 days	12/2/20	1/14/21
Pier 11	**62 days**	**12/16/20**	**3/11/21**
Cofferdam (7,500 s.f.)	62 days	12/16/20	3/11/21
Barge Moorings (50 s.f.)	62 days	12/16/20	3/11/21



Conceptual Schedule Only, April 2010
Note: This is a proposed schedule, so activity dates are likely to change.

Figure 6-30. Sequencing of Temporary In-Water Structures for Demolition in Shallow Water in the Columbia River

Task Name	Duration	Start	Finish
Widening of Existing Bridge	**111 days**	**9/15/13**	**1/30/14**
Bent 4	**20 days**	**9/15/13**	**10/8/13**
Work Bridge (45 - 80 s.f.)	20 days	9/15/13	10/8/13
Oscillator Support Platform (30 - 50 s.f.)	10 days	9/25/13	10/8/13
Barge Moorings (21 - 38 s.f.)	20 days	9/15/13	10/8/13
Bent 5	**10 days**	**10/11/13**	**10/24/13**
Oscillator Support Platform (30 - 50 s.f.)	10 days	10/11/13	10/24/13
Barge Moorings (21 - 38 s.f.)	10 days	10/11/13	10/24/13
Bent 6	**10 days**	**10/27/13**	**11/7/13**
Oscillator Support Platform (30 - 50 s.f.)	10 days	10/27/13	11/7/13
Barge Moorings (21 - 38 s.f.)	10 days	10/27/13	11/7/13
Bent 7	**10 days**	**11/10/13**	**11/21/13**
Oscillator Support Platform (30 - 50 s.f.)	10 days	11/10/13	11/21/13
Barge Moorings (21 - 38 s.f.)	10 days	11/10/13	11/21/13
Bent 8	**22 days**	**11/24/13**	**12/19/13**
Oscillator Support Platform 1 (30 - 50 s.f.)	22 days	11/24/13	12/19/13
Oscillator Support Platform 2 (30 - 50 s.f.)	20 days	11/26/13	12/19/13
Barge Moorings (21 - 38 s.f.)	22 days	11/24/13	12/19/13
Bent 9	**42 days**	**12/12/13**	**1/30/14**
Work Bridge 1 (45 - 80 s.f.)	42 days	12/12/13	1/30/14
Oscillator Support Platform 1 (30 - 50 s.f.)	33 days	12/22/13	1/30/14
Work Bridge 2 (45 - 80 s.f.)	25 days	1/1/14	1/30/14
Oscillator Support Platform 2 (30 - 50 s.f.)	17 days	1/9/14	1/30/14
Oscillator Support Platform 3 (30 - 50 s.f.)	10 days	1/18/14	1/30/14
Barge Moorings (21 - 38 s.f.)	33 days	12/22/13	1/30/14
Light Rail Transit/Multi-Use Plan Bridge	**142 days**	**9/15/14**	**3/12/15**
Bent 2	**30 days**	**9/15/14**	**10/22/14**
Work Bridge (45 - 80 s.f.)	30 days	9/15/14	10/22/14
Oscillator Support Platform 1 (30 - 50 s.f.)	23 days	9/22/14	10/22/14
Oscillator Support Platform 2 (30 - 50 s.f.)	15 days	10/2/14	10/22/14
Barge Moorings (21 - 38 s.f.)	30 days	9/15/14	10/22/14
Bent 3	**21 days**	**10/25/14**	**11/20/14**
Oscillator Support Platform 1 (30 - 50 s.f.)	21 days	10/25/14	11/20/14
Oscillator Support Platform 2 (30 - 50 s.f.)	13 days	11/4/14	11/20/14
Barge Moorings (21 - 38 s.f.)	21 days	10/25/14	11/20/14
Bent 4	**20 days**	**11/23/14**	**12/18/14**
Oscillator Support Platform 1 (30 - 50 s.f.)	20 days	11/23/14	12/18/14
Oscillator Support Platform 2 (30 - 50 s.f.)	12 days	12/3/14	12/18/14
Barge Moorings (21 - 38 s.f.)	20 days	11/23/14	12/18/14
Bent 5	**34 days**	**12/21/14**	**1/29/15**
Oscillator Support Platform 1 (30 - 50 s.f.)	34 days	12/21/14	1/29/15
Oscillator Support Platform 2 (30 - 50 s.f.)	26 days	12/31/14	1/29/15
Oscillator Support Platform 3 (30 - 50 s.f.)	18 days	1/10/15	1/29/15
Barge Moorings (21 - 38 s.f.)	34 days	12/21/14	1/29/15
Bent 6	**41 days**	**1/22/15**	**3/12/15**
Work Bridge (45 - 80 s.f.)	41 days	1/22/15	3/12/15
Oscillator Support Platform 1 (30 - 50 s.f.)	32 days	2/1/15	3/12/15
Oscillator Support Platform 2 (30 - 50 s.f.)	24 days	2/11/15	3/12/15
Oscillator Support Platform 3 (30 - 50 s.f.)	16 days	2/21/15	3/12/15
Barge Moorings (21 - 38 s.f.)	32 days	2/1/15	3/12/15

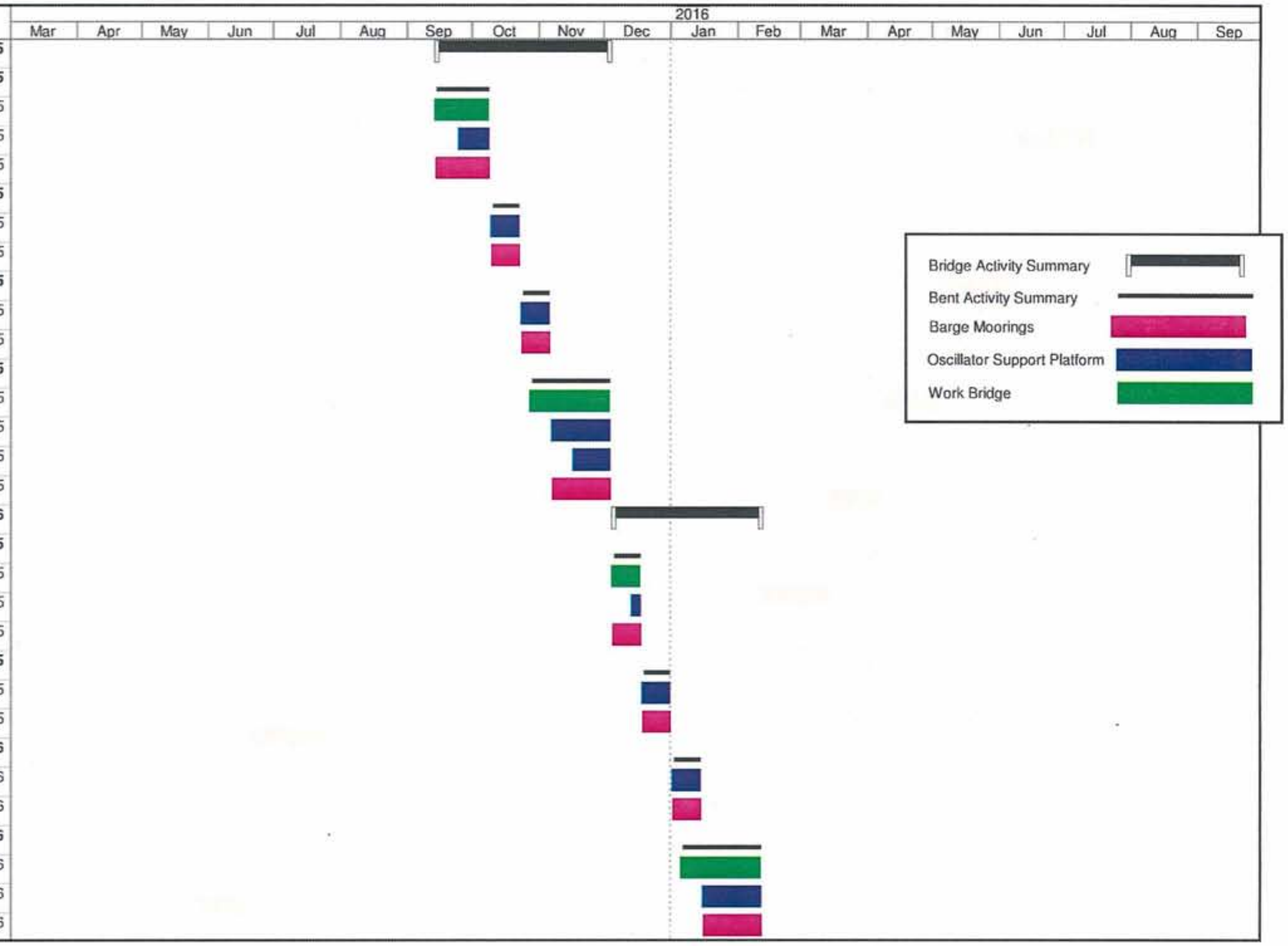


Conceptual Schedule Only, April 2010
Note: This is a proposed schedule, so activity dates are likely to change.

Figure 6-31. Sequencing of Temporary In-Water Structures for Construction in Shallow Water in North Portland Harbor

Columbia River CROSSING

Task Name	Duration	Start	Finish
Northbound Collector Distributor Ramp	**66 days**	**9/15/15**	**12/3/15**
Bent 6	**21 days**	**9/15/15**	**10/8/15**
Work Bridge (45 - 80 s.f.)	21 days	9/15/15	10/8/15
Oscillator Support Platform (30 - 50 s.f.)	10 days	9/26/15	10/8/15
Barge Moorings (21 - 38 s.f.)	21 days	9/15/15	10/8/15
Bent 7	**10 days**	**10/11/15**	**10/22/15**
Oscillator Support Platform (30 - 50 s.f.)	10 days	10/11/15	10/22/15
Barge Moorings (21 - 38 s.f.)	10 days	10/11/15	10/22/15
Bent 8	**12 days**	**10/25/15**	**11/5/15**
Oscillator Support Platform (30 - 50 s.f.)	12 days	10/25/15	11/5/15
Barge Moorings (21 - 38 s.f.)	12 days	10/25/15	11/5/15
Bent 9	**29 days**	**10/29/15**	**12/3/15**
Work Bridge (45 - 80 s.f.)	29 days	10/29/15	12/3/15
Oscillator Support Platform 1 (30 - 50 s.f.)	20 days	11/8/15	12/3/15
Oscillator Support Platform 2 (30 - 50 s.f.)	12 days	11/18/15	12/3/15
Barge Moorings (21 - 38 s.f.)	20 days	11/8/15	12/3/15
Southbound Collector Distributor Ramp	**57 days**	**12/6/15**	**2/11/16**
Bent 2	**12 days**	**12/6/15**	**12/17/15**
Work Bridge (45 - 80 s.f.)	12 days	12/6/15	12/17/15
Oscillator Support Platform (30 - 50 s.f.)	3 days	12/15/15	12/17/15
Barge Moorings (21 - 38 s.f.)	12 days	12/6/15	12/17/15
Bent 3	**10 days**	**12/20/15**	**12/31/15**
Oscillator Support Platform (30 - 50 s.f.)	10 days	12/20/15	12/31/15
Barge Moorings (21 - 38 s.f.)	10 days	12/20/15	12/31/15
Bent 4	**12 days**	**1/3/16**	**1/14/16**
Oscillator Support Platform (30 - 50 s.f.)	12 days	1/3/16	1/14/16
Barge Moorings (21 - 38 s.f.)	12 days	1/3/16	1/14/16
Bent 5	**29 days**	**1/7/16**	**2/11/16**
Work Bridge (45 - 80 s.f.)	29 days	1/7/16	2/11/16
Oscillator Support Platform (30 - 50 s.f.)	20 days	1/17/16	2/11/16
Barge Moorings (21 - 38 s.f.)	20 days	1/17/16	2/11/16



Conceptual Schedule Only, April 2010
Note: This is a proposed schedule, so activity dates are likely to change.

Figure 6-31 (Continued). Sequencing of Temporary In-Water Structures for Construction in Shallow Water in North Portland Harbor

Columbia River CROSSING

Physical loss of shallow-water habitat will have only negligible effects on foraging, migration, and holding of salmonids that are of the yearling age class or older. These life functions are not dependent on shallow-water habitat for these age classes. Furthermore, the lost habitat is not of particularly high quality. There is abundant similar habitat immediately adjacent along the shorelines of the Columbia River and throughout North Portland Harbor. The lost habitat represents only a small fraction of the remaining habitat available for miles in either direction. There will still be many acres of habitat for foraging, migrating, and holding.

Physical loss of shallow-water habitat will have only negligible effects on eulachon and green sturgeon for the same reason as above.

It is impossible to quantify the number of fish that will be exposed to this effect, but it is possible to estimate the extent and duration of the effect. This effect will occur when structures will be present in the water (Table 6-31, Table 6-32, and Figure 6-29) during the timing of fish presence in this portion of the action area (see Figures 4-1 and 4-2).

Increase in Overwater Coverage

The project will place several overwater structures in shallow water in the Columbia River and North Portland Harbor. Temporary overwater structures include temporary work platforms, work bridges, oscillator support platforms, and stationary barges. Permanent overwater structures likely to have effects on fish include only the shaft caps on the Columbia River bridges. Table 6-33 and Table 6-34 quantify the area and duration of project-related overwater structures in the action area.

Table 6-33. Overwater Coverage in Shallow Water Habitat in the Columbia River

	Columbia River	
Structure Type	**Area**	**Duration in Water**
Temporary		
Work bridges (P2, P7)	36,000 sq. ft.	150–300 days/pier complex
Barges for Demolition (Existing Piers 10 & 11)	14,350 sq. ft.	Varies up to 30 days/barge
Total Temporary Impact	**50,350 sq. ft.**	---
Permanent		
Shaft Caps (P7 – Half of SB)	1,688 sq. ft.	Permanent
Pier at Red Lion at the Quay to be Removed	-18,965 sq. ft.	Permanent
Total Permanent Impact	**-17,277 sq. ft.**	---

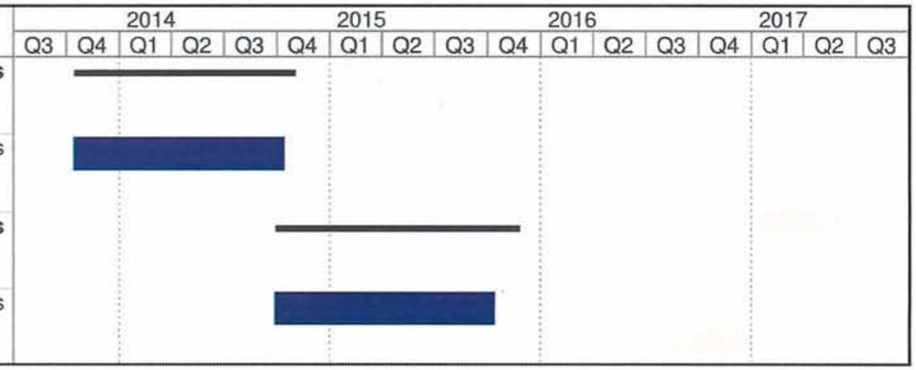
Table 6-34. Overwater Coverage in Shallow Water Habitat in North Portland Harbor

	North Portland Harbor	
Structure Type	**Area**	**Duration in Water**
Temporary		
Work Bridges (8 locations)	29,640 sq. ft.	Up to 42 days each
Oscillator Support Platforms (31 locations)	27,900 sq. ft.	Up to 34 days each
Barges for Construction (31 locations)	64,164 sq. ft.	Up to 34 days each
Total Temporary Impact	**108,164 sq. ft.**	---
Permanent		
None	N/A	Permanent
Total Permanent Impact	**N/A**	---

Temporary structures will not all be present in the action area at the same time. Figure 6-32, Figure 6-33, and Figure 6-34 provide the sequencing of overwater structures in the shallow-water portions of the action area. The maximum amount of shade from overwater structures in shallow water in the Columbia River will be no more than about 18,500 sq. ft. at one time. In North Portland Harbor, the maximum amount of shade in shallow water at one time will be about 112,180 sq. ft.

Effects of overwater coverage on fish and fish habitat are discussed in Section 6.1.3.3.

Task Name	Start	Finish	Duration
Pier 2	**10/16/13**	**1/22/16**	**593 days**
Work Bridge (17,500 s.f.)	10/16/13	10/13/14	259 days
Pier 7	**9/29/14**	**1/23/17**	**606 days**
Work Bridge (18,500 s.f.)	9/29/14	10/13/15	272 days



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Note: This is a proposed schedule, so activity start and finish dates are likely to change.

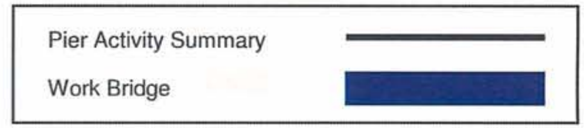
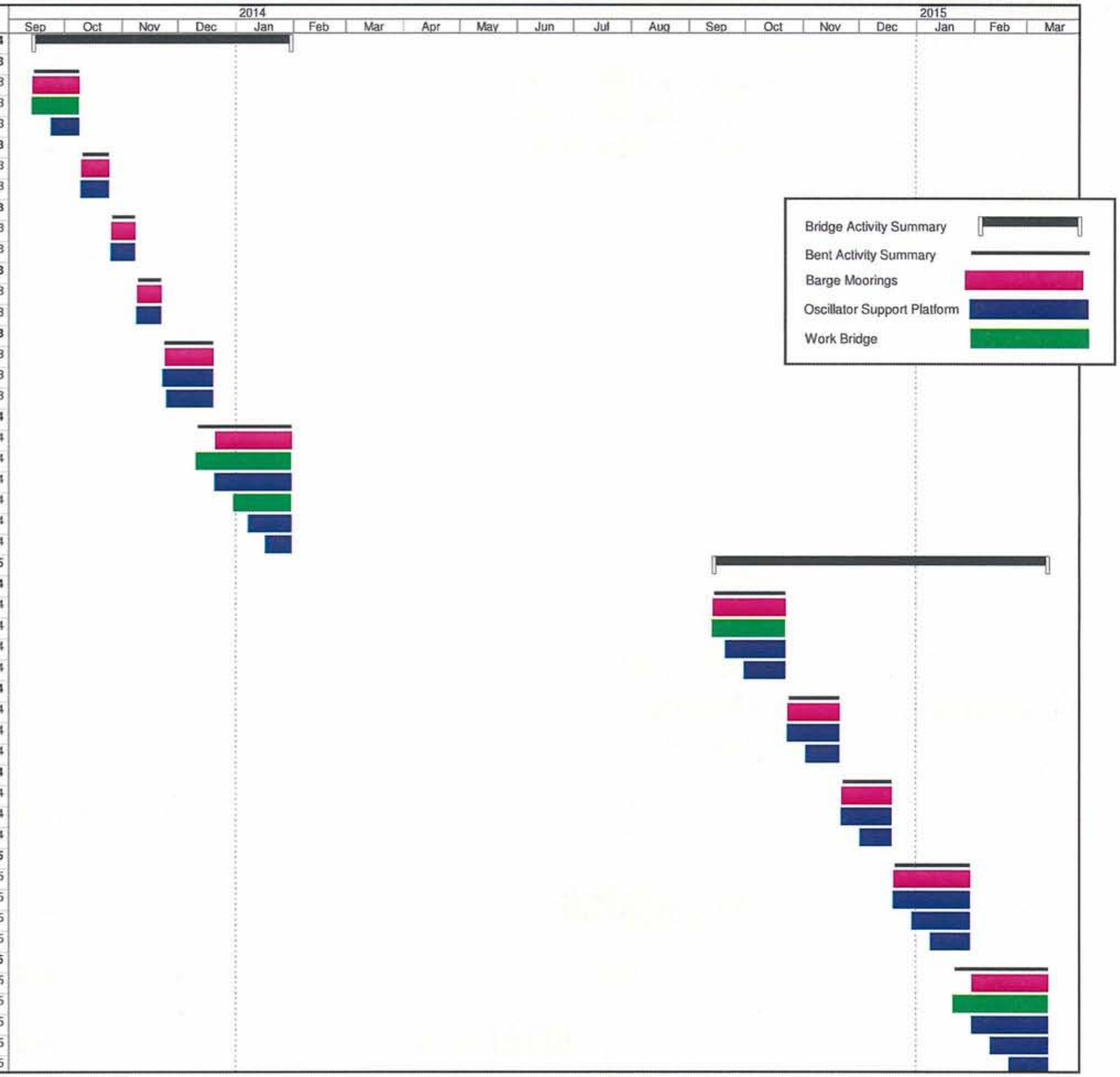


Figure 6-32. Sequencing of Temporary Over-Water Structures for Construction in Shallow Water in the Columbia River

Columbia River CROSSING

Task Name	Duration	Start	Finish
Widening of Existing Bridge	**111 days**	**9/15/13**	**1/30/14**
Bent 4	**20 days**	**9/15/13**	**10/8/13**
Two Medium Crane Barges (35,000 s.f.)	20 days	9/15/13	10/8/13
Work Bridge (3,360 s.f.)	20 days	9/15/13	10/8/13
Oscillator Support Platform (900 s.f.)	10 days	9/25/13	10/8/13
Bent 5	**10 days**	**10/11/13**	**10/24/13**
Two Medium Crane Barges (35,000 s.f.)	10 days	10/11/13	10/24/13
Oscillator Support Platform (900 s.f.)	10 days	10/11/13	10/24/13
Bent 6	**10 days**	**10/27/13**	**11/7/13**
Two Medium Crane Barges (35,000 s.f.)	10 days	10/27/13	11/7/13
Oscillator Support Platform (900 s.f.)	10 days	10/27/13	11/7/13
Bent 7	**10 days**	**11/10/13**	**11/21/13**
Two Medium Crane Barges (35,000 s.f.)	10 days	11/10/13	11/21/13
Oscillator Support Platform (900 s.f.)	10 days	11/10/13	11/21/13
Bent 8	**22 days**	**11/24/13**	**12/19/13**
Four Medium Crane Barges (70,000 s.f.)	22 days	11/24/13	12/19/13
Oscillator Support Platform 1 (900 s.f.)	22 days	11/24/13	12/19/13
Oscillator Support Platform 2 (900 s.f.)	20 days	11/26/13	12/19/13
Bent 9	**42 days**	**12/12/13**	**1/30/14**
Six Medium Crane Barges (105,000 s.f.)	33 days	12/22/13	1/30/14
Work Bridge 1 (2,240 s.f.)	42 days	12/12/13	1/30/14
Oscillator Support Platform 1 (900 s.f.)	33 days	12/22/13	1/30/14
Work Bridge 2 (2,240 s.f.)	25 days	1/1/14	1/30/14
Oscillator Support Platform 2 (900 s.f.)	17 days	1/9/14	1/30/14
Oscillator Support Platform 3 (900 s.f.)	10 days	1/18/14	1/30/14
Light Rail Transit/Multi-Use Plan Bridge	**142 days**	**9/15/14**	**3/12/15**
Bent 2	**30 days**	**9/15/14**	**10/22/14**
Four Medium Crane Barges (70,000 s.f.)	30 days	9/15/14	10/22/14
Work Bridge (2,960 s.f.)	30 days	9/15/14	10/22/14
Oscillator Support Platform 1 (900 s.f.)	23 days	9/22/14	10/22/14
Oscillator Support Platform 2 (900 s.f.)	15 days	10/2/14	10/22/14
Bent 3	**21 days**	**10/25/14**	**11/20/14**
Four Medium Crane Barges (70,000 s.f.)	21 days	10/25/14	11/20/14
Oscillator Support Platform 1 (900 s.f.)	21 days	10/25/14	11/20/14
Oscillator Support Platform 2 (900 s.f.)	13 days	11/4/14	11/20/14
Bent 4	**20 days**	**11/23/14**	**12/18/14**
Four Medium Crane Barges (70,000 s.f.)	20 days	11/23/14	12/18/14
Oscillator Support Platform 1 (900 s.f.)	20 days	11/23/14	12/18/14
Oscillator Support Platform 2 (900 s.f.)	12 days	12/3/14	12/18/14
Bent 5	**34 days**	**12/21/14**	**1/29/15**
Six Medium Crane Barges (105,000 s.f.)	34 days	12/21/14	1/29/15
Oscillator Support Platform 1 (900 s.f.)	34 days	12/21/14	1/29/15
Oscillator Support Platform 2 (900 s.f.)	26 days	12/31/14	1/29/15
Oscillator Support Platform 3 (900 s.f.)	18 days	1/10/15	1/29/15
Bent 6	**41 days**	**1/22/15**	**3/12/15**
Six Medium Crane Barges (105,000 s.f.)	32 days	2/1/15	3/12/15
Work Bridge (1,520 s.f.)	41 days	1/22/15	3/12/15
Oscillator Support Platform 1 (900 s.f.)	32 days	2/1/15	3/12/15
Oscillator Support Platform 2 (900 s.f.)	24 days	2/11/15	3/12/15
Oscillator Support Platform 3 (900 s.f.)	16 days	2/21/15	3/12/15

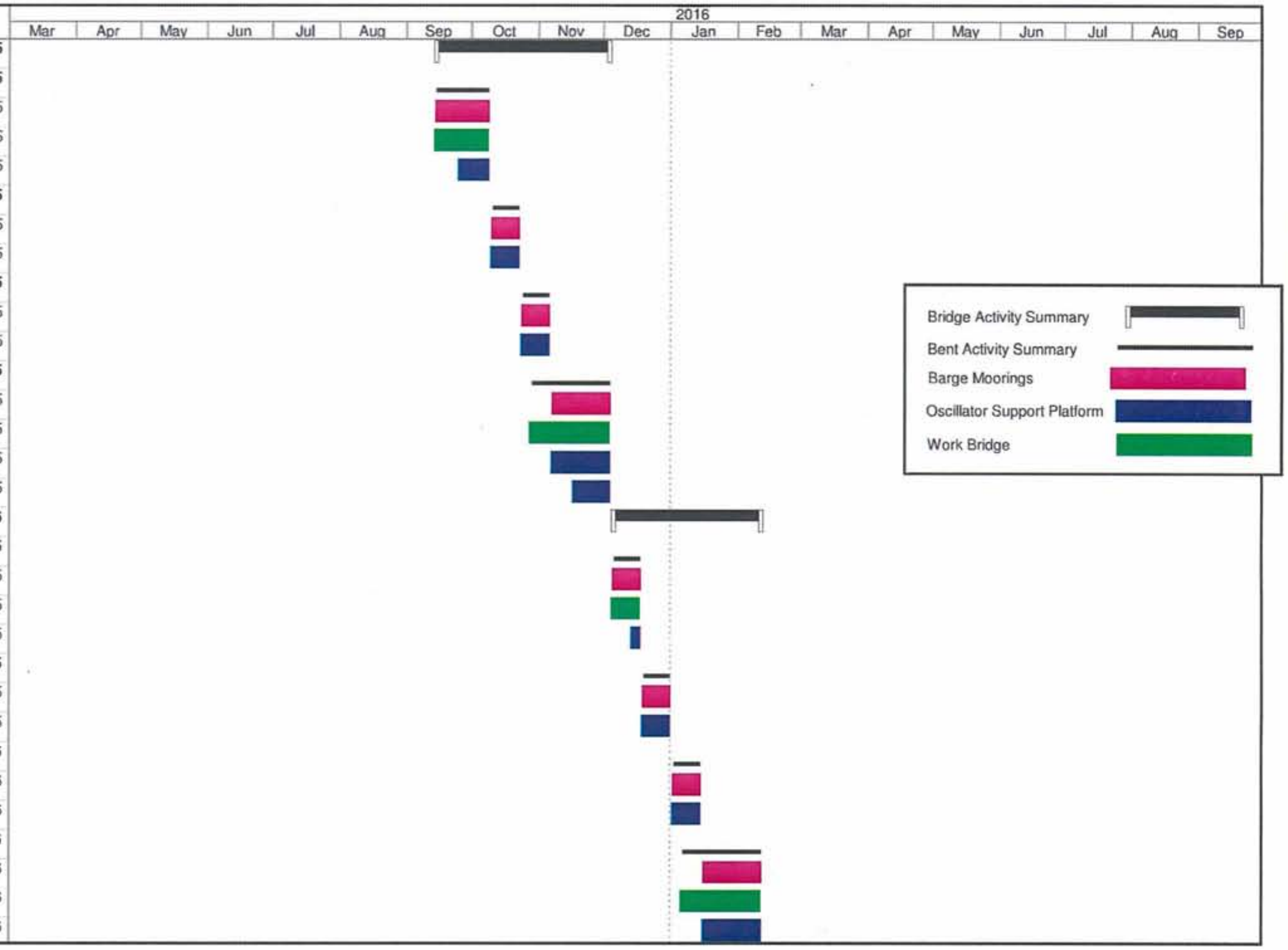


Conceptual Schedule Only, April 2010
Note: This is a proposed schedule, so activity dates are likely to change.

Figure 6-33. Sequencing of Temporary Overwater Structures for Construction in Shallow Water in North Portland Harbor

Columbia River CROSSING

Task Name	Duration	Start	Finish
Northbound Collector Distributor Ramp	**66 days**	**9/15/15**	**12/3/15**
Bent 6	**21 days**	**9/15/15**	**10/8/15**
Two Medium Crane Barges (35,000 s.f.)	21 days	9/15/15	10/8/15
Work Bridge (4,080 s.f.)	21 days	9/15/15	10/8/15
Oscillator Support Platform (900 s.f.)	10 days	9/26/15	10/8/15
Bent 7	**10 days**	**10/11/15**	**10/22/15**
Two Medium Crane Barges (35,000 s.f.)	10 days	10/11/15	10/22/15
Oscillator Support Platform (900 s.f.)	10 days	10/11/15	10/22/15
Bent 8	**12 days**	**10/25/15**	**11/5/15**
Two Medium Crane Barges (35,000 s.f.)	12 days	10/25/15	11/5/15
Oscillator Support Platform (900 s.f.)	12 days	10/25/15	11/5/15
Bent 9	**29 days**	**10/29/15**	**12/3/15**
Four Medium Crane Barges (70,000 s.f.)	20 days	11/8/15	12/3/15
Work Bridge 1 (2,240 s.f.)	29 days	10/29/15	12/3/15
Oscillator Support Platform 1 (900 s.f.)	20 days	11/8/15	12/3/15
Oscillator Support Platform 2 (900 s.f.)	12 days	11/18/15	12/3/15
Southbound Collector Distributor Ramp	**57 days**	**12/6/15**	**2/11/16**
Bent 2	**12 days**	**12/6/15**	**12/17/15**
Two Medium Crane Barges (35,000 s.f.)	12 days	12/6/15	12/17/15
Work Bridge (4,880 s.f.)	12 days	12/6/15	12/17/15
Oscillator Support Platform (900 s.f.)	3 days	12/15/15	12/17/15
Bent 3	**10 days**	**12/20/15**	**12/31/15**
Two Medium Crane Barges (35,000 s.f.)	10 days	12/20/15	12/31/15
Oscillator Support Platform (900 s.f.)	10 days	12/20/15	12/31/15
Bent 4	**12 days**	**1/3/16**	**1/14/16**
Two Medium Crane Barges (35,000 s.f.)	12 days	1/3/16	1/14/16
Oscillator Support Platform (900 s.f.)	12 days	1/3/16	1/14/16
Bent 5	**29 days**	**1/7/16**	**2/11/16**
Four Medium Crane Barges (70,000 s.f.)	20 days	1/17/16	2/11/16
Work Bridge (2,280 s.f.)	29 days	1/7/16	2/11/16
Oscillator Support Platform (900 s.f.)	20 days	1/17/16	2/11/16

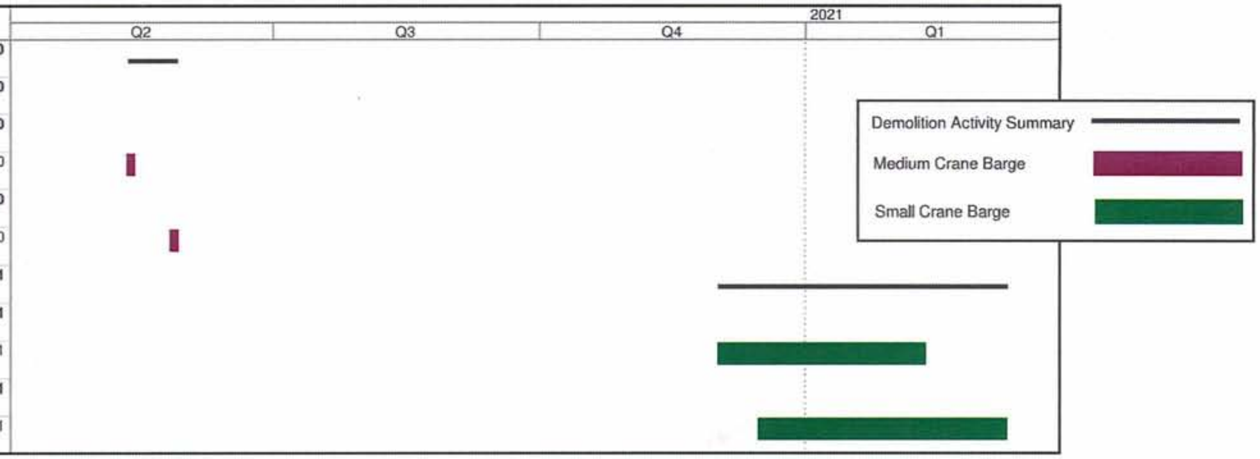


Conceptual Schedule Only, April 2010
Note: This is a proposed schedule, so activity dates are likely to change.

Figure 6-33 (Continued).
Sequencing of Temporary Overwater Structures for Construction in Shallow Water in North Portland Harbor

Columbia River CROSSING

Task Name	Duration	Start	Finish
Superstructure Demolition	**13 days**	**5/12/20**	**5/28/20**
Remove Spans	**13 days**	**5/12/20**	**5/28/20**
Span 9	**2 days**	**5/12/20**	**5/13/20**
Medium Crane Barge (10,500 s.f.)	2 days	5/12/20	5/13/20
Span 10	**2 days**	**5/27/20**	**5/28/20**
Medium Crane Barge (10,500 s.f.)	2 days	5/27/20	5/28/20
Substructure Demolition	**72 days**	**12/2/20**	**3/11/21**
Pier 10	**52 days**	**12/2/20**	**2/11/21**
Small Crane Barge (6,000 s.f.)	52 days	12/2/20	2/11/21
Pier 11	**62 days**	**12/16/20**	**3/11/21**
Small Crane Barge (6,000 s.f.)	62 days	12/16/20	3/11/21



Conceptual Schedule Only, April 2010
Note: This is a proposed schedule, so activity dates are likely to change.

Figure 6-34. Sequencing of Temporary Barges Used for Demolition in Shallow Water in the Columbia River

Columbia River CROSSING

Temporary Turbidity

The project will temporarily degrade shallow-water habitat by creating turbidity. Table 6-35 summarizes the activities likely to generate turbidity in shallow water.

Table 6-35. Activities Likely to Generate Turbidity in Shallow Water

Activity	Timing[a]	Location[b]	Likely Extent of Turbidity	Duration of Effect (hr/day)	Number of Work Days
Install temporary piles, impact methods	Mid Sept – Mid April	Adjacent to P2, P7 in CR Adjacent to 31 NPH shafts	~25 feet	< 0.66	~74 in CR 134 in NPH
Install temporary piles, vibratory methods	Year-round	Adjacent to P2, P7 in CR Adjacent to 31 NPH shafts	~25 feet	up to 24	~590 at P2 ~600 at P7 334 in NPH
Remove temporary piles, direct pull or vibratory	Year-round	Adjacent to P2, P7 in CR Adjacent to 31 NPH shafts	Minimal	up to 24	~590 at P2 ~600 at P7 334 in NPH
Installing steel casings to drill permanent shafts – vibratory hammer, oscillator, or rotator	Year-round	P7 in CR Adjacent to 31 NPH shafts	~25 feet	8 – 10	80 at P7 < 1 / NPH shaft
Drill and excavate permanent shafts	Year-round	P7 in CR Adjacent to 31 NPH shafts	None (contained)	n/a	80 at P7 ≤ 8 / NPH shaft
Operate stationary and moving barges in shallow water	Year-round	P7 in CR Adjacent to 31 NPH shafts Demo existing piers 10 and 11 in CR	<300 feet	numerous times per day	~600 at P7 ~640 in NPH
Debris removal (clamshell)	11/1 – 02/28	Potentially at 31 locations in NPH.	~300 feet (or as prescribed by permits)	4-6 hr/day, Up to 4x/day	Less than 7
Demolish existing Columbia River bridge piers (includes installation and demolition of cofferdams)	Year-round	Existing Piers 10 and 11 in CR	Minimal	8 – 10	~266

a All activities likely to take place throughout the four-year in-water construction period.
b CR = Columbia River; NPH = North Portland Harbor; P = Pier Complex.

General effects of turbidity are described in detail in Section 6.1.5.2. Turbidity will pose fairly limited impacts to shallow-water habitat, as the project will restrict the extent of turbidity to distances specified by regulatory permits (anticipated to be no more than 300 feet). In actuality, many of the activities will restrict the turbidity plume to far shorter distances than the anticipated 300-foot mixing zone (Table 6-35). Permits will also restrict the duration of each turbidity plume to approximately 4 to 6 hours.

Figure 4-1 and Figure 4-2 show when listed fish are present in the action area and could be exposed to this effect. The turbidity plumes may make discrete areas temporarily unavailable for foraging, rearing, holding, and migration, but only for short periods of time (as specified by the regulatory permits). Due to the high dilution capacity of the Columbia River and North Portland Harbor, the turbidity plumes are expected to disperse relatively quickly and within a short distance of the source. Both adult and juvenile fish will be able to use the abundant, similar-quality shallow-water habitat outside of the areas subject to high turbidity.

Underwater Noise

Impact pile driving will create elevated noise levels in North Portland Harbor and the Columbia River. Impact pile driving will occur in shallow water at Pier 2 and Pier 7 in the Columbia River, and at all new bents in North Portland Harbor. Impact pile driving at some of the other Columbia River piers and North Portland Harbor bents will extend into shallow-water habitat (Figure 6-1 through Figure 6-13).

The effect of high underwater noise levels on fish is described in greater detail in Section 6.1.1.1 and Appendix K. Table 6-9 and Table 6-10 outline the extent, duration, and timing of hydroacoustic effects, and Figure 4-1 and Figure 4-2 show when listed fish occur in this portion of the action area and could be exposed to elevated noise levels. Rearing and subyearling-migrant salmonids are more vulnerable to this effect due to their high level of dependence on nearshore habitat. However, all of the fish species addressed by this BA could potentially be exposed to this effect.

In summary, underwater noise will temporarily degrade shallow-water habitat, creating noise above the disturbance threshold in the Columbia River for a minimum of 858 m from the pile being driven and extending from RM 101 to 118 (RKm 163 to 190). In North Portland Harbor, noise will exceed the disturbance threshold for a minimum of 858 m from the pile being driven and extending from 3.5 miles (5,632 m) downstream of the project area to 1.9 miles (3,058 m) upstream of the project area (Figure 6-12 and Figure 6-13).

Additionally, in areas located within 5 to 446 m of pile driving at various piers in the Columbia River and North Portland Harbor, underwater noise is expected to temporarily exceed the injury threshold for fish (Figure 6-1 through Figure 6-11). These areas will be unsuitable for foraging, rearing, migrating, and holding because fish entering this area may potentially be killed or injured. Underwater noise may also create a temporary barrier to migration for both adults and juveniles when above the disturbance threshold in these areas during this time period (Caltrans 2009).

Vibratory pile driving is expected to create noise above ambient levels in shallow-water habitat at pier complex 2 and pier complex 7 in the Columbia River, at existing piers 10 and 11 in the Columbia River, and at 31 shafts in North Portland Harbor. Elevated noise levels are not expected to cause injury to fish in these areas; however, they could prompt avoidance of areas.

6.3.2 Deep-Water Habitat

Deep-water habitat (water greater than 20 feet deep) occurs only in the Columbia River. This section outlines the role of deep water as habitat for fish and provides an analysis of likely effects to fish in deep-water portions of the CRC action area.

6.3.2.1 Fish Distribution in Deep-Water Habitat

Listed fish will have mixed use of deep-water habitat in the action area. Typically, rearing and subyearling-migrant salmonids are highly dependent on shallow-water habitat in the upper estuary (Carter et al. 2009), including the action area, as described in Section 6.3.1.1; however, they do not occur exclusively in shallow water and are known to stray occasionally into the surface layer of deeper waters (Bottom et al. 2005).

Larger juvenile salmonid migrants of the yearling age class or older commonly use deep-water portions of the navigation channel in high numbers while actively outmigrating, taking advantage of higher velocities there (Carter et al. 2009), as described in Section 6.3.1.1.

Adult salmonids do not show any specific preference for deep-water habitat over shallow-water habitat (Bottom et al. 2005). While they generally migrate at mid-channel, they may be found at depths of 1 to 50 feet (NMFS 2006). They commonly use deep-water portions of the action area for foraging and hold in low-velocity areas of deep-water habitat (such as behind bridge piers).

Eulachon adults and juveniles are known to range at depths of greater than 50 feet and are likely to be present in deep-water portions of the action area (Hay and McCarter 2000).

Adult and subadult green sturgeon use waters at depths of 30 feet or less and also could be present in deep-water portions of the action area (73 FR 52084).

6.3.2.2 Effects to Fish in the CRC Action Area

The project will have both temporary and permanent impacts to deep-water habitat in the Columbia River. Impacts include physical loss of habitat, increase in overwater coverage, turbidity, and underwater noise.

Impacts to deep-water habitat will affect the following habitats, species and life stages of listed fish:

- Feeding, holding and migration habitat for juveniles and holding and migration habitat for adults of the following ESUs/DPSs: LCR coho; CR chum; SR sockeye; LCR, MCR, UCR, and SR steelhead; and LCR, UCR spring-run, SR fall-run, and SR spring/summer-run Chinook.
- Rearing habitat for juvenile Chinook (LCR, UCR spring-run, and UWR), LCR coho, LCR steelhead, and CR chum.
- Adult and subadult bull trout migration and holding habitat. (Because of the extremely low numbers of bull trout in this portion of the action area, risk of exposure to this effect is discountable.)
- Adult and subadult green sturgeon feeding and migration habitat. (Because of the extremely low numbers of green sturgeon in this portion of the action area, risk of exposure to this effect is discountable.)
- Adult and larval eulachon spawning and migration habitat.

Figures 4-1 and 4-2 show when these species are likely to be present in this portion of the action area and could be exposed to activities occurring in deep water. Since deep-water impacts will occur continually throughout the 4-year in-water construction period, as many as four migration cycles of salmon, steelhead, and eulachon could be exposed to these effects.

Physical Loss of Deep-Water Habitat

Table 6-36 summarizes the physical impacts to deep-water habitat in the Columbia River.

Table 6-36. Physical Impacts to Deep-Water Habitat in the Columbia River

Impact	Area	Time in Water
Temporary		
Work Platforms – Construction (P 3–6) [a]	3,870 sq. ft.	150–300 days each
Tower Cranes – Construction (P 2–7)	603 sq. ft.	350 days/crane
Barge Moorings – Construction (P 2–6)	226 sq. ft.	120 days/pier complex
Barge Moorings – Demolition (Existing Piers 2–9)	754 sq. ft.	40 days/pier complex
Coffer Dams – Demolition (Existing Piers 2–9)	52,500 sq. ft.	~317
Total Temporary Impact	**57,953 sq. ft.**	---
Permanent		
New Bridge Drilled Shafts (P 2–7)	6,361 sq. ft.	Permanent
Existing Bridges Piers to be Removed (Existing Piers 2–9)	-21,633 sq. ft.	Permanent
Total Permanent Impact	**-15,272 sq. ft.**	---

a P = Pier Complex

The structures shown in Table 6-36 will not all be in place at the same time. Figure 6-35 and Figure 6-36 provide the sequencing of in-water structures in deep-water habitat.

The project will lead to temporary physical loss of approximately 16,635 sq. ft. of deep-water habitat, consisting chiefly of coarse sand with a small proportion of gravel. Project elements responsible for temporary physical loss include the cofferdams and numerous temporary piles associated with in-water work platforms and moorings. The in-water portions of the new structures will result in the permanent physical loss of approximately 6,300 sq. ft. of deep-water habitat at pier complex 2 through 7 in the Columbia River. Demolition of the existing Columbia River piers will permanently restore about 21,000 sq. ft. of deep-water habitat. Overall, there will be a net permanent gain of about 15,000 sq. ft. of deep-water habitat in the Columbia River.

Although there will be a temporary net physical loss of deep-water habitat, this is not expected to have a significant impact on listed fish. None of the fish addressed by this BA are particularly dependent on deep-water habitat. The lost habitat is not rare or of particularly high quality, and there is abundant similar habitat in immediately adjacent areas of the Columbia River and for many miles both upstream and downstream. The lost habitat will represent a very small fraction (far less than 1 percent) of the remaining habitat available. Additionally, the in-water portions of the permanent and temporary in-water structures will occupy no more than about 1 percent of the width of the Columbia River. Therefore, the structures will not pose a physical barrier to migration. Due to the small size of the impact relative to the remaining habitat available, this effect will be insignificant.

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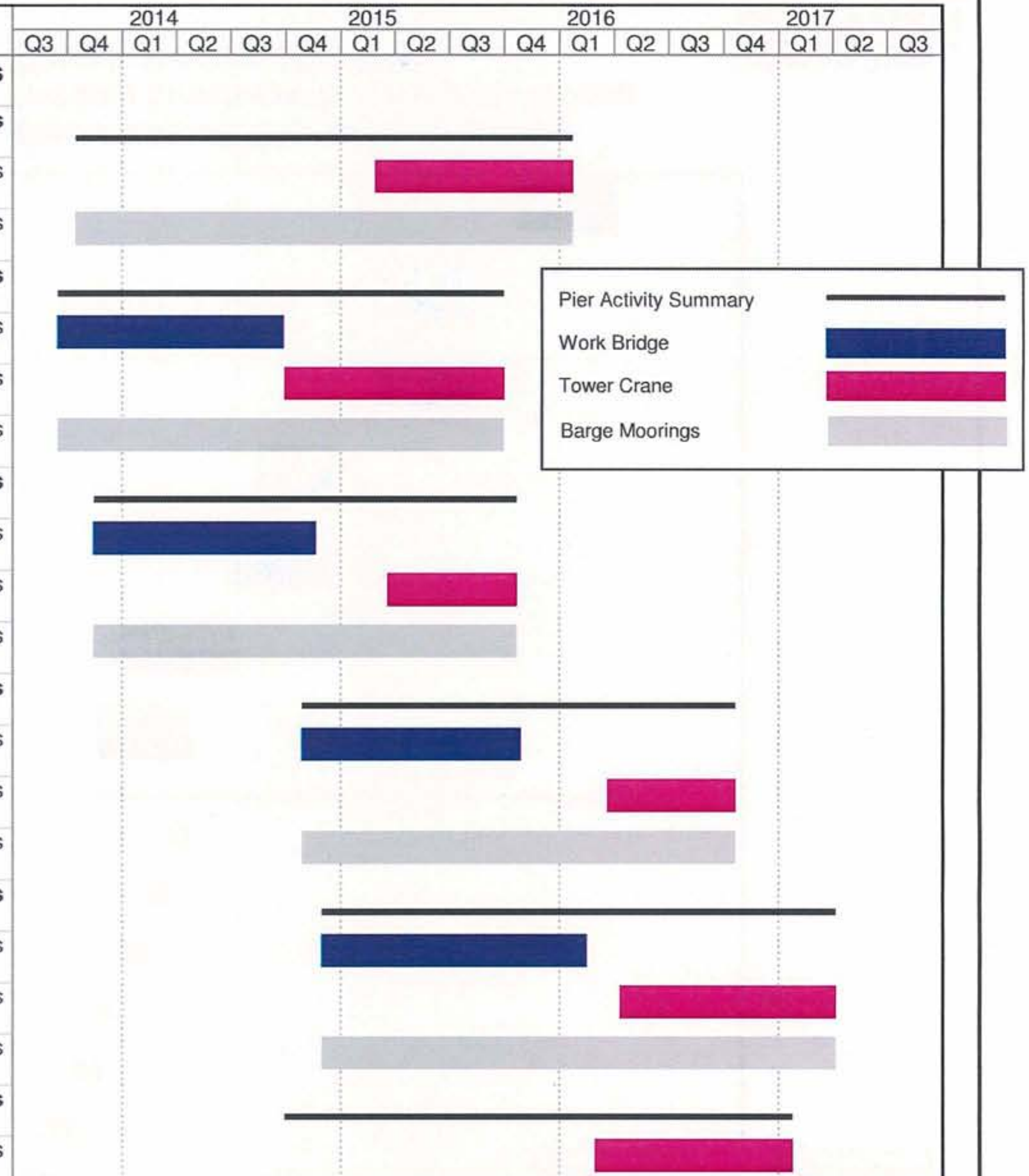
Task Name	Start	Finish	Duration
Bridge Construction Scenario 2/5/13	**9/16/13**	**4/5/17**	**928 days**
Pier 2	**10/16/13**	**1/22/16**	**593 days**
Tower Crane (Aprox. 100 s.f.)	2/27/15	1/22/16	236 days
Barge Moorings (Approx. 45 s.f.)	10/16/13	1/22/16	593 days
Pier 3	**9/16/13**	**9/29/15**	**532 days**
Work Bridge (Approx. 600 s.f.)	9/16/13	9/26/14	270 days
Tower Crane (Approx. 100 s.f.)	9/29/14	9/29/15	262 days
Barge Moorings (Approx. 45 s.f.)	9/16/13	9/29/15	532 days
Pier 4	**11/15/13**	**10/20/15**	**503 days**
Work Bridge (Approx. 600 s.f.)	11/15/13	11/19/14	264 days
Tower Crane (Approx. 100 s.f.)	3/20/15	10/20/15	153 days
Barge Moorings (Approx. 45 s.f.)	11/15/13	10/20/15	503 days
Pier 5	**10/29/14**	**10/19/16**	**516 days**
Work Bridge (Approx. 600 s.f.)	10/29/14	10/27/15	260 days
Tower Crane (Approx. 100 s.f.)	3/21/16	10/19/16	153 days
Barge Moorings (Approx. 45 s.f.)	10/29/14	10/19/16	516 days
Pier 6	**12/1/14**	**4/5/17**	**613 days**
Work Bridge (Approx. 600 s.f.)	12/1/14	2/15/16	315 days
Tower Crane (Approx. 100 s.f.)	4/11/16	4/5/17	258 days
Barge Moorings (Approx. 45 s.f.)	12/1/14	4/5/17	613 days
Pier 7	**9/29/14**	**1/23/17**	**606 days**
Tower Crane (Aprox. 100 s.f.)	2/29/16	1/23/17	236 days

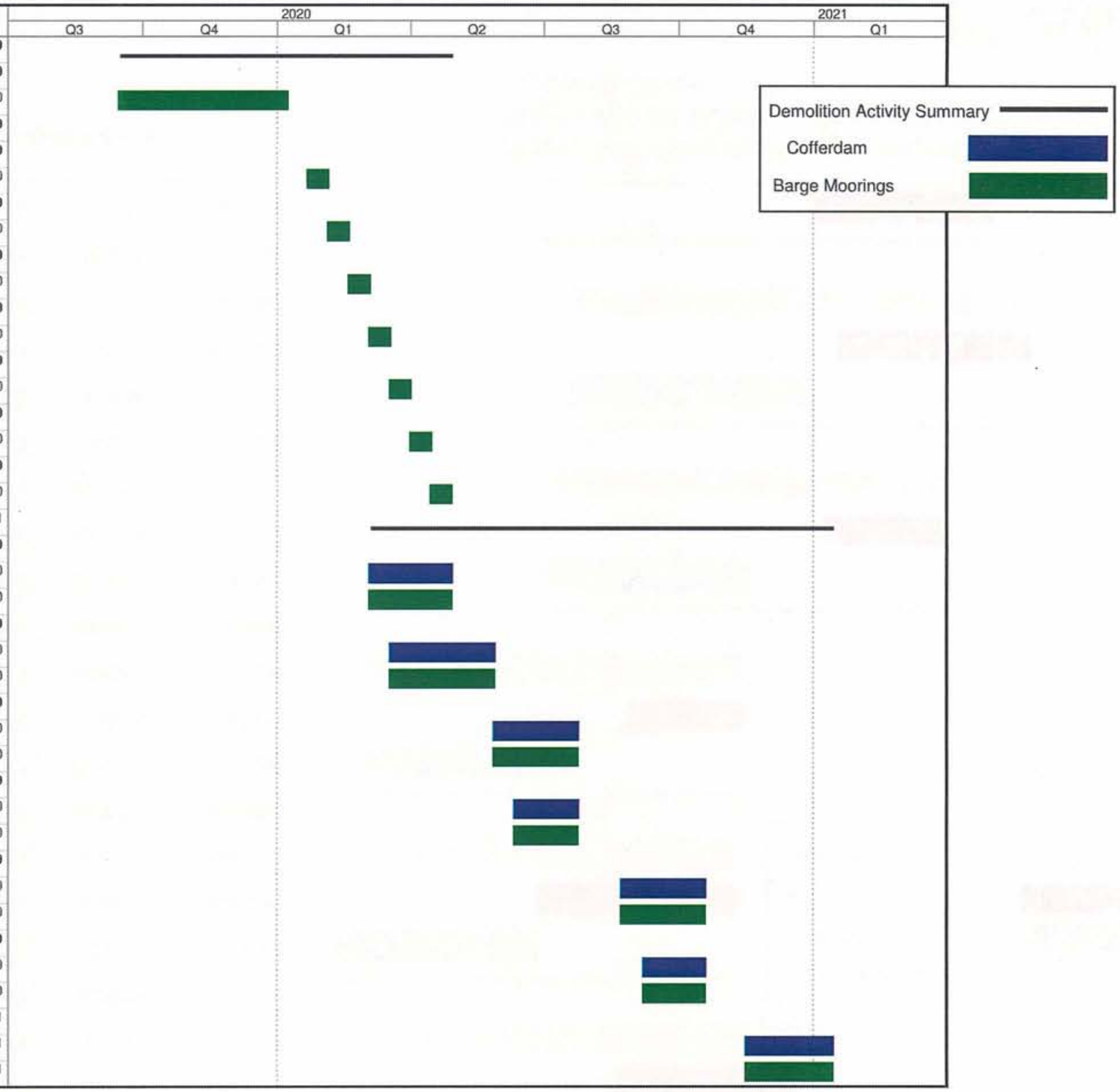


Conceptual Schedule Only, March 2010
Note: This is a proposed schedule, so activity start and finish dates are likely to change.

Figure 6-35. Sequencing of Temporary In-Water Structures for Construction in Deep Water in the Columbia River

Columbia River CROSSING

Task Name	Duration	Start	Finish
Superstructure Demolition	**163 days**	**9/16/19**	**4/29/20**
Demolish Lift Span Towers	**83 days**	**9/16/19**	**1/8/20**
Barge Moorings (~75 s.f.)	83 days	9/16/19	1/8/20
Remove Spans	**70 days**	**1/23/20**	**4/29/20**
Span 2	**10 days**	**1/23/20**	**2/5/20**
Barge Moorings (~56 s.f.)	10 days	1/23/20	2/5/20
Span 3	**10 days**	**2/6/20**	**2/19/20**
Barge Moorings (~56 s.f.)	10 days	2/6/20	2/19/20
Span 4	**10 days**	**2/20/20**	**3/4/20**
Barge Moorings (~56 s.f.)	10 days	2/20/20	3/4/20
Span 5	**10 days**	**3/5/20**	**3/18/20**
Barge Moorings (~56 s.f.)	10 days	3/5/20	3/18/20
Span 6	**10 days**	**3/19/20**	**4/1/20**
Barge Moorings (~56 s.f.)	10 days	3/19/20	4/1/20
Span 7	**10 days**	**4/2/20**	**4/15/20**
Barge Moorings (~56 s.f.)	10 days	4/2/20	4/15/20
Span 8	**10 days**	**4/16/20**	**4/29/20**
Barge Moorings (~56 s.f.)	10 days	4/16/20	4/29/20
Substructure Demolition	**226 days**	**3/5/20**	**1/14/21**
Pier 2	**40 days**	**3/5/20**	**4/29/20**
Cofferdam (7,500 s.f.)	40 days	3/5/20	4/29/20
Barge Moorings (50 s.f.)	40 days	3/5/20	4/29/20
Pier 3	**51 days**	**3/19/20**	**5/28/20**
Cofferdam (7,500 s.f.)	51 days	3/19/20	5/28/20
Barge Moorings (50 s.f.)	51 days	3/19/20	5/28/20
Pier 4	**41 days**	**5/29/20**	**7/24/20**
Cofferdam (7,500 s.f.)	41 days	5/29/20	7/24/20
Barge Moorings (50 s.f.)	41 days	5/29/20	7/24/20
Pier 6	**31 days**	**6/12/20**	**7/24/20**
Cofferdam (7,500 s.f.)	31 days	6/12/20	7/24/20
Barge Moorings (50 s.f.)	31 days	6/12/20	7/24/20
Pier 7	**41 days**	**8/24/20**	**10/19/20**
Cofferdam (7,500 s.f.)	41 days	8/24/20	10/19/20
Barge Mooring (50 s.f.)	41 days	8/24/20	10/19/20
Pier 8	**30 days**	**9/8/20**	**10/19/20**
Cofferdam (7,500 s.f.)	30 days	9/8/20	10/19/20
Barge Moorings (50 s.f.)	30 days	9/8/20	10/19/20
Pier 9	**43 days**	**11/17/20**	**1/14/21**
Cofferdam (7,500 s.f.)	43 days	11/17/20	1/14/21
Barge Moorings (50 s.f.)	43 days	11/17/20	1/14/21



Conceptual Schedule Only, April 2010
Note: This is a proposed schedule, so activity dates are likely to change.

Figure 6-36. Sequencing of Temporary In-Water Structures for Demolition in Deep Water in the Columbia River

Columbia River CROSSING

Increase in Overwater Coverage

The project will place several overwater structures in deep-water portions of the Columbia River. Temporary overwater structures include work platforms, tower cranes, and stationary barges. Permanent new overwater structures likely to have effects on fish include only the shaft caps on the Columbia River bridges. Table 6-37 quantifies the area and duration of project-related overwater structures in deep-water portions of the action area.

Table 6-37. Overwater Coverage in Deep-water Habitat in the Columbia River

Type	Area	Duration in Water (days)
Temporary		
Work Platforms for Drilling Shafts (P 3 – 6) [a]	112,000 sq. ft.	260 – 315 / platform
Tower Cranes (P 2 – 7)	2,400 sq. ft.	150 – 200 /crane
Barges for Construction (P 3 – 6)	106,432 sq. ft.	300 – 480 / complex
Barges for Demolition (Existing Piers 2 – 9)	14,350 sq. ft.	~320
Total Temporary Impact	**235,182 sq. ft.**	
Permanent		
Shaft Caps (P3 – P6)	56,813 sq. ft.	Permanent
Total Permanent Impact	**56,813 sq. ft.**	

a P = Pier Complex

The structures shown in Table 6-37 will not all be in place at the same time. Figure 6-37 and Figure 6-38 provide the sequencing of overwater structures in deep-water habitat.

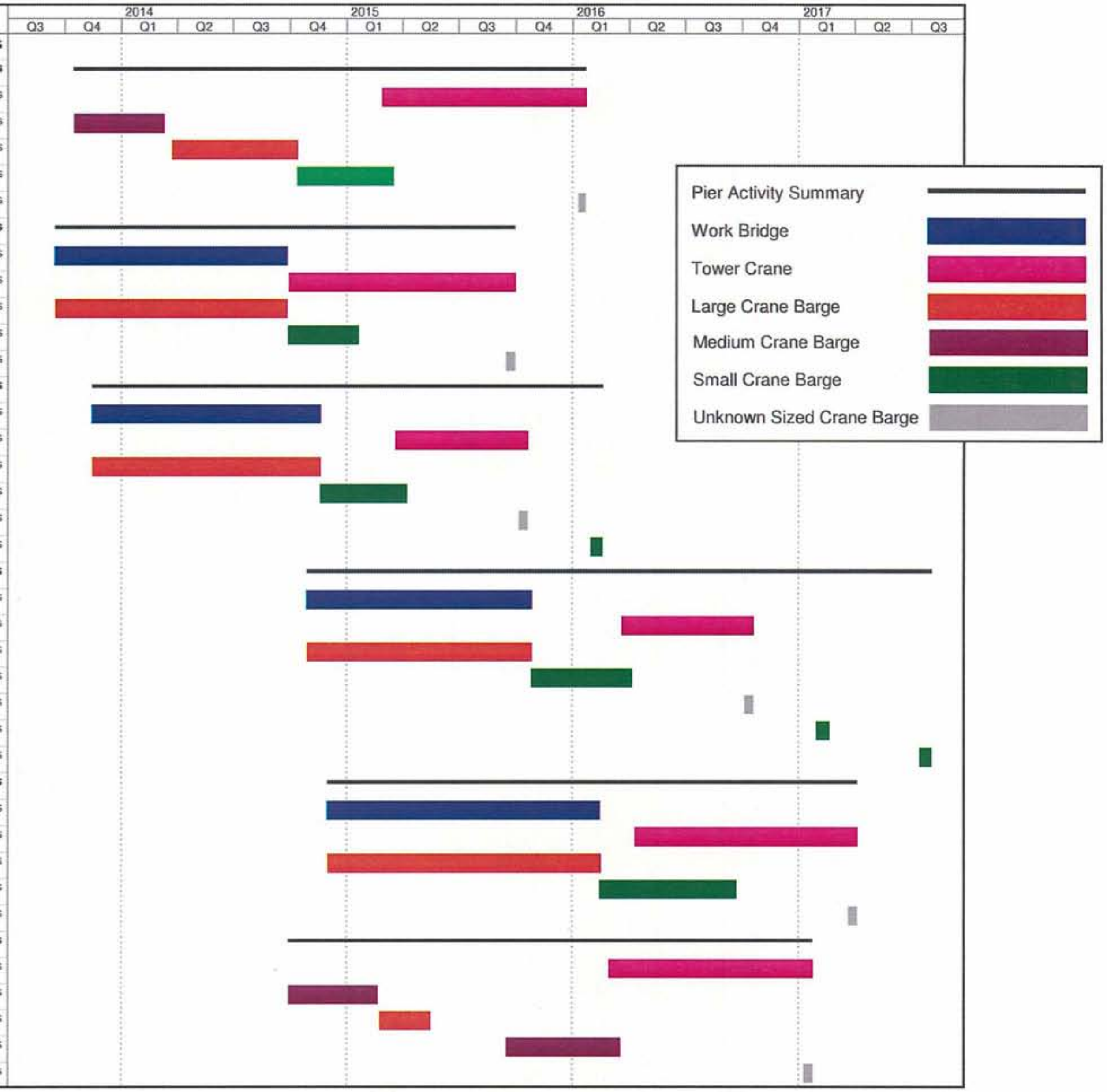
General effects of overwater coverage on fish are described in detail in Section 6.1.3. In summary, overwater coverage creates dense shade that may attract predators and may cause visual disorientation to juvenile fish, which may in turn result in delayed migration and increased vulnerability to predators. Of the juvenile fish that use the action area, rearing juveniles and subyearling-migrant salmonids are highly dependent on shallow-water habitat and therefore are less vulnerable to these effects in deep water. However, as these individuals are not restricted to the nearshore (Bottom et al. 2005), they may stray into deeper water, and there is a small chance of exposure to these effects. Larger juveniles of the yearling age class or older commonly use deep-water habitat during migration, and therefore are likely to be exposed to these effects.

Of the shade sources in the action area, the barges, work platforms, and tower cranes (Table 6-37) are temporary sources of shade that could create a sharp light-dark interface likely to prompt these effects.

The existing and proposed bridge spans in the Columbia River are more than 30 feet above the water surface and are therefore not likely to create dense shade on the water surface. For this reason, shade cast by these structures is unlikely to affect fish.

The shaft caps of the proposed Columbia River structures are at the water line and could create a net gain of permanent new dense shade (approximately 57,000 sq. ft.) in deep water.

Task Name	Start	Finish	Duration
Bridge Construction Scenario 2/5/13	**9/16/13**	**8/4/17**	**1015 days**
Pier 2	**10/16/13**	**1/22/16**	**593 days**
Tower Crane (400 s.f.)	2/27/15	1/22/16	236 days
Medium Crane Barge (10,500 s.f.)	10/16/13	3/11/14	104 days
Large Crane Barge (30,000 s.f.)	3/24/14	10/13/14	145 days
Medium and Small Crane Barges (16,500 s.f.)	10/14/14	3/19/15	112 days
Unknown Sized Crane Barge	1/11/16	1/22/16	9 days
Pier 3	**9/16/13**	**9/29/15**	**532 days**
Work Bridge (29,000 s.f.)	9/16/13	9/26/14	270 days
Tower Crane (400 s.f.)	9/29/14	9/29/15	262 days
Large Crane Barge (30,000 s.f.)	9/16/13	9/26/14	269 days
Small Crane Barge (6,000 s.f.)	9/29/14	1/21/15	82 days
Unknown Sized Crane Barge	9/16/15	9/29/15	10 days
Pier 4	**11/15/13**	**2/19/16**	**591 days**
Work Bridge (29,000 s.f.)	11/15/13	11/19/14	264 days
Tower Crane (400 s.f.)	3/20/15	10/20/15	153 days
Large Crane Barge (30,000 s.f.)	11/15/13	11/19/14	263 days
Small Crane Barge (6,000 s.f.)	11/20/14	4/9/15	100 days
Unknown Sized Crane Barge	10/7/15	10/20/15	10 days
Small Crane Barge (6,000 s.f.)	2/1/16	2/19/16	15 days
Pier 5	**10/29/14**	**8/4/17**	**723 days**
Work Bridge (29,000 s.f.)	10/29/14	10/27/15	260 days
Tower Crane (400 s.f.)	3/21/16	10/19/16	153 days
Large Crane Barge (30,000 s.f.)	10/29/14	10/27/15	259 days
Small Crane Barge (6,000 s.f.)	10/28/15	4/8/16	117 days
Unknown Sized Crane Barge	10/6/16	10/19/16	10 days
Small Crane Barge (6,000 s.f.)	1/31/17	2/20/17	15 days
Small Crane Barge (6,000 s.f.)	7/17/17	8/4/17	15 days
Pier 6	**12/1/14**	**4/5/17**	**613 days**
Work Bridge (29,000 s.f.)	12/1/14	2/15/16	315 days
Tower Crane (400 s.f.)	4/11/16	4/5/17	258 days
Large Crane Barge (30,000 s.f.)	12/1/14	2/15/16	316 days
Small Crane Barge (6,000 s.f.)	2/16/16	9/23/16	158 days
Unknown Sized Crane Barge	3/23/17	4/5/17	10 days
Pier 7	**9/29/14**	**1/23/17**	**606 days**
Tower Crane (400 s.f.)	2/29/16	1/23/17	236 days
Medium Crane Barge (10,500 s.f.)	9/29/14	2/20/15	104 days
Large Crane Barge (30,000 s.f.)	2/23/15	5/15/15	60 days
Medium Crane Barge (10,500 s.f.)	9/16/15	3/18/16	132 days
Unknown Sized Crane Barge	1/10/17	1/23/17	10 days

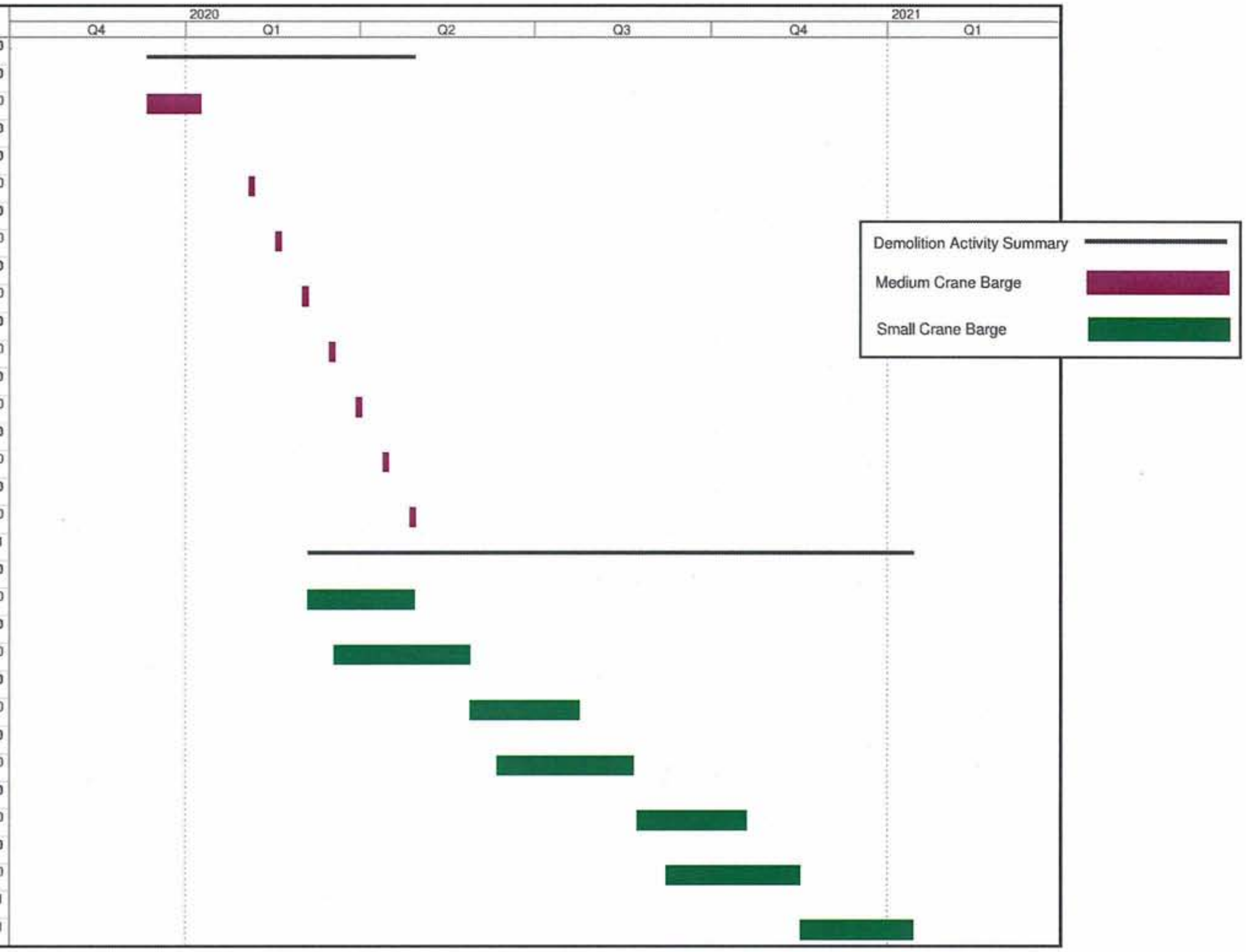


Conceptual Schedule Only, March 2010
Note: This is a proposed schedule, so activity start and finish dates are likely to change.

Figure 6-37. Sequencing of Temporary Over-Water Structures for Construction in Deep Water in the Columbia River

Columbia River CROSSING

Task Name	Duration	Start	Finish
Superstructure Demolition	**100 days**	**12/12/19**	**4/29/20**
Demolish Lift Span Towers	**20 days**	**12/12/19**	**1/8/20**
Two Medium Crane Barges (21,000 s.f.)	20 days	12/12/19	1/8/20
Remove Spans	**62 days**	**2/4/20**	**4/29/20**
Span 2	**2 days**	**2/4/20**	**2/5/20**
Medium Crane Barge (10,500 s.f.)	2 days	2/4/20	2/5/20
Span 3	**2 days**	**2/18/20**	**2/19/20**
Medium Crane Barge (10,500 s.f.)	2 days	2/18/20	2/19/20
Span 4	**2 days**	**3/3/20**	**3/4/20**
Medium Crane Barge (10,500 s.f.)	2 days	3/3/20	3/4/20
Span 5	**2 days**	**3/17/20**	**3/18/20**
Medium Crane Barge (10,500 s.f.)	2 days	3/17/20	3/18/20
Span 6	**2 days**	**3/31/20**	**4/1/20**
Medium Crane Barge (10,500 s.f.)	2 days	3/31/20	4/1/20
Span 7	**2 days**	**4/14/20**	**4/15/20**
Medium Crane Barge (10,500 s.f.)	2 days	4/14/20	4/15/20
Span 8	**2 days**	**4/28/20**	**4/29/20**
Medium Crane Barge (10,500 s.f.)	2 days	4/28/20	4/29/20
Substructure Demolition	**226 days**	**3/5/20**	**1/14/21**
Pier 2	**40 days**	**3/5/20**	**4/29/20**
Small Crane Barge (6,000 s.f.)	40 days	3/5/20	4/29/20
Pier 3	**51 days**	**3/19/20**	**5/28/20**
Small Crane Barge (6,000 s.f.)	51 days	3/19/20	5/28/20
Pier 4	**41 days**	**5/29/20**	**7/24/20**
Small Crane Barge (6,000 s.f.)	41 days	5/29/20	7/24/20
Pier 6	**51 days**	**6/12/20**	**8/21/20**
Small Crane Barge (6,000 s.f.)	51 days	6/12/20	8/21/20
Pier 7	**41 days**	**8/24/20**	**10/19/20**
Small Crane Barge (6,000 s.f.)	41 days	8/24/20	10/19/20
Pier 8	**50 days**	**9/8/20**	**11/16/20**
Small Crane Barge (6,000 s.f.)	50 days	9/8/20	11/16/20
Pier 9	**43 days**	**11/17/20**	**1/14/21**
Small Crane Barge (6,000 s.f.)	43 days	11/17/20	1/14/21



Conceptual Schedule Only, April 2010
Note: This is a proposed schedule, so activity dates are likely to change.

Figure 6-38. Sequencing of Temporary Barges Used for Demolition in Deep Water in the Columbia River

Neither the temporary nor the permanent structures will create a swath of dense shade completely spanning deep-water habitat. Therefore, even if these structures were to create a shadow line that juvenile salmonids avoid crossing during daylight hours, juveniles could simply circumvent the shadow, resulting in no measurable delay to migration. Nighttime migration would be unaffected. Larval eulachon do not have volitional movement and are therefore not subject to visual disorientation or migration delays.

The increase in the shade footprint increases the amount of suitable habitat for predators and therefore could presumably increase the number of predators in this portion of the action area. This could potentially cause a temporary and/or permanent increase in predation rates on juveniles, although it is not possible to quantify the extent of this effect. All of the juveniles (see Figure 4-2) that use this portion of the action area could potentially be exposed to this effect.

Although it is impossible to quantify the extent to which increased shade may affect predation rates or cause visual disorientation in juveniles, it is possible to estimate the physical extent and duration of the effect. This effect will occur both when the structures are present in the water (Figure 6-37 and Figure 6-38) and during the timing of juvenile fish presence in this portion of the action area (see Figure 4-2).

Turbidity

The project will temporarily degrade deep-water habitat by creating turbidity. Table 6-38 summarizes the activities likely to generate turbidity in deep water.

Table 6-38. Activities Likely to Generate Turbidity in Deep Water in the Columbia River

Activity	Timing[a]	Location[b]	Likely Extent of Turbidity	Duration of Effect (hr/day)	Number of Work Days
Install temporary piles, impact methods	9/15 – 4/15	Adjacent to P 2 – 7	~25 feet	0.66	~138
Install temporary piles, vibratory methods	Year-round	Adjacent to P 2 – 7	~25 feet	up to 24	continually over ~928
Remove temporary piles, direct pull or vibratory	Year-round	Adjacent to P 2 -- 7	Minimal	up to 24	continually over ~928
Install steel casings to drill permanent shafts – vibratory hammer, oscillator, or rotator	Year-round	Adjacent to P 2 – 7	~25 feet	8 – 10	60 – 80 days / pier complex
Drill and excavate permanent shafts	Year-round	Adjacent to P 2 – 7	None (contained)	N/A	60 – 80 days / pier complex
Demolish existing Columbia River bridge piers (includes installation and demolition of cofferdams)	Year-round	Existing Piers 2 – 9	Minimal	8 – 10	~320

a All activities likely to take place throughout the 4-year in-water construction period.
b CR = Columbia River; P = Pier Complex

General effects of turbidity are described in detail in Section 6.1.5.2. In summary, turbidity will pose fairly limited impacts to deep-water habitat, as the project will restrict the extent of turbidity to distances specified by regulatory permits. It is anticipated that the regulatory permits will specify a mixing zone of no more than 300 feet. In actuality, many of the activities will restrict the turbidity plume to far shorter distances (Table 6-38). Permits will also restrict the duration of each turbidity plume to approximately 4 to 6 hours at a time.

The turbidity plumes may make discrete areas temporarily unavailable for foraging, holding and migration, but only for short periods of time (as specified by the regulatory permits). Due to the high dilution capacity of the Columbia River, turbidity plumes are expected to disperse relatively quickly and within a short distance of the source. Due to the large size of the water body relative to the small size of the turbidity plume, fish are not likely to become trapped in turbid water. Fish will be able to use the abundant turbidity refugia in deep-water habitat outside of the areas subjected to high turbidity.

Both adult and juvenile fish could be exposed to this effect. Exposure could occur during the overlap of turbidity-generating activities (Table 6-38, Figure 6-35, and Figure 6-36) with the timing of fish presence in this portion of the action area (see Figure 4-1 and 4-2).

Underwater Noise

Both vibratory and impact pile driving will create elevated noise levels in deep-water habitats in the Columbia River. The effect of high underwater noise levels is outlined in greater detail in Section 6.1.1.1 and Appendix K.

Impact pile driving will occur in deep-water portions of the Columbia River at Piers 2 through 7. (Note that pier complexes 2 and 7 occur partially in shallow water and partially in deep water.) Essentially all of the deep-water habitat in the project area will be exposed to elevated noise levels due to impact pile driving at various times, depending on the size and type of pile used and whether or not a noise attenuation device is in place.

In summary, underwater noise from impact pile driving will temporarily degrade deep-water habitat, creating noise above the disturbance threshold in deep-water areas of the Columbia River for a minimum of 858 m from the pile and extending from RM 101 to 118 (RKm 163 to 190). Figure 6-12 and Figure 6-13 show the extent of noise that exceeds the disturbance threshold. Figure 6-14, Table 6-9, and Table 6-10 show the timing and duration of this effect.

Additionally, in areas located within 5 to 446 m of pile driving at various piers in the Columbia River, underwater noise is expected to exceed the injury threshold for fish. Figure 6-1 through Figure 6-11 show the extent of noise that exceeds the injury threshold. Figure 6-14, Table 6-9, and Table 6-10 show the timing and duration of this effect. These areas will be unsuitable for foraging, migrating, and holding because fish entering this area may potentially be killed or injured. Underwater noise may also create a temporary barrier to migration for both adults and juveniles in these areas during this time period.

Vibratory pile driving is expected to create noise above ambient levels in deep-water habitat at pier complex 2 through 7 in the Columbia River and at existing Piers 2 through 9 in the Columbia River. Elevated noise levels are not expected to cause injury to fish in these areas; however, they could prompt avoidance of the areas.

6.3.3 Riparian Habitat

In North Portland Harbor and the Columbia River, effects to riparian habitat will be negligible, as there is very little functioning riparian vegetation in the action area. The project will revegetate disturbed shoreline areas, resulting in a net benefit to riparian habitat in the long term. It has not yet been determined exactly where replanting will take place. However, it is anticipated that replanting will occur on or adjacent to the current sites of the trees where practicable. In any case, the number, type, and size of the replanted trees will be selected to comply with standards outlined in the City of Portland and City of Vancouver tree ordinances.

In Oregon, the project will remove three deciduous trees, all with trunks less than 1 foot in diameter, from the riparian zone on the south bank of the Columbia River. The project will also remove two deciduous ornamental trees from the riparian zone adjacent to North Portland Harbor. These trees are located in a landscaped setting and have trunks of approximately 1 foot in diameter. In Washington, 10 trees with trunks less than 1 foot in diameter will be removed from the riparian zone on the north shore of the Columbia River.

In general, removal of trees from riparian areas results in a reduction of shade in the water column and a concurrent increase in water temperature. However, in the case of the CRC project, only approximately 15 trees will be removed from the Columbia River/North Portland Harbor riparian area. This represents an extremely small amount of shaded water (less than 10,000 sq. ft., patchily distributed among at least three locations) relative to the thousands of acres of unshaded water located immediately adjacent to the area from which trees will be removed. Because of the small size of the shaded area relative to the large volume of water and because of the high current velocity in these water bodies, it is unlikely that these fifteen riparian trees create enough shade to measurably decrease water temperatures in the water column. Thus, the loss of these trees is expected to cause only negligible effects to water temperature, if any.

Additionally, removal of trees from riparian areas may reduce the potential for large woody debris recruitment in a watershed over the long term. However, given the large size of the lower Columbia system and the thousands of remaining riparian trees in this area, removal of 15 trees will not measurably decrease the potential for long-term large woody debris recruitment in the action area or in the lower Columbia system overall.

There will be no excavation, vegetation clearing, or removal of trees from the Columbia Slough riparian area. Therefore, the project will have no effect on Columbia Slough riparian habitat.

The project will not remove any trees from the Burnt Bridge Creek riparian area.

6.3.4 Hydraulic Shadowing

The project will cause both permanent and temporary increases in hydraulic shadowing in the Columbia River and North Portland Harbor. In-water work structures (work platforms, work platforms, tower cranes, oscillator support platforms, and cofferdams) are project elements that will cause temporary increases in hydraulic shadowing. The in-water elements of the new structures (bridge piers and shafts) will permanently increase hydraulic shadowing in North Portland Harbor and the Columbia River.

Figure 6-39 shows the current hydraulic footprint of the existing structures at Columbia River for the 100-year event. In the Columbia River, the hydraulic shadow extends 200 to 1,100 feet downstream of the piers, with velocities in the shadow ranging from 0 to 3 feet per second (fps). The hydraulic footprint was not modeled for the existing North Portland Harbor structures.

Figure 6-40 and Figure 6-41 show the predicted post-project hydraulic footprint for the 100-year event in the Columbia River and North Portland Harbor. In the Columbia River, the hydraulic shadow of the completed structures is expected to increase significantly compared to that of the existing structures, extending up to 1,600 feet downstream of each pier, with velocities in the shadow ranging from 0 to 3 fps. Although the hydraulic shadow was not modeled at the existing North Portland Harbor structures, it is expected to increase in length because of the increase in the number of shafts and the width of the structures. The hydraulic shadow of the completed North Portland Harbor structures is also expected to extend up to approximately 400 feet downstream of each pier, with velocities in the shadow ranging from 0 to 2 fps.

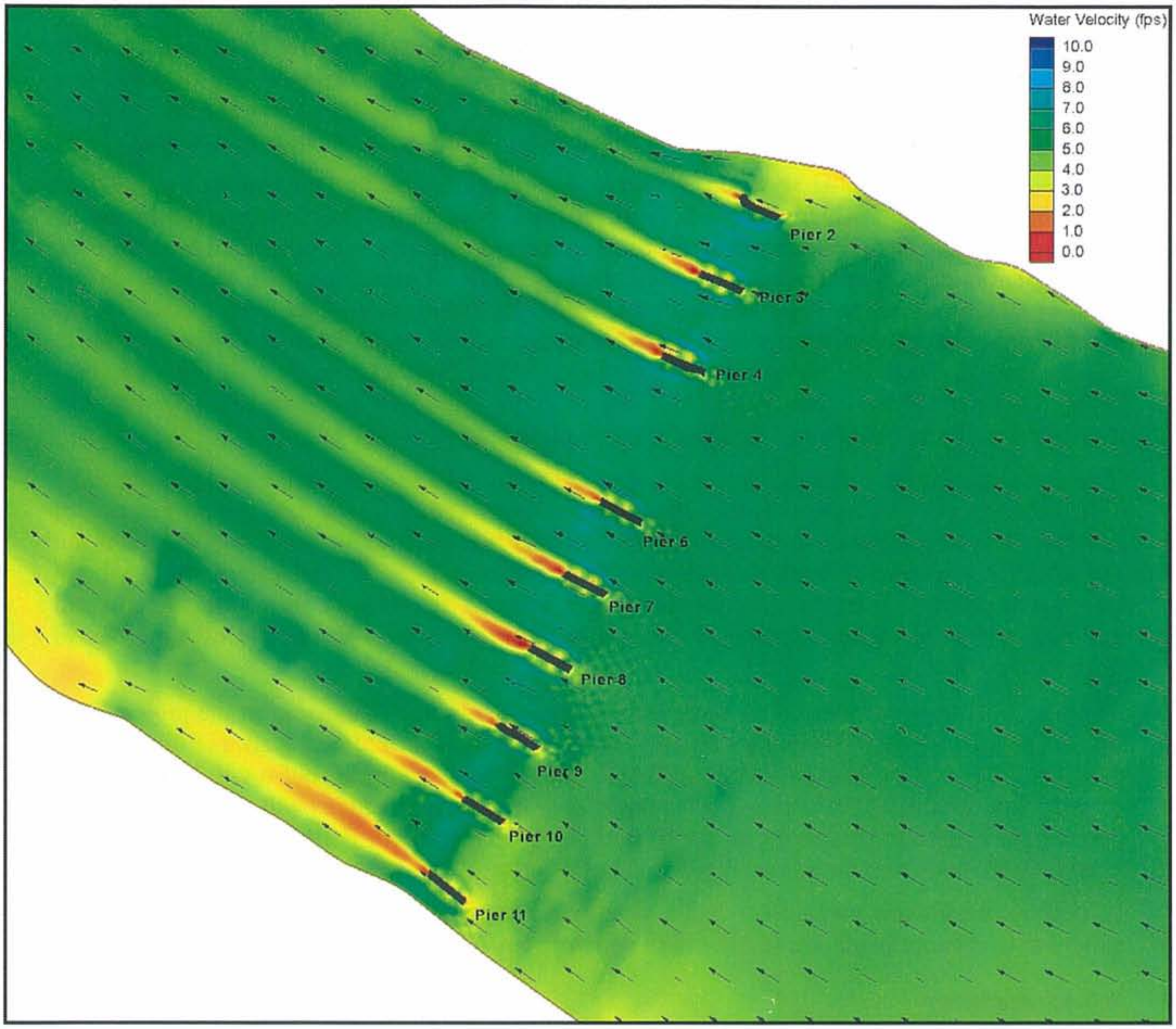
The modeling for the Columbia River bridges in Figure 6-40 uses an earlier design with three sets of bridge piers with up to twelve drilled shafts each. The proposed design now consists of only two sets of piers, with only nine drilled shafts per pier. At present, the design team has not yet revised the hydraulics analysis for the two-pier structure. In lieu of this information, we will continue to use data from the three-pier hydraulics analysis. Because the three-pier scenario will result in a larger hydraulic shadow, it is assumed that this is an overestimate of the effect of hydraulic shadowing.

In-water work structures will also temporarily increase hydraulic shadowing in the project area. No hydraulic analysis of temporary in-water work structures (cofferdams, work platforms, work bridges, tower cranes, and oscillator support platforms) was performed, but it will be completed prior to construction. At this time, it is assumed only that these structures will cause a temporary increase in hydraulic shadowing in the Columbia River and North Portland Harbor during the time they are present in the water (Figure 6-42 and Figure 6-31).

Hydraulic shadowing may affect listed fish by creating low velocity eddies that have the potential to increase predation and interfere with movement patterns.

6.3.4.1 Predation

In general, hydraulic shadowing has the potential to harm fish by creating low-velocity areas or eddies that enhance the foraging success of predaceous fish and birds. While all age classes of juvenile salmonids are vulnerable to predation, the greatest risk may be for subyearling salmonids (Pribyl et al. 2004). Yearling salmon move quickly and migrate when they are of a size that reduces vulnerability to predators. In contrast, subyearling salmon are slower and are of a size that increases their vulnerability to predation (Gray and Rondorf 1986). Additionally subyearling salmonids are highly dependent on low-velocity areas for rearing and resting. This overlaps with the preferred habitat type of northern pikeminnow, smallmouth bass, largemouth bass, and walleye (Pribyl et al. 2004), which are chief predators of juvenile salmon in the lower Columbia River (Gray and Rondorf 1986). Predation on juvenile salmonids by fish generally occurs at velocities of 4 fps or less (NMFS 2008g).



Source: CRC Hydraulic and Scour Parameters Report 2008

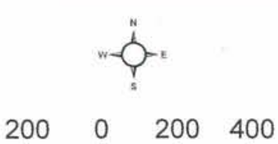
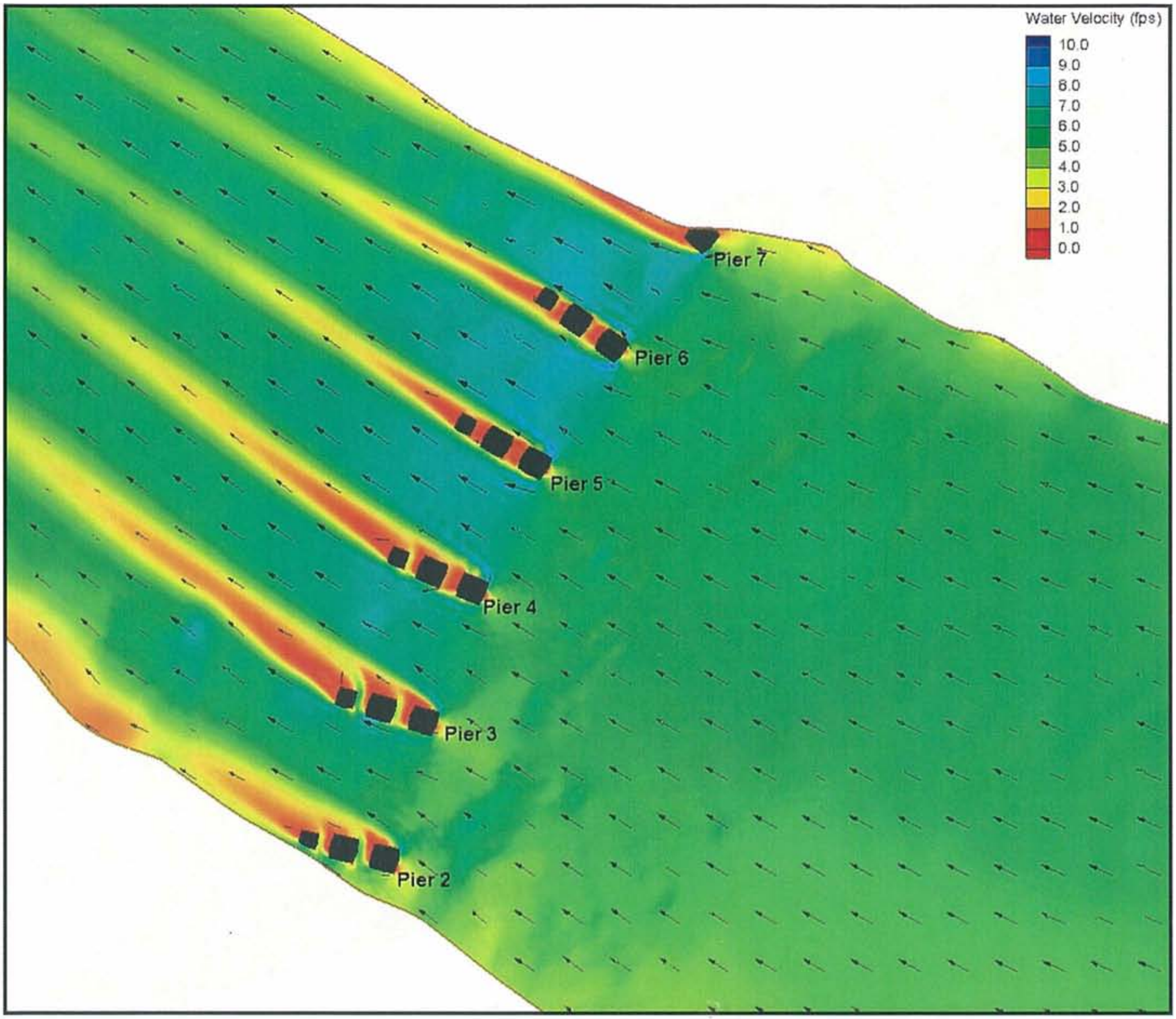


Figure 6-39. Velocity Vector Plot of Existing Structures in the Columbia River for 100-Year Flood

Columbia River CROSSING



Source: CRC Hydraulic and Scour Parameters Report 2008

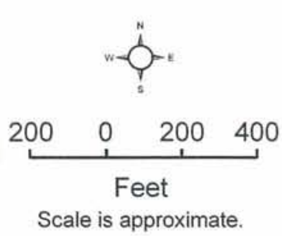
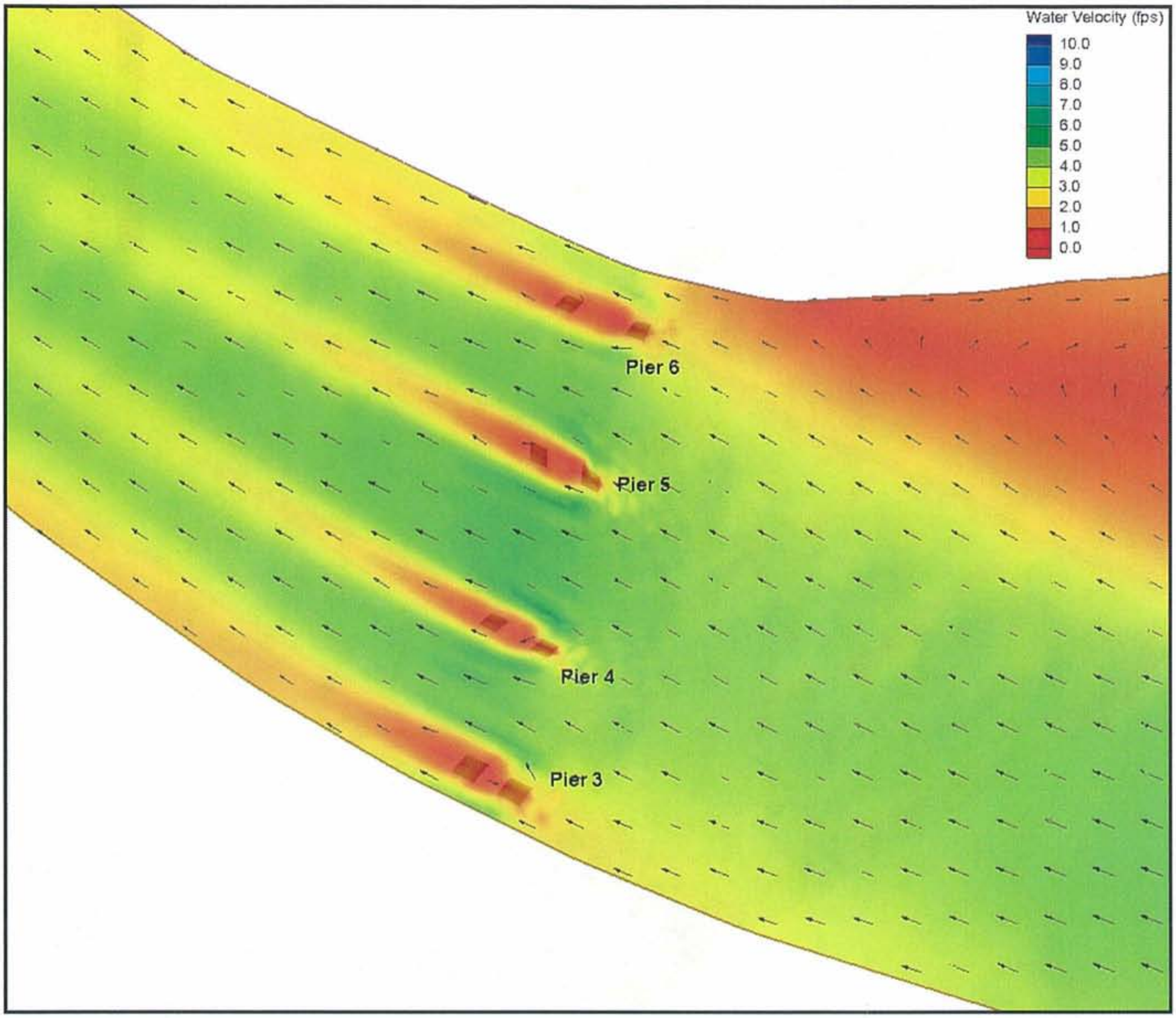


Figure 6-40. Velocity Vector Plot of Proposed Structures in the Columbia River for 100-Year Flood

Columbia River CROSSING



Source: CRC Hydraulic and Scour Parameters Report 2008

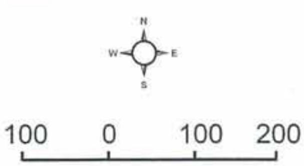


Figure 6-41. Velocity Vector Plot of Proposed Structures in the North Portland Harbor for 100-Year Flood

Columbia River CROSSING

Task Name	Start	Finish	Duration
Bridge Construction Scenario 2/5/13	**9/16/13**	**4/5/17**	**928 days**
Pier 2	**10/16/13**	**1/22/16**	**593 days**
Work Bridge (Approx. 350 s.f.)	10/16/13	10/13/14	259 days
Tower Crane (Aprox. 100 s.f.)	2/27/15	1/22/16	236 days
Barge Moorings (Approx. 45 s.f.)	10/16/13	1/22/16	593 days
Pier 3	**9/16/13**	**9/29/15**	**532 days**
Work Bridge (Approx. 600 s.f.)	9/16/13	9/26/14	270 days
Tower Crane (Approx. 100 s.f.)	9/29/14	9/29/15	262 days
Barge Moorings (Approx. 45 s.f.)	9/16/13	9/29/15	532 days
Pier 4	**11/15/13**	**10/20/15**	**503 days**
Work Bridge (Approx. 600 s.f.)	11/15/13	11/19/14	264 days
Tower Crane (Approx. 100 s.f.)	3/20/15	10/20/15	153 days
Barge Moorings (Approx. 45 s.f.)	11/15/13	10/20/15	503 days
Pier 5	**10/29/14**	**10/19/16**	**516 days**
Work Bridge (Approx. 600 s.f.)	10/29/14	10/27/15	260 days
Tower Crane (Approx. 100 s.f.)	3/21/16	10/19/16	153 days
Barge Moorings (Approx. 45 s.f.)	10/29/14	10/19/16	516 days
Pier 6	**12/1/14**	**4/5/17**	**613 days**
Work Bridge (Approx. 600 s.f.)	12/1/14	2/15/16	315 days
Tower Crane (Approx. 100 s.f.)	4/11/16	4/5/17	258 days
Barge Moorings (Approx. 45 s.f.)	12/1/14	4/5/17	613 days
Pier 7	**9/29/14**	**1/23/17**	**606 days**
Work Bridge (Approx. 350 s.f.)	9/29/14	10/13/15	272 days
Tower Crane (Aprox. 100 s.f.)	2/29/16	1/23/17	236 days
Barge Moorings (Approx. 200 s.f.)	9/29/14	1/23/17	606 days

Conceptual Schedule Only, March 2010
Note: This is a proposed schedule, so activity start and finish dates are likely to change.

Figure 6-42. Sequencing of In-Water Structures for Construction in the Columbia River

Columbia River CROSSING

Northern pikeminnow is the major predator of emigrating juvenile salmonids in the Lower Columbia (Poe et al. 1994; NMFS 2000b). Northern pikeminnow are associated with pilings and other in-water structures during most of the year (Pribyl et al. 2004; Petersen and Poe 1993). Northern pikeminnow select slower-velocity areas, generally avoiding velocities greater than 2.3 fps (NMFS 2000b). Petersen and Poe (1993) reported northern pikeminnow congregating at overwater structures, such as back eddies behind pilings. Consumption rates are especially high in areas where juvenile salmonids congregate.

The literature is not in complete agreement about northern pike minnow consumption rates of juvenile salmonids in the Lower Columbia basin. Buchanan et al. (1981, as cited in NMFS 2000b) reported that only 2 percent of northern pikeminnow found in free-flowing sections of the Willamette River contained salmonids in their diets. In a free-flowing reach of the lower Columbia River, Thompson (1959, as cited in NMFS 2000b) found that only 7.5 percent of northern pikeminnow contained salmonids in their diets. However, in a survey of the lower Columbia River from Bonneville Dam (RKm 235) to Jones Beach (RKm 71–77), Petersen and Poe (1993) found that catches of northern pikeminnow and the number of salmonid prey per pikeminnow were higher in free-flowing sections of the river than in impounded areas in John Day Reservoir. At a sampling site in Vancouver, the spring diet of northern pikeminnow was comprised of 70 percent fish, 92 percent of which were salmonid smolts. In summer, the diet was 25 percent fish, 84 percent of which were salmonid smolts (Petersen and Poe 1993). The study estimated that the average predation rate in spring at the Vancouver site was 1.3 smolts per pikeminnow. In summer, the predation rate in the same location was 1.7 smolts per pikeminnow. Zimmerman (1999) found that daily consumption of juvenile salmonids in unimpounded portions of the Columbia River were about 0.8 prey per northern pikeminnow in the spring and 1.6 in the summer.

Mean maximum length of salmon consumed was 167 mm, although northern pikeminnow consumed both steelhead and Chinook measuring more than 200 mm in length. Of the salmonid smolts consumed, the large majority were juvenile Chinook (64 percent of all fish consumed), but they also ate steelhead (2 percent of fish consumed), and "unidentified salmonids" (26 percent of fish consumed). In another study, NMFS (2000b) estimates that the ratio of northern pikeminnow to the number of salmon smolts consumed between Bonneville Dam to the mouth to the Columbia River is 0.09 smolts per day. Northern pikeminnow are especially abundant in free-flowing reaches of the lower Columbia River. In a 2-year predator sampling study of the Lower Columbia from Bonneville Dam to RKm 70, northern pikeminnow comprised over 90 percent of the predaceous fish species encountered (Poe et al. 1994). Other predators (smallmouth bass and largemouth bass) were few in the study area.

Smallmouth bass are known to exhibit strong cover-seeking behavior and typically seek out pools or deep areas behind rocks where the current is slack (Edwards et al. 1983; Pflug and Pauley 1984; Probst et al. 1984, as cited in Pribyl et al. 2004). They also associate with in-water structures such as pilings and riprap (Pribyl et al. 2004). In the Columbia River basin, smallmouth bass prey heavily on juvenile salmonids (Gray and Rondorf 1986). While Zimmerman (1999) found that the mean maximum length of smolts consumed was 119 mm, they may also ingest very large prey (up to 240 mm) (NMFS 2000b). Subyearling salmonids are at highest risk, not only because their shallow-water habitat overlaps with the preferred habitat of smallmouth bass in summer, but also because they are the ideal forage size for this species (Gray and Rondorf 1986). Rearing subyearling Chinook are particularly vulnerable (Poe at al. 1994;

NMFS 2000b). Zimmerman (1999) estimates that consumption rates exceeded 1.0 juvenile salmonids per smallmouth bass in both impounded and unimpounded reaches of the Columbia River. All of the prey items were either Chinook (12 percent of all fish consumed) or "unidentified salmonids" (3 percent of all fish consumed). No steelhead were detected.

Largemouth bass prefer low-velocity areas, such as backwaters, when in riverine environments (Wheeler and Allen 2003; Wydoski and Whitney 2003). Additionally, when located in high-velocity river channels they are associated with in-water structures (Pribyl et al. 2004). Largemouth bass are present in the Columbia system, but because their numbers are relatively low, they do not have the potential to significantly affect the abundance of juvenile salmonids (Gray and Rondorf 1986).

Walleye are present in the lower Columbia River, but there is disagreement about the impact of this species on the abundance of juvenile salmonids in this area (Gray and Rondorf 1986). Walleye are frequently associated with pilings, as they avoid strong current. During their spring spawning period, walleye may prey preferentially on smaller juvenile salmonids (less than 100 mm) where both overlap in shallow-water habitat (Gray and Rondorf 1986). At other times of the year, walleye may be spatially segregated from juvenile salmonids, occurring more frequently offshore in deep water (Pribyl et al. 2004). In a sampling study, Poe et al. (1994) found that walleye abundance was low in the Columbia River from Bonneville Dam to RKm 70, comprising only 2 percent of all piscivorous fish captured. Zimmerman (1999) also detected very few walleye in the same area and found that 12.5 percent of the walleye diet was Chinook, with no other salmonids species detected. In the lower Columbia River, NMFS (2002) research underscores this point, noting that non-salmonid fish dominated the walleye diet.

While predation may occur on juvenile salmonids at all in-water bridge elements and temporary in-water structures, predation on salmonids is likely to be higher at shallow-water structures where smaller juveniles are expected to congregate in the Columbia River, at Pier Complex 2 and 7 and associated temporary in-water structures (Figure 6-29 and Figure 6-30); in North Portland Harbor, at all new bents and associated temporary structures (Figure 6-31). At deep-water structures, Columbia River pier complexes 3 though 6 and their associated temporary in-water work structures (Figure 6-35), where smaller juveniles are not as common, predation is expected to be less. This effect is discussed in further detail in Sections 6.3.1 and 6.3.2.

It is not possible to quantify the number of individuals potentially exposed to increased predation. However, given that there is a net increase in the extent of suitable predator habitat, it is probable that the project will result in some level of increased predation on juvenile salmonids in the Columbia River and North Portland Harbor.

There are no specific data regarding the impact of hydraulic shadowing on predation rates of eulachon (reports do not specify prey items at the species level); however, because both adult and larval eulachon well within the size range (less than roughly 150 mm) consumed by common predators in the Columbia River, it cannot be discounted that hydraulic shadowing could also increase predation on adult and larval eulachon in the same manner as for juvenile salmonids.

The change in hydraulic footprint is not expected to increase predation on adult salmon and steelhead, adult and subadult bull trout, or adult and subadult green sturgeon, as predation on fish of these size classes is rare (Zimmerman 1999). Additionally, because of the extremely low numbers of bull trout and green sturgeon in this portion of the action area, risk of exposure to this effect is discountable.

6.3.4.2 Outmigration of Juvenile Salmonids

In general, hydraulic shadowing and resulting low-velocity areas have the potential to delay outmigration for smolts. Increased travel time exposes smolts to a variety of mortality vectors, including predation, disease, poor water quality, and thermal stress. Migration delays may also deplete energy reserves and disrupt arrival times in the lower estuary. The latter may cause salmonids to arrive in the estuary when predation levels are high and/or prey species are limited (NMFS 2008e). In the case of this project, effects to outmigration are expected to be slight. Although the size of the hydraulic shadow will increase, the range of velocities found in the hydraulic shadow is comparable to that which fish would encounter in the natural environment. Therefore, none of the juvenile fish addressed by this BA (see Figure 4-2) are likely to become trapped or significantly delayed by the hydraulic shadow. Additionally, none are likely to be directed towards or away from shallow-water habitat because the structures neither pose a complete physical blockage to the shallow-water habitat, produce water velocities low enough to trap fish, nor produce velocities high enough to direct fish into deeper water. The effects of hydraulic shadowing on juvenile migration will be insignificant.

6.3.4.3 Velocity Refugia

Increased hydraulic shadowing may also benefit salmonids by creating larger velocity refugia for both adults and juveniles during periods or in reaches of high flow. A Bonneville Power Administration study showed that upstream passage through reaches with long, relatively uninterrupted stretches of high-velocity flow requires high levels of bio-energetic expenditure, similar to that of ascending a waterfall. Without resting areas, migrating adults use larger amounts of energy, posing risks for spawning success (Brown and Geist 2002). Velocity refugia allow fish to rest and replenish energy reserves. The CRC project area and vicinity consist of long relatively uninterrupted stretches of high-velocity flow. Presumably, the increased size of the hydraulic shadows will increase the area of flow refugia over the preproject condition. The extent to which this increase may benefit listed fish is impossible to quantify, but given that the increase in flow refugia is small relative to the large size of the Columbia River and North Portland Harbor, the effect is probably slight and therefore insignificant.

6.3.4.4 Sediment Transport

The hydraulic effect of the new bridges may alter sediment transport in the Columbia River and North Portland Harbor. Between bridge piers, water velocities are likely to increase, resulting in increased sediment transport. In lower-velocity areas behind the piers, sediment is likely to accumulate. Several new piers are located immediately adjacent to the shoreline (in the Columbia River: pier complexes 2 and 7; in North Portland Harbor, the six new nearshore bridge bents). Low-velocity areas behind these piers will likely accumulate sediment; therefore, the new bridge piers are not anticipated to result in shoreline erosion.

6.3.5 Critical Habitat

Critical habitat in the action area includes the 2005 salmon and steelhead critical habitat designation, the 1993 SR Chinook and sockeye critical habitat designation, and the 2010 proposed critical habitat designation for bull trout.

6.3.5.1 2005 Salmon and Steelhead Critical Habitat Designation

The 2005 critical habitat designation includes:

- Chinook (LCR, UWR, and UCR)
- CR chum
- Steelhead (UCR, SR, MCR, LCR, and UWR)

These critical habitat designations overlap the action area only in North Portland Harbor, the Columbia River, and lower Columbia Slough. These water bodies provide three PCEs:

- Spawning habitat for CR chum only.
- Limited rearing habitat for Chinook (LCR, UCR spring-run, and UWR), LCR coho, CR chum, and LCR steelhead.
- Significant migration habitat for all runs included in the designation.

The project is likely to affect these PCEs through six major pathways: underwater noise; turbidity generated by in-water and overwater work; water quality impacts associated with stormwater runoff; in-water work structures causing temporary partial barriers to juvenile migration; increase of in-water shade, possibly resulting in effects on juveniles in the action area; and traffic and land-use changes. Table 6-39 summarizes effects to these PCEs.

Table 6-39. Summary of Effects to PCEs for 2005 Salmon and Steelhead Critical Habitat Designation

PCE	Effect
Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation, and larval development.	Applies only to CR chum; potential temporary hydroacoustic effects on spawning habitat.
Freshwater rearing sites with: (i) water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility, (ii) water quality and forage supporting juvenile development; and (iii) natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.	Applies to Chinook (LCR, UCR spring-run, UWR), LCR coho, CR chum, and LCR steelhead: • Hydroacoustic impacts may temporarily degrade. • Stormwater treatment may improve water quality. • Applies to runs above, except UWR: • Temporary impacts to water quality from turbidity. • Traffic changes will decrease congestion and ADTs,[a] potentially resulting in net benefit water quality. • Land use changes may increase PGIS,[a] but high level of required runoff treatment will minimize impact to water quality.

PCE	Effect
Freshwater migration corridors free of obstruction and excessive predation with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival.	Hydroacoustic impacts may function as a passage barrier for all runs. For all runs except UWR: • Cofferdams and work platforms may temporarily degrade this PCE by delaying migration for and increasing predation on juveniles • Turbidity may have temporary, limited impact to water quality. • Permanent impact to water quality due to high level of stormwater treatment. • Traffic changes may cause reduction of congestion and ADTs, potentially resulting in net benefit water quality. • Future land use changes may increase PGIS, but high level of required runoff treatment will minimize impact to water quality.

a ADT = average daily traffic; PGIS = pollutant-generating impervious surface.

Underwater Noise

Underwater noise is certain to temporarily degrade all three PCEs during impact pile driving and vibratory pile driving. Section 6.1.1 and Appendix K quantify the areas that are likely to be subjected to elevated noise levels. The text below summarizes the extent, timing, and duration of elevated noise due to pile driving.

Figure 6-1 through Figure 6-13 depict the areas subjected to elevated noise due to impact pile driving. Impact pile driving is expected to occur within a 31–week period of each of the four in-water construction years. Each 31-week period will begin September 15 one year and extend to April 15 of the next (approximately week 38 of one year through week 16 of the following year). During this period, impact pile driving is expected to occur no more than 1 hour each day for 5 days a week. There will be a total of about 138 days of in-water impact pile driving in the Columbia River and 134 days in North Portland Harbor. For the large majority of this pile driving, a noise attenuation device will be use; however, unattenuated impact pile driving may occur for up to 7.5 minutes per week in the Columbia River and up to 5 minutes per week in North Portland Harbor to test the effectiveness of the noise attenuation device or in the case of unexpected equipment failure (Table 6-9 and Table 6-10).

Up to two impact pile drivers may operate at one time on the Columbia River, nearly always at the same pier complex. However, for up to 6 work days over the duration of the entire project, two pile drivers may operate at different pier complexes. No more than one impact pile driver will be used in North Portland Harbor.

The earliest anticipated start and stop dates for impact pile driving are September 2013 and October 2016. The latest anticipated start and stop dates are October 2014 and October 2017. Impact pile driving is expected to intersect up to four migrational/spawning cycles. Hydroacoustic modeling was conducted, as outlined in Section 6.1.1 and Appendix K. The modeling indicates that hydroacoustic impacts generated by impact pile driving may be divided into two geographic zones, based on the distance from the disturbance: the injury zone and the disturbance zone.

The *injury zone* is modeled as all areas within 5 to 446 m of active impact pile driving in the Columbia River and North Portland Harbor. The zone radius depends on the size and number of piles and whether or not a noise attenuation device is in use (Figure 6-1 through Figure 6-11, Table 6-5 through Table 6-6). Underwater noise will degrade the rearing and migration PCEs in this zone to the point where the PCEs may be non-functional during the time that impact pile driving is occurring.

The *disturbance zone* in the Columbia River is at least 858 m, extending up to approximately 8,851 m downstream and up to 20,166 m upstream from the proposed bridge (from approximately RM 101 to 118) (Figure 6-12, Figure 6-13, and Table 6-9). In North Portland Harbor, the disturbance zone is at least 858 m, extending up to approximately 3,058 m upstream and up to 5,632 m downstream from the existing bridge (Figure 6-12, Figure 6-13, and Table 6-10). The disturbance zone spans the width of both channels and encompasses an area of approximately 5,020 acres.

- In the disturbance zone, during impact pile driving, the project will degrade the rearing and migration PCEs shown in Table 6-39 for approximately 40 minutes per day during pile driving periods.
- The chum spawning habitat is located approximately 7 miles from pile driving at RM 113 (RKm 182) and occurs within the disturbance zone. The model predicts that noise will be at levels likely to degrade the spawning PCE only during unattenuated impact pile driving, anticipated to occur less than 7.5 minutes per week on the schedule outlined above. In actuality, the spawning area occurs in shallow water that tends to dampen the effects of noise, meaning that noise levels may actually be less. Also, shadowing from Government Island and mainland landforms may further attenuate noise. While noise may be above ambient levels in this area, it is not likely to prevent spawning or harm eggs. Therefore, this PCE will be degraded but functional for the duration of unattenuated pile driving.

Elevated noise will also occur during vibratory pile driving as described in Section 6.1.1 and Appendix K (Carlson 1996). This effect is likely to occur at any time of day up to 5 hours per day, 7 days per week, and year-round during the in-water construction period (about 40 to 50 months). In areas subjected to elevated noise due to vibratory pile driving, the rearing and migration PCEs will be temporary degraded for the duration of vibratory pile driving, but will likely still be functional.

Temporary Turbidity

In-water and overwater work may temporarily introduce sediments or contaminants to critical habitat in the Columbia River and North Portland Harbor. The pathways, magnitude, timing, and duration of these effects are discussed in detail in Section 6.1.5.2. In summary, turbidity will cause only slight, temporary degradation of small discrete portions of the rearing and migration PCEs. Due to the high dilution capacity of the Columbia River and North Portland Harbor and the limited extent of the turbidity, the PCEs will remain functional for the duration of the project. The spawning area is upstream of the project area; therefore, turbidity will not affect this PCE.

Stormwater Runoff Treatment

Stormwater runoff will permanently affect the rearing and migration PCEs. Stormwater effects are discussed in greater detail in Section 6.2.1. In summary, the project provides a high level of stormwater treatment and could potentially improve water quality in the Columbia River, North Portland Harbor, and Columbia Slough. Therefore, there may be a beneficial effect on these PCEs in perpetuity. Stormwater runoff will have no effect on the spawning PCE, as spawning occurs many miles upstream of all stormwater outfalls associated with the project.

Overwater Structures

Temporary work platforms and cofferdams in shallow water (at P2 and P7 in the Columbia River and at all new North Portland Harbor bents) may temporarily degrade the migration PCE. The pathways, magnitude, timing, and duration of these effects are discussed in detail in Sections 6.1.3 and 6.3.1. In summary, these structures may delay migration by causing a partial barrier for juvenile fish, which may potentially avoid passing under overwater structures. These structures will also increase shade, which may degrade the quality of rearing and migration PCE by increasing predation pressure. Overall, this aspect of the project is likely to degrade migration and rearing PCEs for all ESUs/DPSs except UWR Chinook and steelhead. (Work platforms and cofferdams do not occur in designated critical habitat for Upper Willamette runs.)

Land Use and Traffic Changes

The CRC project is likely to prompt land use changes in the future, including an increase in development in urban areas and a reduction in congestion and ADTs along the I-5 corridor. These elements could cause alteration of adjacent water bodies, including the Columbia River, North Portland Harbor, and Columbia Slough. However, numerous regulations protect these aquatic areas, and changes to the aquatic baseline are expected to be minimal. Section 6.2.2.4 outlines in greater detail the effects to habitat and the laws that will minimize harm to the environmental baseline in these water bodies. Overall, land use changes may affect but are not likely to adversely affect the rearing and migration PCEs for all of the ESUs/DPSs occurring in the action area except for the UWR ESUs/DPSs of Chinook and steelhead.

Land use changes will not cause any in-water work in, adjacent to, or within many miles of the UWR ESUs. Due to the high level of stormwater treatment, any effects due to stormwater runoff will likely be diluted to background levels before entering Upper Willamette ESUs, located approximately 5 miles from the nearest outfall associated with this element of the project. Therefore, land use changes will have no effect on designated critical habitat for UWR Chinook and steelhead.

Land use changes will also have no effect on the spawning PCE of chum, because chum spawn well upstream of the range of all potential effects.

6.3.5.2 1993 Snake River Sockeye and Chinook Critical Habitat Designation

This designation addresses critical habitat for SR spring/summer-run Chinook, SR fall-run Chinook, and SR sockeye. Critical habitat for these ESUs overlaps the action area only in the Columbia River and North Portland Harbor.

Two habitat components occur in the action area: juvenile migration corridors and adult migration corridors. The project is likely to affect the habitat components through the same pathways as for the 2005 designation (Section 6.3.5.1): underwater noise; turbidity generated by in-water and overwater work; water quality impacts associated with stormwater runoff; in-water work structures causing temporary barriers to juvenile migration; increase of in-water shade, possibly resulting in greater predation of juveniles in the action area (and reduction of safe passage); and traffic and land-use changes. The magnitude, timing, and duration of these effects are discussed in greater detail in Section 6.3.5.1.

Table 6-40 summarizes project impacts on the habitat components.

Table 6-40. Summary of Effect to Habitat Components for 1993 Salmon and Steelhead Critical Habitat Designation

PCE	Effect
Juvenile Migration Corridors	Hydroacoustic impacts may temporarily function as a passage barrier, degrading the safe passage essential habitat feature for SR spring/summer-run Chinook and SR fall-run Chinook. (Impact pile driving is not expected to occur during migration of SR sockeye. Therefore, no effect to this habitat component for SR sockeye.) For all runs: • Cofferdams and work platforms may temporarily degrade by delaying migration. • Potential permanent and temporary impacts to safe passage conditions (shading, hydraulic shadow, and structures in shallow water) may increase predation. • Temporary impacts to water quality from turbidity. • Permanent improvement to water quality due to high level of stormwater treatment. • Traffic changes may cause reduction of congestion and ADTs, with a benefit to water quality. • Future land use changes may increase PGIS, but high level of required runoff treatment will minimize impact to water quality. • Increase in hydraulic shadowing will result in temporary and permanent impacts to water velocity. • No effect on other habitat features (substrate, water quantity, water temperature, cover/shelter, food, riparian vegetation, and space).
Adult Migration Corridors	Hydroacoustic impacts may temporarily function as a passage barrier for SR spring/summer-run Chinook and SR fall-run Chinook. (Impact pile driving is not expected to occur during migration of SR sockeye. Therefore, no effect to this habitat component for SR sockeye.) For all runs: • Temporary impacts to water quality from turbidity. • Permanent improvement to water quality due to high level of stormwater treatment. • Traffic changes may cause reduction of congestion and ADTs, with a benefit to water quality. • Future land use changes may increase PGIS, but high level of required runoff treatment will minimize impact to water quality. • Increase in hydraulic shadowing will result in temporary and permanent impacts to water velocity. • No effect on other habitat features (substrate, water quantity, water temperature, cover/shelter, riparian vegetation, space, and safe passage).

6.3.5.3 Proposed Critical Habitat for Bull Trout

Proposed critical habitat for bull trout occurs within the action area in the Columbia River and North Portland Harbor. Six PCEs occur in the action area (Table 6-41). Only adult and subadult bull trout occur in the Columbia River and North Portland Harbor. Therefore, only PCEs related to adult and subadult bull trout apply to the CRC project.

Table 6-41. Summary of Effect to PCEs for Bull Trout Proposed Critical Habitat

PCE	Effect
Migratory habitat	Applies to adult migratory habitat only, as juveniles are not present in the action area. Hydroacoustic impacts may temporarily function as a passage barrier for adult and subadult bull trout. Temporary impacts to water quality from turbidity. Permanent improvement to water quality due to high level of stormwater treatment. Traffic changes may cause reduction of congestion and ADTs, with a benefit to water quality. Land use changes may increase PGIS, but high level of required runoff treatment will minimize impact to water quality.
Food base	Hydroacoustic impacts may temporarily reduce the number of forage fish available. Alternatively, hydroacoustic impacts may enhance foraging opportunities. Increase in in-water shading may cause extremely localized effects to primary productivity and the food web.
Complex aquatic environments	Temporary overwater structures will result in limited, temporary impacts to substrate, shallow-water habitat, and deep-water habitat. Net permanent increase in substrate may slightly enhance.
Water temperature	The project will have no effect on water temperature.
Hydrograph	The project will have no effect on the stream hydrograph.
Water quality and quantity	Temporary impacts to water quality from turbidity. Permanent improvement to water quality due to high level of stormwater treatment. Traffic changes may cause reduction of congestion and ADTs, with a benefit to water quality. Land use changes may increase PGIS, but high level of required runoff treatment will minimize impact to water quality.

Bull trout use of the portions of the action area exposed to these effects is extremely limited. Fewer than 20 individuals have been detected in the area in 40 years. Therefore, even though project-related activities will temporarily degrade some of the PCEs, the risk that the activities will interfere with actual habitat function is highly unlikely and therefore discountable.

Six PCEs occur in the action area: migratory habitat, water quality and quantity, food base, complex aquatic environments, temperature, and hydrograph. The largest area of impact will be from elevated noise levels, which may affect the migration PCE. Elevated noise will be limited in duration to 40 minutes per in-water work day and is not likely to occur when bull trout are present due to low probability of presence in areas subjected to elevated noise. Therefore, elevated noise does not represent significant degradation to the migratory PCE. Other effects to the migratory PCE and to the other three PCEs that occur in the action area will be either extremely slight or beneficial. Thus, the project will not measurably degrade these PCEs. Effects to these PCEs are discussed below and are summarized in Table 6-41.

Migratory Habitat

The project is likely to affect the migratory habitat PCEs through the same pathways as for the 2005 salmon and steelhead critical habitat designation (Section 6.3.5.1): underwater noise, turbidity generated by in-water and overwater work, water quality impacts associated with stormwater runoff, overwater structures, and traffic and land-use changes. The magnitude, timing, and duration of these effects are outlined in greater detail in Section 6.3.5.1. Bull trout use of the portions of the action area exposed to these effects is extremely limited, restricted to less than 20 detections in 40 years. Therefore, even though project-related activities will degrade the migratory habitat PCE, the risk that the activities will interfere with actual migration is highly unlikely and therefore discountable. Thus, the project is not likely to adversely affect this PCE.

Water Quality and Quantity

The project is likely to affect the water quality and quantity PCE through three pathways: temporary turbidity during the course of in-water construction, stormwater runoff treatment, and future land-use and traffic changes, as described in Section 6.3.5.1.

The pathways, magnitude, timing, and duration of the turbidity are discussed in detail in Section 6.1.5.2. In summary, turbidity will cause only slight, brief degradation of small, discrete portions of critical habitat in the Columbia River and North Portland Harbor. Effects are expected to be insignificant. Due to the high level of stormwater treatment, the project could improve water quality in the Columbia River and North Portland Harbor. The project may cause future land-use changes, but numerous environmental regulations will limit these impacts as described in Section 6.2.2.5. Average daily traffic is expected to decrease in areas that drain directly to the Columbia River and North Portland Harbor, potentially resulting in a net benefit to this PCE, but certainly not further degrading it. Overall, the project is not likely to adversely affect this PCE.

Food Base

Elevated levels of underwater noise may cause juvenile salmonids and other forage fish to experience injury or mortality or to avoid the CRC action area. Section 6.1.1 outlines the extent, timing, and duration of this activity, and provides an estimate of the effects as the percent of the juvenile salmonid run that may be affected. Effect to the prey base may be divided into two geographic zones, based on the distance from the disturbance: the injury zone and the disturbance zone.

The injury zone is modeled as all areas within 5 to 446 m of impact pile driving in the Columbia River and North Portland Harbor.

Table 6-4, Table 6-5, and Figure 6-1 through Figure 6-5, all of which occur in proposed critical habitat for bull trout. Underwater noise may injure or kill forage fish in this area. On one hand, injury or mortality of prey fish is likely to temporarily degrade the food base PCE, to the extent that bull trout forage in this portion of the action area. On the other hand, injured prey fish are more easily captured and more readily available for forage, improving the PCE.

In the Columbia River, the disturbance zone is at least 858 m and extends approximately 20,166 m upstream and 8,851 m downstream from the proposed bridge (from approximately RM 101 to 118). In North Portland Harbor, it extends approximately 3,058 m upstream and 5,632 m downstream from the existing bridge (Table 6-8, Figure 6-12, and Figure 6-13). The disturbance zone spans the width of both channels and encompasses a maximum area of approximately 5,020 acres. Prey fish could potentially avoid the disturbance zone, resulting in reduced foraging opportunities and temporarily degrading the PCE. On the other hand, elevated noise levels in this zone could cause prey fish to become disoriented or stunned, resulting in enhanced foraging opportunities and an enhancement to the PCE.

Effects will be limited to the time period when impact pile driving is taking place (Figure 6-14 through Figure 6-16, Table 6-9 and Table 6-10). Because of the limited duration of impact pile driving (no more than 40 minutes per day over the in-water construction period), effects to prey species are expected to be minimal.

Temporary and permanent bridge elements will both cause in-water shading that could result in extremely small and limited effects to primarily productivity and the food web, as outlined in Section 6.1.3.

Overall, the project is not likely to adversely affect this PCE.

Complex Aquatic Environments

The project will place numerous temporary structures throughout the Columbia River and North Portland Harbor stream channels. This will result in a temporary loss of substrate in both shallow-water and deep-water habitats. Table 6-15 shows the areal extent of these structures, and Figure 6-17 shows the timing and duration that they will be present in the Columbia River and North Portland Harbor. This corresponds to the extent, timing, and duration of effects to the PCE. The temporary loss of substrate is expected to cause only slight degradation of the PCE. These effects are outlined in greater detail in Section 6.3.1 and 6.3.2. In summary, lost substrate in the project area represents only a minuscule fraction of the remaining available substrate present for dozens of miles both upstream and downstream of the project area. Therefore, the effect to this PCE will be slight.

In the Columbia River and North Portland Harbor, in-water bridge elements will permanently remove 12,950 sq. ft. of substrate. Demolition of the existing bridge will permanently restore 18,565 sq. ft. of substrate, and removal of an overwater structure at Red Lion at the Quay will permanently restore an unknown area of substrate. In any case, there will be a net gain of at least 5,615 sq. ft. of substrate, all of which occurs in proposed critical habitat for bull trout. This may result in a slight benefit to the PCE.

Neither temporary nor permanent structures are expected to affect habitat features such as large wood, side channels, or undercut banks, as these features are absent or rare in the project area.

Overall, the project is not likely to adversely affect this PCE.

Temperature

The project may slightly increase in-water shading in the action area, as outlined in Section 6.1.3. Shade may result in localized areas of cooler water temperatures where water velocities are slower. However, the large volume of the surrounding water bodies and the high level of mixing of shaded water with the surrounding water volume will likely overwhelm any decrease in temperature, so that increased shade will not measurably lower water temperatures.

The project will also remove a small amount of riparian vegetation along the shoreline of North Portland Harbor and the Columbia River, causing a very slight reduction of underwater shade in the action area, as outlined in Section 6.3.3. Due to the small amount of shade lost relative to the very large volume of the surrounding water bodies, this reduction in shade will not measurably raise water temperatures in the action area. Additionally, the project will replace the vegetation according to local ordinances, so that such effects will be temporary. The project will have no effect on this PCE.

Hydrograph

The hydrograph in the Columbia River and North Portland Harbor is dominated by numerous hydroelectric dams in the upstream direction and by the tidal influence of the Columbia River estuary and the Pacific Ocean in the downstream direction. Although the project will discharge stormwater runoff to the Columbia River and North Portland Harbor, these discharges are negligible relative to the large flow volume and existing hydrograph in these receiving water bodies. Therefore, the additional runoff will have no effect on the stream hydrograph.

Additionally, the project will construct temporary structures in the Columbia River and North Portland Harbor, adding a net volume of fill in these water bodies. However, the dams and the tidal influence will continue to dominate the hydrograph, so that the additional fill will have no effect on stream stage or flows in these water bodies.

The project will add permanent structures in the Columbia River and North Portland Harbor (approximately 12,960 cubic yards below OHW) and will remove the existing Columbia River structures (32,075 cubic yards below OHW), resulting in a net loss of fill (-19,110 cubic yards below OHW) in these water bodies. This will have no effect on the stream hydrograph.

6.4 EFFECTS TO STELLER SEA LIONS

This section provides a detailed analysis of effects to Steller sea lions. Appendix I, the Exposure Matrix, provides a tabular summary of each element of the project that is likely to affect Steller sea lions in the action area. It also provides the timing and duration of each project element as well as summarizing the overall effect that each element will have on Steller sea lions.

6.4.1 Acoustic Effects to Steller Sea Lions – Pile Driving

Project-generated noise, including impact and vibratory pile driving, may have impacts to Steller sea lions, which migrate through the project area. The following sections present background information about how sea lions respond to noise, criteria for noise levels likely to cause injury or disturbance to Steller sea lions, and an analysis of how pile-driving noise is likely to affect Steller sea lions present in CRC action area.

6.4.1.1 How Steller Sea Lions Respond to Noise

There are few studies that quantify reactions of pinnipeds to noise, and even fewer that have directly observed reactions of pinnipeds to pile-driving noise (Southall et al. 2007). (Pinnipeds are a taxonomic category of marine mammals that includes seals and sea lions.) Southall et al. (2007) performed a literature review of all known studies on the effects of noise on marine mammals. The review offers guidelines on how pinnipeds exhibit behavioral effects, temporary hearing loss, and injury resulting from elevated levels of underwater and airborne noise.

Behavioral Effects

Behavioral response to sound is dependent on a number of site-specific characteristics, including the intensity of the noise source, the distance between the noise source and the individual, and the ambient noise levels at the site (Southall et al. 2007). Behavioral response is also highly dependent on the characteristics of the individual animal. Marine mammals that have been previously exposed to noise may become habituated, and therefore may be less sensitive to noise. Such animals are less likely to elicit a behavioral response.

Behavioral responses have been observed experimentally and have been determined to be highly variable. In some cases, marine mammals may detect a sound and exhibit no obvious behavioral responses. In other cases, marine mammals may exhibit minor behavioral responses, including annoyance, alertness, visual orientation towards the sound, investigation of the sound, change in movement pattern or direction, habituation, alteration of feeding and social interaction, and temporary or permanent avoidance of the area affected by sound. Minor behavioral responses do not necessarily cause long-term effects to the individuals involved. Severe responses include panic, immediate movement away from the sound, and stampeding, which could potentially lead to injury or mortality (Southall et al. 2007).

In their comprehensive review of available literature, Southall et al. (2007) noted that quantitative studies on behavioral reactions of seals to underwater noise are rare. A subset of only three studies observed the response of pinnipeds to underwater multiple pulses of noise (a category of noise types that includes impact pile driving) and were also deemed by the authors as having results that are both measurable and representative.

- Harris et al. (2001) observed the response of ringed, bearded, and spotted seals to underwater operation of a single airgun and an eleven-gun array. Received exposure levels were 160 to 200 dB RMS re: (referenced to) 1 μPa. Results fit into two categories. In some instances, seals exhibited no response to noise. However, the study noted significantly fewer seals during operation of the full array in some instances. Additionally, the study noted some avoidance of the area within 150 m of the source during full array operations.

- Blackwell et al. (2004) is the only study directly related to pile driving. The study observed ringed seals during impact installation of steel pipe pile. Received underwater SPLs were measured at 151 dB RMS re: 1 μPa at 63 m. The seals exhibited either no response or only brief orientation response (defined as "investigation or visual orientation"). It should be noted that the observations were made after pile driving was already in progress. Therefore, it is possible that the low-level response was due to prior habituation.

- Miller et al. (2005) observed responses of ringed and bearded seals to a seismic airgun array. Received underwater sound levels were estimated at 160 to 200 dB RMS re: 1 μPa. There were fewer seals present close to the noise source during airgun operations in the first year, but in the second year the seals showed no avoidance. In some instances, seals were present in very close range of the noise. The authors concluded that there was "no observable behavioral response" to seismic airgun operations.

Southall et al. (2007) conclude that there is little evidence of avoidance of SPLs from pulsed noise ranging between 150 and 180 dB RMS re: 1 μPa. Additionally, they conclude that behavioral response in ringed seals is likely to occur at 190 dB RMS. It is unclear whether or not these data apply to Steller sea lions. Given that there are so few data available, it is difficult to draw conclusions about what specific behaviors pinnipeds will exhibit in response to underwater noise.

Southall et al. (2007) also compiled known studies of behavioral responses of marine mammals to airborne noise, noting that studies of pinniped response to airborne pulsed noises are exceedingly rare. The authors deemed only one study as having quantifiable results.

- Blackwell et al. (2004) studied the response of ringed seals within 500 m of impact driving of steel pipe pile. Received levels of airborne noise were measured at 93 dB RMS re: 20 μPa at a distance of 63 m. Seals had either no response or limited response to pile driving. Reactions were described as "indifferent" or "curious."

Due to the extremely limited data on this topic, it is not possible to draw definitive conclusions about what specific behaviors pinnipeds will exhibit in response to airborne noise generated by impact pile driving.

Several field observations indicate that sea lions exhibit mixed responses to elevated noise levels.

During a Caltrans installation demonstration project for retrofit work on the East Span of the San Francisco Oakland Bay Bridge, California, sea lions responded to pile driving by swimming rapidly out of the area, regardless of the size of the pile-driving hammer or the presence of sound attenuation devices (74 FR 63724).

Dyanna Lambourne, marine mammal research biologist at WDFW, noted that Steller sea lions generally avoid unfamiliar loud noises. In response to pile driving, they would be likely to exit areas exposed to elevated noise, unless there were a particularly strong attraction, such as an abundant food source (Lambourne 2010 personal communication). Lambourne also stated that Steller sea lions could become habituated to noises that are continuous and occurring over longer periods of time.

For the past 5 years, the USACE has conducted hazing of sea lions at Bonneville Dam in an attempt to decrease rates of predation on listed salmonids and sturgeon. The 2009 monitoring report (Stansell et al. 2009) documented the response of both California and Steller sea lions to several types of deterrents, including Acoustic Deterrent Devices (ADDs). These devices are deployed underwater and produce noise levels of 205 dB in the frequency range of 15 kHz. The crews also employed above-water pyrotechnics (cracker shells, screamer shells, or rockets) and underwater percussive devices called seal bombs. Hazing occurred seven days a week from March 2 to the end of May. The study did not differentiate between Steller sea lions and California sea lions, so it is uncertain whether these two species respond differently to hazing.

The observers reported that sea lions tended to spend more time underwater and temporarily avoided the area while hazing activities were occurring, but returned to forage soon after the activities ceased. They concluded that hazing only slowed the rate of predation, rather than effectively deterring it. The sea lions slightly shifted foraging times, preying more heavily at dawn and dusk, when hazing activities were beginning or ending. Nevertheless, despite active hazing, the rate of predation on salmon and sturgeon was still quite high. Observers noted that sea lions swam to within 20 feet of the ADDs to forage.

The explosive and percussive noises produced during these hazing activities are quite different from pile-driving noise, as they are abrupt and non-pulsed. These results may not be applicable to pile-driving projects; however, the results were included to demonstrate that high SPLs alone do not necessarily cause significant behavioral responses in sea lions. Also, the study is specific to sea lion behavior in the lower Columbia River, and it observed the same individuals that transit through the CRC project area. The results suggest that these individuals either are already habituated to some loud noises or could readily become habituated.

Temporary Threshold Shift

Temporary Threshold Shift (TTS) is reversible hearing loss caused by fatigue of hair cells and supporting structures in the inner ear. Technically, TTS is not considered injury, as it consists of fatigue to auditory structures rather than damage to them. Pinnipeds have demonstrated complete recovery from TTS after multiple exposures to intense noise, as described in the studies below (Kastak et al. 1999, 2005).

There are no studies of the underwater noise levels likely to cause TTS in Steller sea lions. However, TTS studies have been conducted on harbor seals, California sea lions, and northern elephant seals. Southall et al. (2007) report several studies on non-pulsed noise (a category that includes vibratory pile-driving noise), but only one study on pulsed noise.

- Finneran et al. (2003) studied responses of two individual California sea lions. The sea lions were exposed to single pulses of underwater noise, and experienced no detectable TTS at received noise level of 183 dB peak re: 1 μPa, and 163 dB SEL re: 1 μPa^2-s.

There were three studies of pinniped TTS in response to non-pulsed underwater noise. All of these studies were performed in the same lab and on the same test subjects, and therefore the results may not be applicable to all pinnipeds or in field settings.

- Kastak and Schusterman (1996) studied the response of harbor seals to non-pulsed construction noise, reporting TTS of about 8 dB.
- Kastak et al. (1999) exposed a harbor seal, California sea lion, and elephant seal to octave-band noise at 60 to 70 dB above their hearing thresholds. After 20 to 22 minutes, the subjects experienced TTS of 4 to 5 dB.
- Kastak et al. (2005) used the same test subjects above, exposing them to higher levels of noise for longer durations. The animals were exposed to octave-band noise for up to 50 minutes of net exposure.
    - The study reported that the harbor seal experienced TTS of 6 dB after a 25-minute exposure to 2.5 kHz of octave-band noise at 152 dB re: 1 μPa and 183 dB SEL re: 1 μPa^2-s.
    - The California sea lion demonstrated onset of TTS after exposure to 174 dB re: 1 μPa and 206 dB SEL re: 1 μPa^2-s.
    - The northern elephant seal demonstrated onset of TTS after exposure to 172 dB re: 1 μPa and 204 dB SEL re: 1 μPa^2-s.

Combining the above data, Southall et al. (2007) assume that pulses of underwater noise result in the onset of TTS in pinnipeds when underwater noise levels reach 212 dB peak or 171 dB SEL. They did not offer criteria for non-pulsed sounds.

Southall et al. 2007 reported only one study of TTS in pinnipeds resulting from airborne pulsed noise:

- Bowles et al. (unpublished data) exposed pinnipeds to simulated sonic booms. Harbor seals demonstrated TTS at 143 dB peak re: 20 μPa and 129 dB SEL re: 20 μPa^2-s. California sea lions and northern elephant seals experienced TTS at higher exposure levels than the harbor seals.

Two studies examined TTS in pinnipeds resulting from airborne non-pulsed noise. These studies may not be relevant to the CRC project, but are provided for general reference.

- Kastak et al. (2004) used the same test subjects as in Kastak et al. 2005, exposing the animals to non-pulsed noise (2.5 kHz octave-band noise) for 25 minutes.
    - The harbor seal demonstrated 6 dB of TTS after exposure to 99 dB re: 20 μPa and 131 dB SEL re: 20 μPa^2-s.
    - The California sea lion demonstrated onset of TTS at 122 dB re: 20 μPa and 154 dB SEL re: 20 μPa^2-s.
    - The northern elephant seal demonstrated onset of TTS at 121 dB re: 20 μPa and 163 dB SEL re: 20 μPa^2-s.
- Kastak et al. (2007) studied the same California sea lion as in Kastak et al. 2004 above, exposing this individual to 192 exposures of 2.5 kHz octave-band noise at levels ranging from 94 to 133 dB re: 20 μPa for 1.5 to 50 minutes of net exposure duration. The test subject experienced up to 30 dB of TTS. TTS onset occurred at 159 dB SEL re: 20 μPa^2-s. Recovery times ranged from several minutes to 3 days.

Southall et al. (2007) assume that multiple pulses of airborne noise result in the onset of TTS in pinnipeds when levels reach 143 dB peak or 129 dB SEL.

Lambourne (2010 personal communication) noted that, in a field setting, Steller sea lions are unlikely to remain in areas exposed to noise levels high enough to cause hearing loss, unless there is a particular attraction keeping them in the area.

Injury – Permanent Threshold Shift

Permanent threshold shift (PTS) is irreversible loss of hearing sensitivity at certain frequencies caused by exposure to intense noise. It is characterized by injury to or destruction of hair cells in the inner ear. Southall et al. (2007) note that there are no empirical studies demonstrating the noise levels that prompt PTS in marine mammals. Furthermore, they found that there is virtually no understanding of the relationship between TTS and PTS in marine mammals, as no studies have been performed.

Southall et al. (2007) propose that noise levels inducing 40 dB of TTS may result in onset of PTS in marine mammals. The authors present this threshold with precaution, as there are no specific studies to support it and because there is often recovery from TTS of this magnitude or greater. Because direct studies on marine mammals are lacking, the authors base these recommendations on studies performed on other mammals. Additionally, the authors assume that multiple pulses of underwater noise result in the onset of PTS in pinnipeds when levels reach 218 dB peak or 186 dB SEL. In air, noise levels are assumed to cause PTS in pinnipeds at 149 dB peak or 144 dB SEL (Southall et al. 2007).

6.4.1.2 Criteria for Injury and Disturbance

NMFS is currently developing comprehensive guidance on sound levels likely to cause injury and behavioral disruption in the context of the Marine Mammal Protection Act. Until formal guidance is available, NMFS uses conservative thresholds of sound pressure level likely to cause injury or disturbance to sea lions (Table 6-42) (NMFS 2008f; WSDOT 2009b).

Table 6-42. Injury and Disturbance Thresholds for Sea Lions

Type	Threshold
Underwater Injury	190 dB RMS re: 1 μPa
Underwater Disturbance – Impact Pile Driving	160 dB RMS re: 1 μPa
Underwater Disturbance – Vibratory Pile Driving	120 dB RMS re: 1 μPa
Abovewater Injury	None Designated
Abovewater Disturbance	100 dB RMS re: 20 μPa (unweighted)

Source: NMFS (2009), WSDOT (2009).

6.4.1.3 Estimating Noise Levels and Acoustic Area of Effect

The extent of in-water and airborne project-generated noise was calculated for the locations where pile driving will occur in the Columbia River and North Portland Harbor.

The extent of underwater noise was modeled for several pile driving scenarios:

- For two sizes of pile: 18- to 24-inch pile and 36- to 48-inch pile.
- For impact pile drivers operating both with and without an attenuation device. Use of an attenuation device was assumed to decrease initial SPLs by 10 dB, as outlined in Section 6.1.1 and Appendix K.
- For vibratory pile driving of pipe pile and sheet pile used for installation of temporary structures.

Although two impact pile drivers will operate simultaneously in close proximity to one another in the Columbia River, the two drivers are not expected to generate noise levels greater than a single pile driver. Pile strikes from both drivers would need to be synchronous (within 0.0 and approximately 0.1 seconds apart) in order to produce higher noise levels than a single pile driver operating alone. Because it is highly unlikely that two pile drivers will operate in exact synchronicity, , we assume that two pile drivers will not generate noise levels greater than that of a single pile driver. Therefore, initial noise levels for multiple pile drivers are assumed to be the same as for a single pile driver.

No data were available regarding the initial SPLs generated by vibratory installation of 10-foot diameter steel casings that are proposed for the drilled shafts. Therefore, the project team extrapolated initial SPLs from published values, as described in the subsection on vibratory pile driving below.

The extent of airborne noise was modeled for impact pile driving only.

Impact Pile Driving – Underwater Noise

Underwater noise thresholds for injury and disturbance to Steller sea lions are referenced to dB RMS re: 1 µPa. The Practical Spreading Loss Model was used to calculate the distances from the source at which impact pile driving noise is likely to exceed the underwater injury and disturbance thresholds. This model is described in detail in Appendix K. This model assumes 4.5 dB of transmission loss with each doubling distance, per the following equation:

$$\text{Distance 1} = \text{Distance 0} \times 10^{(TL/15)}$$

Where Distance 1 is the distance from the pile for which SPLs are being calculated, Distance 0 is the distance from the pile for which there is a known decibel level (typically 10 m from the pile), and TL (transmission loss) is the initial sound pressure level minus the relevant threshold level.

We estimated initial noise levels as 201 dB RMS for 36- to 48-inch pile and 189 dB RMS for 18- to 24-inch pile, as outlined in Section 6.1.1 and Appendix K.

For the smaller pile, the results indicate that noise levels will exceed the injury threshold within 2 m from the pile when a noise attenuation device is in use and within 9 m when no attenuation device is in use (Table 6-43 and Figure 6-43). Behavioral disturbance was estimated to occur within 185 m of the pile when a noise attenuation device is in use and within 858 m when no attenuation device is in use (Table 6-43 and Figure 6-44). As described in Appendix K, these numbers are estimates and may vary according to numerous site-specific factors.

Table 6-43. Distance to Underwater Noise Thresholds from Source – Impact Driving of 18- to 24-inch Piles – Calculated Distances

Threshold	Distance Without Attenuation Device (meters)	Distance With Attenuation Device (meters)
Injury: 190 dB RMS	9	2
Disturbance: 160 dB RMS	858	185

For the larger pile, the model calculated that noise levels will exceed the injury threshold within 12 m of the pile when a noise attenuation device is in use, and within 54 m when no attenuation device is in use (Table 6-44 and Figure 6-45). Behavioral disturbance was estimated to occur within 1,166 m of the pile when a noise attenuation device is in use, and within 5,412 m when no attenuation device is in use (Table 6-44 and Figure 6-46).

Table 6-44. Distance to Underwater Noise Thresholds from Source – Impact Driving of 36- to 48-inch Piles – Calculated Distances

Threshold	Distance Without Attenuation Device (meters)	Distance With Attenuation Device[a] (meters)
Injury: 190 dB RMS	54	12
Disturbance: 160 dB RMS	5,412	1,166

a Assumes 10 dB of noise attenuation.

Note that in both cases, the use of a noise attenuation device shrinks the distance at which noise exceeds the threshold by about 80 percent.

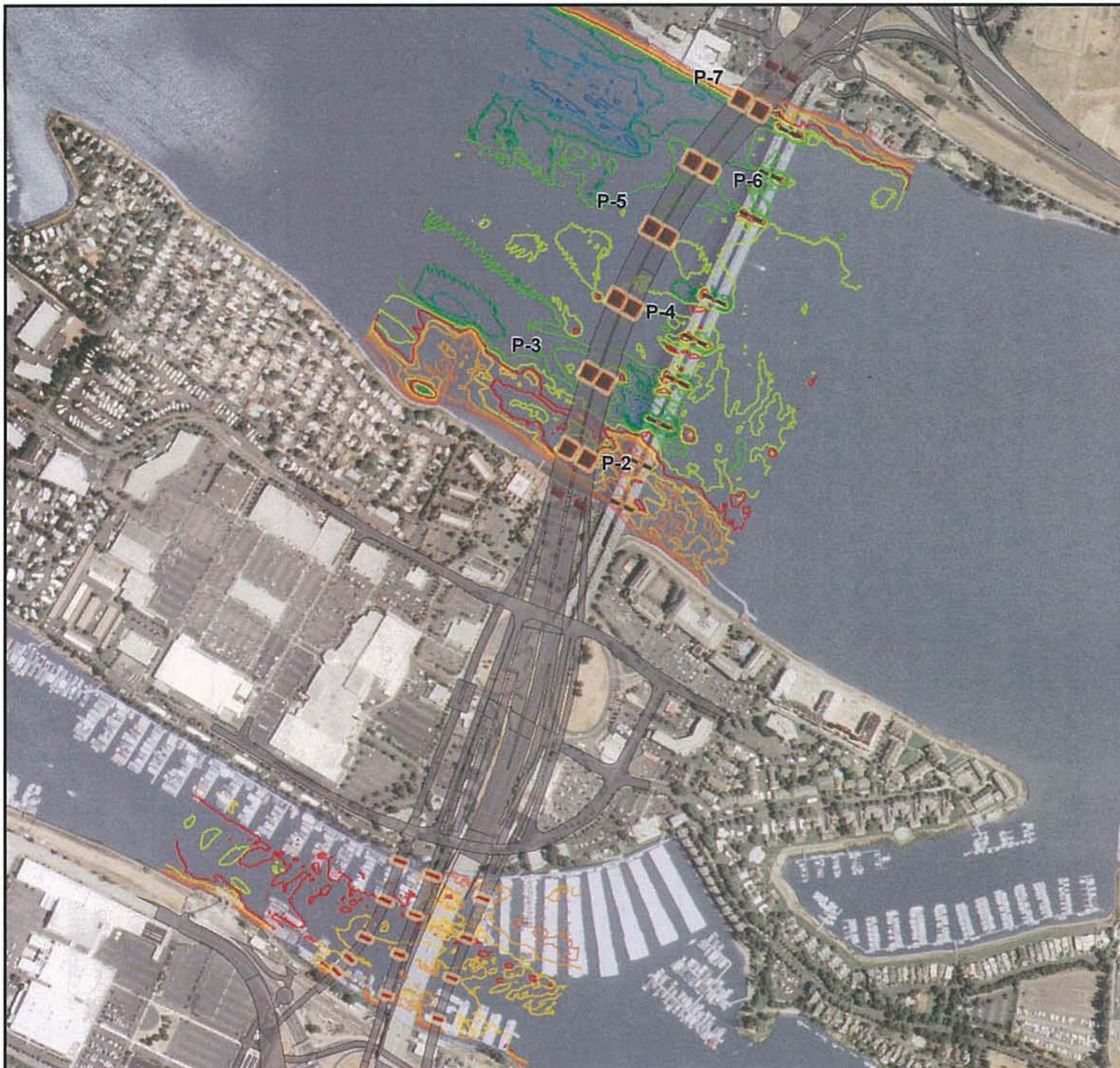


Figure 6-43. Extent of underwater impact pile-driving noise exceeding 190 dB RMS injury threshold for Steller sea lions, 18 to 24-inch pile

Distance to Exceedance of Threshold

- 2 meters with attenuation device
- 9 meters without attenuation device

Bathymetry

Depth (CRD, ft.)

- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55

Design Shapes

- Project Bridge Piers
- Project Design

N
W E
S

0 500 1,000
Feet

Columbia River CROSSING

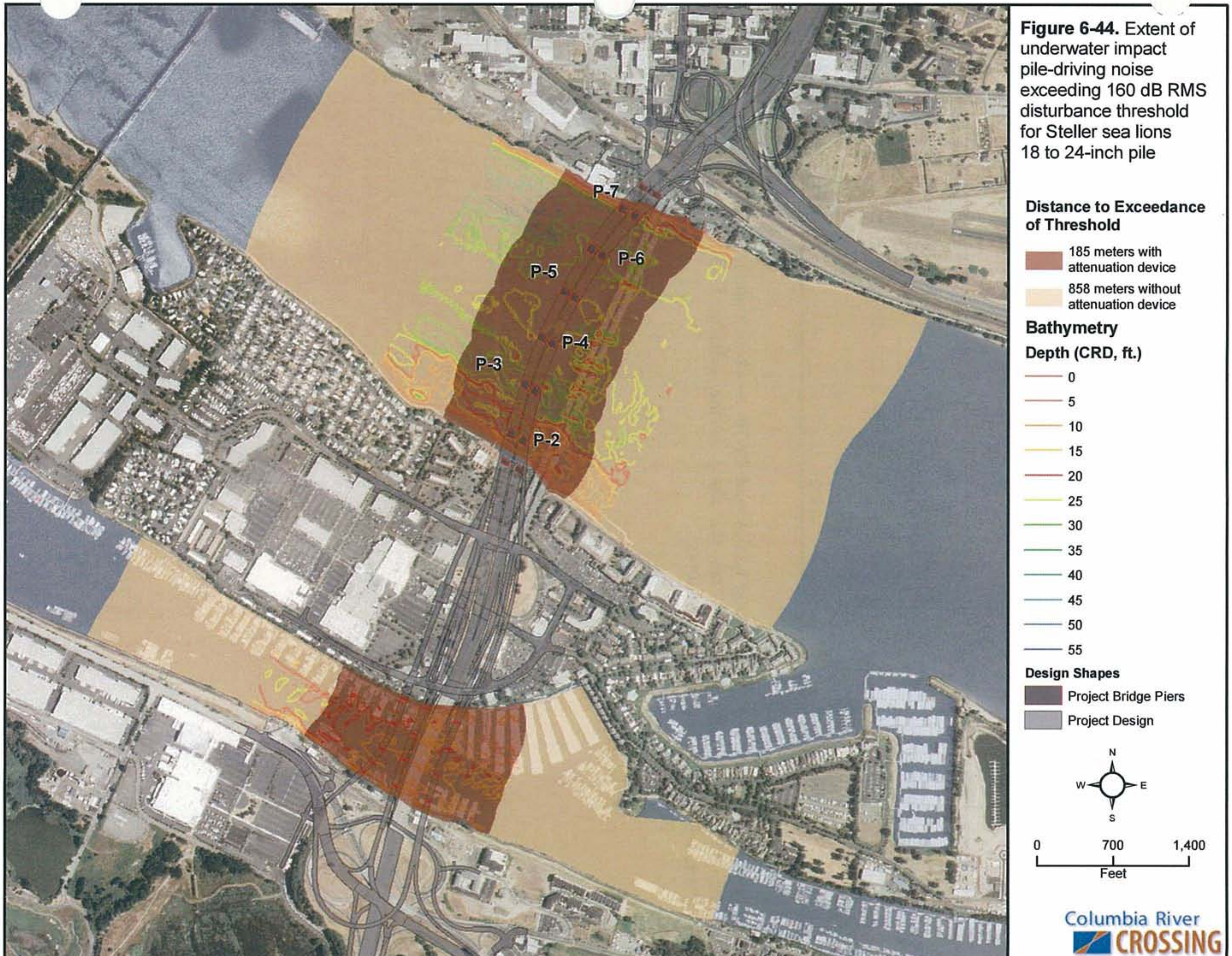


Figure 6-44. Extent of underwater impact pile-driving noise exceeding 160 dB RMS disturbance threshold for Steller sea lions 18 to 24-inch pile

Analysis by J. Koloszar; Analysis Date: Feb. 16, 2010; File Name: HydroSound_MG248_3.mxd

Table 6-43 and Table 6-44 show calculated distances, assuming a free field of spreading with no obstructions. In North Portland Harbor, noise will encounter landforms and dissipate to ambient levels before reaching some of these calculated distances. Table 6-45 shows noise attenuation to threshold levels during impact pile driving of 36- to 48-inch pile in North Portland Harbor, accounting for the distances at which noise will encounter landforms (Figure 6-45 and Figure 6-46).

Table 6-45. Distance to Underwater Noise Thresholds from Source for Impact Driving of 36- to 48-inch Pile in North Portland Harbor

Threshold	Distance Without Attenuation Device (meters)	Distance With Attenuation Device (meters)
Injury: 190 dB RMS	54	12
Disturbance: 160 dB RMS		
Upstream	3,058	1,166
Downstream	5,412	1,166

For 18- to 24-inch pile in both water bodies, and for 36- to 48-inch pile in the Columbia River, the actual, site-specific distances are the same as the calculated distances (Table 6-43, Table 6-44, Figure 6-43, and Figure 6-44).

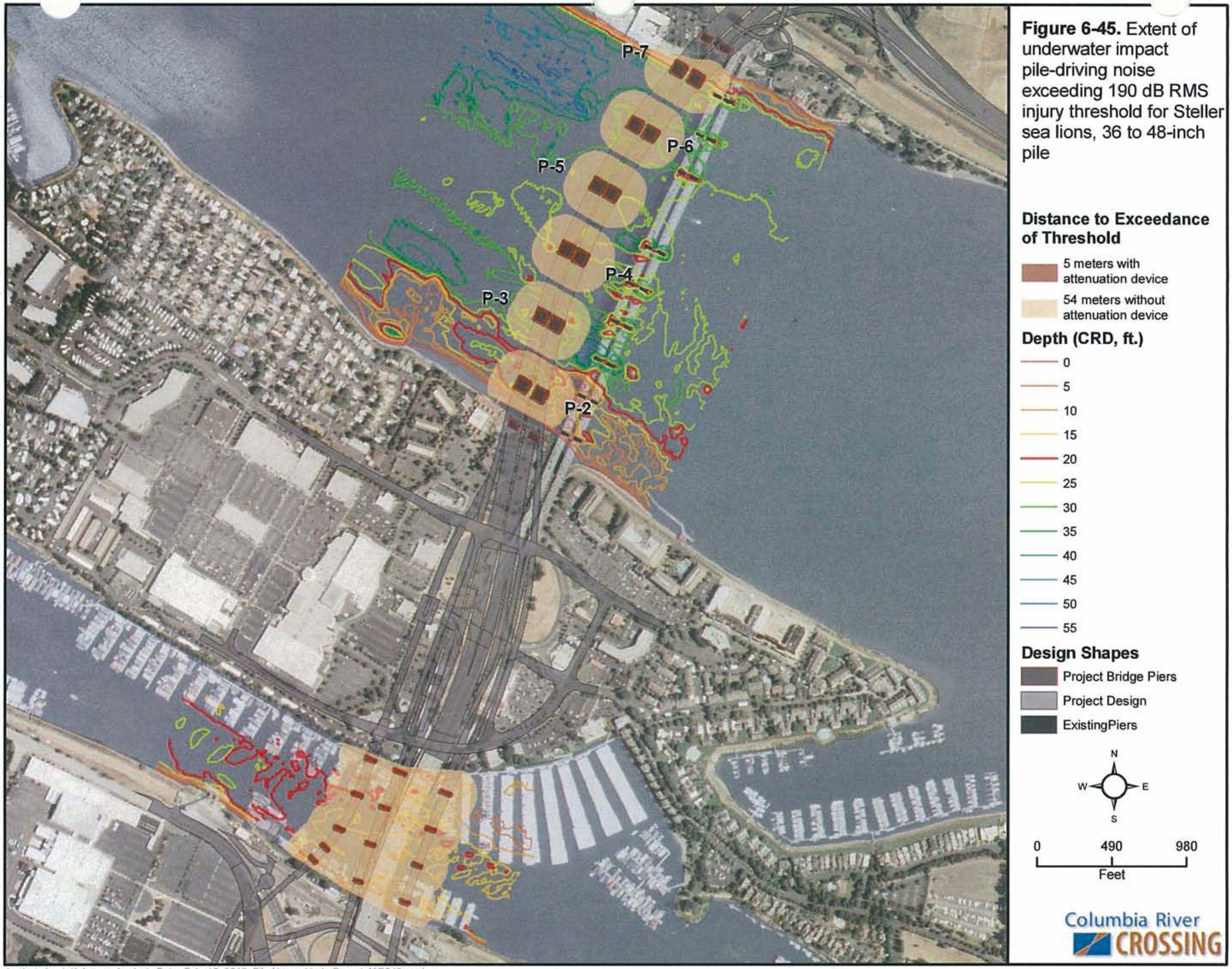


Figure 6-45. Extent of underwater impact pile-driving noise exceeding 190 dB RMS injury threshold for Steller sea lions, 36 to 48-inch pile

Analysis by J. Koloszar; Analysis Date: Feb. 16, 2010; File Name: HydroSound_MG246.mxd

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Figure 6-46. Extent of underwater impact pile-driving noise exceeding 160 dB RMS disturbance threshold for Steller sea lions, 36 to 48-inch pile

Distance to Exceedance of Threshold

- 541 meters with attenuation device
- 5,412 meters without attenuation device

Depth (CRD, ft.)

- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55

Design Shapes

- Project Bridge Piers
- Project Design
- ExistingPiers

N
W E
S

0 2,800 5,600
Feet

Columbia River CROSSING

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Vibratory Pile Driving – Underwater Noise

No studies were available that measured site-specific initial noise levels generated by vibratory pile driving in the CRC action area. However, Table 6-46 outlines a range of typical noise levels produced by vibratory pile driving as measured by Caltrans during hydroacoustic monitoring of several construction projects (Caltrans 2009).

Table 6-46. Summary of Unattenuated Underwater Sound Pressures for Vibratory Pile Driving

Pile Type and Approximate Size	Water Depth (meters)	SPLs (dB RMS)[a]
0.30-meter (12-inch) steel H-type	<5	150
0.30-meter (12-inch) steel pipe pile	<5	155
1-meter (36-inch) steel pipe pile – typical	~5	170
0.6-meter (24-inch) AZ steel sheet – typical	~15	160
0.6-meter (24-inch) AZ steel sheet – loudest	~15	165
1-meter (36-inch) steel pipe pile – loudest	~5	175
1.8-meter (72-inch) steel pipe pile – typical	~5	170
1.8-meter (72-inch) steel pipe pile – loudest	~5	180

Source: Caltrans 2009, Appendix I.

a Impulse level (35 millisecond average).

Pipe Pile

We estimated a worst-case scenario of installing 48-inch steel pipe pile (the largest pile size to be used on the CRC project) at the loudest measured SPLs. Since there were no data for 48-inch pile, we assumed that noise levels for 48-inch pile would be intermediate between noise levels generated by 36-inch pile and 72-inch pile (Table 6-46). Thus, we assumed that initial SPLs for vibratory driving of pipe pile would range from 175 to 180 dB RMS. Thus, this activity is not expected to exceed the 190 dB RMS injury threshold. Table 6-47 shows the distances at which noise is expected to attenuate to the 120 dB RMS vibratory pile driving disturbance threshold, as per the Practical Spreading Model.

Table 6-47. Distance to Underwater Noise Thresholds from Source for Vibratory Driving of Pipe Pile – Calculated Values

Estimated Noise Level (dB RMS)	Distance from Source (m)	
	Initial SPLs 175 dB RMS at 5 Meters	Initial SPLs 180 dB RMS at 5 Meters
120	23,208	50,000

Landforms in the Columbia River and North Portland Harbor will completely block underwater noise well before it reaches either of these distances. Table 6-48 shows site-specific values for the maximum distance at which noise is likely to exceed the 120 dB RMS disturbance threshold until contact with landforms, assuming initial SPLs of 180 dB RMS as a worst-case scenario (Figure 6-47).

Table 6-48. Distance to Underwater Noise Thresholds from Source for Vibratory Driving of Pipe Pile – Site-Specific Values

Water Body	Direction	Distance (m)
Columbia River	Upstream	20,166
	Downstream	8,851
North Portland Harbor	Upstream	3,058
	Downstream	5,632

Sheet Pile

The project may also install sheet pile in numerous locations in the Columbia River. In general, installation of sheet pile produces lower SPLs than pipe pile. Using the Practical Spreading Loss Model, assuming initial SPLs of 160 to 165 dB RMS at a distance of 15 m (from Caltrans data in Table 6-46), we estimated that noise from vibratory driving of sheet pile will likely attenuate to the 120 dB disturbance threshold at a distance of 6,962 to 15,000 m from the source (Table 6-49). In the Columbia River, noise will not attenuate to the threshold before encountering landforms, and therefore the site-specific values are the same as the calculated values.

Vibratory installation of sheet pile is not expected to exceed the 190 dB RMS injury threshold.

Table 6-49. Distance to 120 dB RMS Underwater Noise Threshold for Vibratory Driving of Sheet Pile in the Columbia River

	Distance from Source (m)	
Estimated Noise Level (dB RMS)	Initial SPLs 160 dB RMS at 15 Meters	Initial SPLs at 165 dB RMS at 15 Meters
120	6,962	15,000

Figure 6-47. Extent of underwater vibratory pile-driving noise exceeding 120 dB RMS disturbance threshold for Steller sea lions

Analysis by J. Koloszar; Analysis Date: Jan. 25, 2010; File Name: HydroSound_MG246.mxd

Steel Casings

Vibration may also be used to install the 10-foot-diameter steel casings for the drilled shafts of the permanent structures in the Columbia River and North Portland Harbor. No data were available regarding the initial SPLs generated by installation of steel casings of this size. Therefore, the design team extrapolated from published values, assuming that vibratory driving of 10-foot casings would generate noise at levels of up to 10 dB RMS (an order of magnitude) higher than the highest value for vibratory installation of a 72-inch pile (as shown in Table 6-46). That is, vibratory installation of 10-foot diameter steel casing may yield a maximum value of 190 dB RMS at 5 m from the pile.

Therefore, it is assumed that vibratory installation of 10-foot-diameter steel pile will exceed the 190 dB RMS injury threshold for Steller sea lions at 5 m from the source (Table 6-50). Table 6-50 also shows the distance within which noise is calculated to attenuate to the 120 dB RMS vibratory pile driving disturbance threshold, as per the Practical Spreading Model.

Table 6-50 Distance to Underwater Noise Thresholds from Source for Vibratory Driving of Steel Casings

Estimated Noise Level (dB RMS)	Distance from Source (m) Initial SPL 190 dB RMS at 5 m
190 (injury threshold)	5
120 (disturbance threshold)	233,000

Landforms in the Columbia River and North Portland Harbor will completely block underwater noise well before it reaches the 233,000-m distance calculated for the 120 dB RMS disturbance threshold. Table 6-51 shows site-specific values for the maximum distance at which noise is likely to exceed the injury and disturbance thresholds.

Table 6-51 Distance to Underwater Noise Thresholds for Vibratory Driving of Steel Casings – Site-Specific Values

	Distance from Source (m)	
Estimated Noise Level (dB RMS)	Columbia River	North Portland Harbor
190 (injury threshold)	5	5
120 (disturbance threshold)	20,166 Upstream 8,851 Downstream	3,058 Upstream 5,632 Downstream

Without a precise estimate of initial SPLs, the values shown in Table 6-51 are rough estimates. To refine these estimates, the CRC team proposes to perform hydroacoustic monitoring during vibratory installation of the first steel casing in order to verify: 1) the initial SPLs generated by this activity and 2) the potential injury zone for Steller sea lions. Additionally, hydroacoustic monitoring is likely to be required under the terms of a Letter of Authorization issued by NMFS under the Marine Mammal Protection Act.

Airborne Noise

For calculating the levels and extent of project-generated airborne noise, we assumed a point noise source and hard-site conditions because pile drivers will be stationary and work will largely occur over open water and adjacent to an urbanized landscape. Thus, calculations assumed that pile driving noise will attenuate at a rate of 6 dB per doubling distance, based on a spherical spreading model. The following formula was used to determine the distances at which pile-driving noise attenuates to the 100 dB RMS airborne disturbance threshold:

$$D_1 = D_0 * 10^{((\text{initial SPL} - \text{airborne disturbance threshold})/\alpha)}$$

Where D_1 is the distance from the pile at which noise attenuates to 100 dB RMS, D_0 is the distance from the pile at which the initial SPLs were measured, and α is the variable for soft-site or hard-site conditions. These calculations used $\alpha = 20$ for hard-site conditions.

Appendix K defines the terms used above and outlines these assumptions in greater detail.

Our estimate of initial noise level is based on the results of noise monitoring performed by WSDOT during pile driving at Friday Harbor Ferry Terminal in the town of Friday Harbor, Washington (Laughlin 2005b). The results showed airborne RMS noise levels of 112 dB RMS re: 20 µPa taken at 160 feet from the source during impact pile driving. This project drove 24-inch steel pipe pile, which is only half the size of the largest pile proposed for use on the CRC project. However, airborne noise levels are independent of the size of the pile (Michael Minor 2009 personal communication), and therefore the noise levels encountered at Friday Harbor are applicable to the CRC project.

The model used 112 dB RMS at 48.8 m (160 feet) from the source as the initial noise level for a single pile driver. Because multiple pile drivers will not strike piles synchronously, operation of multiple pile drivers will not generate noise louder than that of a single pile driver. Therefore, initial noise levels for multiple pile drivers were assumed to be the same as for a single pile driver.

The project is not likely to use an airborne noise-attenuation device. Therefore, we did not model transmission of airborne noise with use of an airborne attenuation device. Table 6-52 and Figure 6-48 show that noise generated by impact pile driving in the Columbia River and North Portland Harbor is likely to exceed the airborne disturbance threshold within 195 m of the source.

Table 6-52. Airborne Noise Attenuation to 100 dB Disturbance Threshold During Impact Pile Driving

Distance	Noise Attenuation (-6 dB per Doubling Distance)
49 m (160 ft)	112 dB RMS
98 m (320 ft)	106 dB RMS
195 m (640 ft)	100 dB RMS

Figure 6-48. Extent of airborne impact pile-driving noise exceeding 100 dB RMS disturbance threshold for Steller sea lions

Distance to Exceedance of Threshold

- 195 meters - single pile driver
- 274 meters - multiple pile drivers

Bathymetry

Depth (CRD, ft.)

- 0
- 5
- 10
- 15
- 20
- 25
- 30
- 35
- 40
- 45
- 50
- 55

Design Shapes

- Project Bridge Piers
- Project Design

N
W E
S

0 530 1,060
Feet

Columbia River CROSSING

6.4.1.4 Analysis of Effect

Steller sea lions are likely to be exposed to elevated noise levels in the action area. Exposure is likely to occur from November through May when primarily adult and subadult male Steller sea lions typically forage at Bonneville Dam. Steller sea lions are known to migrate through the action area between the dam and the ocean during this time period, often making multiple round-trip journeys. Individual sea lions also are occasionally present from October to November (Tackley et al. 2008). Therefore, exposure during this time is possible, but less likely.

It is not certain how many sea lions will be exposed to elevated noise levels. As of February 5, 2010, 16 Steller sea lions have been reported at Bonneville Dam (Columbia Basin Bulletin 2010). Since counts at the dam began in 2002, numbers have ranged from 2 to 26 individuals (Stansell et al. 2009). Presumably, the number of sea lions present in the action area at the time of the project will be at least 26 individuals per year. While it is impossible to exactly predict the behavior of transiting sea lions in the action area several years in advance, we estimate that approximately 35 sea lions will transit through the action area, making 10 trips (5 round trips) each year during the approximately 4-year in-water construction period. The total population of the Eastern stock of Steller sea lions is estimated at 45,095 to 55,832 individuals (Angliss and Allen 2007); therefore, effects will only extend to a very small fraction of the total population.

There are no Steller sea lion haulouts or breeding sites in areas likely to be exposed to elevated noise. The nearest known haulout is located approximately 32 miles upstream of the project area (Tennis 2009b personal communication). The nearest breeding site is located more than 200 miles from the project area (NMFS 2008g). Therefore, elevated noise levels will have no effect on individuals at breeding or haulout sites.

Sea lions use the action area primarily for transiting only and are expected to be highly mobile when present in portions of the action area exposed to noise above the threshold levels for injury and disturbance. Additionally, Lambourne (2010 personal communication) notes that Steller sea lions are likely to avoid unfamiliar noises, unless there is a particular attraction keeping them in the area. As the CRC project area does not contain any such attractions (for example, an especially rich food source, breeding area, or haulout site), Steller sea lions will presumably avoid portions of the action area exposed to high levels of elevated noise (for example, noise generated by impact pile driving). Therefore, they will likely experience only brief, temporary behavioral disturbance or harassment as a result of impact pile-driving noise. Lambourne (2010 personal communication) also added that Steller sea lions could become habituated to noises that are continuous and occurring over longer periods of time (such as vibratory pile-driving noise).

Exposure to Underwater Impact Pile-Driving Noise

Table 6-53 and Table 6-54 below quantify the extent, timing, and duration of impact pile-driving noise that will exceed threshold levels for disturbance and injury to sea lions. Impact pile driving is expected to take place over the approximately 4-year in-water construction period. During each year, work will likely occur within a 31-week in-water work window, ranging from week 38 of one year to week 16 of the next (or approximately from September 15 to April 15). There will be a total of about 138 days of impact pile driving in the Columbia River and about 134 days of impact pile driving in North Portland Harbor over the approximately 4-year construction period (Figure 6-14). Impact pile driving will be restricted to approximately 40 minutes per 12-hour work day. During most of this 40-minute period, pile driving will occur only with the use of a noise attenuation device; however, for a short duration (about 7.5 minutes per week in the Columbia River and roughly 2.5 to 5 minutes per week in North Portland Harbor), unattenuated pile driving may occur either during routine testing of the attenuation device. Each work day will include a period of at least 12 consecutive hours with no impact pile driving in order to minimize disturbance to aquatic animals. Likewise, each 7-day work week will include a period of at least 2 days during which no impact pile driving will occur. Impact pile driving will occur only during daylight hours.

Table 6-53. Summary of Extent, Timing, and Duration of Impact Pile-Driving Noise Above 190 dB RMS Underwater Injury Threshold [a]

	Columbia River			North Portland Harbor		
Pile Size and Number	**Distance (m)**	**Duration**	**No. Days**	**Distance (m)**	**Duration**	**No. Days**
Without Attenuation Device						
18- to 24-inch pile	9	7.5 min/week	38	9	2.5 – 5 min/week	18
36- to 48-inch pile	54	7.5 min/week	38	54	2.5 – 5 min/week	31
With Attenuation Device						
18- to 24-inch pile	2	40 min/day	138	2	40 min/day	72
36- to 48-inch pile	12	40 min/day	138	12	40 min/day	62

Note: Elevated noise levels will occur throughout the approximately 4-year in-water construction period. Potential exposure may only occur from approximately October to May, when Steller sea lions are typically present in the action area.

a Sea lions will actually not be exposed to injurious levels of noise, because impact pile driving will stop when sea lions are present in the injury zone.

Table 6-54. Summary of Extent, Timing, and Duration of Impact Pile-Driving Noise Above 160 dB RMS Underwater Disturbance Threshold

	Columbia River			North Portland Harbor		
Pile Size and Number	**Distance (m)**	**Duration**	**No. Days**	**Distance (m)**	**Duration**	**No. Days**
Without Attenuation Device						
18- to 24-inch pile	858	7.5 min/week	38	858	2.5 – 5 min/week	18
36- to 48-inch pile	5,412	7.5 min/week	38	3,058 - U 5,412 - D	2.5 – 5 min/week	31
With Attenuation Device						
18- to 24-inch pile	185	40 min/day	138	185	40 min/day	72
36- to 48-inch pile	1,166	40 min/day	138	1,166	40 min/day	62

U = upstream, D = downstream.

Note: Elevated noise levels will occur throughout the approximately 4-year in-water construction period. Potential exposure may only occur from approximately October to May, when Steller sea lions are typically present in the action area.

Exposure to Underwater Vibratory Pile-Driving Noise

Pipe Pile and Sheet Pile

Table 6-55 summarizes the extent, timing, and duration of noise above the 120 dB RMS disturbance threshold generated by vibratory pile driving during installation of pipe pile and sheet pile. Vibratory driving of pipe pile and sheet pile is not expected to exceed the 190 dB RMS injury threshold, but it is likely to exceed the 120 dB RMS disturbance threshold.

Vibratory driving of pipe pile is likely to occur intermittently throughout the entire in-water project area during construction of all new in-water piers or bents (Figure 6-14 and Figure 6-15). This activity will occur continually throughout the 4-year in-water construction period over approximately 49 to 54 months. This activity is not restricted to an in-water work window, and therefore may take place during any of the 52 weeks of the year. Figure 6-47 shows the estimated extent of in-water noise above the 120 dB RMS disturbance threshold during vibratory driving of pipe pile and sheet pile for construction activities. Table 6-55 shows the estimated extent, timing, and duration of this effect.

Vibratory driving of pipe pile and sheet pile is also likely to occur during demolition of the existing Columbia River bridge piers to install barge moorings and cofferdams. Pipe piles for barge moorings will be installed and removed continuously throughout the entire 18-month demolition period, during any of the 52 weeks of the year (Figure 6-16). Cofferdams will each require about 10 days to install and will likely be installed during the last 13 months of the 18-month demolition period (Figure 6-16). Figure 6-47 shows the estimated extent of in-water noise above the 120 dB RMS disturbance threshold during vibratory driving of pipe pile and sheet pile during demolition. Table 6-55 shows the estimated extent, timing, and duration of this effect.

Table 6-55. Summary of Exposure to Vibratory Pile-Driving Noise Above 120 dB RMS Disturbance Threshold – Pipe Pile and Sheet Pile

		Columbia River			North Portland Harbor		
Pile Type	Timing	Distance (m)	Hours/ Day	No. Days	Distance (m)	Hours/ Day	No. Days
Pipe Pile	Year-round	20,166 - U 8,851 - D	Up to 5	1,470–1,620	3,058 - U 5,632 - D	Up to 5	~334
Sheet Pile	Year-round	6,962	Up to 24	99	N/A	N/A	N/A

U = upstream, D= downstream

Note: Elevated noise levels will occur throughout the approximately 4-year in-water construction period. Potential exposure may only occur from approximately October to May when Steller sea lions are typically present in the action area.

Steel Casings

Table 6-56 summarizes the extent, timing, and duration of noise above the injury and disturbance thresholds during vibratory installation of steel casings. The design team estimates that vibratory installation of 10-foot casings will take approximately 90 days in the Columbia River and 31 days in North Portland Harbor. Vibratory installation of 10-foot casings is not restricted to the in-water work window and therefore may take place any time during the four-year in-water construction period.

Table 6-56. Summary of Exposure to Vibratory Pile Driving Noise Above Disturbance and Injury Thresholds – Steel Casings

		Columbia River		North Portland Harbor	
Threshold	Timing	Distance (m)	No. Days	Distance (m)	No. Days
120 dB RMS	Year-round	20,166 - U 8,851 - D	90	3,058 - U 5,632 - D	31
190 dB RMS	Year-round	5	90	5	31

U = upstream, D= downstream

Note: Elevated noise levels will occur throughout the 4-year in-water construction period. Potential exposure may only occur from approximately October to May when Steller sea lions are typically present in the action area.

As stated earlier, hydroacoustic monitoring will be conducted to field verify the distances within which noise exceeds these thresholds.

Exposure to Airborne Pile-Driving Noise

Figure 6-48 and Table 6-57 summarize the extent, timing, and duration of airborne noise. Airborne noise effects will occur on the same schedule as those described for impact pile driving above.

Table 6-57. Summary of Exposure to Airborne Impact Pile-Driving Noise Above 100 dB RMS Disturbance Threshold

Location	Distance from Source (m)	Mins/Day	No. Days
Columbia River	195	≤40	138
North Portland Harbor	195	≤40	134

Note: Elevated noise levels will occur throughout the approximately 4-year in-water construction period. Potential exposure may only occur from approximately October to May, when Steller sea lions are typically present in the action area.

Injury

The project is not likely to injure Steller sea lions. Although underwater impact pile driving noise is likely to exceed the injury threshold, this effect will be limited to an estimated distance of 2 to 54 m from the noise source, depending on the number and size of the piles or whether a noise attenuation device is in use (Table 6-53). Additionally, as impact pile driving noise will be sporadic, occurring only about 40 minutes per day, Steller sea lions will likely avoid it as an unfamiliar source of disturbance. We would therefore expect them to avoid the injury zone rather than becoming habituated, thus reducing the potential for exposure.

The project will further limit the potential for injury to Steller sea lions through the implementation of a monitoring plan. As an initial worst-case scenario, marine-mammal monitors will ensure that the project curtails pile driving if sea lions are present within the largest area estimated to be exposed to noise above the 190 dB RMS injury threshold. For impact pile driving, this includes all areas within 54 m of the source (Table 6-53). For vibratory driving of steel casings, this includes all areas within roughly 5 m of the source.

The actual extent of injurious underwater noise will be verified in the field through hydroacoustic monitoring (Section 7.2.3.4). This may result in an adjustment in the size of the injury zone to be monitored for presence of Steller sea lions.

Because injurious noise levels will extend only a short distance and because marine mammals will be readily visible within these areas, it is reasonable to expect that qualified marine-mammal monitors will be able to detect sea lions within the injury zones. Impact pile driving is not anticipated to occur at night, making the probability of detection very high. Vibratory driving of 10-foot-diameter steel casings may occur at night. If it is determined that this activity will result in injurious noise levels, marine mammal monitors will use night-vision/night-detection equipment to ensure detection of Steller sea lions within the injury zone while this activity is taking place. For these reasons, we believe that avoidance of injury through implementation of a monitoring plan is an attainable goal. While injury is theoretically possible, it is not probable. Therefore, project-generated noise is not likely to injure sea lions.

Behavioral Effects

The project is likely to create noise above threshold levels for airborne and underwater behavioral disturbance to Steller sea lions. Table 6-54 through Table 6-57 outline the extent, timing, and duration of this effect.

Because studies on behavioral effects to sea lions are limited, and because the few available studies show wide variation in response to noise, it is difficult to quantify exactly how pile driving noise will affect Steller sea lions. The literature shows that elevated noise levels could prompt a range of effects, including no obvious visible response, brief visual orientation towards the noise, curiosity (or movement towards the source), or habituation to the sound (Southall et al. 2007). Southall et al. note that there is little evidence that high levels of pulsed noise will prompt avoidance of an area; however, given the paucity of data on the subject, we cannot rule out the probability that avoidance of the action area could occur.

Overall, we presume that noise generated by pile driving is likely to cause brief temporary harassment of Steller sea lions transiting the action area, potentially causing minor disruption of migration and feeding. Because the Steller sea lions use the action area primarily for transiting only, exposure is likely to be brief. Additionally, because many of the individuals transiting the area are already habituated to high ambient disturbance levels and to hazing at Bonneville Dam, we expect that they will not be especially sensitive to pile driving noise. In fact, they could eventually become habituated to continuous noise sources (such as vibratory pile driving), as they have at Bonneville Dam. Although brief, temporary, harassment will occur within the disturbance threshold areas, it is expected that elevated noise will have only a negligible effect on foraging and migration of individual sea lions, and no effect on the overall population.

Temporary Threshold Shift

Unattenuated impact pile driving will produce maximum initial pulsed noise levels estimated at 214 dB peak and 186 dB SEL. These noise levels are above the levels observed by Southall et al. (2007) for onset of TTS in pinnipeds (212 dB peak and 171 dB SEL). Attenuated impact pile driving is not expected to exceed these levels. Although Southall et al. (2007) suggested criteria have not been adopted by any regulatory body, they are presented as a starting point to discuss the likelihood of TTS on this project.

The literature has not drawn conclusions on levels of underwater non-pulsed noise (for example, vibratory pile driving) likely to cause TTS. We estimate that the extent of the area in which noise levels could potentially cause TTS is somewhere in between the extent of the injury zone and the extent of the disturbance zone (74 FR 63724).

Although underwater noise levels produced by the CRC project may exceed levels that have produced TTS in pinnipeds in other studies (Southall et al. 2007), there is a general lack of controlled, quantifiable field studies related to this phenomenon, and even those studies that have been conducted have had varied results. Therefore, it is difficult to extrapolate from these data to site-specific conditions on the CRC project. For example, because most of the studies have been conducted in laboratories, rather than in field settings, the data are not conclusive whether noise will cause sea lions to avoid the action area, thereby reducing the likelihood of TTS, or whether noise will attract sea lions, increasing the likelihood of TTS. In any case, there are no universally accepted standards for the amount of exposure time likely to induce TTS. Lambourne (2010 personal communication) posits that, in most circumstances, free-roaming sea lions are not likely to remain in areas subjected to high noise levels long enough to experience TTS. While we may infer that TTS could conceivably result from the project, it is impossible to exactly quantify the magnitude of exposure, the duration of the effect, or the number of individuals likely to be affected.

Impact pile driving will produce initial airborne noise levels of approximately 112 dB peak at 160 feet from the source, as compared to the level suggested by Southall et al. (2007) of 143 dB peak for onset of TTS in pinnipeds during multiple pulses of airborne noise. It is not expected that airborne noise levels will prompt TTS in Steller sea lions.

Exposure is likely to be brief because sea lions use the action area chiefly for transiting, rather than breeding or hauling out. In summary, we expect that elevated noise will have only a negligible probability of causing TTS in individual sea lions.

6.4.1.5 Conclusion

Injury to Steller sea lions is avoidable through the implementation of a monitoring plan that requires a cessation of impact pile driving before individuals enter the underwater injury zone, defined as from 2 to 54 m from the noise source. Additionally, if vibratory installation of 10-foot-diameter steel casings produces noise above the injury threshold, this activity will cease before Steller sea lions enter the potential injury zone (anticipated to be 5 m from the activity).

Noise above the behavioral disturbance threshold is likely unavoidable during both impact and vibratory pile driving, but effects to sea lions are expected to be brief and temporary, impacting only a small number of adult and subadult sea lions transiting the action area. No noise disturbance will occur at breeding areas or haulouts. Noise is not expected to significantly interfere with foraging, transiting, breathing, or other essential life functions.

6.4.2 Noise from Underwater Debris Removal

Debris removal in North Portland Harbor is likely to create noise above ambient levels in portions of the underwater action area. The following sections provide background information on typical underwater noise levels produced by underwater excavation, outline the extent of exposure to Steller sea lions, and analyze the potential effects of such exposure. Most of the information about noise and underwater excavation refers to dredging; thus, noise level studies below all refer to dredging studies.

6.4.2.1 Noise Levels Produced by Dredging

Few studies have been conducted on noise emissions produced by underwater dredging (Thomsen et al. 2009). In a literature review of available information, Thomsen et al. (2009) and OSPAR (2009) both found that noise from dredging operations ranged from 168 to 186 dB RMS at 1 m. It should be noted that the majority of these studies were related to trailing suction hopper dredger operations, which produce the highest noise levels of any of the dredge types, including those produced by the grab dredger (also known as a bucket dredger) that will be used on the CRC project. Of the studies reviewed in Thomsen et al. (2009), only one studied grab dredging. Clarke et al. (2002, as cited in Thomsen et al. 2009) monitored grab dredging with a 10 m^3 bucket, measuring 124 dB re: 1 μPa at 150 m (back-calculated as 142 dB at 10 m). Additionally, Dickerson et al. (2001) found that bucket dredging noise produced at most 124 dB RMS at 158 m (142 dB RMS at 10 m) in coarse sand and gravel. Miles et al. (1986, 1987, as cited in Richardson et al. 2005) reported that bucket dredging noise ranged from 150 to 162 dB at 1 m (or 135 to 147 dB at 10 m). Combining the available data sources, we estimate that underwater debris removal will produce noise in the range of 135 dB to 147 dB RMS at 10 m.

The research cited above suggests that underwater debris removal noise will not exceed the 190 dB RMS injury threshold. However, this activity is likely to exceed the 120 dB RMS disturbance threshold within areas approximately 631 m from the source (Table 6-58).

Table 6-58. Underwater Noise Attenuation for Debris Removal Noise – Calculated Values

Noise Level (dB RMS)	Distance from Source (m) Bucket Dredge Initial SPL 147 at 10 m
150	7
140	30
130	136
120	**631**

Underwater debris removal is not expected to generate significant airborne noise. The air-water interface creates a substantial sound barrier and reduces the intensity of underwater sound waves by a factor of more than a thousand when they cross the water surface. The above-water environment is thus virtually insulated from the effects of underwater noise (Hildebrand 2005). Therefore, we do not expect underwater debris removal to measurably increase ambient airborne noise.

6.4.2.2 Potential Exposure of Steller Sea Lions to Underwater Debris Removal Noise

Table 6-59 summarizes potential exposure of Steller sea lions to underwater debris removal noise in the North Portland Harbor. Exposure is presented as an overlap of the areal extent of noise above the 120 dB RMS disturbance threshold, combined with the duration and timing of the impact and the time periods when Steller sea lions are likely to be present in the action area.

Debris removal is not certain to occur, but is included to present the fullest disclosure of effects. Debris removal is discussed in more detail in Section 6.1.1.2. It is possible that debris removal will occur in North Portland harbor at the location of each of the new piers where there is anecdotal evidence that riprap occurs within the pier footprints. The exact location of this material is unknown, but as a worst-case scenario, this activity will remove approximately 90 cubic yards of material over an area of approximately 2,433 sq. ft. from all piers combined.

Table 6-59. Summary of Potential Steller Sea Lion Exposure to Debris Removal Noise Above the 120 dB RMS Disturbance Threshold

Noise Source	Location[a]	Underwater Distance (m)	Hours/ Day	Number of Days	Timing[b]
Bucket dredge	Potentially at all new NPH piers	631	≤12	up to 7 days	Nov 1 – Feb 28

a NPH = North Portland Harbor

b Over the course of in-water construction and demolition period: 2013 to 2018.

6.4.2.3 Effects of Exposure to Debris Removal Noise

The reactions of pinnipeds to dredging noise have received virtually no study. Previous studies indicate that dredging noise has resulted in avoidance reactions in marine mammals; however, the number of studies is few, limited to only a handful of locations. Thomsen et al. (2009) caution that, given the limited number of studies, the existing published data may not be representative and that it is therefore impossible to extrapolate the potential effects from one area to the next.

In a review of the available literature regarding the effects of dredging noise on marine mammals, Richardson et al. (2005) found only studies related to whales and porpoises, and none related to pinnipeds. The review did, however, find studies related to the response of pinnipeds to "other construction activities," which may be applicable to dredging noise. Three studies of ringed seals during construction of artificial islands in Alaska showed mostly mild reactions ranging from negligible to temporary local displacement. Green and Johnson (1983, as cited in Richardson et al. (2005)) observed that some ringed seals moved away from the disturbance source within a few kilometers of construction. Frost and Lowry (1988, as cited in Richardson et al. (2005)) and Frost et al. (1988, as cited in Richardson et al. 2005) noted that ringed seal density within 3.7 Km of construction was less than seal density in areas located more than 3.7 Km away. Harbor seals in Kachemak Bay, Alaska, continued to haul out despite construction of hydroelectric facilities located 1,600 m away. Finally, Gentry and Gilman (1990) reported that the strongest reaction to quarrying operations on St. George Island in the Bering Sea was an alert posture when heavy equipment occurred within 100 m of northern fur seals.

In their study about sea lion hazing at Bonneville Dam, Stansell et al. (2009) note that sea lions showed only temporary behavioral responses to loud noise, which did not cause any measurable interference with foraging or transiting. Sea lions quickly habituated to the noise, some foraging within 20 feet of intense noise. The results suggest that some of individuals that transit through the action area either are already habituated to some loud noises or could readily become habituated.

6.4.2.4 Effect of Exposure at the CRC Project

There are no established levels of underwater debris removal noise shown to cause injury to sea lions. However, since the maximum expected debris removal noise levels on the CRC project are below any known injury thresholds (190 dB RMS, for impulsive noises), it seems probable that this activity will not produce noise levels that are injurious to sea lions. Additionally, the limited body of literature does not include a single report of injuries caused by noise from underwater excavation.

Debris removal noise is likely to exceed the disturbance threshold (120 dB RMS for non-pulsed continuous noises) for only a short distance from the source (approximately 631 m). We presume that specific responses to noise above this level may range from no response to avoidance to minor disruption of migration and/or feeding. Alternatively, Steller sea lions may become habituated to elevated noise levels (NMFS 2005b; Stansell 2009). This is consistent with the literature, which reports only the following behavioral responses to these types of noise sources: no reaction, alertness, avoidance, and habituation. NMFS (2005b) posits that continuous noise levels of 120 dB RMS re: 1 μPa may elicit responses such as avoidance, diving, or changing foraging locations.

Behavioral disturbance is expected to be brief and temporary, restricted to individuals that are transiting the action area and occurring for no more than seven days during the 4-year in-water construction period. Because many of the individuals transiting the area are already habituated to hazing at Bonneville Dam and to high levels of existing noise throughout the lower Columbia River, we expect that they will not be especially sensitive to a marginal increase in existing noise. Therefore, they may eventually become habituated to noise at the CRC project.

Alternatively, because debris removal noise occurs over such a short duration, it is possible that Steller sea lions will not be present in this portion of the action area at the time of the activity, and therefore may experience any exposure to this type of noise.

6.4.3 Vessel Noise

Various types of vessels, including barges, tug boats, and small craft, will likely be present in the project area at various times. Vessel traffic will continually traverse the in-water project area, with activities centered on Piers 2 through 7 of the Columbia River and the new North Portland Harbor bents. Such vessels already use the action area in moderately high numbers, and therefore the vessels to be used in the CRC action area do not represent a new noise source, only a potential increase in the frequency and duration of existing noise levels.

There are very few controlled tests or repeatable observations related to the reactions of pinnipeds to vessel noise and no known studies specifically related to Steller sea lions. However, Richardson et al. (1995) reviewed the literature on reactions of pinnipeds to vessels, concluding overall that seals and sea lions showed high tolerance to vessel noise. One study showed that, in water, sea lions tolerated frequent approach of vessels at close range, sometimes even congregating around fishing vessels.

Because the CRC action area is heavily traveled by commercial and recreational craft, it seems likely that Steller sea lions will become habituated to the additional vessels present in the project vicinity during the course of the project. Therefore, this aspect of the project is not likely to adversely affect the Steller sea lion.

6.4.4 Physical Disturbance

Vessels, in-water structures, and over-water structures have the potential to cause physical disturbance to Steller sea lions.

Various types of vessels already use the action area in high numbers, and therefore the vessels to be used on the CRC project do not represent a new disturbance, only an increase in the existing level of disturbance. Tug boats and barges are slow moving and follow a predictable course. Sea lions will be able to easily avoid these vessels while transiting through the action area, and they are probably already habituated to the presence of numerous vessels, as the lower Columbia River and North Portland Harbor receive high levels of commercial and recreational vessel traffic. Therefore, vessel strikes are extremely unlikely and therefore discountable. Potential encounters will likely be limited to brief, sporadic behavioral disturbance, if any at all. Such disturbances will have only insignificant effects on sea lions.

Figure 6-42 shows the location, timing, and duration of in-water and overwater structures in the Columbia River and North Portland Harbor, including barges, moorings, tower cranes, cofferdams, and work platforms. Although there will be many such structures in the CRC action area, they will cover no more than 20 percent of the entire channel width at one time. There will still be ample room for Steller sea lions to navigate around these structures. Sea lions may need to slightly alter their migration course to avoid these structures, but there is no potential for physical structures to completely block upstream and downstream movement. Due to the small size of the structures relative to the remaining portion of the river available, delays to the migration will be negligible. Therefore, the effect of in-water and overwater structures on sea lions will be insignificant.

6.4.5 Effects on Prey

The prey base of the Steller sea lion consists chiefly of salmon, steelhead, and sturgeon, all of which occur in the action area and may be affected by the project. Effects to each of these species of fish are outlined in detail in Sections 6.1 to 6.3 of this BA.

6.4.5.1 Prey Quality

Prey quality may be affected by levels of turbidity, contaminated sediments, or other contaminants in the water column. The CRC project will minimize, avoid, or contain all potential sources of contamination, minimizing the risk of exposure to prey species of the Steller sea lion.

The CRC project involves several activities that could potentially generate turbidity in the Columbia River and North Portland Harbor, including pile driving, pile removal, installation and removal of cofferdams, installation of steel casings for drilled shafts, and debris removal. These activities are described in greater detail in Section 6.1.5.2. Table 6-16 summarizes the locations, areal extent, and duration of turbidity generated by these activities. Turbidity is not expected to cause mortality in the fish species using this portion of the action area, and effects will probably be limited to temporary avoidance of the discrete areas of elevated turbidity for approximately 4 to 6 hours at a time. Therefore, turbidity will have only insignificant effects to the prey base and insignificant effects on the Steller sea lion.

In-water work is extremely unlikely to mobilize contaminated sediments, as detailed in Section 6.1.5.3. Well in advance of in-water work, the project team will perform an extensive search for evidence of contamination, pinpointing the location, extent, and concentration of the contaminants. The project will then implement BMPs to ensure that the project either (1) avoids areas of contaminated sediment or (2) enables responsible parties to initiate cleanup activities for contaminated sediments occurring within the project construction areas. These BMPs will be developed and implemented in coordination with regulatory agencies. Because the project will identify the locations of contaminated sediments and use BMPs to ensure that they do not become mobilized, there is little risk that the Steller sea lion prey base will be exposed to contaminated sediments. Therefore, this aspect of the project is not likely to adversely affect the Steller sea lion.

In-water and near-water construction will employ numerous BMPs and will comply with numerous regulatory permits to ensure that contaminants do not enter surface water bodies. In the unlikely event of accidental release, numerous BMPs and a Pollution Control and Contamination Plan will be implemented to ensure that contaminants are prevented from spreading and are cleaned up quickly. (These methods are described in greater detail in Section 7.) Section 6.1.5.1 outlines the possible effects of construction-related contaminants on fish that make up the prey base of the Steller sea lion. This section concludes that contaminants are not likely to significantly affect these species of fish. Therefore, effects on the quality of the Steller sea lion prey base will also be insignificant.

6.4.5.2 Prey Quantity

The project is likely to impact a small percentage of all the runs of salmon and steelhead, using the action area through in-water pile driving, as described in Section 6.1.1 and Appendix K. This does not represent a large part of the Steller sea lion prey base in comparison to prey available through the entirety of their foraging range, which includes the Columbia River from Bonneville Dam to the mouth and thousands of square miles of foraging grounds off the Pacific Coast. Overall, effects to the prey base will be temporary, limited to the in-water work period over the project duration, and will not cause measurable changes in the quantity of prey available to sea lions. These effects are therefore insignificant.

6.5 CUMULATIVE EFFECTS

Cumulative effects include state, tribal, local, and private activities that are reasonably certain to occur within the action area and are likely to affect the species considered in this BA. Cumulative effects do not include any federal actions.

State and local government actions include land use planning and permitting (such as, zoning and shoreline management plans); floodplain and watershed management (for example in-stream flow rules and regulations, water acquisitions; HPAs and other permitting, and culvert replacements); water quality management (such as NPDES permitting); recreational and commercial fishing permitting and management; hatchery management; transportation projects; and habitat restoration projects.

Roadside and commercial development, as well as maintenance and upgrading of existing infrastructure, are likely to occur in the foreseeable future within the action area. However, only one known project was identified as reasonably certain to occur. The Gramor Development project is located immediately to the west of the I-5 facility just south of Evergreen Boulevard. This development is a joint public/private partnership. This project is early in the planning stages and therefore it is not possible to quantify effects to listed species at this time. However, at this stage it is safe to assume that the project will involve the following activities: addition of new PGIS, riparian disturbance and revegetation, and potential in-water pile removal. If these activities occur, effects will be similar to those outlined in Sections 6.1.5 (Temporary Effects to Water Quality), 6.2.1 (Stormwater Effects), and 6.3.3 (Riparian Habitat).

Recreational and commercial fishing occurs in the Columbia River and North Portland Harbor within the action area. In addition, recreational and commercial fishing occurs in the Pacific Ocean portion of the action area associated with killer whales. Both of these activities are reasonably certain to occur, affect the listed fish species addressed by this BA, and will lead to the continued mortality of listed fish. At this point, it is impossible to quantify the number of individual fish that will be affected, exact extent of the area of effect, or the timing and duration of the effect.

In addition, ongoing climate change will likely cause alterations to hydrologic conditions within the action area. Based on a review of the literature, the general trend predicted in the Pacific Northwest is for warmer, wetter winters with less snow and higher peak flows, and drier summers with lower summer base flows (JISAO 2002; Hamlet et al. 2003; OSU 2006; Mote et al. 2008; Doppelt et al. 2009). The predictions indicate that climate change will result in a decrease in snowpack, which is a significant factor in Pacific Northwest hydrology (Hamlet et al. 2003). Climate change in the region may result in alterations to salmonid run-timing, productivity, and survival. In smaller systems, it is possible to generate models that predict changes to river flow, but the Columbia River is a highly managed system, and the network of dams and reservoirs could mitigate the potential changes in river hydrology (Hamlet et al. 2003). In addition, new methods of river management, such as groundwater injection, may also play an important role in future river management strategies (DWR 2008). To date, the best available science does not allow for predictions about the potential effect of global climate change on hydrology in the Columbia River and North Portland Harbor.

The actions described above are ongoing and likely to continue in the future. Even though there will almost certainly be future restoration projects that improve habitat for listed species, the overall cumulative effects described above will have adverse impacts on listed species in the action area; however, these effects are difficult if not impossible to quantify.

6.6 EFFECTS FROM INTERRELATED AND INTERDEPENDENT ACTIONS

A BA analyzes the effect of interrelated and interdependent actions together with the effect of the larger action under consultation. This section analyzes the direct and indirect effects of interrelated and interdependent actions. The following have been identified as interrelated and interdependent actions, as described in Section 3.14: compensatory mitigation sites, maintenance and operation of the completed project, utility relocation, unanticipated staging and casting areas, design and operation of a pump station in Columbia Slough, and displacement of floating homes in North Portland Harbor.

6.6.1 Compensatory Mitigation Sites

The project will be required to offset impacts to aquatic habitat by performing compensatory mitigation as required by Section 404 of the Clean Water Act, a WDFW HPA, Oregon Removal/Fill law, and other regulations. The project proposes two mitigation sites: the Lower Hood River Powerdale Corridor Off-Channel Wetland Reconnection and the Lewis River Confluence Side Channel Restoration.

This BA analyzes the effects of the mitigation sites on listed species and critical habitat as required under Section 7. However, this analysis does not represent Section 7 consultation on these mitigation sites. Each site will undergo a separate Section 7 consultation submitted by USACE as an independent federal action.

The following sections outline the occurrence of listed fish and critical habitat in these areas and provide an analysis of effects

6.6.1.1 Oregon Compensatory Mitigation: Lower Hood River Powerdale Corridor Off-Channel Wetland Reconnection

Because state and USACE compensatory mitigation is required to construct the bridges over the Columbia River and North Portland Harbor in Oregon, CRC is providing funding for design and implementation of restoration at the Lower Hood River Powerdale Corridor Off-Channel Wetland Reconnection site. The entire site is owned by Columbia Land Trust and will be constructed and maintained by them. The site is undergoing a separate section 7 consultation as an independent federal action submitted by the USACE.

Listed Species and Critical Habitat Occurrence

CRC evaluated listed species and designated or proposed critical habitats potentially present in the area of the mitigation site; the upstream connection of the side channel with Hood River 100 feet upstream to the downstream end of the connection of the side channel with Hood River and an additional 300 feet downstream based on the NMFS website,[12] the USFWS county species lists obtained for Hood River County, Oregon (USFWS 2010a), information from Hood River Watershed Council, and a site visit conducted on February 23, 2010.

Salmon and Steelhead (and Critical Habitat)

NMFS website lists the following ESUs/DPSs as present in the mainstem Hood River and adjacent to the compensatory mitigation site: LCR Chinook, LCR steelhead, and LCR coho. Designated critical habitat is present in the lower Hood River for LCR Chinook and LCR steelhead (70 FR 52630). The lower Hood River contains the following three PCEs for all salmon and steelhead listings in the lower mainstem Hood River:

- Spawning habitat for LCR Chinook.
- Rearing habitat.
- Migration habitat.

[12] Available at: http://www.nwr.noaa.gov/ESA-Salmon-Listings/Salmon-Populations/Index.cfm.

Bull Trout (and Critical Habitat)

The USFWS county list indicates bull trout are potentially present and critical habitat is designated in the mainstem Hood River (75 FR 2270). In addition, on January 14, 2010, critical habitat for bull trout was proposed in the mainstem Hood River (75 FR 2270). The following PCEs of designated critical habitat are present within the mitigation site's action area:

- Springs, seeps, groundwater sources, and subsurface water connectivity (hyporheic flows) provide thermal refugia and contribute to water quality and quantity.
- Migratory habitats with minimal physical, biological, or water quality impediments between spawning, rearing, overwintering, and freshwater and marine foraging habitats, including but not limited to permanent, partial, intermittent, or seasonal barriers.
- An abundant food base, including terrestrial organisms of riparian origin, aquatic macroinvertebrates, and forage fish.
- Complex river, stream, lake, reservoir, and marine shoreline aquatic environments and processes with features such as large wood, side channels, pools, undercut banks and substrates, to provide a variety of depths, gradients, velocities, and structures.
- Suitable water temperatures ranging from 2 to 15°C (36 to 59°F), with adequate thermal refugia available for temperatures at the upper end of this range.
- A natural hydrograph, including peak, high, low, and base flows within historic and seasonal ranges or, if flows are controlled, they minimize departures from a natural hydrograph.
- Sufficient water quality and quantity such that normal reproduction, growth, and survival are not inhibited.

One PCE is not present in the action area because the mitigation site is not located in upper river reaches where bull trout spawn and fry and juveniles rear: Substrates of sufficient amount, size, and composition to ensure success of egg and embryo overwinter survival, fry emergence, and young-of-the-year and juvenile survival.

The 2010 proposal for critical habitat includes the PCEs listed above and an additional PCE: Few or no non-native predatory (e.g., lake trout, walleye, northern pike, and smallmouth bass), inbreeding (e.g., brook trout), or competitive (e.g., brown trout) species present.

Effects to Listed Species

Temporary adverse impacts could potentially occur during and following construction until the site is stabilized. In preparation for the channel reconnection, the work area will be isolated and juvenile fish that are present will be captured and handled. There will be a temporary increase in water temperatures and total suspended sediment during the channel reconnection as a result of that "first flush" of standing water isolated behind the MHRR tracks. A temporary decrease in forage and cover will occur when vegetation along the existing bank is excavated. Loss of resting, holding, and prey items may occur for fish migrating or rearing in the area. The effect from the decrease in forage and cover will be temporary until the newly planted riparian and wetland vegetation is established. Migrating and holding adult and migrating and rearing juvenile LCR Chinook, LCR coho, and LCR steelhead, as well as adult and subadult bull trout may be exposed to this localized, temporary effect. Adult and subadult bull trout are only documented in very low numbers in the lower Columbia River (see Appendix J) and are expected to be present only in low numbers in the lower Hood River. Bull trout fry or juveniles do not occur in the lower reaches of Hood River.

In-water work, including installation of work area isolation measures, fish handling and removal of the railroad berm separating the side channel from the river and installation of the downstream and then the upstream connections (e.g. bridge or trestle) will only occur during the in-water work window when adult salmon and steelhead and adult and subadult bull trout are not expected to be present. Migrating and rearing juveniles of the following ESUs/DPSs could potentially be exposed: LCR Chinook, LCR coho, and LCR steelhead. The temporary increase in water temperature and total suspended sediment that will occur when the side channel is physically reconnected to the river can have adverse effects to juvenile LCR Chinook, LCR coho, and LCR steelhead. Handling of juvenile salmonids during fish capture and removal in the work isolation areas can have adverse effects. These effects can reduce growth, increase susceptibility to disease, increase competition, and inhibit movements necessary for rearing and migration. However, fish handling and degradation to water quality from sediment inputs during channel re-connection will be temporary, short in duration, and will be spatially limited.

After construction of the mitigation site, some increases in suspended sediment may occur intermittently for weeks or months until restoration plantings are established. Migrating and holding adult and migrating and rearing juveniles of LCR Chinook, LCR coho, and LCR steelhead, as well as migrating and holding adult and subadult bull trout, may be exposed to this localized and temporary effect. Due to the limited number of bull trout in the system and the limited duration and extent of impacts associated with the described activities, all effects would be discountable for bull trout. The longer term effects of the mitigation project will be beneficial due to restoration of river functions through a better functioning floodplain and riparian area. Permanent beneficial effects are listed below.

- Increased spawning and rearing habitat for salmon and steelhead.
- Restoration of the riparian and wetland area through reconnection with the river and plantings will provide allochthonous inputs into the channel, cover, and shade which will improve foraging, rearing, holding, and migrating adult and juvenile salmon and steelhead and adult and subadult bull trout.
- Improvements to the hydrological function in the main channel and restoration in the side channel will result in improved rearing habitat for salmon and steelhead juveniles by creating high flow refuges, potentially improving base flows, attenuating peak flow, and likely improving water quality from flow attenuation and wetland reconnection.
- Placement of large woody debris will create habitat complexity and provide improved rearing and holding conditions for adult and juvenile salmon and steelhead and subadult and adult bull trout.

In the short term, this action is likely to adversely affect salmon and steelhead due to temporary turbidity. Over the long term, however, this action will improve habitat, resulting in an overall beneficial effect to salmon and steelhead.

Due to the extremely low numbers of bull trout potentially occurring in this portion of the action area, risks of exposure to this action are discountable. Therefore, the Hood River compensatory mitigation site may affect, but is not likely to adversely affect bull trout.

Effects to LCR Chinook and LCR Steelhead Critical Habitat

Designated critical habitat for LCR Chinook and LCR steelhead in the mitigation site's action area contains spawning, rearing, and migration PCEs. Anticipated effects to these PCEs from construction and restoration of the mitigation site are described by PCE below.

Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation, and larval development. Turbidity as a result of construction and reconnection of the side channel where it comes into contact with Hood River at the upstream and downstream ends of the project will cause only slight, temporary degradation of small discrete portions of the spawning PCE in the mainstem Hood River. The location of the downstream reconnection outfalls to a large gravel bar used by fall-run LCR Chinook for spawning, but will not be present at the time of reconnection (July 15-August 31). Due to the high dilution capacity of the lower Hood River during the period of side channel reconnection (July 15-August 31) and the fact the river is flowing high with glacial melt water and carrying a large bedload of glacial till the proposed project would have limited effect on in-stream turbidity 100 feet upstream or 300 feet downstream from the reconnection locations. The PCE will remain functional for the duration of the project. The 21 acres of restored side channel habitat will provide additional spawning habitat and larval development. Reconnection of the main channel Hood River with the wetland and side channel area will restore a more natural hydrograph and may prevent high flow events from scouring redds. Overall, this action will have beneficial effects to this PCE.

Freshwater rearing sites with: (1) water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility, (2) water quality and forage supporting juvenile development; and (3) natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks. Turbidity will cause slight, temporary degradation of small discrete portions of the rearing PCE. Due to the high dilution capacity of the lower Hood River during the period of side channel reconnection (July 15–August 31) and the fact the river is flowing high with glacial melt water and carrying a large bedload of glacial till the proposed project would have limited effect on in-stream turbidity 100 feet upstream or 300 feet downstream from the reconnection locations. The PCE will remain functional for the duration of the project. Reconnection of Hood River floodplain habitat with the 21 acres of side channel and associated wetland area will increase rearing area for juveniles, high flow refuge, potentially improving base flows, attenuating peak flow, and likely improving water quality and quantity from flow attenuation and wetland reconnection. Riparian and wetland plantings and addition of large woody debris will provide allochthonous inputs into the channel, cover, and shade which will improve rearing habitat by increasing forage and natural cover.

This action will have a short-term, localized adverse effect to this PCE due to temporary turbidity. Over the long term, however, it will improve rearing habitat and therefore will have an overall beneficial effect to this PCE.

Freshwater migration corridors free of obstruction and excessive predation with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival. Turbidity will cause slight, temporary degradation of small discrete portions of the migration PCE for the same reasons as described for the rearing PCE above. Reconnection of Hood River floodplain habitat with the 21 acres of side channel and associated wetland area will increase migrating area for adults and juveniles, as well as provide a high flow refuge during migration, potentially improve base flows, attenuating peak flow, and likely improving water quality and quantity from flow attenuation and wetland reconnection. Restoration of the riparian and wetland area through reconnection with the river, plantings, and addition of large woody debris will provide allochthonous inputs into the channel, cover, and shade which will improve migration habitat by increasing forage and natural cover, and overall habitat complexity.

This action will have a short-term, localized adverse effect to this PCE due to temporary turbidity. Over the long term, however, it will improve migration habitat and therefore will have an overall beneficial effect to this PCE.

Effects to Bull Trout Critical Habitat

Designated and proposed critical habitat for bull trout occurs within the action area of the mitigation site. Only adult and subadult bull trout occur in the lower Hood River; therefore, only PCEs related to adult and subadult bull trout apply. Anticipated effects to bull trout designated and proposed critical habitat are described by PCE below.

Springs, seeps, groundwater sources, and subsurface water connectivity (hyporheic flows) to provide thermal refugia and contribute to water quality and quantity. The proposed mitigation will reconnect a 21-acre wetland and isolated river side channel with the mainstem Hood River. The reconnection of the wetland to the main channel is expected to improve subsurface water connectivity, contribute to water quality improvements through reconnection of wetland water quality functions, and contribute to thermal refugia from the increase in subsurface flow connections. This action will have a beneficial effect on this PCE.

Migratory habitats with minimal physical, biological, or water quality impediments between spawning, rearing, overwintering, and freshwater and marine foraging habitats, including but not limited to permanent, partial, intermittent, or seasonal barriers. No physical, biological, or water quality impediments are currently present in the action area that disconnect spawning, rearing, overwintering, and freshwater and marine foraging habitats. This action will have no effect on this PCE.

An abundant food base, including terrestrial organisms of riparian origin, aquatic macroinvertebrates, and forage fish. The proposed mitigation will allow contribution of allochthonous input from side channel and wetland productivity, which contribute to stream productivity. Benefits to salmonid spawning, rearing, and migration habitat will benefit the bull trout prey base. These benefits include: side channel improvements for habitat complexity, including placement of large woody debris, increased shading, off channel refugia, hydrology benefits (likely increases in base flows and reductions in peak flows), and the increase in spawning and rearing habitat for fall-run Chinook, coho, and steelhead. This action will have a beneficial effect on this PCE.

Complex river, stream, lake, reservoir, and marine shoreline aquatic environments and processes with features such as large wood, side channels, pools, undercut banks and substrates, to provide a variety of depths, gradients, velocities, and structures. The proposed mitigation will reconnect 1 mile of side channel and a 21-acre wetland with the mainstem Hood River. Channel-enhancing restoration, such as the addition of large woody debris, will add complexity resulting in channel forming processes creating a variety of depths, gradients, velocities, and structures. This action will have a beneficial effect on this PCE.

Suitable water temperatures ranging from 2 to 15°C (36 to 59°F), with adequate thermal refugia available for temperatures at the upper end of this range. Reconnection to the historic wetland will help maintain base flows, which benefits stream summer temperatures. Riparian restoration plantings will shade the mainstem and off-channel areas, which will help maintain in-stream temperatures. This action will have a beneficial effect on this PCE.

A natural hydrograph, including peak, high, low, and base flows within historic and seasonal ranges or, if flows are controlled, they minimize departures from a natural hydrograph. Reconnection of 1 mile of side channel and connection of the main river channel to the wetland will result in a more natural hydrograph as the mainstem river will be more connected to the floodplain. Reconnection to the wetland area may enhance base flows and alleviate channel incision caused from high flows. This action will have a beneficial effect on this PCE.

Sufficient water quality and quantity such that normal reproduction, growth, and survival are not inhibited. Turbidity will cause slight, temporary degradation of small discrete portions of this PCE for a short duration during reconnection of the side channel. Due to the high bedload of glacial till, the turbidity would be limited and the PCE will remain functional for the duration of the project. The increase in turbidity will not inhibit normal reproduction, growth, or survival and therefore, is not likely to adversely affect bull trout. Wetlands provide retention of peak flows, replenish base flows, and provide function to filter sediment and toxicants from entering waterways. The side channel proposed as part of the project will offer refuge from high flows, and provide greater connectivity so that water quantity during high flows is attenuated with the extra volume provided by the side channel. Turbidity from this action is not likely to adversely affect bull trout in the short term. Over the long term, the action will improve habitat and therefore will have an overall beneficial effect to this PCE.

Few or no non-native predatory (e.g., lake trout, walleye, northern pike, smallmouth bass), inbreeding (e.g., brook trout), or competitive (e.g., brown trout) species present (applies to proposed critical habitat only). The proposed mitigation will not affect this PCE.

Overall, this action is not likely to adversely affect bull trout critical habitat in the short term, and will have beneficial effects in the long term.

Relationship of Mitigation Project to Conservation and Recovery Plans

In addition to the beneficial effects listed above, this mitigation project addresses the following limiting factors as identified in the NMFS Columbia River Estuary ESA Recovery Plan Module and ODFW's Lower Columbia River Conservation and Recovery Plan for Oregon Populations of Salmon and Steelhead: reduced spawning and rearing habitat, reduced off-channel habitat opportunity, reduced off-channel complexity (e.g., pools and woody debris) and impaired passage. The proposed project will provide increased spawning and rearing habitat availability and be of direct benefit to LCR Chinook, LCR coho, and LCR steelhead. Due to its close proximity to the Columbia River, it is possible that juveniles from other interior basin ESUs/DPSs may utilize the restored habitat for rearing on their downriver migration. Specific examples of how this project will address recovery measures or critical limiting factors such as those identified in the Basin Recovery Plan Module or the Watershed Assessment and Action Plan include:

- **Restoration of habitat quality and diversity.** Railroad construction and related channelization has reduced habitat quality in much of the lower Hood River. Channelization, road fill, and bank armoring have narrowed stream channels and limited meanders along the mainstem Hood River. This has created shorter channels, steeper gradients, higher velocities, bed armoring, entrenchment, lack of large wood recruitment, and other effects (Coccoli 2004). Channel modifications interact with each flood event to further aggravate these channel changes. The resultant impaired physical habitat quality is a key concern for Hood River coho, fall Chinook, and winter and summer steelhead (ODFW 2009). Pool area, complexity, and frequency are very low in most streams. Flood refuge, hiding cover, overwintering and productive early rearing habitats (i.e., shallow lateral habitats, side channels) are lacking (ODFW 2009). These shallow lateral habitats and side channels have the highest potential for quality fish habitat development, but also are most sensitive to disturbance (Hood River Watershed Action Plan 2008). This mitigation project directly addresses these issues with side channel and floodplain restoration, improved physical habitat quality and complexity, high flow refuge, cover, overwintering, and productive early rearing habitat.
- **Restoration of historic spawning and rearing habitat.** Suitable spawning habitat for Chinook is geographically restricted mostly to the West Fork sub-watersheds, because the East and Middle Fork mainstems are less suitable for fall spawning due to glacial sediment loads (Coccoli 2004). Restoring off-channel habitat and/or access to off-channel habitat will provide rearing habitat for coho and winter steelhead (ODFW 2009). This mitigation project directly addresses restoration of historic spawning and rearing habitat.

Conclusion

<u>Salmon and Steelhead (and Critical Habitat)</u>

The Hood River compensatory mitigation project may affect, and is ***likely to adversely affect*** LCR Chinook, LCR steelhead, and LCR coho due to temporary, limited turbidity that will occur as a result of construction. Over the long term, it will have beneficial effects on these species.

This mitigation project may affect and is ***likely to adversely affect*** designated critical habitat for LCR Chinook and steelhead due to temporary, limited turbidity that will occur as a result of construction. Over the long term, it may have beneficial effects on critical habitat for LCR Chinook and steelhead.

<u>Bull Trout (and Critical Habitat)</u>

Due to the extremely low numbers of bull trout potentially occurring in this portion of the action area, risks of exposure to project activities are discountable. Therefore, the Hood River compensatory mitigation site ***may affect***, but is ***not likely to adversely affect*** bull trout.

Over the short term, the mitigation project ***may affect***, but is ***not likely to adversely affect*** bull trout critical habitat due to temporary turbidity. Over the long term, the mitigation project will have beneficial effects to bull trout critical habitat.

6.6.1.2 Washington Compensatory Mitigation: Lewis River Confluence Side Channel Restoration

Because state and USACE compensatory mitigation is required to construct the bridges over the Columbia River in Washington, CRC is purchasing a conservation easement at the private Lewis River Confluence Side Channel Restoration site. The 700-acre Lewis River restoration site is owned by Wildlands of Washington and will be constructed and maintained by them. The Lewis River restoration site is undergoing a separate Section 7 consultation as an independent Federal action submitted by the USACE.

Listed Species and Critical Habitat Occurrence

CRC evaluated listed species and designated or proposed critical habitats potentially present in the mitigation site's action area based on the NMFS website,[12] the USFWS county species list (USFWS 2010b), information from Wildlands of Washington, and a site visit conducted on March 18, 2010.

<u>**Salmon and Steelhead (and Critical Habitat)**</u>

NMFS website lists the following ESUs/DPSs as present in the mainstem Lewis River: LCR Chinook, CR chum, and LCR steelhead. All the ESUs/DPSs addressed in this BA are present in the mainstem Columbia River.

Critical habitat was established under two designations: 1) the 1993 critical habitat designation for SR spring/summer-run Chinook, SR fall-run Chinook, and SR sockeye (58 FR 68543), and 2) the 2005 salmon and steelhead critical habitat designation (70 FR 52630) for all of the other runs addressed in this BA. Critical habitat is present in the mainstem Lewis River for LCR Chinook, CR chum, and LCR steelhead (70 FR 52630). The Columbia River contains designated critical habitat for all other listed salmon and steelhead addressed in this BA with the exception of LCR coho, for which critical habitat is not designated (58 FR 68543, 64 FR 57399, 70 FR 52630). The lower mainstem Lewis River and lower Columbia River contain the following three PCEs for the 2005 salmon and steelhead critical habitat designation (70 FR 52630):

- Spawning habitat for LCR Chinook, LCR coho, LCR steelhead, and potentially CR chum.
- Rearing habitat.
- Migration habitat.

Two PCEs occur in the mitigation projects action area for the 1993 SR spring/summer-run Chinook, SR fall-run Chinook, and SR sockeye critical habitat designation: juvenile migration corridors and adult migration corridors.

Eulachon

NMFS website lists the Southern DPS of eulachon as potentially present in the lower Lewis River and lower mainstem Columbia River. Critical habitat is not proposed or designated for eulachon.

Green Sturgeon

The website also lists the Southern DPS of green sturgeon as present in the lower Columbia River. Critical habitat for green sturgeon does not occur in this part of the river.

Bull Trout (and Critical Habitat)

USFWS (2010b) indicates critical habitat has been designated in the mainstem Lewis River (75 FR 2270). In addition, on January 14, 2010 critical habitat for bull trout was proposed in the mainstem Lewis River (75 FR 2270). The following PCEs of designated critical habitat are present within the mitigation site's action area:

- Springs, seeps, groundwater sources, and subsurface water connectivity (hyporheic flows) to provide thermal refugia and contribute to water quality and quantity.
- Migratory habitats with minimal physical, biological, or water quality impediments between spawning, rearing, overwintering, and freshwater and marine foraging habitats, including but not limited to permanent, partial, intermittent, or seasonal barriers.
- An abundant food base, including terrestrial organisms of riparian origin, aquatic macroinvertebrates, and forage fish.
- Complex river, stream, lake, reservoir, and marine shoreline aquatic environments and processes with features such as large wood, side channels, pools, undercut banks and substrates, to provide a variety of depths, gradients, velocities, and structures.
- Suitable water temperatures ranging from 2 to 15°C (36 to 59°F), with adequate thermal refugia available for temperatures at the upper end of this range.
- A natural hydrograph, including peak, high, low, and base flows within historic and seasonal ranges or, if flows are controlled, they minimize departures from a natural hydrograph.
- Sufficient water quality and quantity such that normal reproduction, growth, and survival are not inhibited.

One PCE is not present in the action area because the mitigation site is not located in upper river reaches where bull trout spawn and fry and juveniles rear: Substrates of sufficient amount, size, and composition to ensure success of egg and embryo overwinter survival, fry emergence, and young-of-the-year and juvenile survival.

The 2010 proposal for critical habitat includes the PCEs listed above and an additional PCE: Few or no non-native predatory (e.g., lake trout, walleye, northern pike, smallmouth bass), inbreeding (e.g., brook trout), or competitive (e.g., brown trout) species present.

Although currently bull trout occur above existing dams in the Lewis River, due to a recent settlement agreement by FERC, connectivity to the mainstem Lewis River will be provided in the future (USFWS 2009). Therefore, bull trout potentially will be present in the lower Lewis River and lower Columbia River in future years.

Effects to Listed Species and Critical Habitats

Temporary adverse impacts could potentially occur during construction from capture and handling of juvenile and adult fish and a temporary increase in total suspended sediment during channel reconnection. These activities will only occur during the in-water work window when adult and juvenile salmon and steelhead, and adult and subadult bull trout are least likely to be present. Bull trout fry or juveniles do not occur in the lower reaches of the Lewis or Columbia Rivers and adult and subadult bull trout would not be expected during the August in-water work window. Therefore, exposure to bull trout from these effects would be discountable. Adult and subadult green sturgeon and adult and larval eulachon are expected in the Columbia River during this time, but numbers are not expected to be high and exposure would be discountable (see Section 4.17 for distribution). Migrating and rearing juvenile LCR, UCR, and SR Chinook; LCR steelhead; SR sockeye; and LCR coho could potentially be exposed (see Figure 4-2). Migrating adult LCR, UCR, and SR Chinook; LCR, MCR, UCR, and SR steelhead; SR sockeye; and LCR coho could be potentially exposed (see Figure 4-1). However, fish handling and degradation to water quality from sediment inputs during channel re-connection will be temporary, short in duration, and will be spatially limited.

<u>Effects to Salmon and Steelhead and their Critical Habitats</u>

After project construction, some increases in suspended sediment may occur intermittently for weeks or months until restoration plantings are established. Migrating and holding adult and migrating and rearing juveniles of all salmon and steelhead listed DPSs/ESUs may be exposed. This is an adverse effect.

The longer term effects of the mitigation project will be beneficial due to restoration of river functions through the creation of side channel habitat, increased habitat complexity, and a better functioning floodplain and riparian area. Beneficial effects are listed below.

- Increase in spawning and rearing habitat for LCR Chinook, LCR coho, LCR steelhead, and potentially CR chum.
- Restoration of the riparian and side-channel areas will provide allochthonous inputs into the channel, cover, and shade which will improve foraging, rearing, holding, and migrating habitat for adult and juvenile salmon and steelhead and adult and subadult bull trout.
- Improving hydrological function with the additional side channel acreage will result in improved rearing habitat for all salmon and steelhead juveniles by creating high flow refuge, potentially improving base flows, attenuating peak flow, and likely improving quantity from flow attenuation.
- Placement of large woody debris will create habitat complexity and provide improved rearing and holding conditions for adult and juvenile salmon and steelhead and subadult and adult bull trout.

Critical habitat designated in 2005 for salmon and steelhead in the mitigation site's action area contains spawning, rearing, and migration PCEs. Anticipated effects to these PCEs from construction and restoration of the mitigation site are described by PCE below.

Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation, and larval development (LCR Chinook and potentially CR chum only). Turbidity will cause only slight, temporary degradation of small discrete portions of the spawning PCE in the Lewis and Columbia Rivers at a time when spawning does not occur in this portion of the action area. Due to the high dilution capacity of the two rivers and the limited extent of the turbidity (100 feet upstream or 300 feet downstream from the reconnection locations), the PCE will remain functional for the duration of the project and effects to spawning, incubation and larval development are discountable. The 18.5 acres of restored side channel habitat will provide additional spawning habitat for LCR Chinook, LCR steelhead, and potentially CR chum. Reconnection of the side-channel areas will restore a more natural hydrograph and may prevent high flow events from scouring redds. In the short term, the turbidity may affect, but is not likely to adversely affect this PCE. Over the long term, the overall action will have a beneficial effect on this PCE.

Freshwater rearing sites with: (1) water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility, (2) water quality and forage supporting juvenile development; and (3) natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks (all ESUs/DPSs in 2005 critical habitat designation, but especially LCR Chinook, CR chum, and LCR steelhead). Turbidity will cause slight, temporary degradation of small discrete portions of the rearing PCE in the Lewis and Columbia Rivers. Due to the high dilution capacity of the Lewis River and the limited extent of the turbidity (100 feet upstream and 300 feet downstream from the reconnection locations), the PCE will remain functional for the duration of the project and effects to rearing are discountable. Reconnection of the Lewis and Columbia Rivers to floodplain habitat in the side channels will increase rearing area for rearing LCR Chinook, CR chum, and LCR steelhead juveniles. High flow refuge, potential improvements to base flows, attenuation of peak flows, and likely improvements to water quality and quantity from flow attenuation with the additional side channel acreage will occur for lower river ESUs/DPSs, but will also occur for all other ESUs/DPSs as well. In addition, riparian plantings and addition of large woody debris will provide allochthonous inputs into the channel, cover, and shade which will improve rearing habitat by increasing forage and natural cover for all LCR Chinook, CR chum, and LCR steelhead. In the short term, the turbidity is likely to adversely affect this PCE. Over the long term, the action will have a beneficial effect on this PCE.

Freshwater migration corridors free of obstruction and excessive predation with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival (all ESUs/DPSs in 2005 critical habitat designation, but especially LCR Chinook, CR chum, and LCR steelhead). Turbidity will cause slight, temporary degradation of small discrete portions of the migration PCE for the same reasons as described for the spawning and rearing PCEs above. Reconnection of the 18.5 acres of side channels will increase migrating area for adults and juvenile LCR Chinook and LCR steelhead in the Lewis River, as well as provide high flow refuge during migration, potentially improve base flows, attenuate peak flows, and likely improve water quality and quantity from flow attenuation and the additional acreage of the side channels for lower river ESUs/DPSs, but will also occur for all other ESUs/DPSs as well. Restoration of the riparian and wetland area through reconnection with the river, plantings, and addition of large woody debris will provide allochthonous inputs into the channel, cover, and shade which will improve migration habitat by increasing forage and natural cover, and overall habitat complexity. In the short term, the turbidity is likely to adversely affect this PCE. Over the long term, the action will have a beneficial effect on this PCE.

Designated critical habitat for SR spring/summer-run Chinook, SR fall-run Chinook, and SR sockeye occurs in the Columbia River portion of the mitigation site's action area. Two PCEs occur in the action area: juvenile migration corridors and adult migration corridors. Anticipated effects to designated critical habitat are the same as those described in the freshwater migration PCE for the 2005 critical habitat designation.

Overall, the action is likely to adversely affect designated critical habitat for salmon and steelhead in the short term, but will have beneficial effects in the long term.

Effects to Bull Trout and Critical Habitats

Due to the extremely low numbers of bull trout found in this portion of the action area, risks of exposure to project activities are discountable. If adult and subadult bull trout are being transported past the Lewis River dams by this time, numbers are expected to be limited and potential exposure to localized and temporary increases in sediment and turbidity are discountable. Therefore, the Lewis River compensatory mitigation project is not likely to adversely affect bull trout.

Designated and proposed critical habitat for bull trout occurs within the lower Columbia River and Lewis River portion of the mitigation site. Only adult and subadult bull trout will potentially occur in the Columbia or Lewis Rivers; therefore, only PCEs related to adult and subadult bull trout apply. Anticipated effects to bull designated and proposed critical habitat are described by PCE below.

Springs, seeps, groundwater sources, and subsurface water connectivity (hyporheic flows) to provide thermal refugia and contribute to water quality and quantity. The proposed mitigation will reconnect 18.5-acres of side channels with the Lewis and Columbia Rivers. The reconnection of the side channels is expected to improve subsurface water connectivity and contribute to thermal refugia. The action will have a beneficial effect on this PCE.

Migratory habitats with minimal physical, biological, or water quality impediments between spawning, rearing, overwintering, and freshwater and marine foraging habitats, including but not limited to permanent, partial, intermittent, or seasonal barriers. No physical, biological, or water quality impediments are currently present in the mitigation site's action area that disconnect spawning, rearing, overwintering, and freshwater and marine foraging habitats. The action will have no effect on this PCE.

An abundant food base, including terrestrial organisms of riparian origin, aquatic macroinvertebrates, and forage fish. The proposed mitigation will allow contribution of allochthonous input from side channels, which contribute to stream productivity. Benefits to salmonids spawning, rearing, and migration habitat will benefit the bull trout prey base. These benefits include: side channel improvements for habitat complexity, including placement of large woody debris, increased shading, off-channel refugia, hydrology benefits (likely increases in base flows and reductions in peak flows), and the increase in spawning and rearing habitat for fall Chinook, coho, steelhead, and potentially chum. The action will have a beneficial effect on this PCE.

Complex river, stream, lake, reservoir, and marine shoreline aquatic environments and processes with features such as large wood, side channels, pools, undercut banks and substrates, to provide a variety of depths, gradients, velocities, and structures. The proposed mitigation will reconnect 21,100 linear feet of side channels with the Lewis and Columbia Rivers. Channel enhancing restoration, such as the addition of large woody debris, will add complexity resulting in channel forming processes creating a variety of depths, gradients, velocities, and structures. The action will have a beneficial effect on this PCE.

Suitable water temperatures ranging from 2 to 15°C (36 to 59°F), with adequate thermal refugia available for temperatures at the upper end of this range. Reconnection of the historic channels will allow access to thermal refugia in the cooler Lewis River waters for fish in the Columbia River during high summer temperatures. Riparian restoration plantings will shade the off-channel areas, which will help maintain in-stream temperatures. The action will have a beneficial effect on this PCE.

A natural hydrograph, including peak, high, low, and base flows within historic and seasonal ranges or, if flows are controlled, they minimize departures from a natural hydrograph. Turbidity will cause slight, temporary degradation of small discrete portions of this PCE for a short duration during reconnection of the side channel. Due to the high bedload of glacial till, the turbidity will be limited, and the PCE will remain functional for the duration of the project. The increase in turbidity will not inhibit normal reproduction, growth, or survival and therefore, is not likely to adversely affect bull trout. Over the long term, reconnection of the side channels will result in a more natural hydrograph because the mainstem Lewis and Columbia Rivers will be more connected to their floodplain. Reconnection of the side channels may enhance base flows and alleviate channel incision caused from high flows. The project-generated turbidity is not likely to adversely affect bull trout in the short term. Over the long term, the action will improve the hydrograph and therefore will have an overall beneficial effect to this PCE.

Sufficient water quality and quantity such that normal reproduction, growth, and survival are not inhibited. The side channels will offer refuge from high flows, and provide greater connectivity so that water quantity during high flows is attenuated with the extra volume provided by the side channel. The action will have a beneficial effect on this PCE.

Few or no non-native predatory (e.g., lake trout, walleye, northern pike, smallmouth bass), inbreeding (e.g., brook trout), or competitive (e.g., brown trout) species present (applies to proposed critical habitat only). The proposed mitigation will not affect this PCE.

<u>Effects to Green Sturgeon and Eulachon</u>

Due to the extremely low numbers of green sturgeon and eulachon potentially occurring in this portion of the action area, risks of exposure to project activities are discountable. Therefore, the Lewis River compensatory mitigation is not likely to adversely affect green sturgeon.

The Lewis River compensatory mitigation site may potentially increase incubation and spawning habitat for eulachon. Spawning habitats for eulachon are generally described as coarse grained, but developing eggs are sticky and have been found on substrates with a greater range of particle sizes (Smith and Saalfeld 1955; Romano et al. 2002). Therefore, eggs may be deposited in the restored channels. Adults are reported to "shut down" migration activity when waters are too cold or hot (less than 3 or greater than 11°C) (Langness 2009 personal communication; Smith and Saalfeld 1955). Whether they would seek these mitigation habitats cannot be known. However, it is reasonable to expect some exploration if adults are present in the vicinity, regardless of thermal regime. The creation of additional in-stream habitats and channel volume may be reasonably expected to be utilized by more than one eulachon life-stage. However, the extent of utilization and the magnitude and mechanisms of potential biological responses cannot be known or estimated at this time.

Relationship of Mitigation Project to Conservation and Recovery Plans

NMFS's Columbia River Estuary ESA Recovery Plan Module and LCFRB's Mainstem Lower Columbia River and Columbia River Estuary Subbasin Plan identified the following as limiting factors in the lower Columbia River: spawning and rearing habitat, reduced off-channel habitat opportunity, reduced off-channel complexity (e.g., tidal swamp and other shallow water habitats), reduced macrodetrital inputs, and impaired passage. Because of their longer Columbia River estuary residence times and tendency to use shallow-water habitats, ocean-type ESUs (e.g., LCR fall Chinook, LCR chum) are more affected by flow alterations that structure habitat and/or provide access to wetland or floodplain areas than stream-type ESUs, such as coho (LCREP 2007a). Rationale for selection of the Lewis River Confluence Side Channel Restoration project by CRC includes:

- **Restoration of spawning and rearing habitat, off-channel habitat, off-channel complexity, and macrodetrital inputs.** Dikes and channel filling activities have significantly altered the size and function of the Columbia River estuary. Dikes are thought to have caused more habitat conversion in the estuary than any other human or natural factor (Thomas 1983, as cited in NPCCl 2004) and are identified as a primary threat to ocean-type and stream-type salmonids (LCREP 2007a). Removal of the dredge spoil fill in the historic side channels will restore essential off-channel habitat, identified as a limiting factor in the Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead (LCREP 2007a).
- **Restoration of lowland floodplain function, riparian function, and stream habitat diversity of the lower mainstem reach.** In the East Fork Lewis River, critical fish habitat problems include loss of habitat diversity, low summer flow, increased sediment, high summer temperature, and channel instability due to extensive historical gravel mining activities in the lower river (LCFRB 2010). Restoration of lowland floodplain function, riparian function, and stream habitat diversity of the lower mainstem reach has been designated high priority for improvements to fall Chinook, chum and coho (LCFRB 2010). This mitigation project will restore these elements in the lower mainstem to benefit all DPSs/ESUs.

- **Restoration of side channels in the Lower Lewis River.** Peak flow reductions created by the Lewis River hydropower systems limit the occurrence of channel-forming flows that may be important for the formation and maintenance of key habitat types such as river side-channels and backwater areas (LCFRB 2004). Removal of the dredge spoils will restore side channels. The hydrologic analysis of the river system under its present management will direct the restoration methodology to insure the side channels are self-maintaining.
- **Addition of cold water refuge for juvenile salmonids.** The practice of releasing flows from the bottom of Merwin, Yale, and Swift Reservoirs has resulted in lower water temperatures in summer in the North Fork Lewis River (LCFRB 2004). Elevated temperatures of water entering the estuary are a threat to salmon and steelhead. Summer water temperatures entering the estuary are on average 4 degrees warmer today than they were in 1938 (LCFRB 2004). The restoration of historic side channels of the Lewis River will provide cold water refuge for juvenile salmonids (ocean- and stream-type life forms) and upriver migrating adults.

Conclusion

Salmon and Steelhead (and Designated Critical Habitat)

The Lewis River compensatory mitigation site ***may affect*** and is ***likely to adversely affect*** LCR Chinook, CR chum, and LCR steelhead. Elements of the project that are likely to adversely affect these species include: direct handling of fish and temporary turbidity during in-water work. Over the long term, this project will have beneficial effects on these species.

This mitigation project ***may affect*** and is ***likely to adversely affect*** designated critical habitat for salmon and steelhead including the following ESUs/DPSs:

- Chinook (LCR, UCR spring run, SR fall run, and SR spring/summer run)
- Steelhead (LCR, MCR, UCR, SR)
- CR chum
- SR sockeye

Adverse effects are limited to temporary turbidity occurring within 100 to 300 feet from in-water construction. Over the long term, this action may have beneficial effects on these critical habitat units.

Eulachon, Bull Trout, and Green Sturgeon

Due to the extremely low numbers of eulachon, bull trout, and green sturgeon found in this portion of the action area, risks of exposure to project activities are discountable. Therefore, the Lewis River compensatory mitigation site ***may affect***, but is ***not likely to adversely affect*** eulachon, bull trout, and green sturgeon.

Bull trout Critical Habitat

The action will ***not destroy*** or ***adversely modify*** proposed critical habitat for bull trout. In the event that proposed critical habitat is designated before completion of the project, a provisional effect determination of ***may affect, not likely to adversely affect***, is warranted.

Over the short term, the mitigation project ***may affect***, but is ***not likely to adversely affect*** bull trout designated critical habitat due to temporary turbidity. Over the long term, the mitigation project will have beneficial effects to bull trout critical habitat.

6.6.2 Maintenance and Operation of New Project

Elements of the completed project, including the roadway, bridges, stormwater treatment facilities, stormwater conveyances, and others, will require continual maintenance for the foreseeable future. Maintenance is likely to include in-water and over-water work such as deck repairs, pavement rehabilitation, bridge washing, or culvert maintenance. All maintenance work will occur only after obtaining all required regulatory permits. If work may affect listed species or critical habitat, these maintenance projects will either undergo individual Section 7 consultation with NMFS or will be performed under the aegis of programmatic agreements with NMFS for road maintenance activities under Section 4(d) of the ESA (e.g., WSDOT's Road Maintenance ESA Guidelines; ODOT's Routine Road Maintenance – Water Quality and Habitat Guide BMPs).

6.6.3 Utility Relocation

Utility relocation is not expected to affect listed species or critical habitat. This work involves little, if any, excavation and will employ BMPs to ensure that discharge of sediments or other contaminants to water bodies will not occur.

6.6.4 Unanticipated Staging and Casting Areas

Should the project require additional staging and casting areas not addressed in this BA, these areas will be selected such that their construction and operation will be extremely unlikely to have effects on listed fish or critical habitat. Staging and casting will occur on land only, and operations will follow standard BMPs to ensure that sediments, chemicals, and other contaminants do not enter surface water bodies. Such conservation measures will include, but will not be limited to, an ESCP, a SPCC, and maintaining setback buffers from waterways.

6.6.5 Design and Operation of Rebuilt Pump Station

A pump station, operated by Peninsula Drainage District No. 1, moves water from a drainage ditch into the Columbia Slough; this pump station will require upgrading in the near future. The upgrade may increase the capacity of the pump if deemed necessary to accommodate additional runoff that discharges from the CRC project into the drainage area served by this pump station.

Potential effects from the capture, treatment, and release of stormwater from the CRC project into the Columbia Slough Watershed are discussed in Section 6.2.1. In summary, stormwater runoff is not expected to degrade water quality in the Columbia Slough because of the high level of stormwater treatment proposed and because dilution and absorption will dissipate pollutants to ambient levels before discharging to the Slough. Any additional pumping capacity occurring after the CRC project is not expected to result in effects to the Columbia Slough not already addressed by Section 6.2.1. That is, despite the increased capacity, pollutants will still be subjected to high levels of dilution and absorption, dissipating to background levels before entering the Slough. Thus, any additional pumping capacity required would not likely have adverse effects on the Columbia Slough baseline or on listed species of fish.

6.6.6 Floating Home Displacement

Up to 32 floating homes in the Portland Harbor would be displaced by the project. The displaced floating homes will need to be moved to other locations. These locations could be within North Portland Harbor, but may be in other portions of the lower Columbia River subbasin. Other suitable locations would likely be located in shallow, slow-moving waters similar to North Portland Harbor, Multnomah Channel, or portions of the lower Willamette River.

Effects from floating homes, regardless of site location, include shading of the water column, perturbations in near-surface flow, and associated riverbank development. These activities may adversely affect listed fish and their habitat. Effects on shading that could result from the displacement of floating homes are discussed in more detail in Sections 6.1.3.2 and 6.1.3.3.

Section 7

Section 7

SECTION 7

What does this section present?

WSDOT, ODOT, TriMet, and C-TRAN have standard specifications that are added to project contracts to address environmental concerns during project construction. In addition, the project is proposing project-specific measures to avoid or minimize potential project affects to listed species that occur in the area where in-water work will take place. This section summarizes more than 60 impact avoidance and minimization measures that will be placed into contracts for this project. These measures are included as part of the proposed action and are nondiscretionary.

Specific measures relate to:

- Spill prevention and pollution control;
- Site erosion and sediment control;
- Work zone lighting;
- Hydroacoustics minimization and monitoring; and
- Noise and disturbance monitoring for Steller sea lions.

7. AVOIDANCE AND MINIMIZATION MEASURES

This section highlights the impact avoidance and minimization measures that will be placed into contracts for this project. For specific construction BMPs and minimization measures, consult the most current ODOT and WSDOT standard specifications. For transit construction BMPs and minimization measures, refer to the applicable standard specification where TriMet or C-TRAN does not have specifications to address BMPs or minimization measures.

7.1 SUMMARY OF AVOIDANCE AND MINIMIZATION MEASURES

7.1.1 General Measures and Conditions

- A biologist shall re-evaluate the project for changes in design and evaluation methods not previously employed in the BA to assess potential impacts associated with those changes, as well as the status and location of listed species, every 6 months until project construction is completed. Re-initiation of consultation with the Services is required if new information reveals project effects that may affect listed species or critical habitat in a manner or to an extent not previously considered. Re-initiation of consultation is also required if the identified action is modified in a manner that causes an effect to species that was not considered in the BA or if a new species is listed or critical habitat is designated that may be affected by the action.
- All work shall be performed according to the requirements and conditions of the regulatory permits issued by federal, state, and local governments. Seasonal restrictions, e.g., work windows, will be applied to the project to avoid or minimize potential impacts to listed or proposed species based on agreement with, and the regulatory permits issued by DSL, WDFW, and USACE in consultation with ODFW, USFWS, and NMFS.
- Drilled shafts will be installed while water is still in the cofferdam. The drilled shaft casing will function to contain and isolate the work. Cofferdams will be installed to minimize fish entrapment. Sheet piles will be installed from upstream to downstream, lowering the sheet piles slowly until contact with the substrate. When cofferdams are used, fish salvage must be conducted according to protocol approved by ODFW, WDFW, and NMFS (see Appendix E).

  Contractor shall provide a qualified fishery biologist to conduct and supervise fish capture and release activity as to minimize risk of injury to fish, in accordance with ODOT Standard Specification 00290.31(i) or its equivalent; and/or the 2009 WSDOT Fish Exclusion Protocols and Standards, or its equivalent.
- The contractor shall prepare a Water Quality Sampling Plan for conducting water quality monitoring for all projects occurring in-water in accordance with the specific conditions issued in the Oregon and Washington 401 Water Quality Certifications. The Plan shall identify a sampling methodology as well as method of implementation to be reviewed and approved by the engineer. If, in the future, a standard water quality monitoring plan is adopted by ODOT and/or WSDOT, this plan, with the agreement of NMFS and USFWS, may replace the contractor plan.

- State DOT policy and construction administration practice in Oregon and Washington is to have a DOT inspector on site during construction. The role of the inspector will ensure contract and permit requirements. ODOT/WSDOT environmental staff will provide guidance and instructions to the onsite inspector to ensure the inspector is aware of permit requirements.
- If in-water dredging is required outside of a cofferdam, a clamshell bucket shall be used. Dredged material shall be disposed of in accordance with relevant permits and approvals.
- Piles that are not in an active construction area and are in place 6 months or longer will be have cones or other anti-perchings devices installed to discourage perching by piscivorous birds.
- All pumps must employ a fish screen that meets the following specifications:
  - An automated cleaning device with a minimum effective surface area of 2.5 sq. ft. per cubic foot per second, and a nominal maximum approach velocity of 0.4 foot per second, or no automated cleaning device, a minimum effective surface area of 1 square foot per cubic foot per second, and a nominal maximum approach rate of 0.2 foot per second; and
  - a round or square screen mesh that is no larger than 2.38 millimeters (mm) (0.094”) in the narrow dimension, or any other shape that is no larger than 1.75 mm (0.069”) in the narrow dimension; and
  - Each fish screen must be installed, operated, and maintained according to NMFS fish screen criteria.

7.1.2 Spill Prevention/Pollution Control

- The contractor shall prepare a Spill Prevention, Control, and Countermeasures (SPCC) Plan prior to beginning construction. The SPCC Plan shall identify the appropriate spill containment materials; as well as the method of implementation. All elements of the SPCC Plan will be available at the project site at all times. For additional detail, consult ODOT Standard Specification 00290.00 to 00290.90 and/or WSDOT Standard Specification 1-07.15(1). For transit construction in Oregon, consult TriMet Standard Specification 01450{1.04}).
- The contractor will designate at least one employee as the erosion and spill control (ESC) lead. The ESC lead will be responsible for the implementation of the SPCC Plan. The contractor shall meet the requirements of and follow the process described in ODOT Standard Specifications 00290.00 through 00290.30 and/or WSDOT Standard Specification 8-01.3(1)B. The ESC lead shall be listed on the Emergency Contact List as part of ODOT Standard Specification 00290.20(g) and/or WSDOT Standard Specification 1-07.15(1).
- All equipment to be used for construction activities shall be cleaned and inspected prior to arriving at the project site, to ensure no potentially hazardous materials are exposed, no leaks are present, and the equipment is functioning properly. Identify equipment that will be used below OHW. Outline daily inspection and cleanup procedures that will insure that identified equipment is free of all external petroleum-based products. Should a leak be detected on heavy equipment used for the project, the equipment shall be immediately

removed from the area and not used again until adequately repaired. Where off-site repair is not practicable, the implemented SPCC Plan will prevent and/or contain accidental spills in the work/repair area to insure no contaminants escape containment to surface waters and cause a violation of applicable water quality standards.

- Operation of construction equipment used for project activities shall occur from on top of floating barge or work decks, existing roads or the streambank (above OHW). Any equipment operating in the water shall use only vegetable-based oils in hydraulic lines.
- All stationary power equipment or storage facilities shall have suitable containment measures outlined in the SPCC Plan to prevent and/or contain accidental spills to insure no contaminants escape containment to surface waters and cause a violation of applicable water quality standards.
- Process water generated on site from construction, demolition or washing activities will be contained and treated to meet applicable water quality standards before entering or re-entering surface waters.
- No paving, chip sealing, or stripe painting will occur during periods of rain or wet weather.
- For projects involving concrete, the implemented SPCC Plan shall establish a concrete truck chute cleanout area to properly contain wet concrete as part of ODOT Standard Specification 00290.30(a)1 and/or WSDOT Standard Specification 1-07.15(1).

7.1.3 Site Erosion/Sediment Control

- The contractor shall prepare a Temporary Erosion and Sediment Control (TESC) Plan and a Source Control Plan and implemented for the project requiring clearing, vegetation removal, grading, ditching, filling, embankment compaction, or excavation. The BMPs in the plans will be used to control sediments from all vegetation removal or ground-disturbing activities. The engineer may require additional temporary control measures beyond the approved TESC Plan if it appears pollution or erosion may result from weather, nature of the materials or progress on the work. For additional detail, consult ODOT Standard Specifications 00280.00 to 00280.90 and/or WSDOT Standard Specification 1-07.15. For transit construction, consult TriMet Standard Specification 02276.
- As part of the TESC Plan, contractor shall delineate clearing limits with orange barrier fencing wherever clearing is proposed in or adjacent to a stream/wetland or its buffer and install perimeter protection/silt fence as needed to protect surface waters and other critical areas. Location will be specified in the field, based upon site conditions and the TESC Plan. For additional silt fence detail, consult ODOT Standard Specification 00280.16(c) and/or WSDOT Standard Specification 8-01.3(9)A.
- The contractor shall identify at least one employee as the ESC lead at preconstruction discussions and the TESC Plan. The contractor shall meet the requirements of and follow the process described in ODOT Standard Specifications Section 00280.30 and/or WSDOT Standard Specification 8-01.3(1)B. The ESC lead shall be listed on the Emergency Contact List as part of ODOT Standard Specification 00290.20(g) and/or WSDOT Standard Specification 1-05.13(1). The ESC lead will also be responsible for

ensuring compliance with all local, state, and federal erosion and sediment control requirements.

- All TESC measures shall be inspected on a weekly basis. Contractor shall follow maintenance and repair as described in ODOT Standard Specifications 00280.60 to 00280.70 and/or WSDOT Standard Specification 8-01.3(15). Inspect erosion control measures immediately after each rainfall, and at least daily during for precipitation events of more than 0.5 inches in a 24-hour period.
- For landward construction and demolition, project staging and material storage areas shall be located a minimum of 150 feet from surface waters, in currently developed areas such as parking lots or managed fields, unless a site visit by an ODOT/WSDOT biologist determines the topographic features or other site characteristics allow for site use closer to the edge of surface waters. Excavation activities (dredging not included) shall be accomplished in the dry. All surface water flowing towards the excavation shall be diverted through utilization of cofferdams and/or berms. Cofferdams and berms must be constructed of sandbags, clean rock, steel sheeting, or other non-erodible material.
- Bank shaping shall be limited to the extent as shown on the approved grading plans. Minor adjustments made in the field will occur only after engineer's review and approval. Bio-degradable erosion control blankets will be installed on areas of ground-disturbing activities on steep slopes (1V:3H or steeper) that are susceptible to erosion and within 150 feet of surface waters. Areas of ground-disturbing activities that do not fit the above criteria shall implement erosion control measures as identified in the approved TESC Plan. For additional erosion control blanket detail, consult ODOT Standard Specification 00280.14(e) and/or WSDOT Standard Specification 9-14.5(2)A.
- Erodible materials (material capable of being displaced and transported by rain, wind or surface water runoff) that are temporarily stored or stockpiled for use in project activities shall be covered to prevent sediments from being washed from the storage area to surface waters. Temporary storage or stockpiles must follow measures as described in ODOT Standard Specification 00280.42 and/or WSDOT Standard Specification 8-01.3(1).
- All exposed soils will be stabilized as directed in measures prescribed in the TESC Plan. Hydro-seed all bare soil areas following grading activities, and re-vegetate all temporarily disturbed areas with native vegetation indigenous to the location. For additional detail, consult ODOT Standard Specifications 01030.00 to 01030.90 and/or WSDOT Standard Specification 8-01.3(1).
- Where site conditions support vegetative growth, native vegetation indigenous to the location will be planted in areas disturbed by construction activities. Re-vegetation of construction easements and other areas will occur after the project is completed. All disturbed riparian vegetation will be replanted. Trees will be planted when consistent with highway safety standards. Riparian vegetation will be replanted with species native to geographic region. Planted vegetation will be maintained and monitored to meet regulatory permit requirements. For additional detail, consult ODOT Standard Specifications 01040.00 to 01040.90 and/or WSDOT Standard Specification 8-01.3(2)F.

7.1.4 Work Zone Lighting

- Site work shall follow local, state and federal permit restrictions for allowable work hours. If work occurs at night, temporary lighting should be used in the night work zones. The work area and its approaches shall be lighted to provide better visibility for drivers to travel safely travel through the work zone, and illumination shall be provided wherever workers are present to make them visible.
- During overwater construction, contractor will use directional lighting with shielded luminaries to control glare and direct light onto work area; not surface waters.

7.1.5 Hydroacoustics

7.1.5.1 Minimization Measure 1 – Drilled Shafts for Foundations

Permanent foundations for each in-water pier will be installed by means of drilled shafts. This approach significantly reduces the amount of impact pile driving, the size of piles, and amount of in-water noise.

7.1.5.2 Minimization Measure 2 – Piling Installation with Impact Hammers

Installation of piles using impact driving may only occur between September 15 and April 15 of the following year. On an average work day, six piles could be installed using vibratory installation to set the piles; then impact driving to drive the piles to refusal per project specifications to meet load-bearing capacity requirements. This method reduces the number of daily pile strikes over 90 percent. No more than two impact pile drivers may be operated simultaneously within the same waterbody channel.

In waters with depths more than 0.67 meter (2 feet), a bubble curtain or other sound attenuation measure will be implemented for impact driving of pilings. If a bubble curtain or similar measure is used, it will distribute small air bubbles around 100 percent of the piling perimeter for the full depth of the water column. Any other attenuation measure (e.g., temporary noise attenuation pile) must provide 100 percent coverage in the water column for the full depth of the pile.

A performance test of the noise attenuation device in accordance with the approved hydroacoustic monitoring plan shall be conducted prior to any impact pile driving. If a bubble curtain or similar measure is utilized, the performance test shall confirm the calculated pressures and flow rates at each manifold ring.

7.1.5.3 Minimization Measure 3 – Impact Pile Installation Hydroacoustic Performance Measure

Sound pressure levels from an impact hammer will be measured in accordance with the hydroacoustic monitoring plan. Recording and calculation of accumulated sound exposure levels shall be performed. Analysis of the data shall be used to calculate exposure factors as defined in Appendix K of this BA. Exposure factors shall be calculated using the moving fish model, based on a fish of over 2 grams with a movement rate of 0.1 meter per second. Exposure factors shall account for all attenuated and un-attenuated impact pile driving in both the mainstem Columbia River and North Portland Harbor. The accumulated SEL shall be recorded.

The following thresholds must not be exceeded:

1. The maximum weekly exposure factor shall not exceed 0.18649, based on one calendar week. The weekly exposure factor is defined as the proportion of channel affected by impact pile driving as measured by accumulated sound exposure level multiplied by the proportion of a 24-hr day affected multiplied by the proportion of calendar week affected.

2. The maximum yearly (calendar year) total exposure factor shall not exceed 0.202181. The maximum yearly exposure factor is the sum of all weekly exposure factors in one calendar year.

3. The average yearly exposure factor must not exceed 0.120090 per calendar year of construction. The average yearly exposure factor is the mean value of all yearly total exposure factors.

4. A total exposure factor of 0.480359 shall not be exceeded throughout the construction period of the project. The total exposure factor equals the sum of all weekly exposure factors throughout the project.

One 12-hour rest period will occur each work day in which no impact pile driving will occur. In addition, to limit the exposure of migrating fish that may be present in the behavioral disturbance zone,[1] impact striking of piles that produce hydroacoustic levels over 150 dB RMS will not occur for more than 12 hours per work day. Unattenuated pile striking may occur to meet the requirements of the hydroacoustic monitoring plan or account for malfunction of the sound attenuation device, but will not occur for more than 300 impact pile strikes per week in the mainstem Columbia River and no more than 150 impact pile strikes per week in North Portland Harbor. To ensure that this measure is not being exceeded, an approved hydroacoustic monitoring plan will be in place to test a representative number of piles installed during the project (see Section 7.1.5.5, Minimization Measure 5).

If the predicted accumulated sound exposure level exceeds the levels described above, then the Services will be contacted within 24 hours to determine a course of action, so that incidental take estimates are not exceeded. Necessary steps may include modifications to the noise attenuation system or method of implementation.

7.1.5.4 Minimization Measure 4 – Hydroacoustic Monitoring

The project will conduct underwater noise monitoring to test the effectiveness of noise attenuation devices. Testing will occur based on an underwater noise monitoring plan based on the most recent version of the Underwater Noise Monitoring Plan Template.[2] This template has been developed in cooperation with the NMFS, USFWS, and WSDOT, and has been approved by NMFS and USFWS for use in Section 7 consultation for transportation projects in Washington.

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[1] Behavioral disturbance is expressed in dB RMS re: 1 μPa.

[2] Available at: http://www.wsdot.wa.gov/Environment/Air/Noise.htm.

Testing will occur according to protocols outlined in an Underwater Noise Monitoring Plan (WSDOT 2008). Underwater noise monitoring will occur as follows:

- Hydroacoustic monitoring will occur for a representative number of piles per structure (minimum of five piles installed with an impact hammer).
- Monitoring will occur for piles driven in water depths that are representative of typical water depths found in the areas where piles will be driven.
- Ambient noise will be measured as outlined in the template in the absence of pile driving.

A report that analyzes the results of the monitoring effort will be submitted to the Services as outlined in the monitoring plan template.

Unattenuated impact pile driving for obtaining baseline sound measurements will be limited to the number of piles necessary to obtain an adequate sample size for the project, as defined in the final Hydroacoustic Monitoring Plan.

7.1.5.5 Minimization Measure 5 – Biological Monitoring

A qualified biologist will be present during all impact pile driving operations to observe and report any indications of dead, injured, or distressed fishes, including direct observations of these fishes or increases in bird foraging activity.

7.1.5.6 Minimization Measure 6 – Temporary Pile Removal

Temporary piles shall be removed with a vibratory hammer and shall never be intentionally broken by twisting or bending. Except when piles are hollow and were placed in clean, sand-dominated substrate, the holes left by the removed pile shall be filled with clean native sediments immediately following removal. No filling of holes shall be required when hollow piles are removed from clean, sand-dominated substrates. At locations where hazardous materials are present or adjacent to utilities, temporary piles may be cut off at the mud line with underwater torches.

7.2 STELLER SEA LION MINIMIZATION MEASURES[3]

7.2.1 Equipment Noise Standards

To mitigate noise levels and impacts to sea lions, all construction equipment will comply with applicable equipment noise standards of EPA, and all construction equipment will have noise control devices no less effective than those provided on the original equipment.

7.2.2 Sound Attenuation Measures

Specific to pile driving, the hydroacoustic minimization measures listed in Section 7.1.5 will be implemented to reduce impacts to sea lions to the greatest extent practicable.

[3] Because seal and sea lion species present in the Columbia River are protected under the Marine Mammal Protection Act (MMPA), an application for a Letter of Authorization under the MMPA Section 101(a)(5)(A) is being submitted to NMFS's Office of Protected Resources. The project will comply with any additional minimization measures issued for seals and sea lions as part of the authorization.

7.2.3 Marine Mammal Monitoring

7.2.3.1 Establishment of Monitoring Zones

For impact pile driving, a safety zone (defined as where SPLs equal or exceed 190 dB RMS) and a disturbance zone (defined as where SPLs equal or exceed 160 dB RMS) will be established. The initial safety and disturbance zones will be established based on the worst-case underwater sound modeled from impact driving of 36- to 48-inch steel pile.

For vibratory pile or vibratory steel casing installation, an initial disturbance zone (defined as where SPLs equal or exceed 120 dB RMS) will be established based on the worst-case sound modeled from vibratory installation of 36- to 72-inch steel pile for pipe piles or the loudest value modeled for sheet piles. Noise levels for vibratory installation of steel sheet or pipe piles are not anticipated to be above the 190 dB RMS thresholds based on literature values; therefore, no safety zone for vibratory installations of steel pile is anticipated. If steel casings for drilled shafts are installed by a vibratory hammer, an initial safety zone of 5 meters will be established.[4]

Once impact or vibratory installation begins, the safety and disturbance zones will either be enlarged or reduced based on actual recorded SPLs from the acoustic monitoring. The zones will be based on actual acoustic monitoring results collected at an approximate 10-meter distance. If new zones are established based on SPL measurements, NMFS requires each new zone be based on the most conservative measurement (i.e., the largest zone configuration).

Tables 7-1 and 7-2 show initial monitoring distances for safety and disturbance zones in the Columbia River and North Portland Harbor, respectively.

Table 7-1. Initial Underwater Distance to Safety and Disturbance Monitoring Zones in the Columbia River

		Calculated Distance to Monitoring Zones (meters)[a]		
Pile Type	Hammer Type	190 dB RMS[b] Safety Zone	160 dB RMS Disturbance Zone (impulse noise)	120 dB RMS Disturbance Zone (continuous noise)
18- to 24-inch steel pipe	Impact	9	858	N/A
36- to 48-inch steel pipe	Impact	54	5,412	N/A
48-inch steel pipe	Vibratory	N/A	N/A	20,166 upriver 8,851 downriver
120-inch steel casing	Vibratory	~5[c]	N/A	20,166 upriver 8,851 downriver
Sheet pile	Vibratory	N/A	N/A	6,962

a Monitoring zones based on worst case modeled values where the attenuation device is not operating. Upriver and downriver distances vary if a landform is encountered prior to noise attenuating to a threshold value.

b All values unweighted and relative to 1μPa.

c No source value available. To obtain a worst case estimate, distance is based on extrapolation of vibratory sound values from 36- and 72-inch piles.

[4] No published information is available on vibratory installation of 120-inch steel casings. Published information from Caltrans (2007) shows that 36-inch pile produced up to 175 dB RMS and 72-inch pile produced up to 180 dB RMS, both measured at 5 m from the pile. By extrapolating from these published values, the project assumes the energy imparted through a larger casing would be up to 10 dB RMS (an order of magnitude) higher than the highest value for a 72-inch pile. That is, vibratory installation of a 120-inch steel casing may yield a maximum value of 190 dB RMS, 5 m from the pile. As noted, monitoring will be conducted to determine actual values and distances.

Table 7-2. Initial Underwater Distance to Safety and Disturbance Monitoring Zones in North Portland Harbor

		Calculated Distance to Monitoring Zones (meters)[a]		
Pile Type	Hammer Type	190 dB RMS[b] Safety Zone	160 dB RMS Disturbance Zone (impulse noise)	120 dB RMS Disturbance Zone (continuous noise)
18- to 24-inch steel pipe	Impact	9	858	N/A
36- to 48-inch steel pipe	Impact	54	3,058 upriver 5,412 downriver	N/A
48-inch steel pipe	Vibratory	N/A	N/A	3,058 upriver 5,632 downriver
120-inch steel casing	Vibratory	~5[c]	N/A	3,058 upriver 5,632 downriver
Sheet pile	Vibratory	N/A	N/A	3,058 upriver 5,632 downriver

a Monitoring zones based on worst case modeled values where the attenuation device is not operating. Upriver and downriver distances vary if a landform is encountered prior to noise attenuating to a threshold value.

b All values unweighted and relative to 1μPa.

c No source value available. To obtain a worst case estimate, distance is based on extrapolation of values from 36- and 72-inch piles.

7.2.3.2 Visual Marine Mammal Monitoring

The CRC project will develop a monitoring plan in conjunction with NMFS that will collect sighting data for marine mammals observed during activities that include impact or vibratory installation of steel pipe or sheet pile or steel casings. A qualified biologist will be present on site at all times during impact or vibratory installation of steel pile or steel casings. In order to be considered qualified, the biologist will meet the following criteria for marine mammal observers:

- Visual acuity in both eyes (correction is permissible) sufficient for discernment of moving targets at the water's surface with ability to estimate target size and distance. Use of binoculars may be necessary to correctly identify the target.
- Advanced education in biological science, wildlife management, mammalogy, or related fields (Bachelors degree or higher is preferred).
- Experience and ability to conduct field observations and collect data according to assigned protocols (this may include academic experience).
- Experience or training in the field identification of marine mammals (cetaceans and pinnipeds), including the identification of behaviors.
- Sufficient training, orientation, or experience with the construction operation to provide for personal safety during observations.
- Writing skills sufficient to prepare a report of observations that will include information such as the number and type of marine mammals observed; the behavior of marine mammals in the project area during construction, dates and times when observations were conducted; dates and times when in-water construction activities were conducted; dates and times when marine mammals were present at or within the defined safety zone; dates and times when in-water construction activities were suspended to avoid incidental potential injury from construction noise within the defined safety zone; etc.

- Ability to communicate orally, by radio or in person, with project personnel to provide real-time information on marine mammals observed in the area as necessary.

The CRC project proposes the following marine mammal monitoring for steel impact and vibratory sheet or pipe pile or vibratory casing installation:

- Monitoring of safety and disturbance zones will occur for all impact pile driving activities. Monitoring of the disturbance zone will occur for all vibratory pipe or sheet pile installation. No SPLs above 190 dB RMS are anticipated for vibratory installation of pipe or sheet piles; therefore, a safety zone will not be established. If hydroacoustic monitoring of vibratory installation of steel casings for drilled shafts indicates SPLs of 190 dB RMS or higher, then a safety zone will be established and monitored for vibratory installation of steel casings.
- Through acoustic monitoring, the CRC project will determine the actual distance to safety or disturbance zones and establish the new zones at that distance.
- Until determination of safety and disturbance zones is accomplished, monitoring will occur for the area within the calculated zones.
- Safety and disturbance zones will be monitored from a work platform, barge, the existing bridge, or other vantage point or by driving a boat along and within the radius of the zones while visually scanning the area. For activities within a safety zone, full observation of the safety zone will occur. If a small boat is used for monitoring, the boat will remain 50 yards from swimming pinnipeds in accordance with NMFS marine mammal viewing guidelines (NMFS 2007a).
- If vibratory installation of steel pipe piles or casings occurs after dark, the disturbance zone will be monitored with a night vision scope and/or other suitable device. Vibratory installation of steel pipe piles or sheet piles is not expected to produce SPLs at or above 190 dB RMS; therefore, no safety zone will be established or monitored for these activities. If hydroacoustic monitoring of vibratory installation of steel casings for drilled shafts indicates SPLs of 190 dB RMS or higher, then a safety zone will be established and monitored with a night vision scope and/or other suitable device.
- If the safety zone is obscured by fog or poor lighting conditions, pile driving will not be initiated until the entire safety zone is visible.
- The safety zone will be monitored for the presence of sea lions before, during, and after any pile driving activity.
- The safety zone will be monitored for 30 minutes prior to initiating the start of pile driving. If sea lions are present within the safety zone prior to pile driving, the start of pile driving will be delayed until the animals leave the safety zone.
- Monitoring of the safety zone will continue for 20 minutes following the completion of pile driving.
- Monitoring will be conducted using high-quality binoculars. When possible, digital video or still cameras will also be used to document the behavior and response of sea lions to construction activities or other disturbances.
- Each monitor will have a radio for contact with other monitors or work crews.

- A GPS unit or electric range finder will be used for determining the observation location and distance to sea lions, boats, and construction equipment.

Data collection will include a count of all sea lions observed by species, sex, age class, their location within the zone, and their reaction (if any) to construction activities, including direction of movement, and type of construction that is occurring, time that pile driving begins and ends, any acoustic or visual disturbance, and time of the observation. Environmental conditions such as wind speed, wind direction, visibility, and temperature will also be recorded.

7.2.3.3 Shutdown Procedure

The safety zone will also be monitored throughout the time required to drive a pile (or install a steel casing if applicable). If a sea lion is observed approaching or entering the safety zone (190 dB RMS isopleth for pinnipeds), piling operations will be discontinued until the animal has moved outside of the safety zone. Pile driving will resume only after the sea lion is determined to have moved outside the safety zone by a qualified observer or after 15 minutes have elapsed since the last sighting of the sea lion within the safety zone.

7.2.3.4 Acoustical Monitoring

Hydroacoustic monitoring will be conducted for impact driving of steel piles. Acoustic monitoring will be conducted on a representative number of piles as described in the monitoring plan template that has been developed with and approved by NMFS and USFWS for Section 7 consultations (see Appendix K, the CRC Hydroacoustics Technical Report). The number, size, and location of piles monitored will represent the variety of substrates and depths, as necessary, in both the Columbia River and North Portland Harbor. Hydroacoustic monitoring will be condcuted during vibratory installation of at least one pile of the largest diameter used by the project to confirm the distance to the 120 dB RMS threshold level. If steel casings are installed with a vibrator hammer, hydroacoustic monitoring will occur for the first casing installed; this will represent a worst case for size, depth, and substate for vibratory installation of casings. For standard underwater noise monitoring, one hydrophone positioned at midwater depth and 10 meters from the pile is used. Some additional initial monitoring at several distances from the pile is anticipated to determine site-specific transmission loss and directionality of noise. This data will be used to establish the radii of the safety and disturbance zones for sea lions.

7.2.3.5 Marine Mammal Monitoring Reporting

Reports of the data collected during sea lion monitoring will be submitted to NMFS weekly. In addition, a final report summarizing all sea lion monitoring and construction activities will be submitted to NMFS annually.

Section 8

Section 8

SECTION 8

What does this section present?

This section summarizes all of the effects presented in Section 6, providing a single effect determination for each of the listed species and critical habitats present in the action area.

The most stringent effect determination for any of the exposure pathways is the overall effect determination for the species or critical habitat.

The agencies request formal consultation with NMFS for *may affect, likely to adversely affect* determinations for Steller sea lions, eulachon, steelhead, and salmon and designated critical habitat for salmon and steelhead. The action agencies request informal consultation with NMFS for *may affect, not likely to adversely affect* determinations for green sturgeon and Southern Resident killer whales, and with the USFWS for bull trout. Formal consultation will result in the issuance of a biological opinion and incidental take statement from NMFS. Informal consultation will conclude with the issuance of a concurrence letter by USFWS.

This section also requests conference with USFWS for federally proposed bull trout critical habitat.

8. FINDING OF EFFECT - SUMMARY

Table 8-1 summarizes the determinations of effects to all of the species and critical habitats addressed in this BA. The impacts to these ESUs and DPSs are detailed in Section 6 of this document.

Table 8-1. Summary of Effect Determinations for Species and Critical Habitat

ESU/DPS	Determination of Effects to Species	Determination of Effects to Critical Habitat
Lower Columbia River **Chinook** *Oncorhynchus tshawytscha*	May Affect, Likely to Adversely Affect	May Affect, Likely to Adversely Affect
Upper Columbia River Spring-Run **Chinook** *Oncorhynchus tshawytscha*	May Affect, Likely to Adversely Affect	May Affect, Likely to Adversely Affect
Snake River Fall-Run **Chinook** *Oncorhynchus tshawytscha*	May Affect, Likely to Adversely Affect	May Affect, Likely to Adversely Affect
Snake River Spring/Summer-Run **Chinook** *Oncorhynchus tshawytscha*	May Affect, Likely to Adversely Affect	May Affect, Likely to Adversely Affect
Upper Willamette River **Chinook** *Oncorhynchus tshawytscha*	May Affect, Likely to Adversely Affect	May Affect, Likely to Adversely Affect
Lower Columbia River **Steelhead** *Oncorhynchus mykiss*	May Affect, Likely to Adversely Affect	May Affect, Likely to Adversely Affect
Middle Columbia River **Steelhead** *Oncorhynchus mykiss*	May Affect, Likely to Adversely Affect	May Affect, Likely to Adversely Affect
Upper Columbia River **Steelhead** *Oncorhynchus mykiss*	May Affect, Likely to Adversely Affect	May Affect, Likely to Adversely Affect
Snake River **Steelhead** *Oncorhynchus mykiss*	May Affect, Likely to Adversely Affect	May Affect, Likely to Adversely Affect
Upper Willamette River **Steelhead** *Oncorhynchus mykiss*	May Affect, Likely to Adversely Affect	May Affect, Likely to Adversely Affect
Snake River **Sockeye** *Oncorhynchus nerka*	May Affect, Likely to Adversely Affect	May Affect, Likely to Adversely Affect
Lower Columbia River **Coho** *Oncorhynchus kisutch*	May Affect, Likely to Adversely Affect	N/A
Columbia River **Chum** *Oncorhynchus keta*	May Affect, Likely to Adversely Affect	May Affect, Likely to Adversely Affect
Columbia River DPS, conterminous US **Bull trout** *Salvelinus confluentus*	May Affect, Not Likely to Adversely Affect	Will Not Destroy or Adversely Modify, May Affect, Not Likely to Adversely Affect

ESU/DPS	Determination of Effects to Species	Determination of Effects to Critical Habitat
Eastern DPS **Northern (Steller) Sea Lion** *Eumetopias jubatus*	May Affect, Likely to Adversely Affect	N/A
Southern DPS **Green Sturgeon** *Acipenser medirostris*	May Affect, Not Likely to Adversely Affect	N/A
Southern Resident Population **Killer Whale** *Orcinus orca*	May Affect, Not Likely to Adversely Affect	N/A
Southern DPS **Eulachon** *Thaleichthys pacificus*	May Affect, Likely to Adversely Affect	N/A

8.1 SPECIES

8.1.1 Salmon and Steelhead

The project **may affect,** and is **likely to adversely affect,** LCR Chinook, UCR spring-run Chinook, SR fall-run Chinook, SR spring/summer-run Chinook, LCR steelhead, MCR steelhead, UCR steelhead, SR steelhead, SR sockeye, LCR coho, and CR chum.

The project **may affect** these ESUs/DPSs based on the following:

- There are numerous documented detections of individuals from these ESUs/DPSs in the action area.
    - Suitable migration and juvenile rearing habitat occurs within all of the action area water bodies for the salmon and steelhead ESUs/DPSs listed above.
    - Suitable spawning habitat for CR chum occurs in upriver portions of the action area in the Columbia River.
    - Suitable spawning habitat for LCR Chinook and LCR coho occurs in the Hood River at the proposed mitigation site.
- The project will generate noise above ambient levels in the Columbia River and North Portland Harbor.
- The project will temporarily and permanently alter water quality and quantity in the action area water bodies.
- The project will conduct in-water and over-water construction activities in the Columbia River, North Portland Harbor, Hood River, and Lewis River that may result in behavioral harassment, injury or mortality.
- The project will place numerous in-water and over-water structures in the Columbia River and North Portland Harbor, making both permanent and temporary alterations to in-stream habitat, including physical loss, shading, and hydraulic shadowing.
- The project will remove riparian vegetation and revegetate disturbed riparian areas alongside the Columbia River and North Portland Harbor.

- Land use changes may result in added PGIS, in-water work, and loss of in-stream habitat features.
- Spawning and rearing habitat will be increased for LCR Chinook, LCR coho, and LCR steelhead at the Hood and Lewis River mitigation sites. Spawning and rearing habitat may be increased for CR chum at the Lewis River mitigation sites.
- Foraging, rearing, migrating, and holding habitat will be improved with additional allochthonous material, cover, and shade for adult and juvenile LCR Chinook, LCR coho, and LCR steelhead provided by riparian, side-channel, and wetland restoration at the Hood River mitigation site.
- Rearing habitat will be improved with additional allochthonous material, cover, and shade for migrating adult and juvenile LCR Chinook, CR chum, LCR coho, and Lower CR steelhead provided by riparian and side-channel restoration at the Lewis River mitigation site. Foraging, migrating, and holding habitat will be improved for the preceding reasons for all adult and juveniles of the ESUs/DPSs at the Lewis River mitigation site.
- Side channel and wetland restoration at the Hood River mitigation site will provide high-flow refuge, improved hydrologic function for in-river flows, and potentially improved water quality through wetland restoration for adult and juvenile LCR Chinook, LCR coho, and LCR steelhead. This represents a benefit for these fish.
- Side channel restoration at the Lewis River mitigation site will provide high-flow refuge, improved hydrologic function for in-river flows, and potentially improved water quality (cool-water refugia from warmer Columbia River flows) for adult and juveniles of all ESUs/DPSs, but especially for juvenile LCR Chinook, LCR coho, and LCR steelhead.

The project is **likely to adversely affect** these ESUs/DPSs based on the following:

- Noise levels may exceed thresholds for behavioral disturbance and onset of injury. This may potentially delay migration, damage tissues, produce TTS (fatigue of hair cells in the inner ear) or PTS (permanent hearing loss), cause mortality, and increase the potential for predation in the Columbia River and North Portland Harbor.
- The project may temporarily increase turbidity above baseline levels during in-water construction in the Columbia River and North Portland Harbor, potentially resulting in injury or behavioral harassment.
- The project may temporarily increase turbidity above baseline levels during in-water construction in the Hood and Lewis Rivers as side channels are connected to the mainstem lower Hood River and the Columbia River, respectively, and while restoration plantings are being established potentially resulting in injury or behavioral harassment.
- In the Columbia River, North Portland Harbor, and Columbia Slough, increased PGIS may result in increased exposure to contamination during events exceeding the design storm. Exposure during these events may cause injury or behavioral disturbance to fish, but is likely to be lower than the preproject exposure.

- In Burnt Bridge Creek, increased PGIS may result in increased exposure to contamination and altered flow regime during all storm events. Exposure during these events may cause injury or behavioral disturbance to LCR coho and steelhead, but is likely to be lower than preproject exposure.
- Direct handling of fish during salvage poses the risk of injury or mortality in the Columbia, Hood, and Lewis River mitigation sites.
- Fish may become entrained in cofferdams in the Columbia River, where they will likely experience mortality.
- In the Columbia River and North Portland Harbor, temporary physical loss of habitat, increased in-water shade, and changes in hydraulic shadowing could temporarily increase exposure of migrating juveniles to predation and delayed migration.
- In the Columbia River and North Portland Harbor, permanent physical loss of habitat, increased in-water shade, and changes in hydraulic shadowing may result in increased exposure of migrating juveniles to predation and delayed migration.

The project **may affect** UWR Chinook and UWR steelhead based on:

- Suitable migration and rearing habitat occurs near the western extent of the action area in the Columbia River and may be subjected to temporary noise above ambient levels.

The project is **likely to adversely affect** UWR Chinook and steelhead based on**:**

- Noise levels may exceed thresholds for behavioral disturbance. This may potentially delay migration and hinder rearing in the Columbia River.

8.1.2 Bull Trout

The project **may affect** bull trout based on:

- Marginally suitable migration habitat is present in the action area in the Columbia River and North Portland Harbor. Bull trout have the potential to occur in the Columbia River and North Portland Harbor portions of action area, but detections are very few, limited to less than 20 individuals in the entire lower Columbia River over a period of approximately 60 years. This indicates that presence in the action area is extremely limited. Presence is likely limited to the months of September through June.
- Suitable migration habitat is present in the action area at the lower Hood River and Lewis River mitigation sites. Extremely limited numbers of individuals are documented at these sites.
- The project will generate noise above ambient levels in the Columbia River and North Portland Harbor.
- The project will temporarily and permanently alter water quality in the Columbia River and North Portland Harbor.
- The project may temporarily increase turbidity above baseline levels during in-water construction in the Hood and Lewis Rivers as side channels are connected to the mainstem lower Hood River and the Columbia River, respectively, and while restorations plantings are being established.

- Direct handling of fish during salvage poses the risk of injury or mortality in the Columbia, Hood, and Lewis Rivers.
- The project will conduct in-water and over-water construction activities in the Columbia River and North Portland Harbor that may result in behavioral harassment, injury or mortality.
- The project will place numerous in-water and over-water structures in the Columbia River and North Portland Harbor, making both permanent and temporary alterations to in-stream habitat, including physical loss, shading, and hydraulic shadowing.
- The project will remove riparian vegetation and revegetate disturbed riparian areas alongside the Columbia River and North Portland Harbor.
- Land use changes may result in added PGIS, in-water work, and loss of in-stream habitat features.
- Foraging, rearing, migrating, and holding habitat will be improved with additional allochthonous material, cover, and shade by provided by riparian, side-channel, and wetland restoration at the Hood River mitigation site, and potentially in the future, at the Lewis River site if adfluvial bull trout are present in the Lewis River in future years.
- Side channel and wetland restoration at the Hood River mitigation site will provide high-flow refuge, improved hydrologic function for in-river flows, and potentially improved water quality through wetland restoration.
- Side channel restoration at the Lewis River mitigation site will provide high-flow refuge, improved hydrologic function for in-river flows, and potentially improved water quality (cool-water refugia from warmer Columbia River flows).

The project is **not likely to adversely affect** bull trout based on the following:

- Due to the extremely limited numbers of individuals present in the action area, risk of exposure to all of these effects is discountable.

8.1.3 Green Sturgeon

The project **may affect** green sturgeon based on:

- Suitable habitat for adults occurs within the action area in the Columbia River, North Portland Harbor, and Lewis River. However, detections in the action area are rare, and presence is expected to be extremely limited.
- The project will generate noise above ambient levels in the Columbia River and North Portland Harbor.
- The project will temporarily and permanently alter water quality in the Columbia River and North Portland Harbor.
- The project may temporarily increase turbidity above baseline levels during in-water construction in the Lewis River as side channels are connected to the mainstem lower Columbia River and while restorations plantings are being established.
- Direct handling of fish during salvage poses the risk of injury or mortality in the Columbia and Lewis Rivers.

- The project will conduct in-water and over-water construction activities in the Columbia River and North Portland Harbor that may result in behavioral harassment, injury or mortality.
- The project will place numerous in-water and over-water structures in the Columbia River and North Portland Harbor, resulting in both permanent and temporary physical loss of habitat.
- Land use changes may result in added PGIS, in-water work, and loss of in-stream habitat features.

The project is **not likely to adversely affect** green sturgeon based on:

- Due to the extremely limited numbers of individuals present in the action area, risk of exposure is discountable.

8.1.4 Steller Sea Lion

The project **may affect** the northern (Steller) sea lion based on:

- Steller sea lions are known to transit through the action area in the Columbia River and North Portland Harbor. They will likely be exposed to temporary noise above ambient levels.

The project is **likely to adversely affect** the Steller sea lion based on:

- Noise levels will likely be above disturbance thresholds and may cause behavioral harassment to Steller sea lions transiting in the Columbia River and North Portland Harbor.
- Noise levels will likely be above injury thresholds, but effects will be limited to temporary harassment to Steller sea lions transiting in the Columbia River and North Portland Harbor. The project will avoid injury by monitoring Steller sea lion presence and curtailing pile driving when Steller sea lions approach the potential injury zone.

8.1.5 Killer Whale

The project **may affect** the Southern Resident DPS of killer whale based on:

- The project will have adverse effects on the Chinook prey base of the Southern Resident DPS.

The project is **not likely to adversely affect** the killer whale based on:

- The project will adversely impact a small percentage of the Columbia River Chinook salmon population. This represents a negligible proportion of the entire Chinook population occurring in the marine portion of the action area. Therefore, the resulting impact to the Chinook prey base and killer whale is insignificant.

Additional information on Southern Resident DPS killer whale is located in Appendix H of this document.

8.1.6 Eulachon

The project **may affect** eulachon based on:

- Suitable habitat and documented detections occur in the action area in the Columbia River, North Portland Harbor, and lower Lewis River.
- The project will generate noise above ambient levels in the Columbia River and North Portland Harbor.
- The project may temporarily increase turbidity above baseline levels during in-water construction in the Lewis River as side channels are connected to the mainstem lower Columbia River and while restoration plantings are being established.
- Direct handling of fish during salvage poses the risk of injury or mortality in the Columbia River.
- The project will temporarily and permanently alter water quality in the Columbia River and North Portland Harbor.
- The project will conduct in-water and over-water construction activities in the Columbia River and North Portland Harbor that may result in behavioral harassment, injury or mortality.
- The project will place numerous in-water and over-water structures in the Columbia River and North Portland Harbor, making both permanent and temporary alterations to in-stream habitat, including physical loss, shading, and hydraulic shadowing.
- The project will remove riparian vegetation and revegetate disturbed riparian areas alongside the Columbia River and North Portland Harbor.
- Land use changes may result in added PGIS, in-water work, and loss of in-stream habitat features.
- Side-channel restoration at the Lewis River mitigation site will provide high-flow refuge, improved hydrologic function for in-river flows, and potentially improved water quality (cool-water refugia from warmer Columbia River flows).

The project is **likely to adversely affect** eulachon based on:

- Noise levels may exceed thresholds for behavioral disturbance and onset of injury. This may potentially delay migration, damage tissues, produce TTS or PTS, and increase the potential for predation in the Columbia River and North Portland Harbor.
- The project may temporarily increase turbidity above baseline levels during in-water construction in the Columbia River and North Portland Harbor, potentially resulting in injury or behavioral harassment.
- In the Columbia River and North Portland Harbor, increased PGIS may result in increased exposure to contamination during events exceeding the design storm. Exposure during these events may cause injury or behavioral disturbance, but is likely to be lower than preproject exposure.
- Direct handling of fish during salvage poses the risk of injury or mortality in the Columbia River.

- Fish may become entrained in cofferdams in the Columbia River, where they will likely experience mortality.
- In the Columbia River and North Portland Harbor, temporary physical loss of habitat, increased in-water shade, and changes in hydraulic shadowing could temporarily increase exposure of migrating larvae to predation and could alter primary and benthic productivity.
- In the Columbia River and North Portland Harbor, permanent physical loss of habitat, increased in-water shade, and changes in hydraulic shadowing may result in increased exposure of migrating larvae to predation and may alter primary and benthic productivity.

8.2 CRITICAL HABITAT

8.2.1 Designated Critical Habitat for Listed Salmon and Steelhead

The project **may affect** designated critical habitat for LCR Chinook, UCR spring-run Chinook, SR fall-run Chinook, SR spring/summer-run Chinook, UWR Chinook, LCR steelhead, MCR steelhead, UCR steelhead, SR steelhead, UWR steelhead, SR sockeye, and CR chum based on:

- Designated critical habitat occurs within the action area in the Columbia River, North Portland Harbor, and Columbia Slough for all runs listed above.
- Designated critical habitat occurs within the action area in the Hood River for LCR Chinook and LCR steelhead.
- Designated critical habitat occurs within the action area in the Lewis River for LCR Chinook, CR chum, and LCR steelhead.
- For the 2005 critical habitat designation (LCR Chinook, UCR spring-run Chinook, UWR Chinook, LCR steelhead, MCR steelhead, UCR steelhead, SR steelhead, UWR steelhead, and CR chum), PCEs occurring in the action area include:
    - Freshwater spawning sites in the Columbia River (for CR chum only), the Lewis River (LCR Chinook and LCR steelhead), and the Hood River (LCR Chinook and LCR steelhead),
    - Freshwater rearing areas (for LCR Chinook, UCR spring-run Chinook, UWR Chinook, LCR steelhead, and CR chum),
    - Freshwater migration corridors (for all runs).
- For the 1993 critical habitat designation (SR spring/summer-run Chinook, SR sockeye, and SR fall-run Chinook), PCEs occurring in the action area include:
    - Juvenile migration corridors (for all runs)
    - Adult migration corridors (for all runs).
- The project will generate noise above ambient levels in the Columbia River and North Portland Harbor.
- The project will temporarily and permanently alter water quality in the Columbia River, North Portland Harbor, and Columbia Slough.

- The project will temporarily alter water quality in the Lewis and Hood Rivers.
- The project will place numerous in-water and over-water structures in the Columbia River and North Portland Harbor, making both permanent and temporary alterations to in-stream habitat, including physical loss, shading, and hydraulic shadowing.
- The project will remove riparian vegetation and revegetate disturbed riparian areas alongside the Columbia River and North Portland Harbor.
- Land use changes may result in added PGIS, in-water work, and loss of in-stream habitat features, potentially altering the migration and rearing PCEs.
- The 21 acres of restored side-channel habitat at the Hood River mitigation site will provide additional spawning habitat and larval development. Reconnection of the main channel Hood River with the wetland and side-channel area will restore a more natural hydrograph and may prevent high-flow events from scouring redds.
- The 18.5 acres of restored side-channel habitat at the Lewis River mitigation site will provide spawning habitat for LCR Chinook, LCR steelhead, and potentially CR chum. Reconnection of the side-channel areas will restore a more natural hydrograph and may prevent high-flow events from scouring redds.
- Reconnection of Hood River floodplain habitat with the 21 acres of side channel and associated wetland area will increase rearing area for juveniles, high flow refuge, potentially improving base flows and attenuating peak flow, and likely improved water quality and quantity from flow attenuation and wetland reconnection. Riparian and wetland plantings and addition of large woody debris will provide allochthonous inputs into the channel, cover, and shade which will improve rearing habitat by increasing forage and natural cover.
- Reconnection of the Lewis and Columbia Rivers to floodplain habitat in the side channels at the Lewis River mitigation site will increase rearing area for rearing LCR, CR chum, and LCR steelhead juveniles. High flow refuge, potential improvements to base flows and attenuation of peak flows, and likely improvements to water quality and quantity from flow attenuation with the additional side channel acreage will occur for lower river ESUs and DPS, but will also occur for all other ESUs and DPSs as well. In addition, riparian plantings and addition of large woody debris will provide allochthonous inputs into the channel, cover, and shade which will improve rearing habitat by increasing forage and natural cover for all LCR Chinook, CR chum, and LCR steelhead.
- Reconnection of Hood River floodplain habitat with the 21 acres of side channel and associated wetland area will increase migrating area for adults and juveniles, as well as provide a high flow refuge during migration, potentially improve base flows and attenuating peak flow, and likely improve water quality and quantity from flow attenuation and wetland reconnection. Restoration of the riparian and wetland area through reconnection with the river, plantings, and addition of large woody debris will provide allochthonous inputs into the channel, cover, and shade which will improve migration habitat by increasing forage and natural cover, and overall habitat complexity.
- Reconnection of the 18.5 acres of side channels along the Lewis River will increase migrating area for adults and juvenile LCR Chinook and LCR steelhead in the Lewis River, as well as provide high flow refuge during migration, potentially improve base

flows and attenuate peak flows, and likely improve water quality and quantity from flow attenuation and the additional acreage of the side channels for lower river ESUs and DPS, but will also occur for all other ESUs and DPSs as well. Restoration of the riparian and wetland area through reconnection with the river, plantings, and addition of large woody debris will provide allochthonous inputs into the channel, cover, and shade which will improve migration habitat by increasing forage and natural cover, and overall habitat complexity.

The project is **likely to adversely affect** these critical habitat units based on:

- Noise levels may exceed thresholds for behavioral disturbance and injury to fish. This may temporarily degrade the migration PCEs for all ESUs/DPSs and the rearing PCE for LCR Chinook, UCR spring-run Chinook, LCR steelhead, and CR chum.
- Noise levels may degrade the spawning PCE for CR chum, but this PCE will likely still be functional during periods of elevated underwater noise.
- The project may temporarily increase turbidity above baseline levels during in-water construction in the Columbia River and North Portland Harbor, potentially degrading discrete portions of the migration and rearing PCEs for a period of no more than 12 hours per day during operations that disturb sediment.
- The project may temporarily increase turbidity above baseline levels during in-water construction in the Hood and Lewis Rivers, potentially degrading discrete portions of the migration and rearing PCEs for short durations 100 feet upstream and 300 feet downstream of where new side channels are reconnected to the main river channels.
- In the Columbia River, North Portland Harbor, and Columbia Slough, increased PGIS may degrade water quality during events that exceed the design storm. This may degrade the migration and rearing PCEs, but discharge of pollutants will likely be lower than preproject conditions.
- In the Columbia River and North Portland Harbor, temporary physical loss of habitat, increase in in-water shade, and changes in hydraulic shadowing could temporarily increase predation pressure and could alter primary and benthic productivity. This may temporarily degrade the migration and rearing PCEs.
- In the Columbia River and North Portland Harbor, permanent physical loss of habitat, increase in in-water shade, and changes in hydraulic shadowing may result in increased exposure of migrating juveniles to predation and may alter primary and benthic productivity. This may permanently degrade the migration and rearing PCEs.

8.2.2 Designated and Proposed Critical Habitat for Bull Trout

Proposed critical habitat for bull trout occurs within the action area in the Columbia River, North Portland Harbor, Hood River, and Lewis River. The project will have the following effects on the PCEs that occur within the action area:

- The project will generate noise above ambient levels in the Columbia River and North Portland Harbor. This may degrade the migratory habitat PCE.
- The project will temporarily and permanently alter the water quality PCE in the Columbia River and North Portland Harbor.

- The project will place numerous in-water and over-water structures in the Columbia River and North Portland Harbor, making both permanent and temporary alterations to in-stream habitat, including physical loss of substrate and increased in-water shading. This may potentially affect the complex aquatic habitat and food base PCEs.
- The project will remove riparian vegetation and revegetate disturbed riparian areas alongside the Columbia River and North Portland Harbor. This may potentially affect the temperature and complex aquatic habitat PCEs.
- Land use changes may result in added PGIS, in-water work, and loss of in-stream habitat features. This may potentially affect the migratory habitat and water quality/quantity PCEs.

Although the project will have effects to the PCEs, impacts **will not destroy or adversely modify** proposed critical habitat for bull trout based on:

- Noise above ambient levels will be temporary, limited to the duration of in-water pile driving.
- Temporary impacts to water quality will be limited to no more than periods of about 12 hours per day during operations that disturb sediment. Permanent impacts to water quality will be largely beneficial due to the high level of stormwater treatment.
- Physical loss of substrate is extremely small relative to the remaining substrate available.
- Increase in underwater shading will have only negligible and temporary effects on primary productivity and the food web.
- Temporary shading may have a beneficial effect on water temperature. Permanent shading is likely to have only negligible effects on water temperature.
- Removal of riparian vegetation will have only slight and temporary effects to water temperature.

If proposed critical habitat for bull trout is designated before the completion of the project, a provisional effect determination of **may affect, not likely to adversely affect** is warranted.

Designated critical habitat for bull trout occurs in the Hood and Lewis Rivers. The effect determination of may **affect, not likely to adversely affect** also applies for to this designated critical habitat

The project **may affect** critical habitat for bull trout based on:

- The project will generate noise above ambient levels in the Columbia River and North Portland Harbor. This may degrade the migratory habitat PCE.
- The project will temporarily and permanently alter the water quality PCE in the Columbia River and North Portland Harbor.
- The project will place numerous in-water and over-water structures in the Columbia River and North Portland Harbor, making both permanent and temporary alterations to in-stream habitat, including physical loss of substrate and shading. This may potentially affect the complex aquatic habitats and food base PCEs.

- The project will remove riparian vegetation and revegetate disturbed riparian areas alongside the Columbia River and North Portland Harbor. This may potentially affect the temperature and complex aquatic habitats PCEs.
- Land use changes may result in added PGIS, in-water work, and loss of in-stream habitat features. This may potentially affect the migratory habitat and water quality/quantity PCEs.
- Springs, seeps, groundwater sources PCE: The proposed Hood River mitigation will reconnect a 21-acre wetland and isolated river side channel with the mainstem Hood River. The reconnection of the wetland to the main channel is expected to improve subsurface water connectivity, contribute to water quality improvements through reconnection of wetland water quality functions and contribute to thermal refugia from the increase in subsurface flow connections. The proposed Lewis River mitigation will reconnect 18.5 acres of side channels with the Lewis and Columbia Rivers. The reconnection of the side channels is expected to improve subsurface water connectivity and contribute to thermal refugia.
- Food base PCE: The proposed mitigation at the Lewis and Hood River mitigation sites will allow contribution of allochthonous input from side channel and wetland productivity, which contribute to stream productivity. Benefits to salmonids spawning, rearing, and migration habitat will benefit the bull trout prey base. These benefits include: side channel improvements for habitat complexity, including placement of large woody debris, increased shading, off-channel refugia, hydrology benefits (likely increases in base flows and reductions in peak flows), and the increase in spawning and rearing habitat for salmon and steelhead.
- Complex aquatic habitats: The proposed Hood River mitigation will reconnect one mile of side channel and a 21-acre wetland with the mainstem Hood River. Channel enhancing restoration, such as the addition of large woody debris, will add complexity resulting in channel-forming processes creating a variety of depths, gradients, velocities, and structures. The proposed Lewis River mitigation will reconnect 21,100 linear feet of side channels with the Lewis and Columbia Rivers. Channel enhancing restoration, such as the addition of large woody debris, will add complexity resulting in channel-forming processes creating a variety of depths, gradients, velocities, and structures.
- Temperature PCE: At the Hood River mitigation site, reconnection to the historic wetland will help maintain base flows, which benefit stream summer temperatures. Riparian restoration plantings will shade the mainstem and off-channel areas, which will help maintain in-stream temperatures. At the Lewis River mitigation site, reconnection of the historic channels will allow access to thermal refugia in the cooler Lewis River waters for fish in the Columbia River during high summer temperatures. Riparian restoration plantings will shade the off-channel areas, which will help maintain in-stream temperatures.
- Natural hydrograph PCE: At the Hood River mitigation site, reconnection of one mile of side channel and connection of the main river channel to the wetland will result in a more natural hydrograph as the main stem river will be more connected to the floodplain. Reconnection to the wetland area may enhance base flows and alleviate channel incision

caused from high flows. At the Lewis River mitigation site, reconnection of the side channels will result in a more natural hydrograph because the mainstem Lewis and Columbia Rivers will be more connected to their floodplain. Reconnection of the side channels may enhance base flows and alleviate channel incision caused from high flows.

- Water quantity/quality PCE: At the Hood River mitigation site, wetlands provide retention of peak flows, replenish base flows and provide function to filter sediment and toxicants from entering waterways. The side channel proposed as part of the project will offer refuge from high flows, and provide greater connectivity so that water quantity during high flows is attenuated with the extra volume provided by the side channel. At the Lewis River mitigation site, the side channels will offer refuge from high flows, and provide greater connectivity so that water quantity during high flows is attenuated with the extra volume provided by the side channel.

The project is **not likely to adversely affect** critical habitat for bull trout based on:

- Elevated noise will be limited in duration to 40 minutes per in-water work day and is not likely to occur when bull trout are present. Therefore, elevated noise does not represent significant degradation to the migratory PCE.
- Effects to other PCEs will be either extremely slight or beneficial. Thus, these effects will not measurably degrade the PCEs and will therefore be insignificant.

8.3 CONCLUSION

Due to these findings of effect, FHWA and FTA are requesting initiation of **formal consultation** and an **incidental take statement** in accordance with Section 7 of the ESA for the following listed species: LCR Chinook, UCR spring-run Chinook, SR fall-run Chinook, SR spring/summer-run Chinook, UWR Chinook, LCR steelhead, MCR steelhead, UCR steelhead, SR steelhead, UWR steelhead, SR sockeye, LCR coho, and CR chum. **Formal consultation** is also requested for the Eastern DPS of Steller sea lion and eulachon.

Additionally, FHWA and FTA are requesting **formal consultation** for the following designated critical habitats: LCR Chinook, UCR spring-run Chinook, SR fall-run Chinook, SR spring/summer-run Chinook, UWR Chinook, LCR steelhead, MCR steelhead, UCR steelhead, SR steelhead, UWR steelhead, SR sockeye, and CR chum.

Informal consultation is requested for the Southern DPS of green sturgeon, the Columbia River DPS of bull trout, and the Southern Resident DPS of killer whale.

FHWA and FTA also request **formal conferencing** for proposed critical habitat for bull trout.

Section 9

SECTION 9

How will this project affect essential fish habitat?

FHWA and FTA, as federal agencies, are required under the Magnuson-Stevens Act to consult with NMFS on activities that may adversely affect essential fish habitat (EFH). EFH for Chinook and coho is present within the action area. The project will result in both short-term and permanent adverse effects to EFH. The impact avoidance and minimization measure and performance standards described in Section 7 are considered adequate to minimize these effects.

9. ESSENTIAL FISH HABITAT CONSULTATION

The MSA, as amended by the Sustainable Fisheries Act of 1996 (Public Law [PL] 104-267), requires federal agencies to consult with NMFS on activities that may adversely affect EFH.

The objective of this EFH assessment is to determine whether or not the proposed actions "may adversely affect" designated EFH for relevant commercial, federally managed fisheries species within the proposed action area. It also describes measures proposed to avoid, minimize, or otherwise offset potential adverse effects to designated EFH resulting from the proposed action.

EFH is broadly defined to include "...those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity." This language is interpreted or described in the 1997 Interim Final Rule (62 FR 66551, Section 600.10 Definitions). "Waters" include aquatic areas and their associated physical, chemical, and biological properties that are used by fish, and may include historic areas if appropriate. "Substrate" includes sediment, hard bottom, structures underlying the waters, and associated biological communities. "Necessary" means the habitat required to support a sustainable fishery and the managed species' contribution to a healthy ecosystem. "Spawning, breeding, feeding, or growth to maturity" covers a species' full life cycle.

The consultation requirements of Section 305(b) of the MSA (16 USC 1855[b]) provide that:

- Federal agencies must consult with NMFS on all actions or proposed actions authorized, funded, or undertaken by the agency that may adversely affect EFH.
- NMFS shall provide conservation recommendations for any federal or state activity that may adversely affect EFH.
- Federal agencies shall, within 30 days after receiving conservation recommendations from NMFS, provide a detailed response in writing to NMFS regarding the conservation recommendations. The response shall include a description of measures proposed by the agency for avoiding, mitigating, or offsetting the impact of the activity on EFH. In the case of a response that is inconsistent with the conservation recommendations of NMFS, the federal agency shall explain its reasons for not following the recommendations.

9.1 IDENTIFICATION OF ESSENTIAL FISH HABITAT

The Pacific Fishery Management Council (PFMC) has designated EFH for the Pacific salmon fishery, federally managed ground fishes, and coastal pelagic fisheries (PFMC 1999). The proposed action and action area for this consultation are described in Section 3 of this document.

In the estuarine and marine areas, proposed designated salmon EFH extends from the nearshore and tidal submerged environments within state territorial waters out to the full extent of the exclusive economic zone (230.2 statute miles) offshore of Washington, Oregon, and California north of Point Conception. Groundfish and coastal pelagic fisheries are found in the marine portion of the action area, but since impacts to habitat will not extend to this area, the project will have no adverse effect on these fisheries.

The EFH designation for the Pacific salmon fishery includes all those streams, lakes, ponds, wetlands, and other water bodies currently or historically accessible to salmon in Washington, Oregon, Idaho, and California, except above the impassible barriers identified by PFMC (1999). Chief Joseph Dam, Dworshak Dam, and the Hells Canyon Complex (Hells Canyon, Oxbow, and

Brownlee Dams) are among the listed manmade barriers that represent the upstream extent of the Pacific salmon fishery EFH. Salmon EFH excludes areas upstream of long-standing naturally impassable barriers (e.g., natural waterfalls in existence for several hundred years). The Pacific salmon management unit includes Chinook, coho, and pink salmon (*Oncorhynchus gorbuscha*). Of these, only Chinook and coho use the CRC action area. All of the water bodies in the action area (the Columbia River, North Portland Harbor, Columbia Slough, Burnt Bridge Creek, the Pacific Ocean, the Lewis River, and the Hood River) constitute EFH due to current or historical presence of salmon. All of these water bodies provide migration and rearing habitat for Chinook and coho. Spawning habitat for these species occurs only in the Hood River, and does not occur elsewhere in the action area.

9.2 ANALYSIS OF EFFECTS

In summary, likely effects to EFH, as described in detail in Section 6 of this BA, include:

- *Increased in-water noise due to in-water pile driving.* This is likely to cause a temporary degradation of rearing and migration habitat and may cause a temporary barrier to migration.
- *Increased in-water shading from the permanent structures and temporary work structures.* This could result in an increase in predation pressure on juveniles.
- *A temporary increase of suspended sediment during in-water work in the Columbia River, North Portland Harbor, and mitigation sites in the Lewis and Hood Rivers.*
- *Increased PGIS which could result in slight negative impacts to EFH in Burnt Bridge Creek.* The stormwater treatment scenario could result in long-term benefits to EFH in the Columbia River, North Portland Harbor, and Columbia Slough.
- *The permanent loss of shallow-water habitat through construction of new bridge piers and the temporary loss of shallow-water habitat while in-water work platforms and cofferdams are in place.*
- *A permanent increase in the extent of hydraulic shadowing due to the larger piers of the new bridges in the Columbia River and North Portland Harbor.*
- *A temporary increase in the extent of hydraulic shadowing due to temporary in-water work platforms, cofferdams, and tower cranes.*
- *Long-term beneficial effects associated with mitigation activities in the Lewis and Hood Rivers.*

As outlined in Section 7, numerous impact avoidance and minimization measures will be employed to minimize harm to EFH to the extent practicable.

9.3 CONCLUSION

The project will have both short-term and permanent **adverse effects** on EFH for Chinook and coho in the project area. However, the impact avoidance and minimization measures and performance standards described in Section 7 are considered adequate to minimize the effects.

Section 10

Section 10

10. REFERENCES

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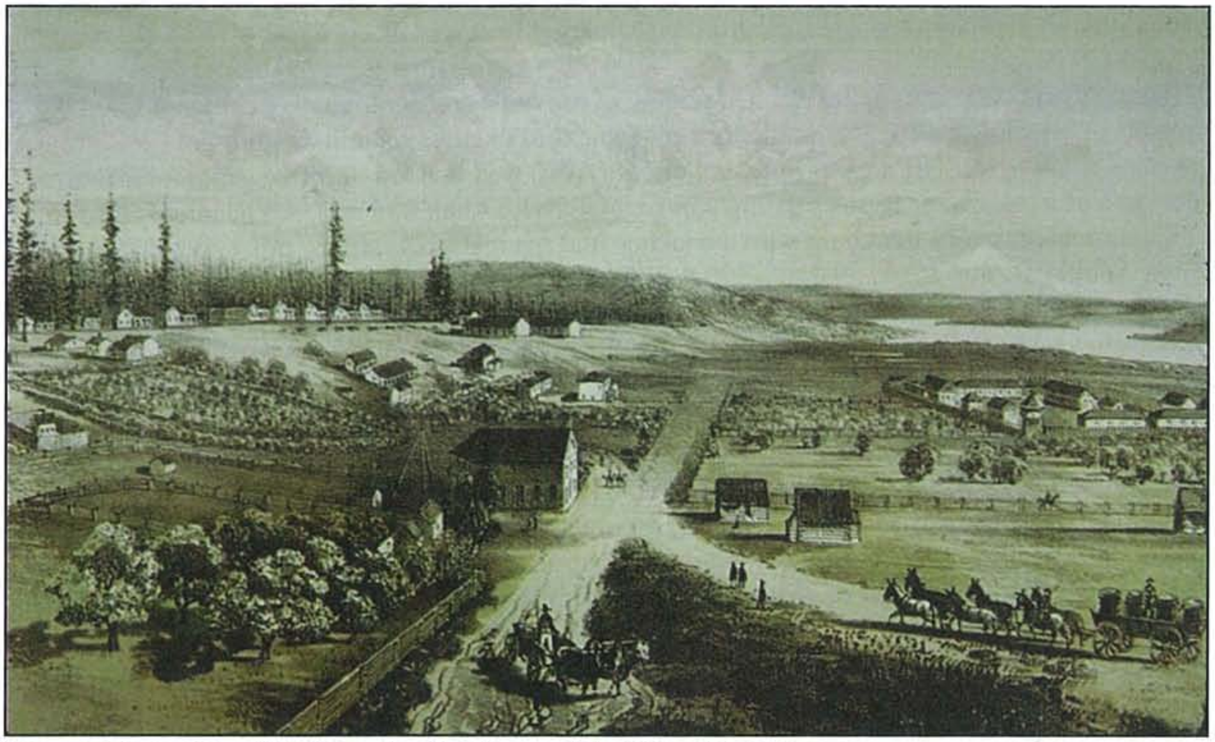
National Park Service
U.S. Department of the Interior
Fort Vancouver National Historic Site
Vancouver National Historic Reserve
Vancouver, Washington

DRAFT

RESULTS OF NATIONAL PARK SERVICE ARCHAEOLOGICAL EVALUATION AND TESTING ON THE VANCOUVER NATIONAL HISTORIC RESERVE FOR THE COLUMBIA RIVER CROSSING PROJECT



Lithograph by Gustav Sohon, 1854. Copy on file at Fort Vancouver National Historic Site Archives.

by

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April 21, 2010

Northwest Cultural Resources Institute Report No. 8

PRELIMINARY

ABSTRACT

This report details the results of archaeological evaluation and testing by the National Park Service (NPS) on the Vancouver National Historic Reserve (VNHR) for the Columbia River Crossing (CRC) project. This document includes the background information contained in the main NPS work plan "Amendments to the Archaeological Research Design and Work Plan for Archaeological Testing, Columbia River Crossing Project, Vancouver National Historic Reserve, Washington" (Northwest Cultural Resources Institute 2009). The NPS work plan was designed as an amendment to the overall research design and archaeology work plan for the CRC project submitted in 2008 by Heritage Research Associates (Minor and Toepel 2008).

Historical and cartographic research, a review of previous archaeological excavations, and the results of geophysical surveys guided the placement of excavation units within the CRC project area on the VNHR. The area of potential effect (APE) was divided into five geographical areas for ease of work and analysis, totaling approximately 1.23 ha (3.05 ac.). Archaeological testing, including exploratory trenching with a backhoe and manual excavations, proceeded within each area. Within all five areas, 50.2 m^2 (540.4 $ft.^2$) was excavated in 52, 1 x 1 m test units; 6.3 m^2 (67.8 $ft.^2$) was excavated in 25, 50 x 50 cm shovel tests. The length of the 79 backhoe trenches excavated was 358.9 m (1177.5 ft.) totaling 409.5 m^2 (4407.8 $ft.^2$). A total of 466 m^2 (5016 $ft.^2$) of surface area of the VNHR was excavated – 3.8% of the CRC APE. Greater than 34,000 artifacts were recovered from excavation units.

Data gained from research, archaeological testing, and the analysis of the artifacts recovered resulted in the identification of 15 cultural resources located within the CRC APE that contribute to the significance of the Vancouver National Historic Reserve District (DT191) under Criteria a-d of the National Register of Historic Places (NRHP). Undiscovered subsurface pits, postholes, cellars, privys, activity areas, and other features related to Hudson's Bay Company and early U.S. Army 19^{th}-century structures may still exist within the CRC APE.

NPS archaeological testing has demonstrated that the CRC project as proposed will have an adverse effect on cultural resources that contribute to the significance of the National-Register-listed VNHR District. Unique and irreplaceable resources on the VNHR within the CRC APE will be destroyed. Resources that may survive the direct effects of the project may lose their eligibility for the NRHP through a loss of integrity. An additional adverse effect will occur when resources are transferred out of federal ownership and lose their protection under federal cultural resources protection laws.

Adverse effects to the cultural resources detailed in this report must be resolved under 36 CFR 800.6. Adverse effects to cultural resources within the CRC APE should be avoided, if possible. If adverse effects cannot be avoided, plans to mitigate these effects should be developed through 36 CFR 800.6 or alternative processes. These efforts should be coordinated with those mitigation requirements associated with Section 4(f) of the U.S. DOT Act of 1966.

ACKNOWLEDGEMENTS

Archaeological testing for the Columbia River Crossing project on the Vancouver National Historic Reserve District was accomplished with the help and support of the VNHR partners: the National Park Service, Fort Vancouver National Trust, City of Vancouver, U.S. Army, and Federal Highway Administration.

Fort Vancouver National Historic Site Superintendent Tracy Fortmann provided the support and resources to facilitate the completion of this project. Doug Wilson, Vancouver National Historic Reserve Archaeologist and Director of the Northwest Cultural Resources Institute (NCRI), served as Principal Investigator.

Curator Tessa Langford and Museum Technician Heidi Pierson provided essential information and technical advice on artifact analysis and curation. A big thanks goes to Fort Vancouver Chief of Maintenance Gary Bickford and his staff for their daily help in transporting equipment and supplies to our work sites, and for their support of our maintenance needs. Contracting and administrative support was provided by Elaine Huff and Diana Cook, Fort Vancouver administration and budget personnel.

Mike True and Kaare Hyde of the Fort Vancouver National Trust assisted in the coordination of archaeological investigations on Officers Row.

Bill Schell, Facility Operations Specialist, 88th Regional Readiness Command at Vancouver Barracks, arranged access to the secure part of the project area on U.S. Army property. Bill was also very generous with his maps of that area, which greatly facilitated our excavations.

Thanks to George Snyder, Dan Donovan, and Wendy Hull of the Federal Highway Administration (FHWA) Western Federal Lands Highway Division for their assistance and support for our excavations on the grounds of the FHWA.

Washington State Department of Transportation (WSDOT) personnel provided valuable input and support services, and conducted tribal consultation. Thanks go to Archaeology Program Manager Scott Williams, Archaeologist Sarah Shufelt, and WSDOT Tribal Liaison Megan Beebe Cotton.

Washington State Department of Archaeology and Historic Preservation (DAHP) Transportation Archaeologist Matthew Sterner and State Physical Anthropologist Guy Tasa provided support services and valuable advice.

Don Day and Brian Krehbiel of the Confederated Tribes of Grand Ronde served as tribal monitors. Thanks go to all tribal members who visited the site and shared their enthusiasm and support for this work.

Assistance from the Columbia River Crossing project personnel and associates was provided by Andrew Beagle, Tom Becker, Derek Chisholm, Mike Gallagher, George Humphries, Lynn Rust, Megan Taylor, and Heather Gunderson Wills.

Kendal McDonald, Z-Too Archaeogeophysical Prospection, conducted the magnetometer surveys. Steve De Vore of the NPS Midwest Archaeological Center conducted the ground penetrating radar surveys. Curt Peterson of Portland State University shared with us the results of the ground penetrating radar surveys he previously conducted in a portion of the project area. Archaeologist Dave DeLyria, Dirty Deeds Done Dirt Cheap, was the backhoe operator for all mechanical excavations. Cartographer Keith Garnett, Anthromaps, conducted the total station surveys of all excavations and converted these data to GIS shapefiles.

NPS Archaeologist Leslie O'Rourke served as Field Director. Archaeological technicians were Jacqueline Cheung, Bob Cromwell, Ben Diaz, Elaine Dorset, Eric Gleason, Beth Horton, Todd Miles, Cheryl Paddock, Frederick Scott Pierson, Heidi Pierson, and Rachel Stokeld.

Thanks to National Park Service parks Aztec Ruins National Park, Lewis and Clark National Historical Park, and Mount Rainier National Park, for their loan of offseason archaeological technicians for the project.

Laboratory analysis and database entry was performed by the archaeological technicians. Bob Cromwell analyzed the ceramics, and Beth Horton analyzed the faunal remains and lithics. Todd Miles analyzed the clay pipes, metal objects, munitions, and small finds. Cheryl Paddock analyzed the beads, nails, and flat glass. Frederick Scott Pierson analyzed the vessel glass and flat glass. Excavation unit volumetrics were done by Beth Horton, Todd Miles, Cheryl Paddock, and Frederick Scott Pierson. Todd Miles generated the graphs and histograms, and compiled the volumetric and artifact analysis tables in the appendices.

Artifact photographs were taken by Todd Miles. Excavation profiles were digitally redrawn by Beth Horton. Artifact illustration was done by Jeremy Harrison. Elaine Dorset assisted with editing the report.

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CHAPTER 1

INTRODUCTION

The proposed Columbia River Crossing (CRC) is a multi-agency project co-sponsored by the Oregon and Washington State Departments of Transportation, to construct a new Interstate 5 bridge across the Columbia River between Vancouver, Washington and Portland, Oregon. The project as proposed would adversely affect archaeological resources located on the Vancouver National Historic Reserve (VNHR) and the historic VNHR District (DT191) adjacent to the current Interstate 5 freeway corridor on the east side of the freeway. Under a Memorandum of Agreement, the National Park Service (NPS) agreed to assist the CRC to comply with Section 106 of the National Historic Preservation Act (NHPA) and Section 4(f) of the National Transportation Act. The NPS agreed to identify any archaeological resources within the CRC area of potential effects (APE) on the VNHR and determine if these resources contribute to the National Register of Historic Places (NRHP) significance of the VNHR District.

The NPS Northwest Cultural Resources Institute (NCRI) at Fort Vancouver National Historic Site developed a work plan for archaeological investigations on the VNHR, on lands within the APE of the CRC project. This work plan ("Amendments to the Archaeological Research Design and Work Plan for Archaeological Testing, Columbia River Crossing Project, Vancouver National Historic Reserve, Washington", NCRI 2009) was designed as an amendment to the Heritage Research Associates (HRA) "Research Design for Archaeological Discovery Field Investigations, Columbia River Crossing (CRC) Project, Oregon and Washington" (HRA 2008) and the "Archaeological Work Plan for Discovery Investigations, Columbia River Crossing Project" (Minor and Toepel 2008).

The CRC project area on the VNHR was divided into five portions (Figure 1):

1. City of Vancouver property at the west end of Officers Row north of Evergreen Boulevard (Old Post Cemetery), plus a small area along the south side of Evergreen Boulevard.
2. City of Vancouver property from Evergreen Boulevard to Anderson Road, Anderson Road and the west edge of West Barracks from the north end of Barnes Hospital south to the Federal Highways Administration (FHWA) Western Federal Lands Highway Division, the FHWA parking lot, and the west end of East 5th Street.
3. U.S. Army property from East 5th Street, south along the Interstate 5 northbound ramp to Vancouver City Center, and the western portion the Fort Vancouver Village ("Kanaka Village"), north of SR 14.
4. National Park Service property in the southwest and south areas of the Fort Vancouver Village, north of SR 14.
5. City of Vancouver property in Old Apple Tree Park and NPS property along the north side of SE Columbia Way, south of SR 14.

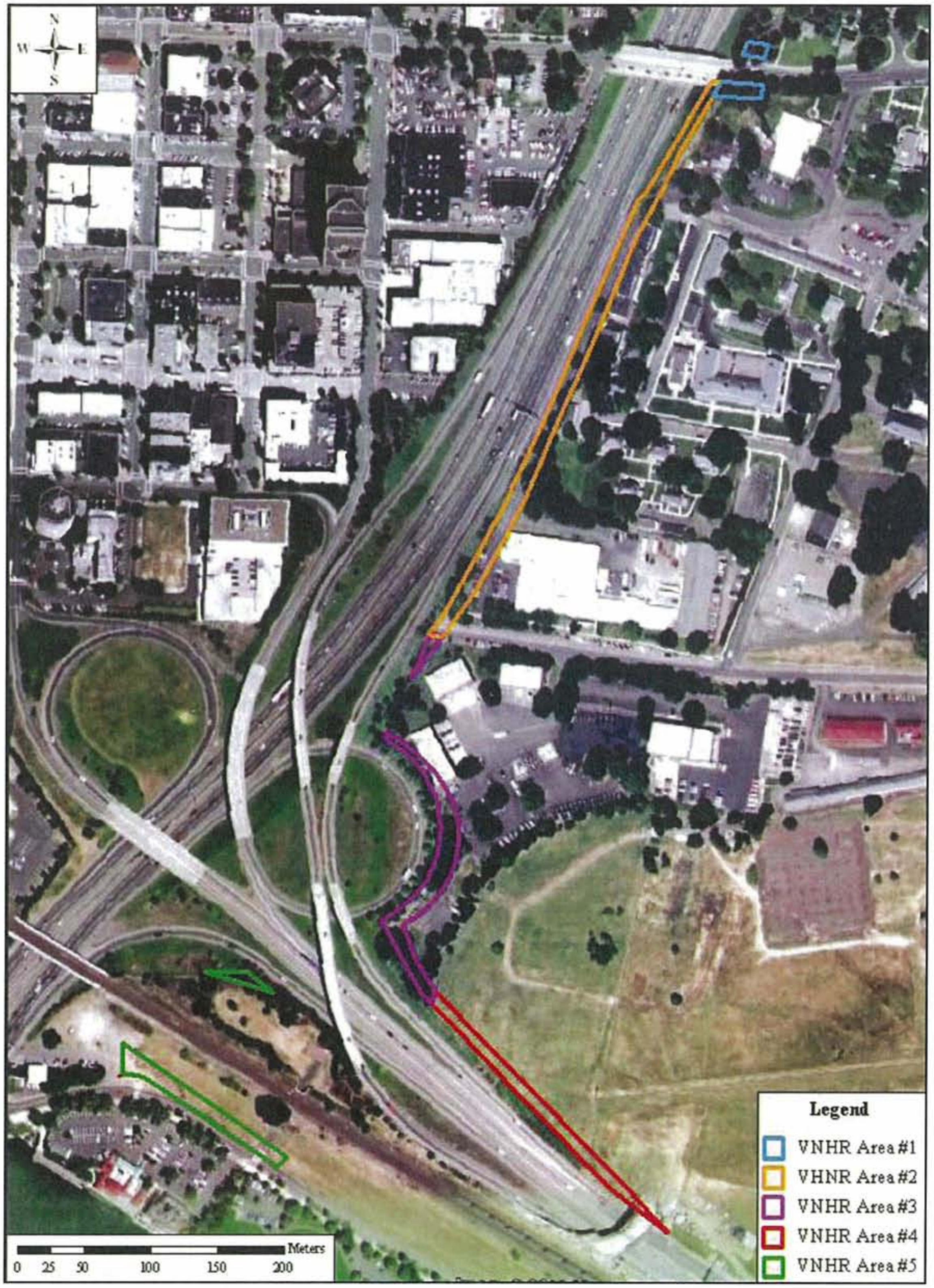

FIGURE 1. The five areas of NPS archaeological testing within the CRC APE on the VNHR. Image from Google Earth. (NPS 2010)

This document provides a detailed report of archaeological investigations in each of the five VNHR areas within the CRC APE, from north to south. A separate chapter devoted to each testing area includes information on the physical description of the area, historical and archaeological context, project goals, anomalies identified during remote sensing surveys that were potential indicators of buried archaeological resources, specific field methods used within that area, archaeological excavations, archaeological resources identified, artifacts recovered and their analysis, and an interpretation of the resources and their potential to contribute to significance of the VNHR District.

A total of 79 exploratory backhoe trenches, 52, 1 x 1 m test units (TU), and 25, 50 x 50 cm shovel tests (ST) were excavated on the VNHR within the CRC APE (Table 1). These test excavations led to the discovery of 15 archaeological and historical resources that contribute to the significance of the VNHR District. These resources are discussed within the chapter on the VNHR area where they were found. The final chapter summarizes the cultural resources located during archaeological testing, and establishes how these resources contribute to the significance of the VNHR District under Criteria a-d of the National Register of Historic Places.

TABLE 1
SUMMARY OF NPS EXCAVATIONS IN THE FIVE AREAS OF THE VNHR

VNHR Area	Magnetic Survey	GPR Survey	Backhoe Trenches	TUs 1 x 1 m	Shovel Tests 50 x 50 cm
1	yes	yes	-	5	5
2	no	yes	19	1	11
3	no	yes	39	22	-
4	yes	yes	-	11	5
5	yes	yes	21	13	4

CHAPTER 2

RESEARCH DESIGN AND METHODS

The VNHR is the location of perhaps the most significant historical archaeological resources in the state of Washington. The VNHR is the site of Fort Vancouver, the Hudson's Bay Company (HBC) post established in 1824, which served as the center of operations for the fur trade on the west coast of North America and beyond from 1829 to 1846. When this area became part of the United States in 1846, the U.S. Army established Camp Vancouver (later Vancouver Barracks) on the bluff above Fort Vancouver. The Hudson's Bay Company relocated to Victoria by 1860.

Archaeological resources associated with the earliest Euroamerican and U.S. military history in the Pacific Northwest can be expected to be present within the CRC APE. Resources from the HBC employee Village houses west and south of the Fort Vancouver stockade may yield important information about the early-to-mid 19th-century fur trade in the Pacific Northwest, and the lives of the working-class engagés and laborers who were employed by the HBC in support of the fur trade. Resources associated with mid-to-late 19th-century U.S. Army structures throughout the CRC APE on the VNHR may be able to provide important information about architecture, support services, materials, and activities at Vancouver Barracks. The remains of early City of Vancouver buildings within the CRC APE near the Columbia River have the potential to reveal important details about mid-to-late 19th-century commercial structures in early Washington civilian settlements. The analysis of artifacts recovered from archaeological testing for the CRC project, together with contextual information from unit and feature excavations, provides the means to address research questions associated with these historical periods.

Project Goals
Project goals were established within each of the five VNHR areas based on the needs of the CRC project to identify and evaluate archaeological resources within the APE, the findings of historical and archaeological research, and the research questions that could be expected to be answered in the process of testing for these resources. These goals are detailed in each VNHR area chapter.

Methods
The general methods used in this project are presented below. Greater detail on these methods was given in the NPS work plan "Amendments to the Archaeological Research Design and Work Plan for Archaeological Testing, Columbia River Crossing Project, Vancouver National Historic Reserve, Washington" (NCRI 2009). When additions or changes to the methods were made within specific testing areas of the VNHR, those additions and changes are included in that chapter.

Historical Research
Research was conducted to establish the historical context for archeological studies. Historical documents, records, books, archaeological reports, and maps were consulted to provide information about the prior use of the landscape on the VNHR, and to determine the potential for encountering historical archaeological resources within the CRC APE not yet revealed through previous research. Structures digitized from historical maps were projected on satellite images of the modern landscape in geographical information systems (GIS) to generate maps to guide the placement of archaeological excavation units. Fort Vancouver National Historic Site (FOVA) archives were a source of most of these materials. Additional resources included the HBC Archives in Winnipeg, Manitoba, Fort Vancouver Regional Library, Clark County Historical Museum, and Oregon Historical Society. The general historical background for the VNHR is presented in Chapter 3. Additional information about historical resources within specific testing areas of the VNHR is provided in each area chapter.

Archaeological Research
Research into past archaeological investigations conducted within the project area provided information about previous findings and helped predict the resources that were likely to be encountered during CRC testing. Reports, results of previous remote sensing studies, field notes, and photographs from the FOVA archives were consulted to benefit from the knowledge gained from previous work. These studies were also evaluated to determine if they were sufficient for the anticipated impacts to the area from the CRC project. Previous archaeological excavations within the project area were projected onto satellite images of the modern landscape in GIS to guide the placement of excavation units. Information about the archaeological resources within each VNHR testing area is provided in the area chapter.

Geophysical Surveys
Non-invasive geophysical survey methods have the potential to locate subsurface anomalies that may be indicative of buried archaeological resources. As detailed in Chapter 8 of the NPS work plan, experts in the fields of magnetometry and ground penetrating radar (GPR) were employed to systematically survey the project areas before start of test excavations. Research in the FOVA archives established the context for geophysical surveys. Historical documents, maps, reports on archaeological excavations, and the VNHR geographical information systems (GIS) database were reviewed to determine the potential for encountering historical archaeological resources within the survey areas. NPS archaeologists provided direction and assistance during the geophysical surveys.

Kendal McDonald of Z-Too Archaeogeophysical Prospection conducted a magnetic survey using a Geometrics G-858 cesium magnetometer configured as a gradiometer, set at a cycle of ten readings per second. The magnetometer survey was conducted systematically in grids along 0.5 m transects. Areas surveyed were those portions of the VNHR that were considered suitable (e.g., areas without extensive fill) for the detection of magnetic anomalies that may be related to potentially significant archaeological deposits. Portions of the CRC APE where magnetometry was used were: Area #1 Old Post Cemetery, Area #4 HBC Village, and Area #5 Old Apple Tree Park. Magnetic surveys were not likely to be effective in detecting archaeological resources in Area #2 West Barracks and Area #3 U.S. Army where the original ground surface is covered by pavement or significant amounts of fill.

Magnetometer data collected were processed and analyzed with Surfer for Windows, version 8.01. Data from both sensors were used to calculate the vertical gradient and create the maps. The vertical gradient data eliminate the influence of solar weather and therefore remove the risk that solar disturbance would be incorrectly identified as a buried archaeological artifact or feature. Data points were interpolated using the minimum curvature grid method. Map contour intervals chosen for the survey areas were subjectively selected to show the finest resolution possible without having the isolines so dense that details of the anomalies were obscured.

A GPR survey was conducted within all five portions of the CRC project area on the VNHR by Steve De Vore of the NPS Midwest Archaeological Center. In areas that had already been magnetically surveyed, the same survey grids were used; new grids were established in the remaining areas. GPR data were collected at 50 scans per meter along 0.5 meter transects, with the antenna mounted on a survey cart. A 400 MHz antenna was used to provide good resolution within one to two meters of the surface. Data were processed using time/depth slice imaging software to enable plan as well as profile views of the subject area at various inferred depths. The location of all remote sensing grids was mapped using a total station by cartographer Keith Garnett so that these data could be accurately displayed on CRC project maps and entered into the VNHR GIS database.

Curt Peterson of Portland State University conducted GPR surveys in VNHR Area #2 in the area between Evergreen Boulevard and Anderson Road, within the FHWA Western Federal Lands Highway Division parking lot, and at the west end of East 5th Street. Four transects were surveyed between Evergreen Boulevard and Anderson Road: two transects using a 200 MHz antenna, and two transects using a 500 MHz antenna. Two transects were surveyed within the FHWA parking lot and six transects were surveyed at the west end of East 5th Street, all using a 200 MHz antenna. These data were displayed in profile views along the transects.

The results of remote sensing surveys are discussed within each VNHR area chapter in the context of the resources located. The full reports of the findings of the magnetic and GPR surveys are presented in Appendix I and Appendix II.

Archaeological Field Methods

Test excavations were conducted within all five areas of the VNHR for the CRC project. The results of archaeological testing are detailed in each VNHR area chapter. Excavation units were sited based on the results of historical and archaeological research, remote sensing surveys, and at regular intervals to ensure thorough coverage of the project area. Where cultural deposits were relatively close to the surface or in sensitive areas, excavations were conducted manually.

Archaeologist Dave DeLyria conducted mechanical excavations with a Massey Ferguson 1575 backhoe under the direction of NPS archaeologists to explore cultural resources buried beneath deep fill deposits within VNHR Area #2 West Barracks, Area #3 U.S. Army, and Area #5 SE Columbia Way. Backhoe excavations proceeded to sterile B-horizon sediments or to the maximum reach of the backhoe. Artifacts encountered during trenching that indicated buried cultural resources were collected as grab samples. When cultural deposits were encountered, the backhoe operator widened out an area either within the trench or to one side for the safe manual excavation of a 1 x 1 m TU to capture the buried cultural layer.

STs were 50 x 50 cm and excavated in arbitrary 10 cm levels. TUs were 1 x 1 m and excavated in natural stratigraphic levels, with levels greater than 10 cm excavated in arbitrary 10 cm levels. Units were oriented to true north, unless otherwise specified. Vertical provenience was maintained using a unit datum, line level, and string. Depths recorded were in cm below surface unless otherwise specified. Units were excavated to at least 50 cm below surface, unless obstacles or impenetrable objects were encountered. Units were terminated after two consecutive culturally sterile levels, or when 20 cm of culturally sterile B-horizon sediments had been excavated. TUs were lined with geocloth before being backfilled.

Matrix from manually excavated STs and TUs was sieved through nested ¼ and ⅛ in. (6 mm and 3 mm) mesh hardware cloth. Collected artifacts were separated by material type and bagged by stratigraphic unit, which was measured vertically and horizontally. A bag catalog for each unit was maintained to track the collections. Information from each level was recorded on a NPS level record form, including the site name and number, unit provenience, feature designator, level, stratum, excavator, date of excavation, excavation technique, plan sketch (if appropriate), detailed sediment description, inventory of samples, and descriptive narrative. At least one wall of each trench and excavation unit was profiled and photographed using both a digital camera and black and white print film. Profiles were drawn to scale at the base of each excavation unit, showing stratigraphic breaks, strata designations, soil constituents, feature boundaries, and evidence of disturbance.

Cultural features were documented photographically, on feature forms, and with scaled plan and profile sketches. Features were given a unique feature number. As deemed appropriate, wood and soil sediment samples were collected. The field director maintained a daily notebook detailing the progress, personnel, techniques, and preliminary interpretations of field excavations.

The location of all four corners of all excavation units and trenches was collected by cartographer Keith Garnett using a total station tied to a global geographic referent (NAD83, Washington State Plane South). These data were converted to GIS layers to be accurately displayed on CRC project maps and entered into the VNHR GIS database.

Inadvertent Discovery of Human Remains

When suspected human remains were discovered during archaeological fieldwork, the field director immediately stopped all work in the vicinity of the discovery, secured the area, and notified the proper agencies and authorities in accordance with the "Plan and Procedures for Dealing with the Inadvertent Discovery of Cultural Resources and Human Skeletal Remains During the Columbia River Crossing Project, Clark, County, Washington and Multnomah County, Oregon". The appropriate section of this plan was followed according to the location of the remains: "The Special Procedures for the Discovery of Human Skeletal Remains and Associated Sacred and Funerary Objects on Non-Federal Lands" (Section 3), or "… on Federal Lands" (Section 4).

The remains were tentatively identified on site by Beth Horton, M.Sc., a Ph.D. candidate at Washington State University who is studying Fort Vancouver for her dissertation, and has expertise in the identification and analysis of human and faunal remains. The remains were then surrendered to Vancouver City Police, and ultimately sent to Guy Tasa, Washington State physical anthropologist, who confirmed their identification and secured the remains while awaiting tribal concurrence on reburial.

Laboratory Methods

Laboratory analysis was conducted at the Northwest Cultural Resources Institute archaeological laboratories. Artifacts recovered from excavation units were prepared, processed, and analyzed according to Fort Vancouver National Historic Site standards. The methods outlined below are covered in greater detail in the Fort Vancouver Archaeology Lab Manual (Wilson et al. 2009).

Artifacts were first catalogued. Bag catalog sheets were completed if they had not been finished in the field. Artifacts from each unit of provenience were assigned a unique lot number. Artifacts were then sorted into types. Bags of ceramics, glass, ferrous metal, other metal, faunal remains, stone artifacts, and diagnostic artifacts from each lot were assigned a unique specimen number. A computer-based database for all recovered materials was maintained to track the materials through the various analysis steps.

All recovered artifacts were cleaned either by washing or by dry brushing as appropriate. After cleaning, artifacts were analyzed by material type, manufacturing and technological characteristics, and formation process traces. The clean, analyzed artifacts were then put into clean bags with new labels and placed into approved artifact boxes. Previously constructed typologies for Fort Vancouver were employed to identify the collected artifacts.

Window glass was dated according to the method developed by Roenke (Chance and Chance 1976:248-255) and further tested in Roenke (1978), for dating window glass in the Pacific Northwest (Table 2). The dating technique relies on the observation that 19^{th}-century window glass in the Pacific Northwest increased in thickness over time and that the modal distribution of thickness can be used to date structures.

TABLE 2
WINDOW GLASS THICKNESS WITH CORRESPONDING DATES

Dates (ca.)	Approximate Primary Mode in Use (in.)
1810-1825	0.055
1820-1835	0.055
1830-1840	0.045
1835-1845	0.045-0.055
1845-1855	0.065
1850-1865	0.075
1855-1885	0.085
1870-1900	0.095
1900-1915	0.105

The mode is the midpoint of the thickness measurement rounded to the nearest 0.01 in. For example, the data plotted as a mode of 0.065 reflect window glass fragments whose thicknesses were in the range of 0.060 in. to 0.070 in., which corresponds to Roenke's mode (or midpoint) of 0.065 (Langford and Wilson 2002:51).

Assemblages of historical artifacts from significant archaeological deposits were classified according to the functional typology developed by Sprague (1981), as a means to better understand the resources observed and to provide an additional method to compare assemblages across the VNHR.

Appendix III, "Faunal Analysis" (Horton 2010) presents the results of the analysis of the faunal materials recovered. The raw data on the results of the excavations, including the volume of sediments excavated, artifact density, and the raw artifact analysis data, are contained in Appendix IV "Lot Catalog by Volume and Density" and Appendix V "Artifact Analysis Data by Artifact Type".

Collection and Curation

A collection/curation plan was developed with the Curator at Fort Vancouver National Historic Site that detailed artifact collection strategies. Artifacts recovered during the CRC project within the State of Washington are to be curated at the Fort Vancouver National Historic Site curation facility. The full collection and curation plan is detailed in Chapter 9 of the NPS work plan.

All artifacts were collected from the excavations on the VNHR, with the exception of the following items that were recorded in the field and backfilled in the excavation unit:

- Modern trash, such as paper, plastic, and foil food wrappers and containers, and materials younger than 50 years (unless of special significance).
- Modern construction materials, such as asphalt, concrete, industrial tile, pipe, conduit, gravels, and other associated items. In some instances, samples of bricks or other objects were collected as type specimens.
- Nondiagnostic ferrous metal fragments.
- Hazardous materials, including asbestos and items contaminated with hazardous chemicals. Lead artifacts were collected.
- Live munitions, except historical small arms ammunition (none were found).
- Oversized objects greater than 0.5 m^3 were recorded, left in the ground, and not collected.
- Coal, coke, clinker/slag, and fire-cracked rock were collected from the ¼ in. screen only, analyzed in the field, and weighed by provenience unit.

Objects taken to the laboratory that later proved to be artifacts that were not to be collected were disposed of in a landfill.

After analysis, artifacts were housed in museum-grade boxes with approved bags and labels, and organized numerically by lot and specimen number within artifact types. All records were kept on archival quality paper, including field and laboratory forms, sketches, and profiles. Supervisor's field notes were recorded on Rite-In-The-Rain notebooks. At the end of the CRC project, all artifacts, analysis data, original field forms, notes, photographs, maps, profiles, CDs, and associated documents will be organized by provenience and delivered to the Fort Vancouver National Historic Site curation facility. The Fort Vancouver National Historic Site curation facility meets the new professional standards for curation repositories in the state of Washington, and exceeds those currently required by the NPS under 36 CFR 79.

Evaluation and Reporting

At the end of test excavations in each of the VNHR areas, a preliminary report was submitted to CRC summarizing the findings of this phase of archaeological investigations. An interpretation of the historical archaeological resources discovered and their potential to contribute to the significance of the VNHR District under the NRHP (Chapter 10 of this document) was reported to CRC for inclusion in Volume 1 of the CRC Cultural Resources Technical Report. The complete report of the details of the results of NPS archaeological investigations for all five CRC project areas on the VNHR was prepared for Appendix 1-D of the Cultural Resources Technical Report (this document).

Site Forms

State of Washington archaeological site inventory forms will be completed for the archaeological resources located that contribute to the significance of the VNHR historical district. These forms will be included in Appendix VI.

CHAPTER 3

HISTORICAL BACKGROUND

The CRC project area lies within the boundaries of the Hudson's Bay Company Fort Vancouver and the U.S. Army's Vancouver Barracks complex. As such, it is associated with the earliest history of Vancouver and the history of the Pacific Northwest. Comprehensive histories of Fort Vancouver and the Fort Vancouver Village ("Kanaka Village") can be found in Hussey (1957), Thomas and Hibbs (1984), Erigero (1992), and Jones & Jones (2005).

Native Americans

The Portland/Vancouver area on the Columbia River, called the "Wapato Valley" by Lewis and Clark for the wapato plant (*Sagittaria latifolia*) whose tubers were a staple in the diet of the peoples of the area, was the location of one of the largest indigenous populations in North America. Native American peoples utilized the Columbia River floodplain within the CRC APE for fishing and hunting, gathering food, trade and transportation, and as a temporary habitation site. The lower prairie area adjacent to Fort Vancouver was called *skit-so-to-ho* by the Chinook and *ala-si-kas* ("the place of mud turtles") by the Klickitat. The Chinookan village of *Ske-chew-twa* was located approximately 2 km (1.2 mi.) upstream at the Vancouver Shipyard site at Ryan Point (Jones & Jones 2005:11-12).

Hudson's Bay Company, 1824-1860

The Hudson's Bay Company moved its original Columbia River location from Fort George in Astoria to the current VNHR area in 1824, determined to hold the north side of the Columbia River for the British in a possible future boundary settlement with the United States. First located on a bluff east of the VNHR at the current site of the Washington School for the Deaf, Fort Vancouver moved closer to the river to the site of the present Fort reconstruction on the open Fort Plain prairie in 1829. The site was ideal for extensive agricultural operations that supplied the Fort's needs and provided a surplus for trade.

From 1829 to 1846, Fort Vancouver was the administrative headquarters and supply depot for all subsidiary forts and trade in the HBC Columbia Department, an area of influence that extended from southeastern Alaska to central California, and the Rocky Mountains to Hawaii. The Company maintained exclusive domain to the land for several miles along the Columbia River including the project area. An extensive work force was employed in support of the Company's activities. Commissioned personnel or officers lived inside the Fort. The engagés or servants were tradesmen, mechanics, trappers, voyageurs, and laborers who lived with their families in the Village or at outlying farms, dairies, and sawmills (Thomas and Hibbs 1984:31).

The Village was home to a diverse population of English, Scottish, French Canadian, Hawaiian, and various Native American peoples. In 1843, Company millwright William Crate stated that, "In the lower town was a street for Canadians, one for Kanakas, and one for English and Americans" (British and American Joint Commission for the Final Settlement of Claims of the Hudson's Bay and Puget's Sound Agricultural Companies 1868:108). This ethnic diversity is reflected in the names of the occupants of the houses shown in a drawing based on an 1846 map by Covington (Figure 2). Hussey (1957:219) states that by at least the early 1850s the area was referred to as "Kanaka Town". According to Towner (in Thomas and Hibbs 1984:793), the name Kanaka Village or Kanaka Town reflected the shift in population from predominantly French Canadian to Hawaiian that accompanied a shift away from the fur trade toward mercantile activities in the late 1830s and 1840s. Towner (in Thomas and Hibbs 1984:795) estimates that from 100 to 200 adult males lived in the Village from 1827 to 1843.

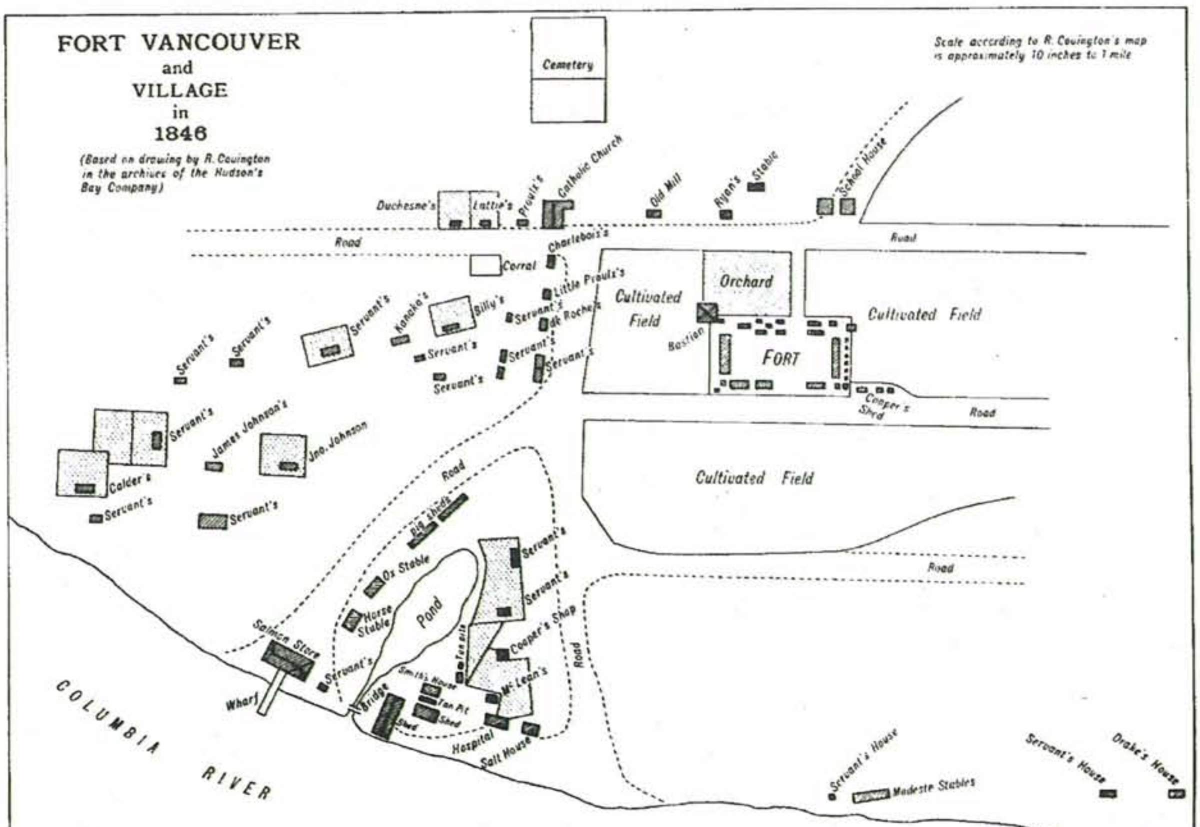

FIGURE 2. Sketch of Fort Vancouver and Village based on the 1846 Covington map.

It is not known when the area to the west of the Fort was first used for housing. David Douglas, who spent the winter of 1825 in a hut by the river in front of the Fort, does not mention the Village in his journal. However, in 1832, John Ball (Ball 1902:98) observed "for servants and Frenchmen there were little houses outside the fort". In 1834, John Kirk Townsend (Townsend 1839:171-172) recounted, "On the farm in the vicinity of the forest are thirty or forty log huts, which are occupied by the Canadians, and others attached to the establishment. These huts areplaced in rows, with broad lanes or streets between them, and the whole looks like a very neat and beautiful village". Thomas Farnham (1843) and Charles Wilkes (1844:349) both report that the Village contained approximately 50 log houses. As many as 75 structures may have been present in the Village by 1848 (Hussey 1957:218). Figure 3 shows a comparison of the number and location of Village structures from various historical maps from 1844 to 1859.

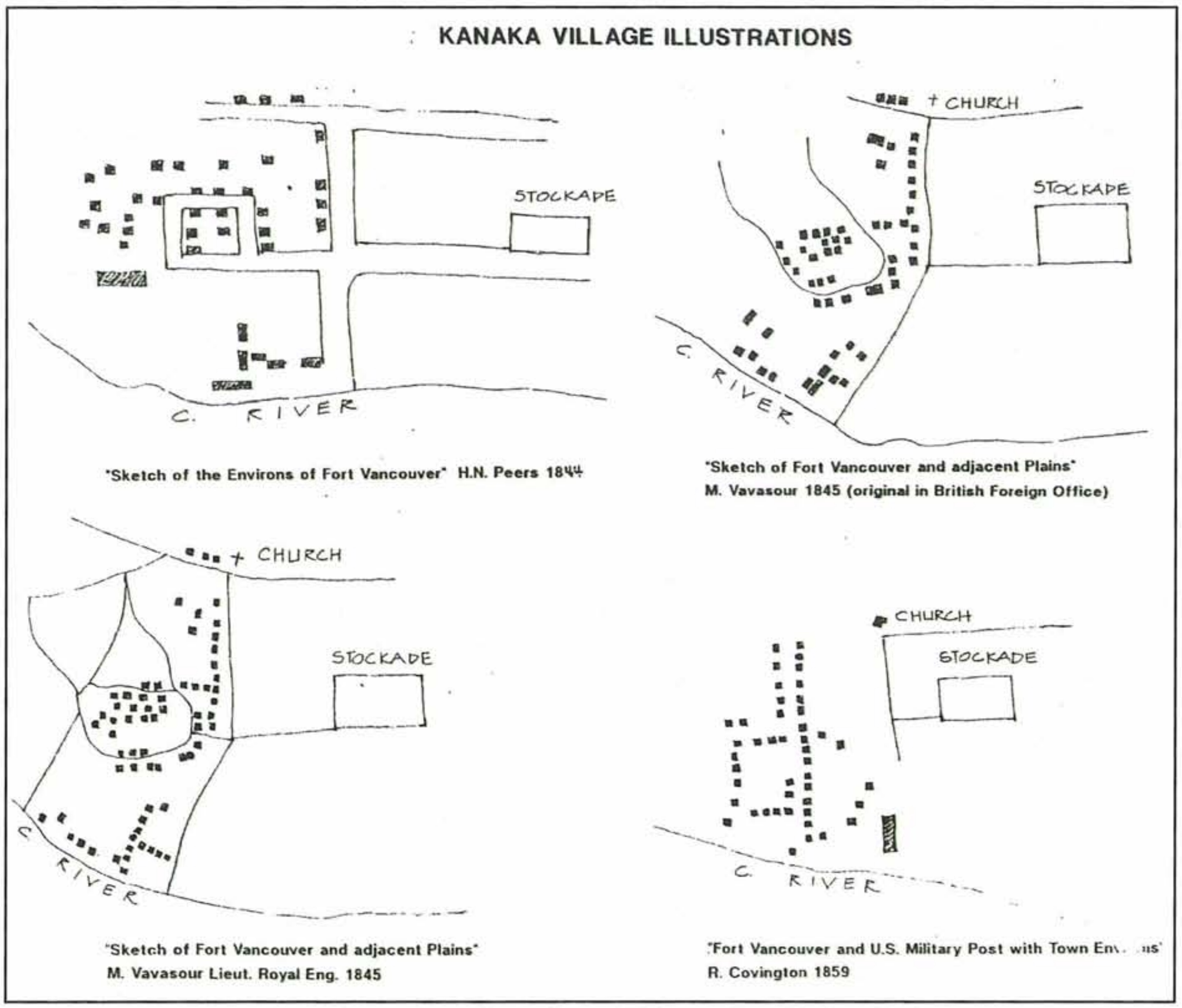

FIGURE 3. Four versions of Kanaka Village from different historical period maps, analyzed and drawn by Terri Taylor, NPS (Erigero 1992:155).

St. James Catholic Mission 1844-1888

Many of the employees of the HBC, especially those of French-Canadian heritage, were of Catholic upbringing. When these employees retired from the Company, many settled with their families south of the Columbia River in the Willamette Valley. With the aid of Chief Factor John McLoughlin, the settlers petitioned the Catholic Church to send missionaries. The petitions went unanswered until 1838, when the Bishop of Quebec sent Reverend Francis Norbert Blanchet and Reverend Modeste Demers to Fort Vancouver. Fort Vancouver became the headquarters for the priests during their early years in the Oregon Country, although they were often away from the Fort at local missions. Initially, the priests' residence was within the stockade walls, but in 1844, a tract of land to the northwest of the Fort was granted by the Company for the establishment of a new church. The church, St. James the Greater, was completed in 1845 and was listed on a HBC inventory of property in 1846-1847 (Cromwell and Gembala 2003:6-7).

When the U.S. Army established Vancouver Barracks in 1849, Quartermaster's Depot and Barracks structures were built on all sides of the fenced-in five-acre mission site. Little documentation is available about the development of the mission in the 1850s, but its success and growth has been attributed to the Catholic patronage of the Vancouver Barracks commander, Lieutenant Colonel Benjamin Bonneville. The Sisters of Providence, who sent five nuns to the mission in 1856, founded St. Joseph's Hospital in 1858. The establishment of this hospital marked the beginning of what is now the Providence Health System, still operating hospitals across the West to this day. A survey of the mission claim in 1872 shows 28 structures, including a convent, school for boys, school for girls, bishop's house, priest's residence, carpenter shop, college, library, and bakery/hospital. Some of the mission structures can be seen on the 1854 Mansfield map (Figure 4) and 1874 F.K. Ward map (Figure 5). Friction between the Army and the mission increased after the departure of the HBC, culminating with the eviction of all mission personnel in 1887. The church and several other mission structures burned in 1888 (Cromwell and Gembala 2003:7-9).

U.S. Army, 1849-1947

The 1846 treaty between Great Britain and the United States established the northernmost boundary of the United States at the 49th parallel, placing Fort Vancouver in U.S. territory. In 1849, U.S. Army troops landed near Fort Vancouver and encamped on the hillside north of the stockade. An American flag was raised and the area was designated Camp Vancouver. Shortly thereafter, construction of quarters began on the bluff behind the camp. The buildings were arranged around a central parade ground with officers quarters on the north and soldiers barracks to the east and west. A palisaded sutler's store, visible on the 1854 Mansfield map (Figure 4), was established just north of the St. James Mission claim. Then Brevet Captain Ulysses S. Grant partnered with Sutler Elisha Camp in the early 1850s (Simon 1967:267).

The 1850s were a period of transition at Fort Vancouver. The number of American settlers in the Oregon Territory increased dramatically, and the Donation Land Claim Law was enacted to provide claims of up to 640 acres of free land for individuals. In 1853, the U.S. Government created Washington Territory, which included the lands on which Fort Vancouver is located. Vancouver City was platted in 1848 and incorporated in 1857. Relations between the HBC and the U.S. Army became increasingly strained and the Company decided to withdraw from Fort Vancouver by the end of the 1850s (Erigero 1992:200).

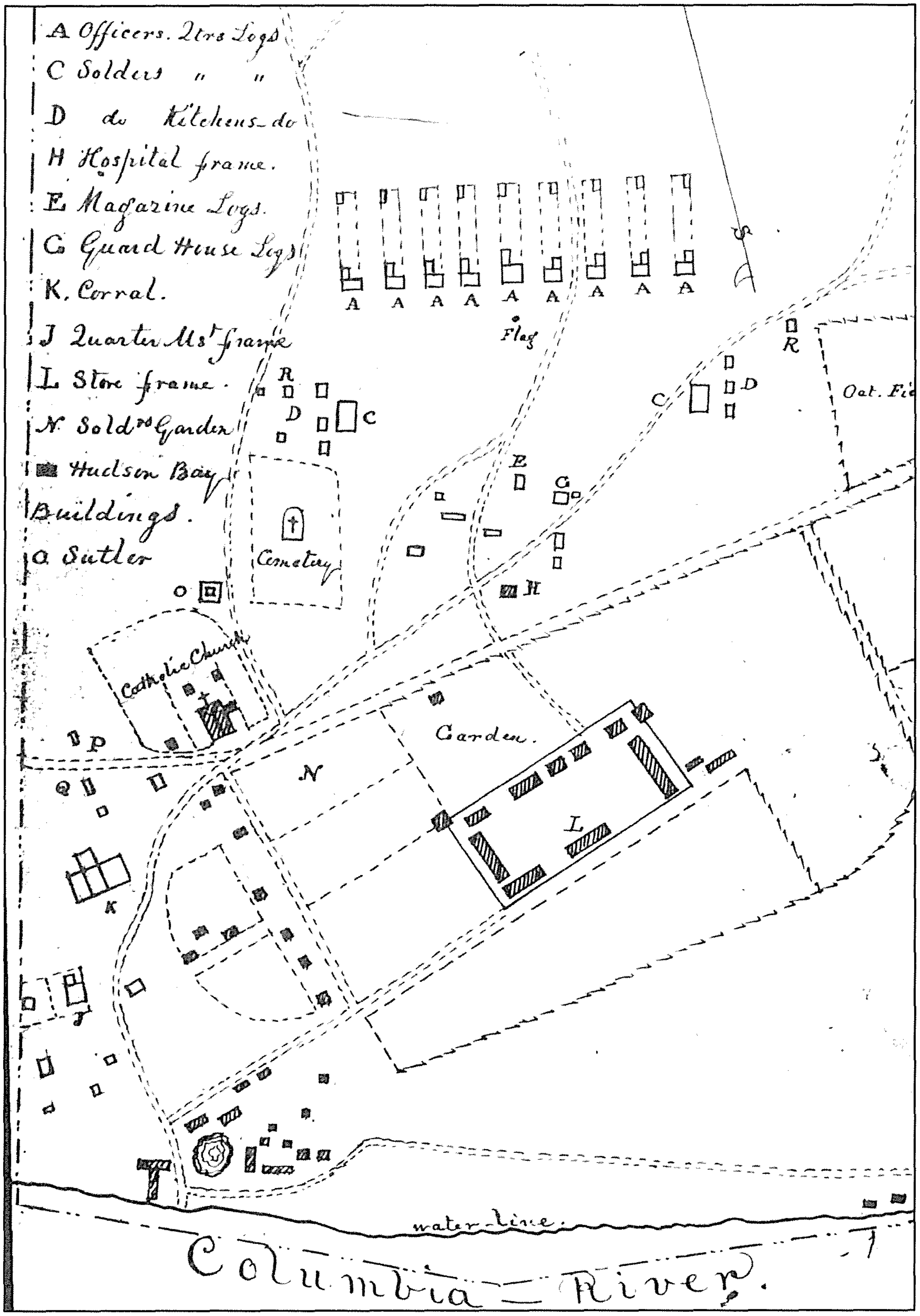

FIGURE 4. Detail of the 1854 Mansfield map of Fort Vancouver.

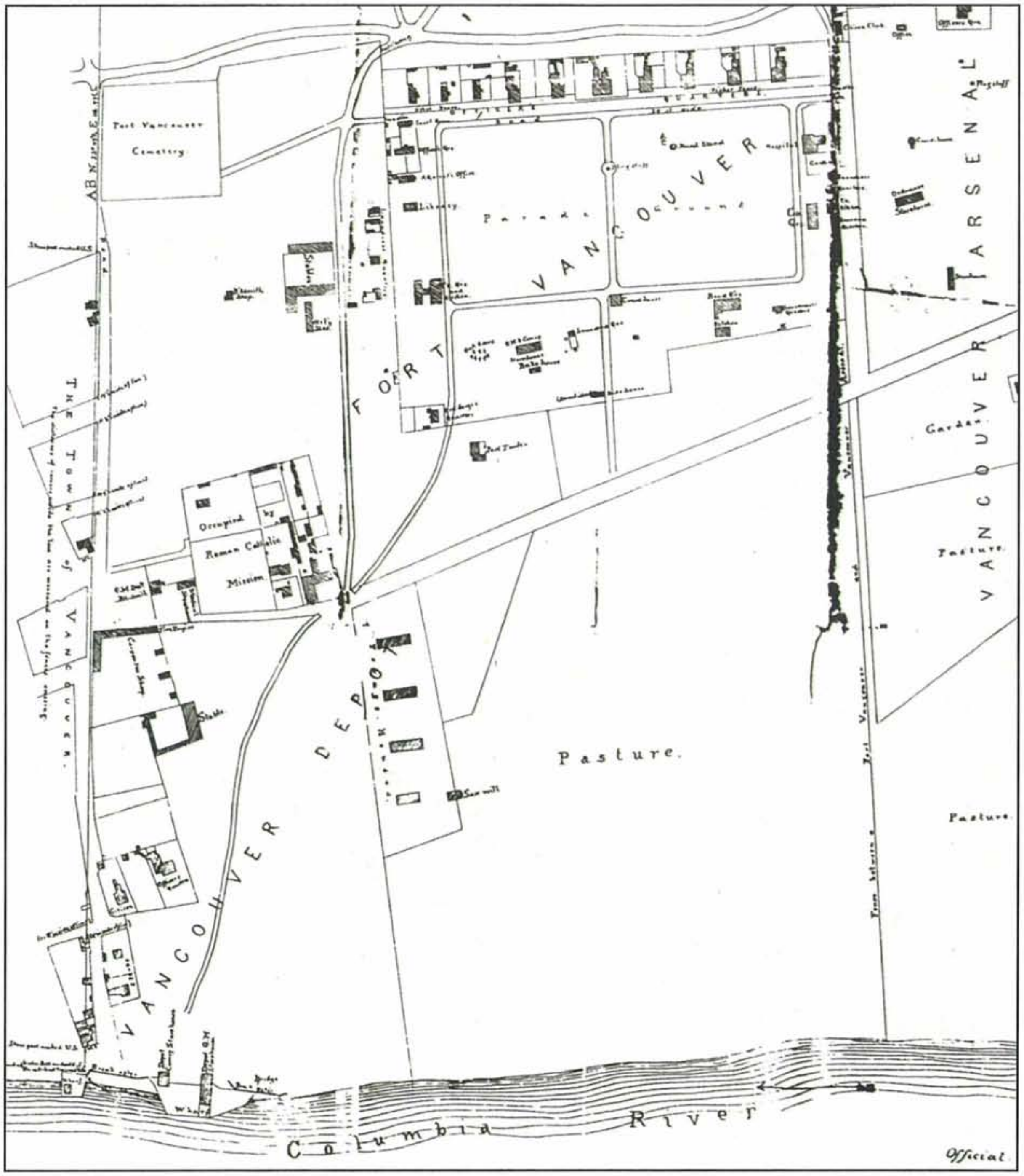

FIGURE 5. Detail of the 1874 F.K. Ward map of the U.S. Military Reserve at Fort Vancouver.

9400

In 1853, Congress set the size of the military reservation at 640 acres and the post's name was changed to Fort Vancouver. With the final departure of the HBC from Vancouver in 1860, the U.S. Army immediately began removing the buildings in the Village and within the Fort Vancouver stockade. Thomas and Hibbs (1984:10) related that based on test excavations by Chance and Chance (1976) it appeared that the remnants of the Village buildings were disposed of in the pond. The Quartermaster's Depot and several new buildings were constructed on the west side of the former Village and at the wharf. By 1865, nearly all traces of the fur trade post were gone (Thomas 1992:64). The military reserve was renamed Vancouver Barracks in 1879 and became the headquarters for the Department of the Columbia, with responsibility for Washington, Oregon, and Idaho territories.

Many new buildings were constructed in the 1870s through the 1890s as Vancouver Barracks expanded, including several improvements and additions in the Vancouver Depot area along Upper Mill Road (now East 5th Street) and south along West Reserve Street, McLoughlin Road, and River Road to the Columbia River. These buildings, shown on the 1888 Patten map (Figure 6), included Commissary and Quartermaster's offices and storehouses; clerks and officers quarters; carriage house and engine house; blacksmith, saddlers, and carpenter shops; and stables, sheds, and corrals. Other buildings constructed during this period on the west side of the Barracks include several infantry barracks and officers quarters, hospital, school, and several stables and sheds. McLoughlin Road, lined with trees planted in 1882, became the southern entrance to Vancouver Barracks. A number of these trees still remain on U.S. Army property on the south side of East 5th Street, and one is located at the southern entrance to Old Apple Tree Park south of the Burlington Northern Santa Fe (BNSF) railroad berm.

In the early 1900s after the Spanish-American War, the military was reorganized and Vancouver Barracks was selected to house an infantry regiment and two batteries of artillery. A major construction phase to upgrade facilities began in 1902 and continued through 1910 (Erigero 1992:286). The U.S. Army granted an easement to the Spokane, Portland and Seattle Railway along the south edge of the military reservation, and from 1906 to 1908 the "North Bank" (of the Columbia River) line was constructed.

In another reorganization in 1913, Vancouver Barracks became the headquarters of the Seventh Brigade. The Barracks became a recruiting and training center during World War I, and served as the location of the Spruce Production Division to supply wood for the production of combat airplanes. In 1917-1918, a cut-up plant for the trees that the soldiers were bringing out of forests was built on greater than 50 acres south of Upper Mill Road. Railroad spurs, constructed to service the Spruce Mill, ran over the edges of the former site of Fort Vancouver and the HBC Village. The mill was disassembled in the early 1920s and all but the main railroad spur was removed. Pearson Airfield expanded into the Village area.

By the end of World War I, many of the currently standing structures in the western portion of Vancouver Barracks had been constructed, including a new hospital, artillery barracks, two mess halls, the Red Cross Convalescent Home, and several smaller buildings. Details of the historical background of the standing structures in Vancouver Barracks may be found in Tonsfeldt and Atwood (2002).

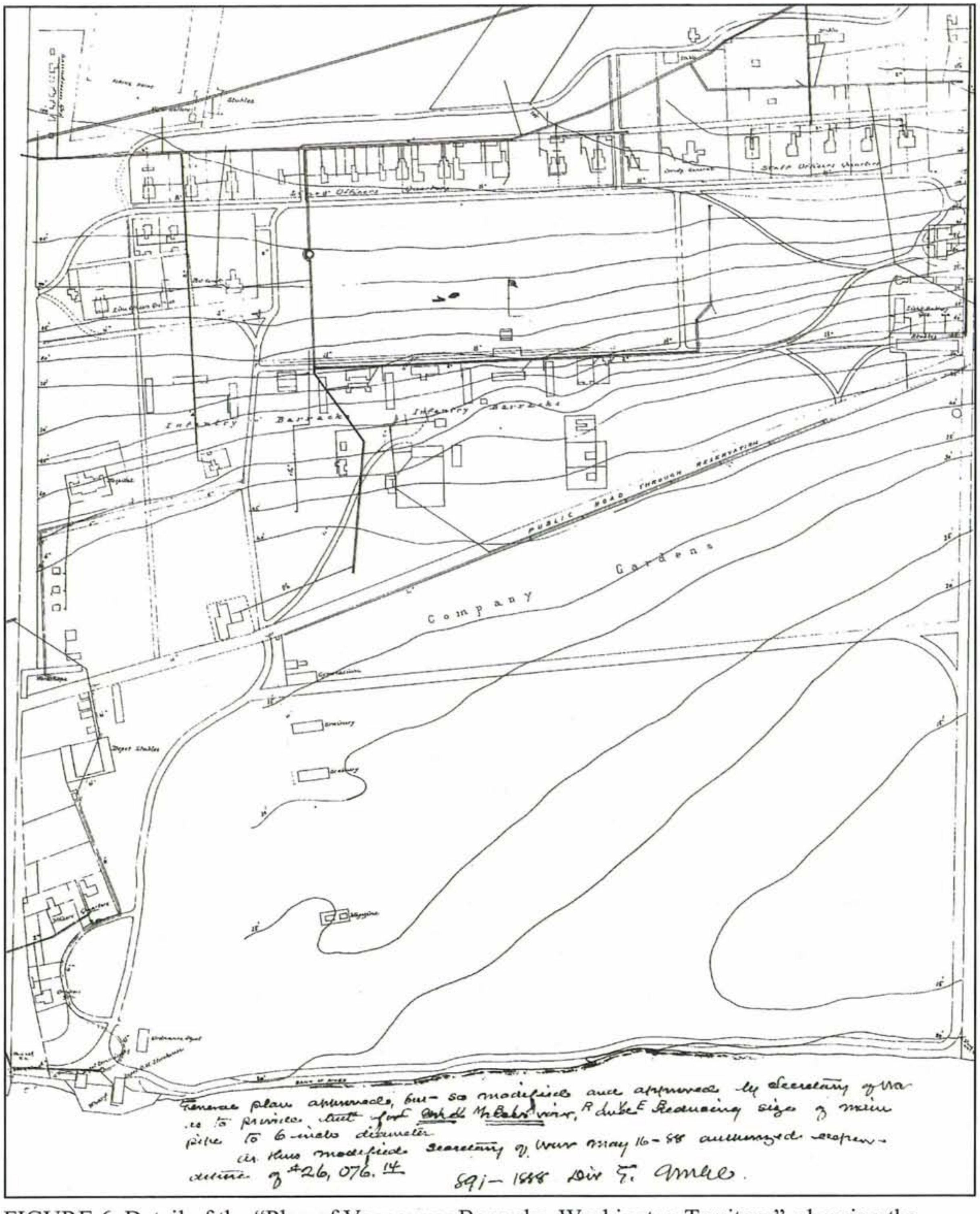

FIGURE 6. Detail of the "Plan of Vancouver Barracks, Washington Territory", showing the proposed water system designed by Assistant Quartermaster Captain W.S. Patten (1888).

In the 1930s, the district headquarters of the Civilian Conservation Corps (CCC) in Oregon and Washington was established at Vancouver Barracks. Several buildings, as well as a coal trestle and concrete coal storage pad, were constructed for the CCC training camp in the former HBC Village area (Figure 7). These buildings continued to be used during World War II and were razed in the 1960s. After World War II, the size of the military force at Vancouver Barracks was significantly reduced and areas of the post were declared surplus. In 1947, the 64 core acres of the Barracks were designated as the headquarters for U.S. Army Reserve training in the Pacific Northwest (Jones & Jones 2005:52).

National Park Service, 1948-present

Efforts to locate and commemorate the Hudson's Bay Company fort began in the early 1900s. In 1915, Fort Vancouver was declared a National Monument under the authority of the Antiquities Act, but recognition was allowed to lapse or was withdrawn (Erigero 1992:339). Another attempt to restore the stockade was made in the 1920s, but no funding was allocated. In 1947, portions of surplus Vancouver Barracks lands were granted to the National Park Service, and Congress established Fort Vancouver National Monument in 1948. NPS archaeologist Louis Caywood quickly located the corners of the HBC stockade and continuing archaeological investigations determined the location of many buildings within the stockade walls. In 1963, the park's name was changed to Fort Vancouver National Historic Site.

The U.S. Army declared portions of land west of the HBC stockade surplus property in 1962, which allowed the NPS to expand Fort Vancouver National Historic Site to the west to include the old site of the Hudson's Bay Company Village. Archaeological investigations to locate historical structures in the Village began in 1968 and continue to the present. The numerous archaeological investigations conducted on the VNHR for more than sixty years, have resulted in the nomination to the National Register of Historic Places of several archaeological sites:

- HBC-U.S. Army Trash Dump/Pond, 45CL54 (45CL47)
- Officer's Row, 45CL160H
- Vancouver Barracks, 45CL162H
- Fort Vancouver National Historic Site, 45CL163H
- Old Apple Tree, 45CL164H
- Pearson Field, 45CL224
- Kanaka Village, 45CL300
- Pearson Airfield Site, 45CL524

In 2007, these resources were nominated together (Owens et al. 2007) as the Vancouver National Historic Reserve District (DT191), which is listed on the National Register of Historic Places. This district contains 252 acres that encompass the full depth of human activity on the landscape of the VNHR – from prehistoric/contact Native American to modern U.S. Army and National Park Service occupations.

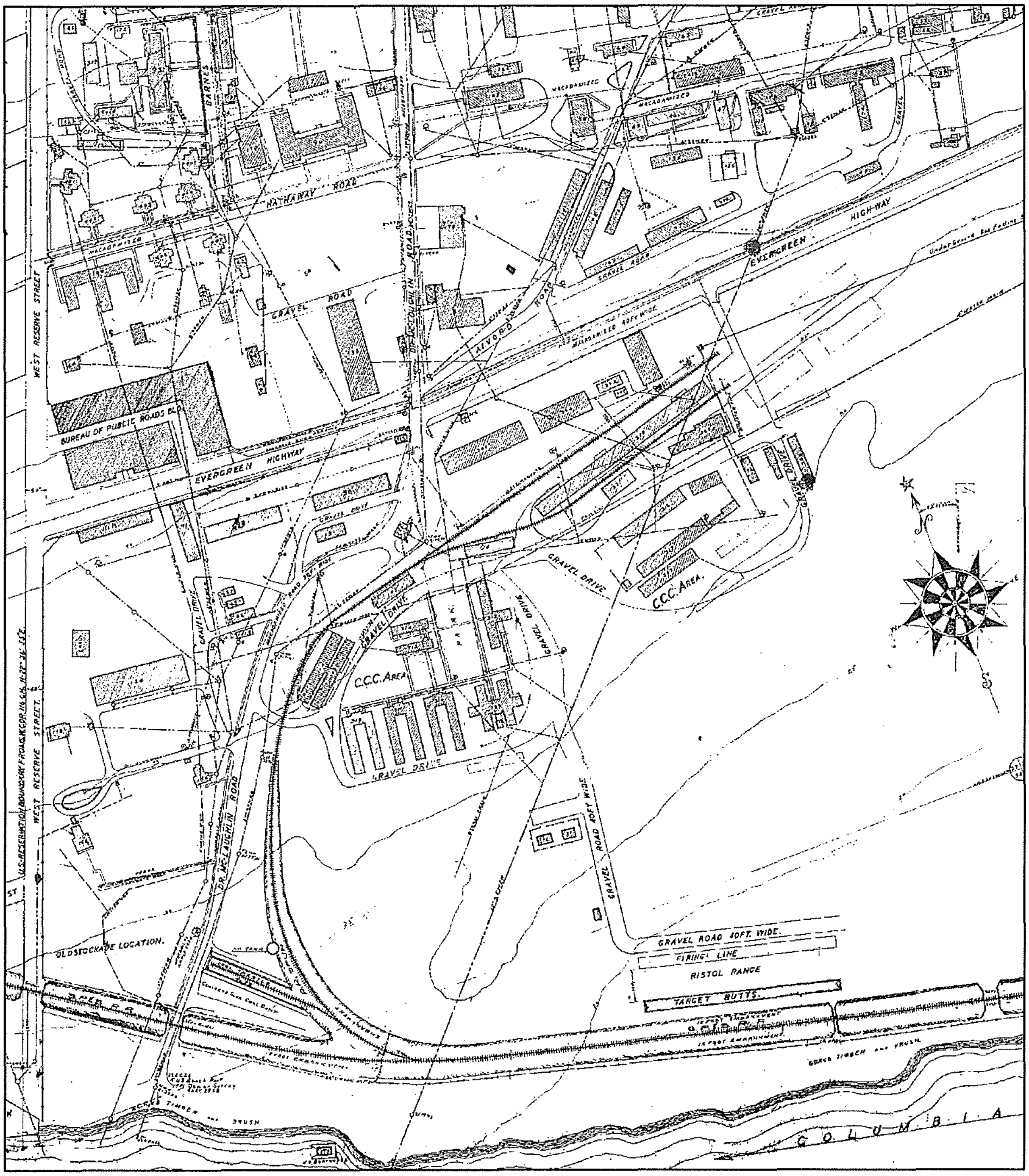

FIGURE 7. Detail of the 1935 Carsner map of Vancouver Barracks.

Prehistoric/Contact Native American Era, 2500 BP-AD 1824

The VNHR Historic District is significant under Criterion d for archaeological sites that have revealed significant prehistoric information regarding Native American activities and for its potential to yield further information. Prehistoric/contact Native American artifacts have been recovered within the Historic District boundary and are especially abundant in the lower elevation areas along the Columbia River (Owens et al. 2007:8-53).

Hudson's Bay Company Fort Vancouver Era, 1824-1860

The VNHR Historic District is significant under Criterion d for archaeological sites that have revealed significant historical information and potential to yield further information regarding HBC activities; Criterion a for its association with HBC establishment of agriculture, commerce, education, exploration/settlement, industry, and politics/government in the Pacific Northwest; and Special Criterion Consideration e for the Fort reconstruction (Owens et al. 2007:8-53).

U.S. Army, Vancouver Barracks Era, 1849-1946

The VNHR Historic District is nationally significant under Criterion a for its association with exploration/settlement, industry, military, and politics/government; Criterion b for its association with significant persons in the history of the Hudson's Bay Company, the early U.S. Army, and the Pacific Northwest; Criterion c for its architecture that reflects a range of historical styles, typical and representative of military-post architecture in 19th and 20th centuries and transportation; and Criterion d for archaeological sites that have revealed significant historical information and have potential to yield further information regarding military activities (Owens et al. 2007:8-55).

National Park Service Mission 66 Era, 1954-1966

The VNHR Historic District is significant at the state level under Criterion a for its association with park master planning during the Mission 66-era, Criterion c for its distinct Mission 66-era Modern style architecture and site design, and Special Criterion Consideration g as a property achieving significance within the past fifty years for the Mission 66 development built within the Fort Vancouver National Historic Site in the early 1960s (Owens et al. 2007:8-56).

CHAPTER 4

ARCHAEOLOGICAL STRATIGRAPHY

From March through August 2009, the sediments of the VNHR were observed within 151 STs, TUs, and backhoe trenches, totaling 466 m^2 (5016 ft.^{2}), extending 1 km (0.6 mi.) from Evergreen Boulevard to the Columbia River. These extensive excavations provided an unparalleled view of the depositional history of the western and southern areas of the VNHR. Field examination included sediment color, texture, structure, consistence, gravel and root content, artifact quantities, and characteristics of the boundaries between the strata. Based on these observations, a general stratigraphic sequence was proposed for the VNHR, ordered from Stratum I at the ground surface through the culturally sterile Stratum V Pleistocene-age flood gravels. These designations were used to label the strata encountered during field excavations (Figure 8). The characteristics below were the main factors used to discriminate between strata, determine the depositional integrity of sediments, and identify the culturally significant deposits. The types and ages of artifacts and features associated with the strata aided in the understanding of the depositional sequence. A generalized summary of stratigraphic layers is presented here, with more detail given in the chapters about specific areas of the VNHR.

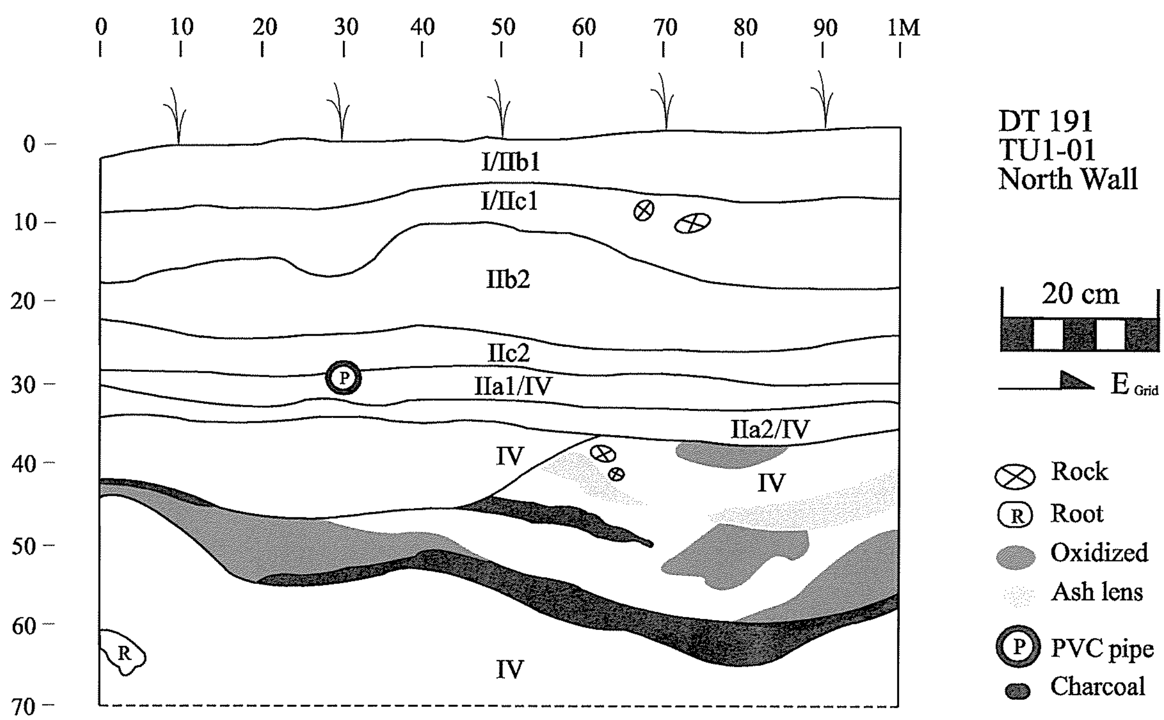

FIGURE 8. North wall profile of TU1-01. (NPS 2010)

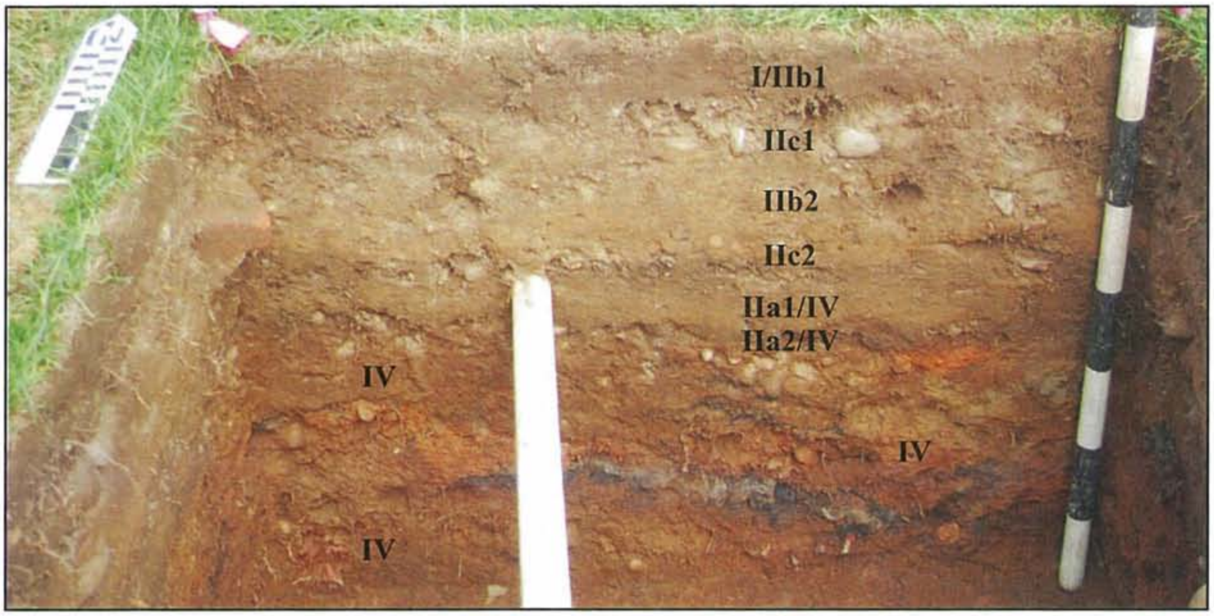

FIGURE 9. North wall of TU1-01 showing stratum designations. (NPS 09-05:13, 3/5/09)

STRATUM I (SOD, PAVEMENT)

The topmost layer, excavated as Stratum I, consisted of topsoil imported for landscaping, barkdust, duff, fine roots, and decaying vegetation. Sediments were generally described as 10YR3/2 (moist) very dark grayish brown silt loam with few gravels. Only modern cultural material was found in this layer unless ground disturbance had caused mixing of the strata or artifacts. This mixing was best observed in VNHR Area #4 HBC Village where rodent activity had brought 19th-century artifacts to the surface. The depth of the sod layer varied across the CRC APE, extending to a maximum depth of about 10 cm. In most of VNHR Area #2, Stratum I consisted of asphalt pavement covering the ground surface.

STRATUM II (FILL)

The number and composition of fill strata observed within the CRC project area on the VNHR varied greatly. Many locations within the APE have been modified significantly throughout the history of Euroamerican occupation of the VNHR. Native soils have been graded away during road, railroad, and building construction. Cuts were made for highways and for building foundations, sometimes deep into the underlying sterile gravels. Fill was imported for railroad construction, to modify the surface grade around buildings, and to protect archaeological resources. Cut and fill episodes often occurred in close proximity to each other.

In some places on the VNHR, the events associated with the deposition of fill layers are known or can be inferred. In the southern portion of VNHR Area #3 U.S. Army, fill was deposited, removed, and then more fill was added at a later date. In other places on the VNHR, the exact fill sequence is unknown.

Some areas – notably VNHR Area #4 HBC Village – contained little or no fill. In portions of the Village, intact Stratum III HBC-era archaeological deposits were located directly beneath Stratum I sod.

Fill layers were recorded as Stratum II: 19th-century fill was designated Stratum IIa; 20th-century fill was designated Stratum IIb; mixed-era or undifferentiated fill was designated Stratum IIc. Each successive fill episode that could be distinguished within these types within an excavation unit received consecutive Arabic number designations (e.g. Stratum IIa1, IIa2, etc.). Because of the variability in fill deposits, these strata could not be correlated across the different VNHR areas (and often not even *within* a VNHR area).

Where present, Stratum II fill deposits generally began at less than 10 cm and extended from 20 cm to greater than 200 cm. The lower boundary of Stratum II was generally smooth and clear. The depth of fill deposits observed during mechanical trenching in VNHR Area #2, VNHR Area #3, and VNHR Area #5 sometimes exceeded the reach of the backhoe.

The color, texture, structure, consistence, and gravel content of the imported fill layers varied, from loose sand and dredge spoils, friable silt loam, and compact gravel, to asphalt and concrete construction debris – as well as a mixture of these materials. Natural deposits of Columbia River flood silts were seen in some units in VNHR Area #4 and VNHR Area #5 on the north side of SE Columbia Way. Because Stratum II deposits are extremely local, they are best reviewed in the chapter pertaining to the specific VNHR area of interest.

The contents of anthropogenic features were also considered to be Stratum II fill deposits. These features included pits, postholes, shafts, cellars, and privys associated with modern, U.S. Army-, and Hudson's Bay Company-era activities. These cultural features included the most artifact-rich, typologically diverse, and culturally sensitive deposits located during archaeological testing within the CRC APE on the VNHR.

STRATUM III (INTACT A HORIZON)

Stratum III consisted of artifact-rich primary historical archaeological deposits, typically 5-30 cm thick. In relatively undisturbed areas without extensive fill deposits (e.g. VNHR Area #4 HBC Village), Stratum III was found within 10 cm of the surface. In other areas (e.g. VNHR Area #3 U.S. Army), Stratum III was capped by up to 118 cm of imported fill.

Sediments were typically dark, from 10YR2/2 to 10YR3/2 (moist) very dark brown to very dark grayish brown silt loam. Organic material from human use of the landscape, wood charcoal, and coal from the U.S. Army coal storage pad contributed to the darkness of the sediments. Few roots were present. Gravel content was 10-20%, and colored subrounded pea-sized gravels were often seen in this stratum. Stratum III was generally compact. The dryness of the southern portion of VNHR Area #3 within a stand of small evergreen trees made Stratum III extremely hard and platy in this location.

Each successive layer of intact archaeological deposits that could be distinguished within an excavation unit received consecutive Arabic number designations (e.g. Stratum III1, III2, etc.). Intact archaeological deposits from 1824-1860 HBC and 1849-1900 Early U.S. Army periods were both represented in Stratum III. Significant deposits related to three HBC Village houses were found in VNHR Area #3 and VNHR Area #4. Some mixing of U.S. Army and HBC material was often found in the top few centimeters of Stratum III due to the reoccupation of the HBC area by the U.S. Army. It was often difficult to distinguish these periods archaeologically. The lower boundary of Stratum III was generally smooth and clear (smooth and wavy in some units in VNHR Area #5 on the north side of SE Columbia Way).

STRATUM IV (B HORIZON)

Culturally sterile B-horizon sediments were recorded as Stratum IV. This stratum was described as 10YR3/4 to 10YR4/6 (moist) dark yellowish brown silt loam, with 15-20 % gravels. The sediments had little structure, and gravel quantity and size increased with depth. In areas with intact A-horizon sediments (Stratum III), some artifacts were usually found pushed into the top of Stratum IV. Several archaeological pit or post features extended into this stratum, but otherwise, this layer appears to date from before human occupation of the area.

The depth of the beginning of Stratum IV varied across the project area depending on previous cut and fill episodes. In relatively undisturbed areas at lower elevations closer to the river (e.g. VNHR Area #4 HBC Village), B-horizon sediments were found at approximately 30 cm. Farther away from the Columbia River at higher elevations in relatively undisturbed areas (e.g. VNHR Area #1 Old Post Cemetery on the north side of Evergreen Boulevard), B-horizon sediments were found at approximately 60 cm. In disturbed areas, the depth of the beginning of B-horizon sediments varied widely, from less than 30 cm to greater than 200 cm. The thickness of this stratum also varied widely, averaging about 40 cm in undisturbed areas. The boundary between Stratum IV and Stratum V was smooth and abrupt.

STRATUM V (C HORIZON)

Sterile C-horizon sediments were recorded as Stratum V. This stratum was described as 10YR3/1 to 10YR4/1 (moist) very dark gray to dark gray gravels in a coarse sandy matrix. Gravels and cobbles generally exceeded 80%. This stratum was loose and had no structure. Sediments were clean, lacking the silt/clay skin that was found on Stratum IV B-horizon rocks. White caliche deposits could be seen on the bottom of cobbles, indicating that they were in the same orientation as when deposited by Pleistocene-age floods.

The depth of the beginning of Stratum V varied across the project area, from a minimum of 45 cm to greater than 200 cm below surface, depending on the amount of original ground surface that had been stripped away and the number and depth of Stratum II fill episodes. Most manual excavations did not reach the C horizon, although it was observed in many of the exploratory backhoe trenches.

CHAPTER 5

VNHR AREA #1: THE OLD POST CEMETERY

PROJECT AREA

VNHR Area #1 is located on City of Vancouver property approximately one km (0.62 mi.) north of the north shore of the Columbia River in the SW quarter of the SE quarter of the NE quarter of Section 27, T2N, R1E, Willamette Meridian. The elevation of this area is approximately 100 ft. above mean sea level (NGVD 29).

The CRC APE in VNHR Area #1 was at the west end of Officers Row, 45CL160H, which is aligned east/west between Interstate 5 and East Reserve Street, and north/south between a service alley and Evergreen Boulevard (Figure 10). Officers Row consists of mid-to-late 19th-century frame and log buildings in a park-like setting, which have been renovated and converted for public, nonprofit, commercial, and residential use.

VNHR Area #1 was divided into two portions: the north side of Evergreen Boulevard, and south side of Evergreen Boulevard. The area on the north side of Evergreen Boulevard consisted of an area of lawn and landscaping between a paved driveway on the west side of the westernmost Officers Row building and a barrier wall that separates City of Vancouver property from the Interstate 5 Freeway right-of-way. This area measured approximately 10 m (32.8 ft.) north/south by 17 m (55.8 ft.) east/west encompassing approximately 170 m^2 (1830 ft.^{2}).

The CRC APE on the south side of Evergreen Boulevard was located on a landscaped south-facing slope, north and west of the City of Vancouver Police Administration building. This area measured approximately 10 m (32.8 ft.) north/south by 34 m (111.6 ft.) east/west encompassing approximately 340 m^2 (3660 ft.^{2}).

PROJECT GOALS

Five goals were addressed through archaeological testing in VNHR Area #1 within the CRC APE that concerned the Early U.S. Army (1849-1900) period:

1. To verify the location and boundaries of the Old Post Cemetery.
2. To verify that the cemetery burials within the project area were completely exhumed and relocated, with no unmarked graves or isolated human remains left behind.
3. To probe for traces of the roads and utilities shown on historical maps from the 1870s and 1880s.

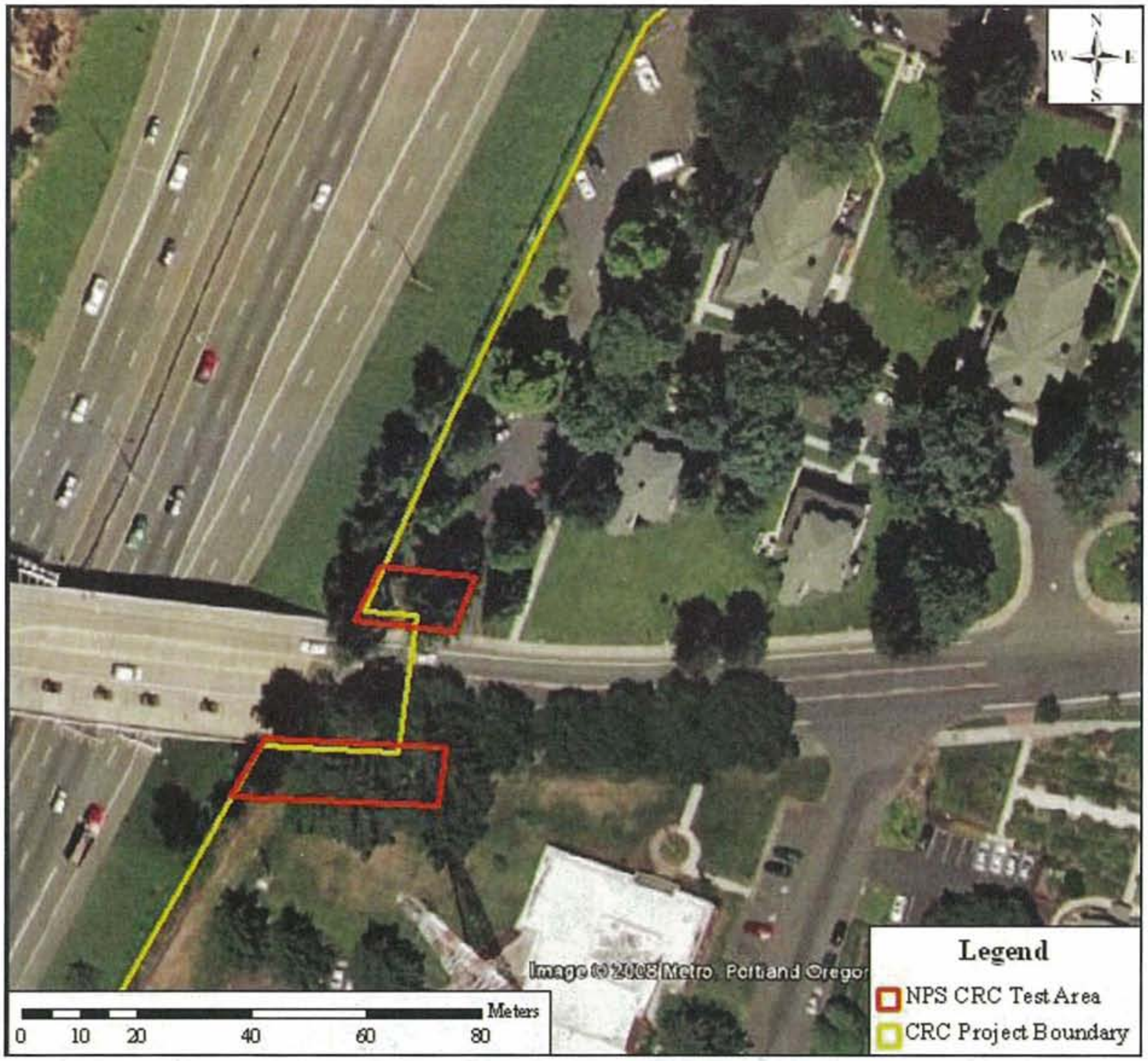

FIGURE 10. The areas of NPS archaeological testing in VNHR Area #1 at the west end of Officers Row for the CRC project. Image from Google Earth. (NPS 2010)

4. To probe for archaeological evidence of the Line Officers Quarters building located on the south side of Evergreen Boulevard.
5. To achieve a better understanding of the archaeological resources in this portion of Officers Row and the VNHR, including testing of potential precontact American Indian remains, to guide further investigations and to better educate the public on the significance and history of the area.

HISTORICAL CONTEXT

Historical records and maps were consulted to help determine the cultural resources that were present in VNHR Area #1, where they were located, and if they were likely to be affected by construction during the CRC project. GIS layers digitized from historic maps in the Fort Vancouver archives were georeferenced to modern satellite images (Figure 11).The location of buildings and features helped guide the placement of archaeological test units.

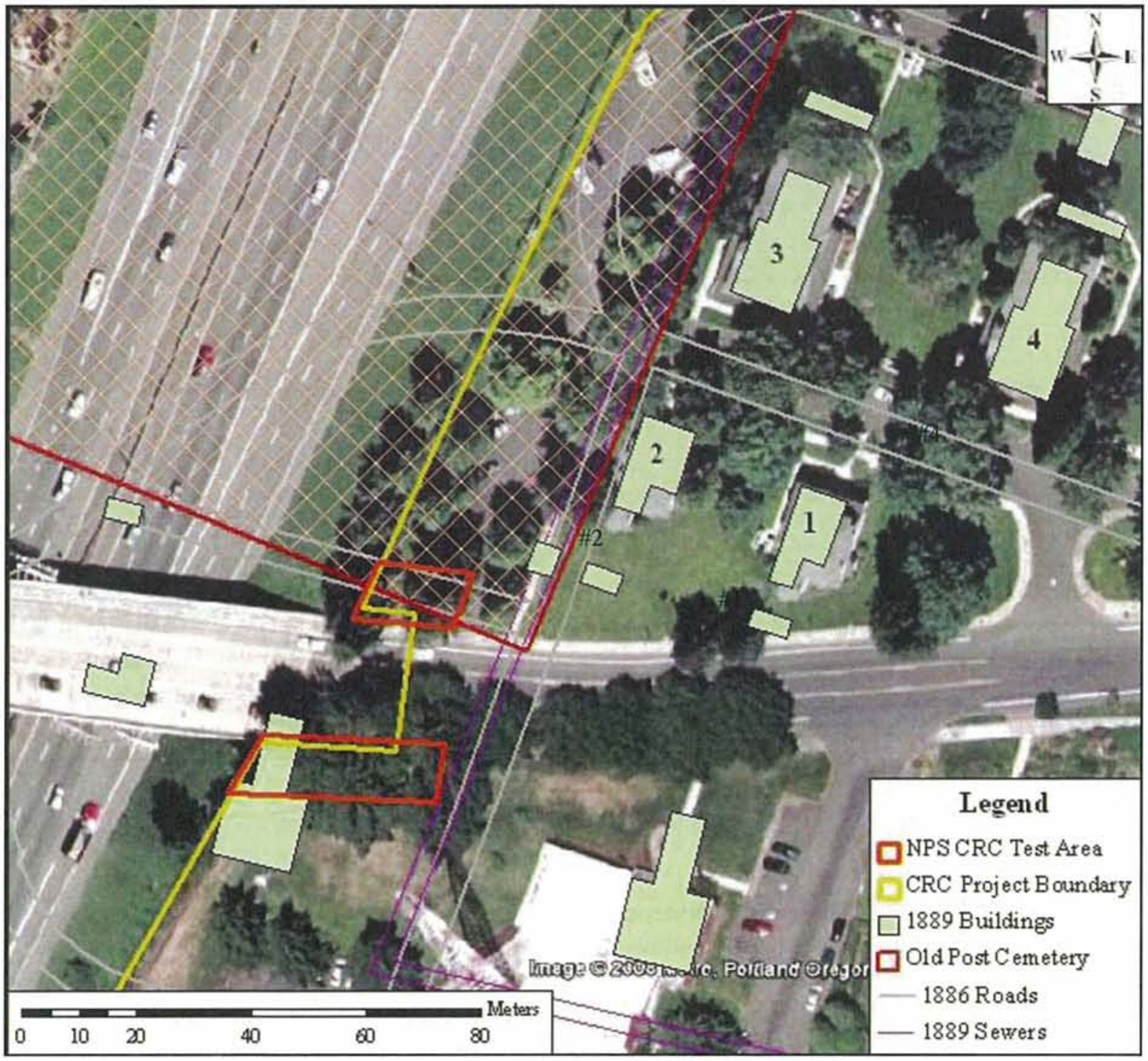

FIGURE 11.VNHR Area #1 at the west end of Officers Row overlain with historical buildings and features. Building numbers are taken from the Officers Row Development Map (Thomas 1987:3). Image from Google Earth. (NPS 2010)

9412

Hudson's Bay Company, 1824-1860

The only known HBC-era features within the project area are roads that carried traffic from the Fort to the farms and mills located to the north and east.

U.S. Army, 1849-1947

The main HBC cemetery can be seen northeast of St. James Mission on the 1854 Bonneville map (Figure 12). By 1855, the U.S. Army required the use of this land for military facilities and relocated some, but not all, of the graves to a new cemetery. This Old Post Cemetery, located immediately west of Buildings 2 and 3, first appears on a "Topographical Sketch of Fort Vancouver and Environs 1855" (Figure 13). It is labeled "Graveyard" and is depicted as a square of land on the western boundary of the "Government Reserve" in line with Officers Row.

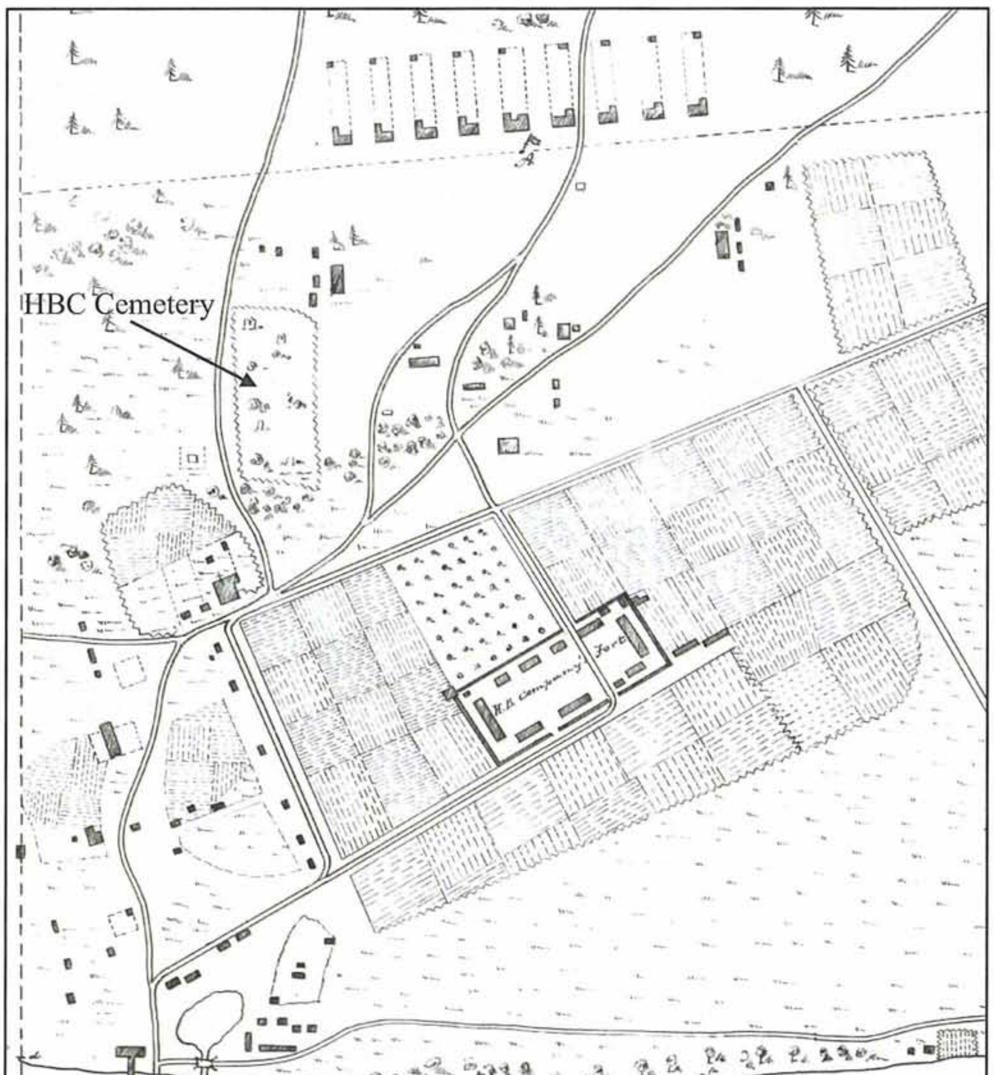

FIGURE 12. Detail of the 1854 map from Bonneville's survey of the military reservation at Fort Vancouver.

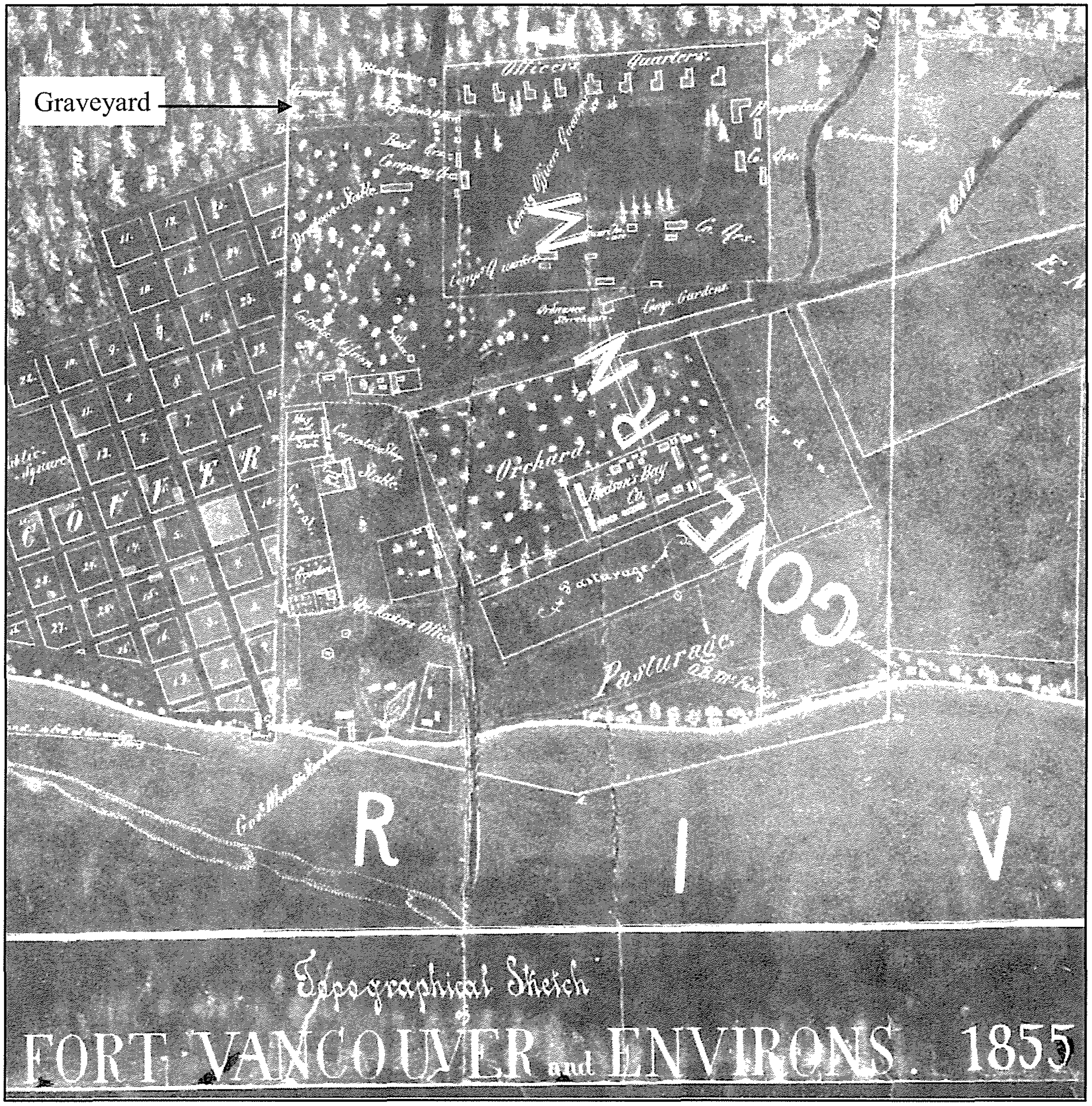

FIGURE 13. Detail of the 1855 topographical sketch of Fort Vancouver and Environs.

The 1859 Harney "Map of the Military Reservation at Fort Vancouver, W.T." depicts the cemetery as a rectangle with crosses located along the western boundary of the military reservation, but this time it is shown north of Officers Row. The 1859 Thom "Map of the Military Reservation at Fort Vancouver, W.T." depicts the cemetery as a rectangle with crosses located along the western boundary of the military reservation, but again in line with Officers Row. The 1859 Covington map of "Fort Vancouver and U.S. Military Post with Town and Environs, &c." shows the "Cemetery New" as a square along the western boundary of the military reserve, again north of Officers Row.

The Post Cemetery was described in 1866 by Brevet Brigadier General James F. Rusling, in his capacity as Inspector for the Quartermaster's Department:

> This consists of some four acres of ground, west of the garrison. It is inclosed by a good paling fence and contains 20 graves. A report on this was forwarded to you May 28 as required by existing orders. Some of the graves are without head boards and the whole spot is overgrown with young fir trees &c. No order or system seems to have been observed in making the interments and the general appearance of the place is unsatisfactory. In addition to these graves, a little southwest of the parade ground, I observed several others, that Col. Hodges told me were those of the Hudson Bay Co. men. They were uninclosed & offended the eye by their publicity. I recommended that these graves be removed to the post Cemetery and that the Cemetery grounds be at once put in complete order and kept so hereafter. Many of the trees should remain as a fitting monument to the place but the balance, with all the bushes, brambles &c. should be cleared away and kept away so the interments hereafter should be according to some well devised system, as prescribed by existing orders [Rusling 1866].

The 1871 Winman map of Fort Vancouver shows the cemetery back in its original position in line with Officers Row. It is depicted as a square with crosses, headstones, and small trees. On the 1874 Ward map (Figure 5), the cemetery is in the same position as on the Winman map and is labeled "Fort Vancouver Cemetery".

In the early 1880s, the cemetery was moved to its present location on the north side of Fourth Plain Boulevard. An article in the *Vancouver Independent* newspaper reports on the cemetery removals:

> Wm. Grinder has the contract for removal of the bodies and monuments from the old military cemetery to the new one, on the northeast [sic] corner of the military reservation. He has a number of men at work, and the exhumations and re-burials are proceeding rapidly. All remains will be removed as soon as it can be accomplished. The remains of civilians will be removed also, having a plot set apart for them in the new military cemetery. Friends have already had removed a large number to other cemeteries, but of many buried in the old plot there are no friends or relatives living in Vancouver. The military authorities will not see such neglected, however [*Vancouver Independent*, September 6, 1883].

On Patten's 1888 "Plan of Present System of Water Supply at Vancouver Barracks" (Figure 6), the cemetery is no longer depicted and the map shows the newly constructed buildings at the west end of Officers Row. The 1889 Lydecker map "Plan of Vancouver Barracks and Military Reservation, Washington" shows the new Post Cemetery in its current location on Fourth Plain.

Buildings at the west end of Officers Row immediately to the east of VNHR Area #1 were constructed during an expansion phase in the 1880s. An 1879 duplex residence identified as a "Line Officers Quarters" on the 1888 Patten map of Vancouver Barracks (Figure 6) was located on the south side of Evergreen Boulevard within VNHR Area #1 and the CRC APE.

ARCHAEOLOGICAL CONTEXT

The five projects summarized below conducted at the west end of Officers Row near the CRC APE are the ones most relevant to the archaeological context of VNHR Area #1 (Figure 14).

Thomas 1987-1988

A cultural resources survey was conducted on Officers Row by Archaeological and Historical Services (Thomas 1987) for proposed historical revitalization and adaptive reuse of the property. A portion of the area surveyed is within the APE of the CRC project. A pedestrian survey of the entire length and width of Officers Row failed to detect any subsurface features because of dense vegetation cover and extensive paving. Historical maps and information obtained from previous archaeological studies identified areas where features might be visible on the ground, and the current use of these areas was documented.

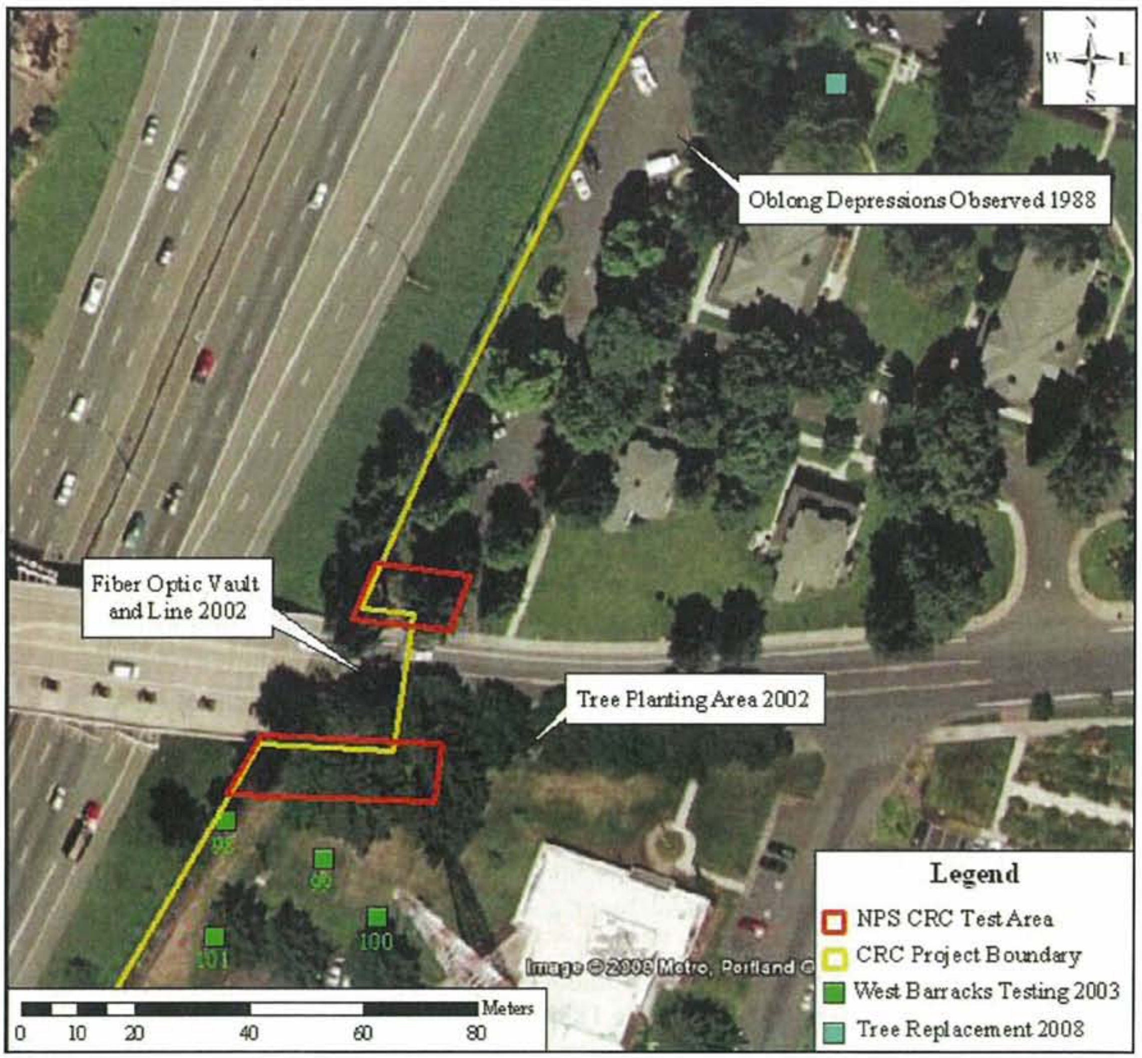

FIGURE 14. Previous archaeological investigations near VNHR Area #1. Image from Google Earth. (NPS 2010)

Two frame buildings located at the far west end of Officers Row, labeled Buildings 2 and 3 on the 1980s Officers Row Development Map (Thomas 1987:3), are identified as officers quarters constructed between 1886 and 1890 (Thomas 1987:27). The Old Post Cemetery was located directly to the west of these buildings, which is within the APE of the CRC project. Thomas (1987:28) recommended the production of a site map illustrating known historical features, test excavations in areas where ground disturbances were likely to disturb historical features, and the monitoring of land altering activities in areas where historical features were not yet known.

An archaeological assessment of the proposed Officers Row development was conducted by Archaeological and Historical Services (Thomas 1988). Ten historical feature complexes had been identified (Thomas 1987) that could be adversely affected by development. The purpose of this study was to review development plans and to develop mitigative alternatives in areas where subsurface disturbance was likely to cause an adverse effect to archaeological resources. Construction monitoring and test excavations were conducted in several areas.

A trench for new water and sewer pipes was dug in the middle of Evergreen Boulevard, with lateral lines to each of the buildings on Officers Row. No archaeological features were observed during monitoring of these trenches. Narrow trenches for an electrical system were monitored in the area of the Old Post Cemetery, with no archeological resources observed. The construction of a new parking lot at the site of the Old Post Cemetery, at the west side of Officers Row adjacent to Buildings 2 and 3, was identified as an area that should be monitored. It was presumed that the cemetery burials had been exhumed and relocated before the construction of these additional officers quarters in the 1880s.

Parking lot construction cuts were horizontally extensive but shallow in depth (Thomas 1988:29), with a few miscellaneous artifacts and an alignment of paving bricks set on edge in front of Building 3 observed. Five oblong depressions oriented east west were observed between the road and the northwest corner of Building 3. Thomas writes:

> The north-south alignment of these depressions encompassed about 30 ft. The spacing between each depression was 5 to 7 ft. The regularity in size, interval, orientation, and provenience in a former cemetery immediately suggested that these were graves. This hypothesis was tested by excavating the southernmost depression to determine whether these were simply a surface phenomena or subsurface intrusions. A 4 ft. wide by 3 ft. deep hole was machine excavated. A shovel was used to clean the excavation floor prior to machine excavations in order to avoid disturbing archaeological material. The test indicate [sic] this was a historic intrusion that extended to 3 ft. below the existing surface. Some wood fragments were found at this depth, but could not be identified for function or association. The test hole was closed and the feature locations recorded by the city surveyor. No further work was authorized in this area. It is not known if these features were gravesites [Thomas 1988:29].

The depressions were subsequently covered by pavement in the new parking lot (Thomas 1988:30).

In a 1997 report, Thomas relates a conversation that he had with an individual in 1987 while monitoring this project. The individual, who was a Washington State Department of Transportation (WSDOT) employee at the time of the construction of Interstate 5, reported that "human remains were unearthed while heavy equipment was making cuts into the hillside within the cemetery area of the highway right-of-way" (Thomas 1997:6). An article in *The Columbian* newspaper in 1953 reported the discovery of human remains in this area during the construction of the freeway, possibly the same incident that was described to Thomas in 1987.

Wilson 2002

In 2002, archaeological monitoring was conducted for the installation of new infrastructure and landscaping for the City of Vancouver Police Administration building (the former Washington State Patrol), which is situated in the northwestern portion of the VNHR (Wilson 2002). Portions of this project area are within the CRC APE. A utility vault for a fiber optic line was installed in Evergreen Boulevard. The hole for the vault was dug to a depth of 1.8 m. The wall profiles showed disturbed sediments to approximately 50 cm, with a disturbed rubble stratum below 50 cm in the east wall and one fragment of orange brick observed.

Bore hole locations south of Evergreen Boulevard and a trenching location on the west side of the Police Administration building were examined, with no archaeological material observed. Sediments in these areas were disturbed. The land on the south side of Evergreen Boulevard in the project area appears to have been built up with fill, as is evidenced by the older trees nearby that are currently approximately one meter below the road grade. Landscaping work conducted in this same area revealed the presence of fill to 40-60 cm. Holes for four trees were excavated on the sloped area on the south side of Evergreen Boulevard. One hole appeared to contain intact sediments, although few artifacts were observed in any of the holes.

Cromwell and Gembala 2003

In 2003, test excavations were conducted for a project to upgrade and renovate the West Barracks area of the VNHR (Cromwell and Gembala 2003). Four 50 x 50 cm shovel test (ST) units were located to the west of the City of Vancouver Police Administration building near the current CRC APE. ST98 was located close to the Interstate 5 freeway and 15 m south of Evergreen Boulevard within the probable footprint of a ca.1879 Line Officers Quarters building. ST98 showed disturbed sediments and fill with a mix of 19th- and 20th-century artifacts to a depth of 90 cm. ST99, located approximately 18 m southeast of ST98, was largely sterile throughout its 70 cm depth, with a few modern artifacts to a depth of 40 cm. ST100, located approximately 14 m southeast of ST99, was largely sterile throughout its 70 cm depth with a few artifacts of mixed 19th- and 20th-century origin to a depth of 40 cm. ST101, located approximately 20 m south of ST98, showed disturbed sediments and a few mixed 19th- and 20th-century artifacts to a depth of 50 cm. A metal pipe was exposed at a depth of 70 cm in ST101.

The sediments in the area west of the Police Administration building appear to be largely disturbed from the numerous road and utility construction episodes that have occurred in the area over the past decades. Figure 15 shows how the construction of the freeway drastically altered the topography of this area. The original ground surface adjacent to the freeway was cleared, graded, and modified during excavations for the freeway and subsequent landscaping.

Cheung et al 2008

In 2008, subsurface testing and archaeological monitoring was conducted for the replacement of seven trees on Officers Row (Cheung et al. 2008). The planting of Tree #4 was proposed on the north side of Building 3 near the site of the Old Post Cemetery near the APE of the CRC project. Because no archaeological excavations had been previously conducted in that area, a single 50 x 50 cm ST was excavated at the planting site.

The ST revealed intact stratified deposits, with 79 artifacts recovered that are indicative of prehistoric, U.S. Army, and modern periods (no artifacts were observed dating to the HBC era), to a depth of 30 cm below the current ground surface. Most of the artifacts were found in a buried A horizon from 16 to 30 cm beneath a stratum of fill that may be associated with the 1988 redevelopment of Officers Row. The ST was culturally sterile from 30 to 60 cm, where it was terminated. Aside from modern debris (38%), the artifact assemblage is dominated by Early U.S. Army (1849-1900) artifacts (34.2%), consisting of an assortment of window glass, machine-cut nails, brick, ceramic, sawn bone, and vessel glass. Late/Modern U.S. Army artifacts comprised 17.7% of the assemblage, and two precontact lithic artifacts were recovered: one quartzite flake and one late prehistoric gray chert projectile point. Tree #4 was planted within the confines of the ST. The authors recommended that any future ground-disturbing activities in the area be subject to archaeological mitigation.

METHODS

The National Park Service conducted archival research, geophysical surveys, and archaeological test excavations within the CRC APE in VNHR Area #1 at the west end of Officers Row to identify archaeological resources that may be adversely affected by the CRC project.

Remote-sensing surveys were conducted within a single survey grid in VNHR Area #1 on the north side of Evergreen Boulevard, the location of the Old Post Cemetery (Figure 16). The magnetometer survey was conducted on January 29, 2009 by Kendal McDonald of Z-Too Archaeogeophysical Prospection. The ground penetrating radar survey was conducted on February 20, 2009 by Steve De Vore of the NPS Midwest Archaeological Center.

FIGURE 15. Ground disturbance in VNHR Areas #1 and #2 at the end of Interstate 5 freeway construction in 1955. Photograph PSH1 155, April 15, 1955, courtesy of WSDOT.

Archaeological Test Excavations

The NPS conducted subsurface testing within VNHR Area #1 to target anomalies seen in the geophysical surveys, in areas of possible historical buildings and features seen on historical maps and documents, to answer the questions outlined in the Project Goals section, and at regular intervals throughout the project area. Excavations in VNHR Area #1 in this phase of testing were limited to locations currently not covered by asphalt, concrete, and walkways. All units in this area were excavated by hand.

Under the direction of CRC, testing extended beyond the APE on the north side of Evergreen Boulevard to fully investigate the area of the Old Post Cemetery. The main goal in this area was to establish whether any graves or disassociated human remains still exist within the Old Post Cemetery, so that measures could be taken to ensure that human remains are not discovered in this portion of the APE during CRC construction. Several anomalies were detected with both GPR and magnetometry that could be indicative of graves or other shaft features. Anticipated findings on south side of Evergreen Boulevard included archaeological deposits associated with the 1879 Line Officers Quarters that was located west of the Police Administration building.

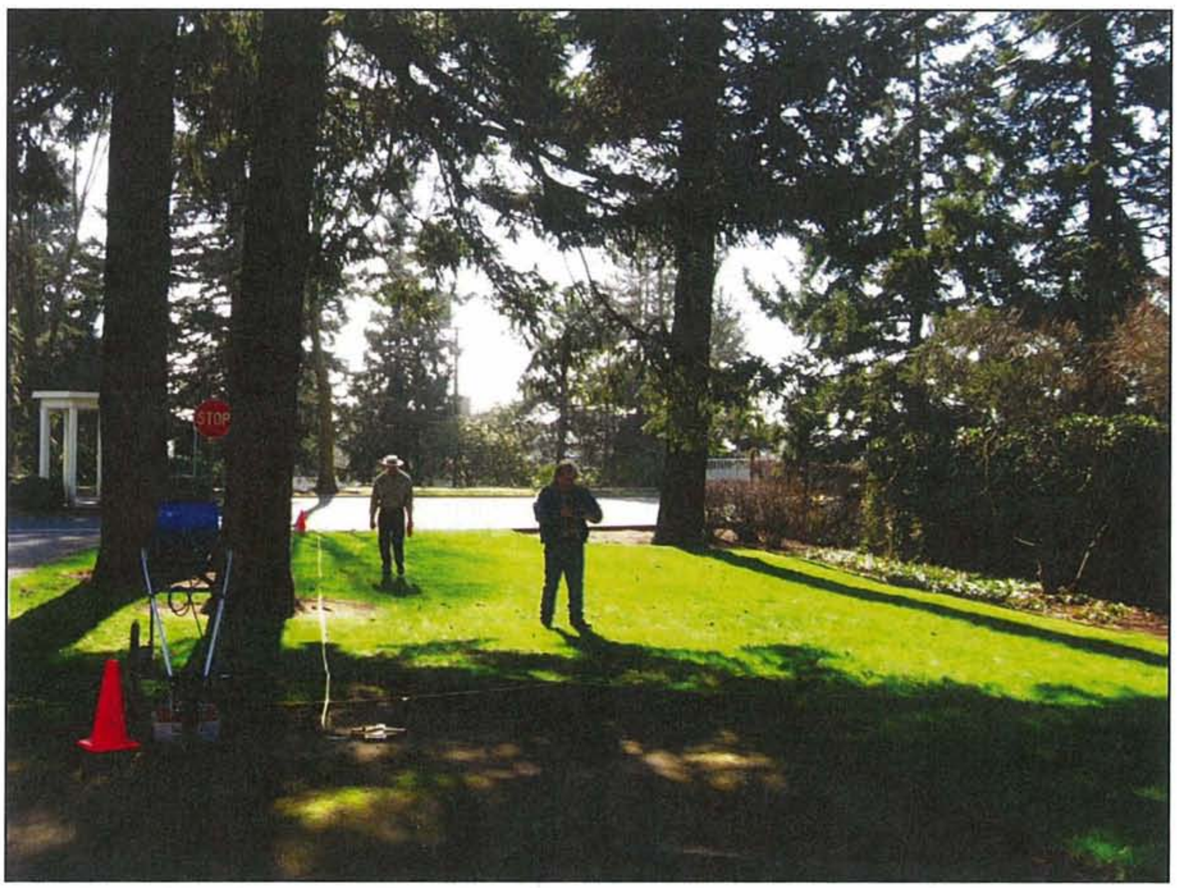

FIGURE 16. Eric Gleason assisting Steve De Vore with the GPR survey of VNHR Area #1 within the Old Post Cemetery on the north side of Evergreen Boulevard, facing grid south. (NPS 09-03:11, 2/20/09)

EXCAVATION RESULTS

From March 2-6, 2009, the NPS conducted archaeological testing in VNHR Area #1 on City of Vancouver property at the west end of Officers Row. VNHR Area #1 was divided into two sections: the north side of Evergreen Boulevard within the location of the Old Post Cemetery, and the south side of Evergreen Boulevard west of the Police Administration building.

Five TUs (5.0 m^2) were excavated on the north side of Evergreen Boulevard, and 5 STs (1.25 m^2) were excavated on the south side of Evergreen Boulevard (Table 3, Figure 17). One feature (Feature 1) was recorded within TU1-03 and TU1-04. TUs were aligned to grid north, which was approximately 20° east of true north. Directions given in the text are relative to the orientation of the remote sensing grid.

TABLE 3
ARCHAEOLOGICAL TEST UNITS AND SHOVEL TESTS WITHIN VNHR AREA #1

Unit	Maximum Depth (cm)	Findings
North Side of Evergreen Boulevard		
TU1-01	70	disturbed
TU1-02	90	disturbed
TU1-03	60	Old Post Cemetery 19^{th}-century grave shaft (Feature 1)
TU1-04	60	Old Post Cemetery 19^{th}-century grave shaft (Feature 1)
TU1-05	16	disturbed
South Side of Evergreen Boulevard		
ST1-01	50	1879 Line Officers Quarters
ST1-02	95	disturbed
ST1-03	130	disturbed
ST1-04	80	disturbed
ST1-05	40	1879 Line Officers Quarters

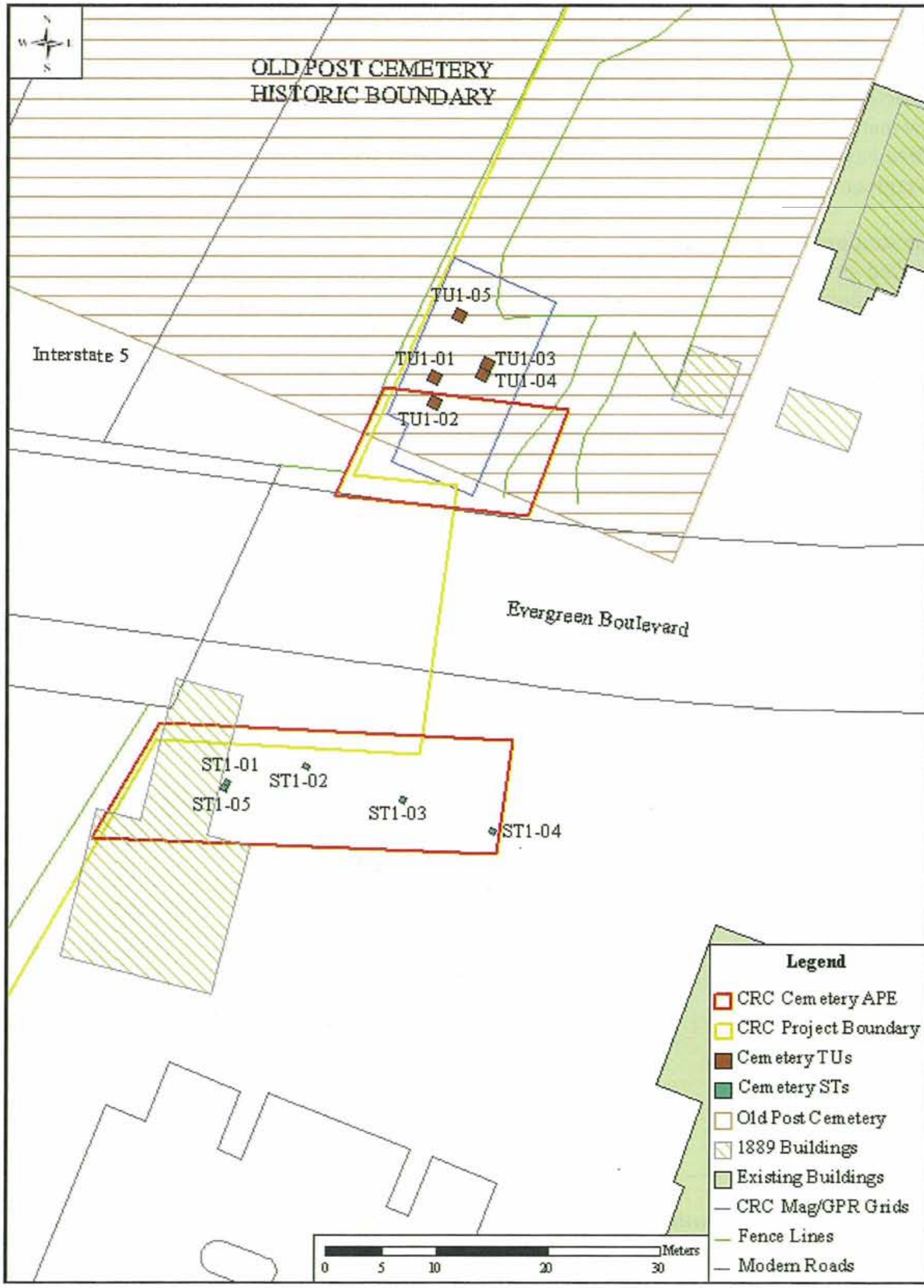

FIGURE 17. Excavation units TU1-01 through TU1-05 and ST1-01 through ST1-05 in VNHR Area #1. (NPS 2010)

North Side of Evergreen Boulevard

The north side of Evergreen Boulevard within VNHR Area #1 was the location of the Old Post Cemetery, in use from ca. 1855-1883. This portion of the CRC APE is now an area of lawn and a few mature Douglas fir trees between a paved driveway and border plantings along the Interstate 5 freeway barrier wall. Five TUs (TU1-01 through TU1-05) were excavated on the north side of Evergreen Boulevard.

The stratigraphic sequence observed within the Old Post Cemetery area of VNHR Area #1 showed ground disturbance from the initial excavation of gravesites and the disinterment of human remains for relocation to the current Post Cemetery. Modern disturbances were also observed from the 1950s construction of the Interstate 5 freeway, and subsequent landscaping and parking lot construction. An example of the stratigraphic sequence for this area is described below for TU1-04 (Figure 18).

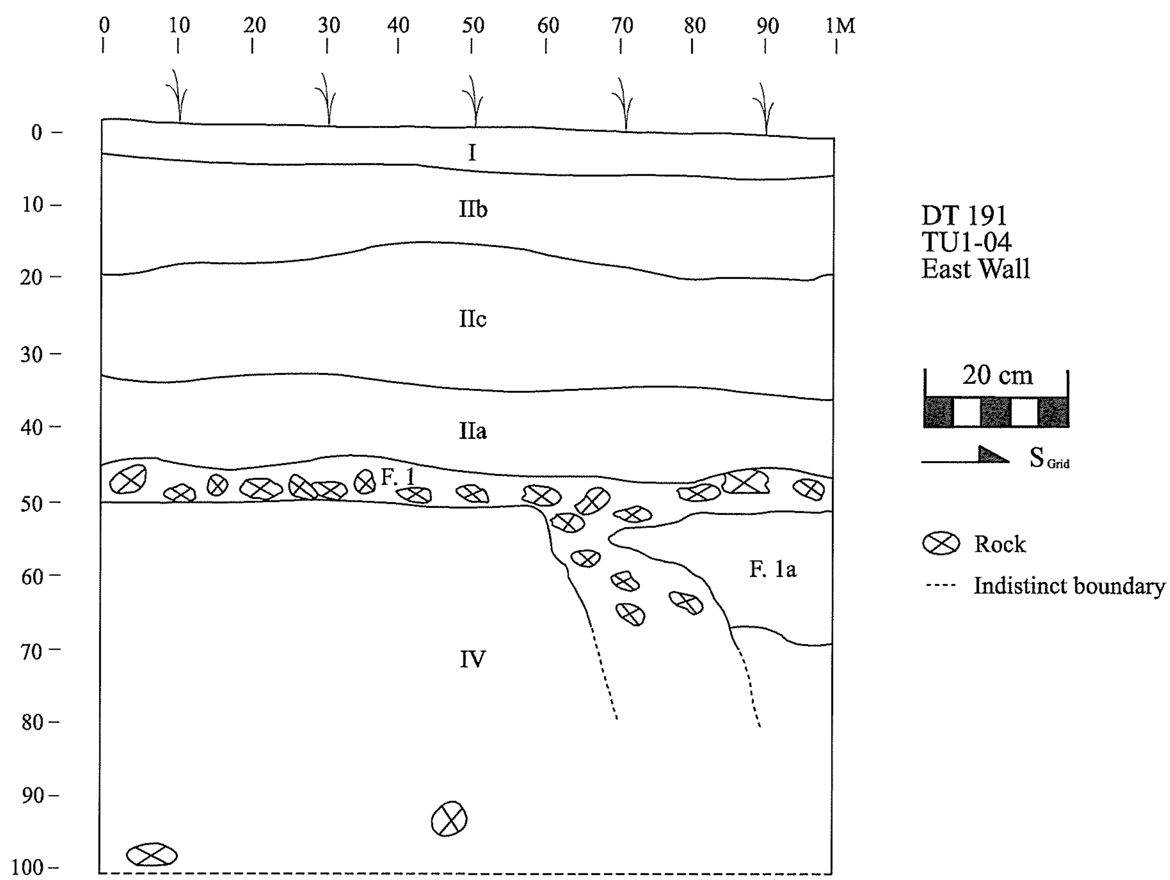

FIGURE 18. East wall profile of TU1-04 on the north side of Evergreen Boulevard in VNHR Area #1. (NPS 2010)

Stratum I:	Sod/topsoil, 10YR3/3 dark brown silt loam, 10% gravels, many cobbles, small roots, modern debris.
Stratum IIb:	10YR3/4 dark yellowish brown silt loam, 10% gravels and increasing cobbles, thicker roots, few 20th-century artifacts.
Stratum IIc:	10YR3/2 very dark grayish brown silt loam, few gravels, few mixed 19th- and 20th-century artifacts.
Stratum IIa:	10YR3/3 dark brown silt loam, few gravels, few 19th-century artifacts. Possible disturbed/redeposited A horizon.
Feature 1:	*F. 1.* Compact 10YR4/3 brown silt loam, few gravels and many medium-to-large cobbles, few 19th-century artifacts. Possible primary grave shaft fill. *F. 1a.* Soft 10YR3/3 dark brown silt loam, fewer gravels, some voids, few 19th-century artifacts. Possible redeposited grave shaft fill from disinterment.
Stratum IV:	B horizon, 10YR3/4 dark yellowish brown gravelly loamy silt, culturally sterile.

North Side of Evergreen Boulevard Test Units

Data on the volume of sediments excavated and the number of artifacts recovered from the TUs on the north side of Evergreen Boulevard in VNHR Area #1 are presented in Table 4.

<u>TU1-01</u>

TU1-01 was excavated in the area of a magnetic anomaly. Sediments were largely disturbed, with 20th-century artifacts and plastics found to a depth of 50 cm. TU1-01 contained an abandoned water line running east/west at 20-30 cm, and a PVC irrigation pipe running north/south across the unit at 30 cm. A burned surface was observed beginning at 40 cm extending to about 60 cm. TU1-01 was terminated at 70 cm at the transition to C-horizon deposits. No pits or other shafts indicative of a burial pit, and no identifiable human remains were found in TU1-01.

<u>TU1-02</u>

TU1-02 was excavated in the area of both magnetic and GPR anomalies. Sediments were largely disturbed, with 20th-century artifacts and plastics found to a depth of 50 cm. TU1-02 contained an abandoned gas line running east/west across the unit at 15-35 cm, and a coaxial cable in the northeast corner of the unit at 35 cm. TU1-02 was terminated at the C-horizon transition at 70-90 cm. No pits or other shafts indicative of a burial pit, and no identifiable human remains were found in TU1-02.

TABLE 4
EXCAVATION RESULTS FOR VNHR AREA #1 ON THE NORTH SIDE OF EVERGREEN BOULEVARD

Level/ Feature	Mean Depth (cm)	Volume (m^3)	Total Artifacts	Artifacts (/m^3)	Ceramics	Flat Glass	Vessel Glass	Nails	Other 19th-c. Artifacts*
TU1-01									
1	0-11	0.1100	33	300	1	2	3	-	-
2	11-21	0.1000	81	810	3	3	13	3	-
3	21-31	0.1025	20	195	-	-	1	3	-
4	31-41	0.0950	73	768	-	7	27	10	-
5	41-51	0.1025	10	98	-	2	3	1	-
6	51-61	0.1025	1	10	-	-	-	-	-
7	61-71	0.1000	-	-	-	-	-	-	-
Total		0.7125	218	306	4	14	47	17	-
TU1-02									
1	0-12	0.1150	66	574	-	9	7	1	-
2	12-22	0.1025	127	1239	-	22	12	5	-
3	22-32	0.1025	73	712	-	2	7	-	-
4	32-37	0.0450	22	489	-	1	5	-	-
5	37-50	0.1275	93	729	2	5	27	7	-
6	50-63	0.1300	1	8	-	-	-	1	-
7	63-73	0.0925	-	-	-	-	-	-	-
8	73-93	0.2000	-	-	-	-	-	-	-
Total		0.9150	382	417	2	39	58	14	-
TU1-03									
1	0-15	0.1450	29	200	1	4	11	1	-
2	15-24	0.0925	52	562	-	3	6	8	-
3	24-40	0.1550	82	529	3	7	12	10	1
4	40-43	0.0275	25	909	1	2	11	5	-
5	43-47	0.0350	3	86	1	1	1	-	-
6	47-57	0.0827	12	145	-	1	3	1	1
F1, L1	57-59	0.0029	-	-	-	-	-	-	-
F1, L2	59-63	0.0046	3	659	-	-	2	-	-
Total		0.5451	206	378	6	18	46	25	2
TU1-04									
1	0-39	0.3875	1	3	-	-	-	-	-
2	39-49	0.1025	11	107	1	2	7	-	-
F1, L1	49-52	0.0036	11	3099	1	1	1	2	-
F1, L2	52-55	0.0049	2	410	1	-	-	-	-
Total		1.0436	25	24	3	3	8	2	-

Continued on next page

TABLE 4
EXCAVATION RESULTS FOR VNHR AREA #1 ON THE NORTH SIDE OF EVERGREEN BOULEVARD (CONT.)

Level/ Feature	Mean Depth (cm)	Volume (m^3)	Total Artifacts	Artifacts ($/m^3$)	Ceramics	Flat Glass	Vessel Glass	Nails	Other 19th-c. Artifacts*
TU1-05									
1	0-8	0.0775	33	426	-	-	-	-	-
2	8-15	0.0650	33	508	1	3	11	11	-
3	15-18	0.0143	34	2386	1	-	2	1	-
Total		0.1568	100	638	2	3	13	12	-
GRAND TOTAL		**3.373**	**1137**	**337**	**17**	**77**	**172**	**70**	**2**

*Personal and domestic items

TU1-03 and TU1-04

TU1-03 and TU1-04 were located in the area of both magnetic and GPR anomalies. Sediments in TU1-03 were disturbed, with abundant modern artifacts to a depth of 40 cm transitioning to sparse historical artifacts such as transferprinted ceramics, square nails, coal, and a Prosser button by 50 cm. Sediments appeared more mottled in the south part of the unit, and then below 55 cm the corner of a possible grave shaft feature became apparent. This east/west-oriented shaft feature was designated Feature 1.

TU1-04 was then begun adjacent to TU1-03 and excavated to the level of Feature 1 to expose more of the shaft feature to attempt to ascertain its function. Sediments were shoveled off to a depth of 45 cm and then excavated stratigraphically to match the level of TU1-03. Feature 1, continuing into the northeast corner of TU1-04, was then excavated in arbitrary 10 cm levels concurrently in both units (Figure 19). An unidentifiable bone fragment was found in the first feature level at approximately 55 cm. At approximately 60 cm, a larger intact bone was observed in the undisturbed B-horizon sediments next to the shaft.

Beth Horton, M.Sc., a Ph.D. candidate at Washington State University who is studying Fort Vancouver for her dissertation and has expertise in the identification and analysis of human and faunal remains, visited the site and judged that the bone was likely a human metatarsal bone. At this point, excavations ceased in this area, the bone was covered and protected, the area was secured, and the Columbia River Crossing project was called to implement the inadvertent discovery plan. The units were backfilled on March 13, 2009; the remains were reburied onsite on June 17, 2009.

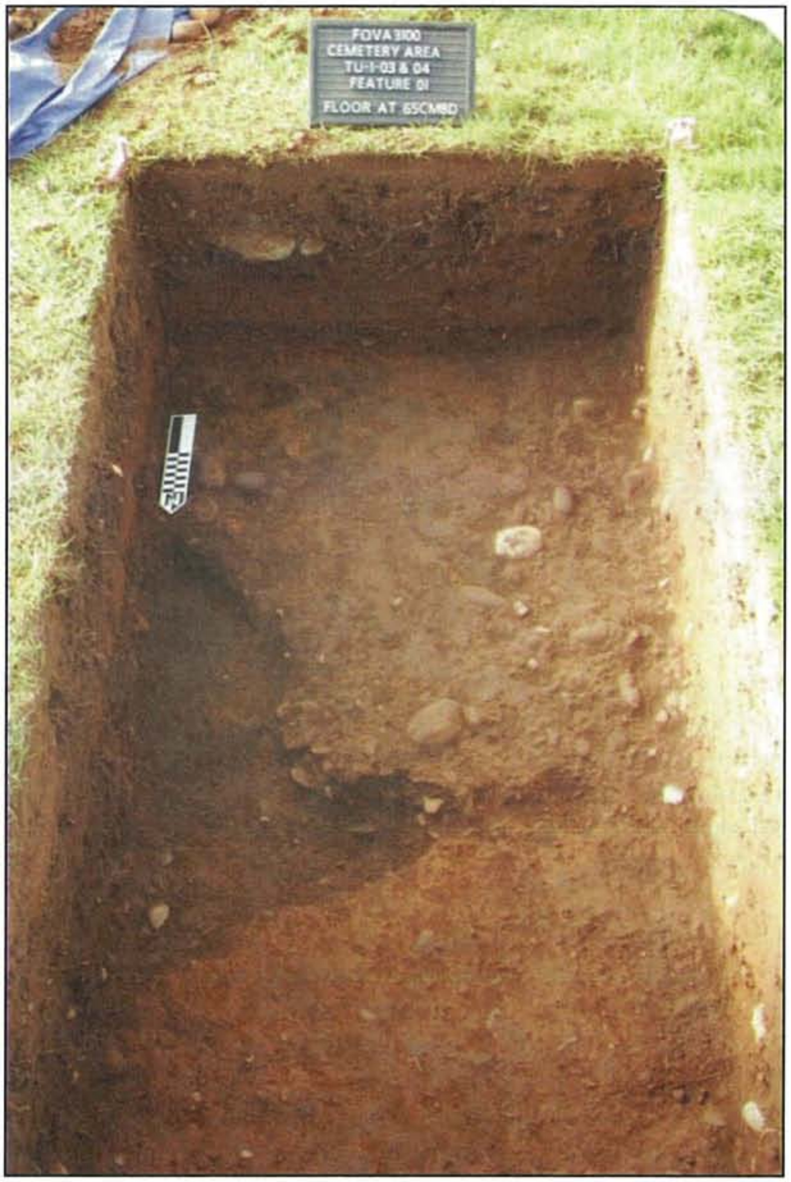

FIGURE 19. TU1-03 and TU1-04 at 65 cm, showing possible grave shaft Feature 1 on the north side of Evergreen Boulevard, facing south. (NPS 09-05:22, 3/4/09)

TU1-05

Excavations in TU1-05 only reached a maximum depth of 16 cm before work in Area #1 on the north side of Evergreen Boulevard was suspended. Sediments consisted of disturbed fill just below the sod, and indications of a trench for an irrigation pipe likely located immediately west of the unit. Other than the abundant modern artifacts found in the fill in other units in this area, only a few mixed 19th- and 20th-century artifacts were recovered. No pits or other shafts indicative of a burial pit, and no identifiable human remains were found in TU1-05.

South Side of Evergreen Boulevard

VNHR Area #1 on the south side of Evergreen Boulevard was located on a landscaped south-facing slope, north and west of the City of Vancouver Police Administration building, within 10 m (33 ft.) of Evergreen Boulevard and extending approximately 34 m (112 ft.). Five STs (ST1-01 through ST1-05) were excavated on the south side of Evergreen Boulevard.

The western portion of this portion of the project area (Figure 20) was the location of a Line Officers Quarters building constructed west of the Post Commander's house (now the Howard House) in 1879. By the 1880s, a road leading from a guard post at the west entrance to Vancouver Barracks branched north to Officers Row and south to the Post Commander's house around the Line Officers Quarters building. The structure was referred to on Vancouver Barracks maps as Building 2&3 in 1906 (Hubbard) and Building 868 in 1936 (Carsner). GIS analysis of historical maps places it in slightly different locations, with the 1889 map appearing to be the most accurate. The building was demolished in 1949 ahead of the construction of Interstate 5. Freeway improvements in the 1980s further affected this area.

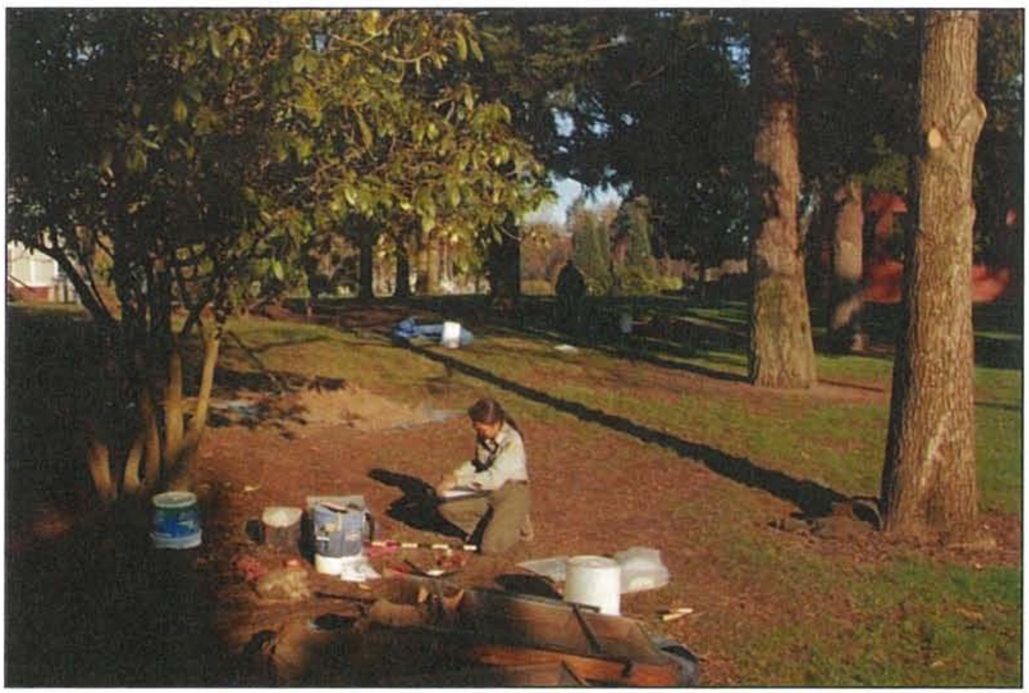

FIGURE 20. Jacqueline Cheung excavating ST1-01 and ST1-05 on the south side of Evergreen Boulevard, facing east. (NPS 09-05:28, 3/5/09)

The stratigraphic sequence observed within this portion of VNHR Area #1 showed ground disturbance from the demolition of the Line Officers Quarters, and from the 1950s construction of the Interstate 5 freeway and subsequent landscaping. Layers of modern fill were observed above B-horizon sediments, which began at about 110 cm. An example of the stratigraphic sequence for this area is described below for ST1-03 (Figure 21).

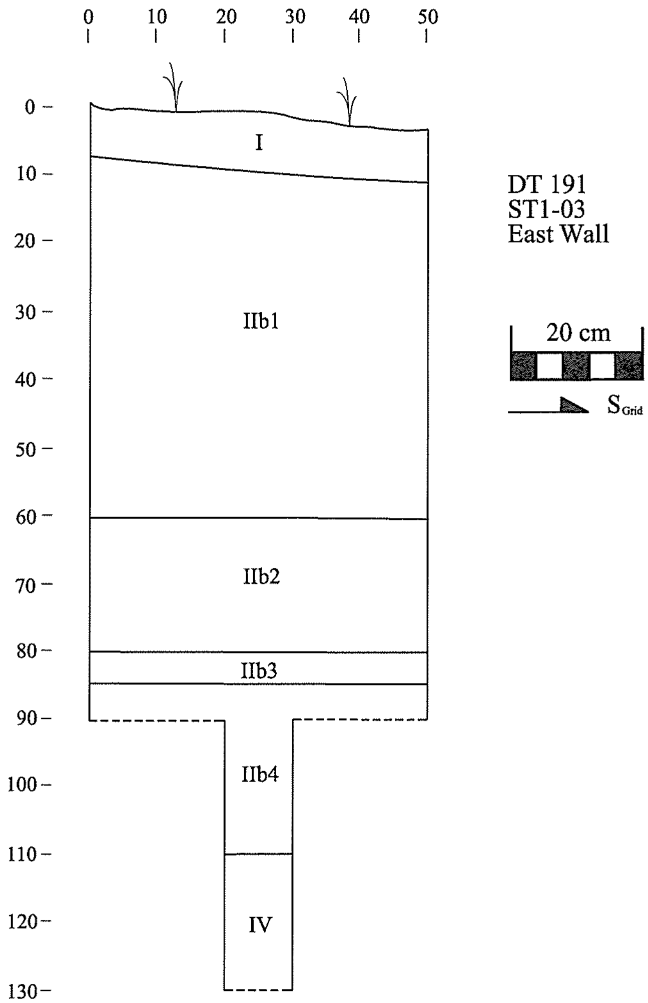

FIGURE 21. East wall profile of ST1-03 on the south side of Evergreen Boulevard in VNHR Area #1. (NPS 2010)

Stratum I:	Sod/topsoil, 10YR4/3 brown silt loam, few gravels, modern debris.
Stratum IIb1:	10YR5/3 brown loose sand, few gravels, very abrupt lower boundary, few 20th-century artifacts.
Stratum IIb2:	10YR3/3 dark brown sandy loam, few gravels, few 20th-century artifacts.
Stratum IIb3:	10YR5/3 brown loose sand, few gravels, few 20th-century artifacts.
Stratum IIb4:	10YR5/3 brown sand, 40% gravels, no artifacts.
Stratum IV:	B horizon, 10YR3/4 dark yellowish brown gravelly silt loam, culturally sterile.

South Side of Evergreen Boulevard Shovel Tests

Data on the volume of sediments excavated and the number of artifacts recovered from the STs on the south side of Evergreen Boulevard in VNHR Area #1 are presented in Table 5.

ST1-01 and ST1-05

ST1-01, located 10 m east of the chain-link fence and 8 m south of Evergreen, contained abundant mixed demolition debris consisting of brick and concrete possibly associated with the historical Line Officers Quarters building known to have been in that location. A second 50 x 50 cm unit, ST1-05, was placed to the south of ST1-01 and yielded similar material. Excavation was blocked by this debris below 40-50 cm in both units.

ST1-02, ST1-03, and ST1-04

ST1-02, ST1-03, and ST1-04 all had the same stratigraphic sequence of fill material, consisting of approximately 60 cm of sand, 20 cm of silt, and then another 50 cm of sand. These units were excavated to 80-110 cm; augering revealed native B-horizon deposits at approximately 130 cm. A few modern artifacts were seen throughout the fill layers.

TABLE 5
EXCAVATION RESULTS FOR VNHR AREA #1 ON THE SOUTH SIDE OF EVERGREEN BOULEVARD

Level/ Feature	Mean Depth (cm)	Volume (m³)	Total Artifacts	Artifacts (/m³)	Ceramics	Flat Glass	Vessel Glass	Nails	Other 19th-c. Artifacts*
ST1-01									
1	0-10	0.0250	-	-	-	-	-	-	-
2	10-20	0.0250	5	200	-	-	1	2	-
3	20-30	0.0250	52	2080	-	-	3	34	-
4	30-40	0.0250	98	3920	-	-	4	58	-
5	40-50	0.0250	135	5400	-	2	2	79	-
Total		0.1250	290	2320	-	2	10	173	-
ST1-02									
1	0-10	0.0250	-	-	-	-	-	-	-
2	10-20	0.0250	-	-	-	-	-	-	-
3	20-30	0.0250	-	-	-	-	-	-	-
4	30-40	0.0250	-	-	-	-	-	-	-
5	40-50	0.0250	3	120	-	-	1	-	-
6	50-60	0.0250	4	160	-	-	-	-	-
7	60-70	0.0250	2	80	-	-	-	-	-
8	70-80	0.0250	1	40	-	-	-	-	-
9	80-90	0.0250	1	80	-	-	1	2	-
10	90-95	0.0125	-	-	-	-	-	-	-
Total		0.2375	11	46	-	-	2	2	-
ST1-03									
1	0-10	0.0250	1	40	-	-	1	-	-
2	10-60	0.1250	1	8	-	-	-	-	-
3	60-70	0.0250	1	40	-	-	-	-	-
4	70-80	0.0250	4	160	-	2	1	-	-
5	80-85	0.0125	1	80	-	-	-	-	-
6	85-90	0.0125	-	-	-	-	-	-	-
7	90-110	0.0500	-	-	-	-	-	-	-
8	110-130	0.0500	-	-	-	-	-	-	-
Total		0.3250	8	25	-	2	2	-	-
ST1-04									
1	0-50	0.1250	4	32	-	-	4	-	-
2	50-55	0.0125	-	-	-	-	-	-	-
3	55-65	0.0250	3	120	-	-	-	-	-
4	65-80	0.0375	2	53	-	1	1	-	-
Total		0.2000	9	45	-	1	5	-	-

Continued on next page

TABLE 5
EXCAVATION RESULTS FOR VNHR AREA #1 ON THE SOUTH SIDE OF EVERGREEN BOULEVARD (CONT.)

Level/ Feature	Mean Depth (cm)	Volume (m^3)	Total Artifacts	Artifacts ($/m^3$)	Ceramics	Flat Glass	Vessel Glass	Nails	Other 19th-c. Artifacts*
ST1-05									
1	0-10	0.0250	4	160	-	-	-	-	-
2	10-20	0.0250	57	2280	-	1	4	18	-
3	20-30	0.0250	82	3280	-	-	14	48	-
4	30-40	0.0250	58	2320	-	3	4	21	-
Total		0.1000	201	2010	-	4	22	87	-
GRAND TOTAL		**0.9875**	**519**	**526**	**-**	**9**	**41**	**262**	**-**

*Personal and domestic items

ANALYSIS RESULTS

Through the review of historical documents and maps, previous archaeological studies, the Fort Vancouver National Historic Site GIS database, and the results of geophysical surveys and archaeological field investigations, two cultural resources were identified in the Old Post Cemetery VNHR Area #1 within the CRC APE: 1850s Old Post Cemetery and 1879 Line Officers Quarters. The 1879 Line Officers Quarters, located on the south side of Evergreen Boulevard, will be discussed in the next chapter on VNHR Area #2 because cultural material from this building was also found in STs in that area. No other significant resources were located, although undiscovered subsurface pits, postholes, cellars, privys, activity areas, and other features related to 19th-century structures, may still exist below fill layers in VNHR Area #1 within the CRC APE.

1850s Old Post Cemetery

The 1850s Old Post Cemetery, located on the north side of Evergreen Boulevard, was encountered in TU1-03 and TU1-04. Excavations revealed a possible grave shaft (Feature 1) and a human metatarsal bone. The cultural material associated with these excavation units consists of a mix of 19th- and early 20th-century artifacts. A typological classification of these objects is presented in Table 6. Probable modern 20th-century items discarded in the field or laboratory that are not included in Table 6 include asphalt, concrete, linoleum, paint, paper, plaster, plastic, roofing debris, rubber, sewer tile, tar paper, and modern debris. These items largely constitute the difference seen between the total artifacts recovered from TU1-03 and TU1-04 in the volumetrics table (Table 5), and the number of artifacts from these units in the typology table.

TABLE 6
CHARACTERISTICS OF ARTIFACTS AT THE 1850s OLD POST CEMETERY

Object	Sprague (1981) Typology	Number	Percent
Personal Items			
Metal Grommet	I.A	1	0.68
Button, 4-Holed	I.A	1	0.68
Bottle, Alcohol	I.G	1	0.68
Bottle, Beer	I.G	10	6.76
Plastic Army Man Figurine	I.H	2	1.35
Total		**15**	**10.1%**
Domestic Items			
Bone, Unworked	II.B.2	10	6.76
Earthenware	II.B.2	3	2.03
Earthenware, Transferprinted	II.B.2	1	0.68
Glassware Sherd	II.B.2	4	2.70
Ironstone	II.B.2	2	1.35
Stoneware	II.B.2	1	0.68
Porcelain	II.B.2	2	1.35
Tumbler	II.B.2	1	0.68
Lamp Glass	II.B.3	6	4.05
Total		**30**	**20.3%**
Architecture			
Brick	III.B.1	13	8.78
Flat Glass	III.B.1	21	14.19
Wood, Unworked	III.B.1	1	0.68
Nail, Machine-Cut	III.B.2	9	6.08
Nail, Square	III.B.2	2	1.35
Nail, Wire	III.B.2	16	10.81
Coal	III.E	1	0.68
Slag	III.E	1	0.68
Total		**64**	**43.2%**
Commerce and Industry			
Coin	V	**1**	**0.7%**
Unknown			
Seed	VIII	1	0.68
Slate	VIII	1	0.68
Unidentified Metal Artifact	VIII.A	2	1.35
Metal Fragment	VIII.A	1	0.68
Wire	VIII.B	1	0.68
Bottle Glass	VIII.B	12	8.11
Glass Sherd	VIII.B	18	12.16
Vial	VIII.B	2	1.35
Total		**38**	**25.7%**
GRAND TOTAL		**148**	

More than 43% (n=64) of the artifact assemblage in Table 6 consists of architectural material, with the most abundant items being flat glass (14.2%, n=21), wire nails (10.8%, n=16), and brick (8.8%, n=13). All varieties of square nails comprise a total of 7.4% (n=11) of the assemblage. There are few domestic (20.3%, n=30) and personal (10.1%, n=15) items. The four-holed Prosser button could be a personal item associated with burials located within the Old Post Cemetery. Glass sherds and bottle glass constitute the bulk of items recovered whose function could not be determined (25.7%, n=38).

The mean ceramic dates at the Old Post Cemetery (Figure 22) show that the majority of ceramic sherds date from ca 1845, which is consistent with the HBC and Early U.S. Army occupation periods at Fort Vancouver. Within the ceramic types, white earthenware is the most common (n=3), followed by ironstone (n=2), and transferprinted earthenware, Chinese porcelain, English porcelain, and stoneware (one each).

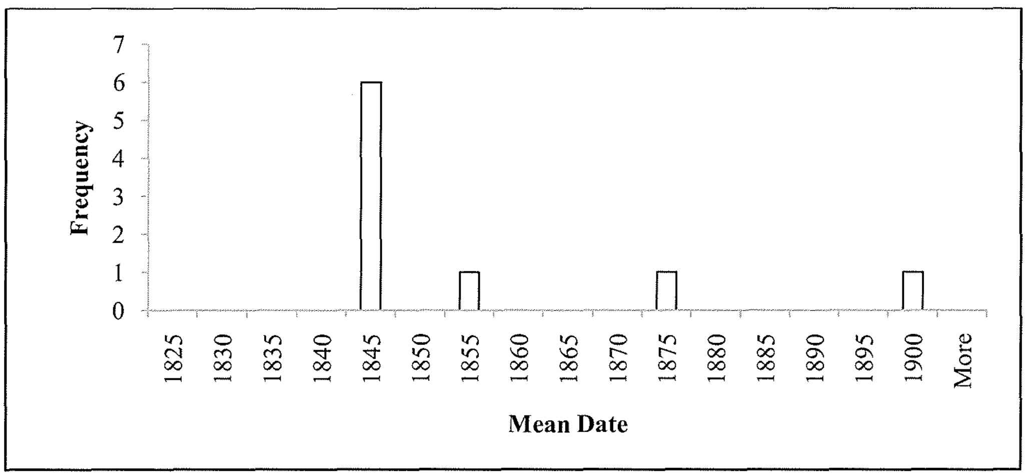

FIGURE 22. Mean ceramic dates for TU1-03 and TU1-04 at the Old Post Cemetery (σ=18.9). (NPS 2010)

The thickness of window glass (n=21) at the Old Post Cemetery (Figure 23) has a primary mode of 0.085 in. corresponding to a date range of 1855-1885, which is consistent an Early U.S. Army use of the area.

In contrast, the vessel glass manufacturing methods for the Old Post Cemetery show that the majority of vessel glass recovered dates either from the 20th century or is from an unknown time period. One fragment shows attributes of a blown-into-mold vessel, which commonly date from before 1900. The remaining fragments of vessel glass (n=53) are either machine made or of unknown manufacture.

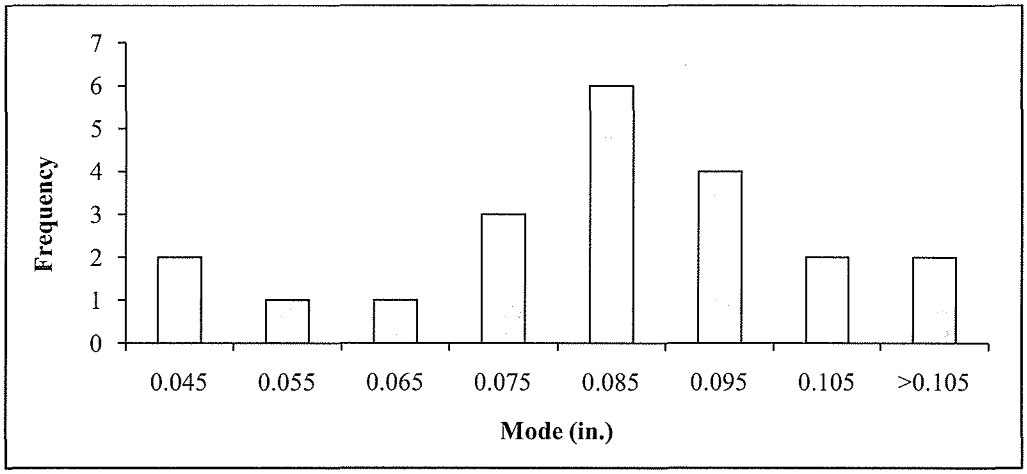

FIGURE 23. Window glass thickness in TU1-03 and TU1-04 at the Old Post Cemetery. (NPS 2010)

The quantity of temporally diagnostic artifacts recovered from TU1-03 and TU1-04 at the Old Post Cemetery attributable to either the 19th century (51%, n=37) or 20th century (49%, n=36) is about equal (Figure 24), although all of the modern items have been removed from Table 6. The majority of artifacts (43.2%, n=64) appear to represent architectural debris related to historical and modern construction activities within the area. With the exception of the Prosser button, discussed above, there are no artifacts observed that directly suggest an association with a burial. However, based on background research and the results of test excavations, there appears to be little doubt that the east/west-oriented shaft Feature 1 is a grave shaft.

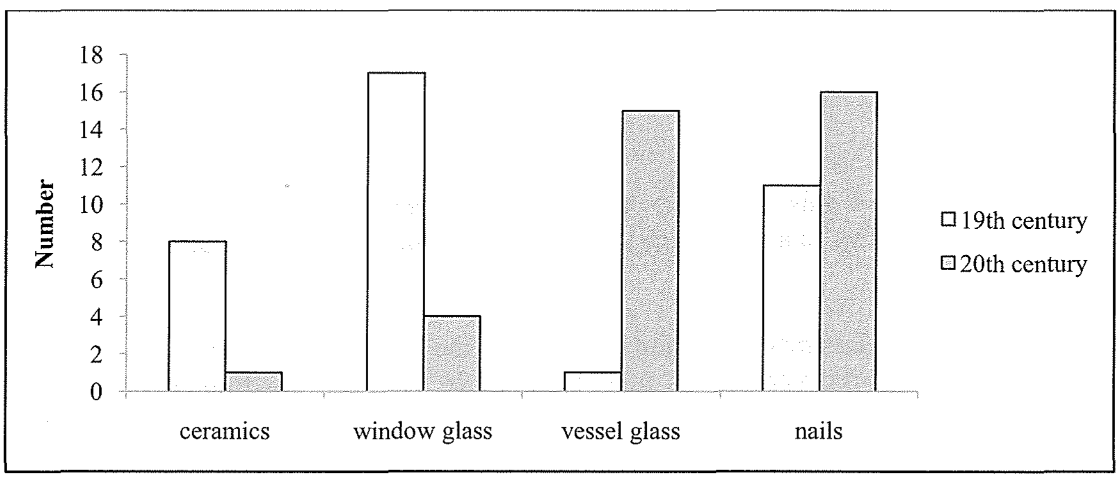

FIGURE 24. Distribution of temporally diagnostic artifacts in TU1-03 and TU1-04 at the Old Post Cemetery. (NPS 2010)

CONCLUSIONS AND RECOMMENDATIONS

The results of test excavations in Area #1 of the VNHR indicate that archaeological resources that were tested that contribute to the significance of the VNHR District are present within this portion of the CRC APE. A thorough discussion of the significance of the observed resources in VNHR Area #1 is presented in Chapter 10.

While there is a great deal of disturbed fill and mixed 19th- and 20th-century artifacts related to late 20th-century construction, human remains are still present within the historic boundaries of the Old Post Cemetery north of Evergreen Boulevard. Additional anomalies – possible grave shafts – seen in the magnetometer and GPR surveys are present within the cemetery area. The Old Post Cemetery does not appear to extend south of Evergreen Boulevard. The Old Post Cemetery contributes to the significance of the VNHR District under Criteria a, b, and d of the NRHP.

The CRC APE on the south side of Evergreen Boulevard is largely fill, except for archaeological remains of the 1879 Line Officers Quarters on the west end of the test area. This resource, present in both VNHR Area #1 and VNHR Area #2, is discussed in detail in Chapter 6 on VNHR Area #2.

NPS archaeological testing in VNHR Area #1 has demonstrated that the CRC project as proposed will have adverse effects on cultural resources contributing to the significance of the National-Register-listed VNHR District. The Old Post Cemetery will likely be adversely affected through disturbance and destruction of human remains and grave features, and through the disassociation of grave goods and human remains. Because of the documented existance of unmarked graves in this cemetery, some of which are likely to be older graves transferred from the HBC cemetery, this effect is a concern under the State of Washington's RCW 27.44 "Indian Graves and Records", and RCW 68.60 "Abandoned and Historic Cemeteries and Historic Graves."

Adverse effects to the cultural resources in VNHR Area #1 must be resolved under 36 CFR 800.6. Adverse effects to cultural resources within the CRC APE should be avoided, if possible. If adverse effects cannot be avoided, plans to mitigate these effects should be developed through 36 CFR 800.6 or alternative processes. These efforts should be coordinated with those mitigation requirements associated with Section 4(f) of the U.S. DOT Act of 1966.

CHAPTER 6

VNHR AREA #2: WEST BARRACKS

PROJECT AREA

VNHR Area #2 is located approximately 490-960 m (1610-3150 ft.) north of the north shore of the Columbia River in the NW quarter of the SE quarter, and the SW quarter of the NE quarter, of Section 27, T2N, R1E, Willamette Meridian. The elevation of this area is approximately 40-90 ft. above mean sea level (NGVD 29).

The CRC APE in VNHR Area #2 included, from north to south: 1) a landscaped area west of the Vancouver Police Administration building along the Interstate 5 freeway right-of-way fence between Evergreen Boulevard and Anderson Road; 2) Anderson Road and the west edge of West Barracks to the FHWA Western Federal Lands Highway Division property; 3) FHWA property from the west side of the parking lot to the Interstate 5 right-of-way fence; and 4) the west end of East 5th Street (Figure 25). The majority of this portion of the CRC APE from Anderson Road south was paved.

The West Barracks area consisted of early-to-mid 20th-century U.S. Army buildings west of Fort Vancouver Way and north of East 5th Street, which have been turned over to the City of Vancouver, and are being renovated and converted for public, nonprofit, commercial, and residential use. VNHR Area #2 measured approximately 470 m (1542 ft.) long and 15 m (49 ft.) wide at its greatest extent, encompassing an area of approximately 0.5 ha (1.24 ac.). This portion of the CRC project area is located on an upslope area beyond the Columbia River floodplain and has been extensively modified by land-altering activities over the past 150 years. An adverse effect from the CRC project is anticipated within Anderson Road, the west side of the FHWA Western Federal Lands Highway Division parking lot, and the west end of East 5th Street. Current plans will see Anderson Road partially demolished in the course of freeway widening. The remaining land between West Barracks and the realigned Interstate 5 right-of-way is intended to be landscaped as a buffer zone between the buildings and the freeway.

PROJECT GOALS

Six goals addressed through archaeological testing in VNHR Area #2 within the CRC APE concerned the Hudson's Bay Company (1824-1860), Early U.S. Army (1849-1900), and Late U.S. Army (1900-1948) periods:

1. To test for archaeological evidence of HBC-era structures and features that were located in this portion of the Fort Vancouver Village.

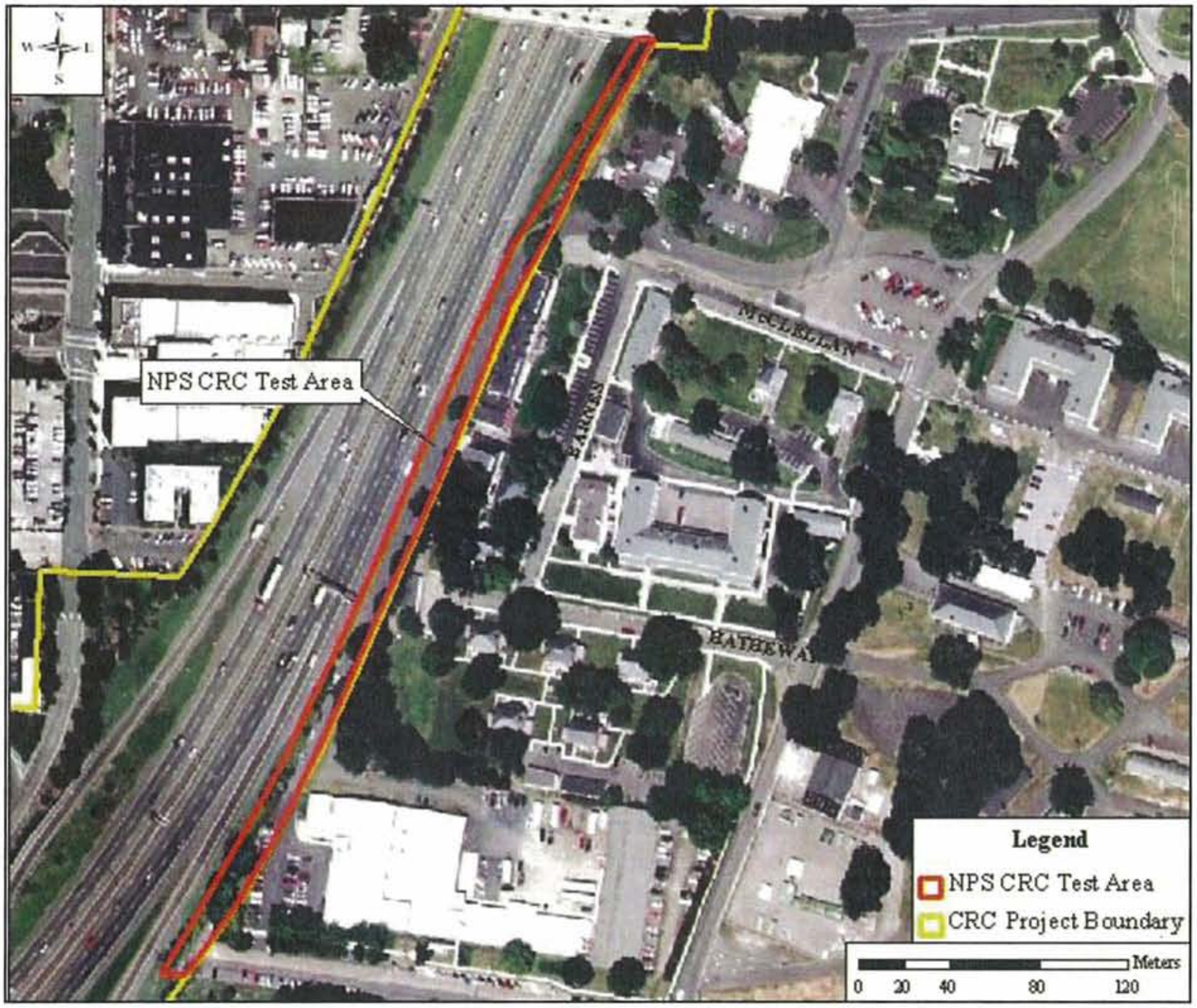

FIGURE 25. The area of NPS archaeological testing in VNHR Area #2 in West Barracks for the CRC project. Image from Google Earth. (NPS 2010)

2. To test for archeological evidence of U.S. Army structures and features that were located in this portion of Vancouver Barracks.
3. To test for traces of the roads and utilities shown on historical maps from the mid-to-late 1800s.
4. To attempt to relocate excavations by Thomas and Hibbs (1984) that may be within VNHR Area #2 to evaluate the extent of these excavations and the significance of the remaining archaeological resources that they left in the ground.
5. To record historical archaeological resources greater than 50 years old.
6. To achieve a better understanding of the archaeological resources in this portion of Vancouver Barracks and the VNHR to guide further investigations and to better educate the public on the significance and history of the area.

HISTORICAL CONTEXT

Historical records and maps were consulted to help determine the cultural resources that were present in VNHR Area #2, where they were located, and if they were likely to be affected by construction during the CRC project. GIS layers digitized from historic maps in the Fort Vancouver archives were georeferenced to modern satellite images (Figure 26).The location of buildings and features helped guide the placement of archaeological test units.

Hudson's Bay Company, 1824-1860

Although historical maps of the Fort Vancouver area of this period do not indicate structures or uses of the West Barracks area, it is located just north of the Village and was likely seen by the HBC as a part of its claims.

U.S. Army, 1849-1947

VNHR Area #2 has been affected by numerous episodes of road and building construction and demolition beginning with the U.S. Army occupation of this area in the 1850s. The southern portion of VNHR Area #2 was the location of several workshop buildings associated with the Vancouver Barracks Quartermaster's Depot beginning in the 1850s. Structures labeled on historical maps include: blacksmith shop, carpenters shop & store room (1851); hay and lumber yard, carpenters shop (1855, Figure 13); engine house, saddlers shop, carpenter shop, granary, carriage house, medical storehouse, blacksmith shop (1871); fire engines, carpenter shop, Quartermaster's Depot blacksmith, medical storehouse (1874, Figure 5); workshops (1888, Figure 6); workshops, blacksmith shop (1906, Figure 27); and blacksmith shop, paint shop, hospital cow barn (1914, Figure 28). Between 1874 and 1888, Upper Mill Road (now East 5th Street) was realigned to pass on the south side of the main workshop building.

Many new buildings were constructed in the 1870s through the 1890s as Vancouver Barracks expanded. Several of these buildings that were located along the west side of the Barracks can be seen in the GIS projections of the 1874 Ward and 1888 Patten maps (Figure 26). Two Line Officers Quarters duplex residences were constructed in the northern portion of VNHR Area #2 west of the Post Commander's house (now the Howard House) in 1879. By the 1880s, a road leading from the guard post at the west entrance to Vancouver Barracks branched north to Officers Row and south to the Post Commander's house around the Line Officers Quarters buildings. The western of the two buildings, referred to on Vancouver Barracks maps as Building 2&3 on the 1906 Hubbard map (Figure 27) and Building 868 on the 1935 Carsner Map (Figure 7), is within the project area. GIS analysis of the historical maps places it in slightly different locations, with the 1889 map appearing to be the most accurate. The building was demolished in 1949 ahead of the construction of Interstate 5.

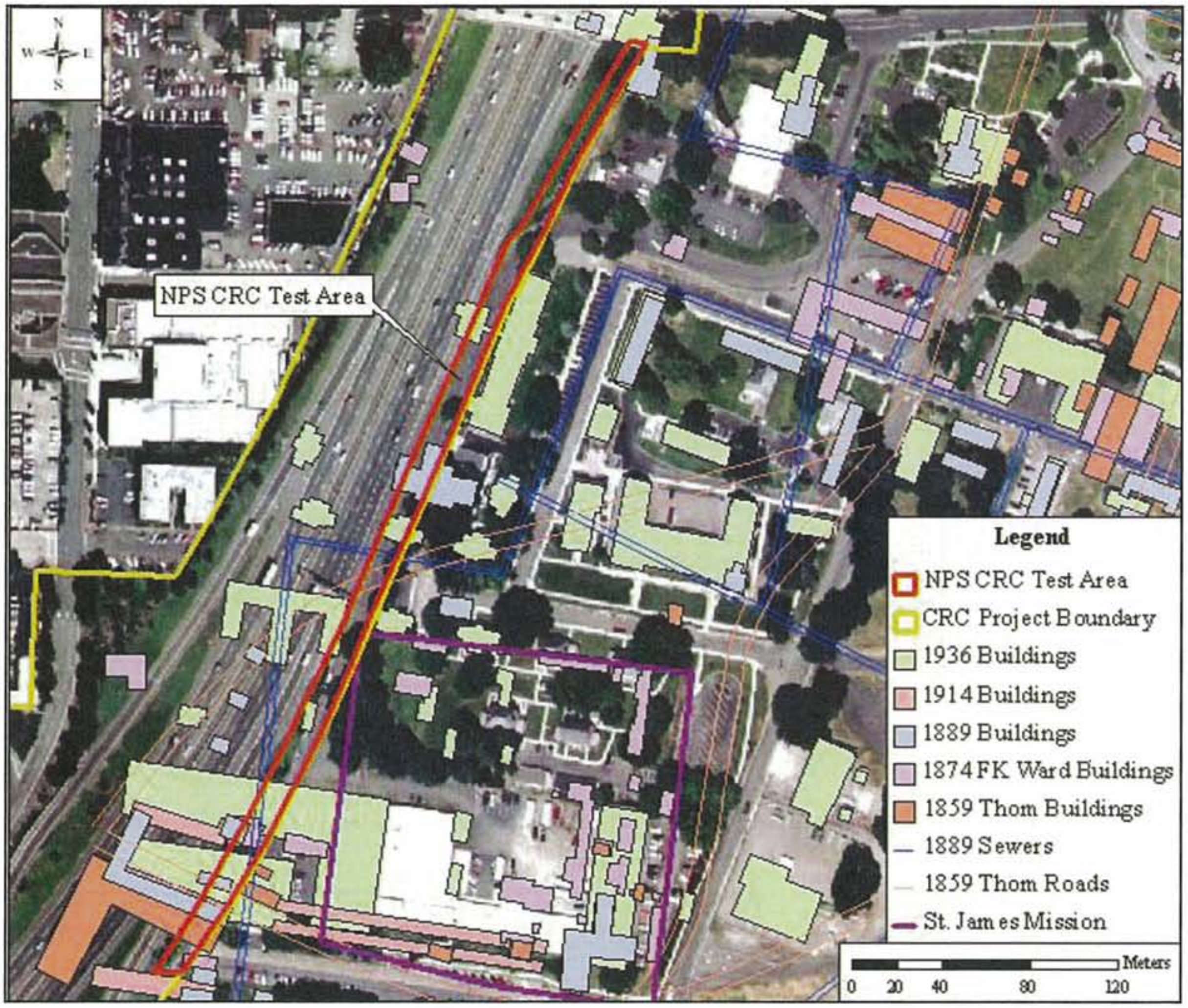

FIGURE 26. VNHR Area #2 in West Barracks within the CRC APE overlain with historical buildings and features. Image from Google Earth. (NPS 2010)

The Old Post Hospital (Building 85, previously numbered 65), which first appears on the 1888 Patten map (Figure 6), was located south of the 1904 Barnes Hospital. It last appears on the 1914 Homan map (Figure 28). The Hospital Stewards Quarters (Building 631, previously numbered 82) built in 1885, and the Hospital Corps Sergeants Quarters (Building 621, previously numbered 128) built in 1907, were originally located northwest of the Old Post Hospital. These two structures were moved south of the Howard House in the mid-1950s ahead of freeway construction. They still serve as residences today.

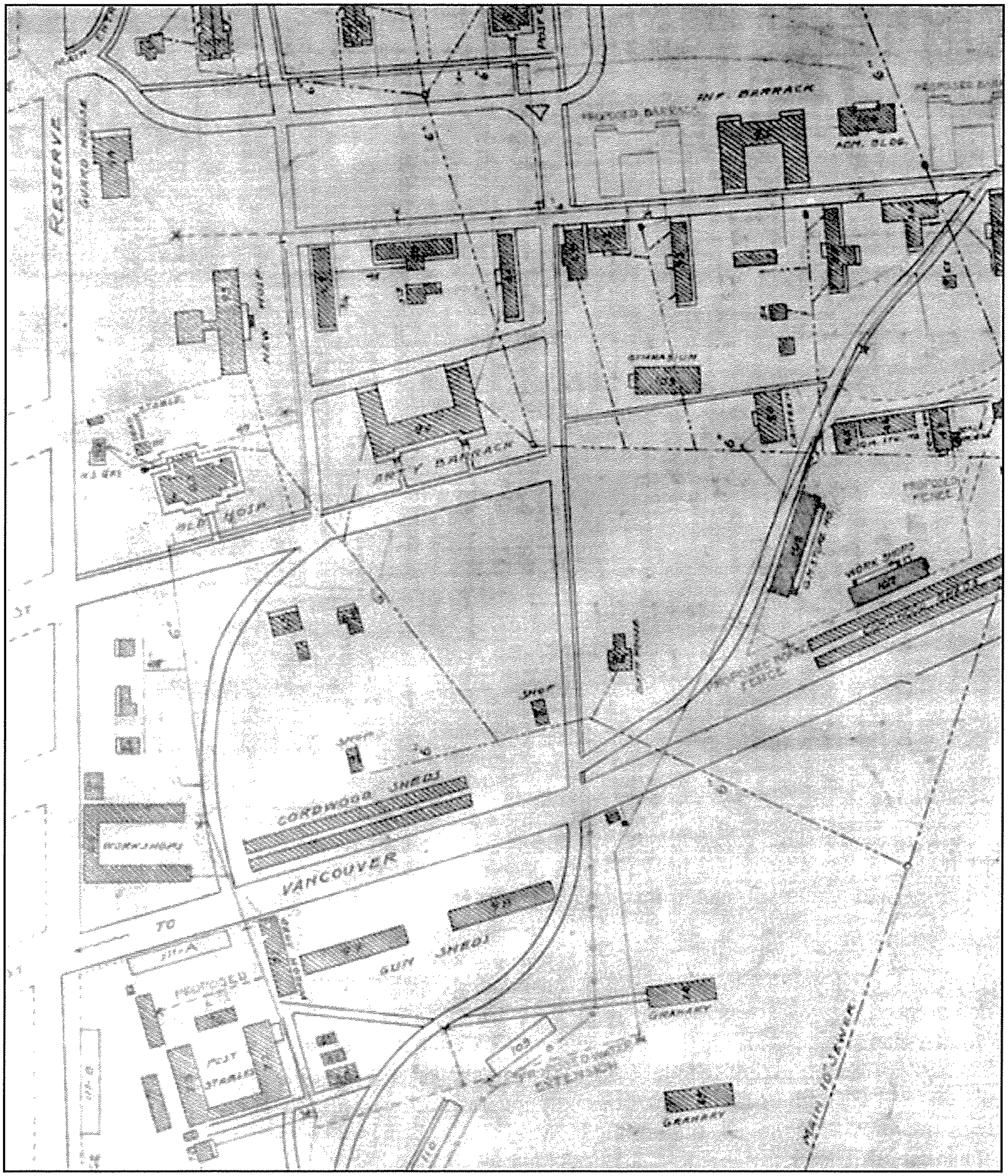

FIGURE 27. Detail of the 1906 Hubbard map of Vancouver Barracks, showing structures within VNHR Area #2.

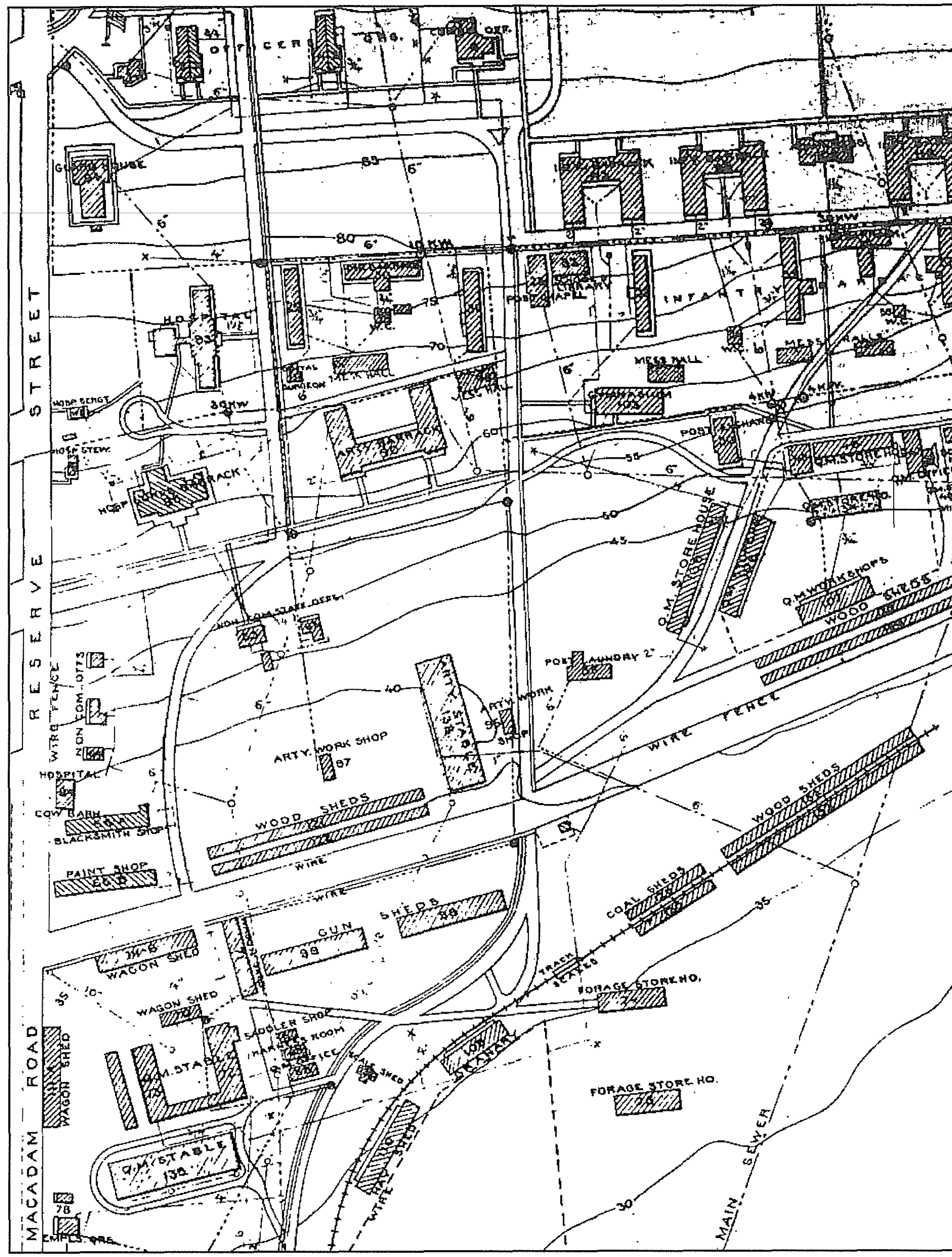

FIGURE 28. Detail of the 1914 Homan map of Vancouver Barracks, showing structures within VNHR Area #2.

By the end of World War I, many of the currently standing structures in West Barracks had been constructed, including a new hospital, several infantry and artillery barracks, officers quarters, two mess halls, the Red Cross Convalescent Home, school, stables, and several smaller buildings. Three buildings, shown on a 1928 Vancouver Barracks map just north of Anderson Road, were remnants of the many wooden overflow wards that were erected to accommodate victims of the 1918 influenza pandemic.

A large 1919 "M"-shaped building (Building 662, previously numbered 180) was originally located south of Hatheway Road. This building served as the Provost Marshal Quarters and later as non-commissioned officers quarters. The structure was relocated to the east (rotated 90°) after 1944. It was demolished by 1963.

Seven, two-story brick duplex residences were constructed in the location of the Old Post Hospital in 1935-1939 (Figure 7). Two of these duplexes, Buildings 641 and 642 (previously numbered 401 and 402) were moved southeast to the south side of Hatheway Road after 1944 ahead of freeway construction. Two other brick duplexes, Buildings 643 and 664 (previously numbered 403 and 406) were moved south of Buildings 641 and 642 by 1980 because of further freeway construction. The brick duplexes still serve as residences today.

The Workshop structures on the north side of East 5th Street were demolished by the early 1930s to make way for two new buildings for the Bureau of Public Roads (now the Federal Highway Administration), constructed in this location in 1932. With the construction of Interstate 5, the west walls of the FHWA buildings were cut off parallel to the freeway by 1953 (Figure 15). A freeway-widening project in the early 1980s resulted in the complete removal of the main FHWA building and the further truncation of the "L"-shaped building behind it.

A western annex to the extant 1904 Barnes Hospital (Building 614, previously numbered 93), reported to have been constructed in a different location in 1887 and added to the hospital in the early 1900s (Owens 2002), was relocated at the south end of the hospital in the early 1950s ahead of freeway construction.

The construction of Interstate 5 in the 1950s caused perhaps the greatest impact to VNHR Area #2. West Reserve Street, a surface road on the western boundary of Vancouver Barracks, was largely replaced by a four-lane freeway that runs in a cut below the original ground surface. The construction of the freeway drastically altered the topography of this area and resulted in the demolition of a number of buildings. The original ground surface was cleared, graded, and modified during excavations for the freeway and subsequent landscaping (Figure 15). Freeway improvements in the 1980s further affected this area.

ARCHAEOLOGICAL CONTEXT

The following projects were conducted on U.S. Army and City of Vancouver property within and near VNHR Area #2 and the CRC APE north of East 5th Street and on the west side of West Barracks. Summaries of the portions of projects most relevant to the archaeological context of VNHR Area #2 are given below (Figure 29).

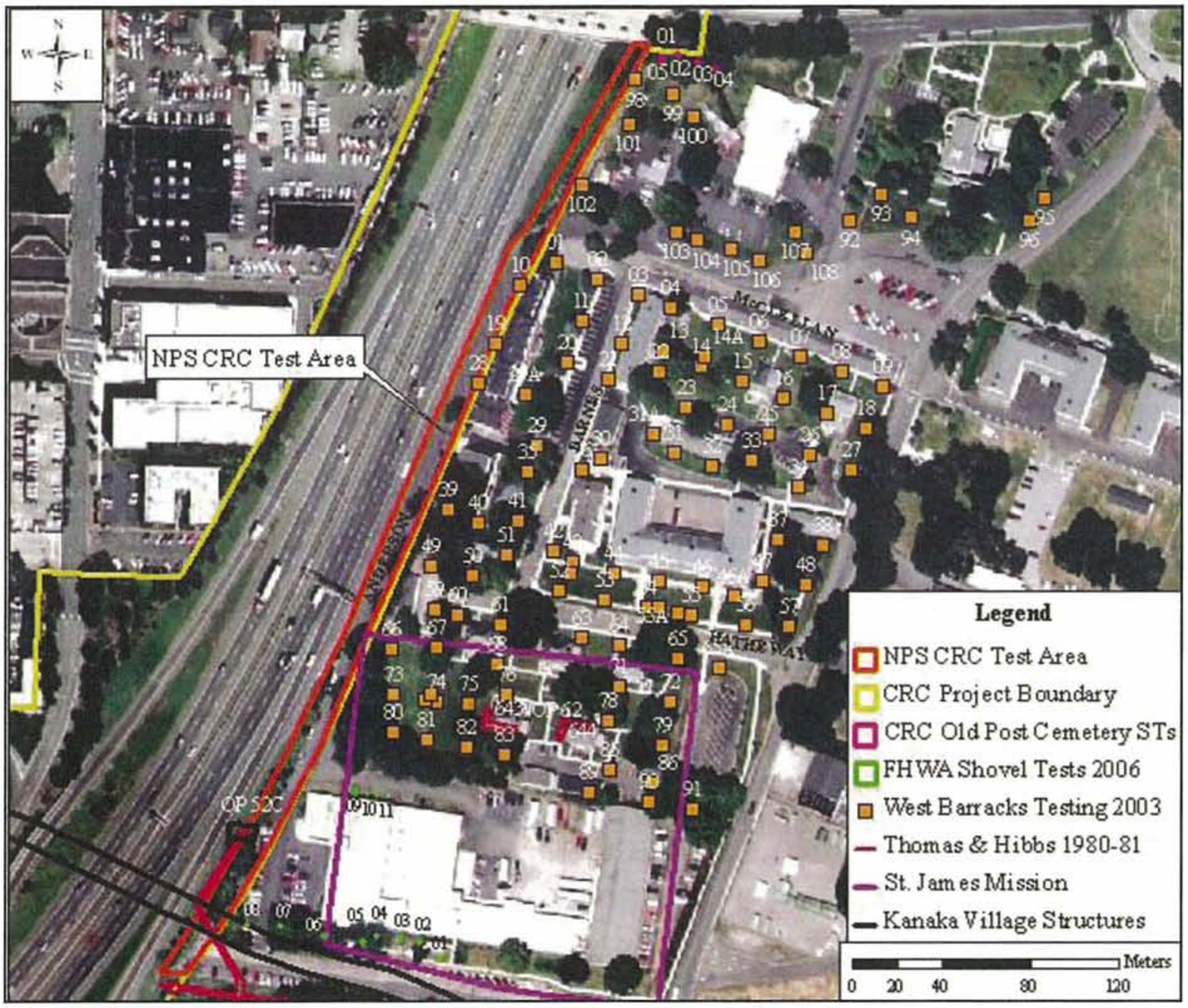

FIGURE 29. VNHR Area #2 in West Barracks overlain with previous archaeological investigations. Image from Google Earth. (NPS 2010)

Thomas and Hibbs 1984

Thomas and Hibbs (1984) conducted excavations in the Village and Vancouver Barracks in 1980-1981 ahead of the proposed relocation of the Interstate 5/SR 14 interchange. As in earlier Village excavations, most features were exposed then backfilled to preserve them for future excavations.

Operation 52C consisted of investigations associated with a machine-excavated trench for an 8 in. water line. The northern end of the trench near VNHR Area #2 revealed strata associated with the 1850-1863 blacksmith shop covered by 2 ft. of fill. This building was among the first constructed in the Quartermaster's Depot. The depth of blacksmith shop deposits extended to 3.5 ft. After being destroyed by fire, the blacksmith shop was rebuilt some time before 1871. Traces of the floor of this second building – and perhaps a third – were observed (Thomas and Hibbs 1984:409-438).

Operation 62 consisted of the construction of utility trenches, grading, landscaping, and demolition of old U.S. Army structures prior to the relocation of two duplexes, 643 and 644, that were being moved from the Interstate 5 right-of-way and relocated on new foundations (Thomas and Hibbs 1984:697-705). Backhoe test trenches were excavated on the south and west sides of 643, and on the north and west sides of 644. Several old utility trenches and concrete footings observed were assumed to be associated with a post-World War II U.S. Army building relocation to the 643 site. A privy/trash pit was observed while monitoring a sewer line trench for 643. Artifacts recovered suggest a late-1800s St. James Mission/U.S. Army use. In the north trench of 644, two wooden stakes and a pig burial with a 19th-century artifact scatter above the burial surface were presumed to be associated with St. James Mission.

In 1984, Thomas conducted an archaeological assessment of the ca. 1844-1888 St. James Mission property for improvements to the Federal Highway Administration property on East 5th Street. The author conducted a review of historical maps, documents, and the findings of Thomas and Hibbs (1984) in their 1980-1983 Village excavations to determine the location of structures and features within the Mission grounds that are now on Federal Highway Administration property. Thomas concluded that the preservation of historical material on the Mission grounds in original depositional contexts is highly likely and recommended the site of St. James Mission eligible for the National Register of Historic Places.

West Barracks 1995-2005

Forrest (1995) conducted an archaeological literature review and limited archaeological survey near the Infantry Barracks building at the corner of Barnes and McClellan in the West Barracks area for a proposed sewer realignment project. Three 20 cm shovel probes were excavated to a depth of 20 cm, with no archaeological resources observed. Because of the possibility of encountering more deeply buried deposits, the author recommended monitoring during excavation for the sewer line.

From 2002-2005, archaeological investigations were conducted in the West Barracks area of the VNHR for the pending lease of property and transfer of the area from the U.S. Army to the City of Vancouver. The project called for the revitalization of 16 historical structures, involving the upgrade and repair of existing and the installation of new subsurface utilities, in and around the historical structures. Ground disturbance for these improvements necessitated the excavation of trenches for sewer, water, electrical, and communication lines to a depth of 1.5 m – even deeper in locations of utility vaults. A review of historical maps and previous archaeological studies was supplemented by a magnetic survey in selected areas. Ninety-four 50 x 50 cm STs were excavated throughout the West Barracks area through early 2003 targeting the former location of U.S. Army buildings, magnetic anomalies, and areas deemed likely to contain significant archaeological deposits. The shovel test results were presented in Cromwell and Gembala (2003). The STs that were located closest to Anderson Road are summarized below.

The units can be grouped into four areas, summarized from north to south. The first area extended from Evergreen Boulevard to Anderson Road. Five 50 x 50 cm STs were located to the west of the Vancouver Police Administration building near the current CRC APE. ST98 was located close to the Interstate 5 right-of-way fence and 15 m south of Evergreen Boulevard within the probable footprint of an 1879 Line Officers Quarters building. ST98 showed disturbed sediments and fill with a mix of 19^{th}- and 20^{th}-century artifacts to a depth of 90 cm. ST99, located approximately 18 m east/southeast of ST98, was largely sterile throughout its 70 cm depth, with a few modern artifacts to a depth of 40 cm. ST100, located approximately 14 m southeast of ST99, was largely sterile throughout its 70 cm depth with a few artifacts of mixed 19^{th}- and 20^{th}-century origin to a depth of 40 cm. ST101, located approximately 20 m south of ST98, showed disturbed sediments and a few mixed 19^{th}- and 20^{th}-century artifacts to a depth of 50 cm. A metal pipe was exposed at a depth of 70 cm in ST101. ST102, located approximately 52 m southwest of ST98, showed disturbed sediments and a few mixed 19^{th}- and 20^{th}-century artifacts to a depth of 50 cm. At 50 cm, a PVC pipe was observed in the southeast corner and the unit was terminated. The sediments in the area west of the Vancouver Police Administration building appear to be largely disturbed from the numerous road and utility construction episodes that have occurred in the area over the past decades.

The second portion of West Barracks, from Anderson Road to just south of Barnes Hospital, generally displayed sparse concentrations of late 19^{th}- to early 20^{th}-century artifacts in intact sediments buried under early-to-mid 20^{th}-century fill (Cromwell and Gembala 2003:30). The depth of fill deposits next to Anderson Road in this area was variable, ranging from 1-3 ft. on the west side of Barnes Hospital adjacent to VNHR Area #2. STs on the west side of the hospital showed a variety of mostly 20^{th}-century artifacts. The authors noted that artifacts recovered from ST10 included bones that show signs of butchering with a hand saw, 11 fragments of plaster weighing 4.7 g, 5 fragments of asbestos masonry tile, 1 metal nut, 1 fragment of a machine-made oil lamp base, 1 cupreous square shoe tack, and 1 fragment of 19^{th}-century mirror glass. ST10 contained the second highest concentration of all architectural material: 14.8%. ST19 contained 1, 1918 shotgun shell, 50.28 g of tin containers, 1 bolt, 1 screw, and 13.1% of the total slate recovered by weight, probably associated with the hospital structure's roof. The only noteworthy artifacts recovered from ST28 were off-white or dark gray-green paint fragments.

The third portion of West Barracks, from just south of Barnes Hospital to Hatheway Road, generally displayed sparse concentrations of late 19th- to early 20th-century artifacts in intact sediments, buried under early-to-mid 20th-century fill (Cromwell and Gembala 2003:31). Fill deposits next to Anderson Road in the northern third of this portion were 2-3 ft. deep; fill deposits in the southern two-thirds of this portion were greater than 3 ft. deep. The artifacts recovered from ST39 were unremarkable; ST49 yielded modern machine-cut bone, and one metal washer. While monitoring the digging of electrical trenches in 2004, a feature was revealed at the south end of Barnes Hospital under one meter of imported sand fill, extending the entire width of the building. Artifacts observed were consistent with cleanout deposits from the hospital incinerator.

The southern portion of West Barracks, from Hatheway Road to East 5th Street, generally displayed sparse concentrations of late 19th- to early 20th-century artifacts in intact sediments, buried under thick deposits (2-5 ft.) of early-to-mid 20th-century fill (Cromwell and Gembala 2003:33). Artifacts found in ST66 include 1 bolt, 1 machine screw, and 1 complete gray and white opaque chert dart point recovered from 20th-century fill. The point was 4.7 cm long, shouldered, had an expanding stem and convex base, and showed evidence of heat treatment. Such projectile points date from approximately 2500-1750 BP. There was also a concentration of wood in ST66 recovered from the fill stratum, judged to be from one of the many NCO quarters that was demolished in that area in the mid-20th century.

A magnetic survey was conducted in the Holy Angels College area in the southwestern lawn area of the West Barracks. Subsurface linear anomalies were located that were associated with utility trenches and a manhole cover. A rectangular array of subsurface anomalies at the location of Holy Angels College (which became U.S. Army NCO Quarters) suggested pedestals associated with a building foundation. ST73, ST74, ST74A, and ST74B were placed in the area of these anomalies and produced architectural remains of the structure.

ST73 was located in the northwest portion of the former St. James Mission property. Below 80 cm of fill was an intact stratum containing a dense (1060 artifacts/m^3) assortment of late 19th- and early 20th-century artifacts. Material recovered included 19 wire nails, 4 fragments of vessel glass, 1 fragment of flat glass, 1 piece of unidentified iron, 3 fragments of machine-pressed opaque white glass jar liner, and 2 fragments of small white glass Prosser molded buttons. Prosser buttons, first patented in 1849 and common into the 1920s, are still made to this day.

Shovel tests ST74, ST74A, and ST74B, located twenty meters east of ST73, were found to contain a similar layer of fill to a depth of approximately 60 cm. At 60 cm, the same buried A horizon was encountered with a similar density of late 19th- and early 20th-century artifacts. Cromwell and Gembala concluded that, based upon cartographic analysis and the high density of late 19th- and early 20th-century artifacts, it is likely that this area is associated with the St. James Catholic Mission Holy Angels College structure, ca. 1865-1937 (Cromwell and Gembala 2003:65). Concentrations of intact, mid-to-late 19th-century and early 20th-century artifacts and features were encountered in ST63, ST64, ST73, ST74, ST74A, and ST78 in the southern portion of West Barracks.

Further archaeological excavations in West Barracks in late 2003 through 2005 consisted of more extensive testing at sites east of VNHR Area #2 on McClellan Road and Martin Court, and data recovery operations at the location of the 1851-1860 palisaded sutler's store in the middle of Hatheway Road in front of the Artillery Barracks building. Discovering the location of the sutler's store has improved our ability to cartographically project the location of other buildings found on historical maps of the VNHR.

Cromwell 2006

In 2006, the NPS conducted archaeological testing for proposed landscaping (Cromwell 2006a) and sidewalk construction (Cromwell 2006b) at the FHWA Western Federal Lands Highway Division facility. Eight 50 x 50 cm STs were excavated between the buildings and East 5th Street at the proposed location of trees to be planted as part of the landscaping plan. Units were excavated in stratigraphic levels, or in 10 cm arbitrary levels within levels greater than 10 cm deep. Sediments were screened through ¼ and ⅛ in. mesh. STs were numbered from east to west, beginning with ST01. ST01 and ST04 were the only units that contained artifacts other than modern construction debris. Fill was observed to a depth of 80-100 cm in all units. ST01 contained fill to a depth of 92 cm, below which was an intact HBC-era stratum. Two ceramic patterns identified in this layer had a mean ceramic date of 1848. The author suggests that these fragments may have been from an undocumented Village house or from the St. James Mission priest's house that was located approximately 50 ft. to the east. ST04 contained fill with mixed 19th- and 20th-century artifacts to a depth of 70 cm. The unit was sterile from 70 to 100 cm. In ST07 and ST08, those units closest to VNHR Area #2, an impenetrable lens of dense gravel was encountered at 90-100 cm (Cromwell 2006a).

Three 50 x 50 cm shovel tests (ST09, ST10, and ST11) were excavated at an interval of 3-5 m on the north side of the FHWA Western Federal Lands Highway Division facility for a proposed sidewalk (Cromwell 2006b). Units were excavated in stratigraphic levels, or in 10 cm arbitrary levels within natural strata greater than 10 cm deep. Sediments were screened through ¼ and ⅛ in. mesh. Three separate imported fill events could be seen in the stratigraphic profiles of all three STs to approximately 50-55 cm, overlying a buried A horizon containing a dense deposit of mid-19th-century artifacts to a depth of approximately 70-85 cm. In ST09, the intact buried A horizon was encountered from 52-62 cm to 72 cm. A 30 cm wide electrical utility trench bisected the unit, and a gray PVC pipe was encountered at a depth of 90 cm. Material from the utility trench were screened separately from intact sediments from a depth of 30-90 cm. Sterile B-horizon sediments were found below 72 cm in the undisturbed portion of the unit. The intact buried A horizon in ST10 and ST11 was observed from approximately 55-85 cm, with sterile B-horizon sediments below 85 cm. The results of these STs suggested a significant mid-19th-century deposit of material associated with either the St. James Catholic Mission (1844-1888) or the U.S. Army's Vancouver Barracks (1849-1900). The density of mid-19th-century material exceeded 500 artifacts/m^3 in ST10 and ST11 from 55 to 100 cm. Because of the depth of fill over these deposits, Cromwell recommended that the sidewalk project be allowed to proceed if ground disturbance did not penetrate the top 50 cm of fill (Cromwell 2006b).

METHODS

The National Park Service conducted archival research, geophysical surveys, and archaeological test excavations within the CRC APE in VNHR Area #2, from the south side of Evergreen Boulevard, south along Anderson Road, in the FHWA Western Federal Lands Highway Division parking lot, and on the west end of East 5th Street, to identify archaeological resources that may be adversely affected by the CRC project.

Geophysical Surveys

Steve De Vore of the Midwest Archaeological Center of the National Park Service conducted a GPR survey of the portions of VNHR Area #2 on Anderson Road and the west end of East 5th Street, using a 400 MHz antenna, on February 21, 2009.

Curt Peterson of Portland State University/HRA conducted GPR surveys in 2008 in the area between Evergreen Boulevard and Anderson Road, the FHWA Western Federal Lands Highway Division parking lot, and the west end of East 5th Street. Four transects were surveyed between Evergreen Boulevard and Anderson Road: two transects using a 200 MHz antenna (June 18, 2008), and two transects using a 500 MHz antenna (August 15, 2008). Two transects were surveyed within the FHWA parking lot and six transects were surveyed at the west end of East 5th Street, all using a 200 MHz antenna, on June 15, 2008. The results of the radar survey were presented as vertical profiles of the surveyed transects. UTM coordinates of the transect ends were provided so that the location of the GPR profiles could be accurately displayed on CRC project maps and entered into the VNHR GIS database.

Archaeological Test Excavations

The NPS conducted subsurface testing within VNHR Area #2 to target anomalies seen in the GPR surveys, in areas of possible historical buildings and features seen on historical maps and documents, to answer the questions outlined in the Project Goals section, and at regular intervals throughout the project area. Anticipated resources in this area included archaeological deposits associated with the 1879 Line Officers Quarters and 1918 temporary U.S. Army hospital structures between Evergreen Boulevard and Anderson Road; 1887 Barnes Hospital Annex, 1888 Old Post Hospital, two 1935 brick duplex residences, 1919 Provost Marshal Quarters, 1885 Hospital Stewards Quarters, and 1907 Hospital Corps Sergeants Quarters on Anderson Road; 1851 Blacksmith Shop in the FHWA parking lot; and 1859 Workshops and 1851 Carpenter Shop and Store Rooms on East 5th Street.

The ground surface of the CRC APE within VNHR Area #2 was largely covered by pavement, with the exception of the landscaped lawn area from Evergreen Boulevard to Anderson Road and a small area west of the FHWA Western Federal Lands Highway Division parking lot. Mechanical excavation of exploratory trenches was conducted to sample the sediments. For each trench within a paved area, a 3.3 x 1.3 m (10 x 4 ft.) rectangle was cut through the asphalt with a pavement saw. A small Bobcat excavator was used to break up and remove the asphalt. A backhoe with an 18 in. (46 cm) toothed bucket was used to excavate within the trenches and in unpaved areas to access cultural strata below deep deposits of cobbly fill and construction debris. Excavation units in paved areas were refilled to the level of the road surface with backdirt from the units after they were excavated, then repaved by WSDOT.

EXCAVATION RESULTS

From June 29 through August 14, 2009, the NPS conducted archaeological testing in VNHR Area #2 from Evergreen Boulevard on the north to East 5th Street on the south. For ease of discussion, VNHR Area #2 is divided into three segments from north to south. The northern area includes the landscaped area west of the Vancouver Police Administration building along the Interstate 5 freeway right-of-way fence between Evergreen Boulevard and Anderson Road. The central area includes Anderson Road and the west edge of West Barracks to the FHWA Western Federal Lands Highway Division property. The southern area includes the FHWA property, from the edge of the parking lot west to the Interstate 5 right-of-way fence, and the west end of East 5th Street.

Nineteen exploratory backhoe trenches totaling 43.1 m in length (102.5 m^2) were excavated within VNHR Area #2 (Table 7). Trenches included 13 trenches in the central portion of VNHR Area #2 on Anderson Road (Trench 2-01 through Trench 2-13), 3 trenches in the southern portion of VNHR Area #2 in the FHWA Western Federal Lands Highway Division parking lot (Trench 2-14 through Trench 2-16), and 3 trenches in the southern portion of VNHR Area #2 at the west end of East 5th Street (Trench 2-17 through Trench 2-19).

One TU (1.0 m^2) and eleven STs (2.75 m^2) were excavated within VNHR Area #2. Units included 10 STs in the northern portion of VNHR Area #2 between Evergreen Boulevard and Anderson Road (ST2-07 through ST2-16), and TU2-01and ST2-06 in the southern portion of VNHR Area #2 (Table 8). No features were observed in this portion of the project area. Directions given in the text are relative to the orientation of the GPR grids.

West Barracks Northern Area

The northern portion of West Barracks VNHR Area #2 was located along a 90 m (295 ft.) transect in a landscaped area between Evergreen Boulevard on the north and Anderson Road on the south within 10 m (33 ft.) of the Interstate 5 right-of-way fence (Figure 30). The northern part of this transect west of the Police Administration building was the location of a 1879 Line Officers Quarters. The southern part of this transect was the location of 1918 temporary U.S. Army hospital structures. Ten STs (ST2-07 through ST2-16) were excavated in this area (Figure 31). STs were oriented to true north (with the exception of ST2-07) and excavated to B-horizon sediments.

The stratigraphic sequence observed within the northern portion of VNHR Area #2 showed ground disturbance from the demolition of the Line Officers Quarters, and from the 1950s construction of the Interstate 5 freeway and subsequent landscaping. An example of the stratigraphic sequence for this area is described below for ST2-08 (Figure 32).

TABLE 7
EXPLORATORY BACKHOE TRENCHES WITHIN VNHR AREA #2

Trench	Dimensions (cm)				Associated Test Unit	
	Width	Length	Depth of Fill	Maximum Depth	Unit	Findings*
Central						
2-01	58	180	>189	189	-	-
2-02	62	200	>192	192	-	-
2-03	53	230	>192	192	-	-
2-04	60	220	>200	200	-	-
2-05	58	200	159	168	-	-
2-06	64	220	>187	187	-	-
2-07	52	250	174	192	-	-
2-08	60	210	>192	192	-	-
2-09	58	220	>191	191	-	-
2-10	62	200	120	142	-	-
2-11	62	260	38	135	-	-
2-12	58	190	65	97	-	-
2-13	62	280	55	96	-	-
Southern						
2-14	70	230	104	148	-	+
2-15	100	250	170	175	-	-
2-16	70	210	>122	122	TU2-01	+
2-17	120	280	102	175	-	+
2-18	60	230	130	143	-	-
2-19	60	250	160	164	-	-

*significant archaeological deposits in intact strata (+ or -)

TABLE 8
ARCHAEOLOGICAL TEST UNITS AND SHOVEL TESTS WITHIN VNHR AREA #2

Unit	Backhoe Trench	Maximum Depth (cm)	Findings
Northern			
ST2-07	-	54	disturbed
ST2-08	-	68	disturbed
ST2-09	-	75	disturbed
ST2-10	-	89	disturbed
ST2-11	-	86	disturbed
ST2-12	-	50	disturbed
ST2-13	-	51	disturbed
ST2-14	-	50	1879 Line Officers Quarters
ST2-15	-	50	1879 Line Officers Quarters
ST2-16	-	80	1879 Line Officers Quarters
Southern			
ST2-06	2-14	150	disturbed, 1851 Blacksmith Shop
TU2-01	2-16	224	1859 Workshops

FIGURE 30. Northern portion of the area of NPS archaeological testing in VNHR Area #2 between Evergreen Boulevard and Anderson Road, facing grid south. (NPS 09-15:2099, 8/17/09)

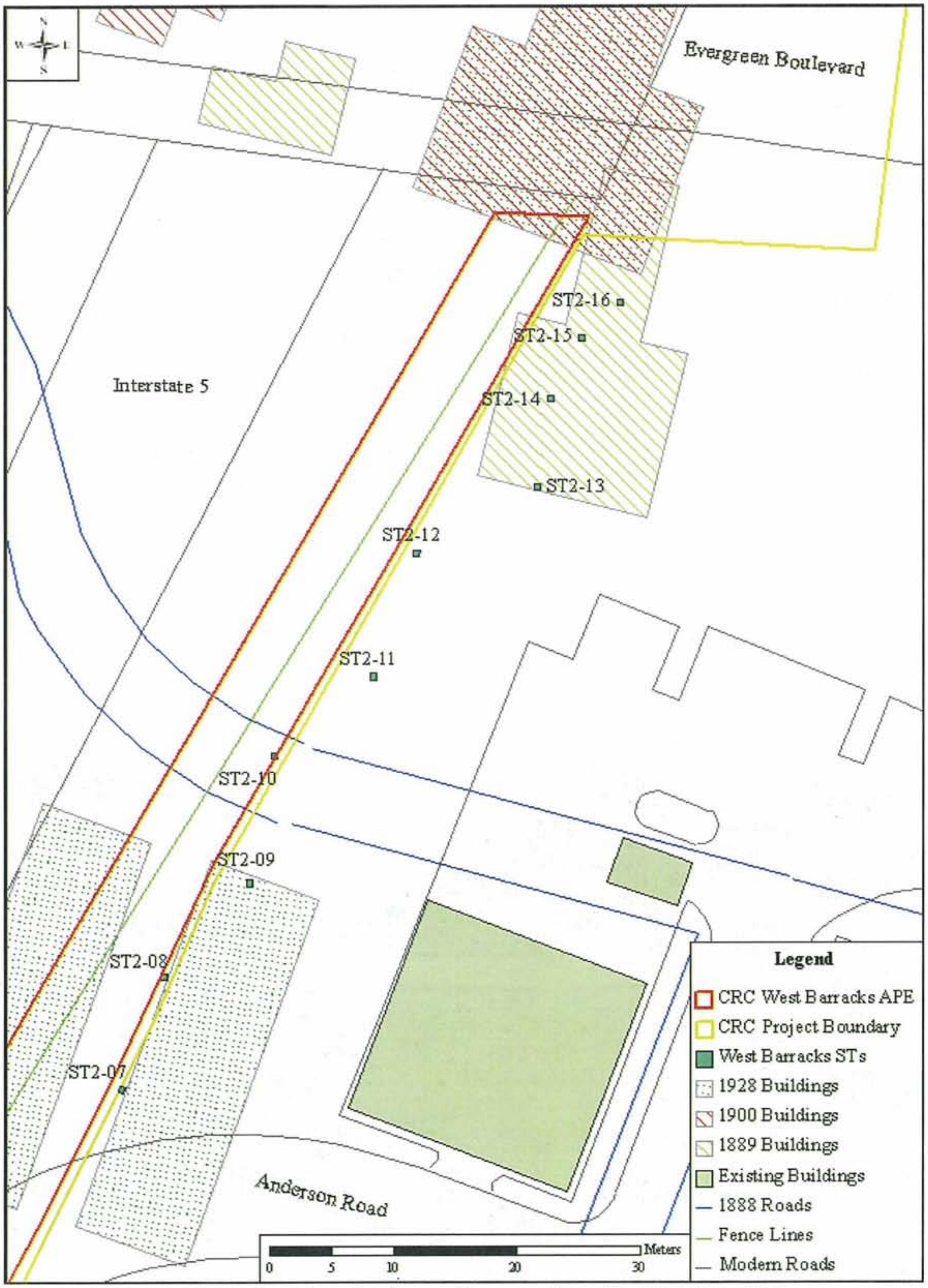

FIGURE 31. ST2-07 through ST2-16 in the northern portion of VNHR Area #2 between Evergreen Boulevard and Anderson Road. (NPS 2010)

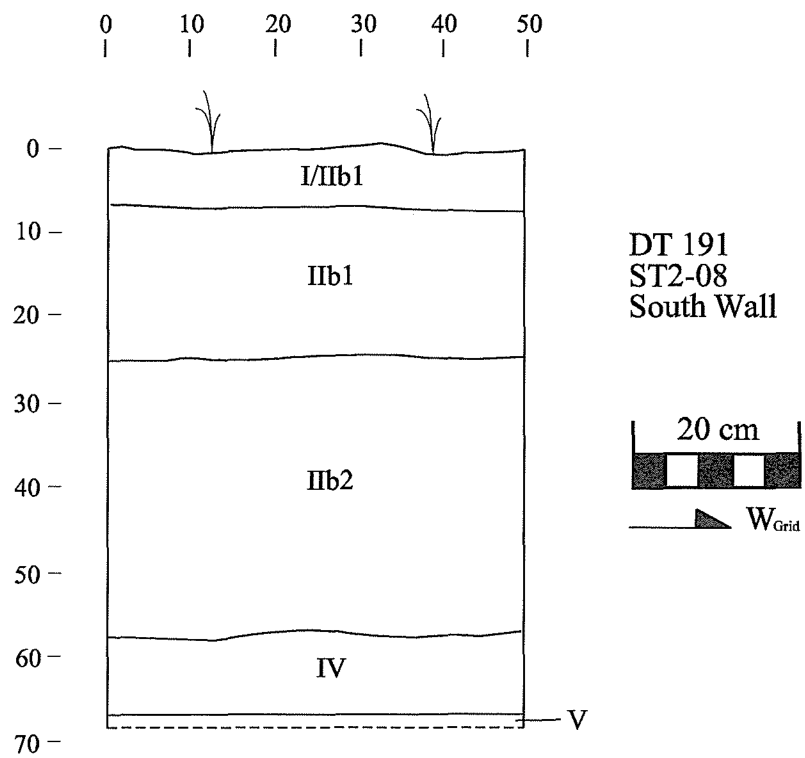

FIGURE 32. South wall profile of ST2-08 in the northern portion of VNHR Area #2. (NPS 2010)

Stratum I:	Sod/topsoil, 10YR3/3 dark brown silt loam, 10% gravels, duff, small roots, modern debris.
Stratum IIb1:	Very dry and compact 10YR3/4 dark yellowish brown silt loam, 70% subrounded gravels and cobbles, road construction debris, few 20th-century artifacts.
Stratum IIb2:	Compact 10YR3/4 dark yellowish brown silt loam, decreasing gravels and increasing cobbles, road construction debris, few 20th-century artifacts.
Stratum IV:	B horizon, 10YR3/4 dark yellowish brown gravelly silt loam, culturally sterile.
Stratum V:	C horizon, loose sand and gravels, culturally sterile.

West Barracks Northern Area Shovel Tests

Data on the volume of sediments excavated and the number of artifacts recovered from the STs in the northern portion of VNHR Area #2 are presented in Table 9.

ST2-07

ST2-07 was excavated beginning 6.5 m grid north of Anderson Road, in the location of the 1918 temporary U.S. Army hospital structures. Two layers of dry, compact gravelly fill were observed beneath the topsoil. The lower stratum contained a greater number of cobbles. B-horizon sediments were observed at 35 cm; the unit was terminated at 54 cm. A few 20th-century artifacts were recovered.

ST2-08

ST2-08 was excavated beginning 9.5 m grid north of ST2-07, in the location of the 1918 temporary U.S. Army hospital structures. Two layers of dry, very compact gravelly fill with road construction debris were observed beneath the topsoil. Gravels decreased and cobbles increased with depth. B-horizon sediments were observed at 57 cm. C-horizon sediments were observed at 66 cm; the unit was terminated at 68 cm. A moderate number of mainly 20th-century artifacts were recovered.

ST2-09

ST2-09 was excavated beginning 10.2 m grid north of ST2-08, in the location of the 1918 temporary U.S. Army hospital structures. Two layers of dry, very compact gravelly fill with road construction debris were observed beneath the topsoil. Gravels decreased and cobbles increased with depth. B-horizon sediments were observed at 60 cm; the unit was terminated at 75 cm. A moderate number of mainly 20th-century artifacts were recovered.

ST2-10

ST2-10 was excavated beginning 10.5 m grid north of ST2-09. Fill sediments below the topsoil consisted of 66 cm of brown coarse sand with 60-70% gravels, over 19 cm of brown silty sand with 40% gravels (both strata possibly from the same fill episode). B-horizon sediments were not reached; the unit was terminated at 89 cm. Several mainly 20th-century artifacts were recovered.

ST2-11

ST2-11 was excavated beginning 10 m grid north of ST2-10. Fill sediments below the topsoil consisted of 25 cm of brown coarse sand with 40% gravels, over 55 cm of dark brown sand with 30% gravels. The lower two strata may represent the same fill episode. B-horizon sediments were not reached; the unit was terminated at 86 cm. A moderate number of mixed 19th- and 20th-century artifacts were recovered.

ST2-12

ST2-12 was excavated beginning 10.5 m grid north of ST2-11. Fill sediments below the topsoil consisted of 42 cm of dark brown silt loam with 50% gravels. The size of the gravels and number of cobbles increased with depth. B-horizon sediments were not reached; the unit was terminated at 50 cm. A moderate number of mainly 20th-century artifacts were recovered.

TABLE 9
EXCAVATION RESULTS FOR THE NORTHERN PORTION OF VNHR AREA #2

Level/ Feature	Mean Depth (cm)	Volume (m^3)	Total Artifacts	Artifacts ($/m^3$)	Ceramics	Flat Glass	Vessel Glass	Nails	Other 19^{th}-c. Artifacts*
ST2-07									
1	0-5	0.0125	1	80	-	-	-	1	-
2	5-11	0.0150	2	133	-	-	-	-	-
3	11-21	0.0250	1	40	-	-	-	-	-
4	21-31	0.0250	2	80	-	1	-	-	-
5	31-41	0.0250	2	80	-	-	2	-	-
6	41-54	0.0325	-	-	-	-	-	-	-
Total		0.1350	8	59	-	1	2	1	-
ST2-08									
1	0-10	0.0250	5	200	1	-	1	-	-
2	10-20	0.0250	27	1080	-	-	11	2	-
3	20-30	0.0250	15	600	-	-	-	-	-
4	30-40	0.0250	28	1120	-	-	-	-	-
5	40-53	0.0325	18	554	-	-	1	-	-
6	53-63	0.0250	-	-	-	-	-	-	-
7	63-68	0.0125	-	-	-	-	-	-	-
Total		0.1700	93	547	1	-	13	2	-
ST2-09									
1	0-10	0.0250	7	280	-	1	1	-	-
2	10-20	0.0250	11	440	-	-	-	-	-
3	20-30	0.0250	27	1080	-	5	2	-	-
4	30-40	0.0250	4	160	-	-	-	-	-
5	40-50	0.0250	7	280	-	1	1	1	1
6	50-60	0.0250	27	1080	-	-	1	-	-
7	60-75	0.0375	-	-	-	-	-	-	-
Total		0.1875	83	443	-	7	5	1	1
ST2-10									
1	0-10	0.0250	13	520	-	-	-	2	-
2	10-20	0.0250	1	40	-	-	-	-	-
3	20-30	0.0250	9	360	-	-	-	-	-
4	30-40	0.0250	4	160	-	-	-	-	-
5	40-50	0.0250	9	360	-	-	1	-	-
6	50-60	0.0250	6	240	-	-	4	-	-
7	60-70	0.0250	9	360	1	-	-	-	-
8	70-80	0.0250	7	280	1	-	1	-	-
9	80-89	0.0225	2	89	-	-	-	-	-
Total		0.2225	60	270	2	-	6	2	-

Continued on next page

TABLE 9
EXCAVATION RESULTS FOR THE NORTHERN PORTION OF VNHR AREA #2 (CONT.)

Level/ Feature	Mean Depth (cm)	Volume (m^3)	Total Artifacts	Artifacts ($/m^3$)	Ceramics	Flat Glass	Vessel Glass	Nails	Other 19th-c. Artifacts*
ST2-11									
1	0-10	0.0250	6	240	-	1	-	-	-
2	10-20	0.0250	3	120	-	-	-	1	-
3	20-30	0.0250	5	200	-	1	1	1	-
4	30-40	0.0250	30	1200	-	-	-	1	-
5	40-50	0.0250	14	560	-	2	-	-	-
6	50-60	0.0250	14	560	-	2	8	-	-
7	60-70	0.0250	1	40	-	-	-	-	-
8	70-80	0.0250	16	640	1	-	5	-	-
9	80-86	0.0150	1	67	-	-	1	-	-
Total		0.2150	90	419	1	6	15	3	-
ST2-12									
1	0-10	0.0250	15	600	-	2	-	-	-
2	10-20	0.0250	9	360	-	-	-	-	-
3	20-30	0.0250	13	520	-	-	-	-	-
4	30-40	0.0250	34	1360	-	1	1	1	-
5	40-50	0.0250	20	800	-	2	9	-	-
Total		0.1250	91	728	-	5	10	1	-
ST2-13									
1	0-10	0.0250	3	120	-	-	1	1	-
2	10-20	0.0250	5	200	-	-	1	2	-
3	20-30	0.0250	-	-	-	-	-	-	-
4	30-40	0.0250	-	-	-	-	-	-	-
5	40-51	0.0275	-	-	-	-	-	-	-
Total		0.1275	8	63	-	-	2	3	-
ST2-14									
1	0-10	0.0250	2	80	-	1	-	-	-
2	10-20	0.0250	36	1440	-	7	2	4	-
3	20-30	0.0250	8	320	-	-	1	-	-
4	30-40	0.0250	4	160	-	-	-	-	-
5	40-50	0.0250	-	-	-	-	-	-	-
Total		0.1250	50	400	-	8	3	4	-

Continued on next page

TABLE 9
EXCAVATION RESULTS FOR THE NORTHERN PORTION OF VNHR AREA #2 (CONT.)

Level/ Feature	Mean Depth (cm)	Volume (m^3)	Total Artifacts	Artifacts ($/m^3$)	Ceramics	Flat Glass	Vessel Glass	Nails	Other 19^{th}-c. Artifacts*
ST2-15									
1	0-10	0.0250	9	360	-	-	-	-	-
2	10-20	0.0250	97	3880	-	77	2	4	-
3	20-30	0.0250	32	1280	-	6	-	-	-
4	30-40	0.0250	45	1800	-	-	1	-	-
5	40-50	0.0250	4	160	-	-	-	-	-
Total		0.1250	187	1496	-	83	3	4	-
ST2-16									
1	0-10	0.0250	14	560	-	1	4	2	-
2	10-20	0.0250	27	1080	-	2	9	2	-
3	20-30	0.0250	54	2160	-	1	4	5	-
4	30-40	0.0250	116	4640	-	3	1	7	-
5	40-50	0.0250	100	4000	-	6	-	13	4
6	50-60	0.0250	196	7840	1	18	-	11	1
7	60-70	0.0250	8	320	-	-	-	-	-
8	70-80	0.0250	-	-	-	-	-	-	-
Total		0.2000	515	2575	1	31	18	40	5
GRAND TOTAL		**1.6325**	**1185**	**726**	**5**	**141**	**77**	**61**	**6**

*Personal and domestic items

ST2-13
ST2-13 was excavated beginning 11 m grid north of ST2-12, in the location of an 1879 Line Officers Quarters building. Fill sediments below the topsoil consisted of 27 cm of very dry dark grayish brown sandy loam with 15% gravels. B-horizon sediments were observed at 30 cm; the unit was terminated at 51 cm. A few 20th-century artifacts were recovered.

ST2-14
ST2-14 was excavated beginning 7.2 m grid north of ST2-13, in the location of an 1879 Line Officers Quarters building. Fill sediments below the topsoil consisted of 15 cm of dark yellowish brown silt loam with 15% gravels (redeposited B horizon?) containing a concentration of building demolition debris. Intact B-horizon sediments were observed at 23 cm; the unit was terminated at 50 cm. A moderate number of mixed 19th-and 20th-century artifacts were recovered.

ST2-15
ST2-15 was excavated beginning 5.6 m grid north of ST2-14, in the location of an 1879 Line Officers Quarters building. Fill sediments below the topsoil consisted of 17 cm of grayish brown silt loam with 20% gravels containing a concentration of building demolition debris, over 15 cm of mottled grayish brown and yellowish brown silt loam with 25% gravels. The size of the gravels and number of cobbles increased with depth. B-horizon sediments were observed at 40 cm; the unit was terminated at 50 cm. A moderate number of mixed 19th- and 20th-century artifacts were recovered.

ST2-16
ST2-16 was excavated 14.5 m south of Evergreen Boulevard, beginning 4 m grid north of ST2-15, in the location of an 1879 Line Officers Quarters building. Fill sediments below the topsoil consisted of 55 cm of dark yellowish brown silt loam with 25% gravels, containing abundant artifacts, brick, and other building demolition debris. This buried cultural layer appears to have undergone some mixing with the underlying B horizon. Undisturbed B-horizon sediments were reached at 60 cm; the unit was terminated at 80 cm. A large number of mixed 19th- and 20th-century artifacts were recovered.

West Barracks Central Area

The central portion of VNHR Area #2 was located within a 240 m (787 ft.) paved portion of Anderson Road parallel to the Interstate 5 right-of-way fence, from the north end of the Barnes Hospital on the north to the FHWA Western Federal Lands Highway Division parking lot on the south (Figures 33-35). This area was the location of several 19th- and 20th-century U.S. Army buildings, including the 1887 Barnes Hospital Annex, 1888 Old Post Hospital, two 1935 brick duplex residences, 1919 Provost Marshal Quarters, 1885 Hospital Stewards Quarters, and 1907 Hospital Corps Sergeants Quarters. Thirteen exploratory backhoe trenches (Trench 2-01 through Trench 2-13) were excavated in this area (Figure 36).

Asphalt was cut with a pavement saw and removed using a Bobcat excavator. Trenches were excavated with a backhoe to the depth of B-horizon sediments or to the maximum reach of the backhoe. Profiles were drawn of a one-meter segment of each trench. Trenches deeper than 120 cm were profiled from the surface, and lower stratum depths were approximated. Directions given in the text are relative to the orientation of the GPR grid: grid north is approximately 24° east of true north.

FIGURE 33. Central portion of the area of NPS archaeological testing in VNHR Area #2 at the north end of Anderson Road, facing grid south. (NPS 09-04:137-3775, 2/19/09)

FIGURE 34. Central portion of the area of NPS archaeological testing in VNHR Area #2 in the middle of Anderson Road, showing a patched trench excavation, facing grid south. (NPS 09-15:2097, 8/17/09)

FIGURE 35. Central portion of the area of NPS archaeological testing in VNHR Area #2 at the south end of Anderson Road, facing grid north. (NPS 09-04:137-3772, 2/19/09)

FIGURE 36. Exploratory backhoe trenches (numbered 1-13) in the central portion of VNHR Area #2 on Anderson Road. (NPS 2010)

The stratigraphic sequence observed within the central portion of VNHR Area #2 is largely disturbed due to many episodes of building and road construction, relocation, and demolition. Sediments were further disturbed during the construction of the Interstate 5 freeway, largely obliterating intact cultural deposits and evidence of disturbances before the early 1950s. Up to seven layers of fill were observed in the area of Trench 2-01 through Trench 2-10, reaching over 200 cm deep in places, with considerable local variation. Conversely, sediments have been cut and removed in the area of Trench 2-11 through Trench 2-13. An example of the stratigraphic sequence for this area is described below for Trench 2-05 (Figure 37).

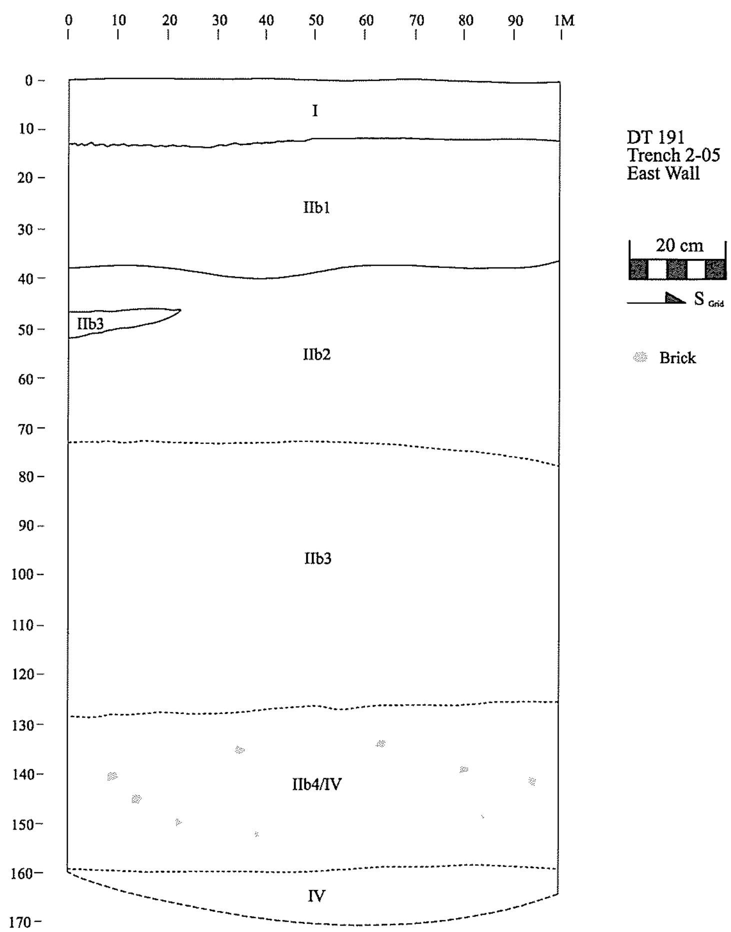

FIGURE 37. East wall profile of backhoe Trench 2-05 in the central portion of VNHR Area #2. (NPS 2010)

Stratum I:	Asphalt pavement over a thin machine-cut gravel base layer.
Stratum IIb1:	5Y2.5/1 black angular machine-crushed gravels, no artifacts.
Stratum IIb2:	10YR3/3 dark brown loamy sand, abundant gravels and cobbles, no artifacts.
Stratum IIb3:	5Y2.5/1 black sand, no artifacts.
Stratum IIb4:	10YR3/3 dark brown gravelly silt loam, few brick fragments.
Stratum IV:	B horizon, 10YR3/4 dark yellowish brown gravelly silt loam, culturally sterile.

West Barracks Central Area Backhoe Trenches

Trench 2-01

Trench 2-01 was excavated beginning 60 cm grid south of the northern boundary of this portion of the project area. Sediments observed consisted of at least five fill episodes below the asphalt: 5 cm of black asphalt underlay, over 18 cm of very dark gray crushed gravel, over 59 cm of dark brown sandy loam, over 44 cm of gray sand, over 55 cm of dark brown sandy loam. B-horizon sediments were not reached; the trench was terminated at 189 cm. No artifacts were observed.

Trench 2-02

Trench 2-02 was excavated beginning 18.4 m grid south of the northwest corner of Trench 2-01, in the location of a GPR anomaly and the previous location of the 1904 Barnes Hospital south wing. Sediments observed consisted of at least three fill episodes below the asphalt: 2 cm of black asphalt underlay, over 17 cm of very dark gray crushed gravel, over 163 cm of dark brown sandy loam. B-horizon sediments were not reached; the trench was terminated at 192 cm. A grab sample consisted of one artifact. The GPR anomaly was judged to have been caused by ground disturbance associated with relocation of the hospital wing.

Trench 2-03

Trench 2-03 was excavated beginning 22.7 m grid south of the northwest corner of Trench 2-02, in the location of a GPR anomaly and the previous location of the 1904 Barnes Hospital south wing. Sediments observed consisted of at least seven fill episodes below the asphalt: 2 cm of black asphalt underlay, over 21 cm of very dark gray crushed gravel, over 17 cm of black silt loam, over 14 cm of dark brown coarse loamy sand, over 6 cm of gray sand, over 12 cm of black macadam, over 112 cm of dark brown silt loam. B-horizon sediments were not reached; the trench was terminated at 192 cm. No artifacts were observed. The GPR anomaly was judged to have been caused by ground disturbance associated with the relocation of the hospital wing.

Trench 2-04

Trench 2-04 was excavated beginning 17 m grid south of the northwest corner of Trench 2-03. Sediments observed consisted of at least three fill episodes below the asphalt: 2 cm of black asphalt underlay, over 20 cm of very dark gray crushed gravel, over 167 cm of dark brown loamy sand. B-horizon sediments were not reached; the trench was terminated at 200 cm. A grab sample consisted of one artifact.

Trench 2-05

Trench 2-05 was excavated beginning 20 m grid south of the northwest corner of Trench 2-04, in the location of a GPR anomaly. This area is also the location of an artifact-rich ash deposit observed in 2004 at the south end of the 1904 Barnes Hospital. Sediments observed consisted of five fill episodes below the asphalt: 2 cm of black asphalt underlay, over 26 cm of very dark gray crushed gravel, over 33 cm of dark brown loamy sand, over 54 cm of gray sand, over 32 cm of dark brown silt loam B-horizon transitional deposits. B-horizon sediments were reached at 159 cm; the trench was terminated at 168 cm. No artifacts were observed. The GPR anomaly was judged to have been caused by ground disturbance associated with the relocation of the hospital wing. It appears that the ash deposit does not extend into Anderson Road.

Trench 2-06

Trench 2-06 was excavated beginning 10.7 m grid south of the northwest corner of Trench 2-05. Sediments observed consisted of at least five fill episodes below the asphalt: 4 cm of black asphalt underlay, over 20 cm of very dark gray crushed gravel, over 9 cm of dark brown loamy sand, over 7 cm of gray sand, over 139 cm of dark brown loamy sand. B-horizon sediments were not reached; the trench was terminated at 187 cm. No artifacts were observed.

Trench 2-07

Trench 2-07 was excavated beginning 15.4 m grid south of the northwest corner of Trench 2-06, in the location of a GPR anomaly and the previous location of the 1888 Old Post Hospital. Sediments observed consisted of at least three fill episodes below the asphalt: 2 cm of black asphalt underlay, over 20 cm of very dark gray crushed gravel, over 142 cm of dark brown loamy sand. B-horizon deposits were reached at 174 cm; the trench was terminated at 192 cm. A grab sample consisted of one artifact. The GPR anomaly was judged to have been caused by ground disturbance associated with the demolition of the Old Post Hospital.

Trench 2-08

Trench 2-08 was excavated beginning 17.2 m grid south of the northwest corner of Trench 2-07, in the location of a GPR anomaly, and near the previous location of the 1888 Old Post Hospital and a 1939 brick duplex. Sediments observed consisted of at least three fill episodes below the asphalt: 2 cm of black asphalt underlay, over 20 cm of very dark gray crushed gravel, over 160 cm of dark brown loamy sand. B-horizon sediments were not reached; the trench was terminated at 192 cm. A grab sample consisted of two artifacts. The GPR anomaly was judged to have been caused by ground disturbance associated with the demolition of the Old Post Hospital and the relocation of the duplex.

Trench 2-09

Trench 2-09 was excavated beginning 16.2 m grid south of the northwest corner of Trench 2-08, in the location of a GPR anomaly and near the previous location of a 1939 brick duplex. Sediments observed consisted of at least three fill episodes below the asphalt: 6 cm of black asphalt underlay, over 16 cm of very dark gray crushed gravel, over 159 cm of dark brown loamy sand. B-horizon sediments were not reached; the trench was terminated at 191 cm. A grab sample consisted of six artifacts. The GPR anomaly was judged to have been caused by ground disturbance associated with relocation of the duplex.

Trench 2-10

Trench 2-10 was excavated beginning 34.3 m grid south of the northwest corner of Trench 2-09, near the previous location of the 1919 Provost Marshal quarters and a 1939 brick duplex. Sediments observed consisted of six fill episodes below the asphalt: 2 cm of black asphalt underlay, over 23 cm of very dark gray crushed gravel, over 2 cm of very dark brown silt loam, over 49 cm of black sandy loam, over 22 cm of dark brown loam, over 13 cm of black silt loam. B-horizon sediments were reached at 120 cm; the trench was terminated at 142 cm. A grab sample consisted of two artifacts.

Trench 2-11
Trench 2-11 was excavated beginning 15 m grid south of the northwest corner of Trench 2-10, near the previous location of the 1919 Provost Marshal quarters. Sediments observed consisted of three fill episodes below the asphalt: 2 cm of black asphalt underlay, over 24 cm of very dark gray crushed gravel, over 2 cm of very dark brown silt loam. B-horizon sediments were reached at 38 cm; an intrusive utility trench with a metal pipe was observed cutting through the B horizon from 40-98 cm. The trench was terminated at 135 cm; no artifacts were observed.

Trench 2-12
Trench 2-12 was excavated beginning 25.5 m grid south of the northwest corner of Trench 2-11, in the location of a GPR anomaly, and near the previous location of the 1919 Provost Marshal quarters and another small 1919 building. Sediments observed consisted of five fill episodes below the asphalt: 2 cm of black asphalt underlay, over 21 cm of gray crushed gravel, over 19 cm of very dark grayish brown sandy loam, over 9 cm of black sandy loam, over 4 cm of very pale brown ash. B-horizon sediments were reached at 65 cm; the trench was terminated at 97 cm. A grab sample consisted of two artifacts. The GPR anomaly was judged to have been caused by ground disturbance associated with the demolition of the small building and the relocation of the Provost Marshal quarters.

Trench 2-13
Trench 2-13 was excavated beginning 21.6 m grid south of the northwest corner of Trench 2-12, 6.4 m from the grid south end of this portion of the project area, and in the previous location of a small 1919 building. Sediments observed consisted of three fill episodes below the asphalt: 2 cm of black asphalt underlay, over 30 cm of gray crushed gravel, over 13 cm of very dark grayish brown sandy loam. B-horizon sediments were reached at 55 cm; the trench was terminated at 96 cm. No artifacts were observed.

West Barracks Southern Area

The southern portion of VNHR Area #2 was located within the FHWA Western Federal Lands Highway Division parking lot and at the west end of East 5th Street within 15 m of the Interstate 5 right-of-way fence (Figures 38-39). This area was the location of the 1851 Blacksmith Shop in the northwest corner of the FHWA parking lot, 1859 Workshops on the north side of East 5th Street, and 1851 Carpenters Shop and Store Room within East 5th Street. Three exploratory backhoe trenches (Trench 2-14 through Trench 2-16), TU2-01, and ST2-06 were excavated on the west side of the FHWA parking lot. Three exploratory backhoe trenches (Trench 2-17 through Trench 2-19) were excavated at the west end of East 5th Street (Figure 40).

Where necessary, asphalt was cut with a pavement saw and was removed using a Bobcat excavator. The trenches themselves were excavated with a backhoe to the depth of B-horizon sediments. Profiles were drawn of a one-meter segment of each trench. Trenches deeper than 120 cm were profiled from the surface, and lower stratum depths were approximated. Trenches were oriented to grid north, which was 30° east of true north in the area of Trench 2-14 through Trench 2-16 and ST2-06; and10° east of true north in the area of Trench 2-17 through Trench 2-19 and TU2-01.

FIGURE 38. Southern portion of the area of NPS archaeological testing in VNHR Area #2 within the FHWA parking lot, facing grid southwest. (NPS 09-15:2096, 8/17/09)

FIGURE 39. Southern portion of the area of NPS archaeological testing in VNHR Area #2 at the west end of East 5th Street, facing grid west. (NPS 09-04:138-3801, 2/21/09)

9468

FIGURE 40. Exploratory backhoe trenches (numbered 14-19), TU2-01, and ST2-06 in the southern portion of VNHR Area #2. (NPS 2010)

The sediments in the southern portion of VNHR Area #2 reflect many episodes of disturbance, the most recent of which occurred during the 1950s construction of the Interstate 5 freeway. Intact 19th-century deposits appear to have been largely obliterated in this area. As many as nine different fill episodes were observed, reaching over 170 cm deep in places, with considerable local variation. An example of the stratigraphic sequence for this area is described below for Trench 2-19 (Figure 41).

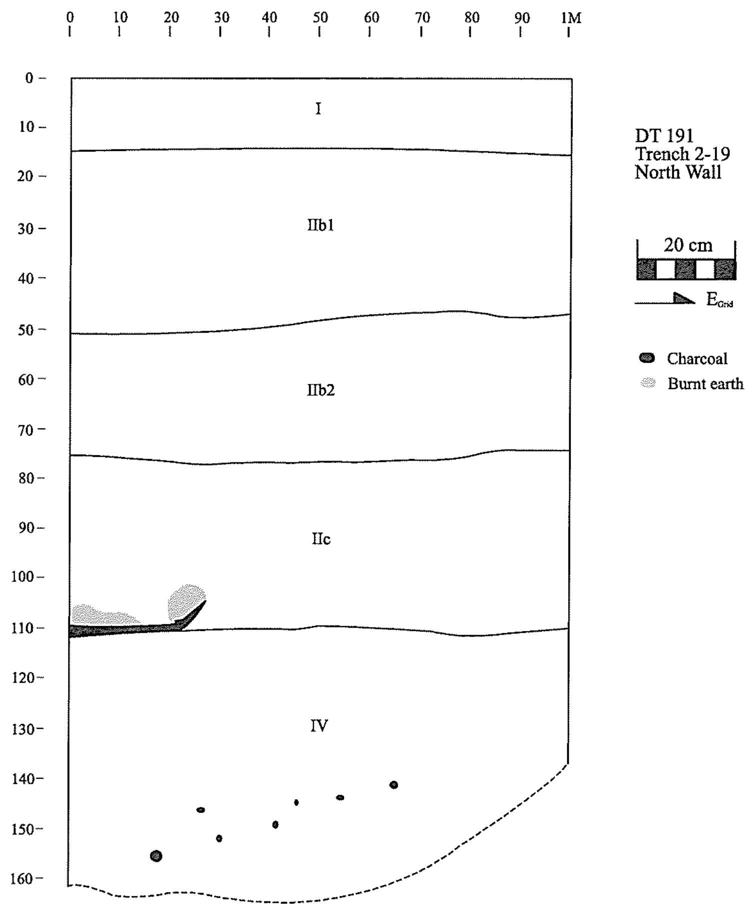

FIGURE 41. North wall profile of backhoe Trench 2-19 in the southern portion of VNHR Area #2. (NPS 2010)

Stratum I:	Asphalt pavement over a thin machine-cut gravel base layer.
Stratum IIb1:	10YR5/2 grayish brown silt, 40-50% angular machine-crushed gravels, no artifacts.
Stratum IIb2:	10YR5/2 grayish brown mottled with 10YR5/4 yellowish brown silt, 40-50% subrounded gravels, cobbles increasing with depth, no artifacts.
Stratum IIc:	10YR3/3 dark brown silt loam with 20% subrounded gravels. Possible redeposited A horizon with building demolition debris, small charcoal fragments, few mixed 19th- and 20th-century artifacts.
Stratum IV:	B horizon, 10YR3/4 dark yellowish brown gravelly silt loam, culturally sterile.

West Barracks Southern Area Backhoe Trenches

Trench 2-14

Trench 2-14 was excavated in the northwest corner of the FHWA parking lot in the previous location of the 1850s Blacksmith Shop (OP52C, Thomas and Hibbs 1984) and a portion of the 1932 FHWA building. Sediments observed consisted of nine fill episodes below the asphalt: 8 cm of very dark gray silt loam, over 11 cm of very dark grayish brown silt loam, over 28 cm of very dark gray silt loam, over 6 cm of brown sandy loam, over 6 cm of black macadam road surface, over 17 cm of dark brown sandy loam, over 3 cm of black macadam road surface, over 7 cm of dark grayish brown sandy loam, over 12 cm of dark grayish brown silt loam. Thomas and Hibbs (1984) located intact archaeological deposits related to the 1850s Blacksmith Shop near this location under six strata 20th-century fill at a depth of 1.2 m. B-horizon deposits were reached at 104 cm; the trench was terminated at 148 cm. A grab sample consisted of two artifacts.

Trench 2-15

Trench 2-15 was excavated in a landscaped area west of the FHWA parking lot, 20.5 m grid south of Trench 2-14. Sediments observed consisted of three fill episodes below 20 cm of topsoil: 80 cm of very dark grayish brown sandy loam, over 40 cm of very dark grayish brown silt loam, over 30 cm of compact very dark grayish brown silt loam. B-horizon deposits were reached at 170 cm; the trench was terminated at 175 cm. No artifacts were observed.

Trench 2-16

Trench 2-16 was excavated in a landscaped area west of the FHWA parking lot, 18.5 m grid south of Trench 2-15 and next to the Interstate 5 right-of-way fence. This area is the previous location of several 19th-century Workshops and a 1932 FHWA building. Sediments observed consisted of at least four fill episodes below the topsoil over a discontinuous buried cultural layer at 94 cm. The trench was terminated at 122 cm. A grab sample from the trench contained several late 19th- and early 20th-century artifacts. TU2-01 was excavated 3 m from the grid north end of this trench (see unit summary below).

Trench 2-17

Trench 2-17 was excavated within East 5th Street 2.5 m south of the north side of the street, in the location of a GPR anomaly and the previous location of several 19th-century Workshop buildings. Sediments observed consisted of five fill episodes below the asphalt: 2 cm of black asphalt underlay, over 75 cm of dark brown gravelly silt loam, over 19 cm of redeposited A-horizon sediments (7 cm of very dark brown silt loam, over 3 cm of black silt loam, over 9 cm of dark yellowish brown silt loam A/B-horizon transitional deposits). A grab sample consisted of several late 19th- and early 20th-century artifacts. B-horizon deposits were reached at 102 cm; the trench was terminated at 175 cm. The GPR anomaly was judged to have been caused by ground disturbance associated with the demolition of the Workshop buildings.

Trench 2-18

Trench 2-18 was excavated within East 5th Street, 9.3 m southwest of Trench 2-17 near the previous location of several 19th-century Workshop buildings. Sediments observed consisted of four fill episodes below the asphalt: 2 cm of black asphalt underlay, over 65 cm of brown gravelly silt, over 28 cm of dark yellowish brown silt loam, over 31 cm of dark gray silt loam. B-horizon deposits were reached at 130 cm; the trench was terminated at 143 cm. A grab sample consisted of one artifact.

Trench 2-19

Trench 2-19 was excavated within East 5th Street, 11.7 m southeast of Trench 2-17, in the previous location of an 1851 Carpenters Shop and Store Room. Sediments observed consisted of four fill episodes below the asphalt: 2 cm of black asphalt underlay, over 36 cm of grayish brown gravelly silt, over 24 cm of grayish brown silt loam, over 36 cm of dark brown silt loam, over 50 cm of dark yellowish brown silt loam A/B-horizon transitional deposits. B-horizon deposits were reached at 160 cm; the trench was terminated at 164 cm. A grab sample consisted of nine late 19th- and early 20th-century artifacts, likely from the 1850s Workshops.

West Barracks Southern Area Shovel Test and Test Unit

Data on the volume of sediments excavated and the number of artifacts recovered from the ST and TU in the southern portion of VNHR Area #2 are presented in Table 10.

ST2-06

ST2-06 was excavated on the west side of the northern driveway into the FHWA parking lot within the previous location of the 1851 Blacksmith Shop and a 1932 FHWA building. Three layers of fill were observed beneath the topsoil and became increasingly compact with depth. The sediments contained a large amount of construction rubble and cobbles. A backhoe was used beyond 40 cm to remove large chunks of concrete and debris to a depth of 150 cm. A tile sewer pipe was encountered at the base of excavations. No buried cultural layer was observed; fifteen artifacts were collected.

TU2-01

TU2-01 was excavated on the south end of Trench 2-16, 3 m south of the northwest corner, when several late 19th- and early 20th-century artifacts were observed during trenching. Sediments observed consisted of seven fill episodes below the topsoil: 14 cm of very dark grayish brown silt loam, over 18 cm of dark brown sandy loam, over 14 cm of very dark grayish brown silt loam with building demolition debris, over 45 cm of dark brown silt loam, over 35 cm of dark gray fine silt loam, over 7 cm of very dark grayish brown silt loam, over 49 cm of dark yellowish brown silt loam A/B-horizon transitional deposits. Level 1 of this unit encompassed the entire extent of the mechanically removed fill. A thin, discontinuous buried cultural layer was observed at 94 cm. In spite of the presence of a large number of late 19th-century artifacts, mottled sediments and the presence of 20th-century artifacts to a depth of 204 cm indicated that these deposits are disturbed. A 1932 FHWA building and several 1850s Workshops have been built and demolished at this location since the 1850s, resulting in the mixture of 19th- and 20th-century material. B-horizon sediments were reached at 204 cm; the unit was terminated at 224 cm.

TABLE 10
EXCAVATION RESULTS FOR THE SOUTHERN PORTION OF VNHR AREA #2

Level/ Feature	Mean Depth (cm)	Volume (m^3)	Total Artifacts	Artifacts ($/m^3$)	Ceramics	Flat Glass	Vessel Glass	Nails	Other 19th-c. Artifacts*
ST2-06									
1	0-2	0.0050	-	-	-	-	-	-	-
2	2-9	0.0175	5	286	-	-	1	-	-
3	9-22	0.0325	5	154	-	2	2	-	-
4	22-30	0.0200	-	-	-	-	-	-	-
5	30-39	0.0225	5	222	-	-	-	-	-
Total		0.0975	15	154	-	2	3	-	-
TU2-01									
1	0-109	1.0900	-	-	-	-	-	-	-
2	109-120	0.1125	5	44	-	-	1	-	-
3	120-129	0.0925	48	519	1	19	18	-	-
4	129-139	0.0950	64	674	2	25	12	3	-
5	139-150	0.1075	171	1591	1	71	22	10	1
6	150-161	0.1100	304	2764	-	123	50	40	1
7	161-172	0.1050	367	3495	-	108	46	93	1
8	172-189	0.1725	122	707	-	52	13	7	1
9	189-200	0.1100	18	164	-	2	-	3	-
10	200-210	0.1000	9	90	-	3	-	-	-
11	210-220	0.1000	12	120	-	8	-	-	-
Total		2.1950	1120	510	4	411	162	156	4
GRAND TOTAL		**2.2925**	**1135**	**495**	**4**	**413**	**165**	**156**	**4**

*Personal and domestic items

ANALYSIS RESULTS

Through the review of historical documents and maps, previous archaeological studies, the Fort Vancouver National Historic Site GIS database, and the results of geophysical surveys and archaeological field investigations, three cultural resources were identified in West Barracks VNHR Area #2 within the CRC APE: 1879 Line Officers Quarters, 1851 Blacksmith Shop, and 1859 Workshops. No other significant resources were located, although undiscovered subsurface pits, postholes, cellars, privys, activity areas, and other features related to 19th-century structures, may still exist below fill layers in West Barracks within the CRC APE.

West Barracks Northern Area

1879 Line Officers Quarters

Archaeological deposits from the 1879 Line Officers Quarters, located on the south side of Evergreen Boulevard, were encountered in ST2-14, ST2-15, and ST2-16 in the northern portion of VNHR Area #2 – as well as in ST1-01 and ST1-05 in VNHR Area #1. The cultural material associated with these excavation units consists of a mix of 19th- and 20th-century artifacts. A typological classification of these objects is presented in Table 11. Probable modern 20th-century items discarded in the field or laboratory that are not included in Table 11 include asphalt, concrete, foil, macadam, paper, plastic, and Styrofoam. These items largely constitute the difference seen between the total artifacts recovered from the Line Officer Quarters STs in the volumetrics table (Table 10), and the number of artifacts from these units in the typology table.

More than 85% (n=1027) of the artifact assemblage in Table 11 consists of architectural material, primarily brick (25.7%, n=310), wire nails (23.1%, n=279), mortar (11.5%, n=139), and flat glass (10.6%, n=128). There are few domestic (2.9%, n=35) and personal (2.6%, n=31) items. Glass sherds, metal fragments, bisque, and bottle glass constitute the majority of items recovered whose function could not be determined (9.0%, n=109).

One piece of ceramic was recovered from the Line Officers Quarters STs, an English porcelain cup fragment. The mean ceramic date for this type of ceramic is 1845. The manufacturing date and method for the vessel glass in these units is either unknown (n=52) or machine made (n=4).

The window glass thickness at the Line Officers Quarters STs (Figure 42) has a primary mode of 0.095 in. (n=45) corresponding to a date range of 1870-1900, which is consistent with the 1879 construction date of the building. Glass fragments with a thickness mode of 0.085 in. (n=21) are also within the date range (1855-1885) of the construction of the Line Officers Quarters. Taken together, these two amounts (n=66) constitute a strong primary mode that matches the date of the construction of the building.

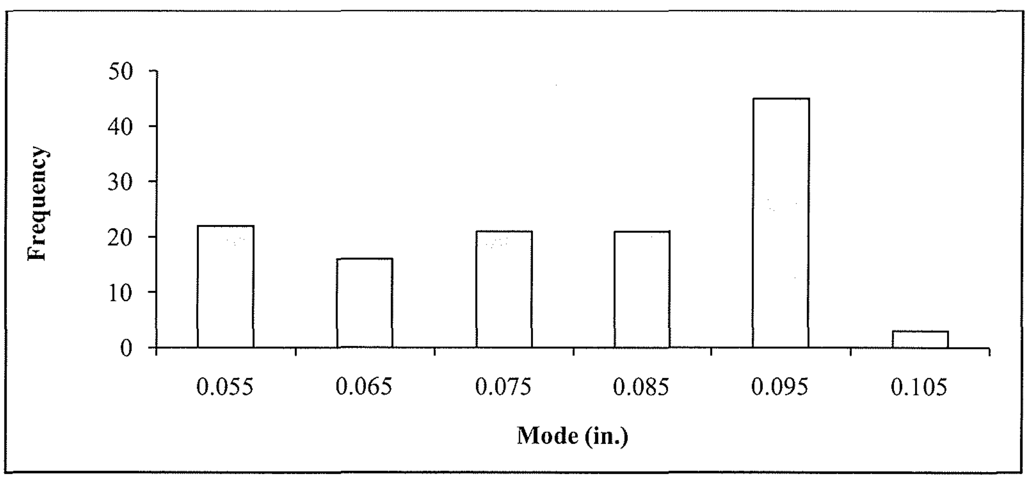

FIGURE 42. Window glass thickness at the Line Officers Quarters. (NPS 2010)

TABLE 11
CHARACTERISTICS OF ARTIFACTS AT THE 1879 LINE OFFICERS QUARTERS

Object	Sprague (1981) Typology	Number	Percent
Personal Items			
Button, Bone	I.A	1	0.08
Leather	I.A	20	1.66
Textile	I.A	8	0.66
Bottle, Soda Water	I.G	2	0.17
Total		**31**	**2.6%**
Domestic Items			
Bone, Butchered	II.B.2	4	0.33
Bone, Unworked	II.B.2	28	2.32
Porcelain	II.B.2	1	0.08
Lamp Glass	II.B.3	2	0.17
Total		**35**	**2.9%**
Architecture			
Brick	III.B.1	310	25.66
Burned Lumber	III.B.1	2	0.17
Burned Lumber Fragments	III.B.1	9	0.75
Flat Glass	III.B.1	128	10.60
Half Brick	III.B.1	2	0.17
Mortar	III.B.1	139	11.51
Charcoal	III.B.1	108	8.94
Metal Wire	III.B.2	11	0.91
Nail, Machine-Cut	III.B.2	9	0.75
Nail, Machine-Cut American	III.B.2	3	0.25
Nail, Square	III.B.2	14	1.16
Nail, Unidentified	III.B.2	5	0.41
Nail, Wire	III.B.2	279	23.10
Washer	III.B.2	1	0.08
Clinker	III.E	2	0.17
Coal	III.E	5	0.41
Total		**1027**	**85.0%**
Commerce and Industry			
Cartridge	V.B or VI.B.4	**2**	**0.2%**
Group Services			
Sewer Tile	VI.E	**4**	**0.3%**

Continued on next page

TABLE 11
CHARACTERISTICS OF ARTIFACTS AT THE 1879 LINE OFFICERS QUARTERS (CONT.)

Object	Sprague (1981) Typology	Number	Percent
Unknown			
Bisque	VIII	21	1.74
Mica	VIII	7	0.58
Unidentified Metal Artifact	VIII.A	1	0.08
Metal Fragment	VIII.A	28	2.32
Bottle Glass	VIII.B	15	1.24
Glass Sherd	VIII.B	36	2.98
Glass Tube	VIII.B	1	0.08
Total		**109**	**9.0%**
GRAND TOTAL		**1208**	

There are more temporally diagnostic artifacts at the Line Officers Quarters attributable to the 20th century (64.8%, n=284) than to the 19th century (35.2%, n=154) (Figure 43). The predominance of wire nails (n=279) over square nails (n=31) suggests a later expansion, renovation, or repair episode at the Line Officers Quarters. The vessel glass, button, and fragments of leather and textile are from 20th-century or mixed 19th- and 20th-century fill sediments; no intact buried cultural layer was observed. The majority of artifacts recovered from the Line Officers Quarters STs appear to represent architectural debris related to historical and modern construction or demolition activities.

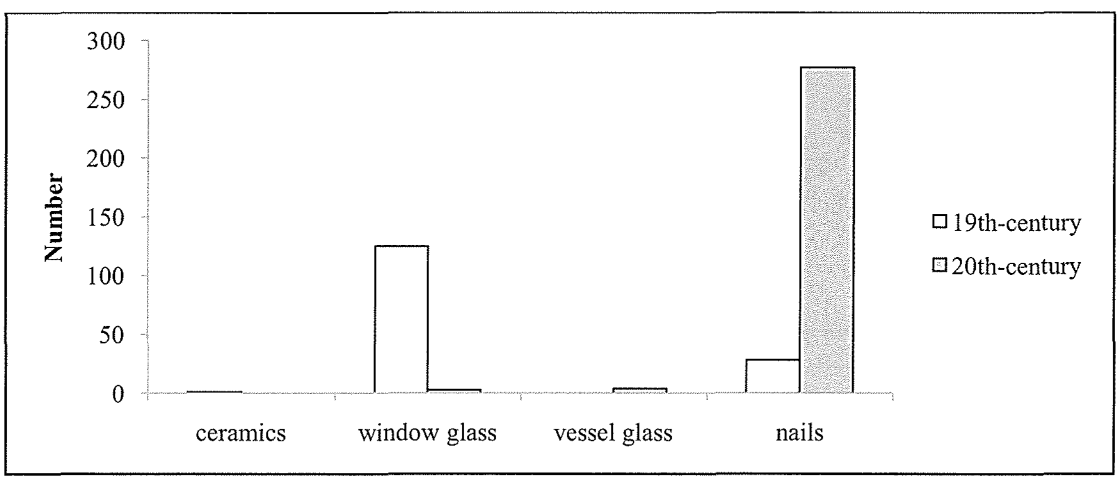

FIGURE 43. Distribution of temporally diagnostic artifacts at the Line Officers Quarters. (NPS 2010)

West Barracks Southern Area

1851 Blacksmith Shop

The 1851 Blacksmith Shop was located in what is now the northwest corner of the FHWA parking lot in the southern portion of VNHR Area #2. Test excavations in this area include ST2-06 and Trench 2-14. Few artifacts (n=15) were recovered from these units.

Over 75% (n=9) of the Blacksmith Shop area artifacts consist of architectural items, primarily brick (n=5, 41.7%). There are no artifacts with provenience that can be classified as personal or domestic items; however, butchered and unworked bone were recovered as a grab sample from Trench 2-14. The presence of the butchered bone suggests domestic activities may have occurred in this area, but the paucity of artifacts other than architectural items makes this difficult to confirm. The majority of artifacts appear to represent architectural debris related to historical and modern construction and demolition activities within the area. Although previously documented just west of this area by Thomas and Hibbs (1984), no archaeological evidence of the 1851 Blacksmith Shop was observed within ST2-06 and Trench 2-14.

1859 Workshops

Archaeological deposits from the 1859 Workshops, located on the north side of East 5th Street, were encountered in TU2-01, Trench 2-16, and Trench 2-17 in the southern portion of VNHR Area #2 (Figure 44). The cultural material associated with these units consists of a mix of 19th- and 20th-century artifacts. A typological classification of these objects is presented in Table 12.

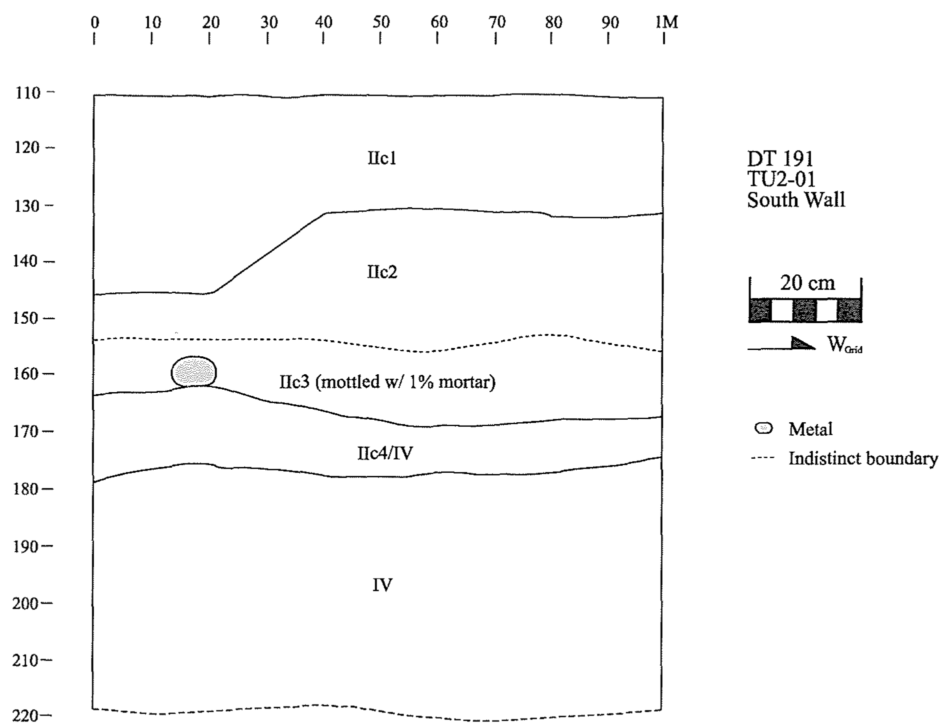

FIGURE 44. South wall profile of TU2-01 in VNHR Area #2. (NPS 2010)

TABLE 12
CHARACTERISTICS OF ARTIFACTS AT THE 1859 WORKSHOPS

Object	Sprague (1981) Typology	Number	Percent
Personal Items			
Bottle, Alcohol	I.G	1	0.09
Pipe, Tobacco	I.G	2	0.18
Total		**3**	**0.3%**
Domestic Items			
Bone, Butchered	II.B.2	1	0.09
Bone, Unworked	II.B.2	8	0.72
Earthenware	II.B.2	3	0.27
Glassware Sherd	II.B.2	1	0.09
Porcelain	II.B.2	1	0.09
Total		**14**	**1.3%**
Architecture			
Brick	III.B.1	48	4.32
Flat Glass	III.B.1	411	37.03
Mortar	III.B.1	65	5.86
Roofing Tile Fabric	III.B.1	5	0.45
Bolt	III.B.2	2	0.18
Metal Wire	III.B.2	10	0.90
Nail, Machine-Cut	III.B.2	17	1.53
Nail, Square	III.B.2	87	7.84
Nail, Unidentified	III.B.2	24	2.16
Nail, Wire	III.B.2	23	2.07
Nail, Wrought	III.B.2	4	0.36
Screw	III.B.2	4	0.36
Tack, Wire	III.B.2	1	0.09
Washer	III.B.2	1	0.09
Coal	III.E	48	4.32
Slag	III.E	4	0.36
Total		**754**	**67.9%**
Commerce And Industry			
Horseshoe	V.A or VI.B.4	**1**	**0.1%**
Group Services			
Button, Military	VI.B.4	**2**	**0.2%**
Unknown			
Bisque	VIII	2	0.18
Chalk	VIII	3	0.27
Lead Fragment	VIII.A	2	0.18
Unidentified Metal Artifact	VIII.A	8	0.72

Continued on next page

TABLE 12
CHARACTERISTICS OF ARTIFACTS AT THE 1859 WORKSHOPS (CONT.)

Object	Sprague (1981) Typology	Number	Percent
Unknown (cont.)			
Metal Disc	VIII.A	1	0.09
Metal Fragment	VIII.A	159	14.32
Metal Ring/Washer	VIII.A	1	0.09
Bottle Glass	VIII.B	31	2.79
Glass Sherd	VIII.B	129	11.62
Total		**336**	**30.3%**
GRAND TOTAL		**1110**	

Grab sample artifacts from TU2-01, Trench 2-16, and Trench 2-17 that are not listed in Table 12 include copper fragments, flat glass, glass sherds, horseshoe, ironstone, machine-cut nails, paint, square nails, tobacco pipes, transferprinted earthenware, tumbler, vessel glass, and wrought nails. These items largely constitute the difference seen between the total artifacts recovered from the Workshops TU in the volumetrics table (Table 10), and the number of artifacts from this unit in the typology table.

Almost 68% (n=754) of the artifact assemblage in Table 12 consists of architectural material, primarily flat glass (37%, n=411), all varieties of square nails (13.4%, n=149), mortar (5.9%, n=65), and brick (4.3%, n=48). There are few domestic (1.3%, n=14) and personal (0.3%, n=3) items. Two identical ca. 1860 Sanders-type military buttons were recovered (Figure 45). Metal fragments, glass sherds, and bottle glass constitute the majority of items recovered whose function could not be determined (30.3%, n=336).

FIGURE 45. Ca. 1860 military button, front (left, NPS 10-01:112, 4/19/10); and back, (right, NPS 10-01:123, 4/19/10), with "* J.H. WILSON * PHILA.", from TU2-01 at the Workshops in VNHR Area #2.

The mean ceramic dates at the Workshops (Figure 46) show that the majority of ceramic sherds date from ca. 1845, which is consistent with the HBC and Early U.S. Army periods at Fort Vancouver. Within the ceramic types, white earthenware is the most common (n=3), followed by transferprinted earthenware (n=2), and ironstone and English porcelain (one each). The ironstone sherd has a mean ceramic date of 1875. The grab sample of one ironstone sherd and two transferprinted earthenware sherds is included in the calculation of the mean ceramic dates.

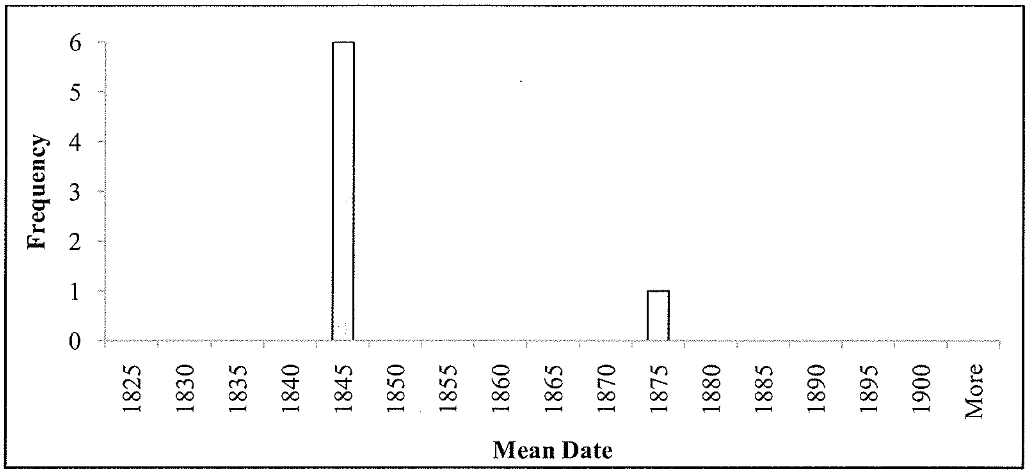

FIGURE 46. Mean ceramic dates in the excavation units at the Workshops (σ=11.5). (NPS 2010)

The thickness of window glass (n=481) at the Workshops (Figure 47) has a mode of 0.075-0.085 in., which corresponds to date ranges of 1850-1865 and 1855-1885, respectively. These dates coincide with the construction date of the Workshops and are consistent with the Early U.S. Army use of the area.

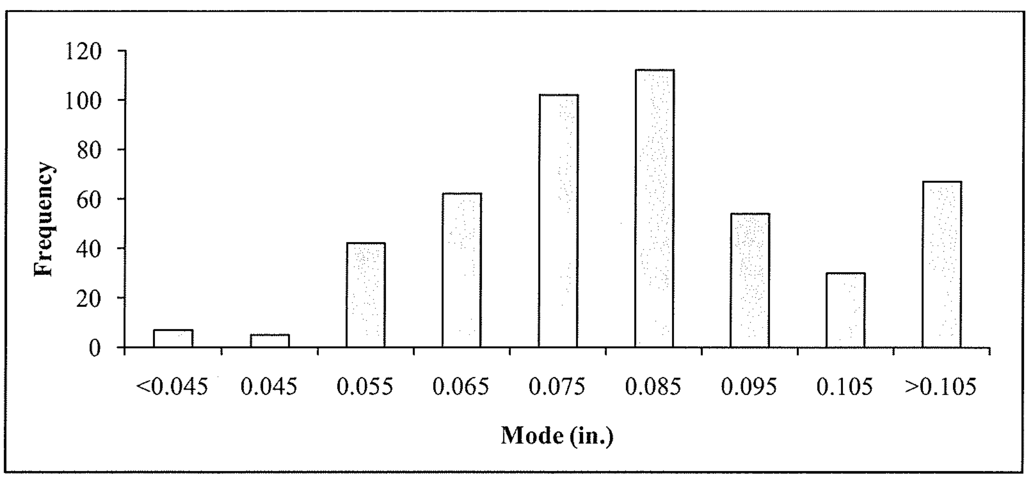

FIGURE 47. Window glass thickness in the excavation units at the Workshops. (NPS 2010)

With the exception of three artifacts (one blown-into-mold fragment and two machine made fragments), no temporally diagnostic attributes are present on the vessel glass fragments (n=171) from the Workshops.

Nail types recovered at the Workshops (n=173) are consistent with the approximate 1859 date for the initial construction of the buildings. Including the square nails that were collected as grab samples from Trench 2-16 (n=4) and Trench 2-17 (n=8), the total number of all varieties of square nails (n=149) heavily outweighs the number of wire nails (n=24) (Figure 48).

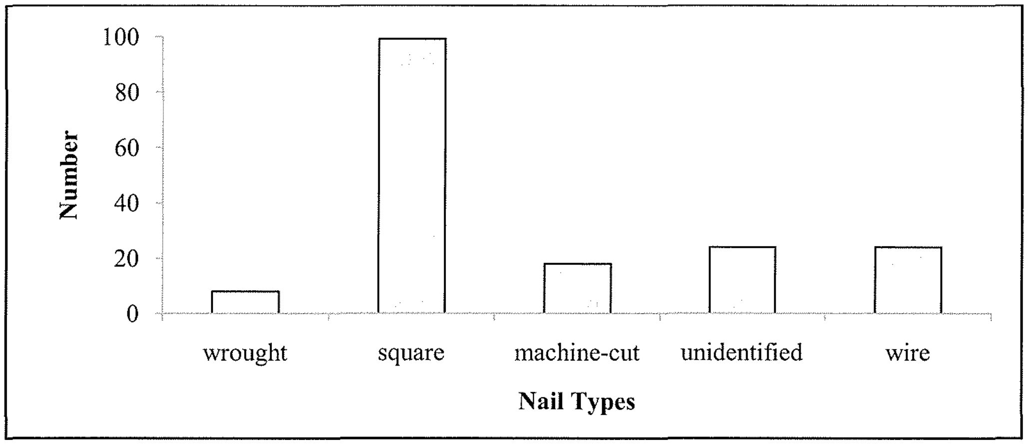

FIGURE 48. Nail types at the Workshops. (NPS 2010)

Of the total number of temporally diagnostic artifacts recovered from the Workshops, there are more artifacts attributable to the 19th century (81.6%, n=542) than to the 20th century (18.4%, n=122) (Figure 49). This is consistent with the first appearance of these buildings on 1854 and 1859 historical maps. The lack of personal and domestic items fits well with what we know of the more industrial use of this area. The majority of artifacts recovered from the Workshops TU and Trenches appear to represent architectural debris related to these historical structures.

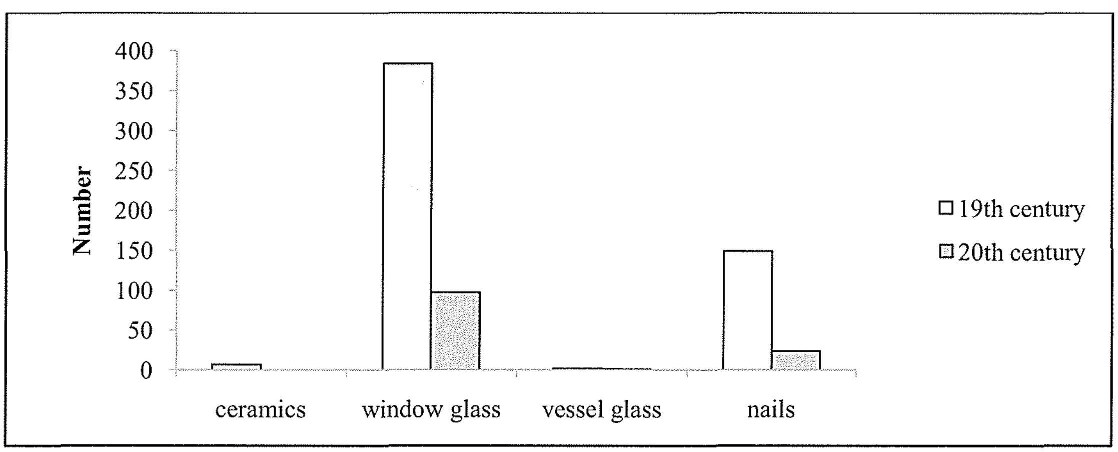

FIGURE 49. Distribution of temporally diagnostic artifacts at the Workshops. (NPS 2010)

CONCLUSIONS AND RECOMMENDATIONS

VNHR Area #2 of the CRC APE (West Barracks) has been affected by numerous episodes of building and road construction, relocation, and demolition over the past 160+ years. Exploratory trenching with a backhoe in this portion of this project area – especially in paved areas – proved to be an efficient and economical method of evaluating the stratigraphy and the presence of surviving cultural deposits. The depth of fill layers observed in these 19 backhoe trenches ranged from 38 cm to greater than 200 cm, averaging 185 cm on Anderson Road north of Hatheway Street, 55 cm on Anderson Road between Hatheway Street and the FHWA parking lot, and 130 cm within the FHWA parking lot and on East 5th Street.

Ground-disturbing activities have largely obliterated intact 19th- and early 20th-century cultural deposits in this area. Buried cultural deposits, when seen, were spotty and discontinuous.

The results of test excavations in Area #2 of the VNHR, however, indicate that archaeological resources were tested that contribute to the significance of the VNHR District are present within this portion of the CRC APE. Observations during test excavations strongly suggest that the 1879 Line Officers Quarters and 1859 Workshops contribute to the significance of the VNHR District under Criterion d of the NRHP. Although not observed directly during these test excavations, potentially intact cultural deposits related to the 1851 Blacksmith Shop, which contributes to the significance of the VNHR District under Criterion d of the NRHP, may be present in the northwest corner of the FHWA parking lot. A thorough discussion of the significance of these resources is presented in Chapter 10.

Undiscovered subsurface pits, postholes, cellars, privys, activity areas, and other features related to 19th-century structures, may still exist below fill layers within the West Barracks area of the CRC APE. The areas of the 1879 Line Officers Quarters, 1851 Blacksmith Shop, and 1859 Workshops will require stripping of overburden and fill to ensure that buried intact deposits and deep features are not present.

NPS archaeological testing in VNHR Area #2 has demonstrated that the CRC project as proposed will have adverse effects on cultural resources that contribute to the significance of the National-Register-listed VNHR District. Unique and irreplaceable resources on the VNHR within the CRC APE will be destroyed. Resources that may survive the direct effects of the project may lose their eligibility for the NRHP through a loss of integrity. An additional adverse effect will occur when resources within the FHWA parking lot are transferred out of federal ownership and lose their protection under federal cultural resources protection laws.

Adverse effects to the cultural resources detailed in this report must be resolved under 36 CFR 800.6. Adverse effects to cultural resources within the CRC APE should be avoided, if possible. If adverse effects cannot be avoided, plans to mitigate these effects should be developed through 36 CFR 800.6 or alternative processes.

CHAPTER 7

VNHR AREA #3: U.S. ARMY

PROJECT AREA

VNHR Area #3 is located approximately 240-520 m (787-1706 ft.) north of the north shore of the Columbia River in the E half of the SW quarter of the SE quarter, and the SE quarter of the NW quarter of the SE quarter, of Section 27, T2N, R1E, Willamette Meridian. The elevation of this area is approximately 30-40 feet above mean sea level (NGVD 29).

The CRC APE in VNHR Area #3 consisted of two portions (Figure 50). The first portion was a small, wedge-shaped area from East 5th Street south along the Interstate 5 right-of-way for a distance of approximately 36 m (118 ft.); it encompassed an area of approximately 85 m^2 (915 $ft.^2$). The main portion of the project area was irregularly shaped and extended approximately 260 m (853 ft.) along the northbound Interstate 5 ramp to Vancouver City Center, and along the northbound SR 14 ramp to Interstate 5, at a maximum width of approximately 20 m (66 ft.); it encompassed an area of approximately 0.35 ha (0.86 ac.). The natural setting consisted of portions of the Columbia River floodplain that have been extensively modified by land-altering activities over the past 150 years. Most of the area was within a landscaped buffer zone between U.S. Army operations and the freeways.

PROJECT GOALS

Six goals that were addressed through archaeological testing in VNHR Area #3 within the CRC APE mainly concerned the Hudson's Bay Company (1829-1860) and Early U.S. Army (1849-1900) periods:

1. To attempt to relocate excavations by Chance and Chance (1976), and Thomas and Hibbs (1984) to evaluate the extent of these excavations and the significance of the remaining archaeological resources that they left in the ground.
2. To test for archaeological evidence of HBC-era structures and features that were located in this portion of the Fort Vancouver Village.
3. To test for archeological evidence of early U.S. Army structures and features that were located in this portion of the Fort Vancouver Village.
4. To test for traces of the roads and utilities shown on historical maps from the mid-to-late 1800s.
5. To record historical archaeological resources greater than 50 years old.
6. To achieve a better understanding of the archaeological resources in this portion of the Fort Vancouver Village and the VNHR to guide further investigations and to better educate the public on the significance and history of the area.

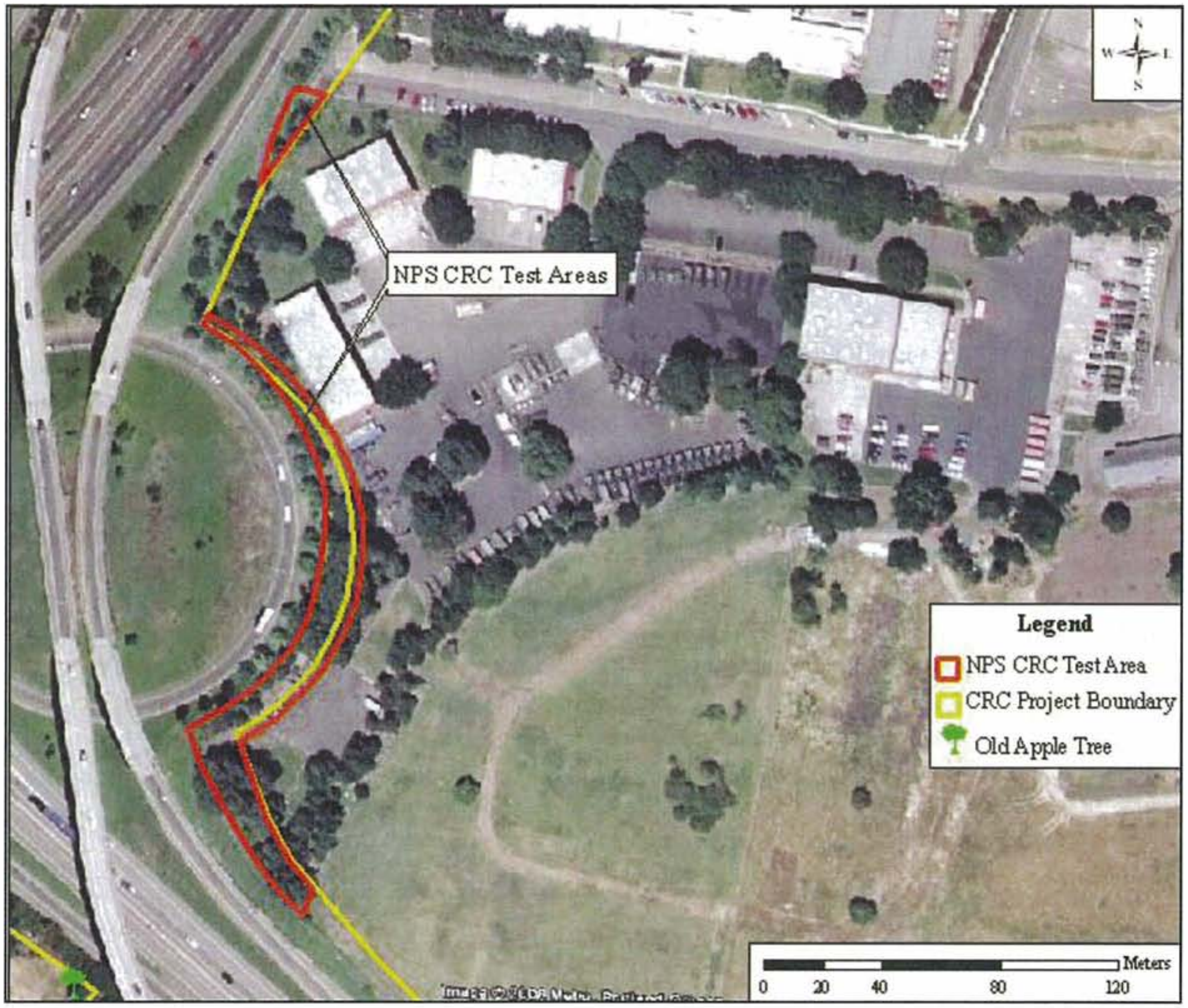

FIGURE 50. The areas of NPS archaeological testing in VNHR Area #3 on U.S. Army property for the CRC project. Image from Google Earth. (NPS 2010)

HISTORICAL CONTEXT

Historical records and maps were consulted to help determine the cultural resources that were present in VNHR Area #3, where they were located, and if they were likely to be affected by construction during the CRC project. GIS layers digitized from historic maps in the Fort Vancouver archives were georeferenced to modern satellite images (Figures 51-52).The location of buildings and features helped guide the placement of archaeological test units.

Hudson's Bay Company, 1824-1860

Historical maps show that VNHR Area #3, west of Fort Vancouver , and between East 5th Street on the north and SR 14 on the south, was part of the HBC Village, a multicultural settlement where the engagés and employees of the Company – servants, tradesmen, laborers, trappers, and voyageurs – lived in small houses with their families.

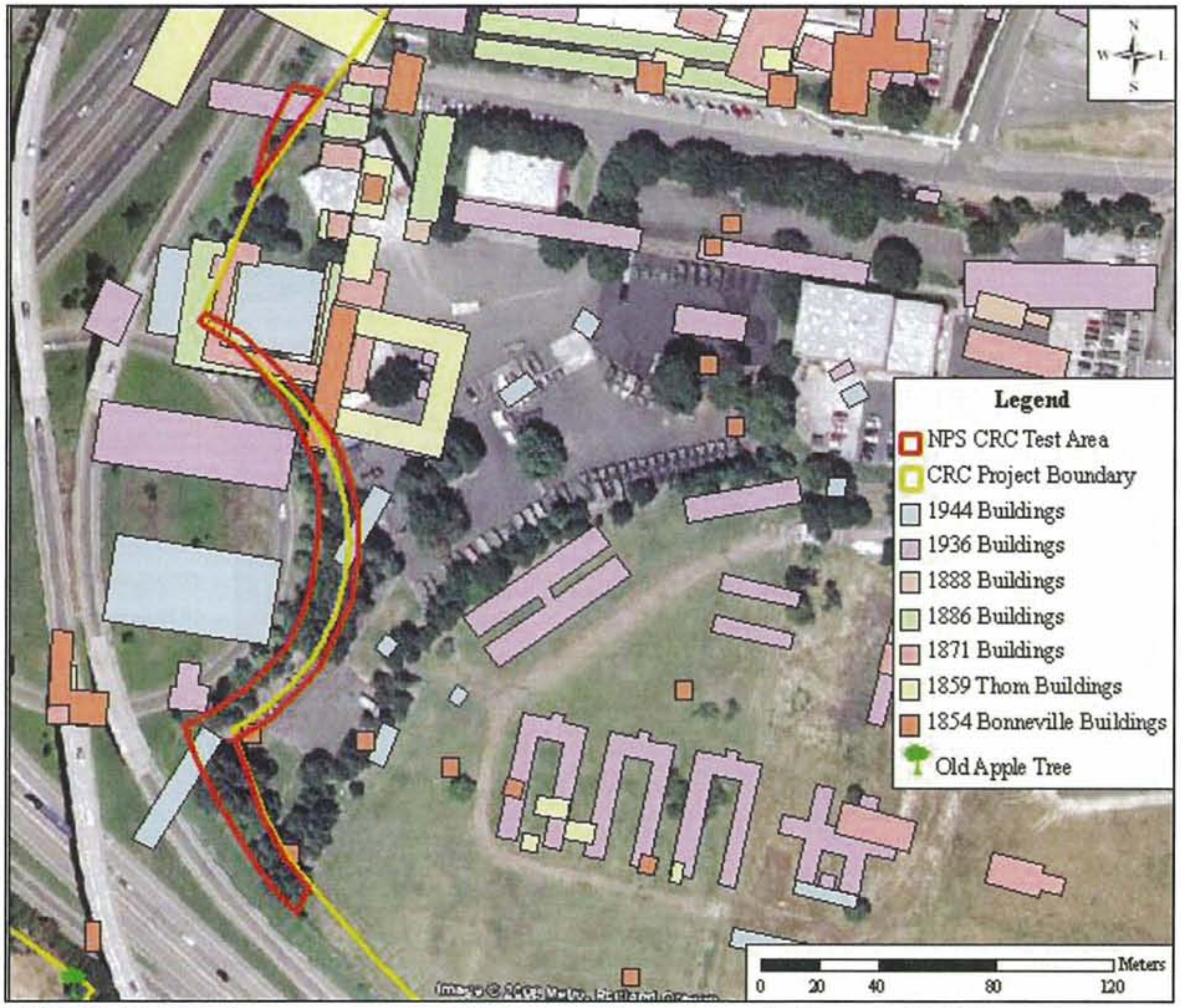

FIGURE 51. U.S. Army property in VNHR Area #3 overlain with historical buildings. Image from Google Earth. (NPS 2010)

Several servants houses were present in this area of the Village – two within the VNHR Area #3 (Figure 51). One was "Kanaka House," located off the southwest corner of the asphalt parking lot in the southern portion of this project area, which was the subject of archaeological investigations in 1981 (Thomas and Hibbs 1984:312-324). The second house, as yet undiscovered archaeologically, was that of Joseph Tayentas, an Iroquois guide employed by the HBC from at least 1832 to 1845. These houses and other Village structures can be seen on the 1846 Covington map (Figure 53).

FIGURE 52. U.S. Army property in VNHR Area #3 overlain with historical roads and features. Image from Google Earth. (NPS 2010)

Archaeologists who conducted excavations in 1980-1981 ahead of improvements to Interstate 5 and SR 14 (Thomas and Hibbs 1984) reported that the ground was essentially flat from the U.S. Army property where they were excavating east into the NPS HBC Village area. The 1982 plans for improvements to this portion of the U.S. Army property indicated that fill from the 1906 railroad spur that ran through the area was partially removed. More fill was later imported to cover those areas where grading and paving would disturb archaeological resources left in the ground (Thomas and Hibbs 1984:718). Fill was also deposited during highway construction. Today, the elevation of most of this area is about one meter higher than the NPS Village.

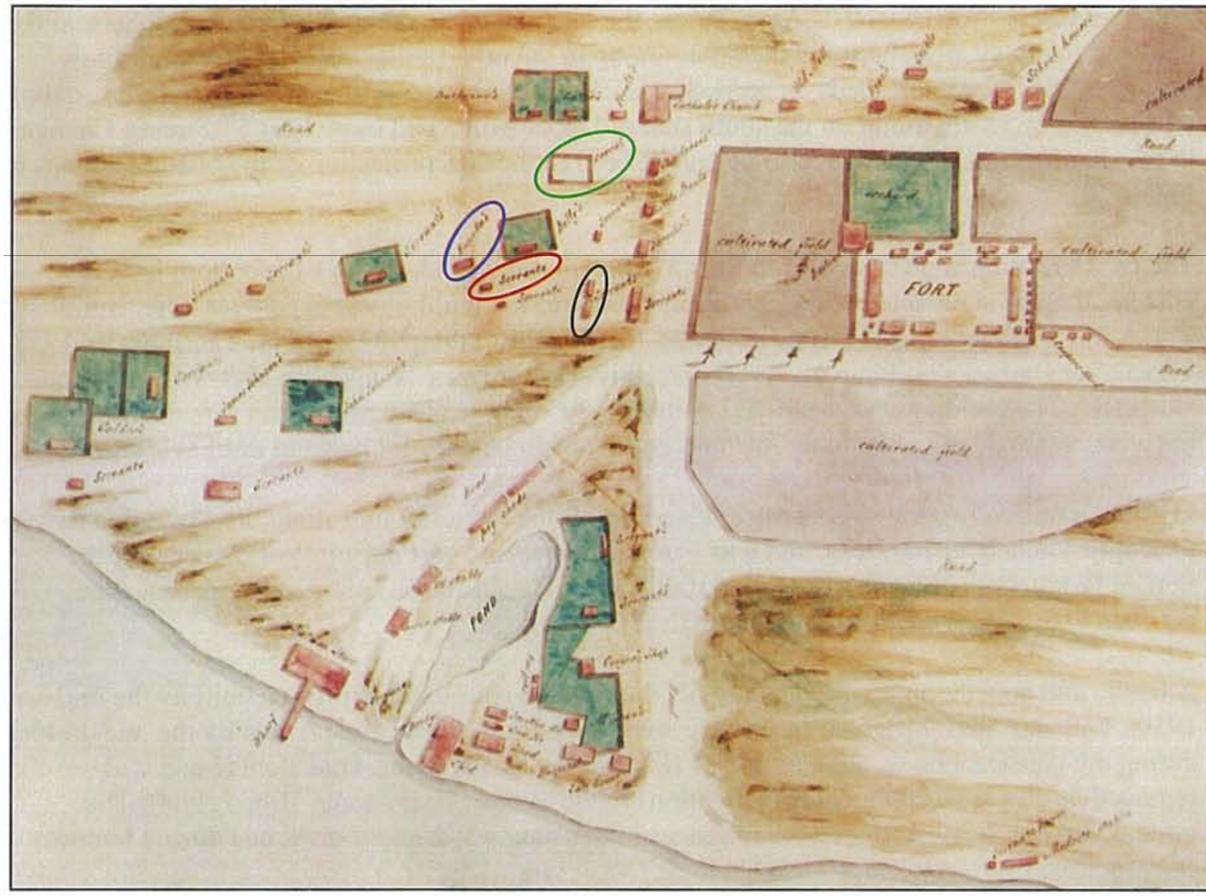

FIGURE 53. Drawing by Covington (1846) showing Kanaka House (blue), the Servants house residence of Joseph Tayentas (red), Houses 4 and 4B (black), and the corral (green) south of Upper Mill Road (East 5th Street) in VNHR Area #3.

A HBC-era road ran from St. James Mission on Upper Mill Road to the waterfront. McLoughlin Road was constructed by the U.S. Army along this route in the early 1850s, connecting East 5th Street with the Quartermaster's Depot area on the banks of the Columbia River. Heritage trees, part of an allée planted along McLoughlin Road in the early 1880s, are still present along the driveway into this portion of the project area, and one is located at the southern entrance to Old Apple Tree Park south of the BNSF railroad berm.

U.S. Army, 1849-1947

Since the final departure of the HBC and the U.S. Army takeover beginning in 1849, VNHR Area #3 has been affected by numerous episodes of road, railroad, building, and utility construction and demolition. Archaeological deposits associated with early U.S. Army structures are still present in this area, buried under as much as 120 cm of fill and disturbed sediments.

The northern portion of VNHR Area #3 was the location of several U.S. Army buildings and the yard and roadway areas between them beginning in the mid-1800s. Many of these buildings served as stables, wagon sheds, or workshops. The large Quartermaster's Stable complex, dating from the early 1850s, stood on the south side of Upper Mill Road (now East 5th Street). Changes in the shape of this complex over time can be seen in the GIS projection of the historical maps in Figure 51.

The ca. 1892 Building 104 bordered East 5th Street on the south (Figure 15, bottom left). Historical maps show that the number designation for the building changed over time: Building 111-A in 1906, Building 111-B in 1915 and 1935, and Building 104 in 1944. The June 30, 1928 Vancouver Barracks building inventory lists this structure as a "Wagon Shed & Vet. Isolation Hospital". The building was destroyed in the 1962 Columbus Day Storm and torn down in 1963, but a concrete pad at the building location continued to be used for parking until at least 1980.

In 1906, a railroad spur was constructed leading off the main rail line along the Columbia River to supply Vancouver Barracks, and was extended north and east during World War I for the Spruce Production Division. The route of this railroad spur follows the chain link fenceline between U.S. Army and NPS property in the HBC Village.

A trestle and coal dump facility leading off the railroad spur to the west was built by the mid-1930s, and was then shifted north into the southern portion of the project area by the mid-1940s during the construction of State Route 14 (Figure 54). The concrete coal storage pad was removed during archaeological investigations in the 1980s (Thomas and Hibbs 1984). The ground near the freeway right-of-way fences in this area was heavily disturbed during highway construction.

Two other buildings within VNHR Area #3 are visible in Figure 54. Building T-165, a short-lived World War II U.S. Army structure with an adjacent paved walkway located just north of the coal pad, was removed in the 1950s. The ground near the freeway right-of-way fences in this area was heavily disturbed during highway construction. Building T-137, another U.S. Army structure of unknown function, stood in the central part of VNHR Area #3 until the 1980s.

The most recent impacts in the northern portion of VNHR Area #3 were from freeway improvements in the early 1980s. That project included the demolition of structures, the removal of paving, and the construction of four large brick buildings (Buildings 400, 402, 404, and 405), roadways, and facilities south of East 5th Street. Sediments appear more intact with greater distance from these buildings.

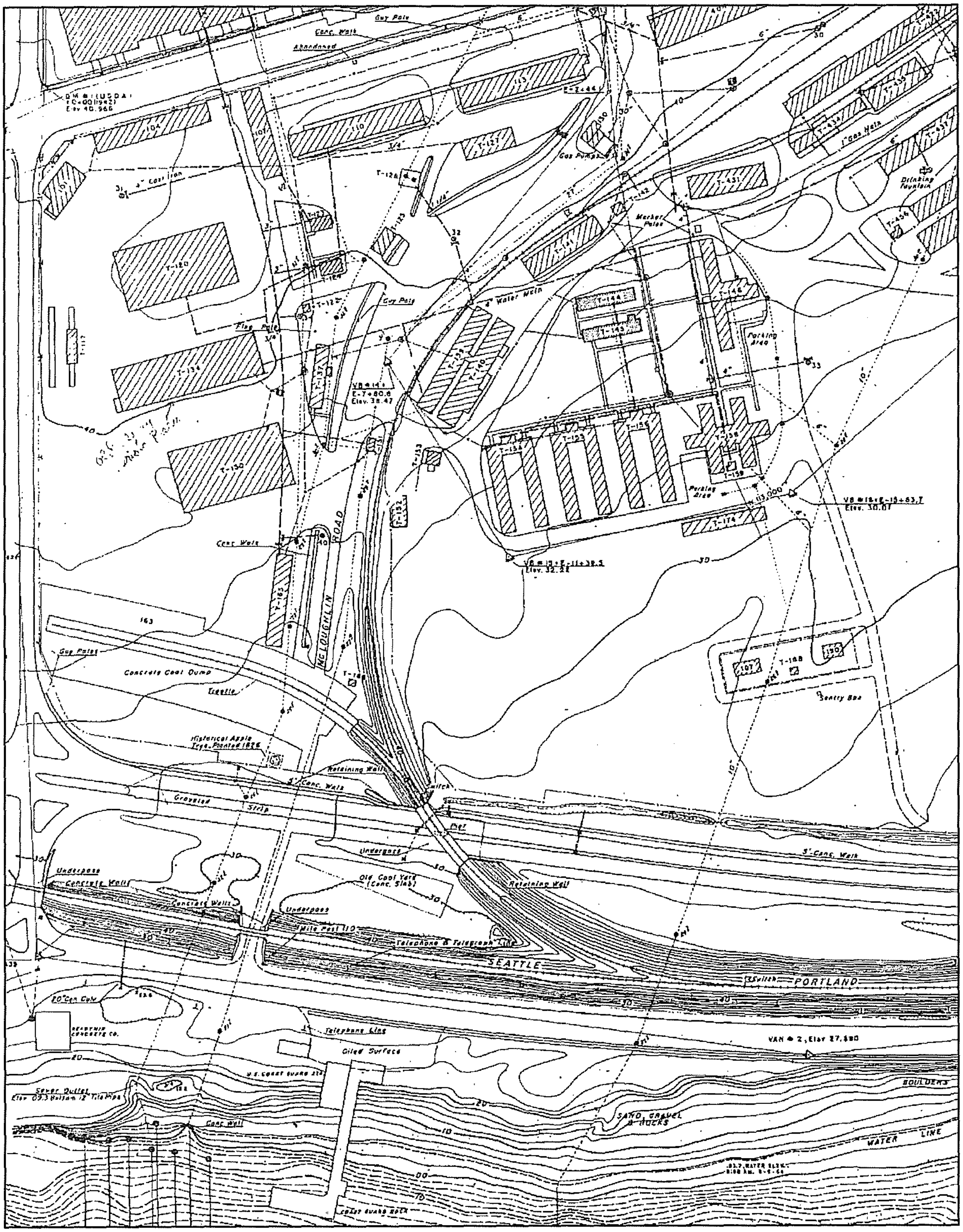

FIGURE 54. Detail of the 1944 Meldrum map of the Vancouver Staging Area, showing the coal pad and structures within VNHR Area #3.

ARCHAEOLOGICAL CONTEXT

The following projects were conducted on U.S. Army property on the western side of the Fort Vancouver Village, 45CL300, within and near VNHR Area #3 and the CRC APE. The earliest excavations were conducted using methods generally accepted before the 1966 passage of Section 106 of the National Historic Preservation Act and probably would not meet 21st-century standards. Summaries of the portions of projects most relevant to the archaeological context of VNHR Area #3 are given below (Figure 55).

Early Village Investigations

The first exploratory archaeological excavations in the Village were probably done by National Park Service archaeologist Louis Caywood in the 1950s when he was establishing the location of the HBC stockade and the buildings within Fort Vancouver. The information was never included in any of his reports (Kardas 1970:9).

The first recorded excavations in the Village took place in 1968 when Larrabee and Kardas (1968) discovered evidence of the Fort Vancouver Village 700-800 ft. west of the HBC stockade. Several 5 ft. wide trenches were dug by hand, and 3 x 3 ft. TUs were excavated within the trenches alternating with 3 x 3 ft. baulks. In general, the artifact-bearing stratum was located 3-6 in. below the ground surface. Limited or no screening for artifacts was done throughout this project. A general scatter of HBC-era artifacts was observed throughout the TUs. One domestic concentration was excavated more extensively and was interpreted as a HBC-era structure (House 1). These excavations were located east of VNHR Area #3.

A second round of investigations was conducted the following year (Kardas 1970, 1971) to locate additional structures and features and to better establish the extent of the Village. A tractor with a 6 ft. blade was used to remove the sod layer; all other excavation was done by hand. Screening of sediments was only done in areas of high artifact concentration. As in 1968, archaeological resources were found close to the surface, within 12 in. Three HBC-era houses (Houses 2, 3, and 4), animal burials (2 horses, 1 pig, and 1 dog), and other features (well, rock feature, wood-lined pit associated with House 3, and a 20th-century trash pit) were located. The maximum depth of any of the features (well and wood-lined pit) was 36 in. Two swaths that extend into VNHR Area #3 paralleled the NPS boundary fence. No mention is made of artifacts that may have been recovered from the surface of these swaths. One test pit was excavated within the westernmost swath with few artifacts and no features located.

Chance and Chance 1976 and 1982

In the 1970s, a series of archaeological investigations was conducted in conjunction with improvements to the Interstate 5/SR 14 interchange. In 1974-1975, Chance and Chance (1976, 1982) conducted salvage excavations in the Fort Vancouver Village within and near the CRC APE. Excavation areas were divided into 25 “operations”; Operations 1, 3, 4, 5, 6, 10, 12, 14, 15, 16, 17, 20, and 25 were within and near VNHR Area #3.

Operation 1 searched for the location of a Village house, but revealed only a sparse scatter of HBC-era artifacts. A small pit was observed with a horizontal timber and heavy iron wire dating from ca. 1900, possibly the remains of a mast and guy wire. The authors reported that it appeared

FIGURE 55. U.S. Army property in VNHR Area #3 overlain with previous archaeological investigations. Image from Google Earth. (NPS 2010)

that much of the topsoil had been removed from this area (Chance and Chance 1976:22). An area of 313 ft.^{2} was excavated with three features recorded (Chance and Chance 1976:23).

Operation 3 revealed a system of heavy wooden sills lying close together in shallow trenches dug to receive them. The authors believed these features to be associated with the northern end of the west wing of the Quartermaster's Stable complex, dating from as early as the 1860s. A thick layer of rubble from the demolition of a middle-to-late 19th-century structure overlaid these sills. An area of 150 ft.^{2} was excavated with three features recorded (Chance and Chance 1976:23). In this Operation, as well as in Operations 4, 5, 6, 10, 12, 16, and 20, there was evidence above the cultural strata of repeated deposition of gravel by the U.S. Army (Chance and Chance 1976:25).

Operation 4 discovered the remains of a 0.9 ft. wide wooden plank drain 4.15 ft. below the present surface. A 20th-century U.S. Army map showed this feature to be an abandoned drain that probably served the nearby 19th-century Quartermaster's structures (Chance and Chance 1976:25). An area of 75 ft.^{2} was excavated with two features recorded (Chance and Chance 1976:23).

Operation 5 yielded the "shadows" of several planks dating stratigraphically from the HBC or Early U.S. Army period, although no Village structure was known to have been present at this location. Few artifacts were recovered in association with the planks. An abandoned water line was also observed (Chance and Chance 1976:25). An area of 25 ft.^{2} was excavated with three features recorded (Chance and Chance 1976:23).

Operation 6 was a multi-component site with features from the HBC Village, Early U.S. Army, and Late U.S. Army. Layers of 20th-century gravel were found above a cobble drain believed to be associated with the extant 1909 building. Below the drain was a square footing, the remains of a fencepost, and evidence of earlier square post molds and round postholes. These features penetrated the probable 1862 flood silts. The earliest stratum consisted of a scattering of HBC-era artifacts and shallow basin-shaped fire pits (Chance and Chance 1976:25-26). An area of 183 ft.^{2} was excavated with eight features recorded (Chance and Chance 1976:23).

Operation 10 showed signs of the 1862 flood silts, but this layer was disturbed (probably no earlier than 1885). An abandoned water line was observed (Chance and Chance 1976:27). An area of 50 ft.^{2} was excavated with four features recorded (Chance and Chance 1976:23). Operation 12 was part of a shallow 20th-century pit filled with coal, ash, and clinker. The few artifacts dated from the HBC or Early U.S. Army period (Chance and Chance 1976:28). An area of 50 ft.^{2} was excavated with one feature recorded (Chance and Chance 1976:23).

Operation 14, consisting of a single 5 x 5 ft. TU and a 2.5 ft. wide, 30 ft. long exploratory trench, yielded evidence of both a U.S. Army structure and an earlier HBC structure (Chance and Chance 1976:29). The 1846 Covington (Figure 53) and 1854 Bonneville maps (Figure 12) suggest that this was the location of a Village residence. The 1914 Homan map shows Building "P" in this location. Chance and Chance (1976:29-30) infer that Building "P" was originally constructed as an ordnance warehouse in about 1883, later converted to a residence, and then to the office of the Commissary Chief (Chance and Chance 1976:290). A comparison of the 1906 Hubbard (Figure 56) and 1914 Homan (Figure 57) maps and other maps of the time suggests that Building "P" was moved north by 1906 to clear the right-of-way for railroad construction. An area of 95 ft.^{2} was excavated with five features recorded (Chance and Chance 1976:23).

Operation 15 consisted of various types of fill containing mixed 19th- and 20th-century artifacts to a depth of 1.7 ft. Below these deposits was a "thick, foul-smelling silty stratum" (Chance and Chance 1976:30) containing brick, mortar, large wood chips, and a few items of post-1850 cultural material. This debris was hypothesized to have been associated with the Quartermaster's House, located approximately 40 ft. to the north. An area of 50 ft.^{2} was excavated with no features recorded (Chance and Chance 1976:23).

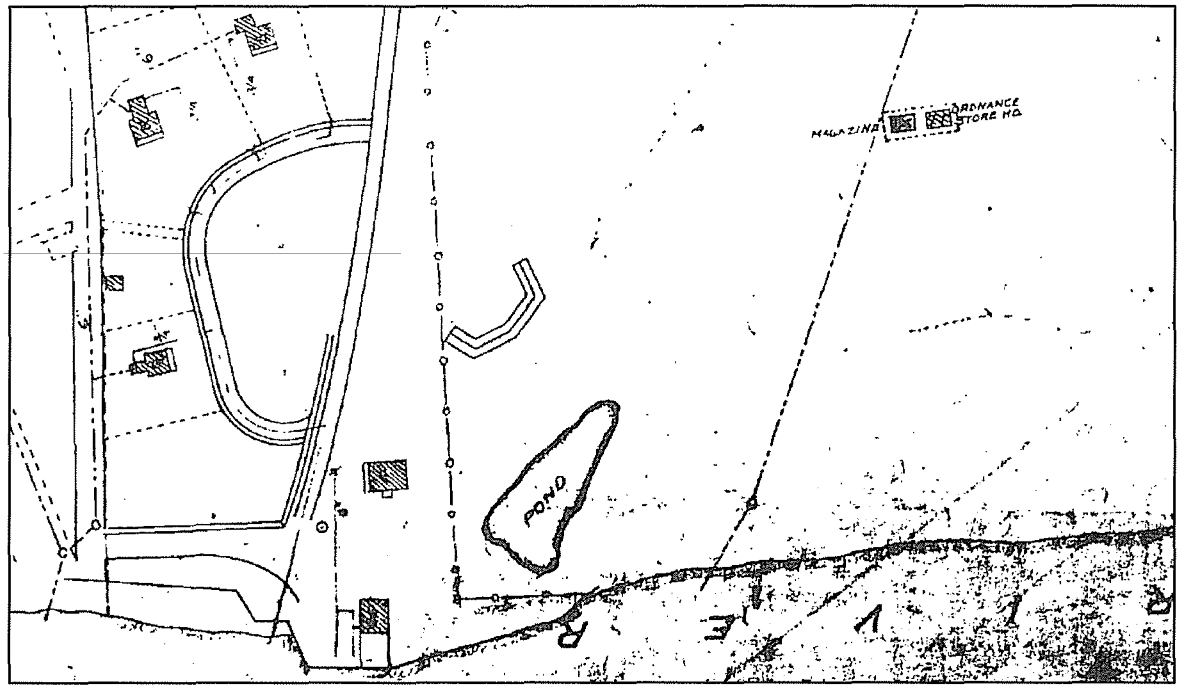

FIGURE 56. Detail of the 1906 Hubbard map of Vancouver Barracks, showing the location of the office of the Commissary Chief north of the wharf.

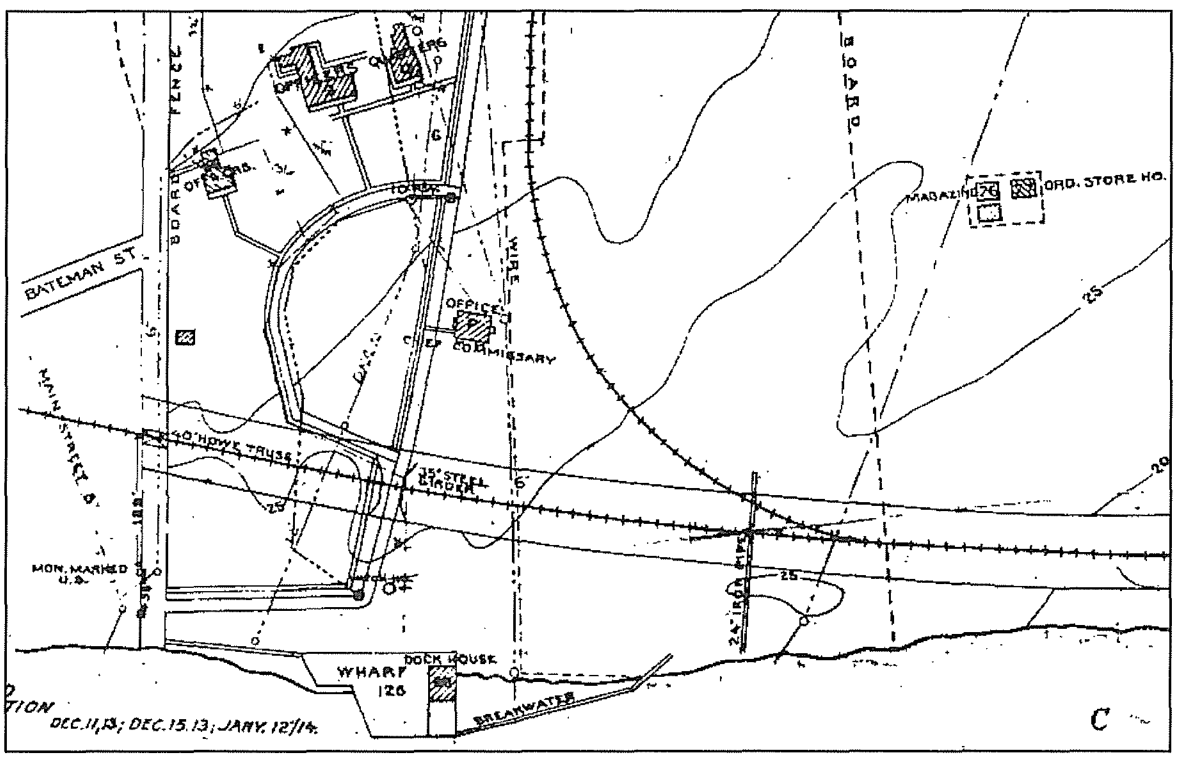

FIGURE 57. Detail of the 1914 Homan map of Vancouver Barracks, showing the relocated office of the Commissary Chief (P).

Operation 16 revealed the tops of two wooden posts 4.5 ft. apart, at a depth of 2 ft. – probably 19th-century corral posts. An area of 25 ft.^{2} was excavated with two features recorded (Chance and Chance 1976:23). Sediments in Operation 17 appear to have been disturbed, possibly during the construction of the U.S. Army concrete coal storage pad, and contained mixed HBC and later artifacts (Chance and Chance 1976:30). An area of 50 ft.^{2} was excavated with one feature recorded (Chance and Chance 1976:23).

Operation 20, located on the northwest side of the coal storage pad, proved to be the remains of the Quartermaster's House built by Rufus Ingalls in 1850. An area of 508 ft.^{2} was excavated with 30 features recorded (Chance and Chance 1976:23). The top cultural stratum below modern gravels, located at a depth of approximately 3.2 ft., contained material from the late 19th and early 20th centuries (Chance and Chance 1976:43). Beneath that, a series of localized lenses contained principally post-1850 material and some items from the HBC era. Excavations established that the house had been built on subsoil and that a HBC artifact-bearing A horizon had been scraped off before construction. Nine brick features were associated with a foundation that was inserted when the house was raised 3 ft. in 1879 to correct a sewage problem. A privy was partially excavated and yielded a large number of artifacts deposited ca. 1855-1870. The house was razed in 1937 (Chance and Chance 1976:32-34).

Work on Operation 20 at the Ingalls House continued in 1975 (Chance and Chance 1982). An area of 1967 ft.^{2} was excavated, with 5 major stratigraphic assemblages, 117 features, and 11,750 artifacts recorded (Chance and Chance 1982:8). It was discovered that the excavated structure was the north wing of the "L"-shaped house, and that sediments over the main wing of the house had been scraped away and covered by the 6 in. thick concrete coal storage pad. Structural remains of the north wing were located under approximately 2 ft. of highly compacted gravelly fill. An extensive array of features was uncovered to a depth of over 4.5 ft., including a clearly defined brick foundation, 2 privies, a fireplace, an assortment of drains and water pipes, and other features generally associated with a residence. Features were exposed, recorded, and then left intact in the ground so that the structure could be studied as a whole, and in the hope that some of them would escape destruction in the upcoming highway project (Chance and Chance 1982:8 31).

Operation 25 was an area of disturbance with a low density of artifacts dating from the HBC era (Chance and Chance 1976:35). An area of 63 ft.^{2} was excavated with one feature recorded.

Thomas and Hibbs 1984

From 1980 through 1983, Thomas and Hibbs (1984) conducted further excavations in the Village and Vancouver Barracks ahead of the proposed relocation of the Interstate 5/SR 14 interchange (Figure 58). The Chance and Chance (1976, 1982) Operations 6, 14, and 20 were expanded, and new Operations 50, 52A, 52B, 52C, 53, 54, 58, and 60, were excavated within and near VNHR Area #3. As in the Chance and Chance excavations, most features were exposed then backfilled to preserve them for future excavations.

Sixty-four 5 x 5 ft. units (1600 ft.^{2}) were excavated at Operation 6, with 68 features recorded. Four pre-1860 components were identified. Component 6-1 (1826-1850) consisted of a scatter of temporary fire areas. Component 6-2 (pre-1845) in the central portion of Operation 6 was a

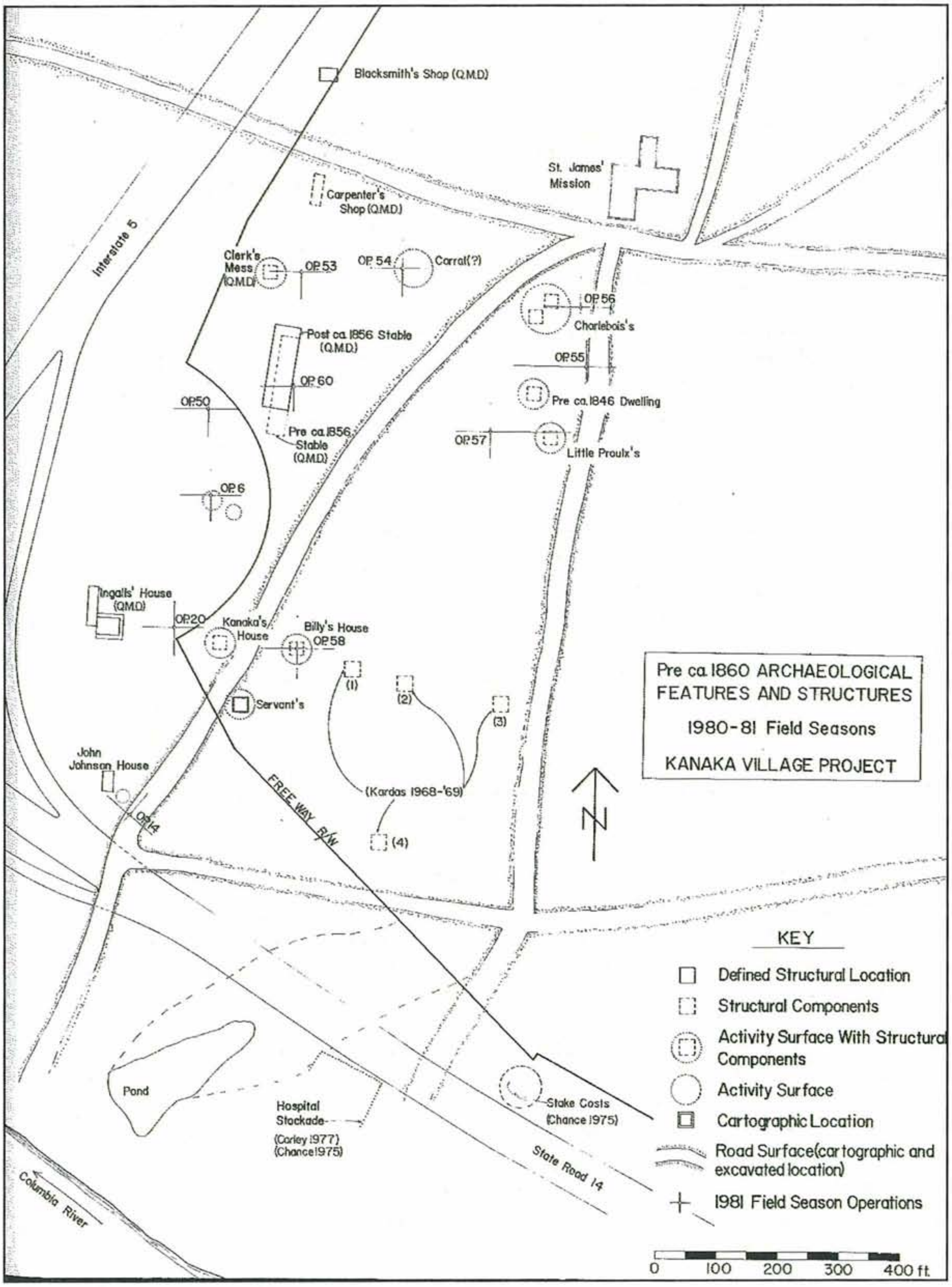

FIGURE 58. The probable locations of pre-1860 archaeological features and structures at the end of the Kanaka Village project (Thomas and Hibbs 1984:725).

possible HBC-era structure. Component 6-3 (post-1850) was the garden of the Quartermaster's residence. Component 6-4 (post-1850) was the remains of an early U.S. Army harness shop (Thomas and Hibbs 1984:65-110).

New excavations at Operation 14 suggested that the house initially excavated by Chance and Chance (1976, 1982) was the first definitively identified Euro-American structure in the Village, that of John Johnson, a cooper at Fort Vancouver (Thomas and Hibbs 1984:111-299). A total of 109, 5 x 5 ft. units (2725 ft.^{2}) and a 210 ft. long backhoe trench were excavated at Operation 14. Approximately 229 features were recorded, including a 5.5 x 7 ft. cribbed cellar (Feature 54) that was excavated to a depth of more than 3 ft.

Operation 14 yielded more historical artifacts (43,388) than any other area excavated in the Village, second only to the Chief Factor's House as being the largest domestic HBC assemblage in the Pacific Northwest (Thomas and Hibbs 1984:152). These artifacts were primarily recovered from pre-1860 refuse from the HBC and from the post-1849 occupation of the John Johnson house (Thomas and Hibbs 1984:164). Fifty-six Native American lithic artifacts were also recovered from pre-1860 contexts (Thomas and Hibbs 1984:154).

Five components were identified (Thomas and Hibbs 1984:282-299). Component 14-1 (ca. 1825-1835) was a Village house, identified by structural elements and a compact silt loam floor. Component 14-2 (ca. 1835-1846) was correlated with the John Johnson house based on structural remnants, and compared with archaeological features found in the 1981 excavations and with cartographic features on historical maps. This component included the earliest deposits of the cellar and evidence of an addition to the house ca. 1846. Component 14-3 (ca. 1846-1857) was identified with the construction of another house addition ca. 1846-1854. Component 14-4 (1857) was associated with the destruction of the house. Component 14-5 (1857-1861/62) was represented by a few linear features dating after the destruction of the house and before the 1861-1862 flood. Silts from the flood cap the pre-1860 deposits, with Stratum 1 features intruding as described above (Chance and Chance 1976:25-26).

Operation 20, located in an area of planned highway cuts and excavations for several large bridge footings, included the U.S. Army coal storage pad and Building S-150, slated for demolition (Thomas and Hibbs 1984:301-361). WSDOT removed the coal pad and underlying imported gravels to facilitate data recovery excavations, leaving the deposits underneath relatively undisturbed. Four large areas were opened: Operation 20A, 20B, 20C, and 20D.

Eleven 5 x 5 ft. units were excavated in Operation 20A Phase 1. Nine pre-1860 features and seven post-1860 features were recorded, but by themselves they provided no significant information about these occupations. Remains of another structure were located at Operation 20A Phase 2 (Thomas and Hibbs 1984:312-324) and presumed to be the house west of "Billy's", labeled "Kanaka's" on the 1846 Covington map (Figure 53). Six 5 x 5 ft. units were excavated. Thirteen features were recorded, all of which were associated with Stratum 3. Two units were excavated to sterile sediments; three units were dug to the 3B activity surface then backfilled to preserve them for future excavation. The remains of a wood block footing, and three posts and their postholes recorded to a depth of 1.1-1.9 ft., were judged to be architectural evidence of the house. Thomas and Hibbs (1984:317) report that there was extensive disturbance in this area from the construction of a sidewalk, sewage and drainage trenches, and pipes, and that excavation units were positioned to minimize encountering these disturbances.

Operations 20B and 20C, located underneath the coal pad, revealed 14 pits and posthole features, although the artifact-bearing A horizon had been destroyed (Thomas and Hibbs 1984:324-330). The postholes were most likely from a fenceline illustrated on many maps from the mid-to-late 1800s. No significant information or artifacts were obtained from these features.

Operation 20D consisted of the basement and structural features of the main portion of the Quartermaster's House and the southeast corner of the north wing, and the northeast yard area, all of which had been underneath the coal pad (Thomas and Hibbs 1984:330-361). The A horizon and structural features from the house had been sheared off at some point, with only remnant lenses of cultural material in low spots and feature depressions. Fifty-two features were recorded, with one pit associated with the pre-1850s Village (Component 20D-1). Component 20D-2 (1850-1851) consisted of wooden footings associated with the original construction of the house. Component 20D-3 (ca. 1866) was defined as structural brick footings and plumbing features associated with renovations to the house. Component 20D-4 (1879) was associated with the renovation of the foundation, when the house was raised 3 ft. on brick piers and connected to a new sewer system. Component 20D-5 (1878-1904) was associated with renovations to the house after a fire in 1882 and extensive flooding. Component 20D-6 (post 1904-1937) represented the last years of the Quartermaster's House and its destruction in 1937, when it was pushed into its basement and graded as part of the coal pad construction.

Operation 50 revealed evidence of stables, sheds, and other unidentified buildings associated with the Quartermaster's Depot, and documented a shift from wood footings to brick piers and pads (Thomas and Hibbs 1984:363-402). Two 10 ft. wide, 200 ft. long swaths were machine-stripped and 37, 5 x 5 ft. units were excavated. Approximately 100 features were recorded, post-dating 1860. A fence line was documented, and the location of two 1906 buildings was verified. It appeared that much of the A horizon had been stripped in this area when the ground was leveled for the construction of Building S-135 in about 1908, and for the construction of the building situated between Buildings S-135 and S-120, built in about 1906.

Operation 52 consisted of investigations of a machine-excavated trench for a new 8 in. water line (Thomas and Hibbs 1984:405-438). The trench was approximately 800 ft. long, 4 ft. wide, and 4 ft. deep. The excavation of the trench was monitored, and intermittent formal excavations were conducted by hand to investigate features observed. Ten features were recorded, all associated with buildings or activities connected with the U.S. Army from 1849 to ca. World War II. The 19th-century surface in Operation 52A was largely intact, covered by 0.4-2.5 ft. of fill. In Operation 52B, foundation remains of two U.S. Army wagon sheds, S-111B and S-71 constructed in 1905-1906, were observed under 2 ft. of fill (Thomas and Hibbs 1984:406).

Operation 52C revealed strata associated with the 1850-1863 blacksmith shop at the northern end, and evidence of the 1851 carpenter shop and storeroom, and a cribbed cellar pit at the southern end, all covered by 2 ft. of fill. These buildings were among the first constructed in the Quartermaster's Depot. The depth of blacksmith shop deposits extended to 3.5 ft. After being destroyed by fire, the blacksmith shop was rebuilt some time before 1871. Traces of the floor of this second building – and perhaps a third – were observed (Thomas and Hibbs 1984:409-420). The carpenter shop is shown at the south end of Operation 52C on historical maps until at least 1855. By 1871, two granaries are shown in this location, and the carpenter shop activities had moved to a nearby L-shaped building. No buildings are known to have been present at the location of the cribbed pit, which was probably used as a cellar and then abandoned and backfilled some time before 1865. Deposits extended to a depth of 3 ft. (Thomas and Hibbs 1984:406).

Excavations at Operation 53 were conducted at the site of the proposed construction of U.S. Army Building B (Thomas and Hibbs 1984:439-556). This location was associated with a building generally referred to as the clerks quarters or clerks mess, identified on the 1851 Bomford map as the "mess and lodging house for Quartermaster men". Seven ft. wide test trenches were dug with a backhoe along the location of the north and west walls of the proposed building, followed by the hand excavation of 91, 5 x 5 ft. units. A total of 282 features were recorded, with 16,625, 19th-century artifacts recovered. Three pre-1860s and two post-1860s components were identified (Thomas and Hibbs 1984:553-556).

Component 53-1 was a pre-1850 Village habitation area located on the western edge of the Village. Although no HBC-era structures are recorded in this location, this area was reported to have been seasonally occupied by HBC employees and Native American traders. Nineteen Native American lithic artifacts were recovered from this component. Component 53-2, the yard area and domestic debris associated with the 1850/1851-1856 clerks quarters, encompasses the construction and demolition of this building. Discrepancies between the pre-1855 cartographic projection of the location of this building and its probable location based on archaeological evidence could not be resolved. The authors believed that further excavations north and west of Operation 53 (within VNHR Area #3 in the CRC APE) could uncover additional structural remains of this building. The Winman map shows granaries in this location by 1871, possibly as early as 1856 (Thomas and Hibbs 1984:554). Component 53-3 was a ca. 1856-1860s road on the east side of Operation 53, which serviced a wagon shed and granaries in this area. The wagon ruts in this component run north/south, unlike the ruts in Component 53-2, which run northwest/southeast (Thomas and Hibbs 1984:540). Components 53-4 and 53-5 are associated with a carriage/wagon shed and granary that are identified on maps from 1874 to 1904.

Excavations at Operation 54 were conducted at the site of the proposed construction of U.S. Army Building C (Thomas and Hibbs 1984:557-576). The earliest structure associated with this location was a square corral depicted on the 1846 Covington map (Figure 53). Six ft. wide test trenches were dug with a backhoe along the location of the north and west walls of the proposed building. Nine pilot units were excavated, which revealed 0.4-1.5 ft. of imported fill associated with the construction of the existing U.S. Army Building 99/110. A backhoe was used to remove all but 0.5 ft. of fill and an additional 40, 5 x 5 ft. units were excavated by hand with 45 features recorded – mostly stakes and posts. Component 54-1 consisted of a small assemblage of HBC-era material, including 32 Native American lithic artifacts. Component 54-2, dating from 1846 to 1854, was associated with the corral.

Operation 58 (Thomas and Hibbs 1984:619-631), located just east of VNHR Area #3, appeared to be the location of a HBC-era house. Based on an analysis of historical maps, this house was inferred to be that of William R. Kaulehelehe, a Hawaiian preacher also known as Kanaka William or Kanaka Billy (labeled "Billy's" on the 1846 Covington map in Figure 53). Billy's house appeared to be in line with and west of Houses 1, 2, and 3 located by Larrabee and Kardas (1968) and Kardas (1970, 1971). Two 5 x 5 ft. units were excavated in 0.5 ft. levels to a depth of approximately 3 ft. Stratum 1 was shoveled out; Strata 2 and 3 were excavated with shovel and trowel. Six features were recorded, including the remains of 2 posts in circular holes, a bowl-shaped intrusion, and a stratified pit that intruded at least 2 ft. into sterile silts. These four features dated from 1845 to 1860. The U.S. Army burned down Kaulehelehe's house in 1860.

Excavations at Operation 60 were conducted at the site of the proposed construction of U.S. Army Building A (Thomas and Hibbs 1984:635-694). No structures are shown on pre-1849 maps in this location. Beginning in 1850-1851, the Operation 60 area was the site of the Quartermaster's Depot stable/corral complex and continued as such into the 20th century. Two 7 ft. wide test trenches were excavated on the northeast and southwest walls of the proposed building, with an additional 4 ft. wide trench opened to expose the west footing of the stable. Test trenches were hand cleared to examine structural footings, which suggested mid-19th-century construction with periodic repair. A backhoe was used to remove approximately 3 ft. of paving and fill gravels to expose lower deposits. One-hundred, 5 x 5 ft. units were excavated in arbitrary 0.5 ft. levels. Baulks 0.5-1 ft. wide were retained to preserve depositional sequences and stratigraphic relationships. Five components were identified.

Component 60-1, a HBC-era component found at a slightly lower level than the stable, suggested a 1830s-1840s Village occupation. Forty-five features, including postholes, stake casts, fire areas, and pits, were associated with this occupation, including three fire pits that were lined with sand. A series of stakes surrounded a feature that was identified as a sweat lodge pit. No definitive evidence of a Village house was found. Component 60-2 represented initial construction events at the Quartermaster's Depot stable ca. 1850-1856. Component 60-3 consisted of renovations to the stable ca. 1856-1879, defined archaeologically by brick footings and supported by historical accounts. Component 60-4 and Component 60-5 represented renovations to the stable from 1879 to ca. 1914, and from ca. 1914 to 1935, respectively. The structure was torn down in 1935. The authors caution that more than one-half of the Quartermaster's Depot stable remains in situ outside of the construction boundaries of Building A in areas that were not explored in the 1980-1981 Kanaka Village excavations (Thomas and Hibbs 1984:677). These deposits may be encountered during archaeological test excavations for the CRC project within VNHR Area #3.

When the railroad spur that was previously located on the west side of the Village was removed in the 1970s, the area was graded flat. After the Thomas and Hibbs excavations (1984) and before the construction of U.S. Army buildings A, B, and C currently occupying the northwest corner of the Village south of East 5th Street, the demolition of the existing buildings was monitored to confine impacts to the previously disturbed areas. A large amount of gravel and sand fill was then placed in this area. Thomas and Hibbs state that this was to protect archaeological resources such as Billy's and Kanaka's houses to mitigate the effect to these resources of building construction (Thomas and Hibbs 1984:718).

The results of the Thomas and Hibbs (1984) excavations have helped ground-truth historical maps and images and have enabled archaeologists to better predict the location of other Village structures (Figure 58). One house that has not been located archaeologically is depicted on the 1854 Bonneville map (Figure 12) as being located just northwest of VNHR Area #4 on its boundary with VNHR Area #3. This house is labeled "Servant's" in Figure 53.

Thomas 1993-1994

Thomas (1993) conducted archaeological investigations for the WSDOT's proposed pedestrian undercrossing of SR 14 in the Village. A surface survey, a ground penetrating radar survey using a 500 MHz antenna, and shovel testing were conducted on a 300 x 140 ft. grid on the north side of SR 14. This grid is located on the edge of VNHR Area #3 and the current CRC APE.

The surface survey recovered a small quantity of 19th-century artifacts, but mostly 20th-century items and modern debris. The ground penetrating radar survey detected several subsurface anomalies that were ground-truthed with shovel tests, with a 71% correlation between the two techniques of archaeological feature discovery (Thomas 1993:34). Six subsurface features were identified with the ground penetrating radar survey adjacent to VNHR Area #3 (Thomas 1993:11-12), including pond deposits (SSF #1), House 4 (SSF #2) discovered by Kardas (1970), a possible house site (SSF #3 and SSF #4), a concentration of coal from a known U.S. Army coal storage area (SSF #5), and a shallow deposit of coal, clinker, and iron fragments (SSF #6).

A total of 112, 1 ft. diameter shovel probes were excavated on the grid at an interval of 20 ft. Sediments were screened through ¼ in. mesh. Five, 5 x 5 ft. TUs were excavated in the area of the proposed pedestrian structure foundations in the west portion of the project area, in places where in situ 19th-century archaeological material was expected (Thomas 1993:16). Four features were observed in these TUs. Feature 1 was a coal deposit located at a depth of 0.5 ft. Feature 2 was an asphalt surface at 0.3 ft. Feature 3 and Feature 4 were HBC-era fire pits that were left in situ at 1.5 ft. In general, probes and features were excavated to a depth of 2-3 ft. Cultural material was generally found within the top foot of sediments below a fine layer of angular crushed rock and a thin lens of coal at 0.5 ft. Randolph reported that cultural disturbance was extensive within the western half of the grid, probably due to the previous leveling of the area for a coal storage facility that resulted in the removal of the B horizon and the mixing of 19th- and 20th-century deposits (Thomas 1993:45).

Thomas concluded that much of the western portion of this project area was disturbed by 20th-century U.S. Army activities including coal storage and other work associated with the nearby railroad spur. HBC and early U.S. Army-era debris from refuse disposal in the pond was found in the eastern portion of the project area. Thomas cautioned that intact HBC-era material containing significant archaeological data probably underlie 20th-century disturbances throughout the project area.

In 1994, Thomas excavated additional shovel probes after the modification of WSDOT's plans for the proposed pedestrian undercrossing of SR 14, to avoid significant archaeological resources in the Village that were located by Thomas in 1993. Nineteen 1 ft. diameter probes were excavated in the right-of-way between the chain link fence that marks the U.S. Army and WSDOT property boundary and SR 14. Probes were dug at an interval of 40 ft. – 20 ft. for