BIOLOGICAL ASSESSMENT

COLUMBIA RIVER CHANNEL IMPROVEMENTS PROJECT

TECHNICAL APPENDICES

Volume II

December 28, 2001

APPENDIX C.

PROPOSED DISPOSAL SITE DESCRIPTIONS

The factsheets included in this appendix provide information for each of the disposal sites proposed for the Columbia River Navigation Channel Improvements Project (the Project). Where available, each factsheet includes the size, elevation, owner and description of the site, as well as aerial and site photographs and a location map. Chapter 3 of this Biological Assessment includes additional information regarding the disposal sites. The factsheets are arranged by state (Washington/Oregon) and from the Bonneville Dam to the mouth of the Columbia River to reflect the organization of the text.

- West Hayden Island, O-105.0
- Gateway 3, W-101.0
- Fazio A, W-97.1
- Fazio B, W-96.9
- Lonestar, O-91.5
- Railroad Corridor, O-87.8
- Austin Point, W-86.5
- Sand Island, O-86.2
- Reichold, O-82.6
- Martin Bar, W-82.0
- Martin Island, W-80.0
- Lower Deer Island, O-77.0
- Sandy Island, O-75.8
- Northport, W-71.9
- Cottonwood Island, W-70.1
- Howard Island, W-68.7
- International Paper Rehandle, W-67.5
- Ranier Beach, O-67.0
- Ranier Industrial, O-64.8
- Lord Island, O-63.5
- Reynolds Aluminum, W-63.5
- Mount Solo, W-62.0
- Hump Island, W-59.7
- Crims Island, O-57.0
- Port Westward, O-54.0
- Brown Island, W-46.3/W-46.0
- Puget Island, W-44.0
- James River, O-42.9
- Tenasillahe Island, O-38.3
- Welch Island, O-34.0
- Skamokawa, W-33.4
- Pillar Rock, O-27.2
- Miller Sands, O-23.5
- Rice Island, W-21.0 and O-21.0

West Hayden Island, O-105.0

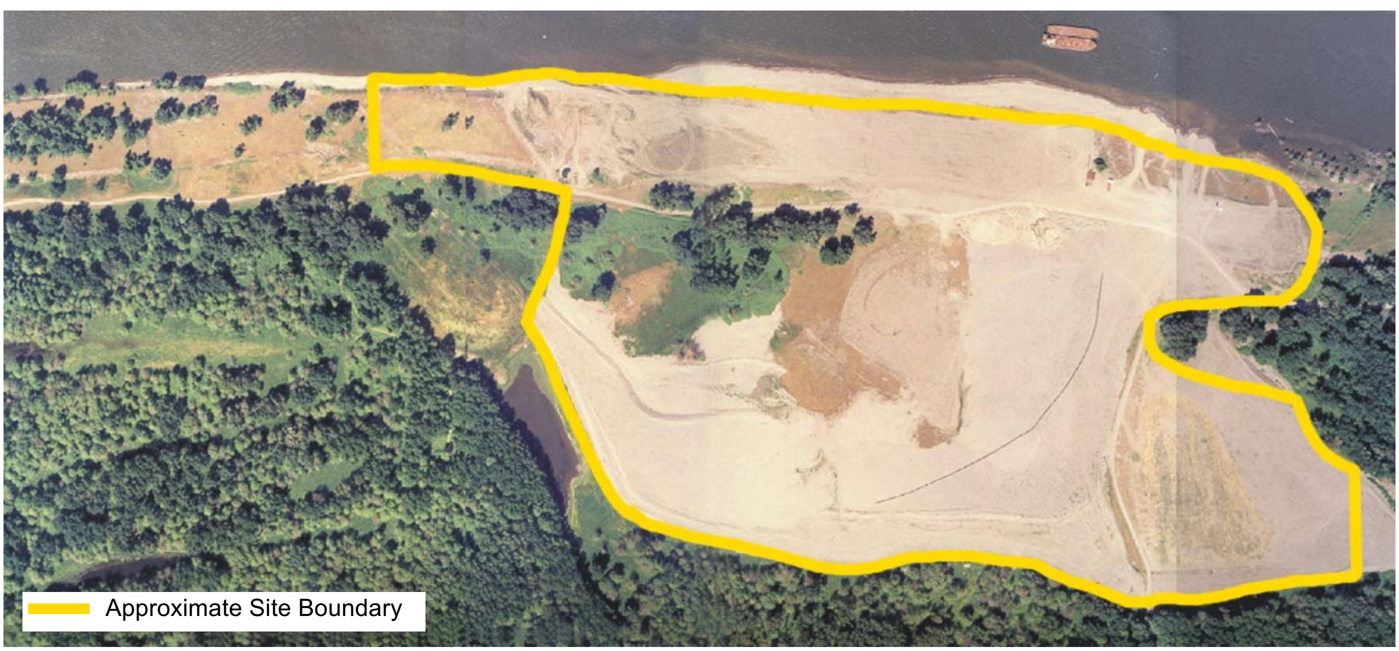
Size: Approximately 102 acres

Elevation: 5 to 30 feet above Mean Sea Level

Owner: Port of Portland

Description: The property is bordered along the southwest, west, and north by deciduous forest and cattle pasture. The adjacent properties to the south contain additional pasture and forest, and a City of Portland municipal sewage treatment and pumping facility. Located approximately 500 feet south of the subject property is a Portland General Electric Company (PGE) substation. The Port has used the property for dredge material placement in the past and much of the property has been covered with material dredged from the Columbia River. The Port has leased the site for cattle grazing. Site improvements include a dredge material retention pond, an unimproved dirt road, and wire fencing for the cattle operation. In the past, WCT operated a heavy equipment training school on two separate portions of the property. That school is now at Austin Point (W-86.5).

An approximately 1,000-foot-long, 20- to 50-foot-wide retention pond is located along the northwest portion of the property. Although one well is located on the site, there is no water service to the property.



Gateway 3, W-101.0

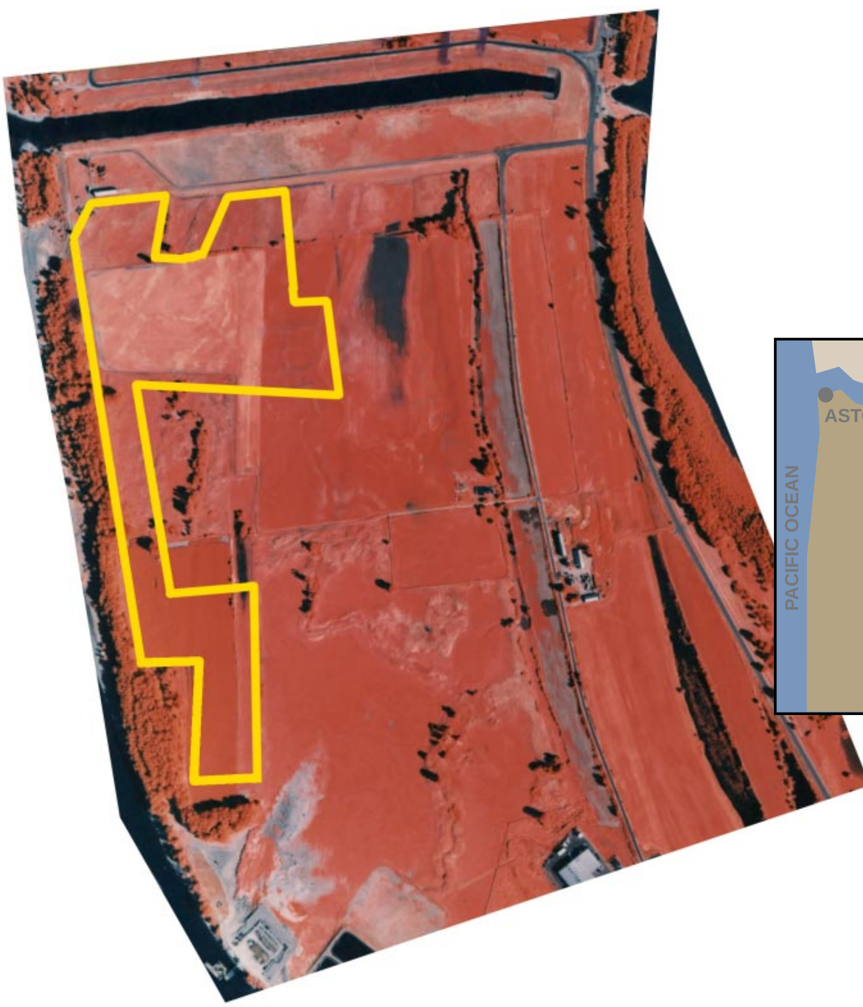
Size: 69 acres

Elevation: 10 to 20 feet above Mean Sea Level

Owner: Port of Vancouver

Description: The site is made up of flood plain deposits. The property is bounded on the north by a farm, the east by agricultural land, the south and west by an undeveloped/forested area, and the west by the Columbia River. About 1/4 mile south-southeast of the subject property is an industrial area, that is occupied by an aluminum plant and docking facilities. A strip of woodland runs adjacent to the property and separates the disposal area from the Columbia River.

Site improvements on the beach include a picnic area and restroom facility. East of the forest, the property is developed for agricultural use and contains pastures and plowed fields. A shallow, 40-feet long rectangular excavation was observed adjacent to the northern end of the subject property (offsite). Two ponds, 1/2 mile apart and connected by a creek that runs north-south along the boundary, are located adjacent to and offsite from the central portion of the eastern boundary.



Approximate Site Boundary

Fazio A, W-97.1

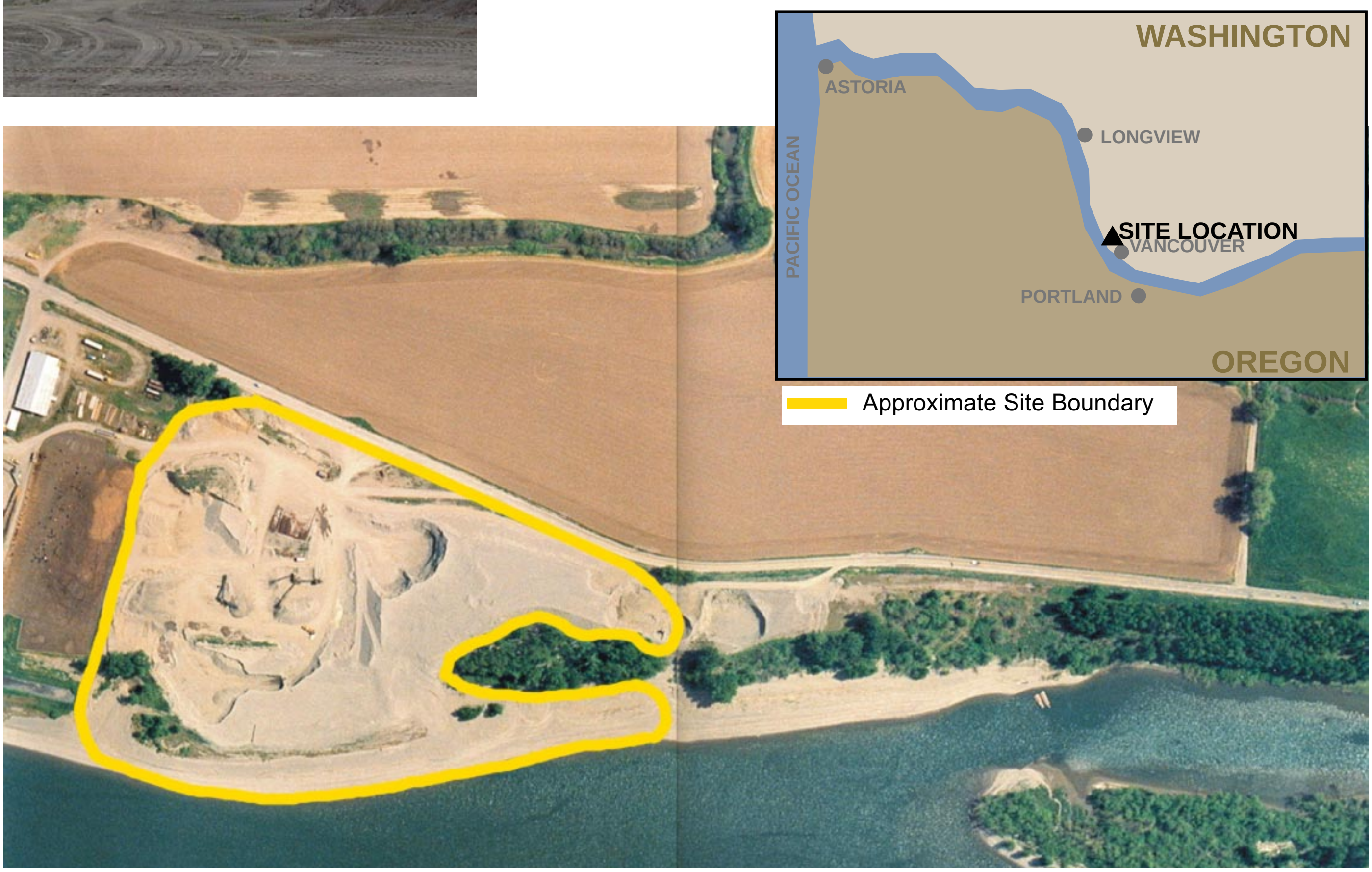
Size: Approximately 27 acres

Elevation: 10 to 40 feet above Mean Sea Level

Owner: New Columbia Garden Co.

Description: Flood plain deposits are almost entirely covered with sand and gravel material dredged from the Columbia River. The site is bounded on the north by the Fazio Brothers/New Columbia compound, the east by NW Lower River Road and agricultural farmland, the south by forest, and the west by the Columbia River. Roughly in the center of the site is the mining operation.

The north-northwest portion of the property is being used as a feedlot for cattle. The northeast corner is used as an equipment storage yard. On-site improvements include a truck scale, two office trailers, and a drainage system for the material dredged from the Columbia River. Prior to the mining operation, the property was reportedly used for agricultural purposes. A pond for the cattle is present on the north-western corner of the property. A 3,000-gallon (est.) former underground storage tank (UST) is on the site. The adjacent Fazio Brothers/New Columbia Garden Co. compound has an Aboveground Storage Tank (AST) farm, pesticide shed, and a maintenance shop.



Fazio B, W-96.9

Size: Approximately 17 acres

Elevation: 10 to 40 feet above Mean Sea Level

Owner: New Columbia Garden Co.

Description: The site is bounded on the north by a dairy farm and pasture. On the east it is bounded by NW Lower River Road and agriculturally developed land and on the west by the Columbia River. The Fazio brothers and New Columbia Garden Co. compound sits along the southern boundary. In the past, Columbia River dredge material was disposed of in the western and northern portions, making them approximately 30 feet above the surrounding area. The eastern portion of the site is situated approximately 10 feet above MSL, and slopes slightly to the north.

The western and northern portions of the property contain a cattle feedlot, while the eastern portion is open pasture. Onsite improvements are limited to a boathouse and outhouse located on the beach of the Columbia River.

Two ponds for the cattle are present along the western portion of the site. Along the eastern boundary is a ditch that runs parallel to NW Lower River Road. No wastewater services exist on the property.

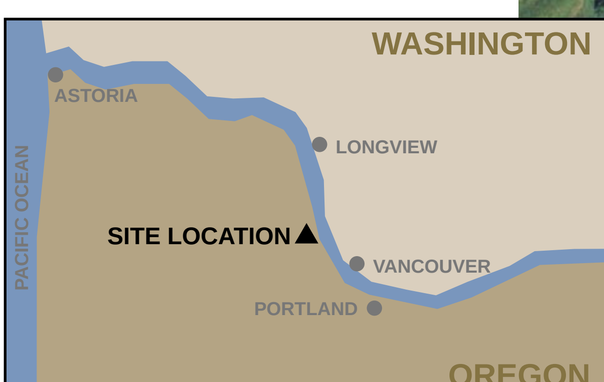
Lonestar, O-91.5

Size: Approximately 45-acre site

Elevation: 25 feet above Mean Sea Level

Owner: Northwest Aggregates (Glacier)

Description: The property lies on the south-eastern corner of a large open-pit mining operation. The site boundary is the 45-acre pit, although the 1 million yards will fill only a small segment. There is standing water in the open pit. The Santosh Wildlife Preserve borders the property to the east. The site is currently covered in sand and water and no improvements have been made.



Railroad Corridor, O-87.8

Size: Approximately 12 acres

Elevation: 5 to 20 feet above Mean Sea Level

Owner: Port of St. Helens

Description: Since 1991 the disposal site and the remaining 49-acre site adjacent to it have been primarily vacant or used for storage. Several groundwater monitoring wells were observed during the site reconnaissance.The site is vegetated with low-lying grasses, shrubs, and weeds. It is unknown whether the former creosote pipeline, which ran across the subject property, was completely removed. No water service exists on the property. Soil and groundwater have been affected by past industrial operations at the site. Creosote constituents have contaminated the site. The site is proposed for disposal of rock removed from the channel.

Most of the subject property lies on a floodplain that has been covered with material dredged from the Columbia River. Moderately steep 15- to 20-foot banks drop off along the shoreline into the Multnomah Channel and Scappoose Bay. The site is bordered on the north by Boise Cascade (St. Helens' pulp and paper mill); adjacent to the south of the site is a single warehouse; across the railroad tracks is an undeveloped, forested area. A railroad spur borders the site to the west. To the east is the Multnomah Channel and the mouth of Scappoose Bay.

Approximate Site Boundary

Austin Point, W-86.5

Size: Approximately 26-acres

Elevation: 5 to 30 feet above Mean Sea Level

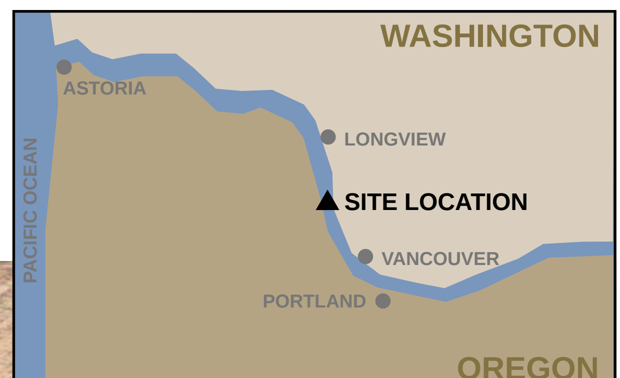
Owner: Port of Woodland

Description: Nearly all of the Austin property has been covered in the past with material dredged from the Columbia River.

The northern portion of the site is currently leased to a heavy equipment, crane, and rigging training school, West Coast Training, Incorporated (WCT), and has relatively little relief. This portion of the property consists of mostly open, level, sand-covered land, devoid of vegetation. One water supply well house is located on the property.

The southern part of the property is leased to Aaron Myers, who uses this land as pasture for four horses. This portion of the site has slightly undulating topography. A dike runs along the western edge of the property and is elevated above the site by about 5 to 10 feet.

There are three double-lined ASTs in the WCT maintenance shop (offsite). There is no water service to the property. One groundwater well is present onsite, due west of the access road that enters the WCT compound.



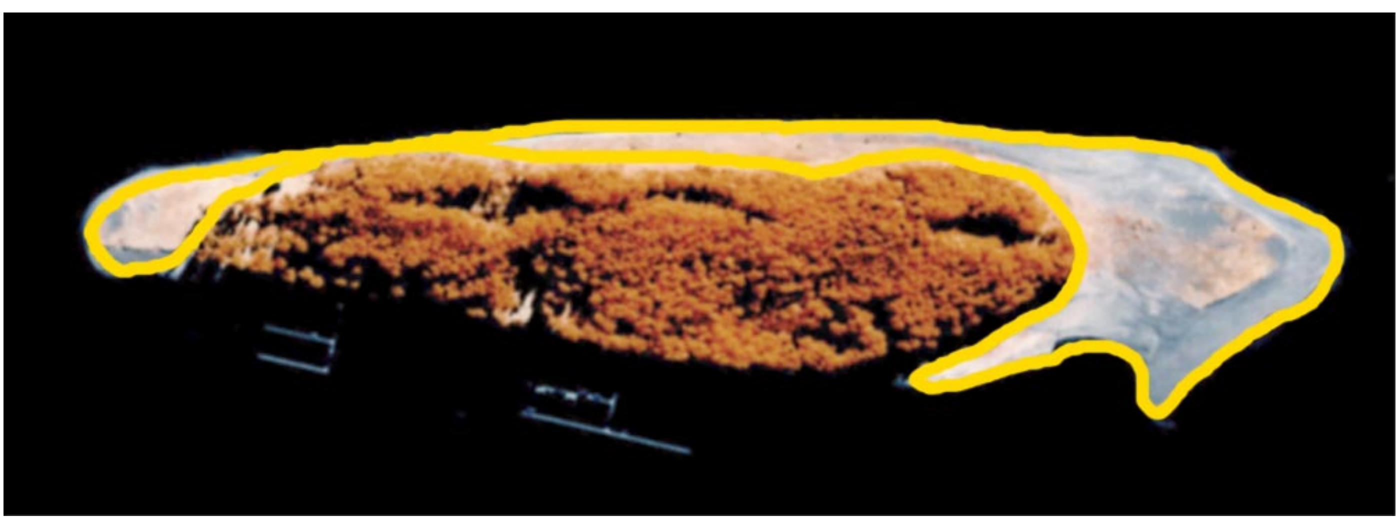
Sand Island, O-86.2

Size: 28 Acres

Elevation: 5 to 20 feet above Mean Sea Level

Owner: Port of St. Helens

Description: Sand Island is adjacent to the town of St. Helens, Oregon. The site is currently a disposal site for maintenance dredging. It occupies most of the entire island and is 4,600 feet long. There are no improvements on the island and no vegetative cover on the disposal area that fringes the island. The sand beach is operated seasonally as a recreational facility by the City of St. Helens. This will be a beach nourishment site.



Approximate Site Boundary

Reichold, O-82.6

Size: Approximately 49 acres

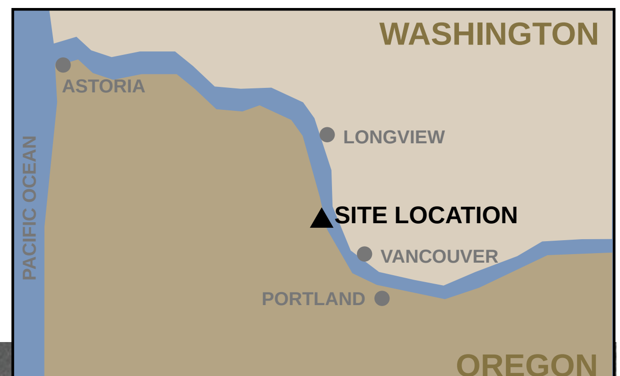
Elevation: 10 to 20 feet above Mean Sea Level

Owner: Morse Brothers, Inc.

Description: The Coastal Plant (63149 Columbia River Highway) is located to the west, and across Columbia River Highway. It owns the pipeline that bisects the site. The site is bounded to the north by Deer Island Slough, to the east by the Columbia River, to the south by the outfall of McBride Creek, and to the west by single-family residences and a cemetery.

Although the topography is nearly level across the entire site, a distinct ridge separates the subject property from the developments to the west. The center is relatively level, but slopes along the northern, eastern, and southern edges toward Deer Island Slough, the Columbia River, and McBride Creek.

The Morse Brothers' mining operation at the northern end of the property has created an approximately 20 feet deep excavation encompassing about 2 acres. A UAN-32 solution pipeline runs from the Coastal Plant to the end of the docking pier. The majority of the site is open field surrounded by forest.



Standing water, most likely from precipitation runoff, has been observed on the property within the western portion of the mining excavation. This pit water was bermed to prevent flooding within active excavation area.

Morse Brothers officials stated that the Coastal Plant pumps water from the Columbia River to use for both fire suppression and cooling water at their facility. This waterline is located beneath the paved access road that parallels the UAN-32 pipeline.

Martin Bar, W-82.0

Size: Approximately 32 acres

Elevation: 10 to 25 feet above Mean Sea Level

Owner: Port of Woodland and Washington Department of Fish and Wildlife

Description: The property is divided into two separate rectangle-shaped parcels, separated by a low vegetation area and Lions Day Park, that have been covered in the past with material dredged from the Columbia River. As a result, the site is slightly elevated (10 to 15 feet) above surrounding properties, and has a slightly undulating topography.

The subject property consists primarily of open field used for raising cattle. Onsite improvements include a navigational aid (beacon) and groin (wood and steel structure located in the river and placed perpendicular to the shoreline), feedlot/pasture fencing, a shed, an outhouse, and several roads. The dredged material has a cover of grasses, scattered cottonwoods (mainly on the northern parcel of the subject property), and brush.

Undeveloped land is present on the adjacent property to the north, a farm and agricultural land are adjacent to the east, and a RV park is adjacent to the south of the property.

Martin Island, W-80.0

Size: 34 acres

Elevation: 0 to 10 feet above Mean Sea Level

Owner: Robert and Richard Colf

Description: This is a project mitigation site that uses dredged material disposal. The 34-acre lagoon on Martin Island would be filled to just below water level to create a wetland/intertidal marsh. The site was historically excavated for road material during the construction of nearby I-5. The lagoon itself is ringed with vegetation. The rest of the island is primarily used for livestock grazing. One house exists on the island and is used by those tending the livestock. There is no road access to Martin Island.

Approximate Site Boundary

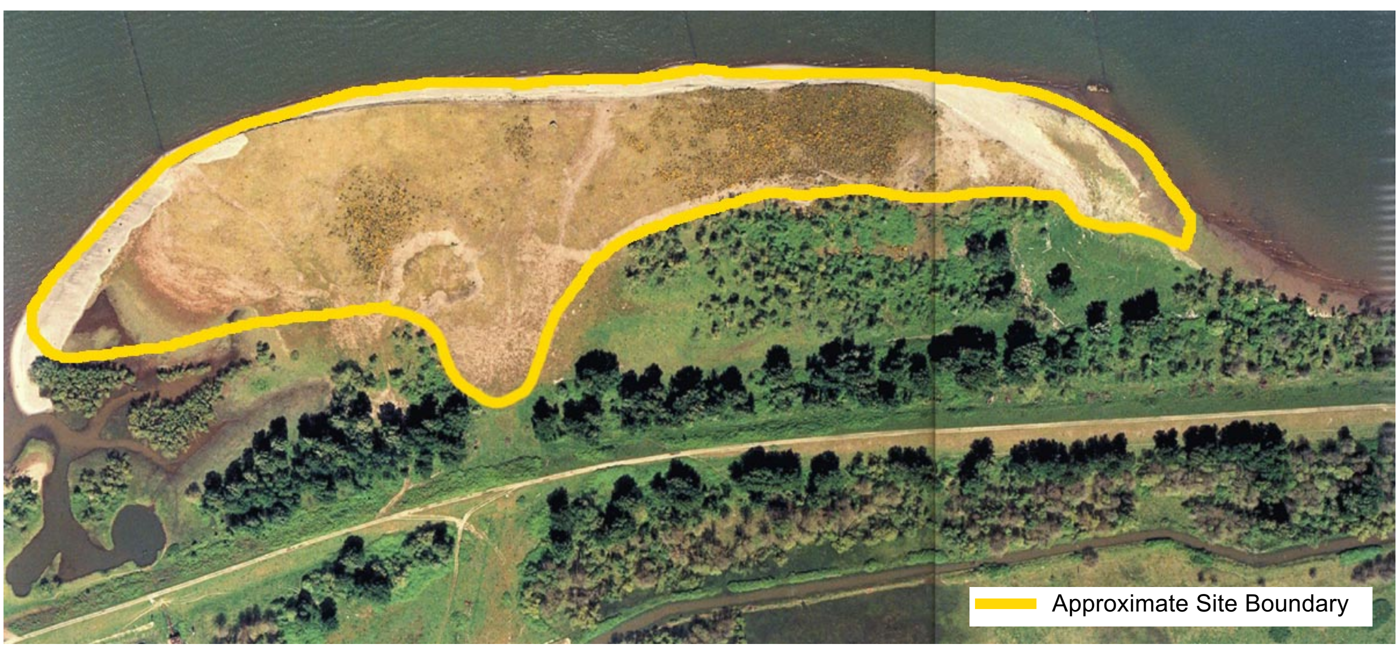
Lower Deer Island, O-77.0

Size: 29 acres

Elevation: 0 to 15 feet above Mean Sea Level

Owner: Arnold Leppin of Hillsboro, OR

Description: The majority of the Lower Deer Island site is a low plateau formed by past deposition of dredged material. The subject site is currently used as pastureland for cattle and as a borrow pit to maintain dikes in the Deer Island Diking District. A natural gas pipeline and fiber optic cable cross the parcel from roughly southeast to northwest. Grasses cover most of the open areas, while some landward portions of the subject property are covered with young cottonwood trees. No water service exists on the property.



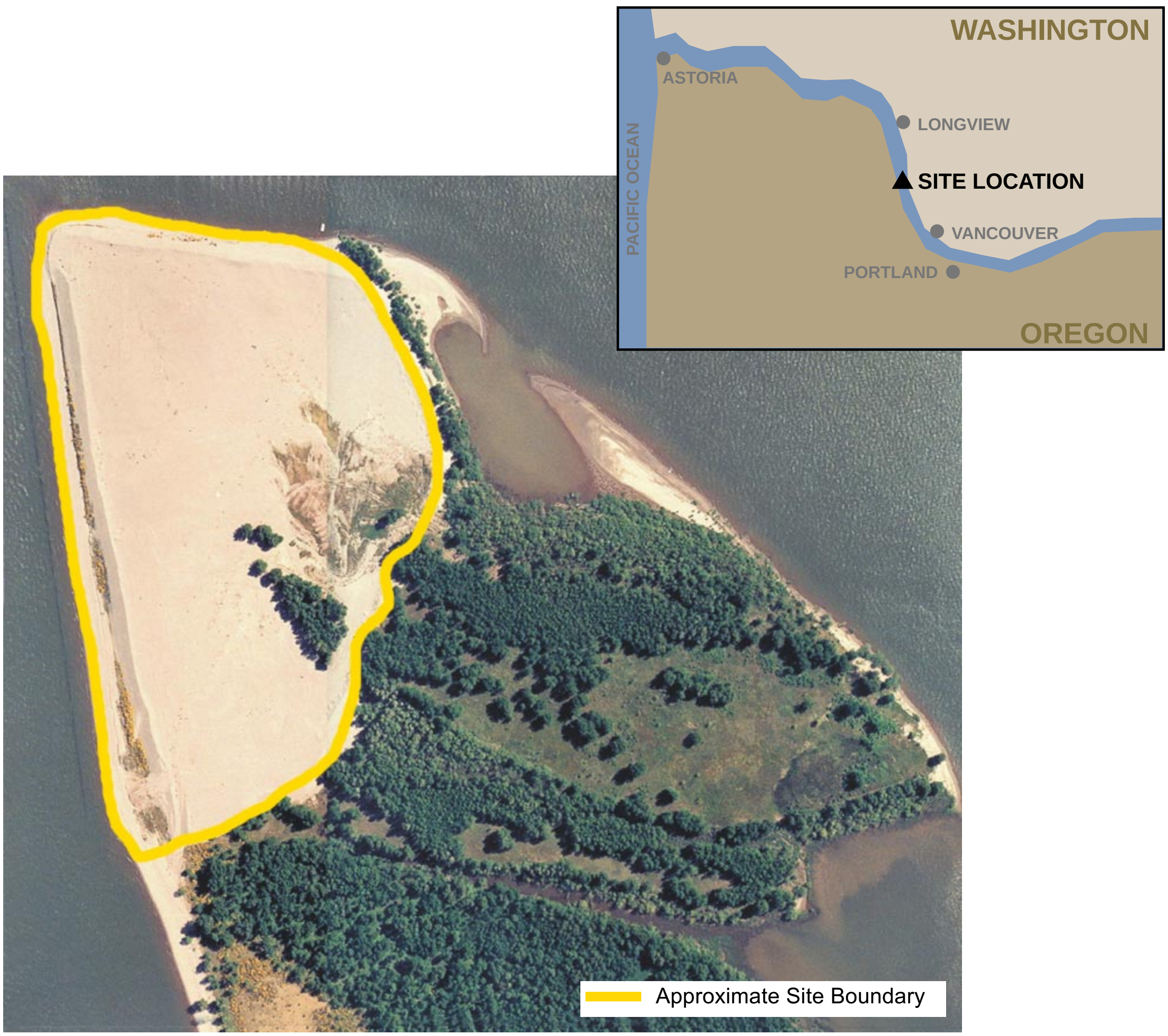
Sandy Island, O-75.8

Size: Approximately 30-acre bar island

Elevation: 5 to 20 feet above Mean Sea Level

Owner: Foss Redevelopment Company

Description: In the past, most of the property was covered with material dredged from the Columbia River, making the topography of the island relatively flat with a slight slope to the south. Steep 10- to 15-foot banks were observed along the north-northeast portion of the site. The only site improvements are dikes to contain dredged material from maintenance dredging.



Northport, W-71.9

Size: Approximately 27 acres

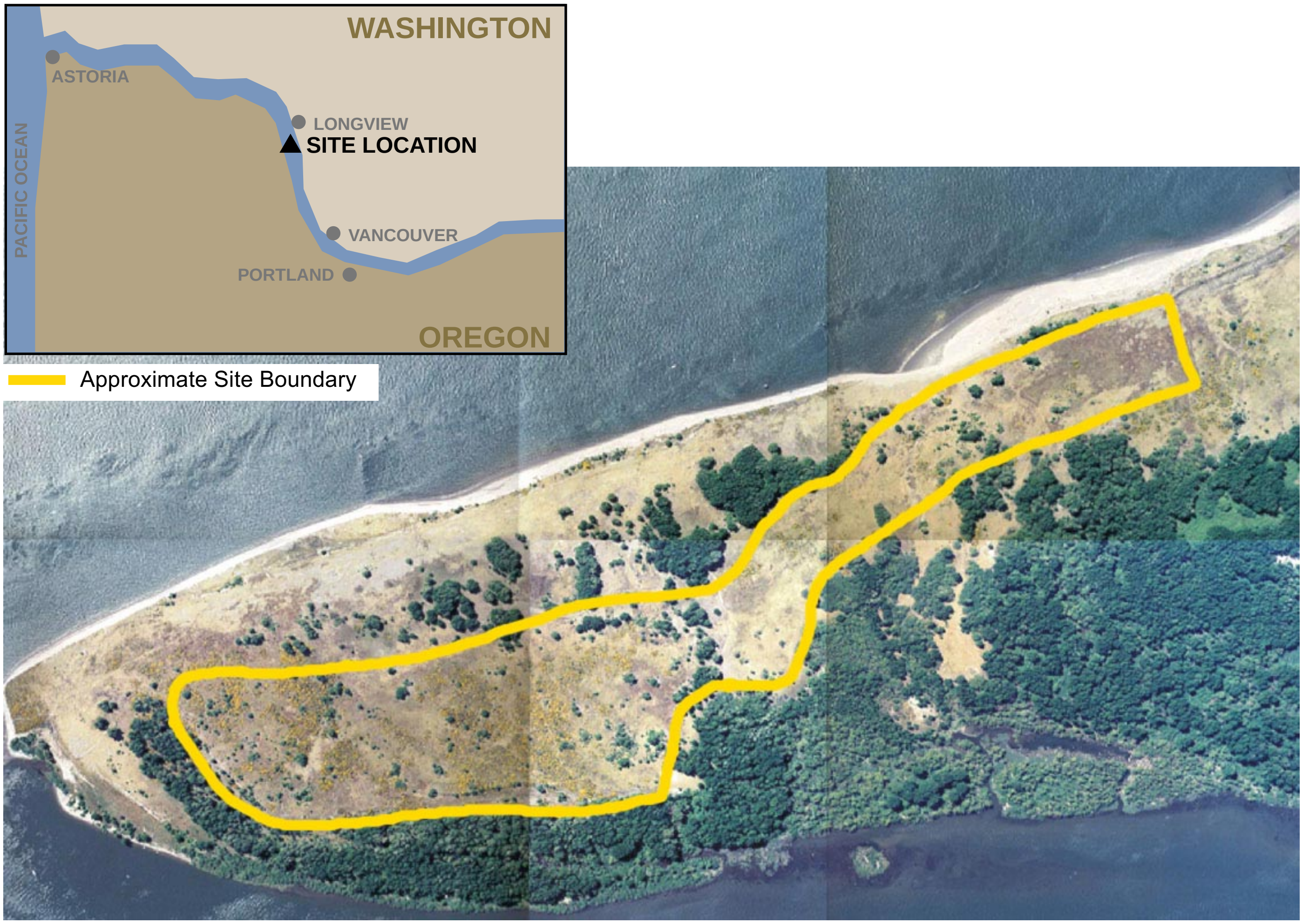
Elevation: 0 to 10 feet above Mean Sea Level

Owner: Port of Kalama

Description: Most of the peninsula and the adjoining properties to the south have received fill from past dredging operations. Sparse grasses cover most of the dredge material. Along the eastern length of the property is a narrow wooded section. A tidal flat, which extends southward from Carrolls Channel, is located just east of the site. A lowland marsh surrounds this tidal flat and extends to the northeastern fringe (onsite) of the property. The wetland will be avoided. Trojan Nuclear Power Plant is situated across the Columbia River and less than one mile to the southwest. Ground surface generally slopes away from the center of the peninsula, towards the surrounding water bodies (the Columbia River, Carrolls Channel, and the tidal flat). The property is oblong-shaped and the majority of it is sparsely vegetated. Most of the property is heavily crossed with vehicle and heavy equipment tracks from filling/dredging operations.
The adjoining areas to the south of the property contain open, dredge spoil-covered land. There is a steel mill to the south (Messer MG Industries).

The site is used currently to mine sand and gravel that is for sale.

Cottonwood Island, W-70.1



Size: 62 acres

Elevation: 10 to 30 feet above Mean Sea Level

Owner: Dr. Gene Davis of Tigard, OR (west), the Washington Department of Natural Resources (central), and Delta Trust (eastern)

Description: Cottonwood and Howard Islands were once separate, but are now contiguous. Nearly all of the subject property has been covered in the past with dredge material. The majority of the island is relatively level and situated approximately 20 feet above the Columbia River with steep banks dropping off to both the Columbia River and Carrolls Channel along portions of the shoreline. A pond and wetlands area are located 1/2 mile northwest of the site. The disposal site is set back 300 feet from the Columbia River and side channel shorelines to avoid ESA Critical Habitat.

The property is nearly devoid of development except for the presence of navigational aids (beacons), groins (wooden piles placed perpendicular to longshore current), and a few campsites. The property is roughly kidney shaped and is located at a northwest trending bend in the Columbia River. There is no water service to the property.

Howard Island, W-68.7

Size: 200 acres

Elevation: 10 to 30 feet above Mean Sea Level

Owners: Dr. Gene Davis of Tigard, OR (west), the Washington Department of Natural Resources (central), and Delta Trust (eastern)

Description: Nearly all of the property has been covered in the past 40 years with material dredged from the Columbia River. The site is roughly crescent shaped and relatively level. Steep 20-foot banks drop off to both the Columbia River and Carrolls Channel along portions of the shoreline. A lowland area with a pond and wetlands area is located adjacent to the north-northeast boundary of the property near Carrolls Channel. A small drainage channel runs north from the pond into Carrolls Channel. The wetland will be avoided during disposal. The northwest and northeast portions of the site are forest. Except for the presence of navigational aids and groins, the property is devoid of development. There is no water service or access to the island property.

International Paper Rehandle, W-67.5

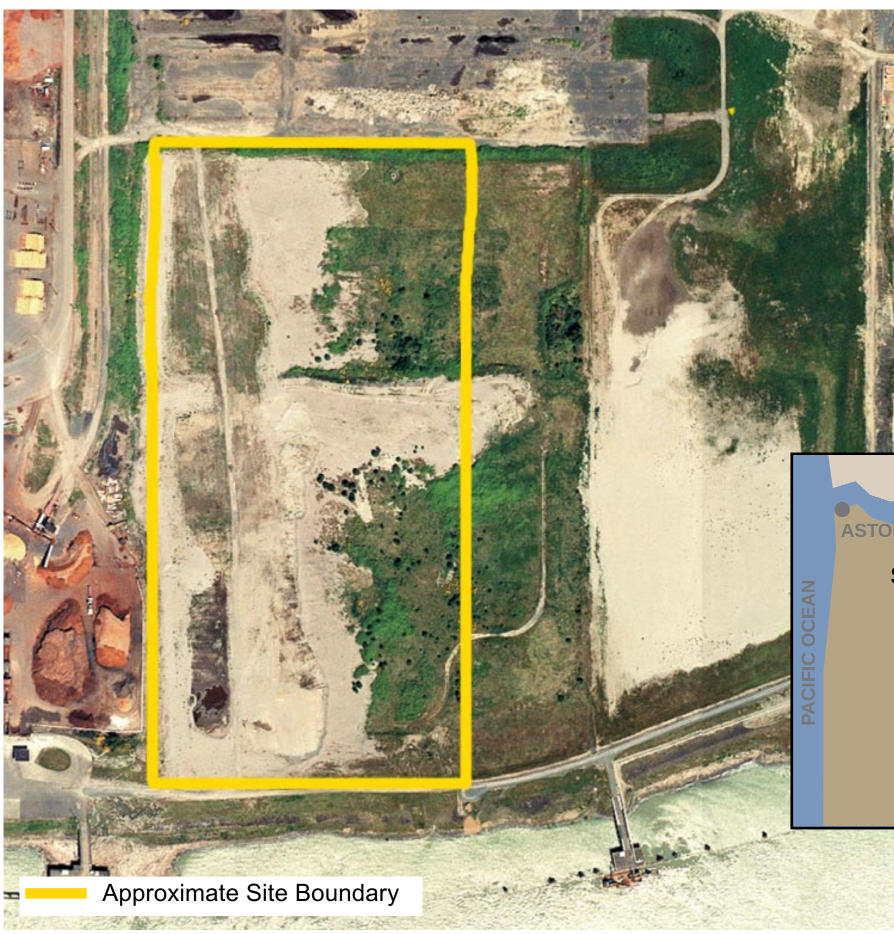
Size: 29 acres

Elevation: 10 to 20 feet above Mean Sea Level

Owner: Port of Longview

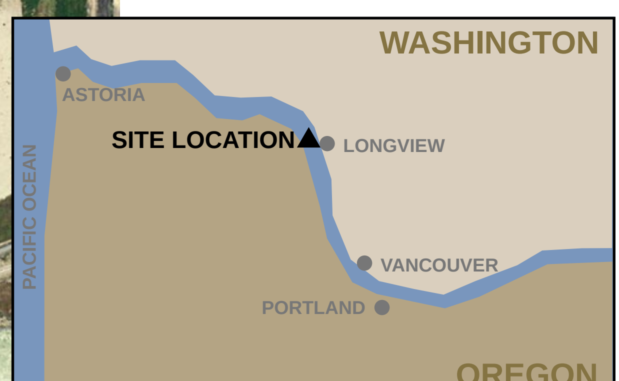
Description: The site is bounded on the north and east by vacant lots, the south by the Columbia River, and the west by a Pacific Fibre wood products facility. The topography of the property was altered by the placement of dredged material, resulting in a relatively flat to gently undulating topography. Steep 10-to-15-foot banks slope off to the north, east, and west from the dredge pile to the adjoining piles. The southern end of the property drops gradually to the Columbia River.

The property is zoned for heavy manufacturing. It is currently being used as a receiving site for dredged material. Improvements on the property include a drainage structure used for dewatering the dredge material.



The port is currently marketing sand from the property.

To the south, an offsite levee separates the site from the Columbia River, located approximately 200 feet south of the property. Pacific Fibre owns and operates a debarking facility on the adjoining property to the west. No water service exists on the property.



Rainier Beach, O-67.0

Size: 52 Acres

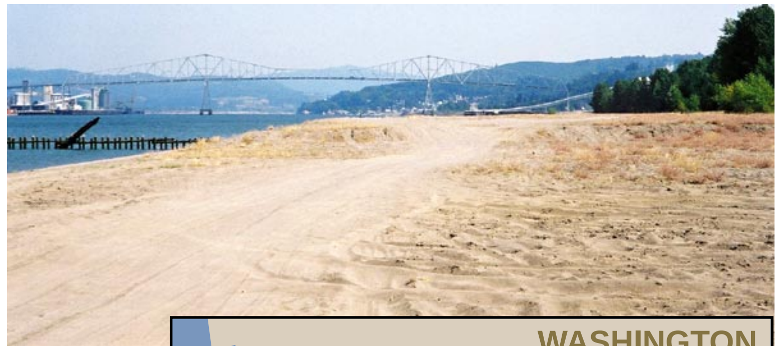
Elevation: 0 to 10 feet above Mean Sea Level

Owner: Rainier Waterfront Development, Inc. (Michael Avent)

Description: Rainier Beach is currently privately owned. The site was cleared and was initially used for dredged materials following the eruption of Mt. St. Helens in 1980. The site is currently covered by dredged material deposited there from maintenance dredging. It is bordered on the north by an active log decking yard and on the east by a railroad line that parallels the entire site.

There are no improvements on the site and no vegetation cover. There is rip-rap along the Columbia River that borders the site to the east.

Rainier Industrial, O-64.8



Size: Approximately 53 acres

Elevation: 5 to 30 feet above Mean Sea Level

Owner: Oregon Division of State Lands

Description: The entire Dibbley Point peninsula on which the site is located has received dredge spoils from past dredging operations. Ground surface generally slopes away from the center of the peninsula, toward the Columbia River to the north and toward a backwater slough off the Columbia River to the south. The southeast corner of the property contains an active sand and gravel mining operation. Dredge spoils in this area rise about 10 to 20 feet above the surrounding area.

Approximately 1/4 mile east of the property is the United States Gypsum (USG) sheet-rock plant. The southeast portion of the property is currently being mined for sand and gravel.

Lord Island, O-63.5

Size: Approximately 46 acres

Elevation: 0 to 30 feet above Mean Sea Level

Owner: Oregon Division of State Lands

Description: Most of the subject property has been covered in the past with material dredged from the Columbia River. The adjacent (downstream) portion of Lord Island, to the west and northwest of the property, is mostly covered with riparian forest and lowland marsh. Steep 20- to 25-foot banks drop off along the edges of the dredge pile to the Columbia River and the offsite portion of Lord Island. The island was historically formed from dredged material. The central portion of the disposal site is relatively level.

The disposal site is diked. There are no other improvements. Offsite (downstream) portions of Lord Island contain slack water, lowland areas, and marsh. Wooded areas extend along the southern and western boundaries of the site. These will be avoided.

Reynolds Aluminum, W-63.5

Size: Approximately 13-acre site

Elevation: 5 to 30 feet above Mean Sea Level

Owner: Reynolds Aluminum

Description: The property is bordered on the northwest, northeast, and southeast by the former Reynolds Aluminum plant, which is now closed. The entire site is diked and used for disposal. Reynolds Aluminum has used this site in the past as a disposal site for the dredging of the access channel from the main Columbia River Channel to their docking facility. The capacity at this site is limited. The property has been covered in dredge material that is being sold under contract. The only improvement on the site is a drainage system for the material dredged from the Columbia River.

Mount Solo, W-62.0

Size: Approximately 50 acres

Elevation: Approximately 10 feet above Mean Sea Level

Owner: Radakovich family

Description: The property is bounded on the north by a meandering surface water drainage, the east by a Cowlitz County Consolidated Diking District drainage, the south by a dike and the Columbia River, and the west by an undeveloped field.

The topography is nearly level across the entire site. The dike has gentle north and south slopes, and separates the majority of the site from the Columbia River. The center of the site has a slight depression, which was partially filled with water during the site reconnaissance. The northern half of the site slopes slightly to the north-northwest into the meandering surface water drainage ditch. To the west, the topography is relatively flat and similar to that of the subject property

The site has been vacant since 1996. The majority of the adjacent property to the north appears to be an equipment storage yard for Terra Firma, Inc. Adjacent to this property, to the northwest, is the Mt. Solo Landfill. Adjacent to the east of the property, and across the diking district drainage, is a disposal pond. At the southeast corner of the property (offsite) are a Cowlitz County Consolidated Diking District Number 1 pumping station and four large Bonneville Power Administration (BPA) high-voltage towers. West of the site is an undeveloped field that has historically been used for agricultural purposes.

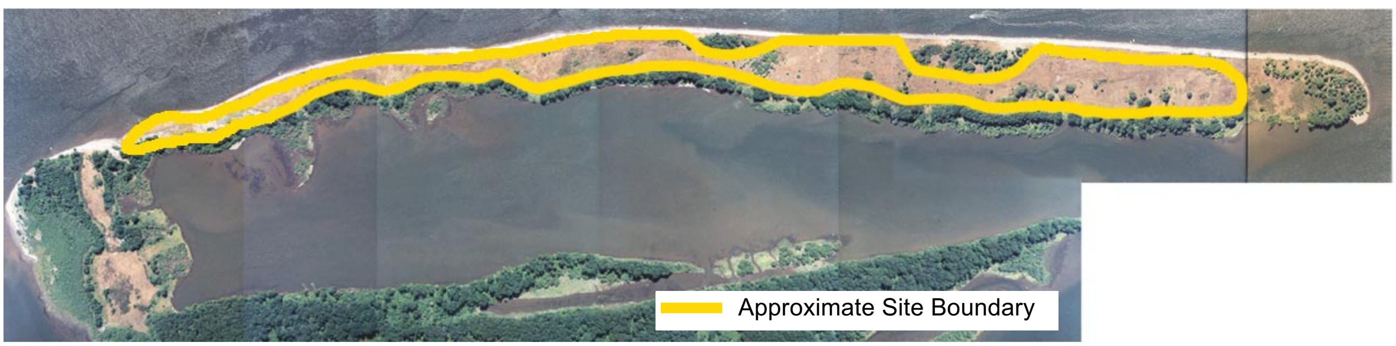
Standing water was observed in the center of the property as well as in two drainage ditches. There are no wastewater services at the property.

Hump Island, W-59.7

Size: 69 Acres

Owner: Washington Department of Fish and Wildlife/Washington Department of Natural Resources.

Description: Hump Island is a long thin island located between Walker Island and the Columbia River. It is approximately 9,500 feet in length with an average width of 600 feet. There are clusters of cottonwoods on the north and south ends of the island. The site is currently covered by disposal material deposited during maintenance dredging.



Crims Island, O-57.0

Size: Approximately 40 acres

Elevation: 0 to 20 feet above Mean Sea Level

Owner: Oregon Division of State Lands

Description: Most of the subject property has been covered in the past with material dredged from the Columbia River. Steep 5- to 25-foot banks drop off the edges of the sand pile to the Columbia River and adjacent offsite portions of Crims Island. The oblong-shaped property is approximately 3,300 feet long by 500 feet wide and is diked. It is situated along the upstream end of the island.

A narrow slough is located on the south-southwest side of the site, and nearly separates the site from the main body of Crims Island. Wooded areas extend along the southern and western boundaries of the property. These wooded areas will be avoided during disposal.

Port Westward, O-54.0

Size: Approximately 50-acre site

Elevation: 5 to 20 feet above
Mean Sea Level

Owner: Port of St. Helens

Description: The site is bordered on the northeast by the river and on all other sides by a PGE gas generating facility. The site was once a storage facility and also the location for US Army materiel and weapons loading construction during the World War II era. The entire site is currently grassy open space with no structures. A decommissioned railroad line runs the length of the property.

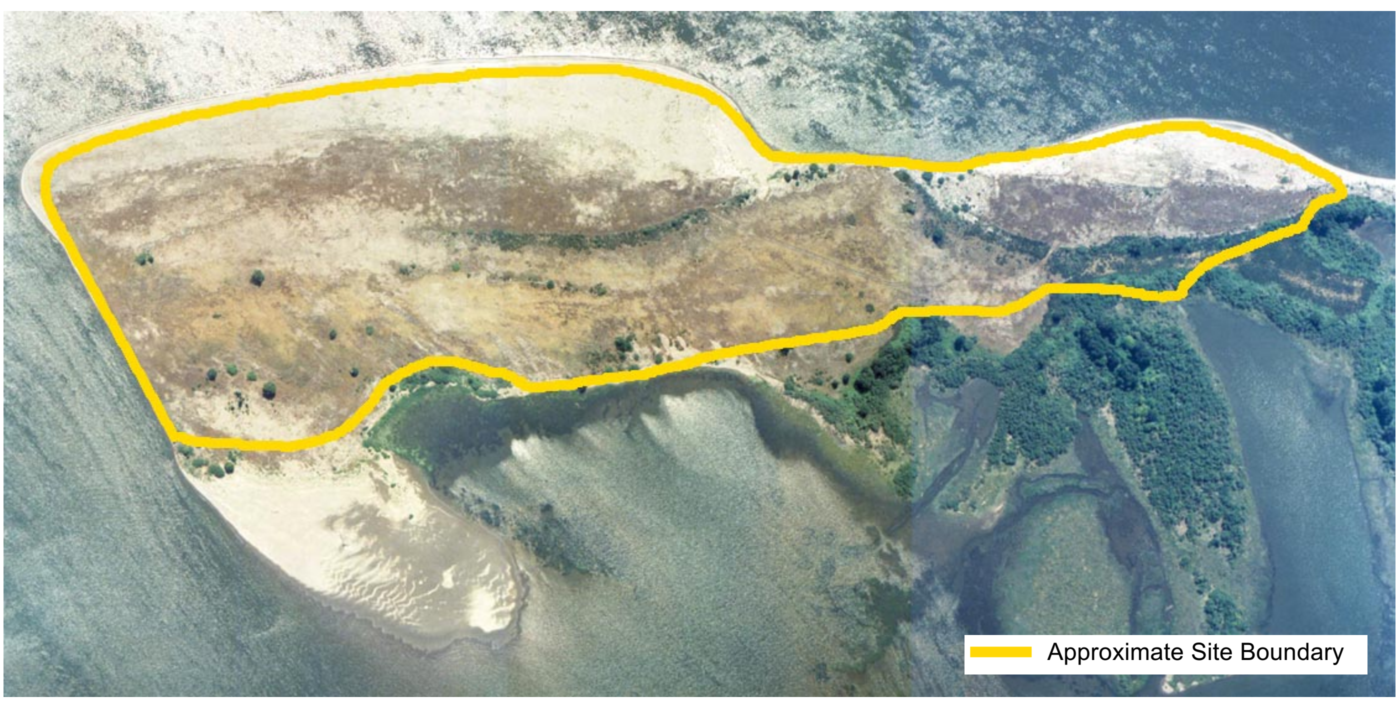
Brown Island, W-46.3/W-46.0

Size: 72 Acres

Elevation: 5 to10 feet above Mean Sea Level

Owner: Washington Department of Natural Resources

Description: Brown Island is located at the upper end of Puget Island and is an established disposal site for maintenance dredge material. There is no tree cover on the site. Brown Island is bordered by White Island. A low swale separates the two and is inundated seasonally. No other improvements are located on the island.



Puget Island, W-44.0

Size: Approximately 100-acre site

Elevation: 0 to 15 feet above Mean Sea Level

Owner: Vik family

Description: The site is bordered on the north, west, and east by other agricultural lands and by private residences to the south. The current use of the subject property is agriculture. There are several structures related to the farming operation and one home will be relocated to accommodate material disposal.

Approximate Site Boundary

James River, O-42.9

Size: 53 Acres

Elevation: 15-30 feet above Mean Sea Level

Owner: Fort James (Georgia Pacific)

The site is located below the mouth of the Westport Slough. The original site was 59 acres, but was reduced to 53 acres to avoid a small wetland. The site was used previously for maintenance dredging disposal and is currently covered with disposal material and small clusters of trees and ground vegetation.

Approximate Site Boundary

Tenasillahe Island, O-38.3

Size: 42 acres of a 75-acre island

Elevation: 0 to 10 feet above Mean Sea Level

Owner: Oregon Division of State Lands

Description: The property has been covered in the past with material dredged from the Columbia River. The majority of the island is relatively level and elevated above the Columbia River. Steep 10-foot banks drop off to both the Columbia River and Clifton Channel along portions of the shoreline. A lowland marsh is located adjacent to the northeast edge of the property. The site is nearly devoid of improvements except for temporary campsites and an outhouse. No wetlands will be impacted by disposal.

Welch Island, O-34.0

Size: Approximately 42 acres

Elevation: Approximately 0 to 20 feet above Mean Sea Level

Owner: Oregon Division of State Lands

Description: Most of the property has been covered in the past with material dredged from the Columbia River. A slightly uneven topography was observed on the interior of the site, indicating uneven dredge spoil placement. The interior of the property is bermed, and steep 10-foot banks drop off from the site to the Columbia River and along the southwestern side of the property. A lowland marsh and riparian forest is located adjacent to the southwest of the property. There is no water service to the property.

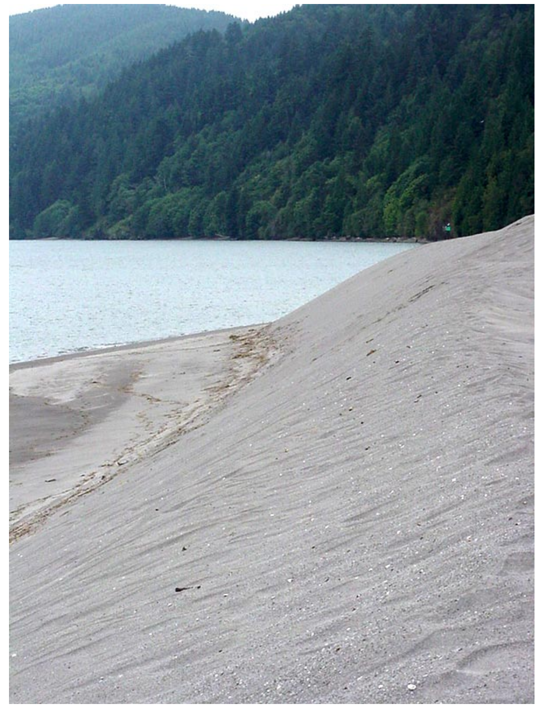
Skamokawa, W-33.4

Size: Approximately 11-acre site

Elevation: 10 to 30 feet above Mean Sea Level

Owner: Port of Wahkiakum, City of Skamokawa

Description: The site is currently used for material disposal from the Columbia River. A day-use park borders the property to the southeast and northeast. The southeast corner of the property contains an active sand and gravel mining operation. There are no other improvements on the site. Only about 50% of the park is covered with sand, which is sold to offset operating costs.



Pillar Rock, O-27.2

Size: Approximately 56 acres

Elevation: 0 to 25 feet above Mean Sea Level

Owner: Oregon Division of State Lands

Description: The property occupies the majority of a roughly east-west trending bar island and is within the Lewis and Clark National Wildlife Refuge. Most of the site has been covered in the past with sandy material dredged from the Columbia River. The topography of the island interior is relatively level, as the dredged material has been evenly distributed across it. Steep 10- to 25-foot banks exist along portions of the dredge pile.

A tidal flat/marsh area is located (offsite) along the southern side of the island. Improvements to the site include two pile dikes that extend out from the northwest side of the site into the Columbia River channel. Wetlands will be avoided during disposal.

Miller Sands, O-23.5

Size: Approximately 151 acres

Elevation: 0 to 20 feet above Mean Sea Level

Owner: Oregon Division of State Lands

Description: The site is within the Lewis and Clark National Wildlife Refuge. Much of the subject property has been covered with material dredged from the Columbia River. The site has an undulating topography. Steep10-foot banks drop off from portions of the interior to the north and south sides of the island.

An offsite tidal flat/marsh area and narrow channel are located to the south of the site. The southeastern (upstream) end of the site is vegetated with small shrubs and trees. There is no water service to the property.

Approximate Site Boundary

Rice Island, W-21.0 and O-21.0

Size: Approximately 228 acres

Elevation: 0 to 40 feet above Mean Sea Level

Owner: Oregon Division of State Lands (DSL) and Washington Department of Natural Resources (DNR) are the sole owners.

Description: The property occupies the majority of a roughly northeast-southwest trending bar island. The island was created in the past with material dredged from the Columbia River. The topography of the island interior is relatively level, as the dredged material has been evenly distributed across it. Steep 20- to 35-foot banks drop off from the dredge pile.

A small amount of standing water, which was located within the retention pond used for dredge spoil dewatering, was observed on the property. Improvements observed onsite include a retention pond and metal drainage structure for the dredge material dewatering. The downstream end of the island is used by terns and access to the island is limited. Rice Island will be a future maintenance dredging disposal site after Channel Improvement.

No aerial photo available for this site

VOLUME II – TECHNICAL APPENDICES INCLUDE:

APPENDIX A

Reconsultation Related Correspondence and SEI Panel Vitae

Appendix A contains an assortment of letters that are important to the reconsultation process and the issues discussed in Section 1 of the BA. These letters have been organized according to the order in which they are referenced within the document. Accordingly, they appear in the following order within this appendix:

- The first letter is a November 26, 1999 open letter from NMFS notifying the public of the transfer of jurisdiction of coastal cutthroat trout to USFWS.
- The second letter is the August 25, 2000 withdrawal of the original BO by NMFS.
- The third inclusion is an October 26, 1998 letter from USFWS expressing concern about potential effects from contaminated sediments on peregrine falcons and an April 22, 1999 response from the Corps.
- The fourth letter is the December 7, 2000 recommendation by USFWS for re-initiation of consultation for coastal cutthroat and initiation of consultation for bull trout with a responding letter from the Corps dated January 6, 2001.
- The fifth inclusion in this appendix is a series of six letters documenting the designation of the six co-sponsoring ports as non-Federal representatives in the ESA § 7 process pursuant to 50 CRF § 402.08. Letters are included from May 21, 2001 and July 11, 2001 (2); October 27, 2000 (2); and October 16, 2000.

November 26, 1999

Final Jurisdiction of Coastal Cutthroat Trout Under the U.S. Endangered Species Act

Dear Interested Parties:

This letter is to inform you that, except as indicated below, the U.S. Fish and Wildlife Service (USFWS) will from this date be the agency with sole regulatory jurisdiction over all life forms of coastal cutthroat trout (Oncorhynchus clarki clarki) under the U.S. Endangered Species Act (ESA).

In the past, ESA jurisdiction over the coastal cutthroat trout has been shared by the USFWS and National Marine Fisheries Service (NMFS). However, in a *Federal Register* notice published on April 5, 1999, the two agencies announced that they would decide which agency would have sole jurisdiction over the species. Sole jurisdiction is expected to provide a more expeditious means for dealing with ESA issues involving both resident and migratory forms of the species. Regardless, both agencies will continue to coordinate activities such as ESA Section 7 consultations and Habitat Conservation Plans involving watersheds shared by coastal cutthroat trout and salmonid species under NMFS jurisdiction (e.g., steelhead and chinook salmon).

There are presently two pending ESA determinations involving coastal cutthroat trout. The first is a proposed de-listing of Umpqua River cutthroat trout published on April 5, 1999. Because the original status review and listing decisions for this cutthroat population were conducted by NMFS, the final de-listing determination and associated regulatory responsibilities will be handled by NMFS, with FWS concurrence on any final de-listing determination. The second determination involves cutthroat trout populations in southwest Washington and the lower Columbia River currently proposed for listing under the ESA as threatened. The USFWS will assume sole responsibility over the final listing determination for these populations. This determination is expected by April 2000.

If you have any questions regarding this matter, please contact Barry Mulder at the USFWS, (503) 231-6179, or by calling Garth Griffin at NMFS at (503) 231-2005.

With regards,

William Stelle, Jr.
Regional Administrator
Northwest Region
National Marine Fisheries Service

Anne Badgley
Regional Director
Region One
U. S. Fish and Wildlife Service

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE

Northwest Region
7600 Sand Point Way NE
Bin C15700, Bldg. 1
Seattle, Washington 98115-0070

Refer to:
OSB99-0270-RI

August 25, 2000

Colonel Randall J. Butler
Department of the Army
Corps of Engineers, Portland District
P.O. Box 2946
Portland, OR 97208-2946

Dear Colonel Butler:

RE: Withdrawal of the Biological Opinion for the Columbia River Federal Navigation Channel Deepening Project and Request to Reinitiate Consultation

On December 16, 1999, National Marine Fisheries Service (NMFS) issued a biological opinion for the Columbia River Federal Navigation Channel Deepening Project (Project). The objective of the biological opinion was to determine whether proposed deepening of the Federal Navigation Channel jeopardized the continued existence of the 13 salmonid species listed or proposed for listing under the Endangered Species Act (ESA), or resulted in the destruction or adverse modification of their designated or proposed critical habitat.

Pursuant to the consultation regulations (50 CFR 402.16) reinitiation of formal consultation is required if: 1) New information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not considered in the consultation; 2) the action is subsequently modified in a manner that causes an effect to the listed species or critical habitat not considered in the consultation; or 3) a new species is listed or critical habitat is designated that may be affected by the action. As described below, NMFS believes there are circumstances relative to these criteria that warrant reinitiation of formal consultation. Accordingly, NMFS hereby withdraws its December 16, 1999, biological opinion for the Project and requests reinitiation with the Corps.

As described in the biological opinion, the no-jeopardy conclusion and terms and conditions to support that conclusion were based in part on a letter dated December 3, 1999, from Colonel Randall J. Butler, District Engineer, Portland District Corps of Engineers (Corps) to Mr. Rick Applegate, Assistant Regional Administrator of NMFS Northwest Region, amending the Corps' April 5, 1999 biological assessment. The letter described a number of measures proposed by the Corps designed to: 1) Take early action to restore critical shallow water habitat in the estuary; 2) perform a series of studies, analyses, and monitoring to verify the project's impacts and gage the effectiveness of fish protection and habitat restoration

activities; and 3) prepare a multi-year plan for estuary restoration that is closely coordinated with other parties, including the Lower Columbia River Estuary Program.
From the issuance of the biological opinion until the present time, NMFS and Corps staff have engaged in a series of meetings to reach consensus on the appropriate studies, analyses, and monitoring requirements to implement the measures described in the amended biological assessment and biological opinion. To date, our agencies have not been able to reach consensus on the specific details of some of these studies, which calls into question the conclusions in the biological opinion. As a result, we have missed the opportunity to collect baseline information during this field season. It is essential that we reach agreement and begin the studies described in the biological assessment and biological opinion so that we may better understand the project's impacts and verify that the conservation measures, including the proposed habitat restoration program, are adequate prior to commencing the Project.

Since NMFS issued its biological opinion on the Project, our Northwest Fisheries Science Center has completed further studies on the effects of bathymetry (configuration of the estuary bottom) on ecological conditions in the estuary. A report is expected later this month which addresses issues relevant to the Project, such as the effects of flow and bathymetry on shallow-water habitat at the estuary's periphery. Because these shallow-water habitats play a key role in the estuary's ability to support fish, this new information underscores the need to be sure that we understand the probable effects of the Project, and to ensure that the conservation measures provided in the biological opinion are appropriate.

NMFS is also evaluating new information which suggests that salmon may be susceptible to a wider range of sub-lethal impacts from certain contaminants, and at lower ranges of exposure, than was previously believed to be true. Some toxic chemicals can have sub-lethal effects on outmigrant juvenile salmon, including reduced growth and impaired disease resistance. The biological opinion addressed the potential for toxic chemicals to be released or redistributed to low velocity, shallow water habitats during dredging activities. Consequently, there is a need to ensure that the conservation measures provided in the biological opinion take this new information into account.

NMFS is also concerned over issues that have arisen regarding the Corps' ability to restore estuary habitat identified in the biological opinion.

In light of the need to reach agreement on required studies, to consider the new information described above, and to assess effects to newly designated critical habitat, NMFS hereby withdraws its biological opinion on the Project and requests reinitiation of formal consultation with the Corps. By reinitiating consultation NMFS expects to work closely with the Corps to: 1) Thoroughly assess the implications of any relevant new information; 2) reach agreement on the specific details of required studies and monitoring, and a schedule for conducting this work; 3) clarify expectations for the completion of restoration work; and 4) make any necessary refinements in the conservation measures, including terms and conditions, that are provided in the biological opinion to protect listed species and their designated critical habitat. These tasks must be completed before NMFS' can re-issue a biological opinion for the Project.

We look forward to continuing our work on this project. My staff will be calling your office to arrange a meeting to scope the issues to be addressed and to develop a schedule for the reinitiation process. In the meantime, if you have any questions, please call me at (206) 526-6150.

Sincerely,

Donna Darm
Acting Regional Administrator

BCL-L

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Oregon State Office
2600 S.E. 98th Avenue, Suite 100
Portland, Oregon 97266
(503) 231-6179 FAX: (503) 231-6195

Reply To: 8330.4324 (98)
File Name: credPEFA.wpd

October 26, 1998

Howard B. Jones
Portland District, Corps of Engineers
P.O. Box 2946
Portland, OR 97208-2946

Subject: Informal consultation on Columbia River Channel Deepening and its effects on Peregrine falcons (1-7-98-I-432)

Dear Mr. Jones:

We are writing to express our concerns regarding impacts of the referenced project on the Federally threatened Peregrine falcon (*Falco peregrinus*). Our comments are provided in accordance with section 7 of the Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq.*). These comments are provided in response to your letter dated September 24, 1998, received in this office September 25, 1998.

The proposed project consists of dredging the Columbia and Willamette Rivers to a depth of 43 feet and disposal of dredged material at approved sites. It is our understanding that the proposed project includes the possibility of dredging contaminated sediments from the Willamette River. The dredging of these materials could cause contaminated sediments to be reintroduced to the water column. The dredging and resuspension of contaminated sediments may augment toxins already affecting the resident Peregrine falcons in the Willamette and Columbia Rivers downstream of the proposed project.

The biological assessment indicated that the Corps determined the proposed project would not be likely to adversely affect Peregrine falcons. However, the Service believes that the resuspension of contaminated sediment is likely to result in adverse effects that constitute harm and harassment of Peregrine falcons, and therefore, formal consultation and receipt of an incidental take permit are necessary.

In order to complete formal consultation, the Service will need the following information:

1. The location of contaminated sediments that may be dredged;

2. The proposed method of dredging these materials;

3. The location of contaminated dredged material disposed sites; and

4. The proposed method of disposal of contaminated dredged materials.

If you have any questions or need more information, please contact Laura Todd or Rollie White at (503) 231-6179. Thank you for your cooperation in the effort to protect endangered and threatened species.

Sincerely,

Russell D. Peterson
Acting State Supervisor

APR 22 1999

Engineering and Construction Division (1165-2-26a)

Russell D. Peterson, State Supervisor
U.S. Fish and Wildlife Service, Oregon State Office
2600 SE 98th Avenue, Suite 100
Portland OR 97266
Attn: Laura Todd

Dear Mr. Peterson:

The issue of contaminated sediments in the lower Willamette River is presently a high profile issue with strong federal, state, city and local interest. The Service expressed their concerns in October 26, 1998 letter regarding potential adverse impacts to peregrine falcons that might arise from dredging contaminated sediments in the Willamette River upon implementation of the Columbia River Channel Improvement Project (CRCIP; reference 1-7-98-I-432). Your letter stated the Service's belief that, "the resuspension of contaminated sediment is likely to result in adverse effects that constitute harm and harassment of peregrine falcons, and therefore, formal consultation and receipt of an incidental take permit are necessary.

We propose to seek authorization for CRCIP construction but delay implementation of the Willamette River portion of the channel improvement efforts until the contaminated sediments issue is resolved. This would allow for all interested parties to address contaminated sediment concerns, including the Service's concern over Willamette River sediments. The Service's four specific information requests, in order to complete the formal consultation for peregrine falcons, are anticipated to be answered during future efforts by all interested parties. They were:

1. The location of contaminated sediments that may be dredged;
2. The proposed method of dredging these materials;
3. The location of contaminated dredged material disposal sites; and.
4. The proposed method of disposal of contaminated materials.

Once a resolution of the contaminated sediment issue in the Willamette River has been attained, the Corps would seek to implement deepening of the Willamette River navigation channel. Consultation with the Service for peregrine falcons and other listed species would be reinitiated at that time for the Willamette River segment of the overall project. The issue of take and whether an incidental take permit would be necessary would be addressed during that consultation.

Your letter of October 26, 1998 did not indicate any concerns for other listed species relative to the Corps biological assessment for CRCIP. Our determination(s) for each listed species are listed by action in the attached table (Enclosure 1). We request a letter of concurrence on listed species for the CRCIP, including peregrine falcons, given the aforementioned proposal and our existing determinations. Please provide a concurrence letter by May 15, 1998 for inclusion with the final Environmental Impact Statement for the project.

Sincerely,

H Robert Wille

Howard B. Jones, P.E.
Chief, Engineering and Construction Division

U.S. Fish and Wildlife Service
Ecological Services
Oregon State Office
2600 SE 98th Avenue, Suite 100
Portland, OR 97266

Office phone: (503) 231-6179
FAX Number: (503) 231-6195

Date: December 8, 2000
Time: 1:34pm

FAX Transmittal

To: Colonel Randall J. Butler, Portland District Corps; cc: Kim Larson
FAX Number: (503) 808-4505

From: Rollie White, Supervisory Fish and Wildlife Biologist

Distribution

- [x] Urgent - Hand Carry
- [ ] Call Recipient at #____
- [ ] Usual Routing

Subject: Columbia River Channel Improvement Project; Consultation

Number of pages (including transmittal sheet): 4

Comments:

Dear Colonel Butler,

At the request of State Supervisor Kemper McMaster I am faxing this letter to you today. Kemper and our Regional Director, Ms. Anne Badgley, are meeting with Mike Thorn of the Port of Portland this afternoon, and may share this letter with him if appropriate. We wanted to make certain, however, that you had received a copy before we shared it with the Port, and since it was only signed yesterday we felt that normal mail delivery was unlikely to have reached you yet. Please do not hesitate to call if you have questions.

Sincerely,

Rollie White, Endangered Species Division Manager

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Oregon Fish and Wildlife Office
2600 S.E. 98th Avenue, Suite 100
Portland, Oregon 97266
(503) 231-6179 FAX: (503) 231-6195

Reply To: 8330.0563 (01)
File Name: COE notification1.wpd

December 7, 2000

Colonel Randall J. Butler
Department of the Army
Corps of Engineers, Portland District
P.O. Box 2946
Portland, OR 97208-2946

Re: Recommendations for Conferencing and Consultation on the Columbia River Channel Improvement Project

Dear Colonel Butler:

On November 29, 2000, U.S. Army Corps of Engineers (Corps) biologists initiated dialog with the U.S. Fish and Wildlife Service (Service) about a conferencing and consultation process for the Columbia River Channel Improvement Project (Project). Of particular concern to the Service are effects of the Project on Southwestern Washington/Columbia River coastal cutthroat trout and bull trout.

The Southwestern Washington/Columbia River population of coastal cutthroat trout (coastal cutthroat trout) was proposed for listing under the Endangered Species Act (Act) as a threatened species on April 5, 1999 (64 FR 16397). On April 21, 2000, the Service assumed all jurisdiction under the Act for coastal cutthroat trout (65 FR 20123). The Columbia River and estuary are utilized by coastal cutthroat trout. The Service listed the Columbia River Distinct Population Segment of bull trout as a threatened species on June 10, 1998 (63 FR 31647). We have recently become aware of historic and recent records of bull trout in the Columbia River estuary.

The National Marine Fisheries Service (NMFS) transmitted a final biological/conference opinion on the Project to the Corps on December 16, 1999. Potential effects to coastal cutthroat trout from the Project were addressed by NMFS in that opinion. On December 6, 1999, the Service transmitted a biological opinion (log number 1-7-99-F-280) on the Project's effects to bald eagle and Columbian white-tailed deer.

Since the aforementioned listing and consultation/conferencing actions, a number of issues associated with the Project have arisen. The following is a brief list of concerns and Service recommendations:

- On August 25, 2000, NMFS withdrew its biological opinion, removing any coverage under the Act for Project effects to coastal cutthroat trout. Due to the change in jurisdiction for coastal cutthroat trout, and withdrawal of NMFS' biological opinion for this project, we recommend that the Corps continue informal conferencing with the Service to address effects of the Project on coastal cutthroat trout. Additionally, for the purpose of formal conferencing on Project effects to coastal cutthroat trout, we recommend the Corps develop a biological assessment for the Project.

- We have recently become aware of historic records of bull trout in the Columbia River estuary. The Corps has not requested initiation of consultation for Project effects on this species, but we recommend that you do so.

- NMFS and the Corps have recently established a "reconsultation process", wherein the baseline conditions, and physical, chemical, and biological effects of the proposed action will be robustly re-analyzed. For instance, a week-long workshop is tentatively scheduled to begin addressing these biological, physical, and chemical issues. Because the Service believes the Project effects for species under NMFS' authority will be similar to those for coastal cutthroat trout, and the three agencies have a strong history of cooperatively addressing complex consultation issues jointly, it will be advantageous for the Service to fully join into the "reconsultation process" with NMFS and the Corps. It will be more difficult to comprehensively and completely address all issues involving listed and proposed aquatic species without the Service's full involvement in the ongoing cooperative approach.

- Currently, we have received no information regarding the Corps' intent to implement the Bald Eagle Term and Condition #4 listed in the Service's December 6, 1999, opinion. We recommend the Corps begin implementation of Term and Condition #4, or provide us a strategy and timeline for implementation of this Term and Condition, before the Project actions begin. Without implementing the Terms and Conditions from this opinion, the Corps may not have incidental take coverage for the bald eagle. In addition, if any changes to the Project's action or effects are expected, that weren't previously described or disclosed in the Corps' 1999 biological assessment, you also may need to reinitiate consultation on the December 6, 1999, opinion for bald eagle and/or Columbian white-tailed deer.

- If any non-Federal entities will be involved with the Corps in the conferencing/consultation process for coastal cutthroat trout and bull trout or reinitiation of our previous consultation, the Service requires the Corps to transmit a letter to us designating non-Federal representatives.

We believe that full participation by the Service in all ongoing data review, analysis, and Project effects discussions, as outlined in the NMFS/Corps "reconsultation process" briefing documents, will benefit all agencies involved in this Project. Please contact Rollie White, Endangered Species Division Chief, or Doug Young, Fish and Wildlife Biologist, if you have any questions regarding the conferencing and consultation process.

Sincerely,

for Kemper M. McMaster
State Supervisor

cc: NMFS (Torterici)

DEPARTMENT OF THE ARMY
PORTLAND DISTRICT, CORPS OF ENGINEERS
P.O. BOX 2946
PORTLAND, OREGON 97208-2946

Reply to
Attention of:

JAN 6 2001

Planning, Programs and Project Management Division

Mr. Kemper McMaster
Field Supervisor
U.S. Fish and Wildlife Service
2600 SE 98th, Suite 100
Portland, OR 97266

Dear Mr. McMaster:

This letter is to formally respond to your recommendations for conferencing and consultation on the Columbia River Channel Improvement Project contained in your letter of December 7, 2000. This addresses the constructive discussions we held on December 21, 2000 on this matter.

The primary issue we discussed was the participation by your agency in the formalized reconsultation process we have underway with National Marine Fisheries Service. It was agreed that you would attend the meeting that is to be held on January 5, 2001, to determine the value of this process to consultations or conferencing relevant to your agency. The level of participation of your and my technical staff will be determined as this process develops. Future technical discussions may be relevant to issues pertaining to coastal cutthroat trout and bull trout.

You have stated in your letter that, "Currently, we have received no information regarding the Corps' intent to implement the Bald Eagle Term and Condition #4 listed in the Service's December 6, 1999, opinion. We recommend the Corps begin implementation of Term and Condition #4, or provide us a strategy and timeline for implementation of this Term and Condition, before the Project actions begin." As we discussed at our meeting, the timeframe for the Channel Deepening project is dependent upon the satisfactory conclusion of the consultation process currently underway. Once the direction of this project is determined, a strategy and timeline for this term and condition will be provided. Currently, an implementation timeline for the Channel Deepening project has not been established and thus it is premature to fully scope such monitoring actions. We will implement the monitoring plan concurrent with project dredging and disposal operations.

Finally, your letter asked us to designate any non-Federal representatives that would be involved in the conferencing/consultation process. We declare that Port of Portland representatives may be involved in the conferencing/consultation process. However, the Port has only been formally designated as a non-Federal representative in the consultation with National Marine Fisheries Service. If the Port is formally designated as a non-Federal representative for species under you jurisdiction, we will notify your agency. For purposes of our conferencing and consultation, the Corps remains the primary point of contact.

If you have any questions, or need further information concerning this matter, please feel free to contact Bob Willis, Chief of my Environmental Resources Branch at 503-808-4760.

Sincerely,

Davis G. Moriuchi
Deputy District Engineer
For Project Management

Copies Furnished:

CENWP-OC (Janice)

National Marine Fisheries Service
525 NE Oregon St., Suite 500
Portland, OR 97232-5435

Port of Portland
P.O. Box 3529
Portland, OR 97208

COPY

Interstate Columbia River Improvement Project
121 N.W. Everett Street
Portland, OR 97208
(503) 944-7226/FAX (503) 944-7250

May 21, 2001

Randall J. Butler
Colonel, Corps of Engineers
District Engineer
P.O. Box 2946
Portland, OR 97208-2946

Dear Colonel Butler:

The port co-sponsors of the Columbia River Channel Improvement Project hereby request the Corps of Engineers designate us non-Federal representatives for the Endangered Species Act consultation with the United States Fish and Wildlife Services (USFWS) to prepare a biological assessment on the project. The authority for this request is contained in 50 CFR Section 402.08.

Because of the timeline for the consultation, we would appreciate a determination as early as practicable. Thank you for your consideration.

Very truly yours,

Stuart Shelly, FINANCE MGR.
FOR Lanny Cawley, EX. DIR.

Lanny H. Cawley, Executive Director
Port of Kalama

Ken B. O'Hollaren, Executive Director
Port of Longview

Larry L. Paulson, Executive Director
Port of Vancouver

E.B. Galligan, Executive Director
Port of Portland

Dave Ripp

David Ripp, Manager
Port of Woodland

Peter Williamson, Executive Director
Port of St. Helens

DEPARTMENT OF THE ARMY
PORTLAND DISTRICT, CORPS OF ENGINEERS
P.O. BOX 2946
PORTLAND, OREGON 97208-2946

Reply to
Attention of:

JUL 1 1 2001

Planning, Programs and Project
Management Division

Ken O'Hollaren, Executive Director
The Interstate Columbia River Improvement Project
P.O. Box 1258
Longview, Washington 98632

Dear Mr. O'Hollaren:

Thank you for your letter, dated May 21, 2001, requesting designation as the non-Federal representative for the ongoing Endangered Species Act (ESA) consultation with the USFWS, for the Columbia River Channel Improvement Project. This request was pursuant to 50 CFR 402.08.

The U.S. Army Corps of Engineers has considered your request and hereby designates the six co-sponsoring ports for the project, as the non-Federal representative for ESA consultation with USFWS.

Please call Laura Hicks, Project Manager, at (503) 808-4705 with further questions.

Sincerely,

Randall J. Butler
Colonel, Corps of Engineers
District Engineer

Copy Furnished:

Dianne Perry, Project Manager
121 NW Everett Street
Portland, Oregon 97208

DEPARTMENT OF THE ARMY
PORTLAND DISTRICT, CORPS OF ENGINEERS
P.O. BOX 2946
PORTLAND, OREGON 97208-2946

Reply to
Attention of:

JUl 1 1 2001

Planning, Programs and Project
Management Division

Kemper McMaster, State Supervisor
U.S. Fish and Wildlife
2600 SE 98th Avenue, Suite 100
Portland, Oregon 97266

Dear Mr. McMaster:

The purpose of this letter is to notify you that the U.S. Army Corps of Engineers has designated the six lower Columbia River ports for the Columbia River Channel Improvement Project, as the non-Federal representative with your agency, for the Endangered Species Act consultation. This action is pursuant to 50 CFR 402.08.

Please call Laura Hicks, Project Manager at (503) 808-4705, with further questions.

Sincerely,

Randall J. Butler
Colonel, Corps of Engineers
District Engineer

Copy Furnished:

Ken O'Hollaren, Executive Director
The Interstate Columbia River Improvement Project
P.O. Box 1258
Longview, Washington 98632

Dianne Perry, Project Manager
121 NW Everett Street
Portland, Oregon 97208

RECEIVED NOV 02 2000

DEPARTMENT OF THE ARMY
PORTLAND DISTRICT, CORPS OF ENGINEERS
P.O. BOX 2946
PORTLAND, OREGON 97208-2946

Reply to
Attention of:

OCT 27 2000

Planning, Programs and Project
Management Division

Ken O'Hollaren, Executive Director
The Interstate Columbia River Improvement Project
121 NW Everett Street
Portland, Oregon 97208

Dear Mr. O'Hollaren:

Thank you for your letter dated October 16, 2000 requesting designation as non-Federal representative for the Endangered Species Act (ESA) consultation for the Columbia River Channel Improvement Project (project), pursuant to Title 50, Code of Federal Regulations, Section 402.08 (50 CFR 402.08). The U.S. Army Corps of Engineers has considered your request and has decided to designate the six co-sponsoring ports for the project as the non-Federal representative for ESA consultation. We will provide written notification of the designation to the National Marine Fisheries Service.

Sincerely,

Randall J. Butler
Colonel, Corps of Engineers
District Engineer

DEPARTMENT OF THE ARMY
PORTLAND DISTRICT, CORPS OF ENGINEERS
P.O. BOX 2946
PORTLAND, OREGON 97208-2946

Reply to
Attention of:

OCT 27 2000

Planning, Programs and Project
Management Division

Donna Darm
Acting Regional Administrator, NW Region
7600 Sand Point Way, NE
BIN C15700, Building 1
Seattle, Washington 98115-0070

Dear Ms. Darm:

The purpose of this letter is to notify you that the U.S. Army Corps of Engineers has designated the six lower Columbia River ports for the Columbia River Channel Improvement Project as the non-Federal representative for the Endangered Species Act consultation, pursuant to Title 50, Code of Federal Regulations, Section 402.08 (50 CFR 402.08). The designation covers both consultation and preparation of a biological assessment.

Sincerely,

/Signed/

Randall J. Butler
Colonel, Corps of Engineers
District Engineer

Copy Furnished:

OC, Sorenson

Interstate Columbia River Improvement Project

Interstate Columbia River Improvement Project
121 N. W. Everett Street
Portland, OR 97208
(503) 944 7226 FAX (503) 944 7250

October 16, 2000

Randall J. Butler
Colonel, Corps of Engineers
District Engineer
P.O. Box 2946
Portland, OR 97208-2946

Dear Colonel Butler:

The port co-sponsors of the Columbia River Channel Improvement Project hereby request the Corps of Engineers designate us non-Federal representatives for the Endangered Species Act consultation with the National Marine Fisheries Service (NMFS) on the project. The authority for this request is contained in 50 CFR Section 402.08.

Because of the timeline for the consultation, we would appreciate a determination as early as practicable. Thank you for your consideration.

Very truly yours,

Lanny Cawley

Lanny Cawley, Executive Director
Port of Kalama

Ken O'Hollaren

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APPENDIX B

An Assessment of Potential Risks Posed by PAHs, PCBs, and DDT in Dredged Material to Juvenile Salmonids in the Lower Columbia River: Mouth to Bonneville Dam

1 EXECUTIVE SUMMARY

The objective of this report is to determine whether improvements to the Columbia River navigation channel will exacerbate the risks posed by bioaccumulative contaminants to juvenile salmonids that rear in the lower Columbia River and feed on epibenthic invertebrates. The report also examines potential risks to these prey. The contaminants assessed include compounds that are environmentally persistent and bioaccumulate in fish and invertebrates, namely total polychlorinated biphenyls (ΣPCBs); DDT and its metabolites, DDD and DDE (ΣDDT); and total polycylic aromatic hydrocarbons (ΣPAHs). Preliminary evidence obtained by the National Marine Fisheries Service (NMFS) suggests that some endangered salmonid stocks may be at risk from the effects of the contaminants contained in the tissues of their epibenthic prey. The origin of these contaminants is unclear and could even be from exposures incurred upstream before the fish reach the estuary. However, it is generally assumed that some types of dredging suspend fine particulates. It has been hypothesized that if these types of particulates are suspended by dredging operations in the lower Columbia River the particulates may be entrained within the estuarine turbidity maximum (ETM) zone. The ETM is an area where epibenthic prey of juvenile salmon are assumed to thrive. Therefore, there may be a potential risk to juvenile salmonids as well as their prey, and the purpose of this assessment is to examine it.

A risk-based approach was used to address possible effects of contaminants on salmonids in the Columbia River Basin. Risks were evaluated by comparing the frequency and magnitude of contaminant exposures in sediments with aquatic toxicological data to predict the frequency and magnitude of adverse effects expected from sediment exposures. Data defining contaminant exposures in Columbia River sediments from the mouth to the head of the tidewater near Bonneville Dam were obtained from the majority of available data sources. These included a regional sediment database (SEDQUAL) maintained by the Washington State Department of Ecology, data obtained by the U.S. Army Corps of Engineers, and data obtained by Tetra Tech, Inc., in a "Bi-State Survey" of sediment contamination in the lower Columbia River. Exposures were defined for three reaches of the Columbia estuary: River Mile (RM) 0-40, RM 41-101 (the confluence with the Willamette River), and RM > 101 (from the Willamette confluence to the head of the tidewater). Data defining the range of potential effects were obtained from sediment screening guidelines developed by regional state and federal agencies, from scientific literature, and from technical reports and data analyses conducted by scientists with NMFS. Risks were defined by comparing the probabilities of exposure with those of effects. Many of the effects occurring at the lowest contaminant concentrations are sublethal, indirect responses, such as histopathological changes, changes in enzyme activity, decreased growth, or decreased disease resistance. For the purposes of this report, it has been assumed that such responses result in mortality although direct evidence linking sublethal effects to increased mortality or decreased reproductive success has not been demonstrated anywhere at the low contaminant concentrations typical of sediments in the Columbia estuary.

Figures B-1 through B-3 summarize the results of the analyses for juvenile salmonids exposed in the lower Columbia estuary (RM 0-40) to all three contaminant classes. As indicated in all three figures, only negligible risks were predicted for the channel sediments proposed for dredging. Risks were present in some of the sediment that had been sampled nearshore, outside of the shipping channel, but they appeared localized to certain sources and sediment types. All ΣPCB exposures in the shipping channel were just below the effects threshold (10% effects) proposed by a NMFS scientist (Meador 2000a), and 10 times below the regional sediment screening guideline (Figure B-1). Consequently, ΣPCB risks in the channel should be negligible. Likewise, all ΣDDT exposures via channel sediments were below both the regional screening guideline and a lowest observed effect threshold developed from testing of cutthroat trout (Figure B-2). Cutthroat trout appear to be the salmonid most sensitive to DDT, so these results may be applied as a conservative standard to other juvenile salmonids. Finally, all ΣPAH exposures via channel sediments were lower than four criteria establishing potential effects. For example, channel sediment PAH concentrations were 41 parts per billion (ppb) dry weight (dw) or lower, whereas the lowest potential effect criterion proposed by Johnson (2000) was 54 ppb dw. Other effect criteria were much higher, ranging from 1,000 to 15,100 ppb dw (Figure B-3).

Risks to the sediment-dwelling prey of juvenile salmon in the shipping channel were also below all effect thresholds. Some of the sediments nearshore, outside of the shipping channel, posed risks. The magnitudes and character of the risks basically were the same from the lower estuary to Bonneville Dam.

The main reason why risks were negligible to juvenile salmon and their prey is because most lower Columbia River channel sediments are essentially devoid of organic carbon, the substrate to which the persistent, bioaccumulative contaminants adsorb. The microbial biofilm that accumulates on the surface of organic particles is the food of epibenthic invertebrates and the apparent pathway by which these contaminants enter food chains involving juvenile salmon. The channel sediments, which are almost exclusively sand, are largely devoid of organic carbon because channel currents sweep away most of the fine particulates. As a consequence, concentrations of contaminants, if present at all, are actually lower than those in nearshore (depositional) environments. Accordingly, if resuspension of sediments during dredging did occur, it is not expected to change the concentration of contaminants found in nearshore environments.

The potential for cumulative risks from exposure to all three contaminant classes is negligible because none of the classes exceeded effects thresholds and these risks do not appear to be additive or more-than-additive (synergistic). Because the specific modes of action of all PCB and PAH compounds considered, as well as those of DDT, DDD, and DDE, are believed to be different, and because exposures were below effects thresholds, risks from the different classes of compounds should not be added. The overall conclusion is one of negligible risk to juvenile salmonids and their sediment-dwelling prey in the lower Columbia River as a result of the dredging associated with the lower Columbia River navigation channel deepening project.

2 INTRODUCTION

2.1 Background

The Portland District of the U.S. Army Corps of Engineers (Corps,) has proposed to deepen the lower Columbia River navigation channel and has prepared an environmental impact statement (EIS) on this proposal (Corps, 1998). In its biological opinion concerning the potential effects of proposed channel improvements on endangered salmonid stocks, the National Marine Fisheries Service (NMFS, 1999) questioned whether dredging associated with channel deepening would pose risks to juvenile salmonids in the lower Columbia River by enhancing the availability and toxicity of certain chemicals in their prey. It specifically requested assessment of "…potential impact of contaminants from redistribution by dredging activities, incorporating appropriate endpoints to derive realistic sediment quality standards and utilizing bioaccumulation potential from salmon-associated prey base as an additional source of transfer of contaminants to juvenile salmon."[1]

This study focused specifically on the lower Columbia River and estuary. The estuary is especially important in the life cycle of juvenile salmon and steelhead trout because that is where they delay their seaward migration, usually for days to weeks, to feed and adapt to seawater (Aitkin, 1998). In his review, Casillas (1999) identified two studies that documented significantly improved smolt-to-adult survival of salmon from residence in the Columbia River estuary. Specific attention is paid to ocean-type juvenile chinook because they – along with chum salmon – appear to be most dependent on the lower estuary for rearing.[2] In addition, their diet tends to consist predominantly of the invertebrates that live on or at the sediment's surface (epibenthic) until the salmon grow large enough to feed pelagically in deeper waters (Aitkin, 1998).

Chemicals with certain properties can be toxic when consumed in the diet of fish. For at least the past 20 years, the literature has shown that chemicals with certain properties – namely hydrophobicity and resistance to metabolism and excretion (Macek, et al., 1979) – will tend to attach to fine particulate organic matter, be bioaccumulated, and persist in the food web of fish and wildlife (Lake, et al., 1987). Some of the sediment-dwelling (benthic) prey of juvenile salmon, such as the amphipod *Corophium salmonis*, are known to feed in part on organic matter (detritus). Thus, because some types of dredging may suspend the detritus, dredging could potentially make the detritus – and any contaminants bound to it – more accessible to benthic organisms, as shown in Figure B-4. Chemicals having the highest potential risk because of these properties (i.e., hydrophobicity and resistance to metabolism and excretion) are the highly chlorinated hydrocarbons (PCBs [3]) and insecticides (DDT[4]). The risks posed by these chemicals via food chain (i.e., dietary) exposure of fish-eating birds are well known (Hoffman, et al., 1990). Until the mid-1980s, most studies examining the risks posed to fish have suggested that these chemicals were bioaccumulated primarily via uptake across the gills (e.g., Adams, et al., 1985; Dobroski and Epifanio, 1980; Macek, et al., 1979). The water and dietary exposure pathways, both of which are now known to contribute variably to bioaccumulation (Di Toro, et al., 1991; EPA, 2000), are depicted in Figure B-5. In

[1] Here, salmon (*Oncorhynchus*), trout (*Salmo*), and char (*Salvelinus*) are referred to as salmonids because they are in the same family, Salmonidae.
[2] Ocean-type chinook spend less than 1 year and as little as 3 months in freshwater before migrating seaward. They enter the estuary as small as 40 millimeter (mm) in length and usually leave when they reach 70 mm or larger size (Aitkin, 1998). The larger chum salmon juveniles that reside in the channel should have switched from feeding on epibenthic to feeding on primarily pelagic invertebrates, and thus should incur limited exposure to epibenthic prey in the channels.
[3] Polychlorinated biphenyls are a large group of chlorinated hydrocarbons constituting dozens of compounds.
[4] Chemical Name for DDT: 1,1'-(2,2,2-Trichloroethylidene)bis(4-chlorobenzene) (CAS # 50-29-3).

the Columbia River estuary, the relationships between the dietary pathway and the food webs pertinent to juvenile salmon and trout (salmonids) are shown in Figure B-6.

In addition, other chemicals have been identified as being of special concern to NMFS. Research by NMFS and others in the Pacific Northwest have confirmed that polycyclic aromatic hydrocarbons (PAHs) and the antifouling biocide, tributyltin (TBT), behave similarly to chlorinated hydrocarbons and insecticides in terms of sorption to organic carbon and dietary accumulation (McCain, et al., 1990; Meador, et al., 1995; Meador, 2000a). Moreover, work by NMFS scientists has documented that concentrations of PAHs, PCBs, and DDE[5] are elevated in the sediments of urban Puget Sound estuaries and that juvenile salmon may be ingesting elevated residues of these substances when they feed (Johnson, 2000; McCain, 1990; Stein, et al., 1995; Varanasi, et al., 1993). However, most PAHs are considered inherently less hazardous than PCBs and chlorinated insecticides because they are metabolized relatively rapidly (Niimi and Palazzo, 1986) and consequently do not biomagnify up the food web as the chlorinated insecticides and PCBs do (Suedel, et al., 1994). Nevertheless, this does not imply that PAHs are unimportant environmental contaminants. Elevated sediment PAH concentrations have been associated with many pathologies in aquatic organisms, especially species like brown bullhead (*Ictalurus punctatus*), English sole (*Parophyrys vetulus*), and amphipods, which live near or on the sediment (e.g., see Balch, Metcalfe, and Huestis, 1995; Johnson, 2000; Myers et al. 1991; Swartz, 1999).

When salmonids ingest chemicals bioaccumulated in their prey, a variable fraction is bioaccumulated and the remainder is excreted with unassimilated organic carbon in the feces (Gobas, et al., 1989). The bioaccumulated residues can elicit toxic effects if their concentrations are high enough (Jarvinen and Ankley, 1999; Johnson, 2000; Meador, 2000). Above a certain concentration, called a threshold, the number and severity of toxic effects increases with the dose.

The effects of dredging activities have been studied extensively for several decades, and these studies have resulted in development of criteria defining the suitability of dredging and disposal of sediments based on their concentrations of toxic substances. In the Pacific Northwest, marine sediment quality criteria have been developed by a consortium of state and federal agencies under the Puget Sound Dredged Disposal Analysis Program (Corps, et al., 2000). The Washington State Department of Ecology (WSDOE) has developed sediment quality standards (*http://www.ecy.wa.gov/programs/tcp/smu/sed_chem.htm*), but they pertain mainly to sediments discharged from point and non-point sources and hazardous waste sites.

Because dredging is a transient, temporary action, there has long been concern about possible acute sublethal effects of toxicants on juvenile salmon and steelhead, which are exposed only for brief periods in lower rivers and estuaries (Servizi, 1990). Concern about dredging effects has historically focused on dissolved oxygen, physical effects from turbidity (e.g., on fish gills), and fish's ability to see food and avoid predators. Recently, concern has shifted to effects resulting from subtle, sublethal responses. The NMFS (1999) biological opinion and many studies identified by NMFS (e.g., Varanasi, et al., 1993; Arkoosh, et al., 1998) re-emphasized concerns about adverse sublethal effects of contaminants in foods being consumed by salmon juveniles. Sublethal effects include a broad range of behavioral, biochemical, immune, oncological, physiological, and whole organismic responses to toxicant exposure. Sublethal effects should be evaluated to determine whether there is evidence that they result, directly or indirectly, in the mortality of the organism and, if so, whether mortalities affect enough individuals to constitute harm to each endangered stock of salmonid, i.e., evolutionarily significant unit (ESU).

[5] DDE is a metabolite of DDT that is highly refractory to degradation.

Sublethal effects resulting from ingestion of bioaccumulative chemicals of concern in food (i.e., the dietary exposure pathway) are difficult to study. Data relating dose to response with respect to sublethal effects, or relating sublethal effects to those on the ESU population, are limited. Exposure pathways are especially difficult to study because the sublethal effects that arise from the variable and short durations (a few weeks to several months, averaging perhaps one month), that ocean-type juvenile chinook spend in estuaries (Aitkin, 1998). Most of the aquatic toxicological data reported in the scientific literature has focused on acute effects on survival and chronic effects on survival, growth, and reproduction rather than sublethal effects (see EPA's Ecotox database – *http://www.epa.gov/cgi-bin/ecotox_search*). This reflects a long-standing scientific consensus that effects on survival, growth, and reproduction clearly have the potential to affect the species population (Mount and Stephan, 1967).

In expressing its concerns about sublethal effects, NMFS cited two white papers prepared by its scientists (Johnson, 2000; Meador, 2000) that not only specifically examined the literature concerning this question, but more importantly concluded that there was sufficient information available to relate the specific amount of toxicant consumed by the juvenile salmonid in its food (i.e., the dose) to adverse sublethal effects. The availability of these analyses enabled the study team to address of the issue of dietary toxicity to juvenile salmon.

2.2 Objectives

The purpose of this report is to address the issues raised by NMFS concerning the risks posed to juvenile salmon that consume estuarine prey contaminated with persistent and bioaccumulative chemicals[6]. Concern focused on certain compounds within three classes of chemicals that are well known for their environmental persistence, bioaccumulation, and aquatic toxicity at low concentrations: PAHs, PCBs, and DDT and its metabolites. These chemicals are generically referred to as contaminants throughout the remainder of this report. A second objective is to evaluate whether the dredging activities associated with the lower Columbia River navigation channel deepening project increase concentrations of these contaminants in the sediments, especially within the estuarine turbidity maximum (ETM) (Figure B-4). A third objective is to determine whether the proposed dredging activities increase access to these contaminants by endangered salmonids via dietary uptake (Figures B-5 and B-6) and if so, whether the amounts consumed while feeding are high enough to pose risks.

2.3 Scope

The issues posed by NMFS were addressed by conducting a preliminary risk assessment to evaluate potential risks based on the following information.

- Dietary toxicity of total PAHs (ΣPAHs), total PCBs (ΣPCBs), and DDT and its metabolites DDD and DDE (ΣDDT) to fish

- Toxicity of sediment-associated ΣPAHs, ΣPCBs, and ΣDDT to sediment-dwelling invertebrates.

- Sediment concentrations of contaminants in the lower Columbia River, as reported by state and federal agencies

A risk assessment was undertaken to address concerns about potential risks to salmonids and their prey that were posed in the NMFS Biological Opinion (1999). Contaminant risk is the probability of adverse

[6] DDT (+DDD +DDE) and PCBs are termed PBTs (Persistent, Bioaccumulative and Toxic) Chemicals, and there is a national strategy for controlling sources of release of these chemicals (Davey 1999).

effects from a defined exposure or exposures (EPA, 1992[7]). A risk assessment would not have been possible without having data available that defined potential exposures and potential effects. Otherwise the risk assessment would have had to be qualitative rather than quantitative.

2.4 Report Organization

The remainder of this report is organized into four sections that correspond directly to the risk assessment paradigm used nationally for more than 10 years (EPA, 1992). Section 3 includes the methodological details for the risk-based approach, including data sources, assumptions and uncertainties concerning the data, and data analysis methods. Findings are presented in Section 4. Uncertainties and assumptions underlying the findings are outlined in Section 5. Section 6 details the literature cited in this report.

[7] EPA has formally defined ecological risk assessment as a process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors. (EPA, 1992).

3 RISK-BASED APPROACH

3.1 Introduction (Problem Formulation)

3.1.1 Issues

Five issues were addressed in this analysis. Each is presented below as a question, along with its basis and rationale.

Issue 1: Do risks increase in the lower Columbia River proceeding from below Bonneville Dam (RM >101) to the lower Columbia River estuary (RM 0-40)?

If contaminant concentrations increase proceeding from below Bonneville Dam (RM >101) to the estuary (RM 0-40), then risks to estuarine-rearing salmonids, especially ocean-type chinook, may be greater when they rear for variable durations (days to weeks to months) in the lower river estuary (Aitkin, 1998).

Issue 2: Are concentrations of organic carbon and fine particulate matter higher in the Columbia River ETM zone than in other locations, and could the potential suspension of fine particulates during channel dredging operations increase these risks?

The ETM has been identified as being of special importance to the food web on which some life stages of salmonids depend, especially ocean-type juvenile chinook. The ETM is the site of a food web founded on microorganisms that consume the microscopic detritus produced upstream (e.g., dissolved and particulate organic carbon, including phytoplankton). Dissolved and particulate organic carbon (detritus) will precipitate upon mixing with seawater and reflux, by tidal action, in the lower river, until it is consumed or swept seaward. The ETM generates much of the secondary production in the Columbia River estuary (Simenstad, et al., 1990a,b, 1992, 1994a,b; Jay and Musiak, 1994). It occurs near the upstream head of saltwater intrusion, and within it water quality and biological productivity are highly interrelated. Microorganisms feed on the detrital flocs that form and settle during periods of weak currents. Various invertebrates (e.g., epibenthic zooplankton, and amphipods) feed on the aggregates by removing the microbial biofilms. In turn, they are fed upon by other invertebrates and certain life stages of juvenile salmon (see Figures B-4 and B-6). Theoretically, contaminant concentrations within the ETM should also be augmented because they tend to be sorbed to both dissolved and particulate organic carbon, reflecting their extreme hydrophobicity. Therefore, if the concentration of organic carbon increases in the ETM, the concentration of contaminants should also increase.

Issue 3: Are chemical concentrations in the Columbia River navigation channel higher than those in nearshore sediments?

In theory, navigation channel concentrations should be lower rather than higher because the fine particulates, which contain the highest concentrations of organic carbon and accordingly of contaminants (Karickhoff and Morris, 1985), are swept out of higher energy areas like channels and settle out in low energy, nearshore depositional areas.

Issue 4: Are sediment concentrations high enough to pose risks to juvenile salmonids?

This is the main question posed by NMFS. Its studies in the lower Duwamish River estuary (Seattle) and in the Hylebos Waterway (Port of Tacoma) suggest, based on multiple lines of evidence, that juvenile salmonids are not only being exposed to increased contaminants, but are responding immunologically and biochemically in ways that may signal stress and decreased fitness.

Issue 5: Are sediment concentrations high enough to pose risks to the sediment-dwelling invertebrate prey of juvenile salmon?

If a significant fraction of the sediment-dwelling invertebrate prey of juvenile salmonids is affected at similar or lower contaminant concentrations than those directly affecting the juvenile salmon, then there could be indirect effects on the growth and hence the predation susceptibility of salmonid juveniles.

3.1.2 Description of the Overall Approach to Risk Analysis

This risk assessment relies on EPA's risk-assessment paradigm, as shown in Figure B-7, and a standard methodology for conducting aquatic ecological risk assessments (Parkhurst, et al., 1995). Figure B-7 shows that the risk assessment process begins with a problem formulation, which essentially defines the issues, how they will be addressed, and the assessment's scope. The scope of this project is to evaluate the potential risks to juvenile salmonids posed by contaminants that may be released during dredging in the navigation channel of the lower Columbia River, downstream of the confluence of the Willamette River and Columbia River at RM 101.

The substances assessed are mixtures of PCBs, DDT and metabolites, and PAHs. These chemicals are the sole focus of this risk assessment, based on previous studies. A variety of agencies have examined the effects posed by other water quality variables during and after dredging activities (e.g., Servizi, 1990) and these chemicals are the only ones that are currently considered to pose potential risk, mainly because of their bioaccumulative potential, persistence, and tendency to interfere with endocrine and immune systems (Dillon, et al., 1995; Varanasi, et al., 1993; Arkoosh et al., 2001). Each of the chemical groups of interest consists of many chemicals that have similar modes of action – so similar that it is possible to express their toxicity by summing their concentrations.

The compounds included in these summations are usually reported analytically as ΣPCB, ΣPAH, and ΣDDt (the sum of DDT, including its metabolites DDD and DDE and their isomers). The PAHs are often analyzed as individual compounds and then summed. For this report, ΣPAH was based on the 18 compounds used by Johnson (2000) in her paper on PAH effects (Table B-1) and reported analytically. Specifically, if only 8 of the 18 PAHs addressed by Johnson (2000) were reported analytically, only those 8 were included. It was assumed that the ΣPAHs, ΣDDT, and ΣPCBs reported analytically represented those compounds that occurred in the highest concentrations in each sediment sample.

Table B-1. Low molecular weight (LMW) and high molecular weight (HMW) PAHs included in Johnson's (2000) analysis of the relationship between sediment PAH concentrations and the effects on >2-year old English sole (*Parophrys vetulus*).

Analyte Number	Analyte Name	Molecular Weight Categorization
1	Biphenyl	LMW
2	Naphthalene	LMW
3	1-Methylnaphthalene	LMW
4	2-Methylnaphthalene	LMW
5	2,6-Dimethylnaphthalene	LMW
6	Acenaphthalene	LMW
7	Fluorene	LMW
8	Phenanthrene	LMW
9	1-Methylphenanthrene	LMW
10	Anthracene	LMW

11	Fluoranthene	HMW
12	Pyrene	HMW
13	Benzo(a)anthracene	HMW
14	Chrysene	HMW
15	Benzo(a)pyrene	HMW
16	Benzo(e)pyrene	HMW
17	Perylene	HMW
18	Dibenz(a,h)anthracene	HMW

The next step in the risk assessment methodology is to characterize exposure by defining the frequency and magnitude of the concentrations that will be encountered by salmonid juveniles when feeding on epibenthic organisms in the lower Columbia River. In this report, exposure is characterized with a cumulative probability distribution, as shown in Figure B-8. It depicts the frequency and magnitude of contaminant concentrations measured in sediment samples from the three reaches studied: lower Columbia River estuary (RM 0-40), Columbia River to the Willamette River confluence (RM 41-101), and Columbia River from its confluence with the Willamette to below Bonneville Dam (RM >101). The probability distributions defining exposure convey considerable information about contamination . For example, as shown from the data in Figure 8, ΣPCB concentrations range from 0.05 parts per billion (ppb) dry weight (dw) to 28,000 ppb dw. Thirty-four percent of the measured concentrations are <12.5 ppb, 66% are >12.5 ppb, and the top 20% are above 150 ppb.

The objective of the third component of the risk-assessment paradigm, the effect characterization, is to characterize the effects that might be expected in juvenile salmon or other aquatic life upon exposure to different concentrations of contaminants. Data come mainly from laboratory tests of these substances, although in a few cases they are based on field data.

The effect characterizations for each contaminant were summarized using graphs like the one shown in Figure B-9. Figure B-9 presents four sets of criteria. The first consists of a set of responses occurring at different concentrations developed by Johnson (2000) for marine fish (English sole, *Parophrys vetulus*) exposed for at least 2 years to PAHs in sediments. The effects range from 54.1 ppb dw (preneoplastic foci of cellular degeneration in the liver) to 4,000 ppb dw (inhibited gonadal growth). In Johnson's (2000) analysis, note that as the sediment PAH concentration increases, the probability and severity of adverse responses also increase. A second criterion, proposed by Collier (2001), specifies 1,000 ppb dw as the approximate concentration at which no observed effects in marine fish have been noted. The third criterion (5,000 ppb dw), also proposed by Collier (2001), represents the lowest concentration where adverse effects have been observed in juvenile salmon The fourth criterion is the regional screening guideline (15,100 ppb dw) used by regional, federal, and state agencies to evaluate whether sediments require further testing and assessment (Corps, et al., 2001). Effects of all the substances were characterized in the foregoing manner.

The final step in the risk assessment is the risk characterization. The basic approach was to graphically compare the probability of exposure to the probability of effect see Figure B-40. Risk potential was expressed in terms of the percentage of samples from (1) the Columbia River navigation channel and (2) all sediments that exceeded one or more of the screening criteria.

3.1.3 Conceptual Model

Three separate models were used to demonstrate how toxic substances in sediments could ultimately affect juvenile salmon adversely. The first model (Figure B-5) shows the expected fates of the contaminants in water and sediments and their uptake by juvenile salmonids. It mainly reveals that contaminants will partition among water, sediment, and prey, and that juvenile salmonids and their prey will take up contaminants via both the water and dietary pathways. The contaminants are bound to the suspended particles and to the sediments. Figure B-6 shows the sources of suspended particles and other foods eaten by prey of juvenile salmonids. Figure B-10 depicts the Columbia River ecosystem-based conceptual model for juvenile salmonids. It identifies contaminants as one of the factors that have the potential to affect survival of juvenile salmonids via effects on their physiology.

3.2 Exposure Characterization

3.2.1 Data

3.2.1.1 Justification for Reliance on Sediment Data Versus Tissue Residue or Water Concentration Data

Data on chemical concentrations in sediment were used preferentially over data on tissue residues and water concentrations for several reasons. For at least the past 15 years, data concerning total contaminant concentrations in sediment have been collected preferentially for evaluating the risks of dredging and disposal (Corps, et al., 2000). This preference reflects professional convictions that sediments usually are less variable, easier to collect, and more ecologically relevant to sediment-dwelling organisms, which are preyed upon by a variety of fish and invertebrates, compared to contaminant concentrations in tissue and water. Perhaps most importantly, there is a direct relationship between sediment exposure and effects on sediment-dwelling organisms (Di Toro, et al., 1991), whereas more uncertain extrapolations (models) are required to estimate sediment risks based on water and tissue concentrations of PCBs, DDT, and PAHs. For these reasons, substantial amounts of sediment data have been collected over the years, and they were sufficient to accomplish this detailed risk assessment.

If sufficient data concerning contaminant concentrations in epibenthic invertebrate prey of juvenile salmon had been available, it would have been preferred, even more than sediment data, because it would have been most relevant to the risk issues. To our knowledge, however, data are available from less than a dozen samples from one site near Sand Island in the lower river estuary (NMFS, unpublished data), too few to support a comprehensive risk assessment. Most available tissue residue data for the lower Columbia River pertain to subadult/adult specimens of fish and invertebrates. These data were considered inappropriate for this specific risk assessment for several reasons: the exposure histories of the specimens were unknown; there were insufficient data to normalize for exposure duration or age; and lipid contents and diet were unknown.

Exposure history is important because a specimen caught in one location could have been exposed at a different site. In other words, its exposure may be unrepresentative of sediments at its capture site. Specimen age is also important because the longer the exposure duration, the greater the residues accumulated, since PCBs and DDE cannot be materially metabolized or depurated (Wisconsin Division of Health and Wisconsin Department of Natural Resources, 1997). Further, bioaccumulation magnitude depends greatly on lipid content (Lake, et al., 1990), which varies greatly in the many types and ages of specimens sampled. Finally, the diet of the specimens sampled needs to be specific to the pathway of interest, namely sediment ⇒ invertebrate prey ⇒ juvenile salmon (Figures B-5 and B-6). The diets of the sampled specimens cannot be assumed to reflect this pathway.

Surface water concentrations of the contaminants presumably contribute marginally to the tissue residues measured in the epibenthic invertebrates eaten by juvenile salmonids because their concentrations are extremely low and because surface water and sediment concentrations cannot be presumed to be in equilibrium. McCarthy and Gale (1999) estimated dissolved water concentrations in the picogram-per-liter range. Such low surface water concentrations are believed to be less important in determining exposure than concentrations in the particulate and interstitial water phases of the sediments (Brueggeman, et al., 1984; Di Toro, et al., 1991) for these particular contaminants[8]. Moreover, sediment concentrations cannot be estimated readily from water concentrations without modeling other chemical and hydrological variables.

3.2.1.2 Data Sources

The data used in the exposure characterization were collected from three basic sources: WSDOE, the Corps, and a federally funded study conducted by Tetra-Tech, Inc., for the Lower Columbia River Bi-State Committee. The data used for this risk assessment are available from Parametrix, Inc., 1600 S.W. Western Blvd., Suite 165, Corvallis, OR 97333. Version 3.0 of WSDOE's Sediment Quality Information System (SEDQUAL 3.0) (WSDOE, 2000) was the first database queried concerning sediment data for the lower Columbia River and Willamette River. It represents a compilation of data entered by a wide range of users, based on templates available on SEDQUAL's Web site (*http://www.ecy.wa.gov/programs/tcp/smu/sedqualfirst.htm*). Most of this database represents studies of localized hotspots, i.e., known point sources of contamination.

SEDQUAL 3.0 provided a large amount of applicable data, but not all data were relevant to this assessment. Version 4.0 of SEDQUAL (WSDOE, 2001) was released midway through this project, and its data were compared to Version 3.0 to determine whether it contained any new data. No additional data applicable to the exposure characterization were provided in Version 4.0, but it was used as a Quality Assurance/Quality Control (QA/QC) tool (see Section 3.2.1.3 below). Accordingly, data were sought from other sources.

More data were known to have been collected in the lower Columbia River than were included in SEDQUAL. To augment the database, Corps data were used. Corps data were available for a large number of sites along the Columbia River and its tributaries, but only data that were relevant to the issues addressed in this Biological Assessment were used. The data included in-channel sediment samples (Corps, 1999) and recent sediment samples collected in the estuary as part of maintenance dredging (Corps, 2001). The majority of Corps sediment data, collected primarily to determine appropriate disposal sites for routine maintenance dredge spoils, was not included because it was not useful for indexing potential exposure of juvenile salmonids in the areas of the navigation channel proposed for dredging. Also, some Corps data were unusable because latitudes and longitudes were unavailable to pinpoint locations.

The final data set included in the exposure characterization consisted of the survey done as part of the lower Columbia River Bi-State Program (Tetra Tech, 1993). Tetra Tech, Inc. conducted a reconnaissance survey of contaminant residues in water, sediment, and biota (fish and crayfish) from the lower Columbia River (mainstem and backwater areas) below Bonneville Dam. These data were downloaded from the lower Columbia River Estuary Program Web site (LCREP, 2001). To supplement data collected in the 1993 study, Tetra Tech, Inc. later surveyed contaminants in the backwater areas of the lower Columbia River (Tetra Tech, 1994). Data collected from the backwater study were already included in the SEDQUAL 3.0 data set and therefore did not need to be added to our database.

In summary, the data available in SEDQUAL identified sediment concentrations for localized nearshore hotspots. The Corps data addressed the main shipping channels, where the proposed dredging would

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[8] Excepting PAHs with $\log_{10}$ octanol-water coefficients of 3-5, for which water exposure is the most important uptake pathway (Thomann 2001).

actually occur, and supplemented the estuarine data contained in SEDQUAL. The Bi-State Surveys (1993 and 1994) are unique because they appear to be unbiased, systematic samples of sediments throughout the lower Columbia River and do not focus on hotspots. Accordingly, they may index contamination generally throughout the lower Columbia River system.

3.2.1.3 Materials and Methods

SEDQUAL

To retrieve information from SEDQUAL, both a station group and two chemical groups were constructed. The station group made use of the Geographic Information System interface provided in SEDQUAL to retrieve stations only from below RM 145 (Bonneville Dam) to the mouth of the Columbia River. It also included data for the lower Willamette River, specifically the reach from Portland Harbor to the confluence, including Columbia Slough[9]. The chemical group option was used to access all applicable DDT and PAH sediment concentrations. The other chemical of interest (PCBs) could be queried without use of this option.

Data from SEDQUAL were modified after export to Microsoft Excel® spreadsheets. If the unit of concentration was parts per million (ppm), it was converted to parts per billion by multiplying by 1,000. Additionally, if samples had microgram per liter (μg/L) as the unit of concentration, they were deleted from the data set. Values recorded as undetectable were halved to approximate the true concentration, which lies somewhere between the detection limit and zero (Gleit, 1985). If there were multiple, same-day samples for the same location, the sediment concentrations were averaged (arithmetic) and their qualifier codes combined (except for the unknown or null value qualifier, "#"). In a few instances, all limited to the Willamette River, values from certain jurisdictions were eliminated from the data set if they had multiple samples at the same spot collected on the same day, but varied dramatically in their sediment concentrations. Such values were deleted because the nature of the chemicals queried is such that they do not biodegrade quickly, and the data were considered suspect as a result. Concentrations were deleted only if they repeatedly varied by up to a factor of six for the same chemical on the same day at the same station (e.g., 930 vs. 6,100 ppb dw for 4,4'-DDT). It was only necessary to eliminate certain ΣDDT and ΣPAH values from the Willamette River. No data were eliminated from the Columbia River data sets.

Concentrations labeled in SEDQUAL as percent fines, total organic carbon (TOC) and total PCBs were used as output, but data for DDT and metabolites and PAHs were modified before being used. Fine particulate matter was queried as "Percent Fines," TOC as "Total Organic Carbon," and ΣPCBs as "Total Polychlorinated Biphenyls." For exposure characterization, ΣDDT consisted of the sum of 2,4'- and 4,4'-congeners of DDE, DDD, and DDT[10]. When one of these was reported as undetected, its concentration was set equal to one-half its detection limit (Gleit, 1985), and this value was added to those of the detected ones. If a congener was not analyzed for, it was ignored in the summation. This procedure was conservative and probably tended to overestimate the concentrations of undetected analytes because most jurisdictions did not analyze for the 2,4'-DDE, DDD, or DDT congeners; only Tetra Tech, Inc. (1993), sampled for all six.

The remaining chemical group, which required preprocessing prior to risk analysis, consisted of the 18 individual PAHs considered in Johnson's (2000) characterization of PAH effects on marine fish (Table B-

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[9] Columbia Slough is an urban tributary in north Portland that enters the lower Willamette River near its confluence with the Columbia River. It was only included here to provide further comparison to chemical concentrations observed in the lower Willamette and lower Columbia Rivers.
[10] A congener here is a compound having the same basic structure as others in the same class of compounds.

1). Most study sponsors analyzed for 12 of the 18 compounds. Data were summed for all PAHs analyzed. When a compound was reported as undetected, its value was set equal to one-half the detection limit and added to the full value of the detected ones. If a PAH from Johnson's Table B-1 (2000) was not analyzed for, it was ignored in the summation. For both ΣDDT and ΣPCB values, the qualifier codes that existed for each part of the total were conserved and denoted for the summed value. If none of the analytes making up the summed value had qualifiers, the "#" symbol was denoted. If one or more of the analytes was qualified, the "#" symbol was dropped and only the qualifiers denoted.

U.S. Army Corps of Engineers

Corps sediment data were obtained from several documents available on the Internet (Corps, 1999, 2001). Sediment data were entered into Microsoft Excel® spreadsheets using the SEDQUAL format. As described in the preceding subsection, undetected concentrations were halved to approximate the true concentration. Additionally, data collected in the navigation channel versus nearshore were identified based on maps provided with the data on the Internet or by Corps personnel. The in-channel data set consisted of the mouth of the Columbia River sediment evaluation data collected in September 2000 (Corps, 2001), as well as Appendix B of the EIS (Corps 1999) data collected in June 1997 (without out-of-channel stations 05, 06, 07, 57, 75, 75A) (Siipola, pers. Comm.,).

The in-channel data from Appendix B of the EIS (Corps, 1999a) consisted of percent fines, TOC, the sum of PCBs, the sum of 4,4'-DDE, DDD, and DDT, and the sum of 12 PAHs. The ΣDDT and ΣPAH data were summed in the same manner as the SEDQUAL data. The qualifier codes that existed for each part of the total were conserved and combined into one qualifier code for the total value (except for the unknown or null value qualifier, "#"). If a congener was not analyzed for, it was ignored in the DDT summation. Also, if a PAH from Johnson's Table B-1 (2000) was not analyzed for, it was ignored in the PAH summation. The PCBs sampled by the Corps (1999a) were Aroclors 1016, 1221, 1232, 1242, 1248, 1254, and 1260. If all Aroclors were undetected, one-half of the detection limit was entered as the value to be plotted. In the one instance where PCBs were detected, the sum of the two detected Aroclors was adopted as the value.

The procedures described above were applied to the four remaining Corps data sets used: Columbia River mouth, Baker Bay/Ilwaco Channel, Chinook Channel, and RM 29-34 (Corps 2001). These data were collected in support of maintenance dredging in the estuary. The same seven Aroclors (1016, 1221, 1232, 1242, 1248, 1254, and 1260) that had been analyzed for in Appendix B were analyzed for in these evaluations. No Aroclors were detected in any of the samples, so one-half of the detection limit was plotted as the ΣPCBs concentration.

Bi-State Surveys

Sediment data collected by Tetra Tech, Inc., for the Bi-State Survey were downloaded from the Lower Columbia River Estuary Program Web site (LCREP, 2001). The resulting Microsoft Excel® spreadsheets contained multiple columns representing a wide range of studies. Only data from the Bi-State Surveys were used, and they were organized into the database's standard format. Undetected concentrations were treated as described above. Data used consisted of percent fines, TOC, the sum of 2,4'- and 4,4'-DDE, DDD, and DDT, and the sum of 12 PAHs. The ΣDDT and ΣPAH data were summed as described previously. The same seven PCBs that were sampled for the Corps (1999, 2001) sediment evaluations were sampled for this survey. If a PCB was undetected, one-half the detection limit was specified as its value. When one congener was detected in a sample, it became the ΣPCB value. If multiple congeners were detected, their concentrations were summed to compute ΣPCB. Data qualifiers for ΣDDT and ΣPCB were applied as described above.

Three measurements were adjusted because they were regarded as outliers, reflecting either matrix interference, inconsistency with all other measurements from the same and nearby sites, or both[11]. For station D1 (Baker Bay), one ΣDDT value was adjusted from 60 to 6.0 ppb and one ΣPCB value from 125 to 12.5 ppb because all other sampling in the area of Baker Bay showed nondetects and the Bi-State samples showed evidence of matrix interference[12]. Specifically, all Corps (2001) sampling in the Ilwaco-Baker Bay region (n=9) has failed to detect ΣPCBs (DL = 10-15 ppb dw), and the ΣDDT values have ranged from 0.9 – 2.6 ppb dw. For station E9, the value for 4,4'-DDT was adjusted from 100 to 1.0 ppb dw because all other ΣDDT congeners measured at this site were undetected (DL = 2 - 3 ppb dw).

3.2.1.4 Data Quality Assurance/Quality Control

SEDQUAL

WSDOE does not conduct any additional quality control (QC) or quality assurance (QA) of the data that study sponsors load onto the SEDQUAL database. As a result, some of the data in the templates may have been entered incorrectly before being sent to WSDOE, but this is impossible to determine without verifying data authenticity with the study sponsor. For this reason, some values that were inconsistent with other data for the same location were eliminated as described above; otherwise the data were used as is.

WSDOE sometimes uses some of the available data sets in SEDQUAL to derive sediment quality standards. To determine which data can be used to derive standards, each study has a QA level code assigned to its data if its overall quality has been certified by WSDOE personnel (Personal Communication, Martin Payne, WSDOE, 2001). If the study's overall quality has not been evaluated, it receives a U (unknown) QA level code. Approximately one-third of the SEDQUAL data used for this report had been assigned the U code. The QA codes were not consulted in establishing the data used in these analyses.

After being exported from the SEDQUAL 3.0 database and modified in Microsoft Excel® spreadsheets, all data modifications were checked by Parametrix, Inc. As a further check, the exact same procedures were performed on the data set that was output from SEDQUAL 4.0 and compared with the data from SEDQUAL 3.0 to ensure that the modifications were performed correctly.

Corps

The Corps data were taken directly from Corps documents available on its Web site and entered into Microsoft Excel® spreadsheets by Parametrix, Inc. personnel. After the data were entered into spreadsheets and modified as described above, all data entry and modifications were checked by Parametrix personnel.

Bi-State Surveys

The sediment data collected by Tetra Tech, Inc., for the Bi-State survey were downloaded and saved as a Microsoft Excel® spreadsheet at the Lower Columbia River Estuary Program Web site, so the data did not have to be entered by Parametrix personnel. After the spreadsheets were organized in the same

[11] Personal Communication from Dr. Steve Ellis to Mr. Mark Siipola, Corps.
[12] Matrix interference occurs when other substances in the sample interfere (in this case positively) with quantification of the substance. When positive, it has the effect of raising the detection limit.

format as the other data sets and modified as described above, all data entry and modifications were checked by Parametrix personnel.

3.2.1.5 Data Analysis

To address the five issues, the distributions of the data in terms of the frequency and magnitude of sediment were processed as follows. After the QA/QC procedures were complete, all data for each chemical class or sediment property were placed into one comprehensive Microsoft Excel® spreadsheet. Data that had been collected in the channel (Corps 1998) and at the Columbia River's mouth (Corps, 2001) were coded to compare channel and nearshore values. Also, data that had been collected from the Columbia Slough and lower Willamette River were segregated from mainstem Columbia River data.

River miles were assigned to each station in the mainstem, and the data were broken out into three reaches of the Columbia River: RM 0-40, 41-101, and >101. River mileages for the Willamette River and the Columbia Slough were separately distinguished with codes. RM 0-40 has been designated in this report as the lower estuary. It represents a large open area from the mouth up to near Puget Island, as shown in Figure B-11. The middle reach extends from RM 41 to the Willamette River confluence (RM 101; Figure B-11 and B-14), and the upper reach extends to the uppermost end of tidewater, near Bonneville Dam (RM 145; Figure B-14). For each river reach, the concentrations measured in the channel and those measured at all sites, channel plus nearshore, were ranked in terms of percentage occurrence from lowest to highest concentration and expressed as cumulative frequency distributions (Figure B-8).

3.3 EFFECTS CHARACTERIZATION

The goal of an effects characterization is to define the range of effects expected from each of the three chemical classes. Effects here are limited to adverse effects, and adverse effects do not necessarily include all changes in the organism in response to contaminant exposure. Responses may reflect changes in some attribute of the animal's biochemistry or physiology, which are not necessarily adverse effects. Adverse effects can be sublethal or lethal, but both types need to ultimately affect attributes believed to influence the viability of species populations – namely growth, survival, and reproductive success. An adverse, sublethal effect is one that leads to reduced growth, survival, or reproductive success. Another goal is to define each chemical's no adverse effect threshold, which constitutes the concentration below which there appears to be negligible risk. Each threshold is important because it is used to screen all exposures for risk potential. Risk occurs when an exposure exceeds a threshold. Exposures creating potential risks require further assessment, whereas those below the threshold pose insignificant (negligible) risks and usually do not receive further evaluation.

The published literature and the database Ecotox (EPA, 2001) were surveyed to identify what dietary concentrations of the contaminants adversely affected fish. Emphasis was placed on juvenile salmonids to the extent such data were available; however, data on effects on fish and invertebrates were used to evaluate risks to sediment-dwelling invertebrates.

The categories of chemical concentrations shown in Table B-21 constitute regional sediment screening guidelines for dredged material that were developed by state and federal agencies (Corps, et al., 2000). The guidelines are based on correlations between sediment concentrations and effects on a variety of organisms, and they are meant to protect fish, their prey, and all other aquatic life[13]. Each value represents a threshold that triggers further testing and evaluation when exceeded (Corps, et al., 2000).

[13] Primarily amphipods, larvae of bivalve molluscs or echinoderms, and polychaetes.

When a concentration falls below this threshold, the sediment is suitable for unconfined, open-water disposal at designated sites, provided no other chemical exceeds its respective screening guideline.

There are other sediment standards available, but they apply to uses of the water that are different from dredging activities. For example, the bioaccumulation screening values listed in Table 5-1 of Corps, et al., (2000) are applied when risks to human health from consumption of contaminated fish is an issue. In terms of other sediment standards, WSDOE has developed a marine sediment standard for total PCBs of 12,000 ppb organic carbon. This would be equivalent to 240 ppb dw for a sediment containing 2% TOC. This standard represents the Sediment Cleanup Screening Level/Minimum Cleanup Level for marine hazardous waste sites (WSDOE, 2001).

The toxicological endpoint for analysis of PCB and DDT effects was the residue associated with effects in a toxicity test. Usually, this was the lowest observed effect residue (LOER) in the fish's tissues. The LOERs had to be converted to an equivalent sediment concentration. To do this, it was assumed that each contaminant's residue in the fish's tissues was in equilibrium to that in the prey and then to the corresponding sediment concentration (Figure B-5; Di Toro, et al., 1991). This is a conventional assumption for such substances (EPA, 2000), but there are uncertainties, as discussed in Section 5. To express LOERs in terms of dry weight sediment concentrations, the following equation was used (following Meador 2000):

$$\text{Sediment Concentration (ng/g dw)} = (\mu\text{g/g lipid x TOC x 1000}) / \text{BSAF}$$

The TOC was assumed to be the arithmetic mean TOC content for the reach in question (i.e., RM 0-40, 41-101, >101). This conversion was not performed for the PAH effects data because Johnson (2000) expressed effects in terms of sediment dry weight.

3.3.1 PCBs

An analysis by Meador (2000a) was used to represent potential dietary effects of PCBs because it appeared to be the most recent and complete analysis of potential relationships between PCB tissue residues and effects on juvenile salmonids. The data used by Meador (2000) are graphically depicted using the concentration-response relationship shown in Figure B-12. Based on the TOC normalization, PCB effects range from 10.6 to 17,363 µg/g (ppm) TOC. Meador (2000) suggests the effect threshold should be set equal to effects associated with 10% or more of the endpoints, i.e., approximately 15.0 µg/g TOC (Figure B-12).

3.3.2 DDT and Metabolites

Data are limited concerning either sublethal or chronic effects of DDT and metabolites on the salmonid life stages found in the Columbia estuary, based on a screening of toxicity values from EPA's Ecotox database: http://www.epa.gov/cgi-bin/ecotox_search. Most of the available data concern toxicity from water-only exposures, and there are few data defining toxicity from dietary exposures or the tissue residues found in the salmon. However, there is a regional sediment screening guideline of 6.9 ppb dw (Table B-2), based on sediment toxicity tests of several invertebrates.

The best study appears to be a 612-day chronic exposure of cutthroat trout (*Oncorhynchus clarki*) to DDT by the U.S. Fish and Wildlife Service (Allison, et al., 1963; 1964). It is considered most relevant to the exposure scenarios typical of the Columbia estuary where juveniles, mainly smolts or older, are the life stages being exposed. Equally important, the exposures lasted for months and toxicity was expressed in terms of the residues measured in the specimen's tissues. The test was started with 21-month-old specimens and encompassed reproduction. A variety of endpoints were measured, such as growth, mortality, reproductive success, histopathology, and resistance to stress, including disease and temperature stress. Fish were either fed various concentrations of DDT in the diet once a week or were placed once a month for 30 minutes in water containing various concentrations of DDT. These simulated intermittent, but long-term water and dietary exposures. Tissue residues of total chlorinated hydrocarbons were measured frequently throughout the experiment. It was possible to relate these residues to mortality, which combined with growth effects, was the most sensitive endpoint. It was assumed that measurement of total chlorinated hydrocarbons was equivalent to measuring ΣDDT and its metabolites because fish metabolize DDT to DDE fairly rapidly, but DDE resists metabolism and persists within the organism. Allison, et al., (1963, 1964) reported that mortality of fish given DDT baths became statistically different from controls when tissue residues reached between 1,900 and 4,200 ppb wet weight (ww)[14]. Likewise, mortality became significantly different from controls (i.e., issue residues between 5,600 and 7,000 ppb ww) when fish were fed DDT in their diet. These are regarded as estimates of LOERs. The difference between water and dietary LOERs may reflect different assimilation efficiencies, as discussed by Gobas, et al., (1989).

Other studies of DDT's effects on juvenile salmon were consulted, including Halter and Johnson (1974) and Dill and Saunders (1974). Unfortunately, it is difficult to extrapolate these studies to exposures characteristic of the Columbia estuary, principally because they tested life stages that either do not occur or do not rear in the estuary, specifically the shipping channel (embryos, alevins, fry). The life stages and species of interest in this risk assessment stop and rear in the Columbia estuary prior to migrating seaward. The life stages comprise pre-smolt, smolt and post-smolts of chinook, coho, cutthroat, and steelhead.

Table B-2. Regional Sediment Screening Guidelines for Judging Suitability of Dredged Material for Unconfined Disposal

Chemical	Guideline, μg/kg dw
ΣPCB	130
ΣDDT	6.9
ΣPAH	15,100[a]

[a]Based on the screening levels shown in Table 5-1 of Corps, et al., (2000) that matched the PAHs identified in Table 1 of Johnson (2000).

Source: Table 5-1 of Corps, et al., (2000).

The LOERs were converted to equivalent sediment concentrations by assuming that sediments were in equilibrium with the tissues of the juvenile salmonids living in the lower Columbia River. This is a worst-case estimate of exposure because equilibrium is unlikely, especially close to the mouth, where water from the Pacific Ocean dilutes estuarine water and the degree of dilution fluctuates with tides and river flow. The field-derived biota-sediment accumulation factor (BSAF) developed by Wong, et al., (2001) of the U.S. Geological Survey, was used. The BSAF is defined as follows:

$$\text{BSAF} = Ct_{(l)}/Cs_{(foc)}$$

[14] The values are taken from Figure 1 and Table 9 of Allison et al. (1964) and the paper's discussion of which concentrations were significantly different from controls and when. Allison et al. (1963, 1964) did not indicate whether the units were wet or dry weight. Wet weight was assumed because most papers written in that era used wet weight unless another unit was specified. If units were actually dry weight, then tissue residues reported by Allison would be approximately 20% of those reported, i.e., between 380 and 840 ppb ww in tissue or 1120 to 1400 ppb ww in food.

where $Ct_{(l)}$ refers to the tissue concentration normalized to the lipid content of the tissue and $Cs_{(foc)}$ refers to the sediment concentration of DDE, normalized to the sediment's total organic carbon content.

Based on field-studies of many species of fish across the United States, Wong, et al. (2001) found that the BSAF for DDE (median =8.6) was the highest reported for the substances examined. Using the LOER range of 1,900 to 5,600 ppb ww and this BSAF, the sediment concentrations corresponding to the LOERs were estimated to be as low as 46,027 ppb TOC to as high as 135,659 ppb TOC. These sediment concentrations were adjusted further for the median TOC observed within each river reach. For example, within RM 0-40, channel and channel plus nearshore sediments averaged 0.05% and 0.76% TOC, respectively. Upstream sediments were virtually identical in TOC to those downstream. For example, channel sediments averaged 0.24% and 0.06% within RM 41-101 and RM > 101, respectively, and nearshore and channel sediments averaged 0.52% and 0.58%, respectively. Moisture content was assumed to be 20% and the lipid content of the juvenile salmon was assumed to be 2.4%, the median value in data summarized by Meador (2000a).

3.3.3 PAHs

Three screening criteria and one study of concentration-response relationships involving PAHs and fish were used to define the range of potential effects to juvenile salmon. The Regional Screening Guidelines (Corps et al., 2000) specify two screening levels for PAHs – 5,200 ppb (µg/g) dw for low molecular weight PAHs and 12,000 ppb dw for high molecular weight PAHs. These equated to 15,100 ppb dw as ΣPAH when only compounds analyzed by Johnson (2000) were totaled. Johnson's (2000) analysis of 18 low and high molecular weight PAHs (Table B-1) was used because it represented NMFS' most recent analysis of potential relationships between sediment concentrations and effects on fish.It is specific and limited to English sole and similar sediment-dwelling species that have received long-term exposure (more than 2 years) to PAHs. Consequently, it cannot be applied directly to juvenile salmon, which spend an average of 25 days or less (Aitkin, 1998) feeding on a combination of epibenthic and pelagic prey as they grow in the estuary. However, it can be used as a reference point. Johnson (2000) based her analysis on a variety of changes that NMFS observed in laboratory and field populations of sole, which they assumed were caused only by PAHs. These responses ranged from preneoplastic foci of cell degeneration in the liver, correlated with a sediment PAH concentration of 54 ppb dw (2% TOC assumed), to inhibited gonadal growth at a sediment PAH concentration of 4,000 ppb dw (Table 2-4; Johnson, 2000). The same data are plotted in Figure B-13 in the manner that they are used in risk assessment.

Dr. Tracy Collier (2001) has proposed two screening criteria for ΣPAH effects on fish. Based on NMFS analysis of the existing data, Collier suggested that a ΣPAH sediment concentration of 5,000 ppb dw represents the lowest observed effect concentration (LOEC) for juvenile salmon exposed to PAHs in sediments, and 1,000 ppb dw approximates the no observed effect concentration (NOEC) for marine fish like English sole. All of the foregoing sediment concentrations were used to assess the potential for and magnitude of risks to juvenile salmon.

4 FINDINGS (RISK CHARACTERIZATION)

The risk characterization is presented in terms of the five issues (questions) first discussed in Section 3 (Risk-Based Approach) of this report:

- **Issue 1**: Do chemical exposures increase in the Lower Columbia River from Bonneville Dam (RM >101) to the Lower River estuary (RM 0-40)?
- **Issue 2**: Are concentrations of organic carbon and fine particulate matter higher in the estuarine turbidity maximum zone relative to other locations, such that suspension of fine particulates during channel dredging operation could augment risks?
- **Issue 3**: Are chemical concentrations in the navigation channel higher than those in nearshore sediments?
- **Issue 4**: Are sediment concentrations high enough to pose risks to juvenile salmon?
- **Issue 5**: Are sediment concentrations high enough to pose risks to the invertebrate prey of juvenile salmon?

4.1 Issue 1

Finding: Contaminant concentrations decrease rather than increase proceeding from Bonneville Dam to the mouth and are lowest in the estuary. The basis is described in the remainder of this subsection.

The first issue addressed here is whether chemical exposures increase on the Columbia River from above Bonneville Dam (RM >101) to the lower estuary (RM 0-40). Because juvenile salmon tend to rear most extensively in the lower river and estuary, it is important to learn whether they are receiving greater chemical exposure in the lower river. Increased exposure increases the potential for risk but is not necessarily associated with risk. This issue was addressed by plotting sediment concentrations on the Columbia River from the upper reaches of the project study area to the mouth for ΣPCBs, ΣDDT, and ΣPAHs.

All chemical concentrations reported in this section have been normalized to dry weight rather than TOC in order to use all the sediment data that were available from SEDQUAL, Tetra Tech, Inc., and the Corps. In particular, reliance upon dry weights allowed use of all data for channel sediments whose TOC contents usually were too low – i.e., below the detection limit (usually 0.05%) – for normalization to TOC.

4.1.1 PCBs

Sediment concentrations of ΣPCBs were all less than 130 ppb dw at all sites throughout most of the Columbia and Willamette River except for a few locations, as identified in Figures B-11 and B-14. Data presented in Section 4.2 indicate that elevated concentrations occur in nearshore depositional environments near to point or non-point sources of contamination. There was no evidence of concentrations increasing in the ETM (i.e., lower Columbia River estuary) (Figure B-11).

4.1.2 DDT and Metabolites

Concentrations of DDT and its metabolites (DDD and DDE) were lower in the estuary (<6.9 ppb dw) than farther up the Columbia River, and they were highest (up to and exceeding 60 ppb dw) in the lower Willamette River and the Columbia Slough, which drains an agricultural area near Gresham and urban, northwest Portland along its length (Figures B-15 and B-16). Therefore, there is no evidence that ΣDDT concentrations were higher in the ETM compared with upstream locations.

4.1.3 PAHs

Total PAH (ΣPAH) concentrations observed in the estuary appeared to be comparable to those found in the mainstem Columbia to above the Willamette River confluence and do not indicate any obvious augmentation in the region of the ETM (Figures B-17 and B-18). Most were less than 1,000 ppb dw and all were less than 5,000 ppb dw, which in turn are both less than the regional sediment screening guideline of 15,100 ppb dw (Table B-2). The ΣPAH concentrations recorded for the lower Willamette and its tributary Columbia Slough were considerably higher than those in the mainstem Columbia (Figure B-18).

4.2 Issue 2

Finding: Organic carbon and fine particulate contents are not elevated in navigation channel sediments in the lower estuary, within which the ETM occurs. The basis for this conclusion is provided in the remainder of this subsection.

Because organic carbon tends to be trapped temporarily within the ETM, any chemicals bound to these particles will likely behave similarly. The ETM zone may extend approximately from the mouth of the Columbia River to RM 10-16. Trapping occurs when charged particles bind to the ions in saltwater, precipitate, and reflux with the tides (Reed and Donovan, 1994).

The ETM within the Columbia estuary has been studied extensively. It is confined to the Columbia River's channel (Simenstad, et al., 1994), and mixes vertically (Baross, et al., 1994; Simenstad, et al., 1994a). Enhanced turbidity associated with the microbial decomposition of organic matter also is found there (Reed and Donovan, 1994). Owing to this turbidity, the ETM's productivity has been questioned compared to less turbid environments (Small and Morgan, 1994). However, the detrital floc represents an important food source for the invertebrates that live within (infauna) and upon (epibenthos) the bottom sediments. Zooplankton have been documented feeding within the ETM, due to the organic detritus there (Baross, et al., 1994; Reed and Donovan, 1994). *Corophium* amphipods are thought to be associated with the ETM, because they feed on the organic matter. Theoretically, these processes may increase exposure and therefore potential risk to salmon when the juveniles feed upon the invertebrates living with the ETM.

The question of whether concentrations of organic carbon and fine particulate matter increase in the ETM relative to other estuarine locations was specifically addressed. Both of these substances would tend to be suspended and could remain on the sediment's surface after channel dredging.

Maps depicting spatial changes in organic carbon suggest TOC is slightly augmented in the lower river estuary compared with most sediments upstream to Bonneville Dam (Figures B-19 and B-20). However, all sediments within the Columbia River study area are lower than those in the lower Willamette River (Figure B-20). Figure B-21 suggests the increased TOC is associated with shallow, nearshore depositional habitats rather than with channel sediments. This reflects the higher energy typical of the channel environment; the TOC particles usually are too small and light to settle in the high-energy environment of the Columbia channel. Instead, they settle in low-energy areas, which generally are close to shore and in embayments. A comparison of TOC concentrations in nearshore versus channel sediments indicates that the latter are so sandy that 93% of them contain negligible TOC (< 0.08%) (Figure B-21). All sediments sampled in the lower Columbia River contain low concentrations of TOC: approximately 81% of the samples contained ≤ 1% TOC.

Organic carbon and fine particulate concentrations are known to be correlated; however, in the data analyzed, the correlation between fine particulate and TOC concentrations was only moderate (r=0.77). The channel sediments are so sandy, compared with nearshore sediments, that 93% contained 4% or less fines (Figure B-22). Although nearshore sediments contained higher concentrations than the channel, fine particulate concentrations were still low; half the samples contained ≤ 17% fines (Figure B-22). The spatial distribution of fines within the lower Columbia shows that concentrations are very low in the navigation channel and higher at sites nearshore (Figures B-23 and B-24). Near the Willamette confluence, channel sediments still contain mostly low percentages of fines, but the lower Willamette and Columbia Slough contain much higher concentrations of fines (Figure B-24).

4.3 Issue 3

Finding: In all instances, concentrations of PCBs, DDT and metabolites, and PAHs in the channel were markedly lower compared with samples collected nearshore, as discussed in the following three subsections. These differences were consistent throughout the reaches studied, from the mouth of the Columbia River to near Bonneville Dam.

4.3.1 PCBs

ΣPCB concentrations increased from the mouth to Bonneville Dam, were consistently at the detection limit in channel sediments, and were lower below the Willamette River confluence than above it. In the lower estuary (RM 0-40), ΣPCB concentrations were at the detection limit (5-6.5 ppb dw) in the channel and only 12.5 ppb dw or less in nearshore sediments (Figure B-25). Upstream, all channel sediments were at the detection limit (5 ppb dw) except one. Most (78%) nearshore sediments also contained very low (≤ 12.5 ppb dw) PCB concentrations, but 22% contained higher concentrations, up to 110 ppb dw (Figure B-26). Above the Willamette confluence, ΣPCB concentrations in the channel remained at the detection limit (5 ppb dw), but 34% of the sediments, all nearshore, ranged from 12.5 ppb dw up to 28,000 ppb dw. Ten percent of the sediments, all nearshore, exceeded 1,500 ppb dw (Figure B-27).

4.3.2 DDT and Metabolites

Concentrations of DDT and metabolites in sediments were always lowest in channel sediments and higher in nearshore sediments. Concentrations in nearshore sediments were lowest in the lower river estuary (RM 0-40) and distributed similarly from RM 40 to above the Willamette River confluence. In the lower river estuary (RM 0-40), 71% of the ΣDDT concentrations in channel sediments were at the detection limit of 0.28 ppb dw, and the remainder were at a higher detection limit of 3.0 ppb dw (Figure B-28). Nearshore sediments were higher, up to 6.5 ppb dw. Upstream (RM 41-101), all channel sediments were ≤ 5 ppb dw, compared to 70% of all (nearshore + channel) sediments being 6.5 ppb dw or less. Thirty percent of the samples, all collected nearshore, ranged up to 33 ppb dw (Figure B-29). Above the Willamette confluence (RM >101), channel sediments remained at ≤ 3.0 ppb dw, whereas sediments nearshore ranged up to 30 ppb dw, the same range observed downstream (Figure B-30).

4.3.3 PAHs

Unlike ΣPCBs and ΣDDT, concentrations of PAHs in navigation channel sediments usually were above detection limits, though still significantly below concentrations observed in nearshore sediments. Nearshore sediments appeared to possess similar ΣPAH residues from the Columbia River mouth to above the Willamette confluence, although about 10% of RM 41-101 sediments were higher than those sampled upstream and downstream. In the lower river estuary (RM 0-40), concentrations ranged from 6.6-41 ppb dw in the channel (Figure B-31). Sixty-five percent of the nearshore samples exceeded the highest concentration observed in the channel, and nearshore sediments ranged up to 1,008 ppb dw, with one sample reporting 4,259 ppb dw. Between RM 41 and the Willamette confluence, 80% of channel sediments contained less than 41 ppb dw, and the maximum observed in the channel was 396 ppb dw (Figure B-32). Fifty percent of all sediment samples, all of them sampled nearshore, exceeded the maximum concentration observed in the channel. The two highest concentrations observed in nearshore sediments were 3,105 and 14,254 ppb dw (Figure B-32), three times higher than concentrations observed in the lower estuary (Figure B-31). Few channel sediments (n=5) have been sampled above the Willamette confluence, and the levels are comparable to those observed at the majority of sites sampled all the way to the mouth (Figure B-33). Nearshore sediments contained almost as much PAHs as observed below the Willamette confluence; the maximum concentration observed nearshore at RM >101 ranked in the 90th percentile of all sediments sampled from RM 40-101 (compare Figure B-32 to Figure B-33).

4.4 Issue 4

Finding: Contaminant concentrations in navigation channel sediments posed only negligible risks to juvenile salmon, whereas some nearshore sediments close to point sources of contamination posed risks. Risks associated with nearshore sediments were lowest in the lower estuary compared to upstream reaches (RM 40-145), as explained below.

In this subsection, the sediment concentrations identified in Section 4.2 are compared with data that relate predicted effects to specific sediment concentrations. The comparisons enable judgments to be made concerning whether potential risks exist and if so, their magnitude. Because of the many assumptions and other uncertainties in the data on which they are based, the risks should only be regarded as potential. Whereas negligible risks typically warrant no further investigation, potential risks warrant further investigation. Such investigations usually focus on reducing uncertainties in the data and evaluating whether effects, suggested by laboratory tests of other species, are actually manifesting in the species in the field. In the United States, Europe, and Australia, risks affecting fewer than 5% of the species are regarded as negligible provided they do not affect species that are endangered, threatened, economically important, or ecologically keystone (Australian and New Zealand Environment and Conservation Council, 2000; Crommentuijn, et al., 2000; Stephan, et al., 1985). Keystone species are ones that will change a community's structure and function if removed.

Because concern here focuses on whether individuals within populations of endangered species are at risk, the question focuses on the level of impact required to place the population at risk. Meador (2000a) has suggested that effects on fewer than 10% of the individuals in a population of endangered or threatened species can be considered negligible, with exceedances requiring further investigation. In bioassays of substances, effects on 10% or fewer of the test specimens are considered comparable to controls (e.g., ASTM, 1998). Endpoints like the EC25 or IC25, which refer to the concentrations affecting 25% of the specimens, are widely used for estimating the NOEC level on the population (ASTM, 1998). Moore and Caux (1997) note that most (77%) NOECs from aquatic toxicity testing have been associated with effects on between 10 and 30% of the individuals in the test population. Conversely, most (62%) LOECs were associated with effects greater than or equal to 30% of the individuals. Based on these data, there may be a consensus that effects on fewer than 10% of the individuals and perhaps as high as 25% may be indistinguishable from the effects normally observed in controls in toxicity tests. A higher level of mortality may be tolerated by salmon in nature, but it depends entirely on the cumulative magnitude of all sources of mortality. For example, in natural populations of some fish species, as many as 50 to 70% of the prospective spawners can be lost from the population (i.e., die), as a result of natural mortality, fishing, predation, toxicants, and other factors, without affecting spawning success and recruitment of the next generation. This is based on an a study performed by Waller, et al. (1971). It is recognized, however, that agency decisions concerning appropriate levels of protection for species populations usually consider a complex set of social and political judgments and priorities in addition to scientific data.

The following risk characterization pertains only to Columbia River sediments proposed for navigation channel dredging. Nearshore sediments are expected to be unaffected by dredging activities associated with this project. If they do receive suspended solids as a result of channel deepening dredging, the overall level of contamination should remain unchanged because channel concentrations appear to be lower than nearshore concentrations. Dredging resuspends only minor (≤ 3 milligrams per liter) amounts of particulate matter, and the suspended sediments contain a lower level of contamination than nearshore sediments.

4.4.1 PCBs

PCBs in channel sediments appear to pose negligible risk to juvenile salmonids from the mouth to above the Willamette confluence, based on comparison to all screening criteria concerning potential effects (Figures B-34 to B-36). Fewer than 10% of all sediments, all nearshore, posed potential risks to juvenile salmonids from the Columbia River mouth to the Willamette confluence, based on a comparison to the 10% screening criterion proposed by Meador (2000a) (Figures B-34 and B-35). Potential risks were higher above the Willamette confluence; about 20 % of the sediments – all nearshore – exceeded Meador's lowest screening criterion and 20% exceeded the regional screening guideline (Figure B-36). Based on these findings, dredging associated with this project is not expected to augment PCB risks in the navigation channel sediments because they are uniformly negligible in the lower river and estuary. Risks are higher in certain upstream, nearshore sediments. All these risk estimates are based on a number of important assumptions, which are discussed in Section 5.

4.4.2 DDT and Metabolites

Sediment concentrations calculated from the lowest observed effect residues discussed in Section 3.3.2 suggested that DDT and its metabolites would pose only negligible risks to juvenile salmonids from the mouth of the Columbia River to near Bonneville Dam (Figures B-37 through B-39). Moreover, there appeared to be a large margin of safety between the concentrations observed in the sediments and those associated with mortality in cutthroat trout, which appears to be the most sensitive salmonid tested to date with DDT.

The Regional Screening Guideline for DDT was lower than the LOERs calculated from Allison's (1963, 1964) studies (Figure B-37). The guideline also indicates that DDT in channel sediments should pose negligible risks, to aquatic life, but it suggests that about 25% of the sediments upstream of RM 41 –all nearshore –may pose risks.

4.4.3 PAHs

Risks from dietary ingestion of PAHs by juvenile salmonids were examined according to four criteria. The NMFS white paper (Johnson, 2000) analyzed laboratory and field data for English sole (Figure B-

40). She proposed a relationship between sediment concentrations of PAHs from 54 to 4000 ppb dw, and a variety of responses in English sole. Collier (2001) evaluated those data and suggested that 1,000 ppb dw was the NOEC for resident marine fish in the Columbia estuary. He also identified 5,000 ppb dw as the approximate LOEC for juvenile salmon based on evidence of DNA damage and immunosuppression. Assuming 5,000 ppb dw is the LOEC for juvenile salmonids, then by definition this would be the lowest concentration at which any effects should be observed, with higher concentrations being required to directly elicit more definitive effects, such as mortality. Sediment concentrations of ΣPAHs were evaluated in terms of all four criteria, plus the Regional Screening Guideline of 15, 100 ppb dw, recognizing that these criteria are based on laboratory and field studies elsewhere and may not be wholly applicable to conditions in the lower Columbia estuary.

In the lower estuary (RM 0-40), no navigation channel sediments exceeded any of the four criteria (Figure B-40). Sixty-four percent of all sediments, all nearshore, exceeded the lowest effect endpoint specified by Johnson (2000), but only 4% and 2%, respectively, exceeded Collier's (2001) proposed screening criteria for marine fish and juvenile salmonids. No sediment exceeded the Regional Screening Guideline. Upstream in the Columbia River (RM 41-101), all navigation channel sediments were below three criteria, and 10 of 11 samples were below all of Johnson's (2000) criteria (Figure B-41). Between RM 41 and 101, 80% of all sediments (all but one nearshore) exceeded Johnson's most conservative criterion; 12% exceeded Collier's (2001) marine fish criterion; and 2% exceeded Collier's (2001) juvenile salmon criterion. None exceeded the Regional Screening Guideline (Figure B-42). Above the Willamette River confluence (RM >101), all channel sediments were below all four screening criteria. Eighty five percent of all sediments, all nearshore, exceeded Johnson's (2000) minimum criterion, 6% exceeded Collier's (2001) marine fish criterion, and none exceeded either Collier's (2001) juvenile salmon criterion or the Regional Screening Guideline.

In conclusion, the preceding risk analyses suggest negligible risks to juvenile salmon resulting from exposure to the contaminants sorbed to sediments in the navigation channel that may be dredged for the proposed project. Only one channel sediment sample exceeded any of the screening criteria concerning potential effects. Nearshore sediments presented greater potential risks, but their magnitude depended greatly on the screening criterion. The most conservative criteria, set forth for PAHs by Johnson (2000), suggested the greatest risk potential, whereas the two PAH screening criteria set forth by Collier (2001) suggested negligible to low risks. Compared to the Regional Screening Guidelines, most sediments would be classified as having negligible risk potential. Based on a weight of evidence involving all four criteria, nearshore sediments in some locations pose potentially significant risks. Given the conservative assumptions in the risk calculations (see Section 5), which should tend to overestimate both exposure and potential effects, dredging activities on the navigation channel sediments are not likely to pose any significant risk potential to juvenile salmon rearing in the lower Columbia River.

4.5 Issue 5

Finding: Contaminant concentrations in navigation channel sediments posed negligible risks to salmonid prey, as explained below.

The risks posed by the three contaminant classes to sediment-dwelling prey (benthos and epibenthos) of juvenile salmon were examined. A risk-based approach was used that defined exposure, effects, and risk potential.

There appears to be a consensus in the scientific community that equilibrium partitioning theory can be used to estimate exposures of sediment-dwelling invertebrates to contaminants bound within the sediments (Di Toro, et al., 1991; US EPA, 1994). This method was used because it accounts for the bioavailability of these substances in sediments and provides a cause-and-effect foundation for comparing exposures to the existing data on aquatic toxicity. Based on this theory, contaminant concentrations in the sediments are assumed to be in equilibrium between the three sediment phases—water, solids, and tissues. Thus, one can assume that concentrations estimated for one phase are proportional to exposures in the other phases (Di Toro, et al., 1991). Therefore, it is possible to base exposures on either water concentrations, tissue concentrations, or sediment concentrations, whichever is available.

Exposures were estimated for ΣDDT using equilibrium partitioning. Specifically, a sediment-water partition coefficient was estimated using a $\log_{10}$ octanol-water partition coefficient of 6.86 for DDT (Table I in Chiou, 1985) and the following equation from Di Toro, et al., (1991):

$$\log 10\ Koc = 0.00028 + 0.983 \times \log 10\ Kow$$

Then, the organic carbon-normalized sediment concentration (e.g., ng ΣDDT/g TOC) was divided by the antilog of the Koc to yield the equivalent porewater concentration.

To gauge the reliability, the estimated porewater concentrations of ΣDDT were compared to the average concentration estimated by McCarthy and Gale (1999) for surface waters downstream of Bonneville Dam using semipermeable membrane devices.

Exposures for ΣPAH and ΣPCB were based on concentrations in the solid rather than aqueous phase because they could be compared to Swartz's (1999) effects threshold for ΣPAH and the study of McDonald et al. (2000) concerning ΣPCB. Both studies defined effect thresholds based on empirical testing and equilibrium partitioning studies by a variety of investigators.

Effects of the three contaminants were based on the scientific literature. For ΣDDT, effects data from US EPA's (1980) DDT water quality criteria document were used. Because the US EPA (1980) chronic criterion of 0.001 µg/L is based on protection of brown pelicans from food chain exposure to DDT, a surrogate criterion for protecting fish and invertebrates had to be derived from their data using EPA guidelines (Stephan, et al., 1985). Accordingly, the final acute value of 1.1 µg/L was divided by 2 to estimate the acute criterion (0.550 µg/L), and this was divided by a generic acute-chronic ratio of 100 to estimate the concentration (0.0055 µg/L) that is expected to protect 95% of the aquatic species. For ΣPAH, Swartz's (1999) threshold effect concentration of 290,000 ng/g TOC was used. This threshold equated to dry weight concentrations of 145 to 696 ng/g in channel sediments and 1508 to 2204 ng/g for both nearshore and channel sediments. The ranges reflect the different average TOC concentrations characteristic of each reach. The study by McDonald et al. (2000) was used because it provided a consensus threshold effect concentration for ΣPCB of 48 ng/g dw that reflected both empirical studies and equilibrium partitioning.

Risk potential to sediment-dwelling invertebrates was indexed by comparing the range of predicted exposures in Columbia River sediments, both those in the channel and nearshore, to the threshold effects concentrations (Figures B-43 through B-49). All concentrations of ΣDDT in both channel and nearshore sediment porewaters were below the concentration expected to protect 95% of aquatic species (0.0055 µg/L) (Figures B-43 and B-44). The estimates of porewater concentrations appeared to be very close to dissolved concentrations estimated by the U.S. Geological Survey for surface waters downstream of Bonneville Dam, using semipermeable membrane devices (McCarthy and Gale, 1999) (Figures B-43 and B-44). All ΣPCB concentrations in channel sediments except one were below the threshold effect concentration developed by McDonald, et al. (2000) for the protection of estuarine and saltwater organisms (Figure B-45). About 10-25% of all sediments, all collected nearshore and above RM 40, exceeded the threshold effect concentration for ΣPCB, and about 15% of these samples exceeded the median effect concentration developed by McDonald, et al. (2000) (Figure B-46). According to that study, samples exceeding this median effect concentration are likely toxic to sediment-dwelling organisms. All ΣPAH concentrations in channel sediments were below the respective threshold effects concentration developed by Swartz (1999), and fewer than 10% of all sediments, all collected nearshore, exceeded the respective threshold (Figures B-47-B-49). Overall, this analysis suggests that the invertebrate prey of juvenile salmonids inhabiting channel sediments should be at negligible risk of adverse effects from DDT, PCB, and PAH compounds. Most nearshore sediments also pose negligible risks to salmonid prey, but there are a few locations where there is some risk of toxicity, presumably mostly from PCBs.

4.6 Cumulative Risks

Toxicology theory – i.e., response addition (Könemann and Pieters, 1996) – suggests that the substances of concern in this assessment (PAHs, PCBs, and DDT and its metabolites) may interact in some additive fashion to augment adverse effects to juvenile salmon, provided exposures are of sufficient magnitude and duration. In this case, virtually all channel sediments appeared to pose only negligible risks to juvenile salmonids; therefore, there should be additive risks for channel sediments only if the contaminants possess the same mode of action. Within their classes, the congeners of PAHs and PCBs and of DDT and its metabolites can be assumed to possess the same mode of action, but it cannot be assumed that PAHs have the same mode of action as PCBs or DDT, DDD or DDE[15]. For example, Halter and Johnson (1974), in their testing of DDT and PCB in combination using coho salmon embryos and alevins, observed much different toxicity signs and no additive toxicity; the toxicity of DDT-PCB combinations was due solely to DDT, reflecting its more rapid mode of action. The PAHs exert narcosis in acute toxicity and a variety of immunological and physiological responses in chronic toxicity that differ from chronic PCB and DDT toxicity. Therefore, as Könemann and Pieters (1996) point out for accumulating like responses to different toxicants, effects should be added only when the exposures to each of the stressors exceed their thresholds. In other words, if they do not exert an effect on their own, response addition will not occur. Nevertheless, these judgments are uncertain because they are based on the general aquatic toxicology literature rather than site-specific studies. This requires extrapolation to the exposures, life stages, and species examined here.

[15] A congener is a compound having the same basic chemical structure as others in a chemical class, such as the different Aroclors of PCBs.

5 ASSUMPTIONS AND UNCERTAINTIES IN RISK PREDICTIONS

All of the risk predictions are based on a variety of assumptions and limited data concerning the fate and effects of the three chemical groups in aquatic ecosystems. Both the assumptions and data used in this assessment carry uncertainties that are important to consider in evaluating the risk estimates. In general, it is necessary to assume that studies conducted elsewhere can be extrapolated to the juvenile salmonid life stages, water quality, and sediment quality that typify the lower Columbia River and estuary.

5.1 Key Assumptions Concerning Exposure

The principal assumptions concerning exposure relate to the biota-sediment accumulation factor and the degree of exposure juvenile salmon receive in the estuary.

Biota-Sediment Accumulation Factor

Biota-sediment accumulation factors are known to be quite variable, and Wong et al. (2001), Watanabe and Bart (2001), and Thomann (2001) have recently reviewed the reasons for this variability. They identified the following factors as potentially influencing BSAF magnitude:

- **Assuming That a Single BSAF Applies to All PAHs and PCBs Included in The Summations:** For example, Thomann (2001) notes that the food chain contributes minimally to bioaccumulation of low molecular weight PAHs. This reflects the reduced hydrophobicity and increased lability to degradation of these compounds. Consequently, including low molecular weight PAHs in the BSAF for ΣPAH likely overestimates risk potential.

- **Biomagnification Up the Food Chain:** BSAFs do not account for biomagnification. Biomagnification may not be important at the base of food chains – for example transfer of detritus to epibenthic invertebrates (primary consumer); see Figure 3 in Suedel et al., 1994. Biomagnification of chlorinated hydrocarbons becomes more important farther up the food chain. Biomagnification potential is expected to be greatest for the most chlorinated PCBs and DDE. Any biomagnification would underestimate risk potential.

- **Actual Exposures *In Situ* Are Different Than Assumed:** It takes time (e.g., weeks) for the contaminants present at very low concentrations and having great hydrophobicity (and hence high potential BSAFs) to bioaccumulate. The longer juvenile salmon spend in the estuary, the larger the BSAF. Conversely, the shorter the time, the smaller the BSAF. One major factor affecting BSAF magnitude for each chemical and species/life stage of juvenile salmonid is the duration each stock spends in the estuary and the degree to which they eat sediment-dwelling prey rather than prey that live in the water column (i.e., plankton and nekton). Meador (2000a) notes that BSAF will increase up to a theoretical maximum with increasing residence time, all other factors being constant. Because the chemicals being considered partition slowly from food into tissue, it may take weeks to months for the maximum theoretical BSAF to be achieved when contaminant concentrations in the sediments are very low, as they certainly are in most lower Columbia River sediments. Therefore, the BSAF estimates used here (from Meador, 2000a; Wong, et al., 2001) may have overestimated risks to ESU stocks that do not feed epibenthically or spend less time in the estuary to achieve maximum transfer of contaminants from sediment to fish tissues.

- **Species and Life Stage:** Different species of juvenile salmonids have different feeding habits, and these change during their ontogeny in the estuary. Reliance on epibenthic prey decreases as fish grow, and some species do not prey significantly on epibenthic invertebrates at any time. The BSAF should decrease proportionately to the degree juvenile salmonids feed on fish or pelagic invertebrates. In this report, it was assumed that juvenile salmon fed exclusively on epibenthic prey, thus likely overestimating risk potential (Watanabe and Bart, 2001).

- **Type of Organic Carbon:** The chemicals considered here have different affinities for different types of organic carbon, and the carbon types present in the lower Columbia River have not been compared to the ones used to derive BSAFs. It is unknown whether this factor will increase or decrease risk.

- **Equilibrium Between Contaminant Concentrations in The Different Environmental Phases (e.g., Sediment or Tissue):** Steady-state BSAFs are based on the assumption that tissue residues are in equilibrium with the sediment. In a dynamic (tidally driven) environment like the Columbia River estuary, this assumption appears unlikely, and therefore BSAF may be overestimated.

Overall, the assumptions above tend to be conservative and should overestimate risks.

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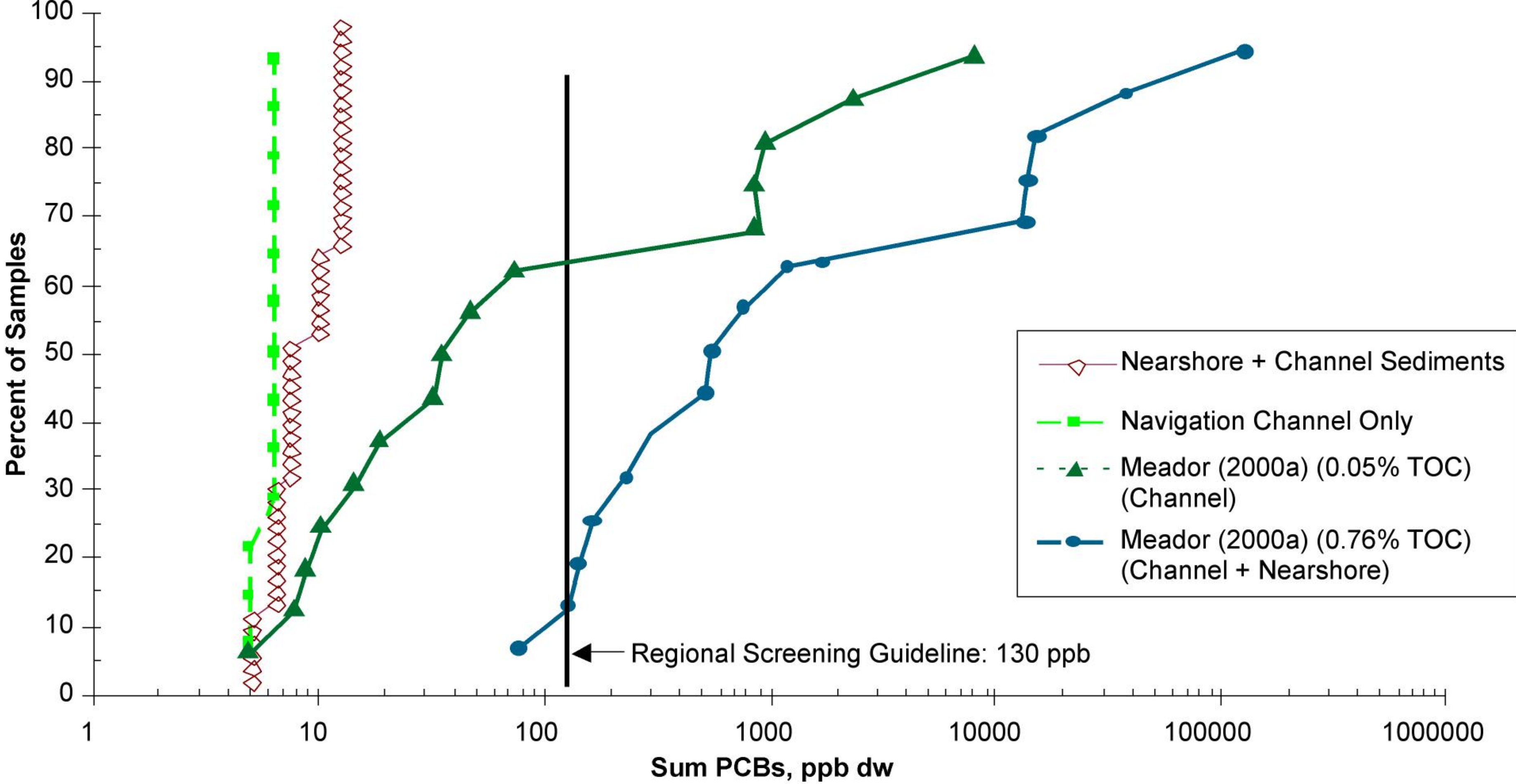


Source: Meador 2000a

Figure B-1
Concentrations of PCBs in Sediments Compared to Those Associated with Adverse Effects in Fish: River Miles 0-40

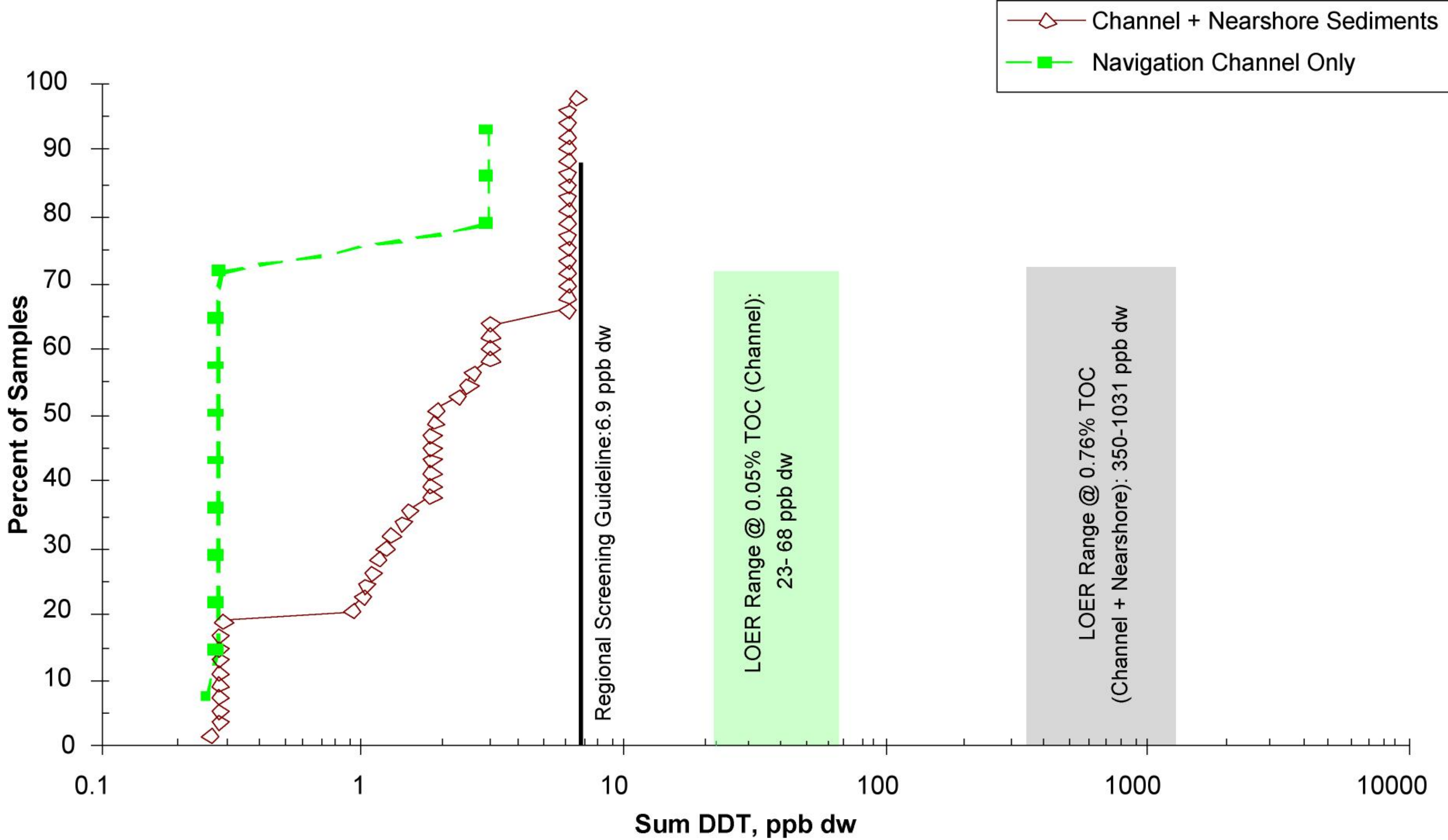


Figure B-2
Concentrations of DDT and Metabolites in Sediments
Versus All Sampling Sites: River Miles 0-40

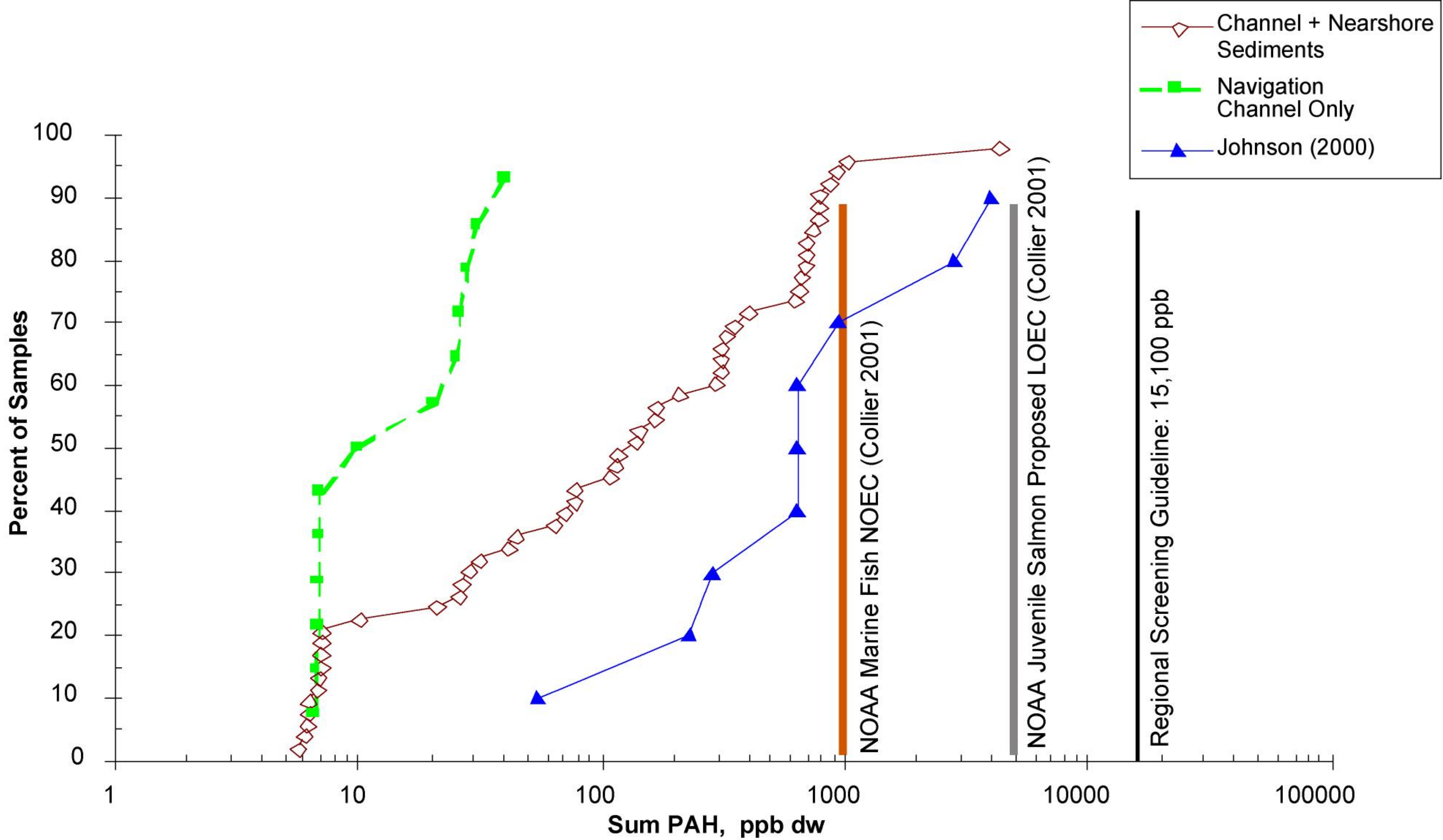


Figure B-3
Concentrations of PAHs in Sediments Compared to Those Associated with Adverse Effects in Fish: River Miles 0-40

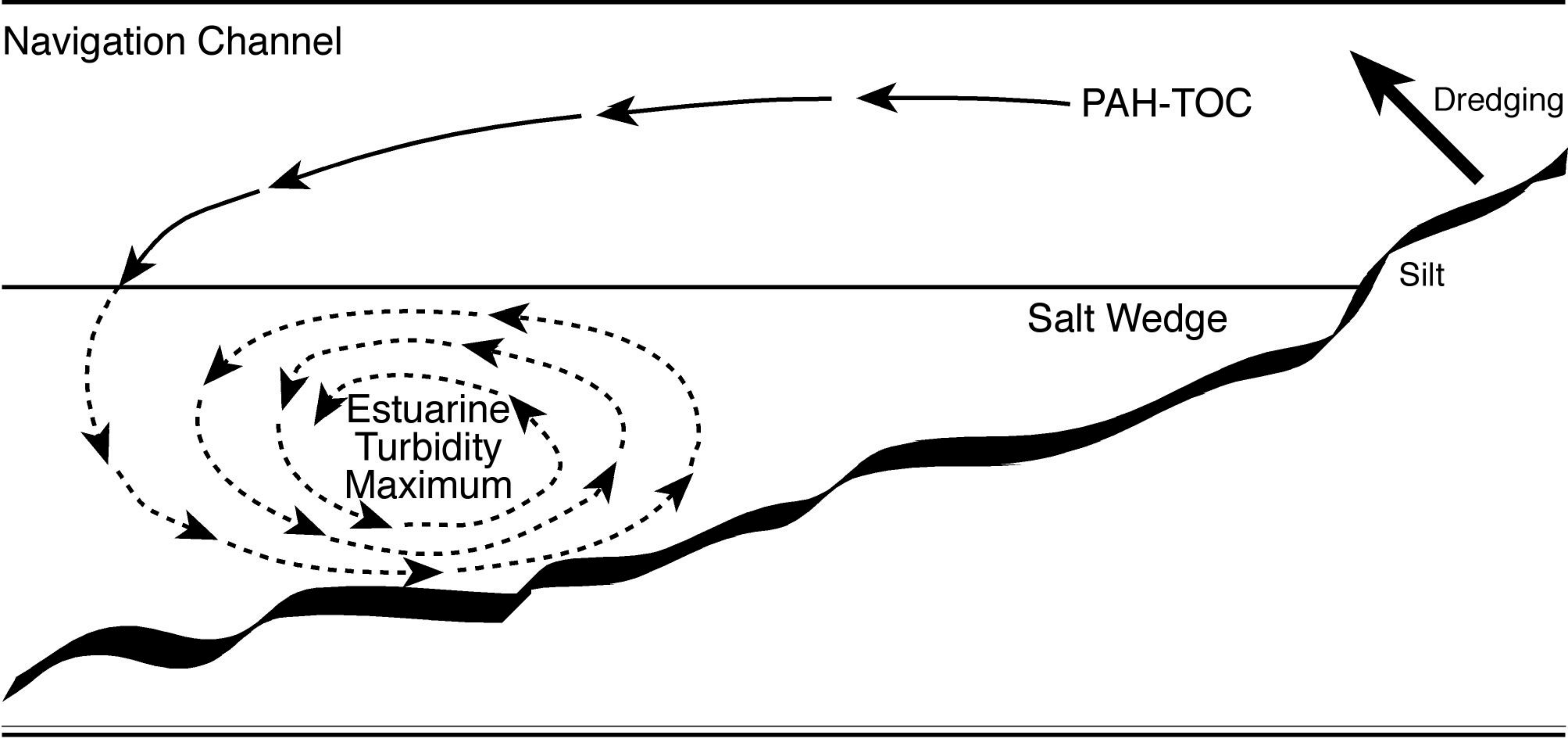
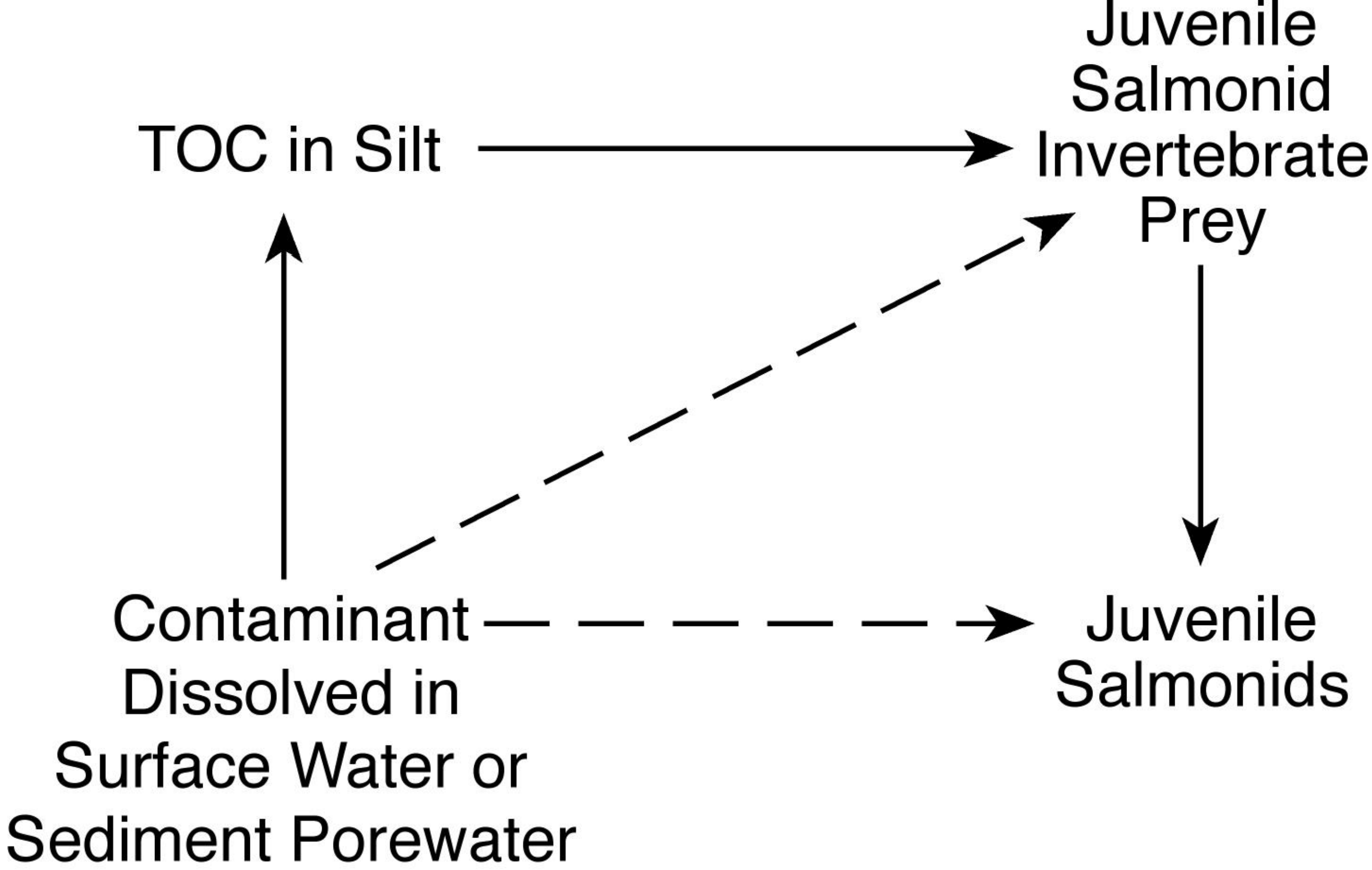


Figure B-4
Hypothesized Relationships Between Dredging Activities in the Main Columbia River Navigation Channel, Suspension of Detritus, and Reflux of Detritus in the Estuarine Turbidity Maximum Zone



Note: Solid lines are assumed dominant pathways and dashed lines are assumed to be subordinant

Figure B-5
Pathways by Which Salmonids will be Exposed to Chemicals Like PCBs, DDT and Metabolites, and PAHs

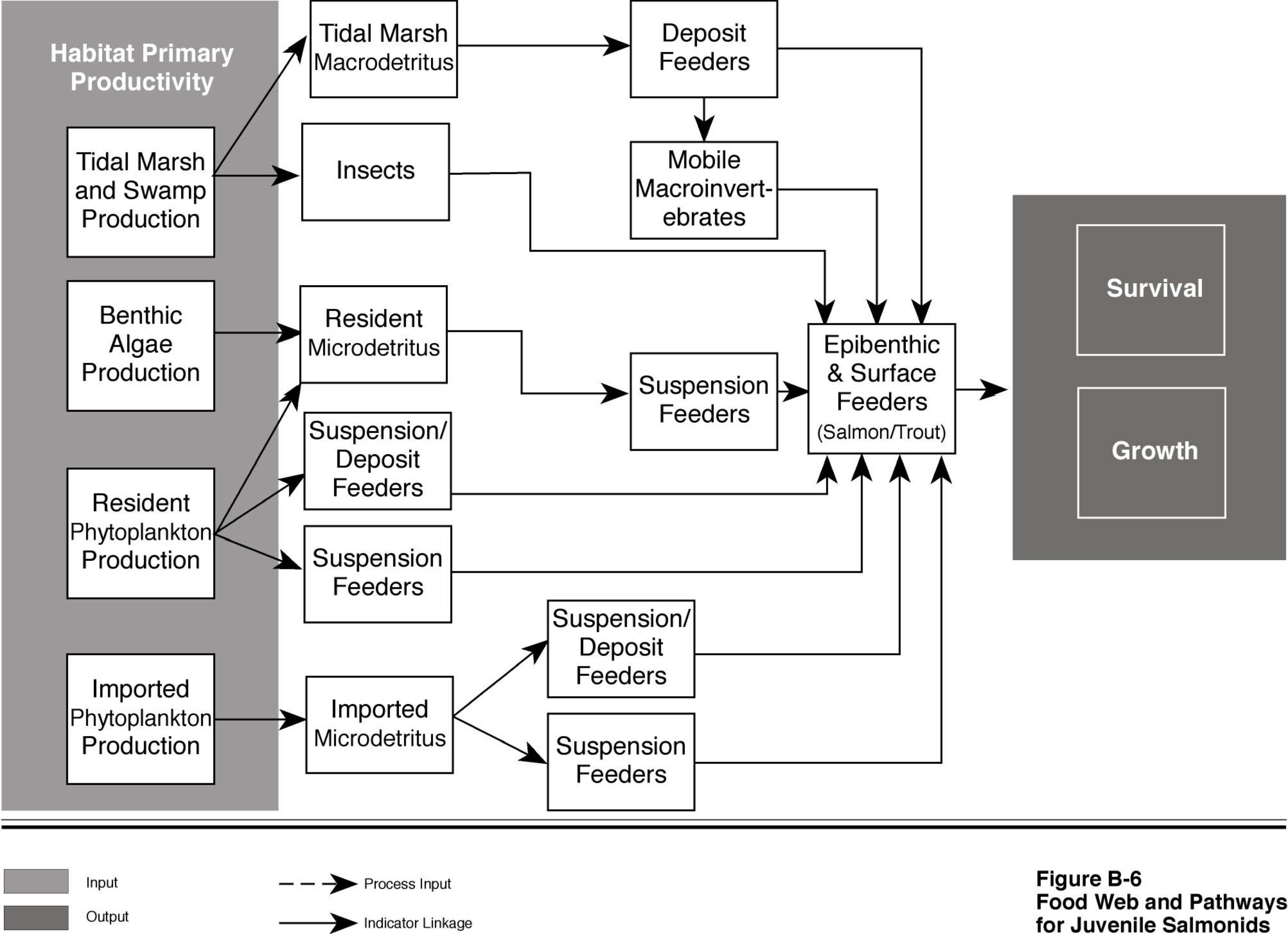
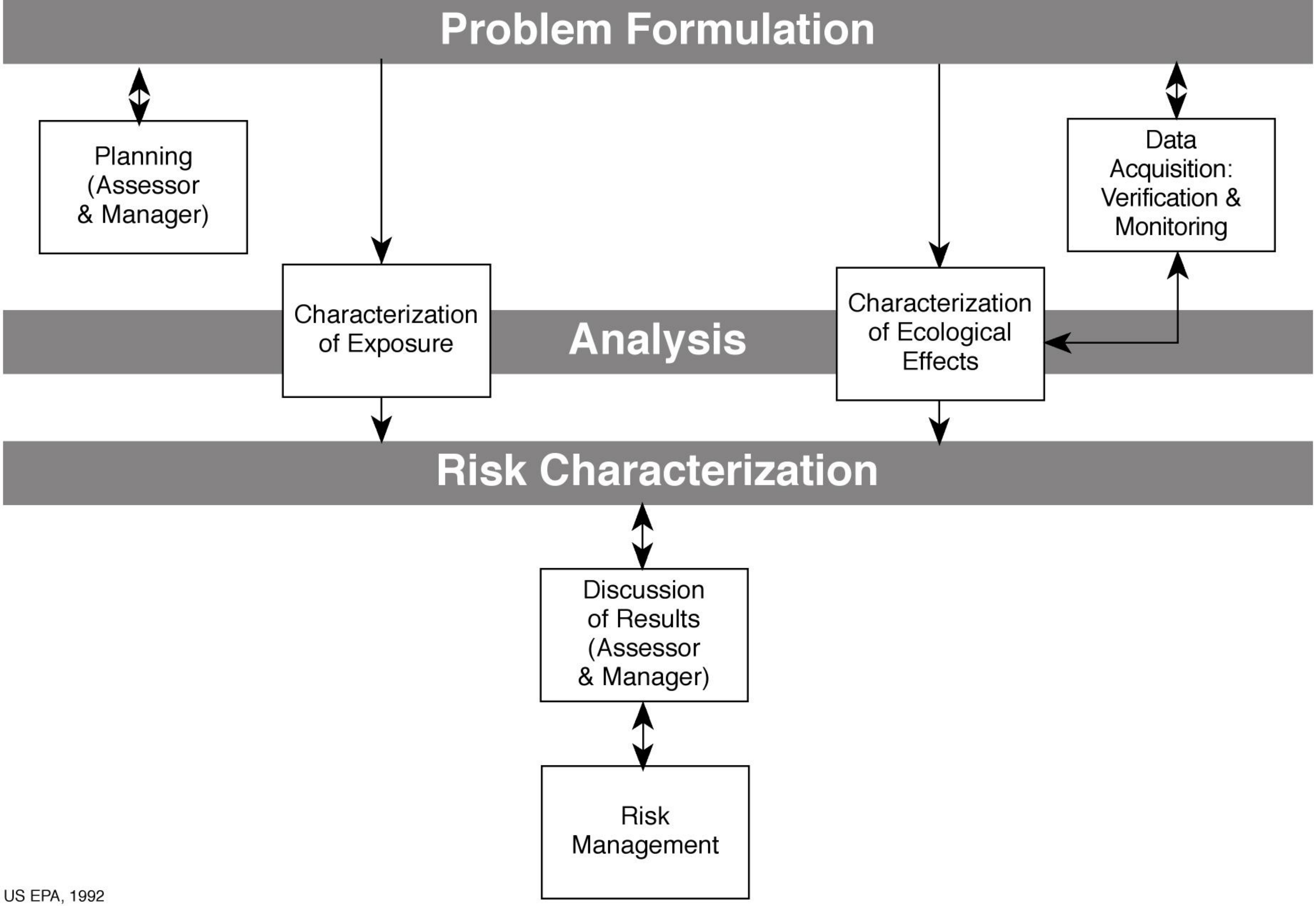


Figure B-6
Food Web and Pathways for Juvenile Salmonids



Source: US EPA, 1992

Figure B-7
Framework for Ecological Risk Assessment

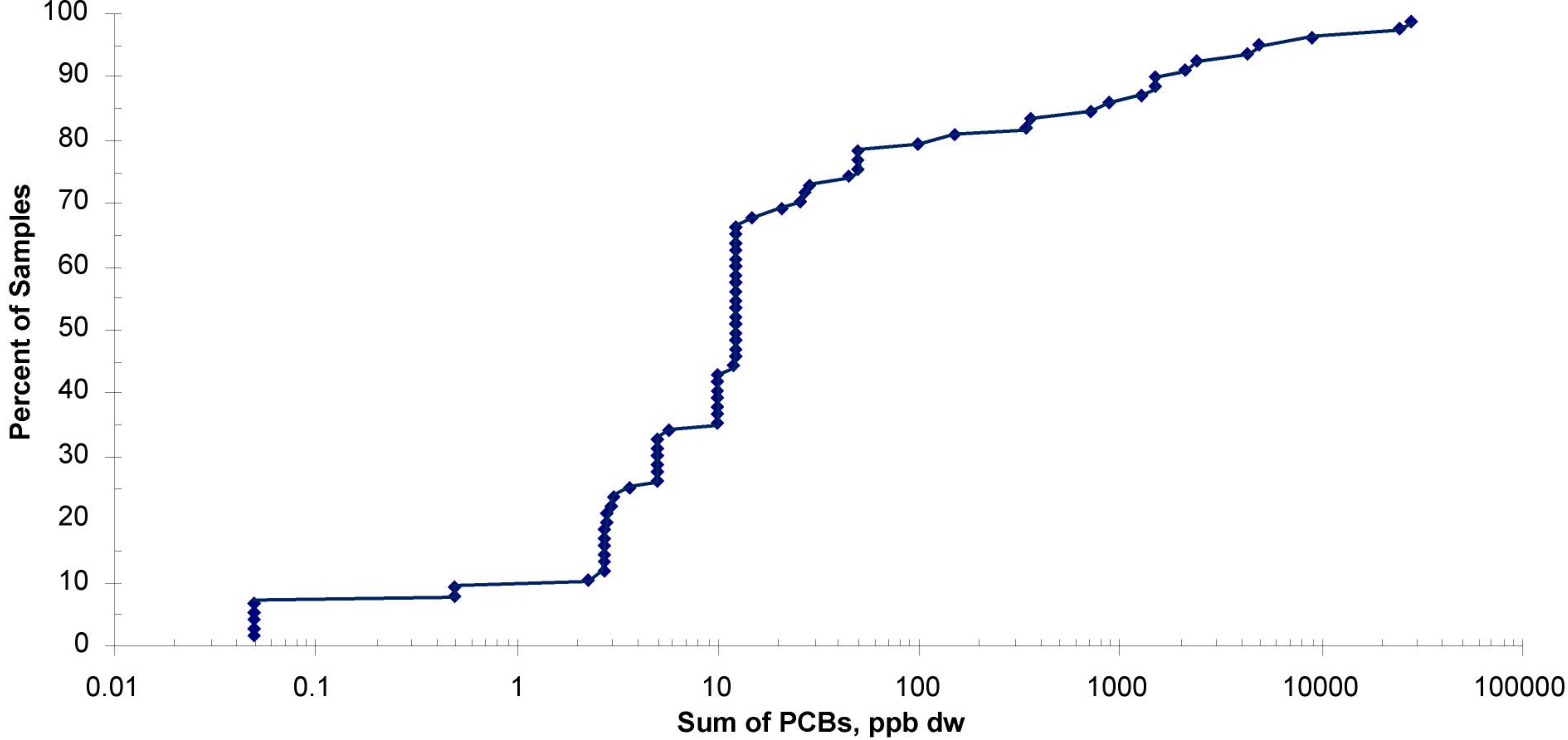


Figure B-8
How Exposure was Characterized for Contaminants in Sediment Using Cumulative Probability Distributions Relating Each Contaminant's Concentration to its Frequency of Occurrence in Sampled Sediments

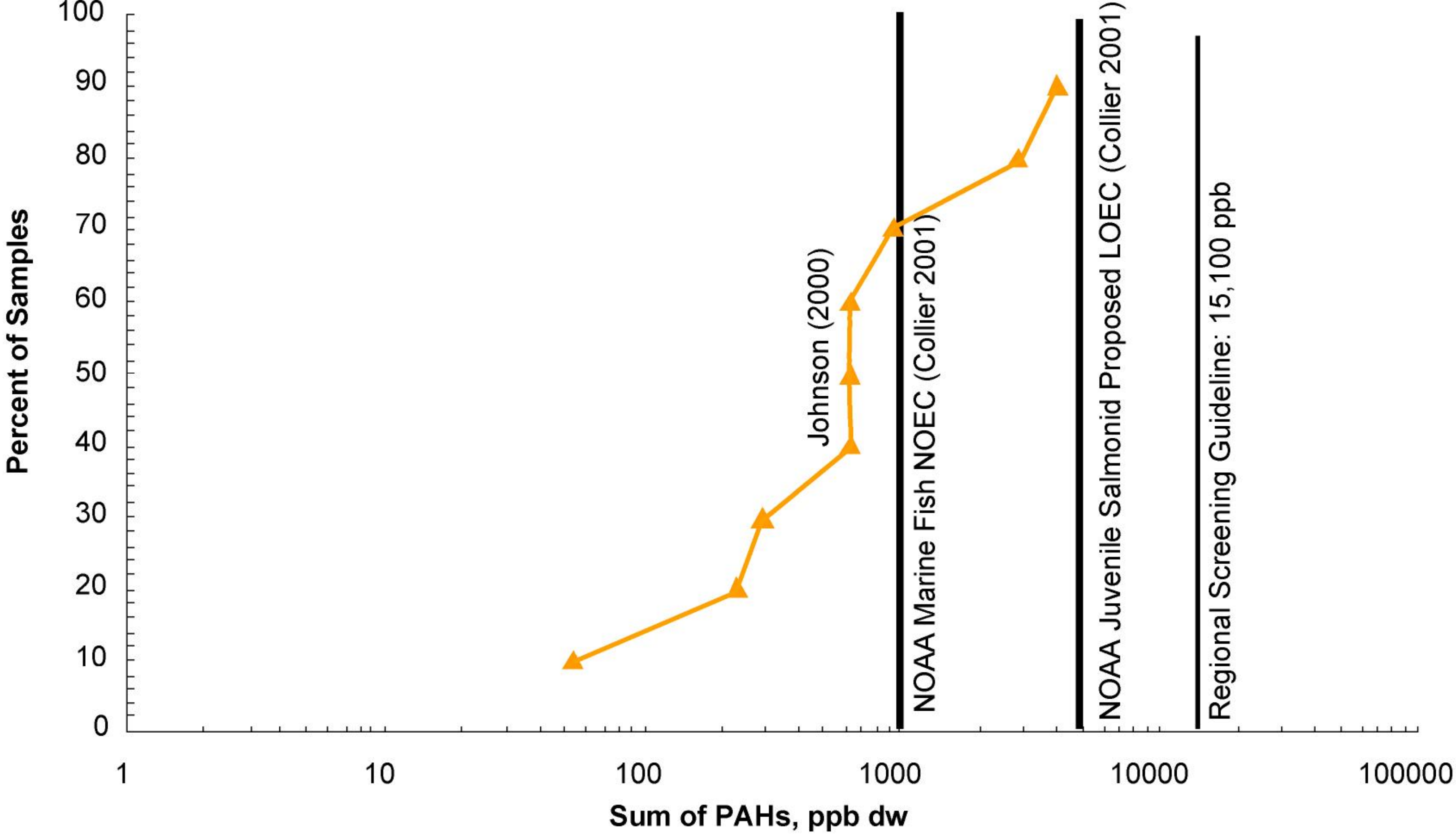


Figure B-9
How Effects were Characterized Using Cumulative Probability Distributions that Related Contaminant Concentrations to Expected Effects or to Threshold Concentrations, Above Which Adverse Effects May be Anticipated

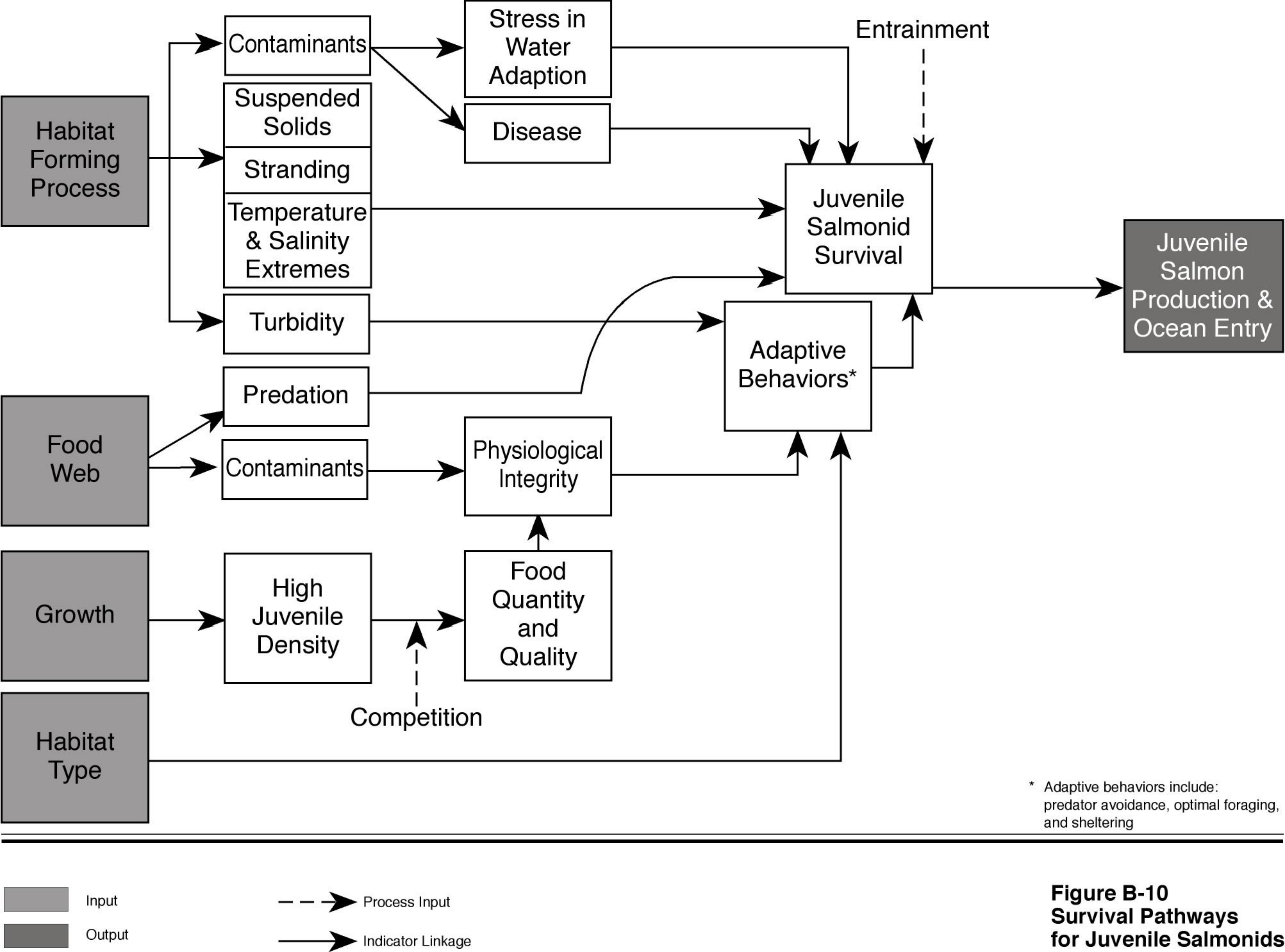


Figure B-10
Survival Pathways for Juvenile Salmonids

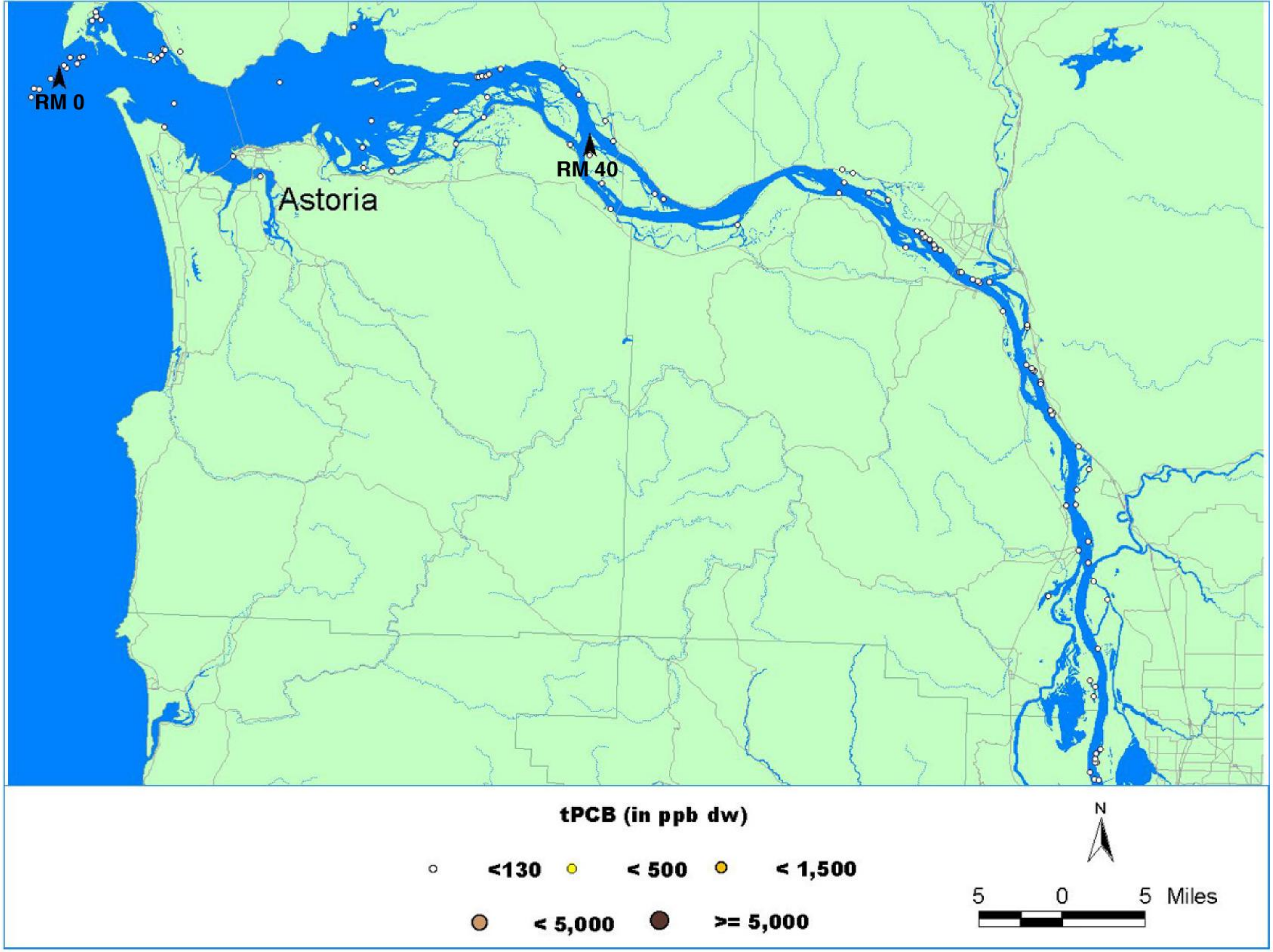
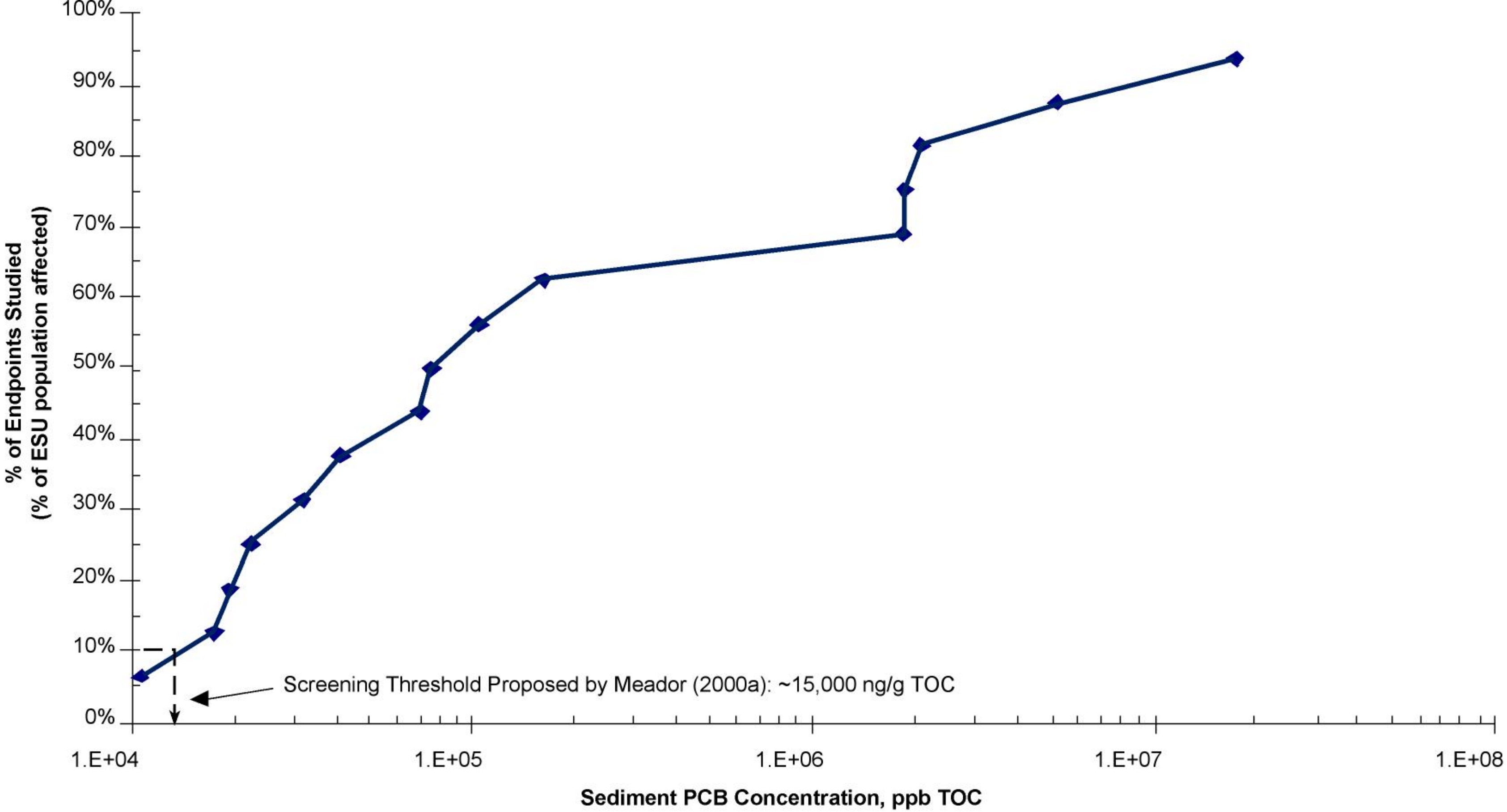
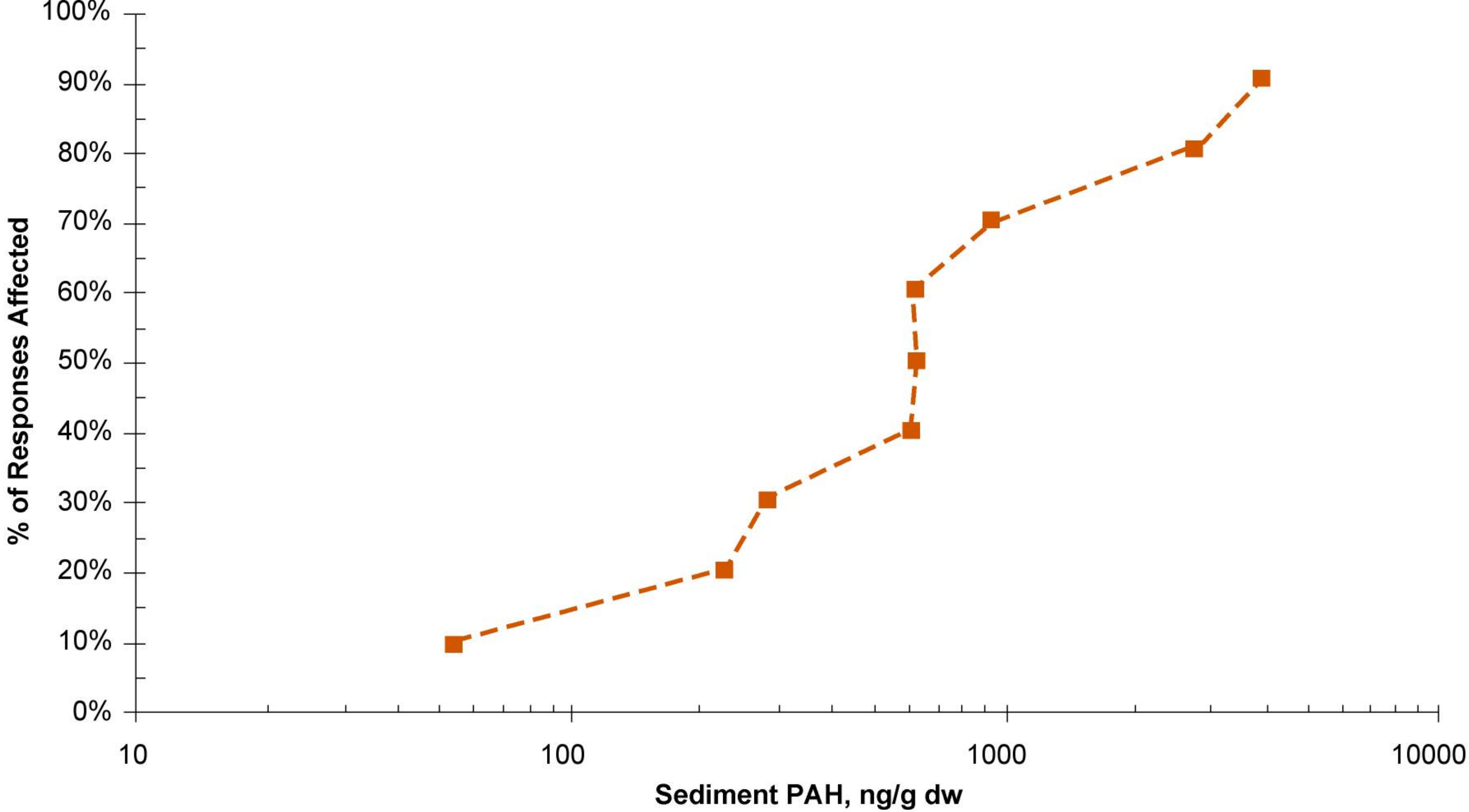


Figure B-11
Spatial Distribution of ∑PCB Concentrations from the Mouth of the Columbia to Willamette River Confluence



Source: Meador (2000a)

Figure B-12
Concentration-Response Relationship for Salmonids Exposed to PCBs in Their Diet



Source: Johnson, 2000

Figure B-13
Distribution of Responses in >2-Year-Old English Sole that were Correlated with Sediment Concentrations of 18 PAHs in Puget Sound

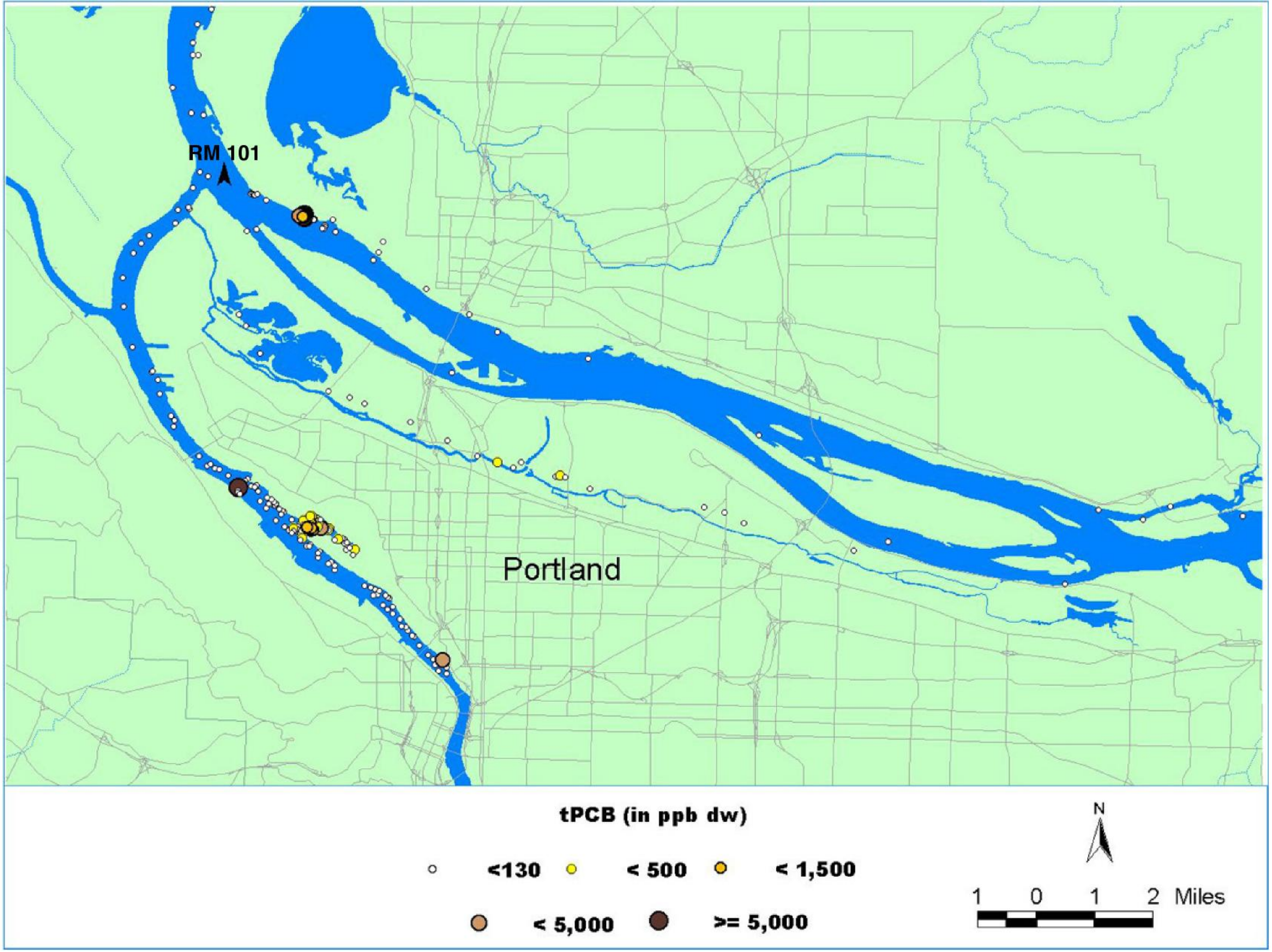


Figure B-14
Spatial Distribution of ∑PCB Concentrations Near Willamette-Columbia Confluence

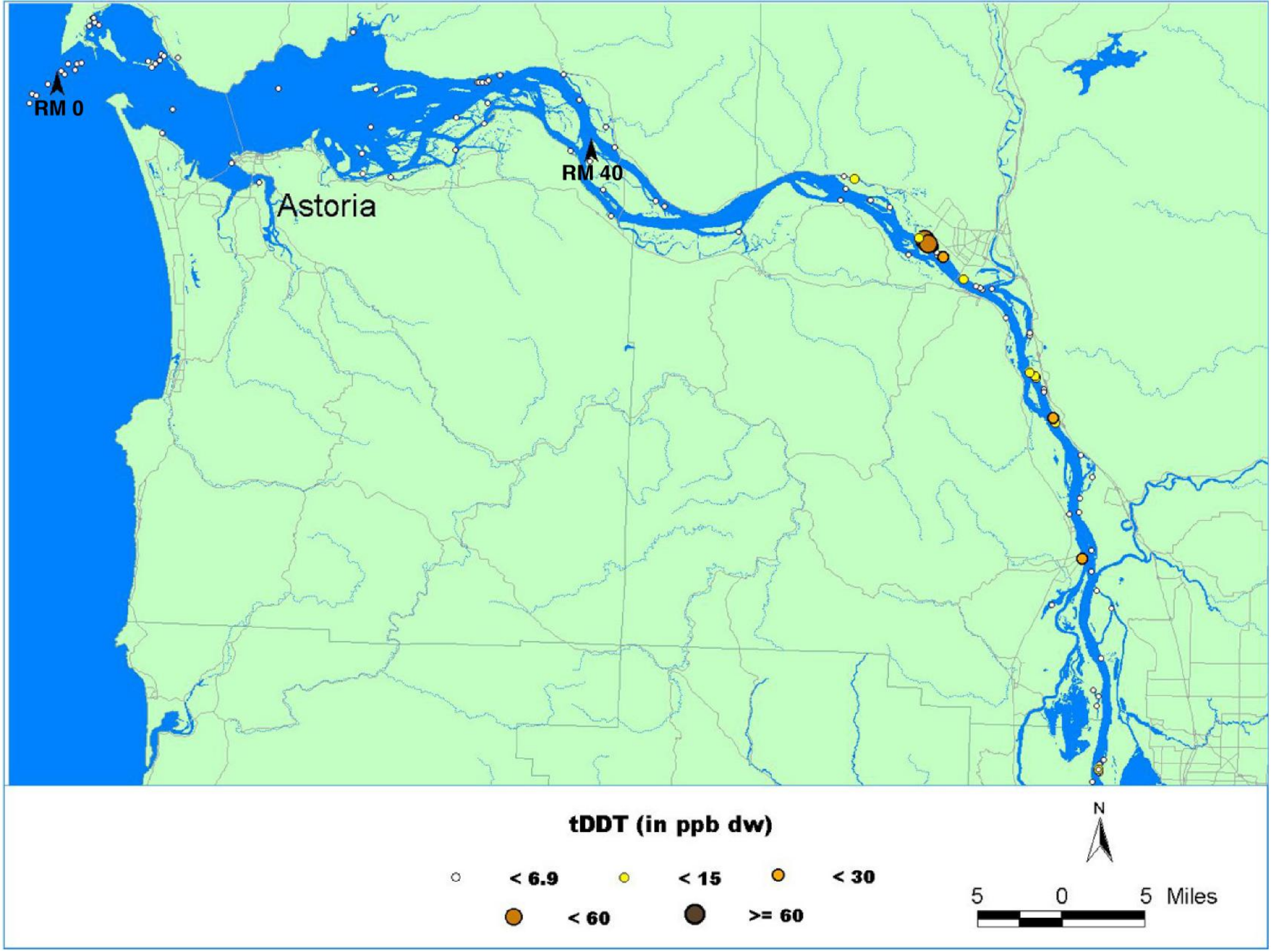


Figure B-15
Spatial Distribution of ∑DDT Concentrations
From Mouth to Willamette River Confluence

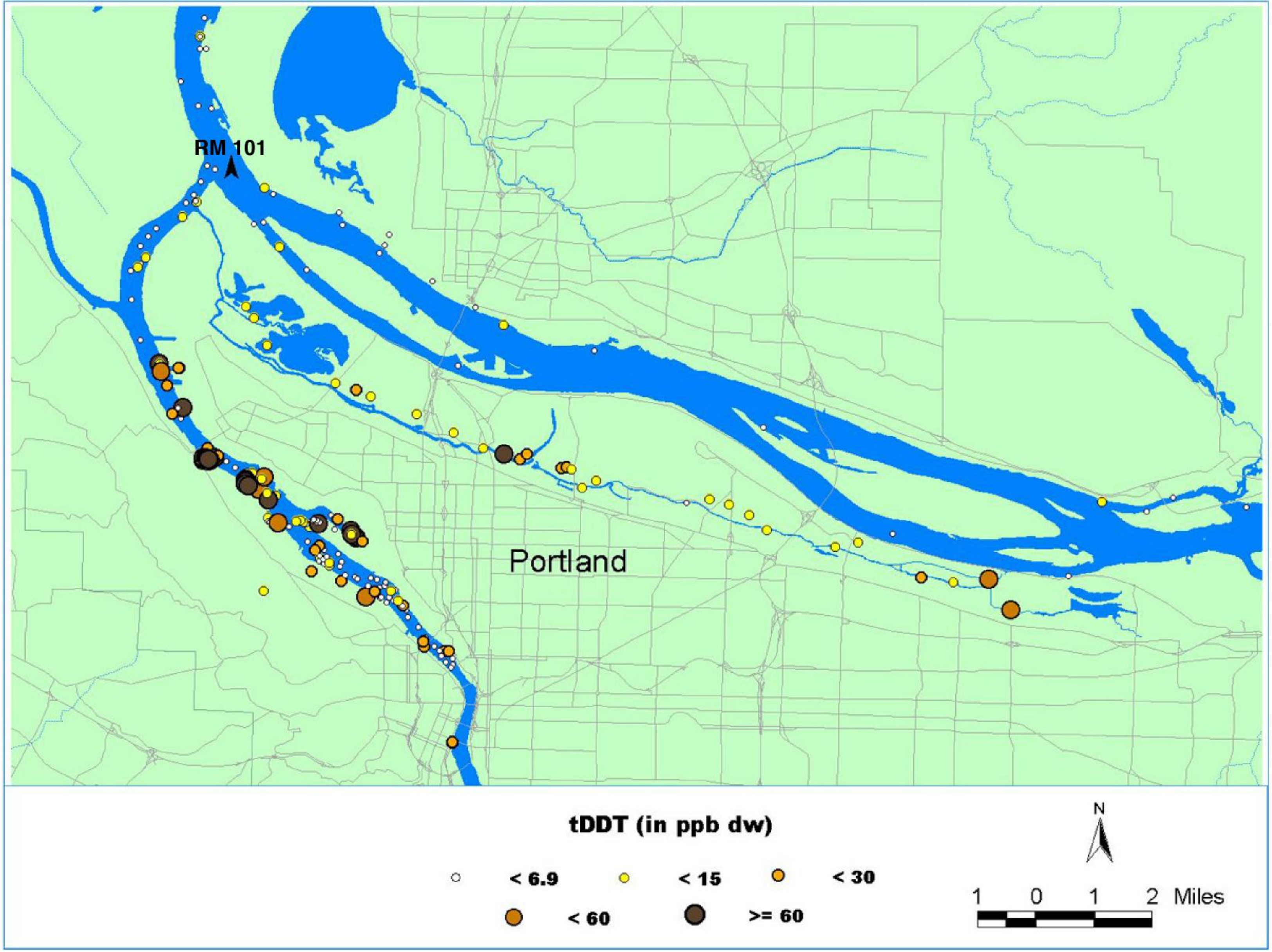


Figure B-16
Spatial Distribution of ∑DDT Concentrations Near Willamette-Columbia Confluence

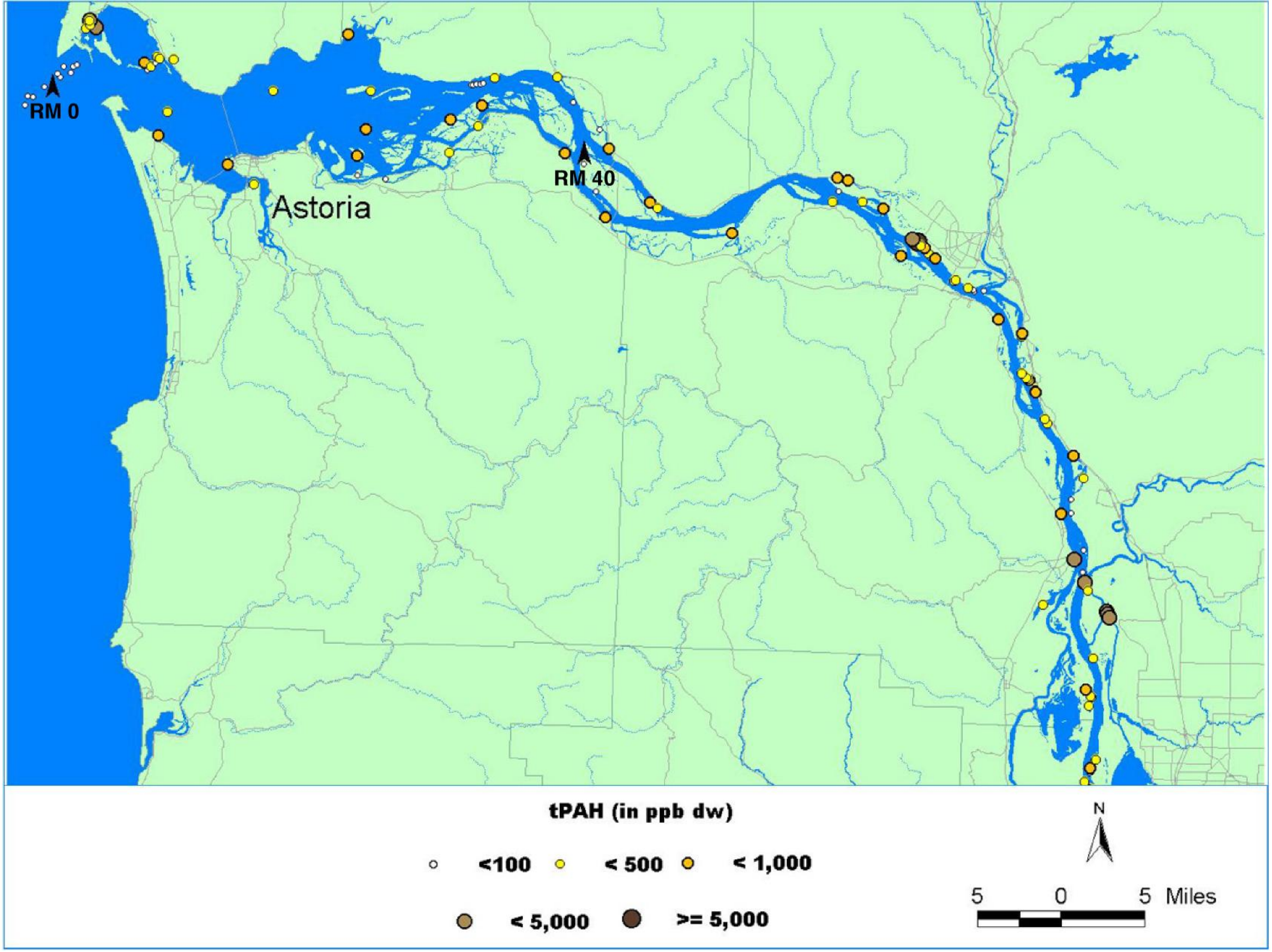


Figure B-17
Spatial Distribution of ∑PAH Concentrations From Mouth to Willamette River Confluence

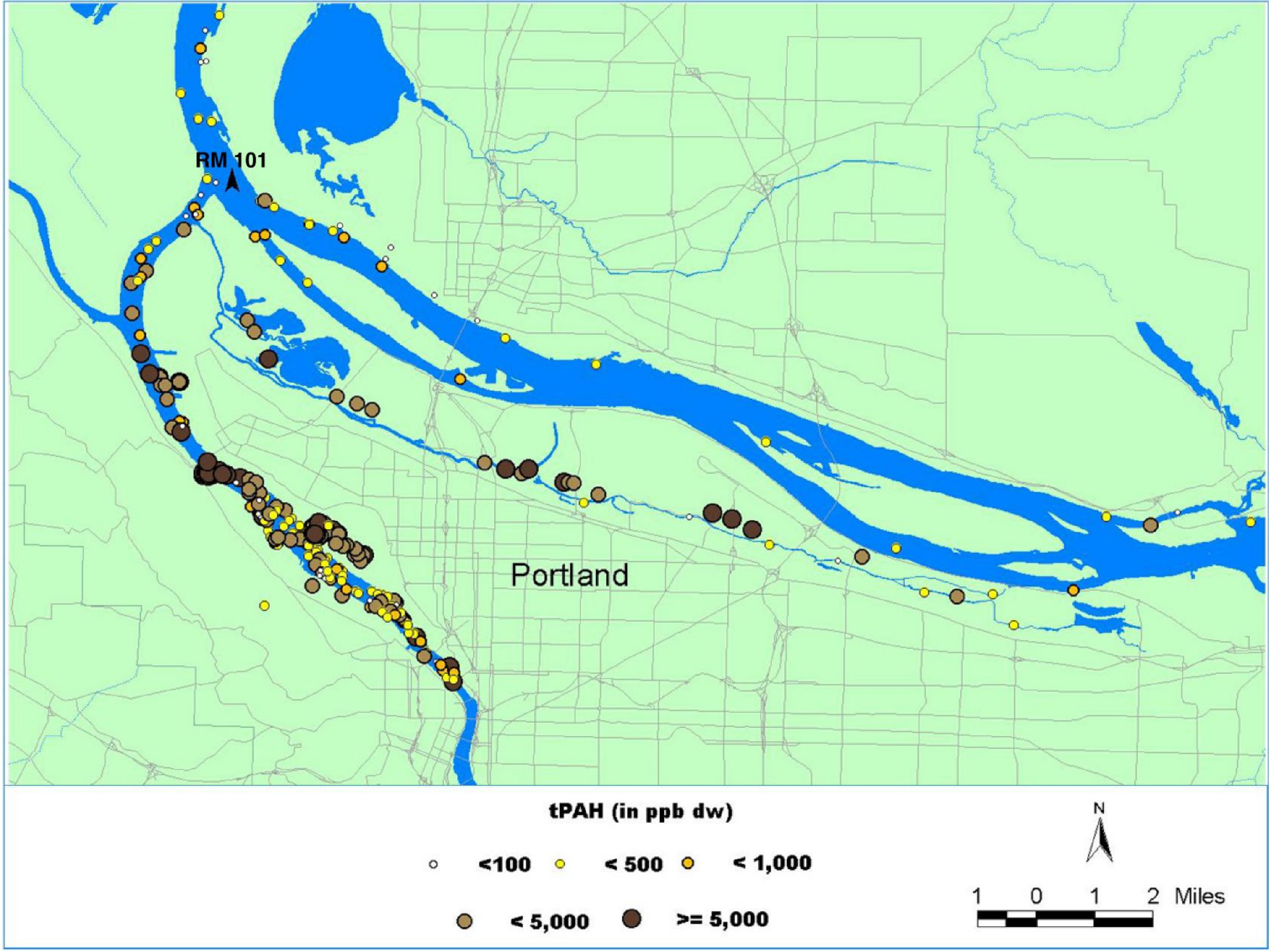


Figure B-18
Spatial Distribution of ∑PAH Concentrations Near Willamette-Columbia Confluence

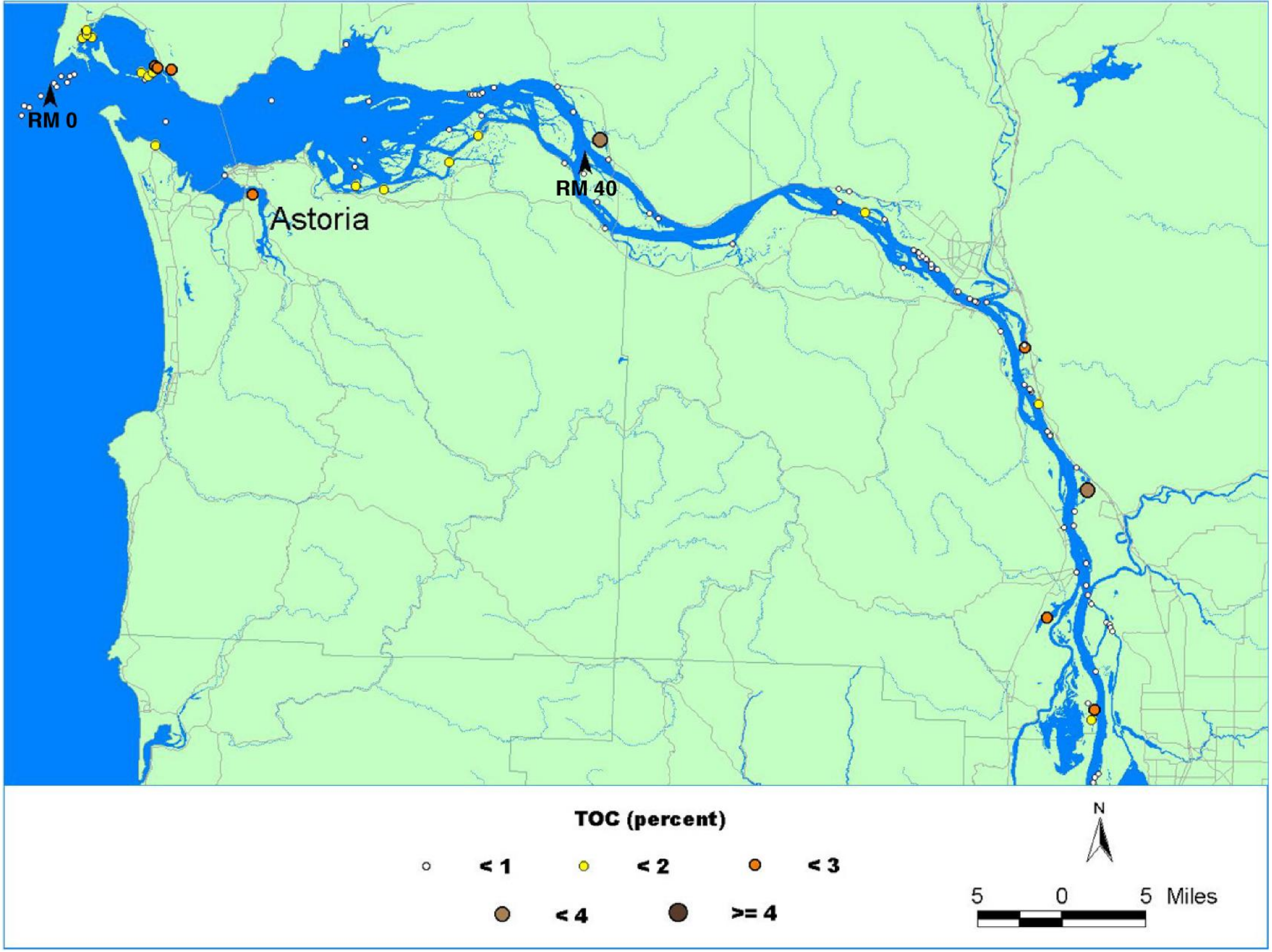


Figure B-19
Spatial Distribution of TOC Concentrations from Mouth to Willamette River Confluence

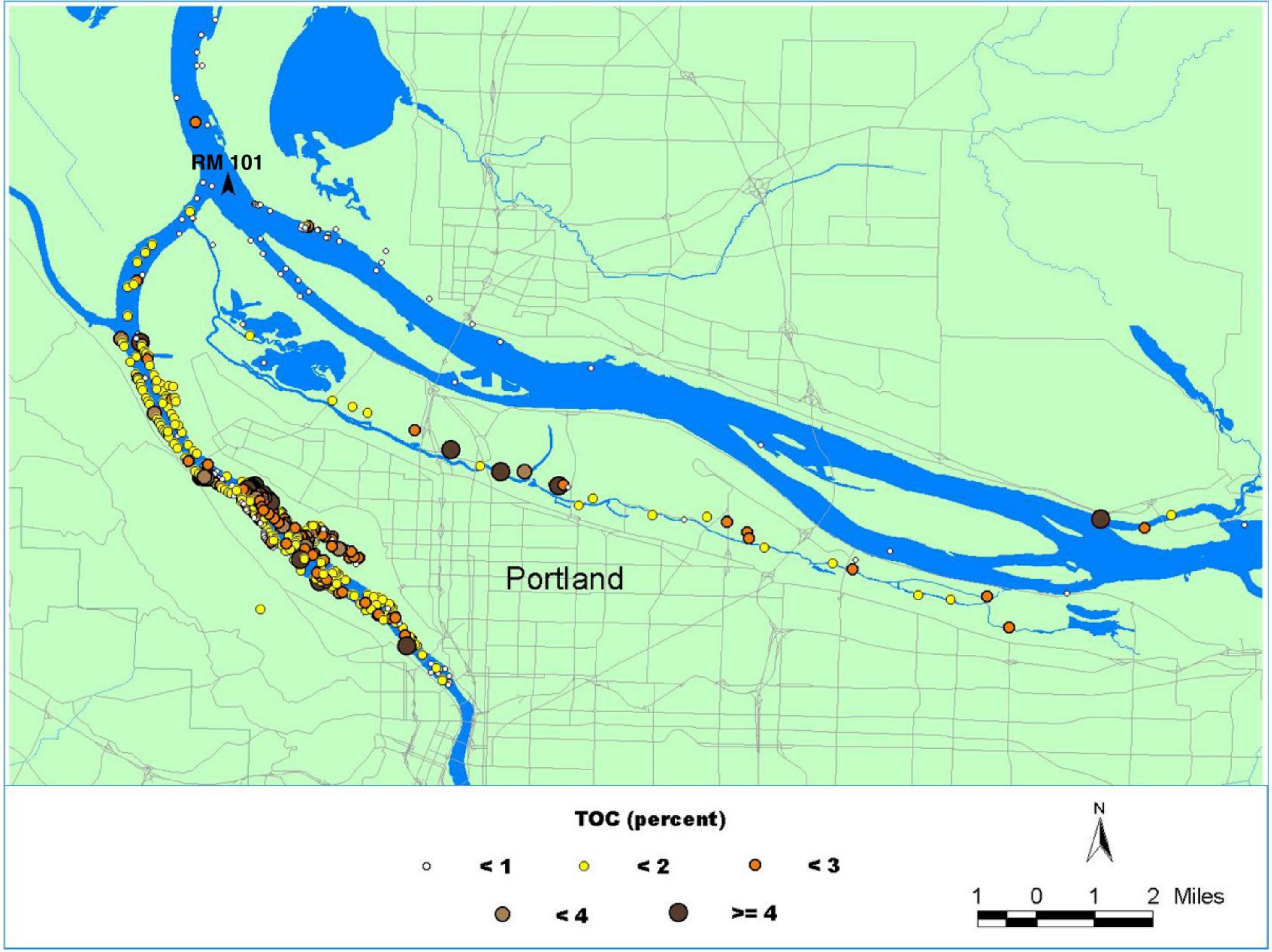


Figure B-20
Spatial Distribution of TOC Concentrations Near Willamette-Columbia Confluence

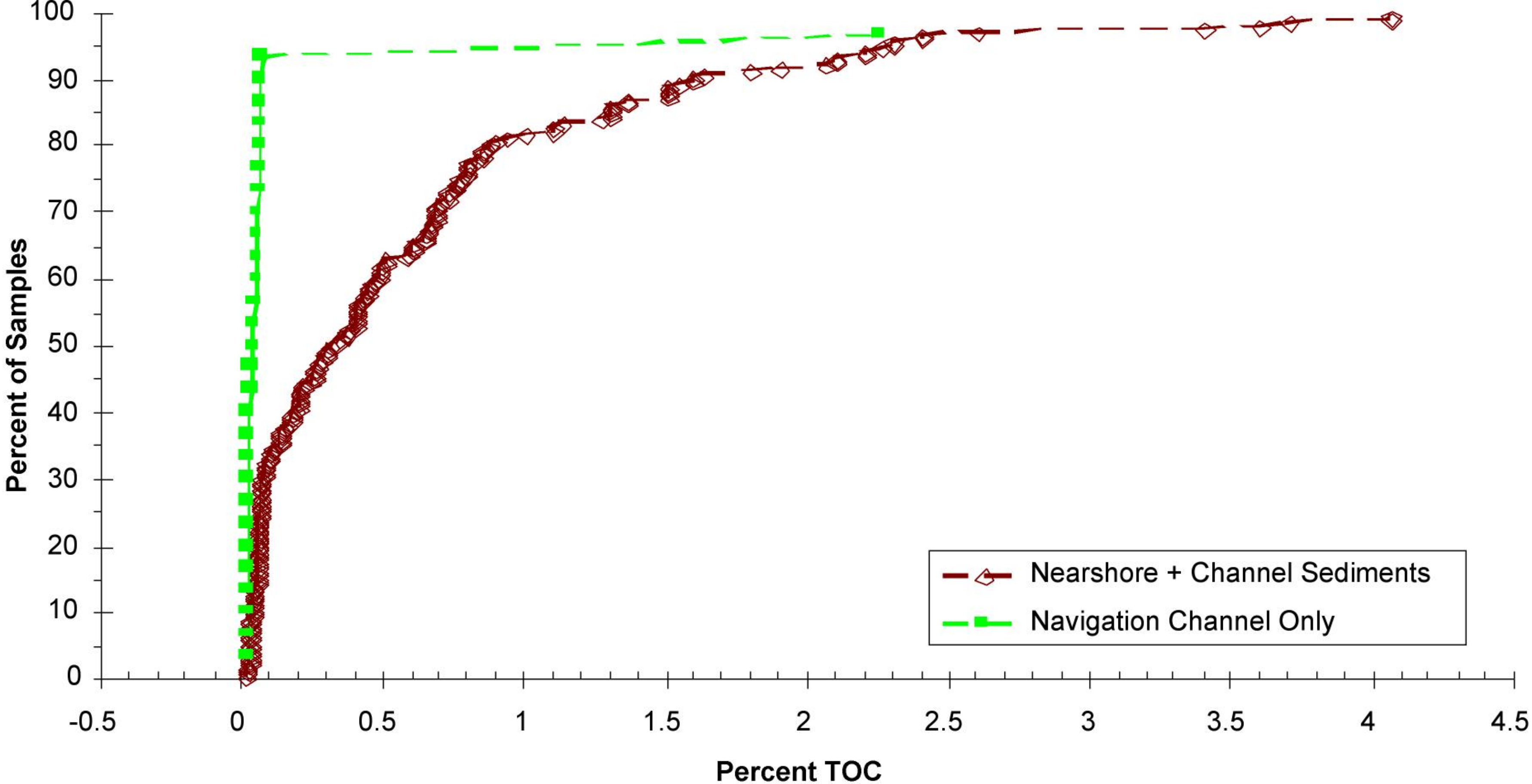


Figure B-21
Total Organic Carbon (TOC) in
Columbia River Sediments (RM 0-145)

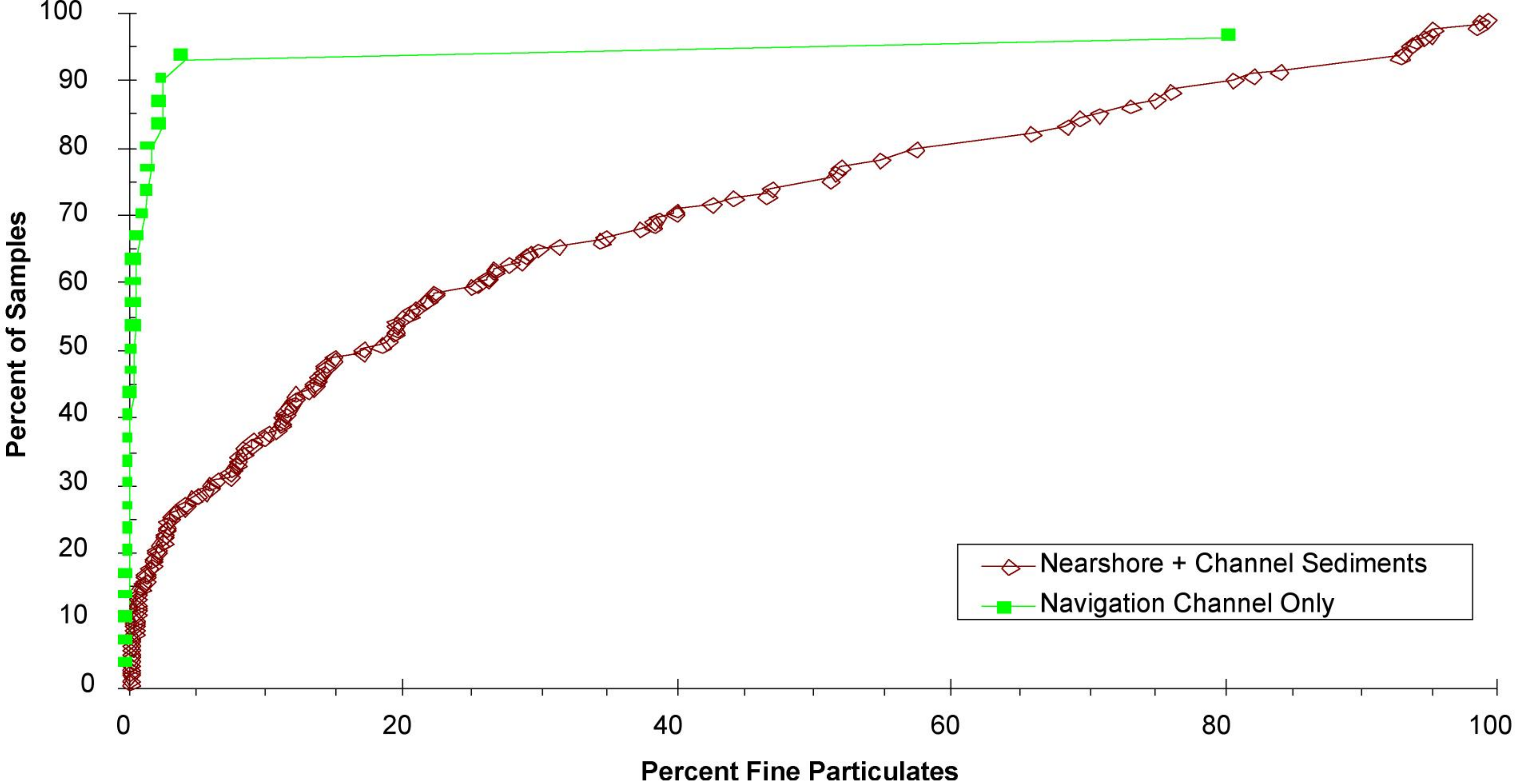


Figure B-22
Fine Particulates in Columbia River Sediments (RM 0-145)

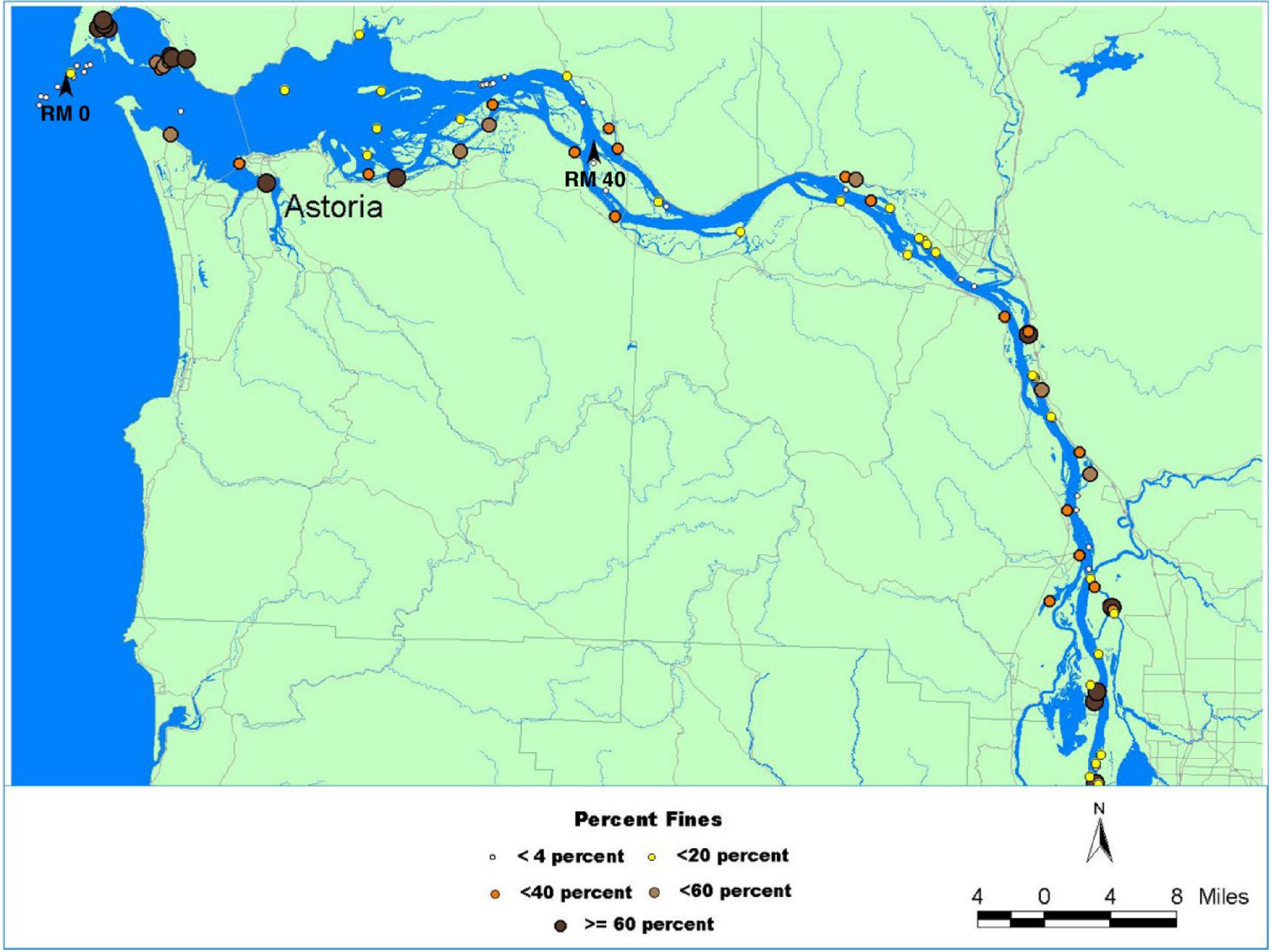


Figure B-23
Spatial Distribution of Fine Particulate Concentrations from the Mouth to Willamette River Confluence

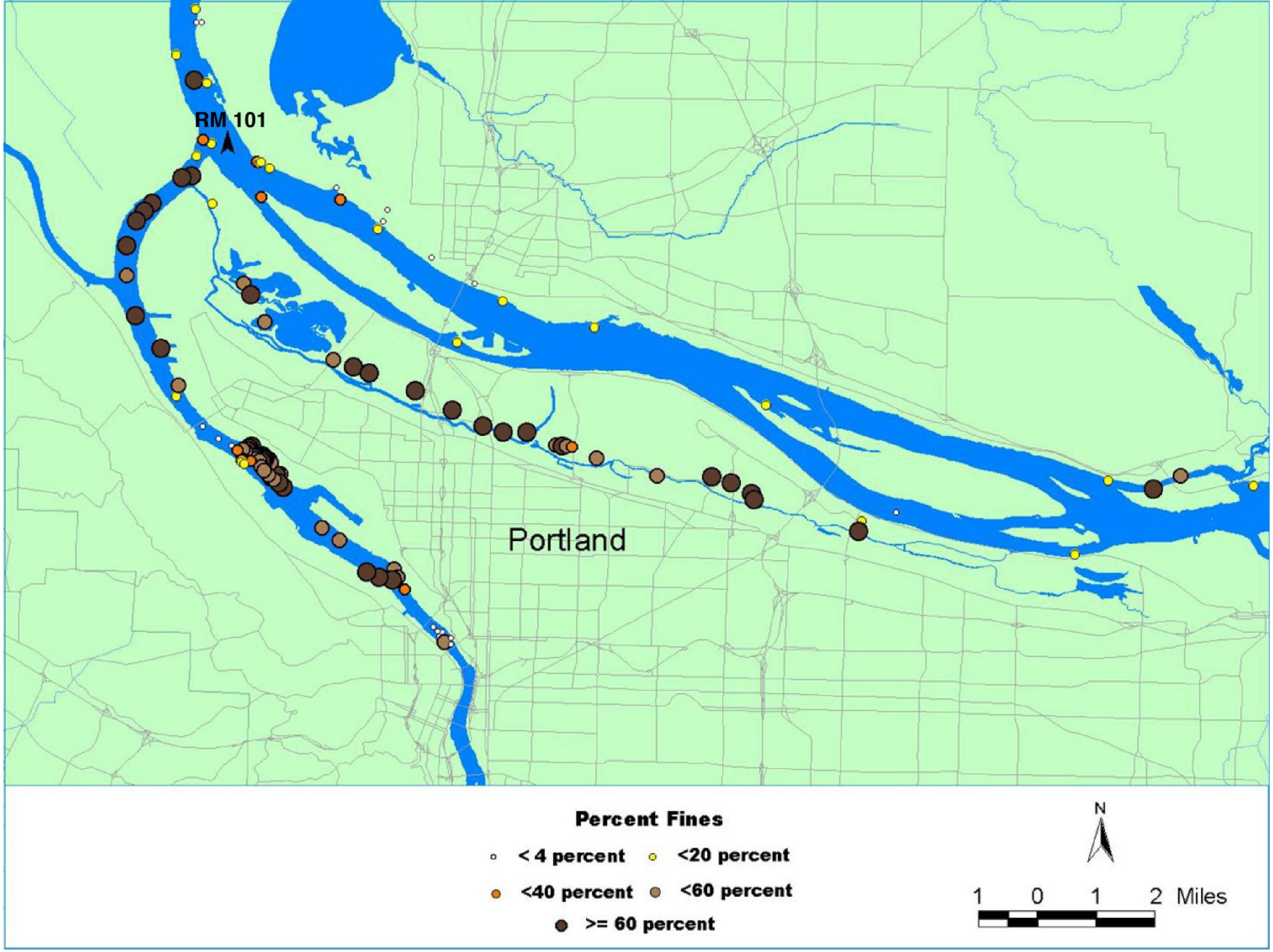


Figure B-24
Spatial Distribution of Fine Particulate Concentrations Near Willamette-Columbia Confluence

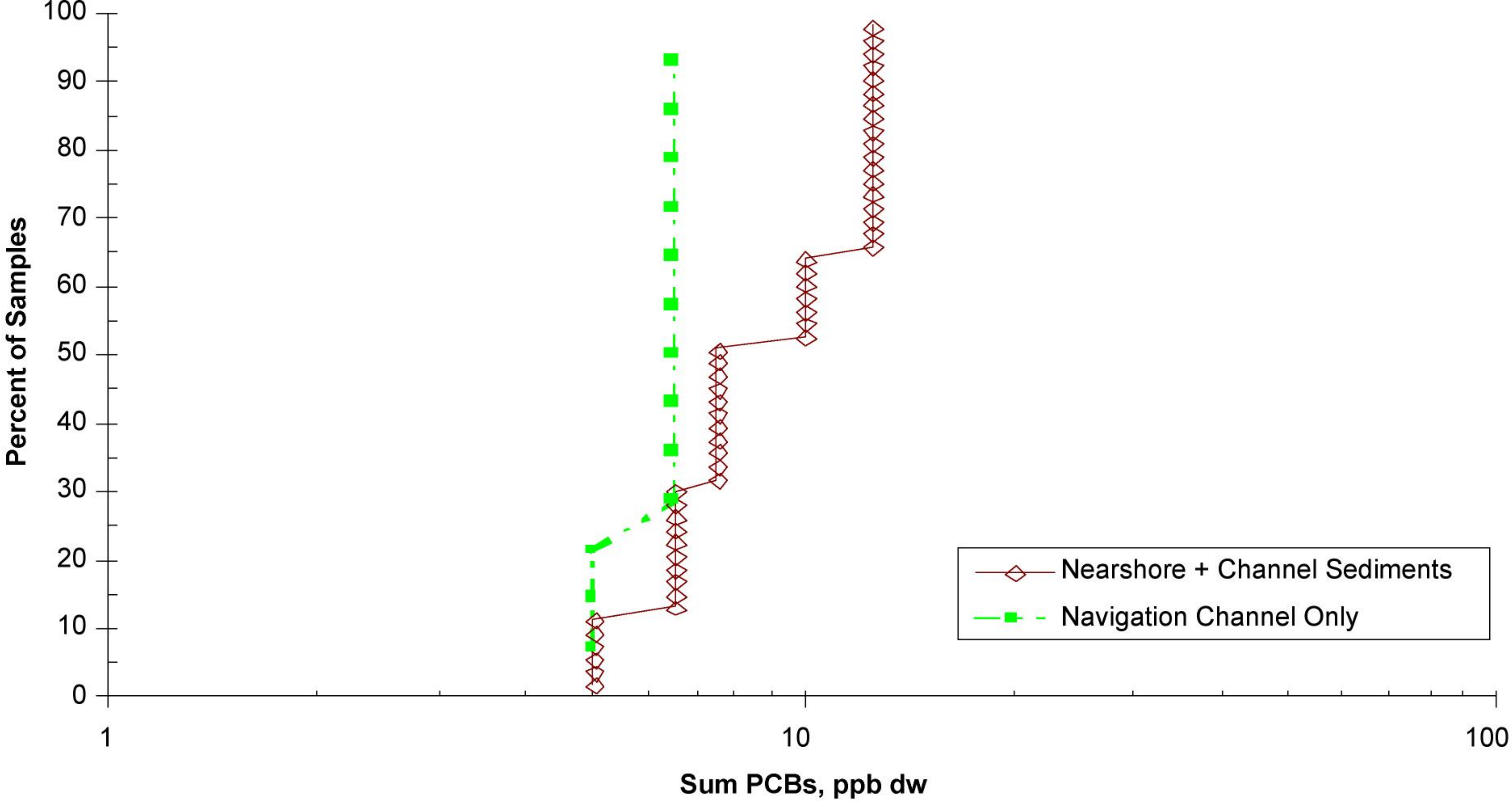


Figure B-25
Sum PCB Concentrations in Columbia River Channel Sediments Versus All Sampling Sites: River Miles 0-40

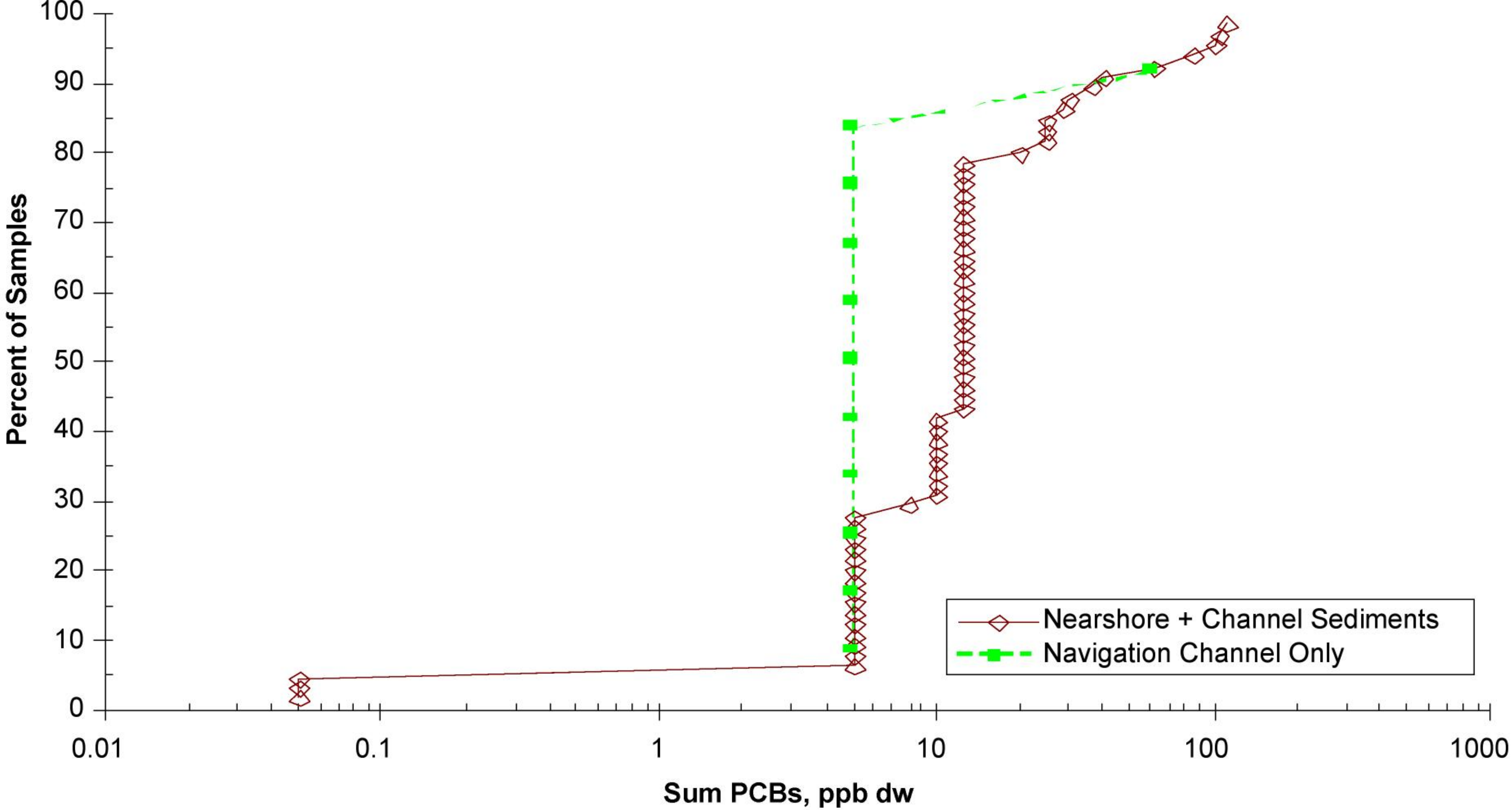


Figure B-26
Sum PCB Concentrations in Columbia River Channel Sediments Versus All Sampling Sites: River Miles 41-101

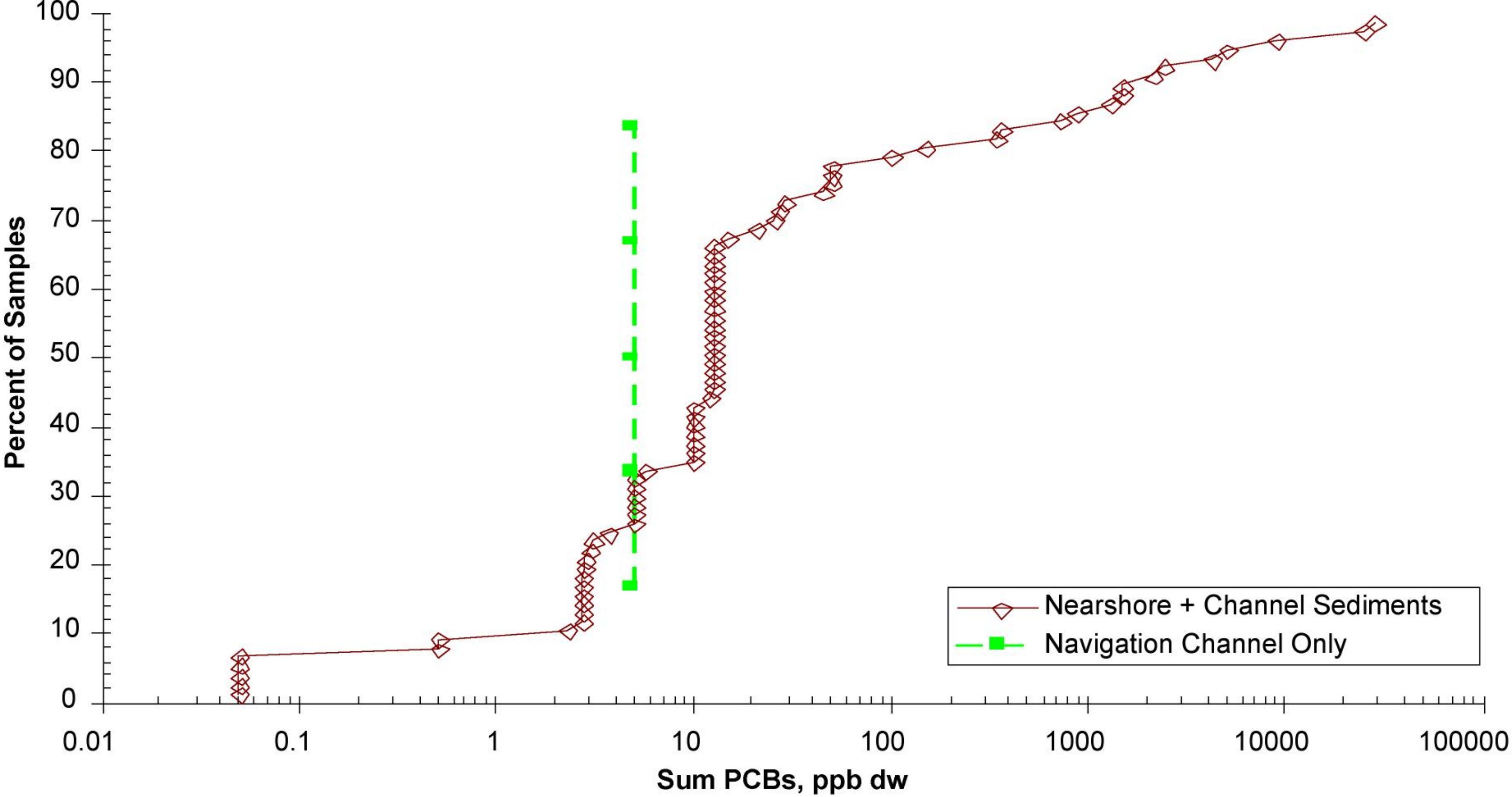


Figure B-27
Sum PCB Concentrations in Columbia River Channel Sediments Versus All Sampling Sites: Upstream of River Mile 101

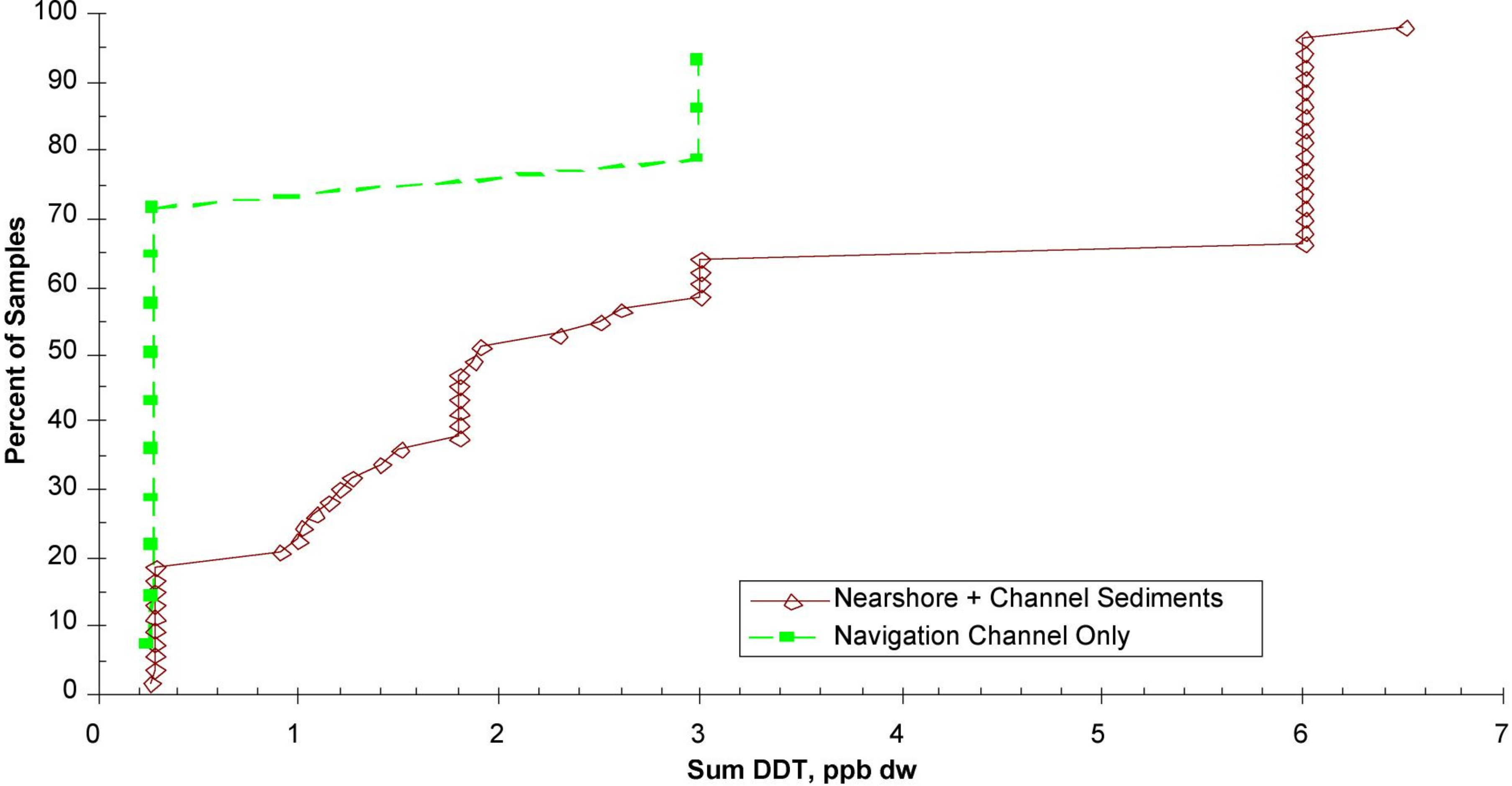


Figure B-28
Concentrations of DDT and Metabolites in Columbia River Channel Sediments Versus All Sampling Sites: River Miles 0-40

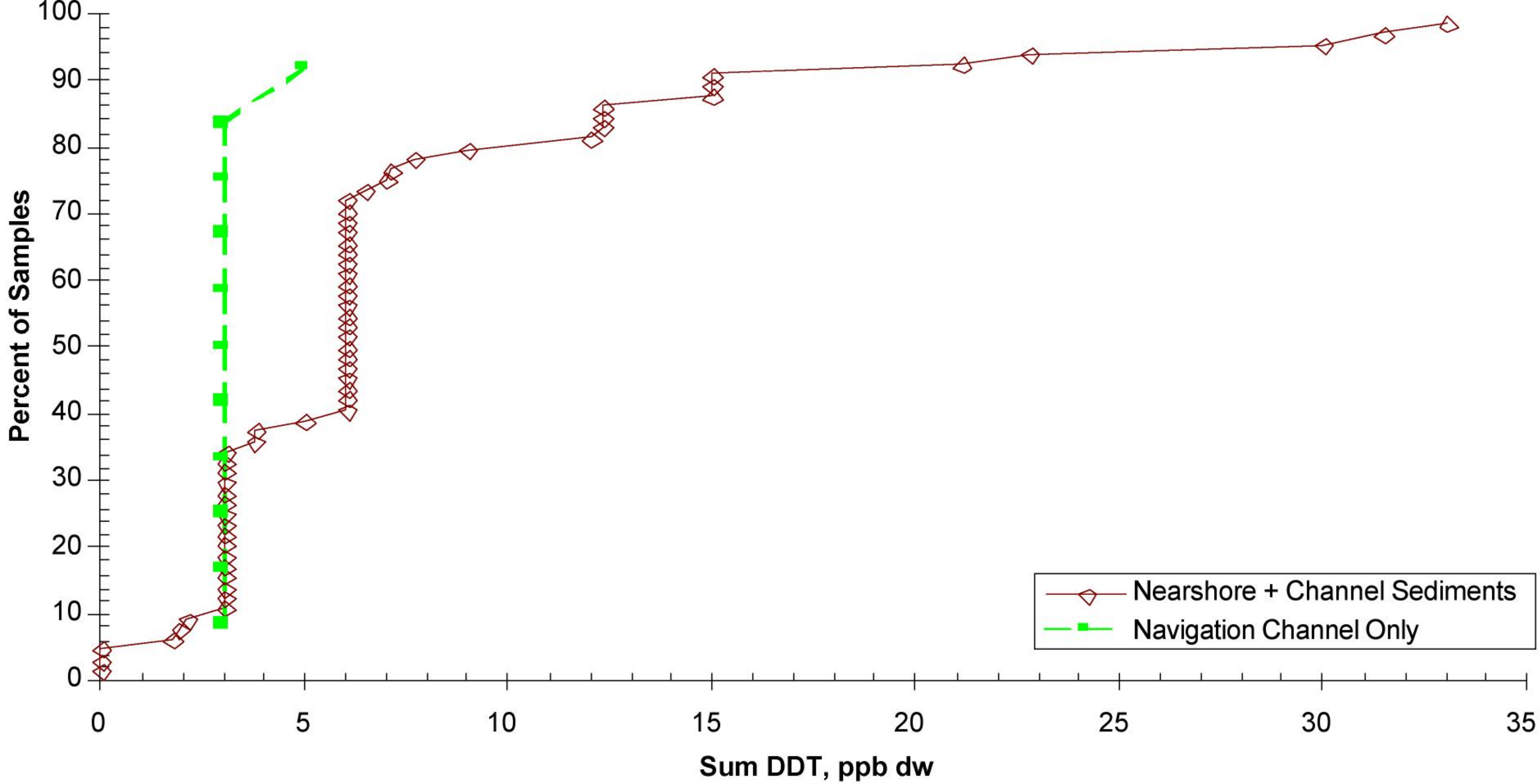


Figure B-29
Concentrations of DDT and Metabolites in Columbia River Channel Sediments Versus All Sampling Sites: River Miles 41-101

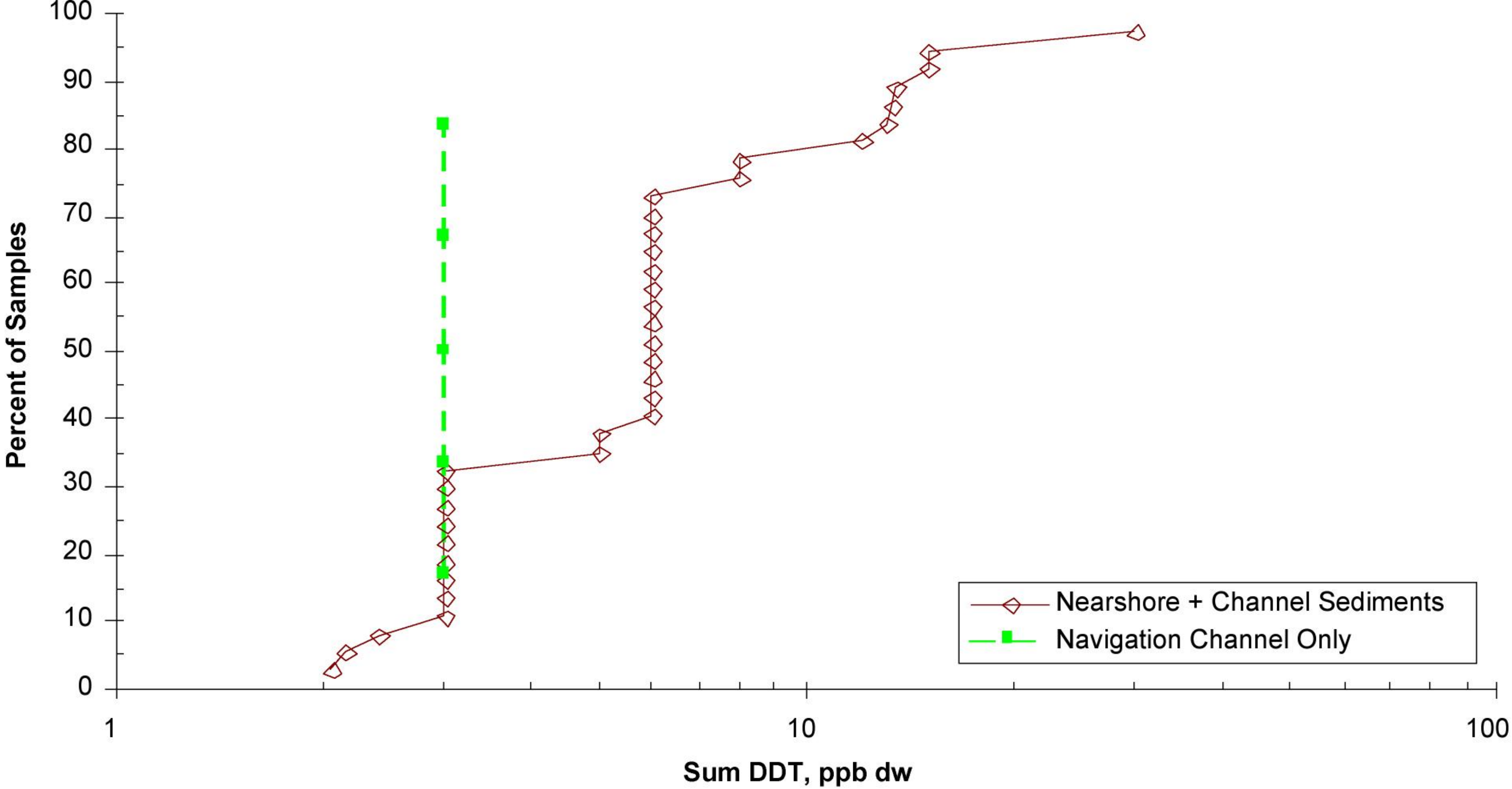


Figure B-30
Concentrations of DDT and Metabolites in Columbia River Channel Sediments Versus All Sampling Sites: Upstream of River Mile 101

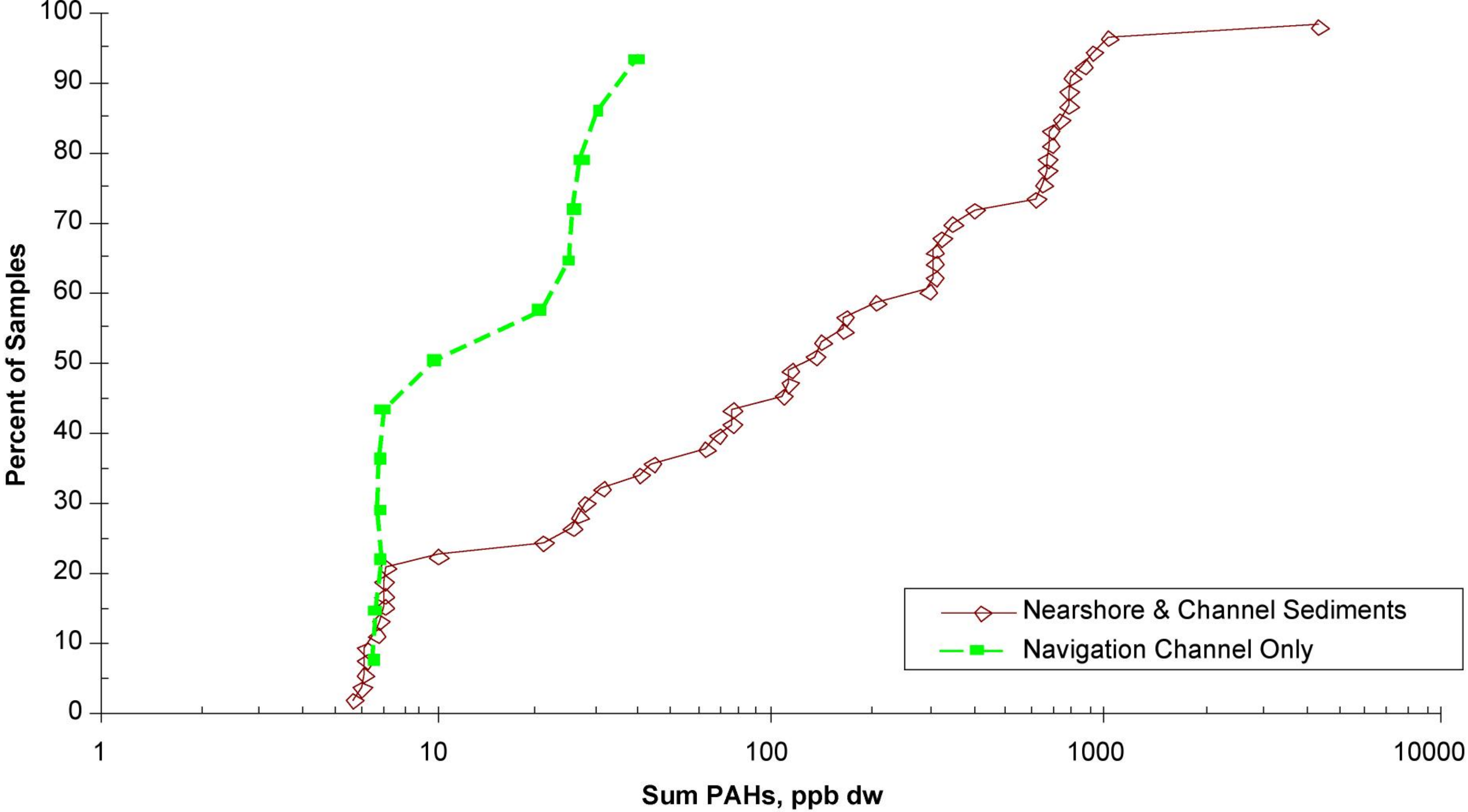


Figure B-31
Sum PAH Concentrations in Columbia River Channel Sediment Versus All Sampling Sites: River Miles 0-40

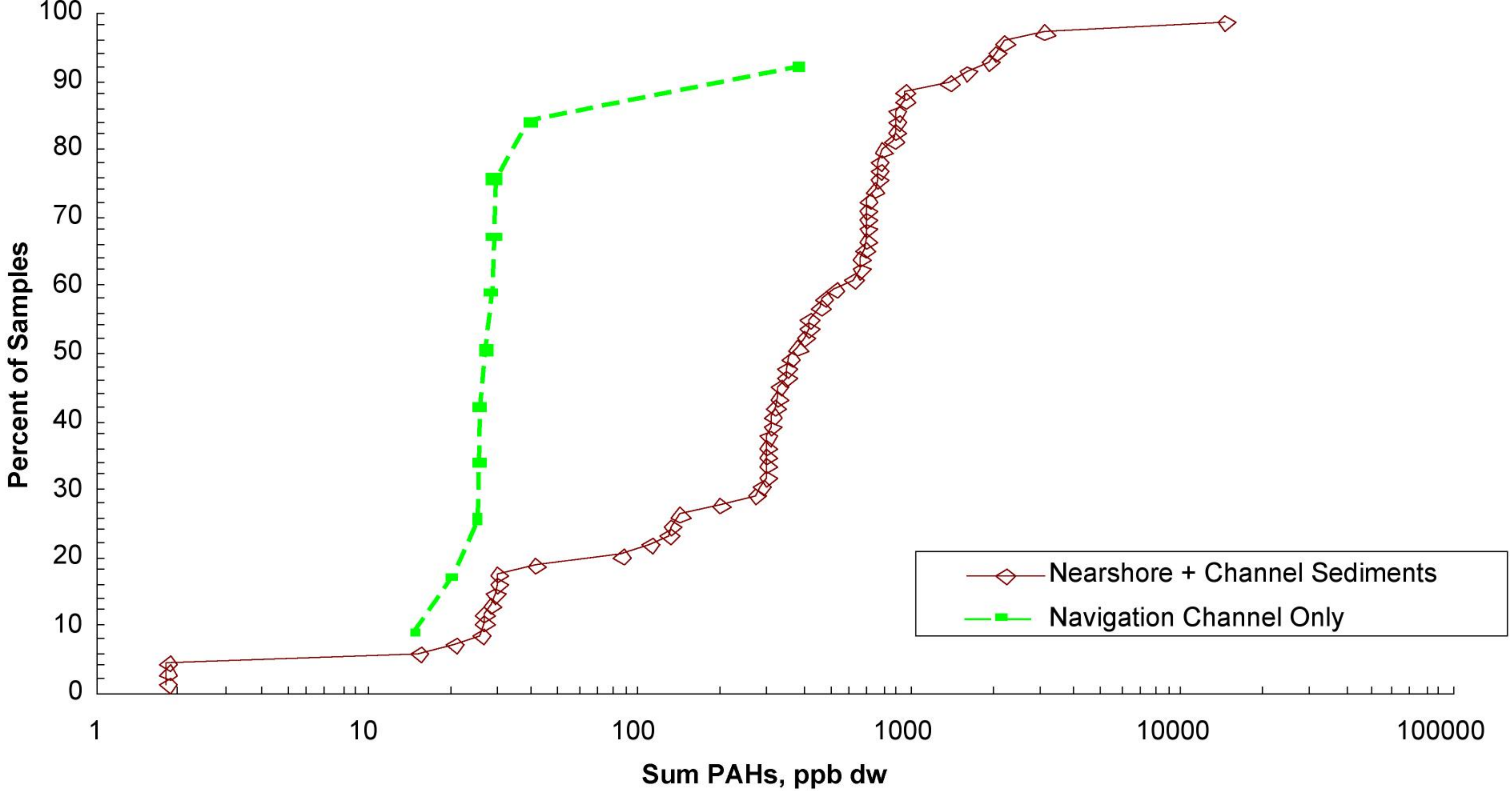


Figure B-32
Sum PAH Concentrations in Columbia River Channel Sediment Versus All Sampling Sites: River Miles 41-101

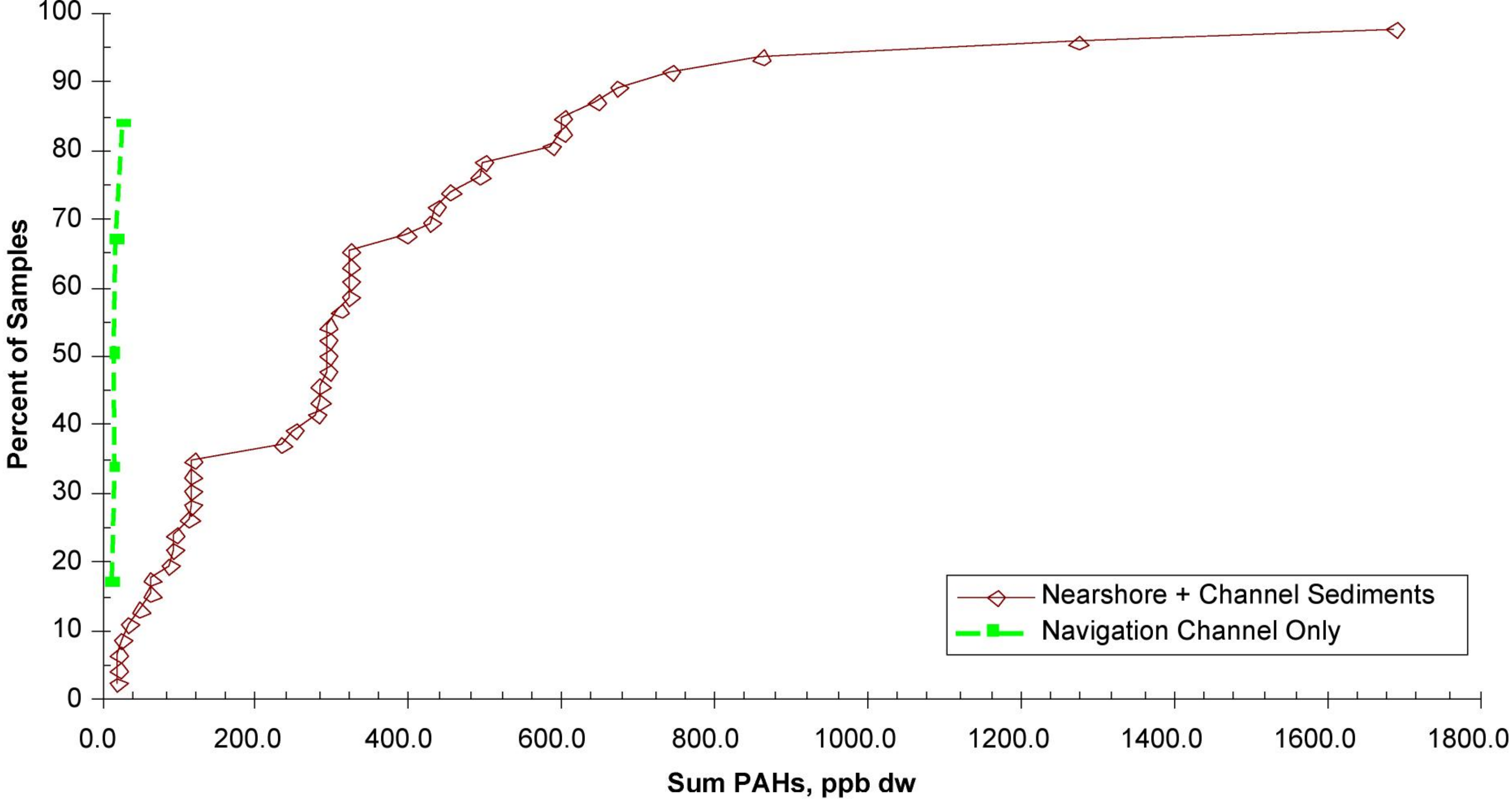
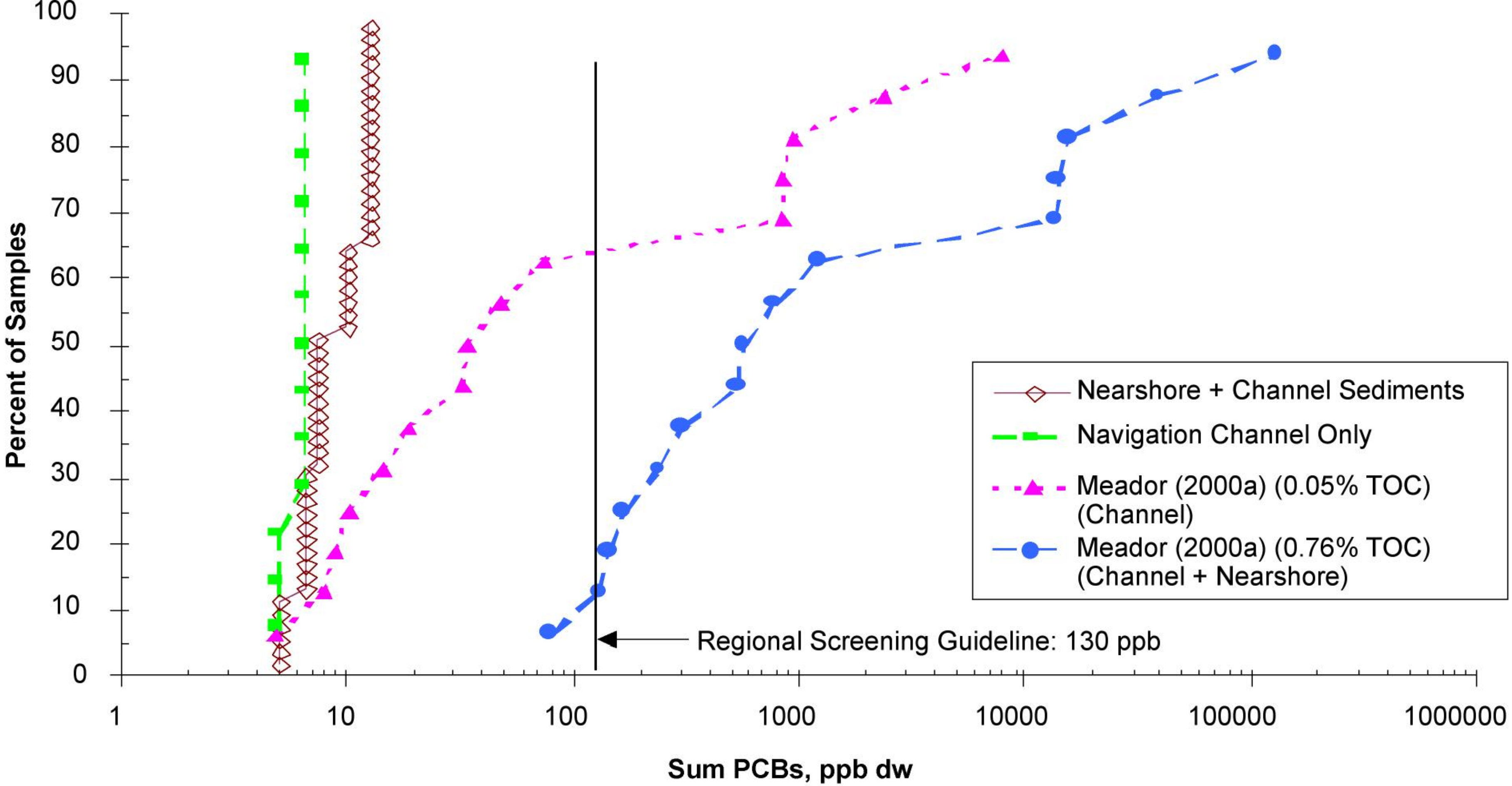
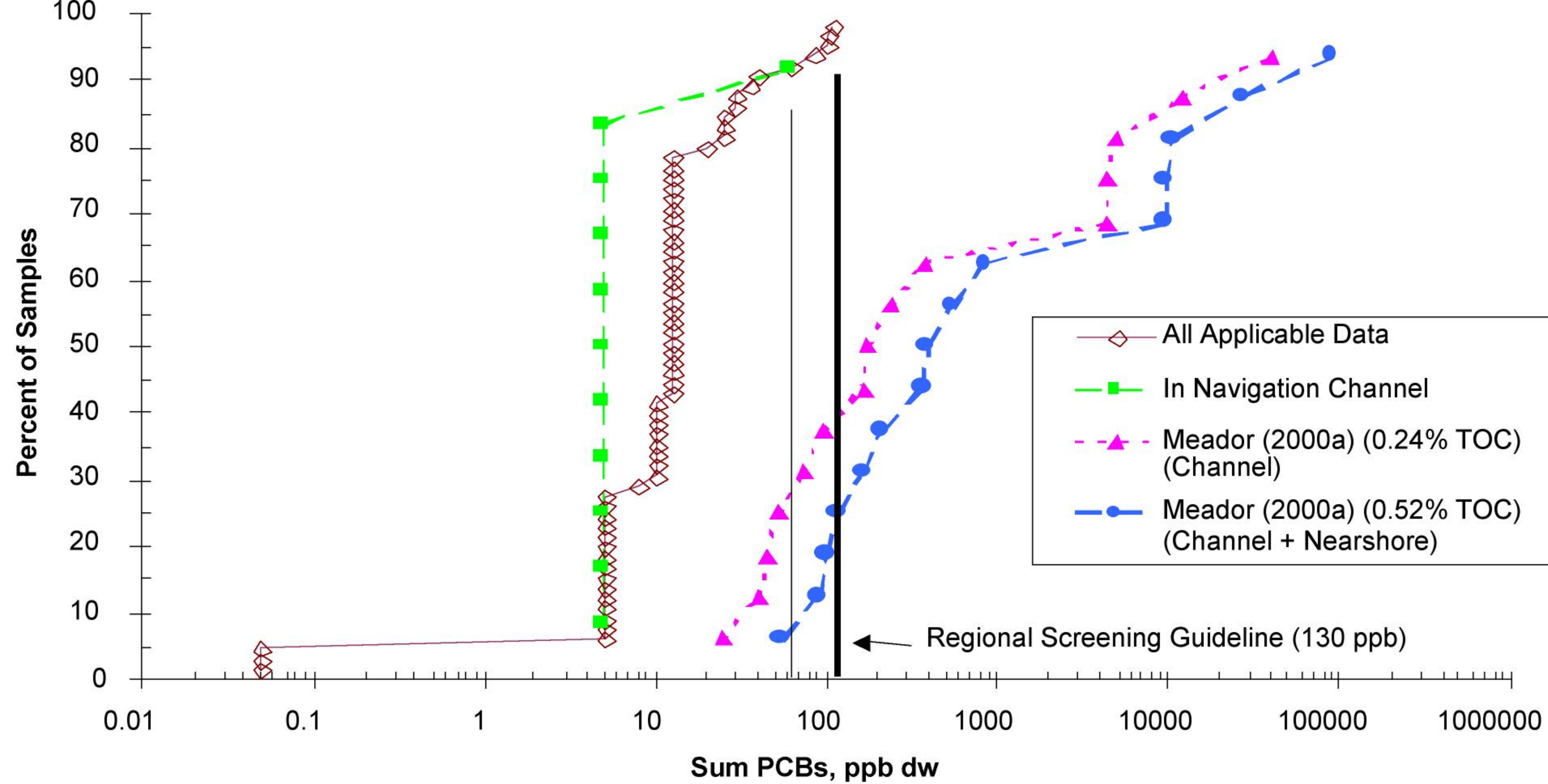


Figure B-33
Sum PAH Concentrations in Columbia River Channel Sediment Versus All Sampling Sites: Upstream of River Mile 101



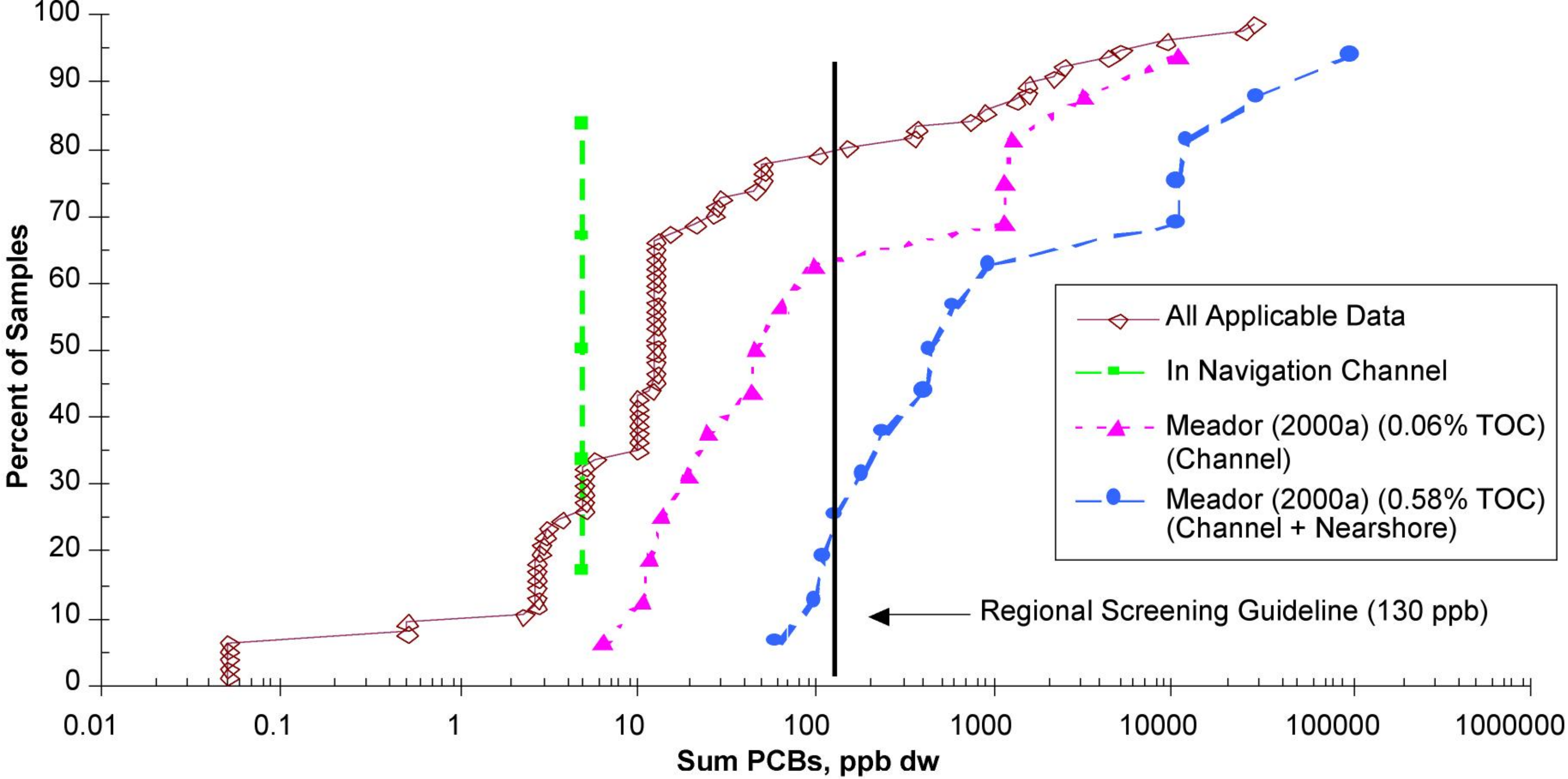
Source: Meador, 2000a

Figure B-34
Concentrations of PCBs in Sediments Compared to Those Associated with Adverse Effects in Fish: River Miles 0-40



Source: Meador, 2000a

Figure B-35
Concentrations of PCBs in Sediments Compared to Those Associated with Adverse Effects in Fish: River Miles 41-101



Source: Meador, 2000a

Figure B-36
Concentrations of PCBs in Sediments Compared to Those Associated with Adverse Effects in Fish: Upstream of River Mile 101

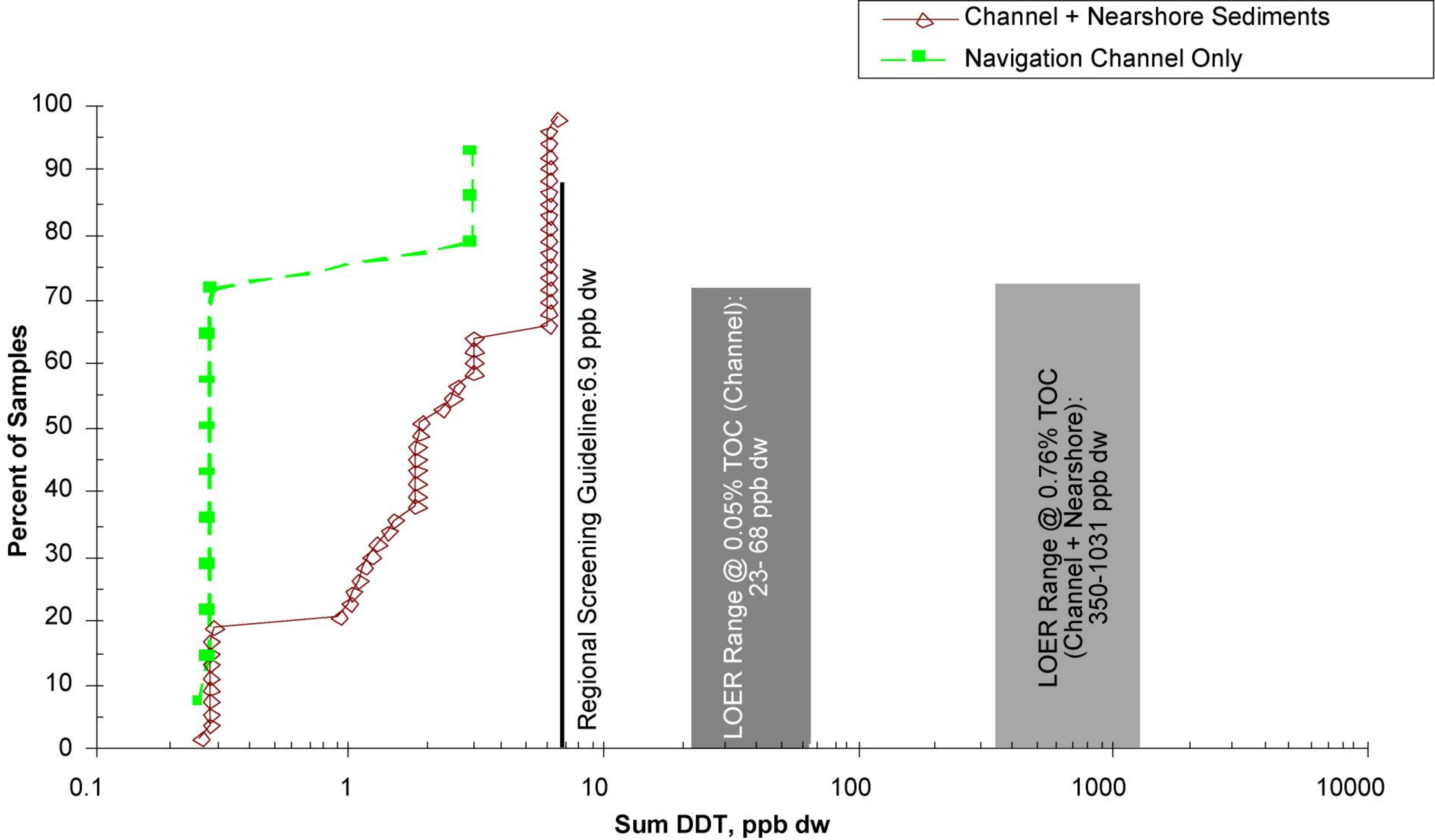
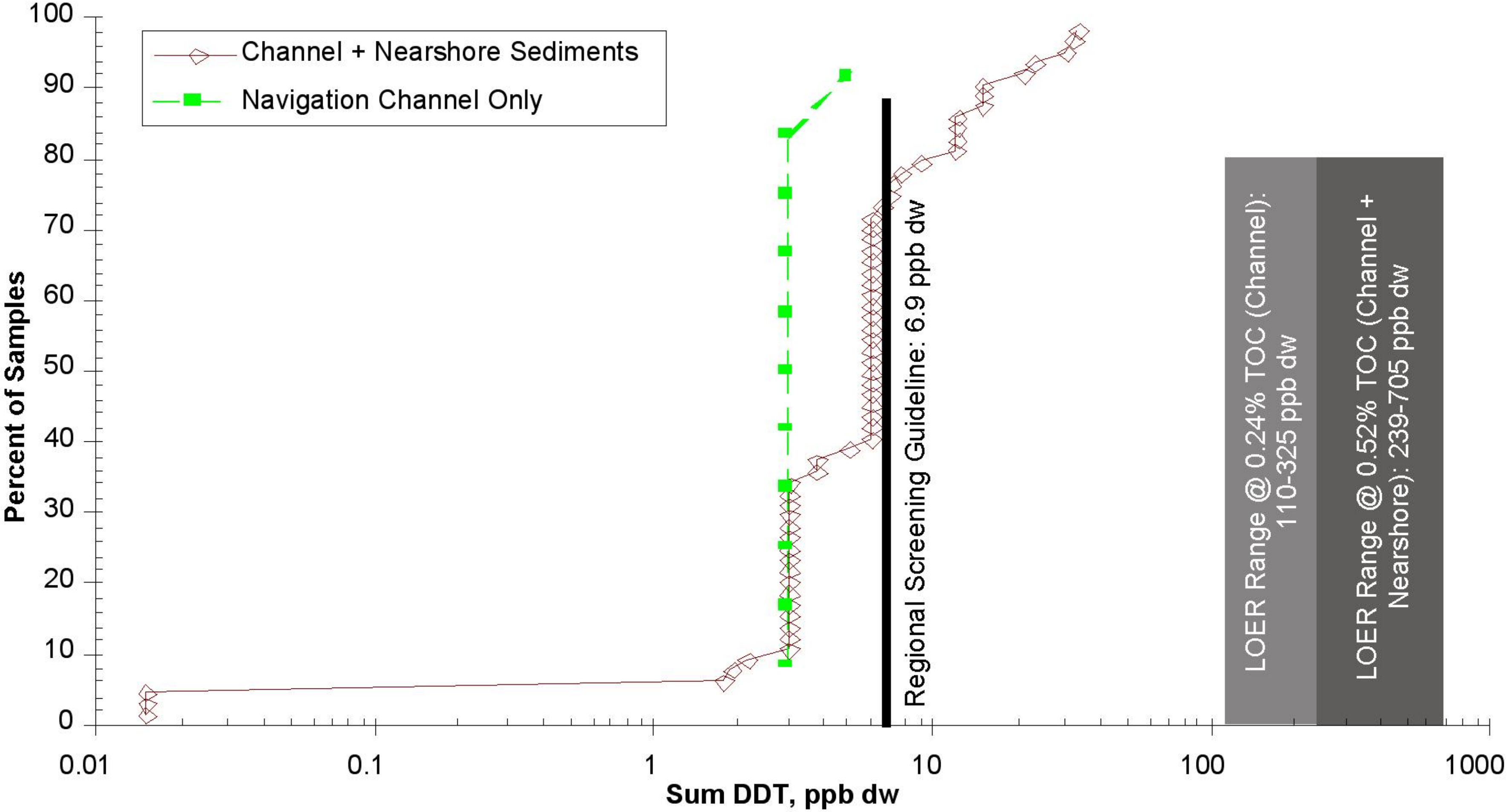


Figure B-37
Concentrations of DDT and Metabolites in Sediments Compared to Three Effects Criteria: River Miles 0-40



Nearshore): 239-705 ppb dw

Figure B-38
Concentrations of DDT and Metabolites in Sediments Compared to Three Effects Criteria: River Miles 41-101

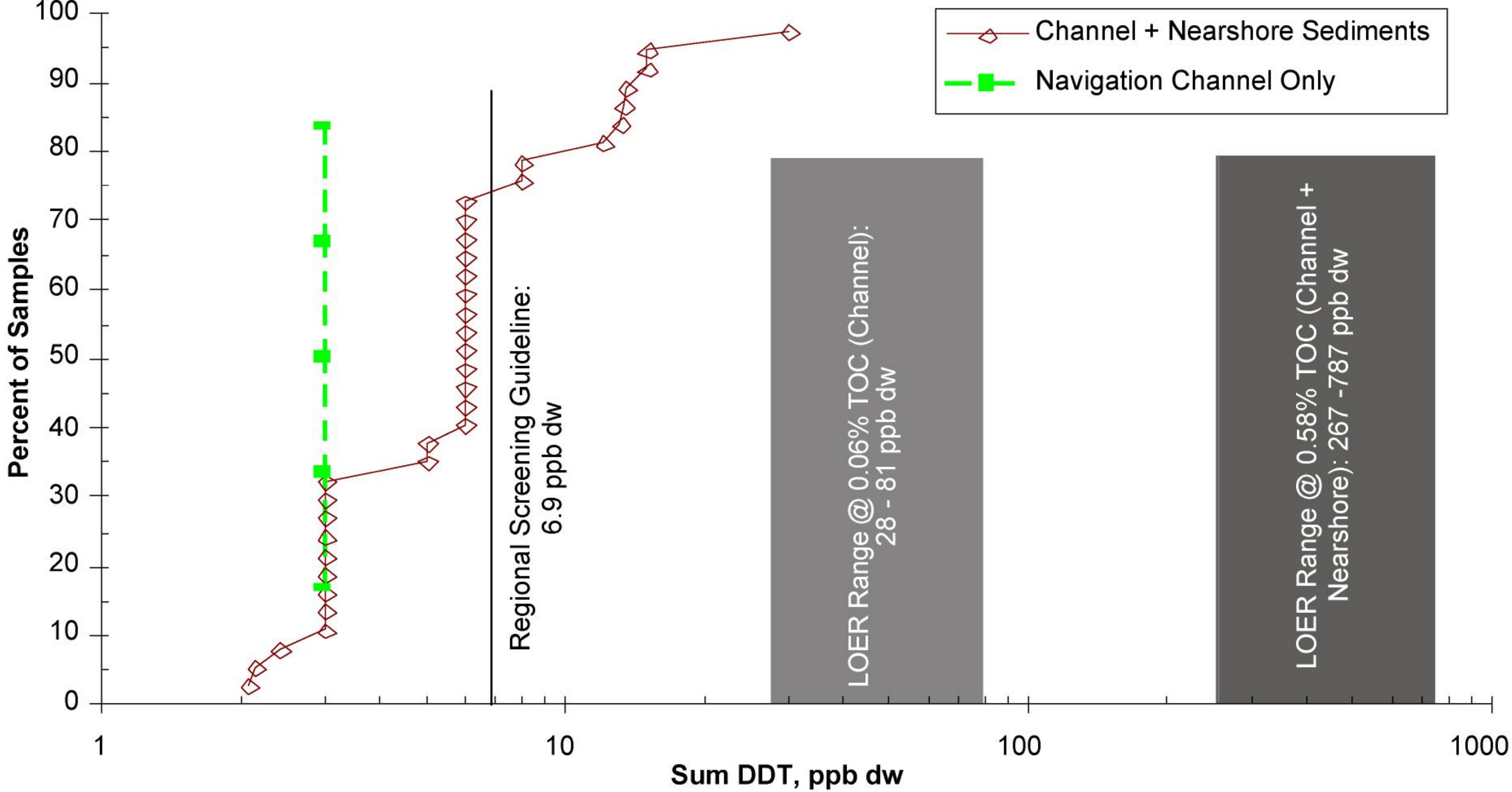


Figure B-39
Concentrations of DDT and Metabolites in Sediments Compared to Three Effects Criteria: Upstream of River Mile 101

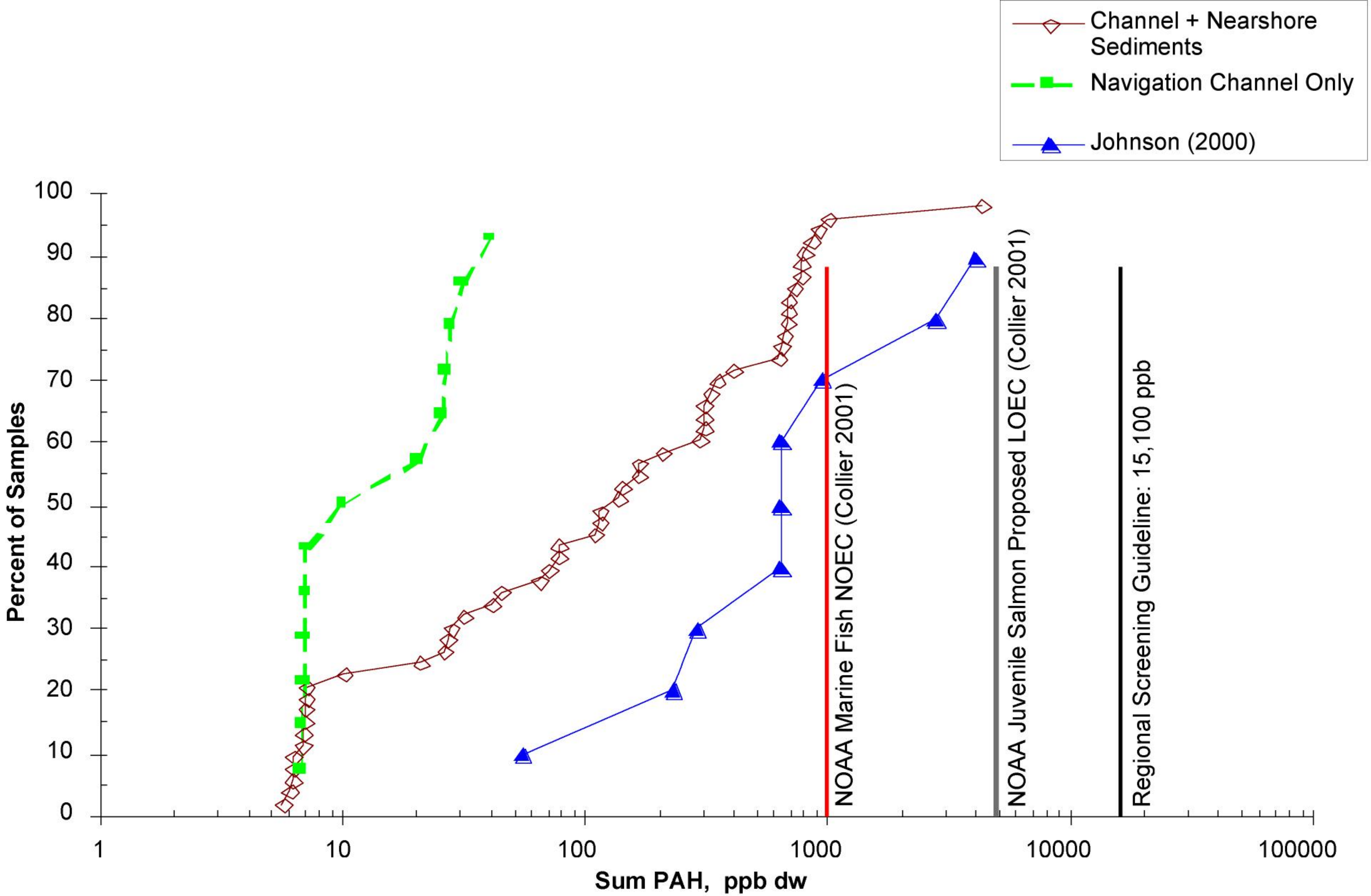


Figure B-40
Concentrations of PAHs in Sediments Compared to Four Effects Criteria: River Miles 0-40

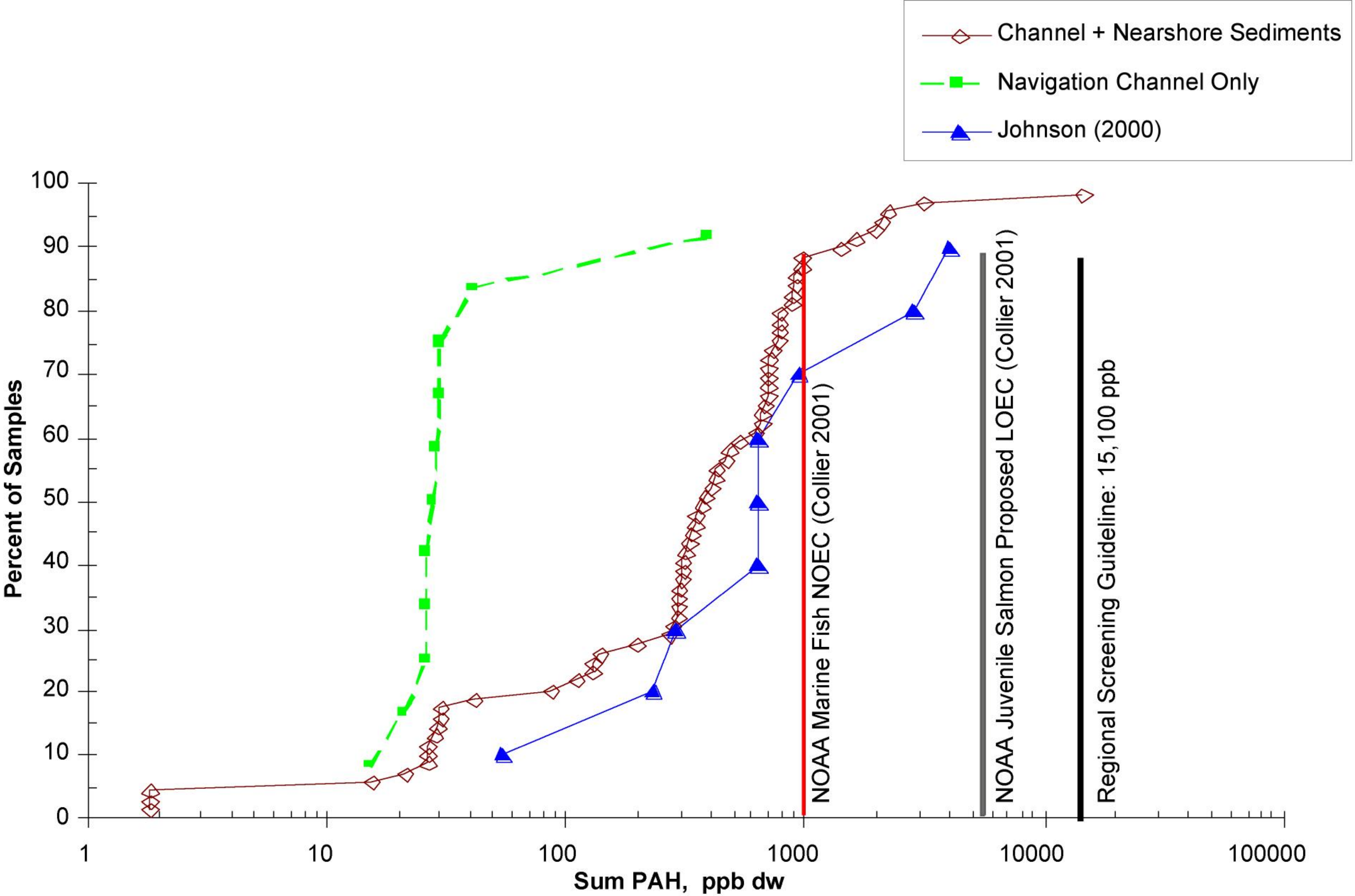


Figure B-41
Concentrations of PAHs in Sediments Compared to Four Effects Criteria: River Miles 41-101

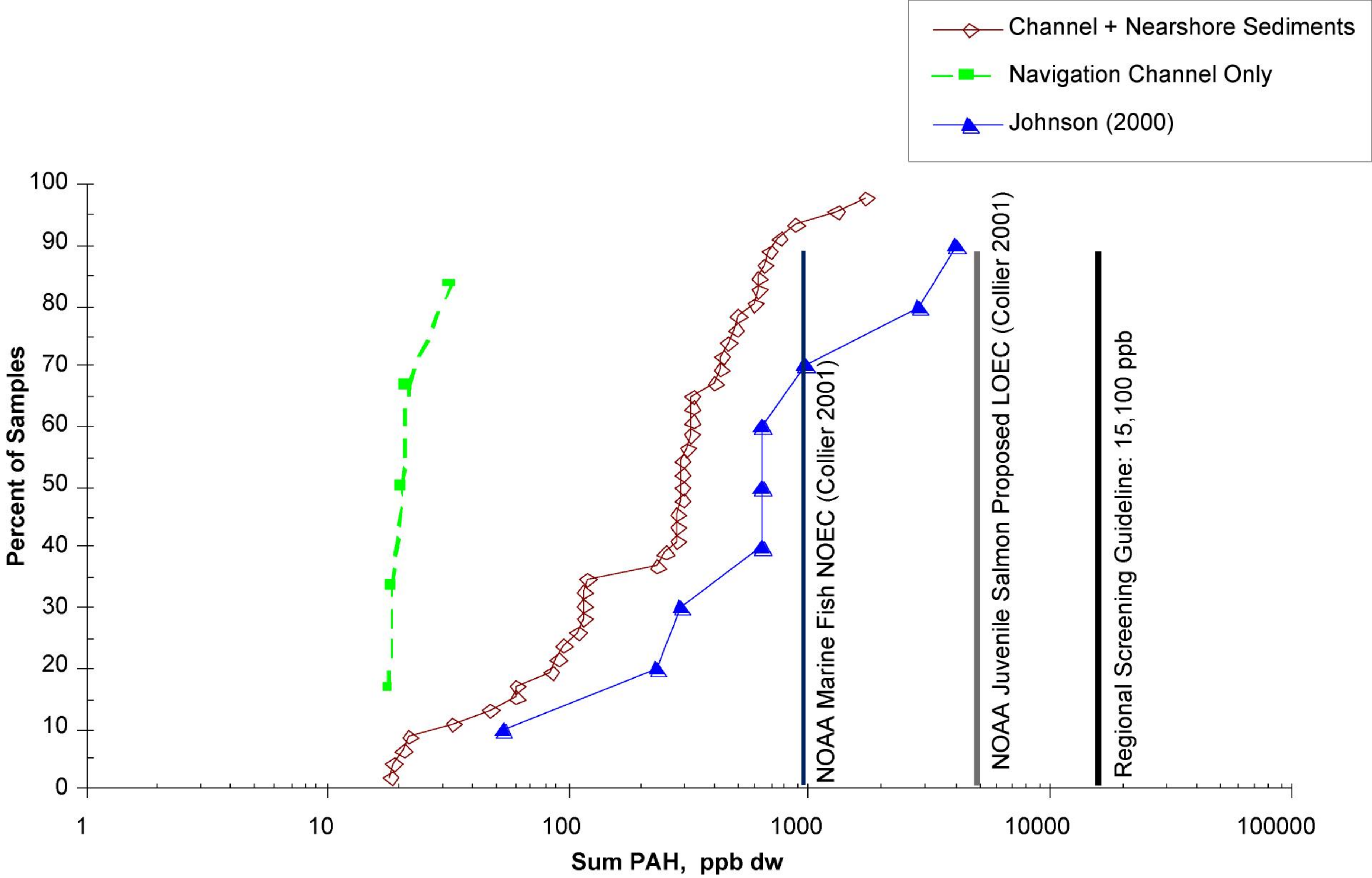


Figure B-42
Concentrations of PAHs in Sediments Compared to Four Effects Criteria: Upstream of River Mile 101

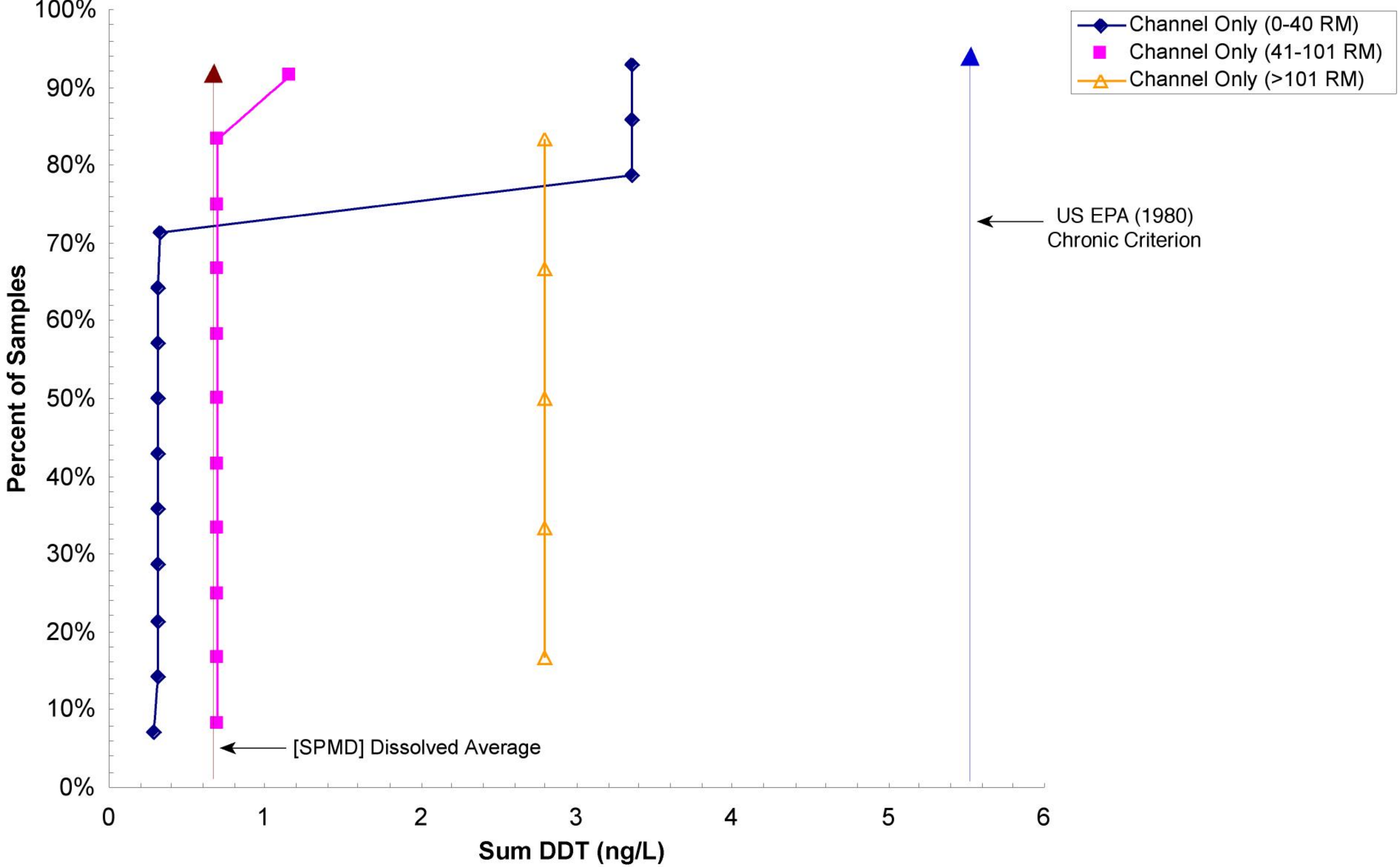


Figure B-43
Estimated Aqueous Concentrations of DDT and Metabolites in Sediment Porewaters Compared to Those Associated with Adverse Effects to Aquatic Organisms: Channel Sediments

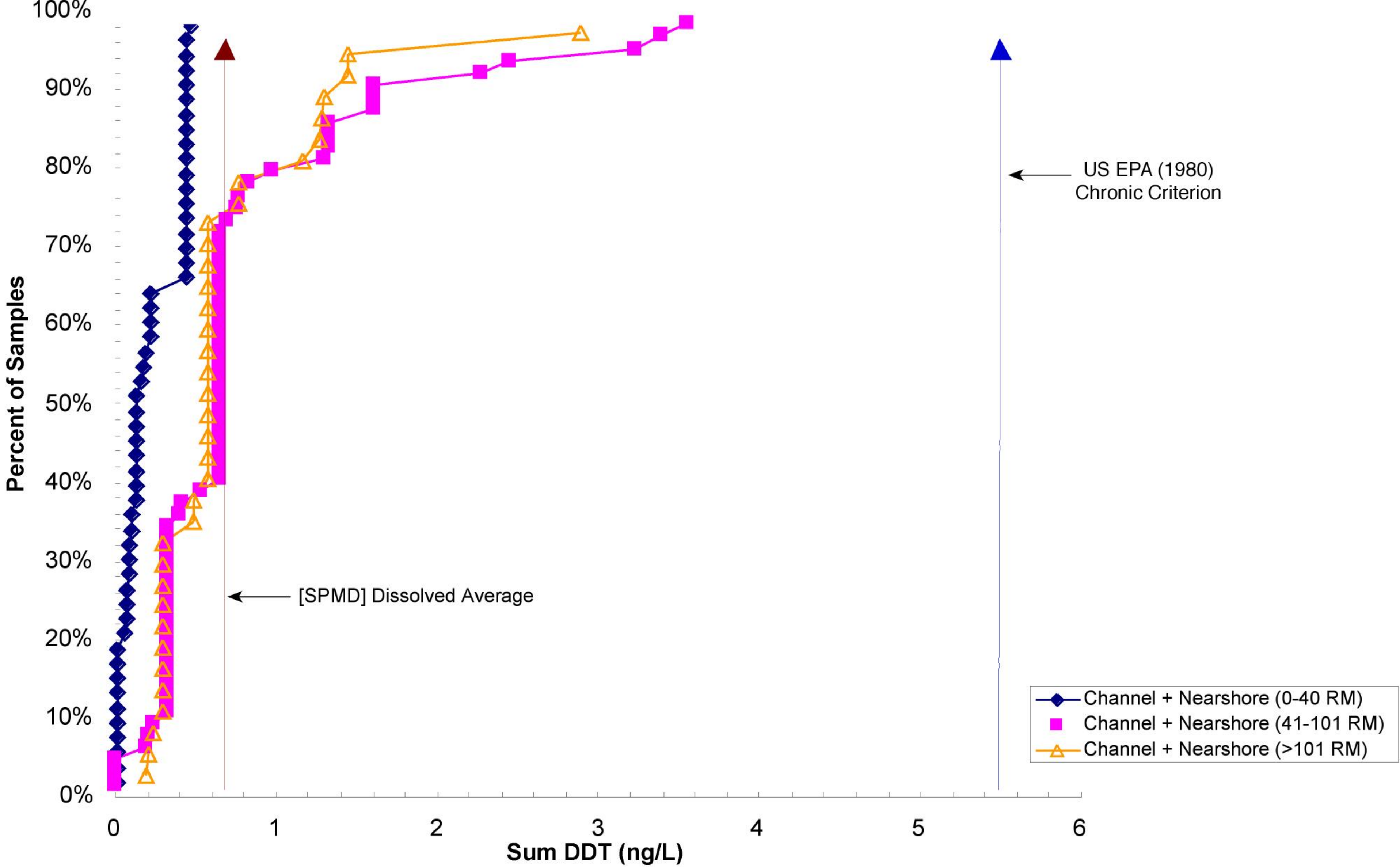


Figure B-44
Estimated Aqueous Concentrations of DDT and Metabolites in Sediment Porewaters Compared to Those Associated with Adverse Effects to Aquatic Organisms: Channel and Nearshore Sediments Combined

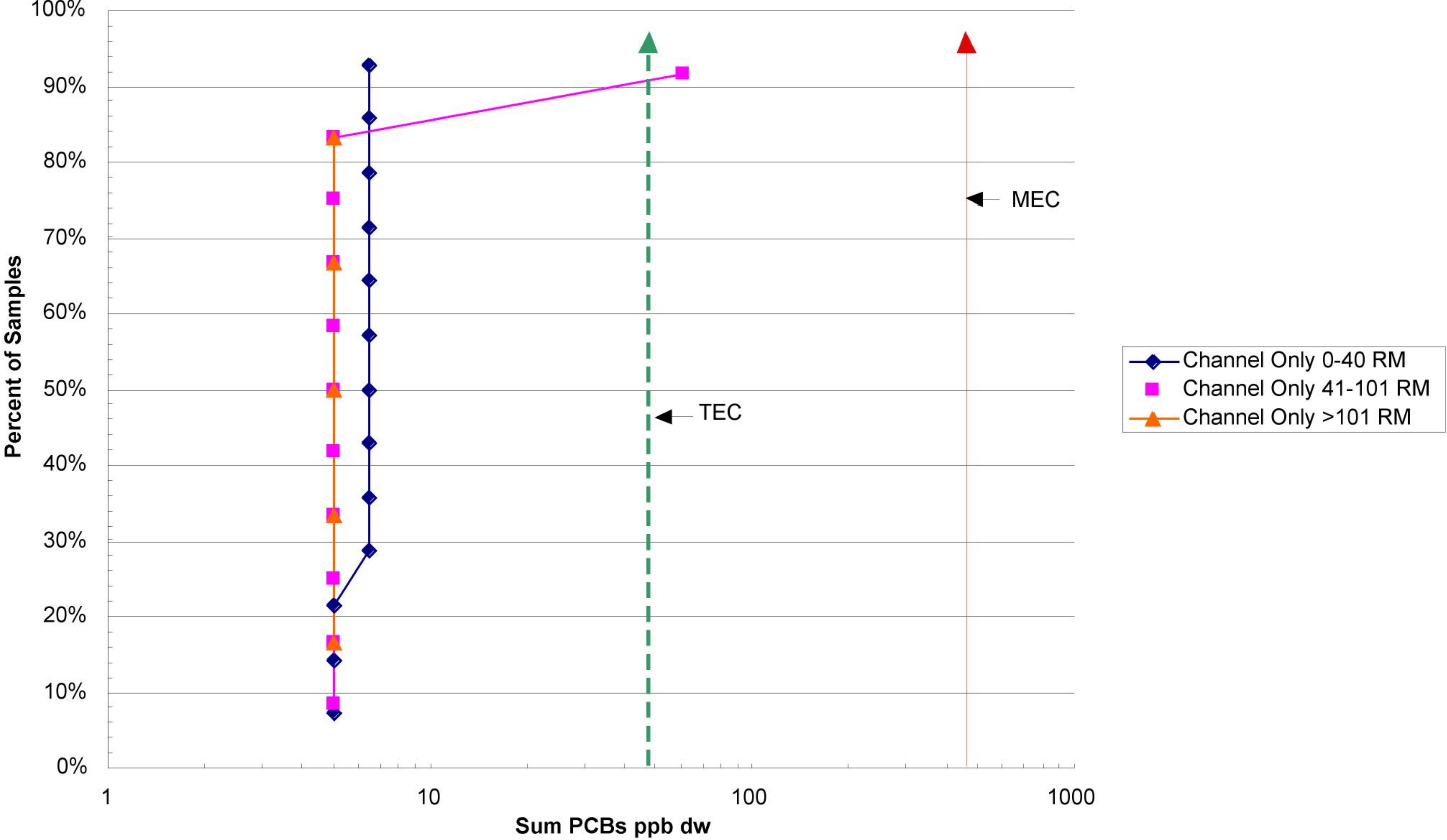


Figure B-45
Estimated Dry Weight Concentrations of PCBs in Sediment Compared to Those Associated with Adverse Effects to Aquatic Organisms: Channel Sediments

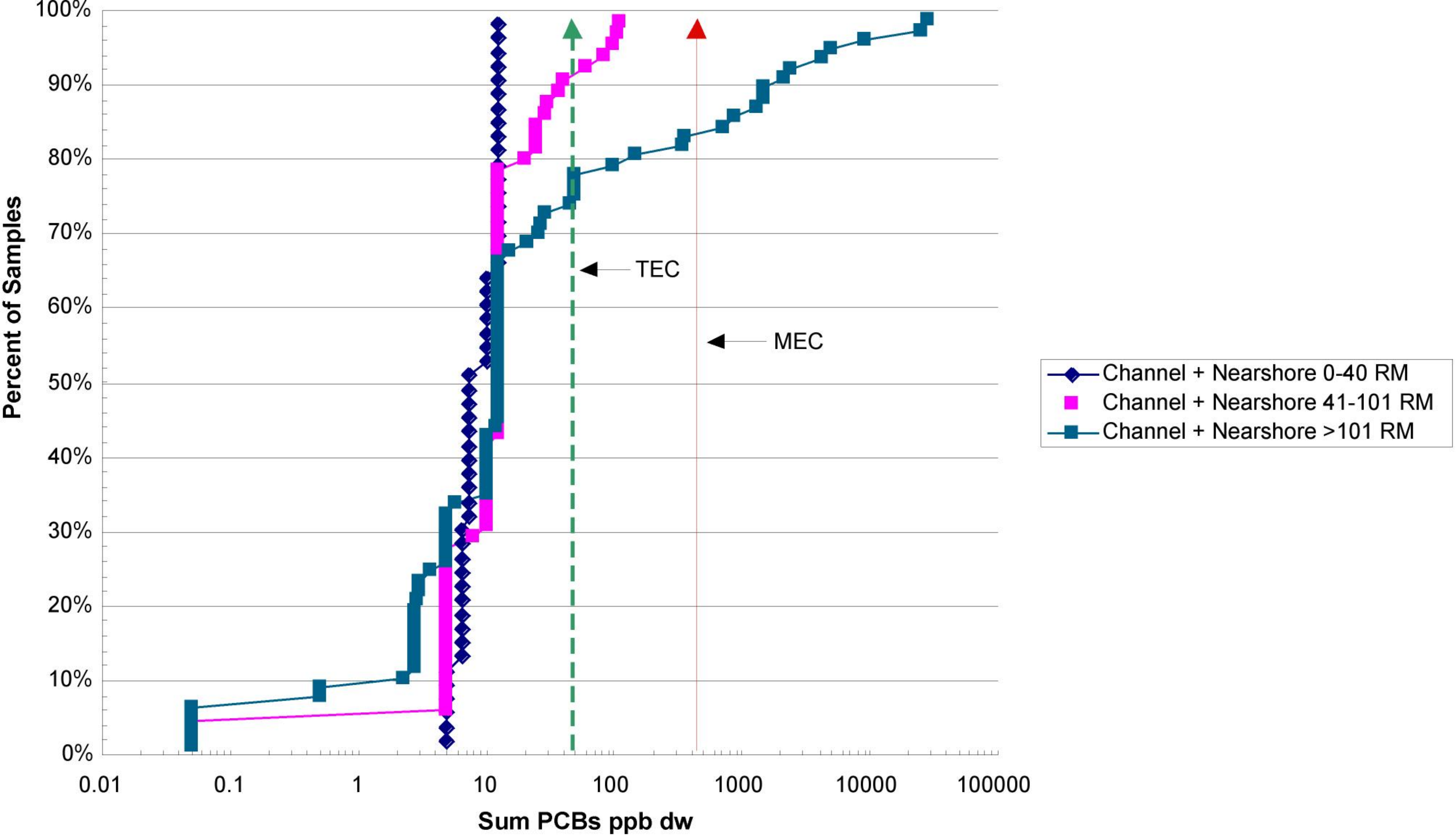


Figure B-46
Estimated Dry Weight Concentrations of PCBs in Sediment Compared to Those Associated with Adverse Effects to Aquatic Organisms: Channel and Nearshore Sediments Combined

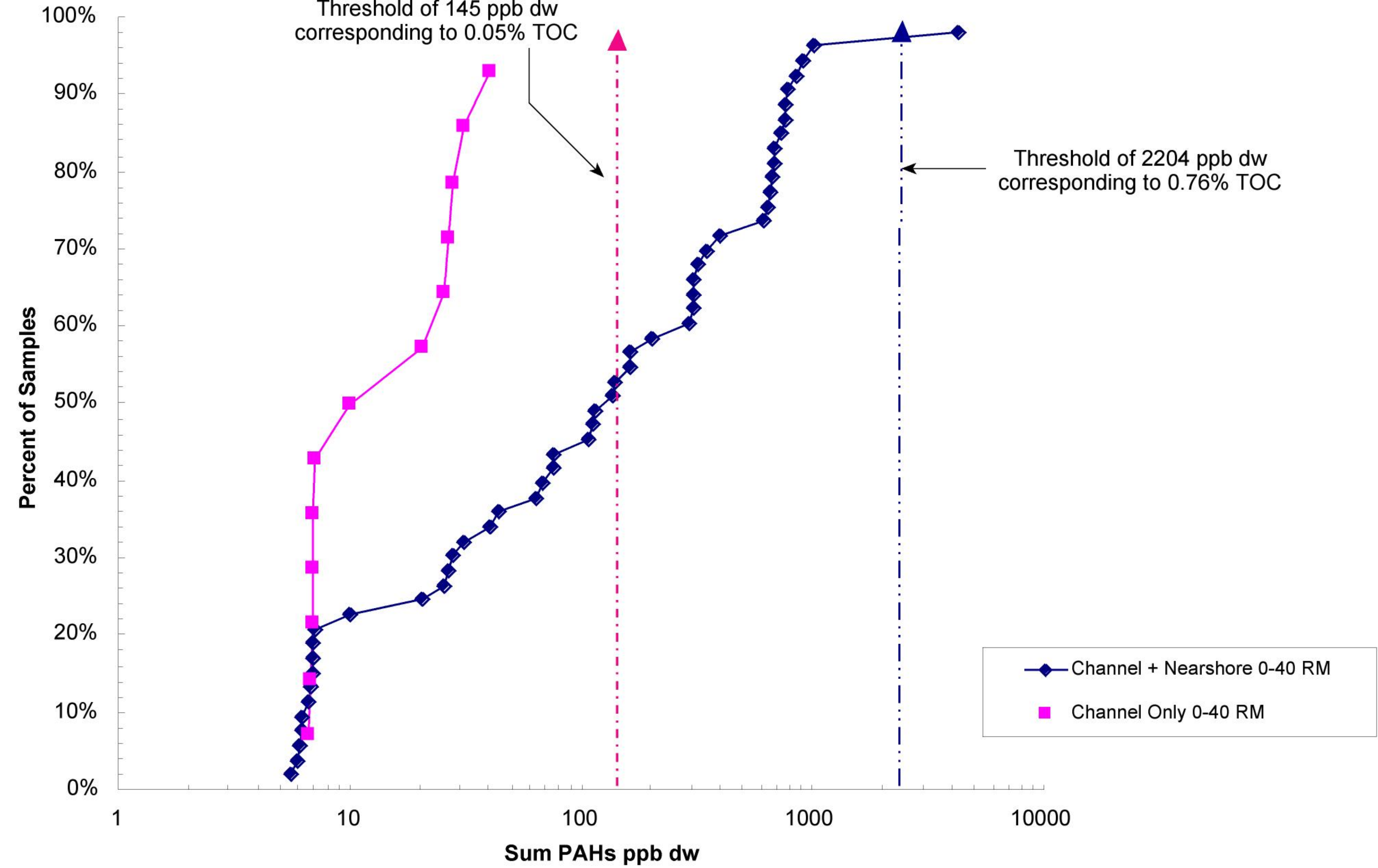


Figure B-47
Estimated Dry Weight Concentrations of PAHs in Sediment Compared to Those Associated with Adverse Effects to Aquatic Organisms: River Mile 0-40

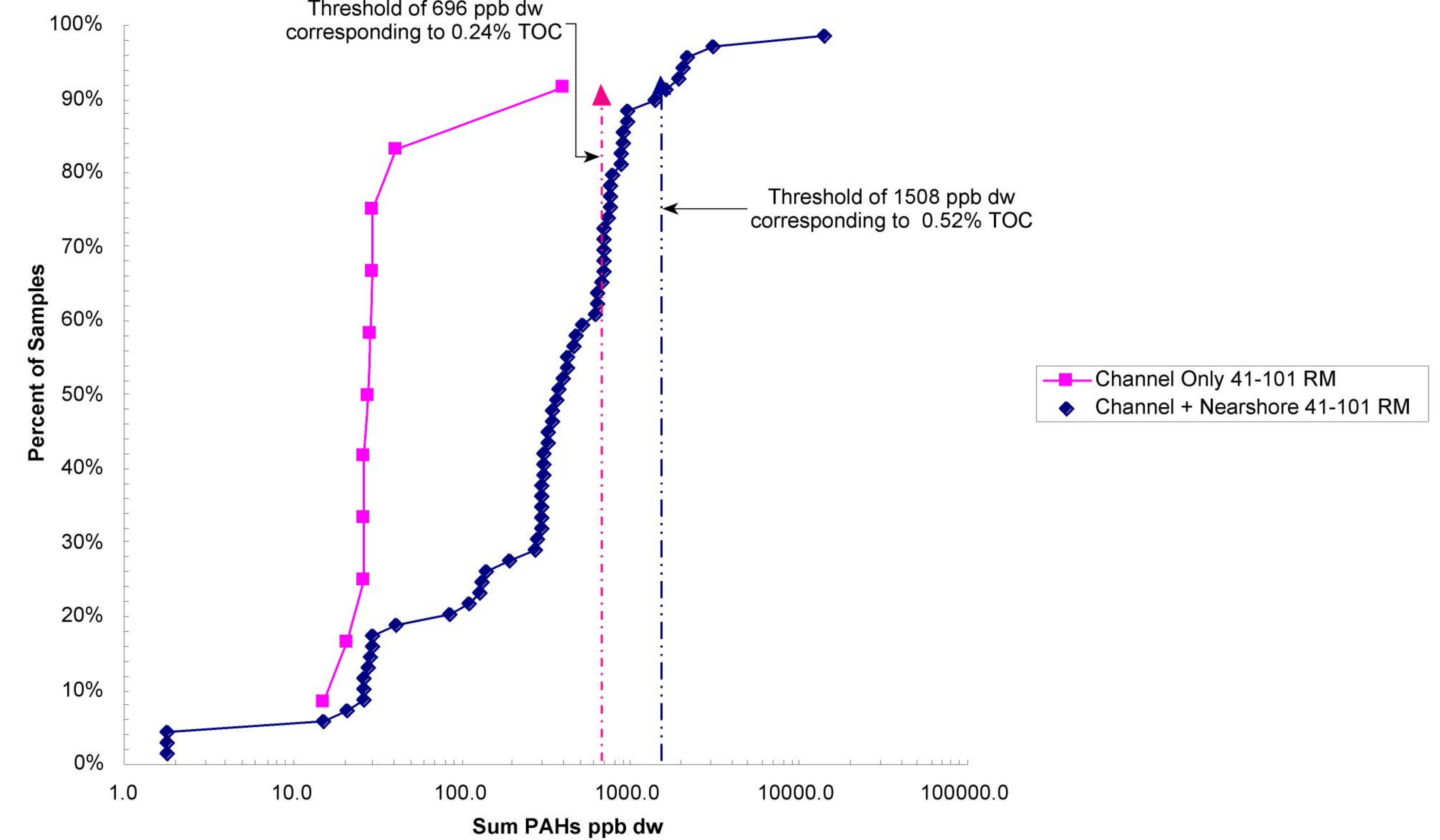


Figure B-48
Estimated Dry Weight Concentrations of PAHs in Sediment Compared to Those Associated with Adverse Effects to Aquatic Organisms: River Mile 41-101

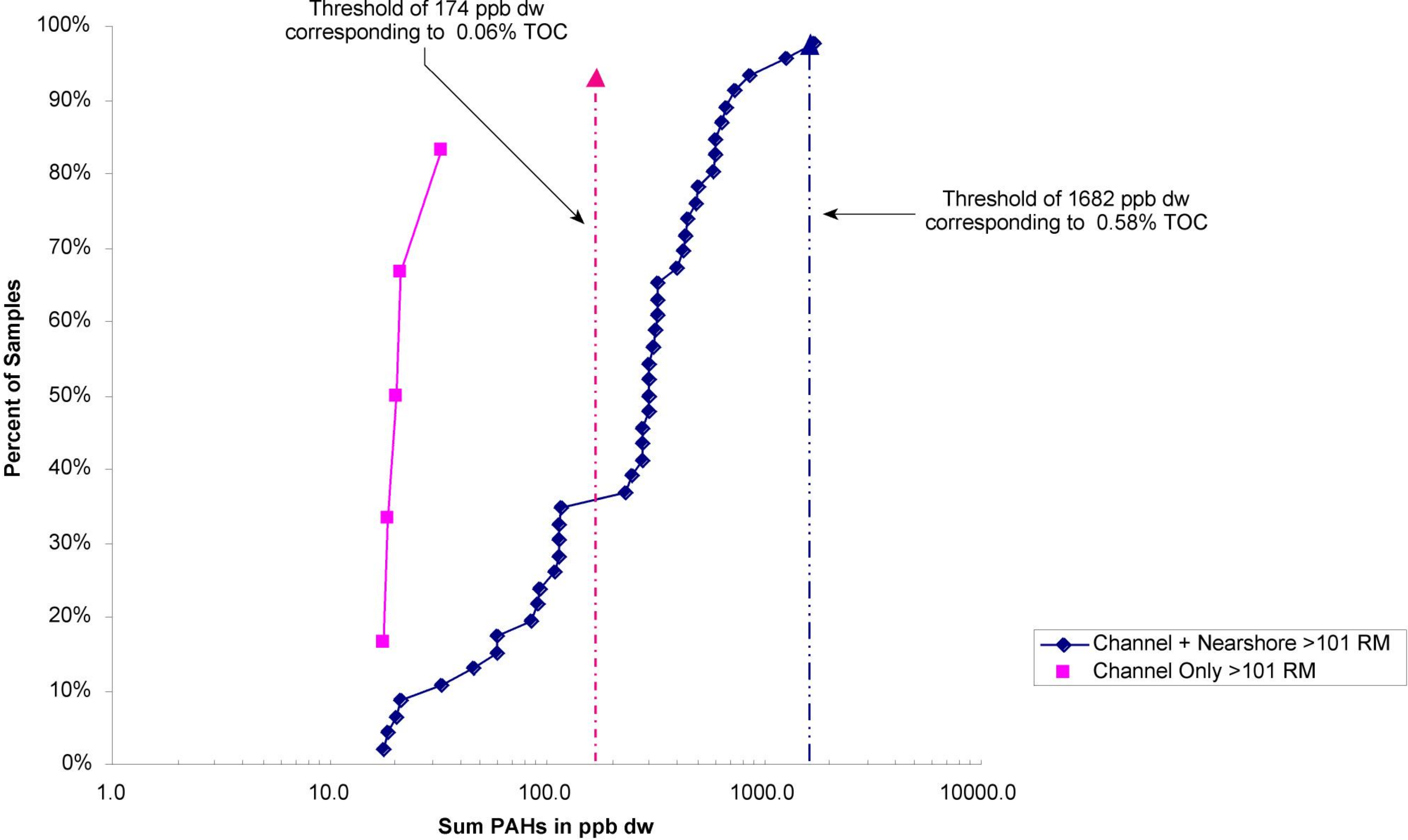


Figure B-49
Estimated Dry Weight Concentrations of PAHs in Sediment Compared to Those Associated with Adverse Effects to Aquatic Organisms: River Mile >101

APPENDIX D

Biological Data on Columbia River Salmonids

Appendix D provides technical information on the Evolutionary Significant Units (ESUs) and Distinctive Population Segments (DSPs) of concern in the Columbia River study area. This section is subdivided into four separate technical analyses, each summarizing specific information. The appendix is organized as follows:

D-1: Descriptions of Lower Columbia River Listed Salmonids – Evolutionarily Significant Units and Distinct Population Segments

D-2: Use and Importance of the Lower Columbia River, Estuary, and Ocean Plume to Coastal Cutthroat Trout

D-3: Review of Columbia River Estuary Studies Indicating Size and Location of Cutthroat Trout in the Columbia River Estuary 1967-1971 and 1978-1980

D-4: Ecology and Behavior of Columbia River Salmonids

D-1 DESCRIPTIONS OF LOWER COLUMBIA RIVER LISTED SALMONIDS – EVOLUTIONARILY SIGNIFICANT UNITS AND DISTINCT POPULATION SEGMENTS

1.1 Snake River Fall Chinook

From: Status Review for Snake River Fall Chinook Salmon. Northwest Fisheries Science Center. June 1991.

The Columbia River Basin has historically produced more chinook salmon than any other river system in the world (Van Hyning, 1973). Fall chinook salmon were widely distributed throughout the Snake River and many of its tributaries, from its confluence with the Columbia River upstream 990 kilometers (km) to Shoshone Falls, Idaho (Columbia Basin Interagency Committee, 1957; Haas, 1965; Fulton, 1968; Van Hyning, 1968; Lavier, 1976).

The construction of 12 dams on the mainstem Snake River substantially reduced the distribution and abundance of Snake River fall chinook salmon (Irving and Bjornn, 1981a). Fish passage facilities proved unsuccessful at several projects, and spawning habitats, particularly areas most frequently used by fall chinook salmon, were eliminated with the formation of reservoirs.

The upper reaches of the mainstem Snake River were the primary areas used by fall chinook salmon, with only limited spawning activity reported downstream from river kilometer (RKm) 439. The construction of Brownlee Dam (1958; RKm 459), Oxbow Dam (1961; RKm 439), and Hells Canyon Dam (1967; RKm 397) eliminated the primary production areas of Snake River fall chinook salmon. Habitat was further reduced with the construction of four additional dams on the Lower Snake River. Apart from the possibility of deep-water spawning in lower areas of the river, the mainstem Snake River from the upper limit of the Lower Granite Dam reservoir to Hells Canyon Dam (approximately 165 km) and the lower reaches of the Imnaha, Grande Ronde, Clearwater, and Tucannon Rivers are the only remaining areas available to fall chinook salmon in the Snake River Basin.

Adult Snake River fall chinook salmon enter the Columbia River in July and August and reach the mouth of the Snake River from the middle of August through October. Spawning occurs in the mainstem and in the lower reaches of large tributaries in October and November. Based on what is known of upper Columbia River fall chinook salmon, juveniles in the Snake River presumably emerge from the gravel in March and April and downstream migration usually begins within several weeks of emergence (Chapman, et al., 1991).

Rich (1922) studied the downstream migration of chinook salmon in the lower Columbia River and concluded that fry were present from June to October. Fall chinook salmon fry were found to be abundant in May and June (Reimers, 1964). Van Hyning (1968) reported that chinook salmon fry tend to linger in the lower Columbia River and may spend a considerable portion of their first year in the estuary.

1.2 Lower Columbia River Chinook

From: Status Review of Chinook Salmon from Washington, Idaho, Oregon, and California. Northwest Fisheries Science Center. February 1998.

The Columbia River exerts a dominant influence on the biota of the Pacific Northwest, although smaller, regional distinctions exist within the basin. In the lower Columbia River Basin, the Cowlitz, Kalama, Lewis, White Salmon, and Klickitat Rivers are the major river systems on the Washington side, while the

Willamette and Sandy Rivers are foremost on the Oregon side. Spring chinook salmon, which spawn above the Willamette Falls, will be discussed separately because of their geographic and life-history distinctiveness.

The fall run is predominant in this region. These fall chinook salmon are often called "tules" and are distinguished by their dark skin coloration and advanced maturity at the time of freshwater entry. Tule fall chinook salmon populations may have historically spawned from the mouth of the Columbia River to the Klickitat River (RKm 290). Whatever spawning grounds were accessible to fall chinook salmon on the Klickitat River (below Lyle Falls at RKm 3) would have been inundated following the construction of Bonneville Dam (RKm 243) in 1938 (Bryant, 1949; Hymer, et al., 1992a; WDF, et al.; 1993) There is no record of fall chinook salmon using this lower portion of the Klickitat River (Fulton, 1968). A significant fall run once existed on the Hood River (RKm 272) prior to the construction of Powerdale Dam (1929) and other diversion and irrigation dams (Fulton, 1968); however, this run has become severely depleted and may have been extirpated (Howell, et al., 1985; Nehlsen, et al., 1991; Theis and Melcher, 1995). The Big White Salmon River (RKm 270) supported runs of chinook salmon prior to the construction of Condit Dam (RKm 4) in 1913 (Fulton, 1968). Tule fall chinook salmon begin the freshwater phase of their return migration in late August and the peak spawning interval does not occur until November (WDF, et al. ,1993).

Among other fall-run populations, a later returning component of the fall chinook salmon run exists in the Lewis and Sandy Rivers (WDF, et al., 1993; Kostow, 1995; Marshall, et al., 1995). Because of the longer time interval between freshwater entry and spawning, Lewis and Sandy River fall chinook salmon are less mature at freshwater entry than tule fall chinook salmon and are commonly called lower river "brights" (Marshall, et al., 1995).

The Cowlitz, Kalama, Lewis, Clackamas, and Sandy Rivers currently contain both spring and fall runs; the Big White Salmon River historically contained both spring and fall runs but currently only contains fall-run fish (Fulton, 1968; WDF, et al., 1993). The Klickitat River probably contained only spring chinook salmon because falls blocked access to fall chinook salmon during low autumn flows (Fulton, 1968). The spring run on the Big White Salmon River was extirpated following construction of Condit Dam (Fulton, 1968), while a variety of factors may have caused the decline and extinction of spring chinook salmon on the Hood River (Nehlsen, et al., 1991; Kostow, 1995).

Spring chinook salmon on the lower Columbia River, like those from coastal stocks, enter freshwater in March and April well in advance of spawning in August and September. Fish migrations historically were synchronized with periods of high rainfall or snowmelt to provide access to upper reaches of most tributaries where fish would hold until spawning (Fulton, 1968; Olsen, et al., 1992; WDF, et al., 1993). Dams have reduced or eliminated access to upriver spawning areas on the Cowlitz, Lewis, Clackamas, Sandy, and Big White Salmon Rivers. A distinct winter-spawning run may have existed on the Sandy River (Mattson, 1955) but is believed to have been extirpated (Kostow, 1995).

1.3 Upper Columbia River Spring Chinook

From: Status Review of Chinook Salmon from Washington, Idaho, Oregon, and California. Northwest Fisheries Science Center. February 1998.

East of the Cascade Crest, many river systems support populations of both ocean- and stream-type chinook salmon. Fall-run (ocean-type) fish return to spawn in the mainstem Columbia and Snake Rivers and their tributaries, primarily the Deschutes and Yakima Rivers (Hymer, et al., 1992b; Olsen, 1992). Numerous other Columbia River tributaries in Washington, Oregon, and Idaho historically supported fall runs, but for a variety of reasons these are now extinct (Fulton, 1968; Nehlsen et al.,1991; Hymer et al., 1992a; Olson, et al., 1992; WDF, et al., 1993). Fall salmon historically migrated as far as Kettle Falls on the Columbia River (RKm 1,090) prior to the completion of Grand Coulee Dam (RKm 961) in 1941 (Mullan, 1987). Chapman (1943) observed chinook salmon spawning in deep water just below Kettle Falls in October 1938. Similarly, fall-run chinook salmon migrated up the Snake River to Shoshone Falls (RKm 976), although Augur Falls (RKm 960) probably blocked the passage of most fish (Evermann, 1896; Fulton, 1968).

Summer chinook salmon populations on the Columbia River exhibit an ocean-type life history, while summer chinook salmon on the Snake River exhibit a stream-type life history (Taylor, 1990a; Chapman, et al., 1991; Chapman, et al., 1994; Matthews and Waples. 1991; Waknitz, et al., 1995). Summer-run fish return to freshwater in June through mid-August—slightly earlier than the fall-run fish, which return from mid-August through October (Fulton, 1968). Summer-run fish were able to ascend Kettle Falls (Evermann,1896; Bryant and Parkhurst, 1950) and probably migrated as far as Lake Windermere in British Columbia (Hymer, et al., 1992b; Chapman, et al., 1994). With the completion of the Grand Coulee Dam in 1941 (RKm 961) and Chief Joseph Dam in 1955 (RKm 877) migration of salmon is blocked at Chief Joseph Dam. Naturally spawning ocean-type summer-run chinook salmon are also found in the Wenatchee (RKm 753) and Methow Rivers (RKm 843) (Waknitz, et al., 1995). Summer chinook are also reported to spawn in the lower Entiat and Chelan Rivers, in addition to below mainstem Columbia River dams (Marshall, et al., 1995); however, it has not been determined whether or not these are self-sustaining populations.

Among ocean-type Columbia River populations above Celilo Falls, summer-run chinook salmon spawn in the mid and lower reaches of tributaries, with peak spawning occurring in October; fall chinook salmon spawn in the mainstem Columbia and Snake Rivers and the lower reaches of the Deschutes and Yakima Rivers, with peak spawning occurring in November (Howell, et al., 1985; Marshall, et al., 1995; Mullan, 1987; Garcia, et al., 1996). Additionally, fall chinook salmon in the mainstem Columbia and Snake Rivers have been observed spawning in water 10 meters (m) deep or more (Chapman, 1943; Bruner, 1951; Swan et al., 1988; Hymer, et al., 1992b; Dauble, et al., 1995).

Ocean-type fry west of the Cascade Crest emerge in April and May, and the majority rear from 1 to 4 months in fresh water prior to emigrating to the ocean (Mullan, 1987; Olsen, et al., 1992; Hymer, et al., 1992a; WDF, et al., 1993; Chapman, et al., 1994; Marshall, et al., 1995). A small proportion of summer- and fall-run fish remains in fresh water until their second spring and emigrate as yearlings (Chapman, et al., 1994; Waknitz, et al., 1995). The proportion of yearling outmigrants varies from year to year, perhaps as a result of to environmental fluctuations. Among summer-run populations, the lowest incidence of yearling outmigrants is found in the Okanogan River, where the waters are relatively warm and highly productive (Chapman, et al., 1994).

1.4 Upper Willamette River Chinook

From: Status Review of Chinook Salmon from Washington, Idaho, Oregon, and California. Northwest Fisheries Science Center. February 1998.

Willamette Falls (RKm 42) has historically limited access to the upper river and thus defines the boundary of a distinct geographic region. High flows over the falls provided a window when returning chinook salmon could ascend the falls in the spring, while low flows prevented fish from ascending the falls in the autumn (Howell et al. 1985). The predominant tributaries to the Willamette River that historically supported spring-run chinook salmon—the Molalla (RKm 58), Santiam (RKm 174), McKenzie (RKm 282) and Middle Fork Willamette Rivers (RKm 301)—all of which drain the Cascades to the east (Mattson, 1948; Nicholas, 1995).

Three major populations of spring chinook salmon are currently located above Willamette Falls (McKenzie River and the North and South Forks of the Santiam River) (Kostow, 1995). Fall chinook salmon are present in the upper Willamette River, but these fish are transplants that have obtained access to the upper Willamette River as a result of the construction of fish passage facilities in 1971 and 1975 (Bennett, 1988). Adult spring-run chinook enter the Columbia River in March and April, but they do not ascend the Willamette Falls until May or June. The migration past the falls generally coincides with a rise in river temperatures above 10ºC (Mattson, 1948; Howell, et al., 1985; Nicholas, 1995). Spawning generally begins in late August and continues into early October, with spawning peaks in September (Mattson, 1948; Nicholas, 1995; Willis, et al., 1995).

1.5 Snake River Spring/Summer Chinook

From: Status Review for Snake River Spring and Summer Chinook Salmon. Northwest Fisheries Science Center. June 1991.

Spring and/or summer chinook salmon have historically spawned in virtually all accessible and suitable habitat in the Snake River upstream from its confluence with the Columbia River (Evermann, 1896; Fulton, 1968). Human activities have substantially reduced the amount of suitable spawning habitat in the Snake River. Even prior to hydroelectric development, many small tributary habitats were lost or severely damaged by construction and operation of irrigation dams and diversions; inundation of spawning areas by impoundments; and siltation and pollution from sewage, farming, logging, and mining (Fulton, 1968). More recently, the construction of hydroelectric and water storage dams without adequate provisions for adult and juvenile passage in the upper Snake River has precluded the use of all spawning areas upstream from Hells Canyon Dam.

The Snake River contains five principal subbasins that produce spring and/or summer chinook salmon (CBFWA, 1990). Three of the five subbasins (Clearwater, Grande Ronde, and Salmon Rivers) are large, complex systems composed of several smaller tributaries, which are further composed of many small streams. In contrast, the other two principal subbasins (Tucannon and Imnaha Rivers) are small systems in which the majority of salmon production is in the main rivers themselves. In addition to the five major subbasins, three small streams (Asotin, Granite, and Sheep Creeks) that enter the Snake River between Lower Granite and Hells Canyon Dams provide small spawning and rearing areas (CBFWA, 1990).

Adult spring chinook salmon migrate upstream past Bonneville Dam from March through May; summer chinook salmon migrate June through July. In both rivers, spring chinook salmon tend to use small, higher elevation streams (headwaters), and fall chinook salmon tend to use large, lower elevation streams or mainstem areas. Summer chinook salmon are more variable in their spawning habitats; in the Snake River, they inhabit small, high-elevation tributaries typical of spring chinook salmon habitat; conversely, in the upper Columbia River they spawn in larger, lower-elevation streams more characteristic of fall chinook salmon habitat. Differences are also evident in juvenile outmigration behavior. In both rivers, spring chinook salmon migrate swiftly to sea as yearling smolts, and fall chinook move seaward slowly as subyearlings. Summer chinook salmon in the Snake River resemble spring-run fish in migrating as yearlings, but they migrate as subyearlings in the Upper Columbia River (Schreck, et al., 1986).

1.6 Columbia River Chum

From: Status Review of Chum Salmon from Washington, Oregon, and California. Northwest Fisheries Science Center. December 1997.

At least one Evolutionary Significant Unit (ESU) of chum salmon was historically present in the Columbia River. Chum salmon were historically abundant in the lower reaches of the Columbia River and may have spawned as far upstream as the Walla Walla River (more than 500 km inland). Today, only remnant chum salmon populations exist, all in the lower Columbia River. Small spawning populations of chum salmon are regularly found as far south as the lower Columbia River and Tillamook Bay. They are few in number, low in abundance, and of uncertain stocking history.

Chum salmon are limited to tributaries below Bonneville Dam, with the majority of fish spawning on the Washington side of the Columbia River. Chum salmon have been reported in October in the Washougal, Lewis, Kalama, and Cowlitz Rivers in Washington and in the Sandy River in Oregon (Salo, 1991). Only three Washington runs (Grays River, Hamilton Creek, and Hardy Creek) were listed in the SASSI report, and all return in about October (the peak is mid-November), a run time similar to that of chum salmon in rivers along the Washington coast (WDF, et al., 1993). Grays River chum salmon enter the Columbia River from mid-October to mid-November, but apparently do not reach the Grays River until late October to early December. These fish spawn from early November to late December. Fish returning to Hamilton and Hardy Creeks begin to appear in the Columbia River earlier than Grays River fish (late September to late October) and have a more protracted spawn timing (mid-November to mid-January). The Oregon Department of Fish and Wildlife (ODFW) cited 25 locations in that state where chum salmon spawn in the lower Columbia River, but run times for these fish are unavailable (Kostow, 1995).

Observations of chum salmon fry are often more difficult to make than are observations of juveniles of other salmonids because chum salmon outmigrants (1) are smaller than outmigrants of other salmonids; (2) migrate at night; (3) usually have shorter distances to migrate to reach salt water than do other species; and (4) do not school as tightly as some other salmonids. Nonetheless, several key facets of fry outmigration are known. Downstream migration may take only a few hours or days in rivers where spawning sites are close to the mouth of the river, or it may take several months. Juvenile salmon at southern localities, such as those in Washington and southern British Columbia, migrate downstream earlier (late January through May) than fry in northern British Columbia and southeastern Alaska (April to June) do.

1.7 Snake River Sockeye

From: Status Review for Snake River Sockeye Salmon. Northwest Fisheries Science Center. April 1991.

Sockeye salmon are native to the Snake River and historically were abundant in several lake systems in Idaho and Oregon. In this century, a variety of factors have led to the demise of all Snake River sockeye salmon except those returning to Redfish Lake in the Stanley Basin of Idaho. Adults migrate upstream to Redfish Lake from July to September. Juveniles migrate downstream from Redfish Lake during April and May.

1.8 Lower Columbia River Steelhead

From: Status Review of West Coast Steelhead from Washington, Idaho, Oregon, and California. Northwest Fisheries Science Center. August 1996.

The ESU occupies tributaries to the Columbia River between the Cowlitz and Wind Rivers in Washington and the Willamette and Hood Rivers in Oregon, inclusive. Excluded are steelhead in the upper Willamette River Basin above Willamette Falls and steelhead from the Little and Big White Salmon Rivers, Washington. This ESU comprises both winter and summer steelhead. Genetic data show distinction between steelhead of this ESU and adjacent regions, with a particularly strong difference between coastal and inland steelhead in the vicinity of the Cascade Crest. The majority of stocks for which there are data within this ESU have been declining in the recent past, but some have been increasing strongly.

1.9 Upper Willamette River Steelhead

From: Status Review of West Coast Steelhead from Washington, Idaho, Oregon, and California. Northwest Fisheries Science Center. August 1996.

This ESU occupies the Willamette River and its tributaries upstream from Willamette Falls. The native steelhead of this basin are late-migrating winter steelhead, entering fresh water primarily in March and April. This unusual run timing appears to be an adaptation for ascending Willamette Falls. The falls function as an isolating mechanism for upper Willamette River steelhead. Early migrating winter steelhead and summer steelhead have been introduced to the Upper Willamette River Basin; however, these non-native populations are not components of this ESU. Native winter steelhead within this ESU have been declining on average since 1971 and have exhibited large fluctuations in abundance. The main production of native (late-run) winter steelhead is in the North Fork Santiam River, where estimates of hatchery proportion in natural spawning range from 14 percent to 54 percent. The native steelhead of this basin are late migrating winter steelhead, entering fresh water primarily in March and April.

1.10 Middle Columbia River Steelhead

From: Status Review of West Coast Steelhead from Washington, Idaho, Oregon, and California. Northwest Fisheries Science Center. August 1996.

This ESU occupies the Columbia River Basin from above the Wind River in Washington and the Hood River in Oregon upstream to include the Yakima River, Washington. Steelhead of the Snake River Basin are not included. This ESU includes the only populations of winter inland steelhead in the United States, in the Klickitat River and Fifteenmile Creek. Some uncertainty exists about the exact boundary between coastal and inland steelhead, and the western margin of this ESU reflects currently available genetic data. There is good genetic and meristic evidence to separate this ESU from steelhead of the Snake River Basin. The boundary upstream of the Yakima River is based on limited genetic information and environmental differences, including physiographic regions, climate, topography, and vegetation. Total abundance in the ESU appears to have been increasing recently, but the majority of natural stocks for which there are data within this ESU have been declining, including those in the John Day River, which is the largest producer of wild, natural steelhead. There is widespread production of hatchery steelhead within this ESU, but it is largely based on within-basin stocks. Habitat degradation due to grazing and water diversions has been documented throughout the range of the ESU.

Life-history information for steelhead of this region indicates that most middle Columbia River steelhead smolt at 2 years and spend 1 to 2 years in salt water prior to re-entering fresh water, where they may remain up to a year prior to spawning (Howell, et al., 1985; Bonneville Power Administration, 1992). Within this ESU, the Klickitat River is unusual in that it produces both summer and winter steelhead, and the summer steelhead are dominated by age-2-ocean steelhead, whereas most other rivers in this region produce about equal numbers of both age-1- and age-2-ocean steelhead.

1.11 Upper Columbia River Steelhead

From: Status Review of West Coast Steelhead from Washington, Idaho, Oregon, and California. Northwest Fisheries Science Center. August 1996.

This ESU occupies the Columbia River Basin upstream from the Yakima River. All upper Columbia River steelhead are summer steelhead. The streams of this region that are used by steelhead primarily drain the northern Cascade Mountains of Washington. Stream flow is supplied by snowmelt, groundwater, and glacial runoff, often resulting in extremely cold water temperatures that retard the growth and maturation of steelhead juveniles, causing some of the oldest smolt ages reported for steelhead and residualization of juvenile steelhead that fail to smolt. While total abundance of populations within this ESU has been relatively stable or increasing, this appears to be true only because of major hatchery supplementation programs. Estimates of the proportion of hatchery fish in spawning escapement are 65 percent (Wenatchee River) and 81 percent (Methow and Okanogan Rivers).

Life-history characteristics for Upper Columbia River steelhead are similar to those of other inland steelhead ESUs; however, some of the oldest smolt ages for steelhead, up to 7 years, are reported from this ESU. This may be associated with the cold stream temperatures discussed by Mullan et al. (1992), who stated that the cold water in some of the streams of this area may cause some fish to be "thermally fated to a resident (rainbow trout) life history, regardless of whether they were the progeny of anadromous or resident parents." The relationship between anadromous and nonanadromous *Oncorhynchus mykiss* in this geographic area is unclear. Based on limited data available from adult fish, smolt age in this ESU is dominated by 2-year-olds. Again based on limited data, steelhead from the Wenatchee and Entiat Rivers return to fresh water after 1 year in salt water, whereas Methow River steelhead are primarily age-2-ocean (Howell, et al., 1985). As with other inland steelhead, these remain in fresh water up to a year prior to spawning.

1.12 Snake River Steelhead

From: Status Review of West Coast Steelhead from Washington, Idaho, Oregon, and California. Northwest Fisheries Science Center. August 1996.

This ESU occupies the Snake River Basin of southeast Washington, northeast Oregon, and Idaho. This region is ecologically complex and supports a diversity of steelhead populations; however, genetic and meristic data suggest that these populations are more similar to each other than they are to steelhead populations occurring outside of the Snake River Basin. Snake River steelhead spawning areas are well isolated from other populations and include the highest elevations for spawning (up to 2,000 m) as well as the longest migration distance (up to 1,500 km). Snake River steelhead are often classified into two groups, A-run and B-run, based on migration timing, ocean age, and adult size. While total (hatchery plus natural) run size for Snake River steelhead has increased since the mid-1970s, the increase has resulted from greater production of hatchery fish, and there has been a severe recent decline in natural run size. Parr densities in natural production areas have been substantially below estimated capacity in recent years. Downward trends and low parr densities indicate a particularly severe problem for B-run steelhead, the loss of which would substantially reduce life-history diversity within this ESU. Snake River steelhead enter fresh water from June to October and spawn during the following spring from March to May.

1.13 Cutthroat Southwest Washington/Columbia River

From: Status Review of Coastal Cutthroat Trout from Washington, Oregon, and California. Northwest Fisheries Science Center. January 1999.

The proposed boundaries of this ESU are similar to the Southwestern Washington/Lower Columbia River ESU for coho salmon (Weitkamp, et al., 1995). Support for this ESU designation comes primarily from ecological and genetic information. Ecological characteristics of this region include the presence of extensive intertidal mudflats and sandflats, similarities in fresh water and estuarine fish faunas, and substantial differences from estuaries north of Grays Harbor and south of the Columbia River. The coastal cutthroat trout samples from southwestern Washington show a relatively close genetic affinity to the samples from the Columbia River.

Coastal cutthroat trout parr generally remain in upper tributaries until they are 1 year of age, when they may begin moving more extensively throughout the river system. Once these movements begin, it is difficult to determine whether fish caught in upstream or downstream traps are parr making a freshwater migration or smolts on a seawater-directed migration; many unpaired coastal cutthroat trout of similar size caught in these traps have characteristics of either life-history stage or intermediate characteristics. In Oregon, Lowry (1965) and Giger (1972) found that downstream-directed movement by juveniles in the Alsea River system began with the first springs rains, usually in mid-April with peak movement in mid-May. Giger (1972) also reported that some juveniles entered the estuary and remained there over the summer but apparently did not smolt or migrate to the open ocean. He was unable to determine how many of these parr continued moving seaward and how many remained in the estuaries. Such movement further confounds the difficulty in separating nonanadromous downstream migrations from seaward migrations.

Coastal cutthroat trout may return to freshwater feeding/spawning areas from late June through the following April. Re-entry timing has been found to be temporally consistent from year to year within streams, but varying widely between streams (Giger, 1972). As in other species of anadromous salmonids, entry to large rivers seems to occur consistently earlier than entry to shorter coastal rivers (Giger, 1972; Johnston and Mercer, 1976; Johnston, 1982). These streams usually have low flows. Sumner (1953) found fall-winter movements in Sand Creek, first with large adults (up to 10 years old), followed by smaller (<25 cm) mature freshwater migrants coming from the lower reaches of the estuary. In the Nestucca River, Sumner reported a late reproductive migration in early to mid-May, with large ripe females in rivers as late as June. In large river systems within Washington and Oregon (such as the Stillaguamish, Columbia, Cowlitz, Alsea, and Umpqua Rivers), coastal cutthroat trout return migrations usually begin as early as late June and continue through October, with peaks in late September and October (Lavier, 1963; Bulkley, 1966; Hisata, 1971, 1973; Duff, 1972; Giger, 1972; Wright, 1973; Tipping and Springer, 1980; Tipping, 1981, 1986; ODFW, 1993a).

1.14 Bull Trout

From: Federal Register Notices of Final Listing. November 1, 1999 and June 10, 1998.

Bull trout are char native to the Pacific Northwest and western Canada. They historically occurred in major river drainages in the Pacific Northwest from about 41° N to 60° N latitude, from the southern limits in the McCloud River in northern California and the Jarbidge River in Nevada, north to the headwaters of the Yukon River in Northwest Territories, Canada (Cavender, 1978; Bond, 1992). To the west, bull trout range includes Puget Sound, various coastal rivers of Washington; British Columbia, Canada; and southeast Alaska (Bond, 1992; Leary and Allendorf, 1997). Bull trout are relatively dispersed throughout tributaries of the Columbia River Basin, including its headwaters in Montana and Canada. Bull trout also occur in the Klamath River Basin of south-central Oregon.

The Columbia River Distinct Population Segment (DPS) occurs throughout the entire Columbia River Basin within the United States and its tributaries, excluding bull trout found in the Jarbidge River, Nevada. Although Williams, et al. (1995), identified two distinct clades in the Columbia River basin (upper and lower Columbia River) based on genetic diversity patterns, a discrete geographical boundary between the two clades was not documented. The Columbia River DPS is significant because the overall range of the species would be substantially reduced if this discrete population were lost.

The Columbia River DPS includes bull trout residing in portions of Oregon, Washington, Idaho, and Montana. Bull trout are estimated to have occupied about 60 percent of the Columbia River Basin and currently occur in 45 percent of the estimated historical range (Quigley and Arbelbide, 1997). The Columbia River population segment comprises 141 subpopulations. For discussion and analysis, the U.S.

Fish and Wildlife Service (USFWS) considered four geographic areas of the Columbia River basin: (1) lower Columbia River (downstream of the Snake River confluence), (2) mid-Columbia River (Snake River confluence to Chief Joseph Dam), (3) upper Columbia River (upstream from Chief Joseph Dam), and (4) Snake River and its tributaries (including the Lost River drainage).

The lower Columbia River area includes all tributaries in Oregon and Washington downstream of the Snake River confluence near the town of Pasco, Washington. USFWS identified 20 subpopulations in watersheds of nine major tributaries of the lower Columbia River (number of subpopulations in each watershed): the Lewis River (2), Willamette River (3), White Salmon River (1), Klickitat River (1), Hood River (2), Deschutes River (3), John Day River (3), Umatilla River (2), and Walla Walla River (3). The current distribution of bull trout in the lower Columbia River Basin is less than the historical range (Buchanan, et al., 1997; Oregon Department of Fish and Wildlife [ODFW], 1993). Bull trout are thought to have been extirpated from several tributaries in five river systems in Oregon: the Middle Fork Willamette River, the North and South Forks of the Santiam River, the Clackamas River, the upper Deschutes River (upstream of Bend, Oregon) and the Crooked River (tributary to the Deschutes River) (Buchanan, et al., 1997). Hydroelectric facilities and large expanses of unsuitable, fragmented habitat have isolated these subpopulations. Large dams, such as McNary, John Day, The Dalles, and Bonneville, separate four reaches of the lower Columbia River. Although fish may pass each facility in both upstream and downstream directions, the extent to which bull trout use the Columbia River is unknown. In addition, the nine major tributaries have numerous facilities, many of which do not provide upstream passage.

Migratory bull trout are present with resident fish or exclusively in at least 13 of the 20 subpopulations in the lower Columbia River. Many migratory fish are adfluvial and inhabit reservoirs created by dams. However, this area includes the only extant adfluvial subpopulation in Oregon, which exists in Odell Lake in the Deschutes River basin (Ratliff and Howell, 1992; Buchanan, et al., 1997). The Metolius River-Lake Billy Chinook subpopulation is also found in the Deschutes River basin. It is the only subpopulation considered “strong” and exhibits an increasing trend in abundance. USFWS considers 5 of the 20 subpopulations at risk of extirpation caused by naturally occurring events exacerbated by isolation, single life-history form and spawning area, and low abundance.

The mid-Columbia River area includes watersheds of four major tributaries of the Columbia River in Washington, between the confluence of the Snake River and Chief Joseph Dam. USFWS identified 16 bull trout subpopulations in the four watersheds: Yakima River (8), Wenatchee River (3), Entiat River (1), and Methow River (4). Bull trout have historically occurred in larger areas of the four tributaries and Columbia River. Bull trout are thought to have been extirpated in 10 streams within the area: Satus Creek, Nile Creek, Orr Creek, Little Wenatchee River, Napecqua River, Lake Chelan, Okanogan River, Eightmile Creek, South Fork Beaver Creek, and the Hanford Reach of the Columbia River. Most bull trout in the mid-Columbia River geographic area are isolated by dams or unsuitable habitat created by water diversions. Bull trout in the mid-Columbia River area are most abundant in Rimrock Lake of the Yakima River basin and Lake Wenatchee of the Wenatchee River basin. Both subpopulations are considered "strong" and increasing or stable. The remaining 14 subpopulations are relatively low in abundance, exhibit “depressed” or unknown trends, and primarily have a single life-history form. USFWS considers 10 of the 16 subpopulations at risk of extirpation because of naturally occurring events due to isolation, single life-history form and spawning area, and low abundance.

The upper Columbia River geographic area includes the mainstem Columbia River and all tributaries upstream of Chief Joseph Dam in Washington, Idaho, and Montana. Bull trout are found in two large basins, the Kootenai River and Pend Oreille River, which include the Clark Fork River. Bull trout were historically found in larger portions of the area. Numerous dams and degraded habitat have fragmented bull trout habitat and isolated fish into 71 subpopulations in nine major river basins: Spokane River (1), Pend Oreille River (3), Kootenai River (5), Flathead River (24), South Fork Flathead River (3), Swan River (3), Clark Fork River (4), Bitterroot River (27), and Blackfoot River (1). Bull trout are thought to be extirpated in 64 streams and lakes of various sizes: Nespelam, Sanpoil, and Kettle rivers; Barnaby, Hall, Stranger, and Wilmont Creeks; 8 tributaries to Lake Pend Oreille; 5 tributaries to Pend Oreille River below Albeni Falls Dam; Lower Stillwater Lake; Arrow Lake (Montana); upper Clark Fork River, 12 streams in the Coeur d'Alene River basin; and approximately 25 streams in the St. Joe River basin.

Bull trout typically spawn from August to November during periods of decreasing water temperatures. However, migratory bull trout may begin spawning migrations as early as April and may move upstream as far as 250 km to spawning grounds in some areas of their range.

1.15 References

Northwest Fisheries Science Center. February 1998. Status Review of Chinook Salmon from Washington, Idaho, Oregon, and California.

Northwest Fisheries Science Center. December 1997. Status Review of Chum Salmon from Washington, Oregon, and California.

Northwest Fisheries Science Center. August 1996. Status Review of West Coast Steelhead from Washington, Idaho, Oregon, and California.

Northwest Fisheries Science Center. June 1991. Status Review of Snake River Fall Chinook Salmon.

Northwest Fisheries Science Center. June 1991. Status Review of Snake River Spring and Summer Chinook Salmon.

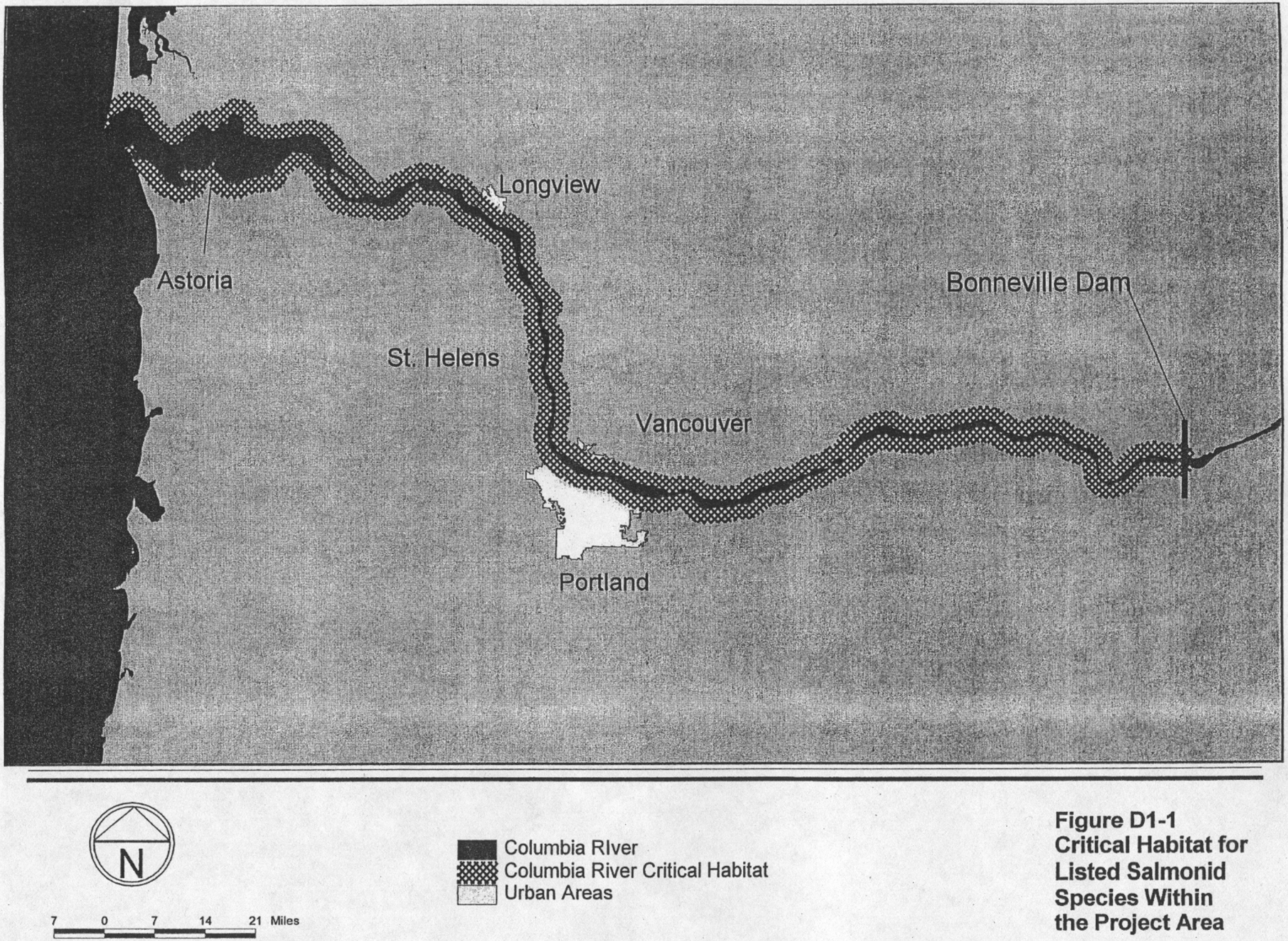
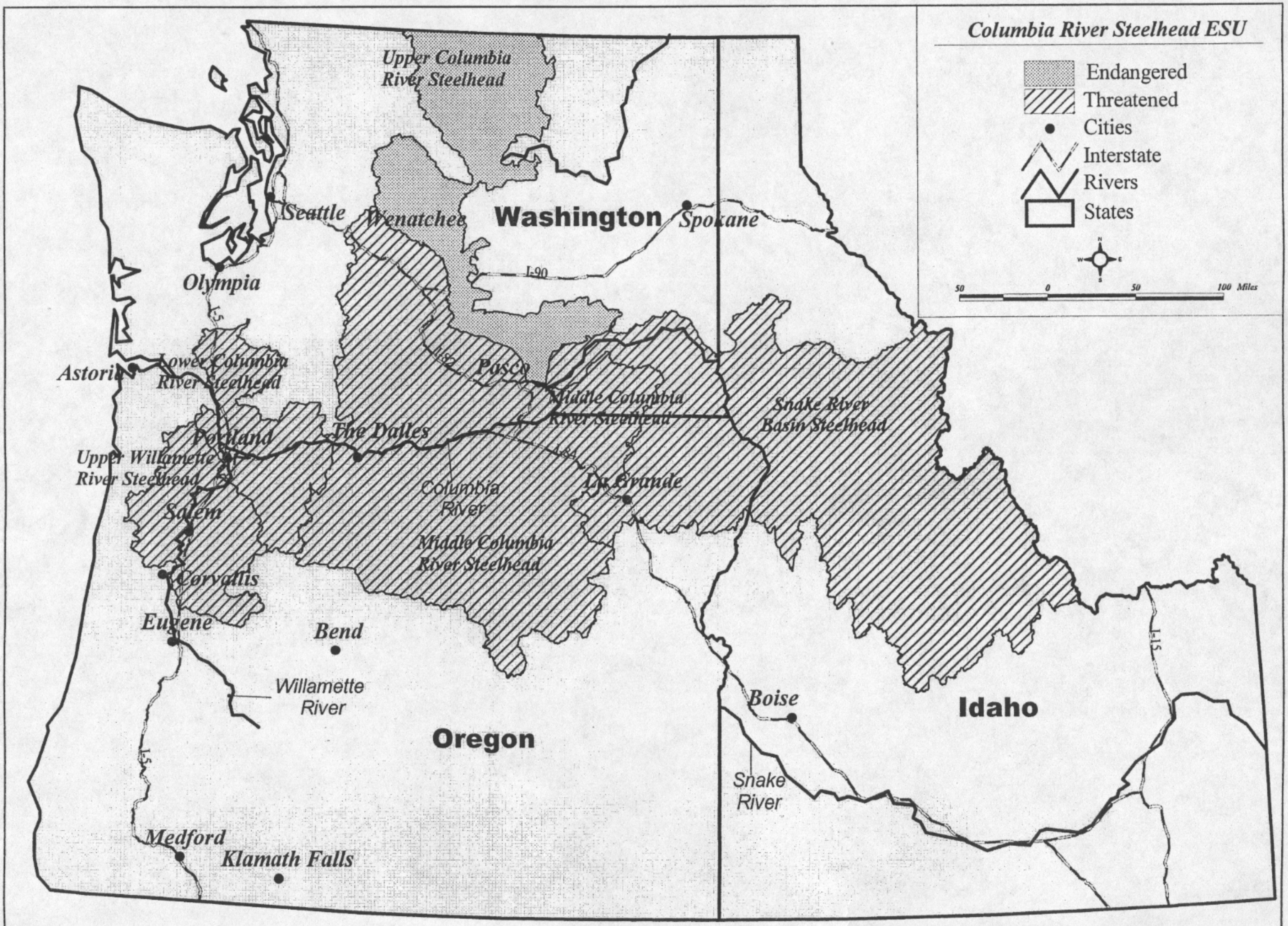


Figure D1-1
Critical Habitat for Listed Salmonid Species Within the Project Area



Columbia River Steelhead ESU
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Spokane
Olympia
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Astoria
Lower Columbia River Steelhead
I-82
Pasco
Middle Columbia River Steelhead
Snake River Basin Steelhead
Portland
The Dalles
Upper Willamette River Steelhead
I-84
La Grande
Columbia River
Salem
Middle Columbia River Steelhead
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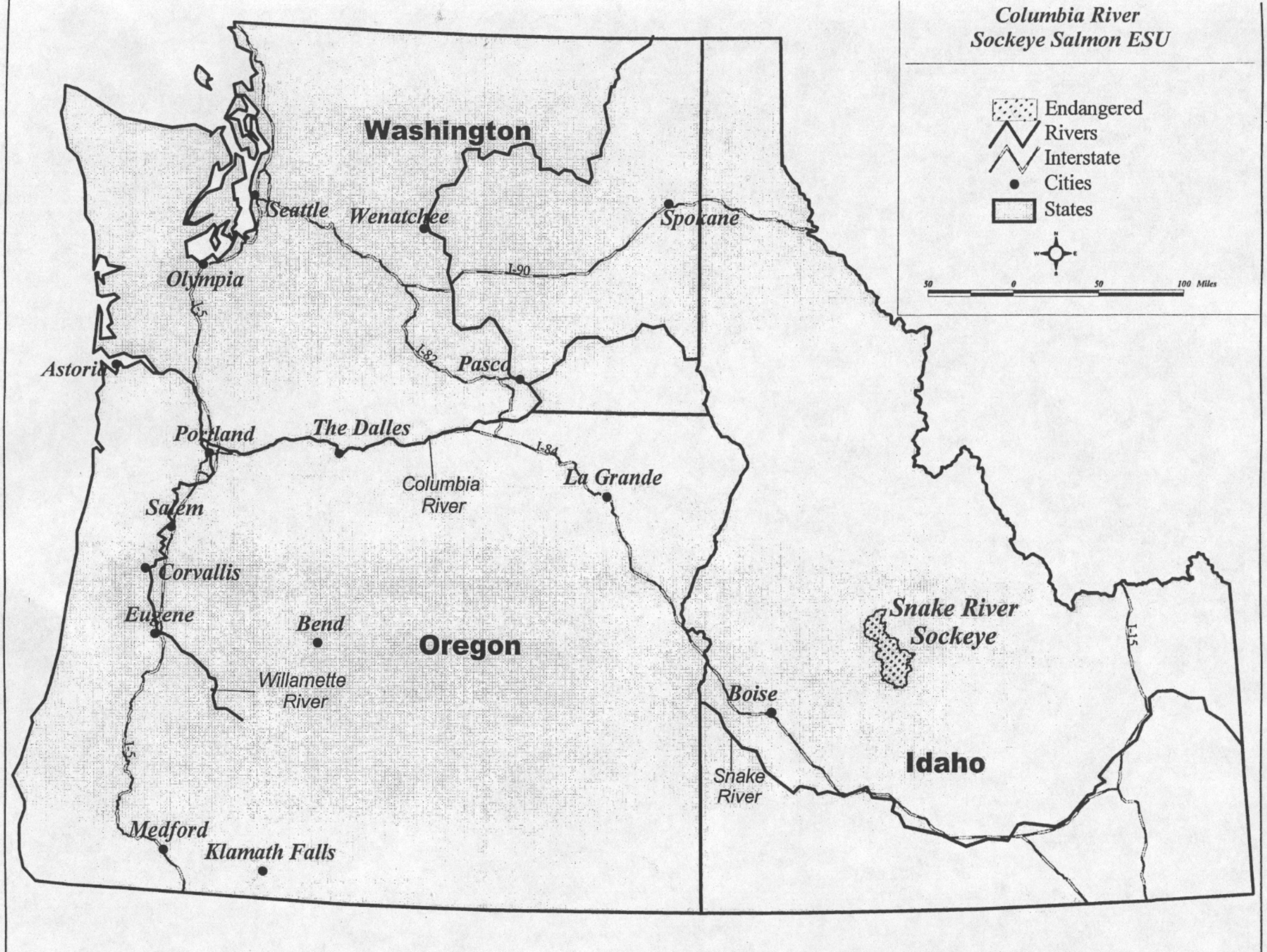
Klamath Falls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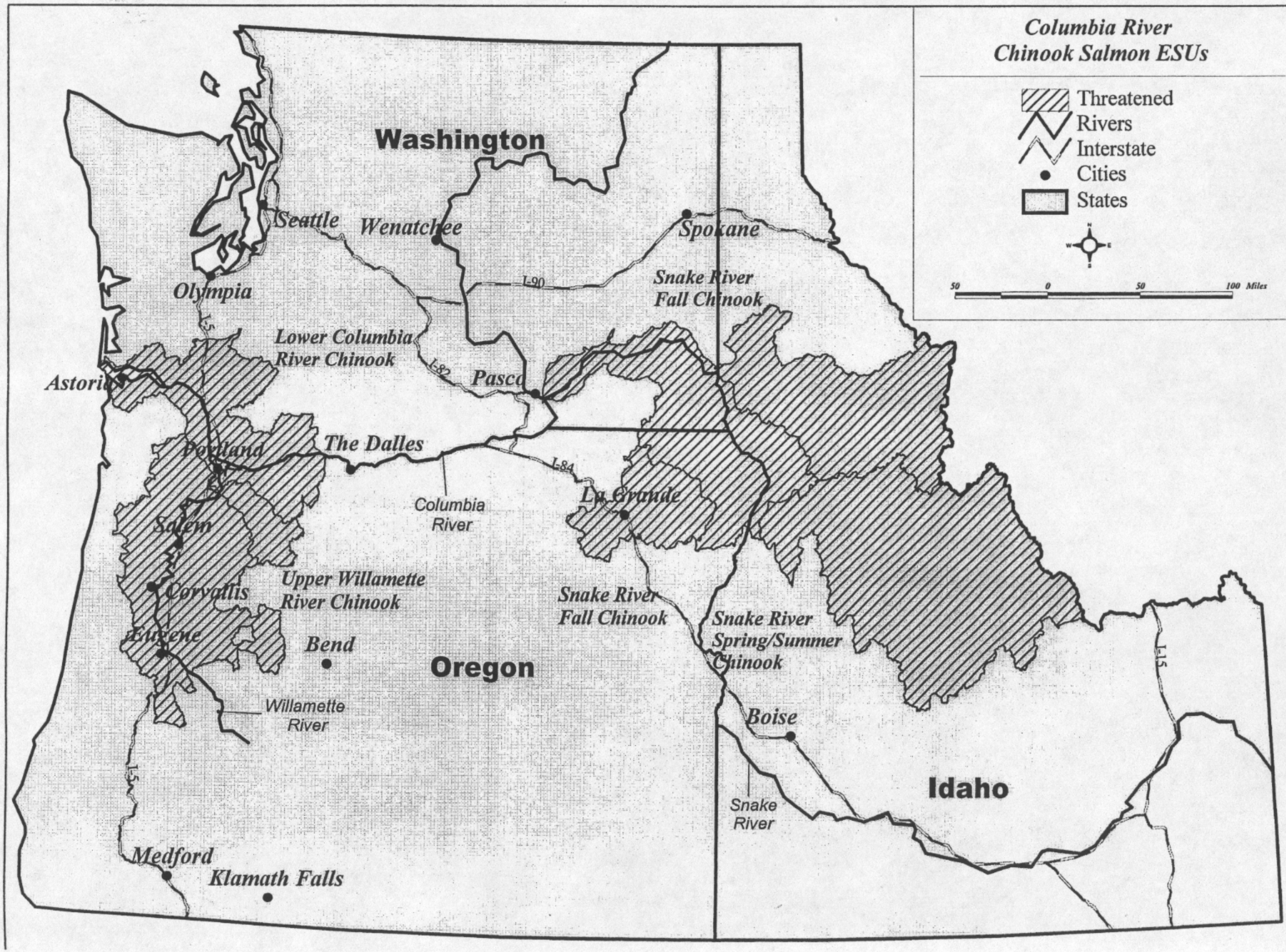
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Astoria
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Portland
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I-84
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River
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Salem
Upper Willamette
River Chinook
Corvallis
Snake River
Fall Chinook
Snake River
Spring/Summer
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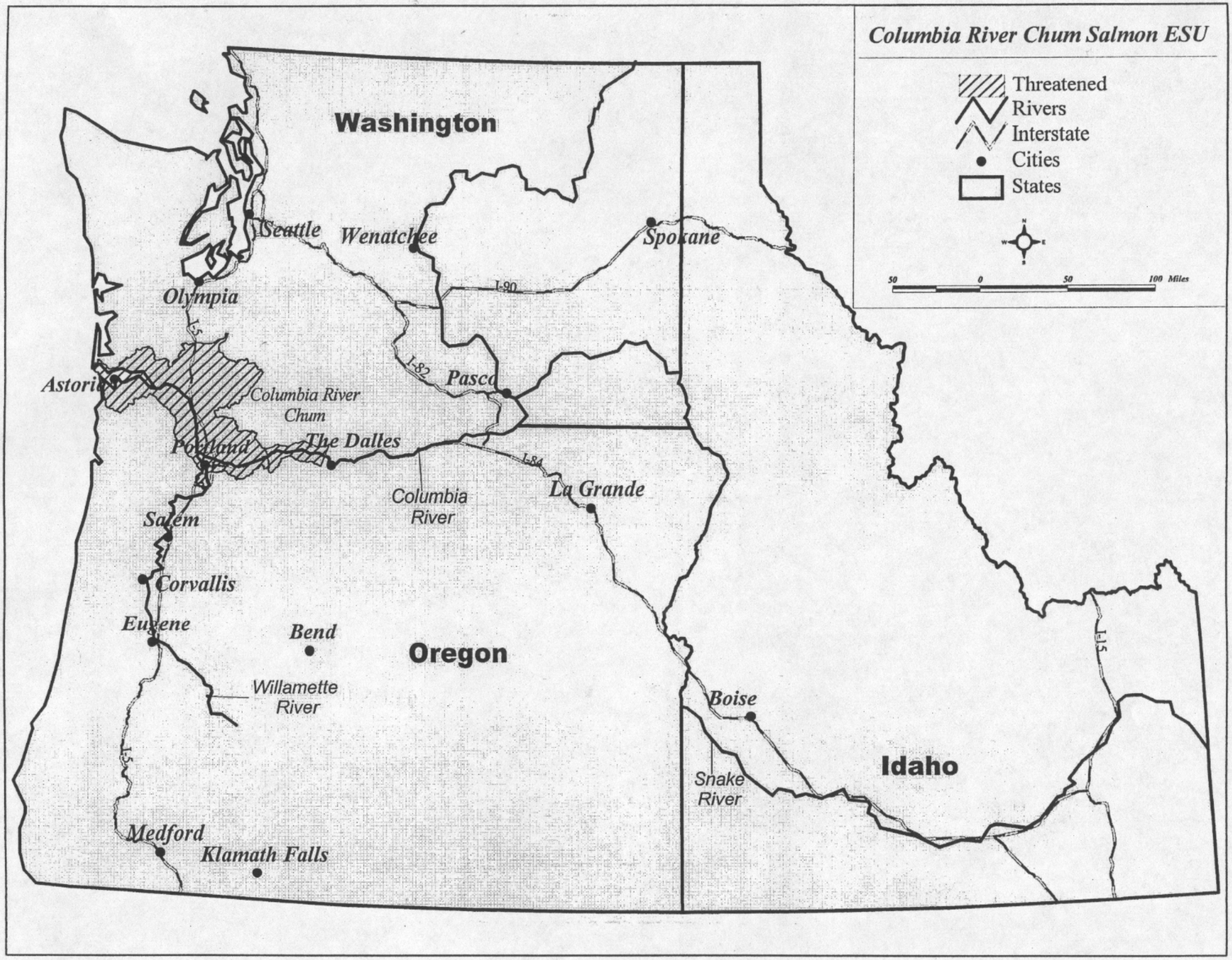
Snake
River
Medford
Klamath Falls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Columbia River
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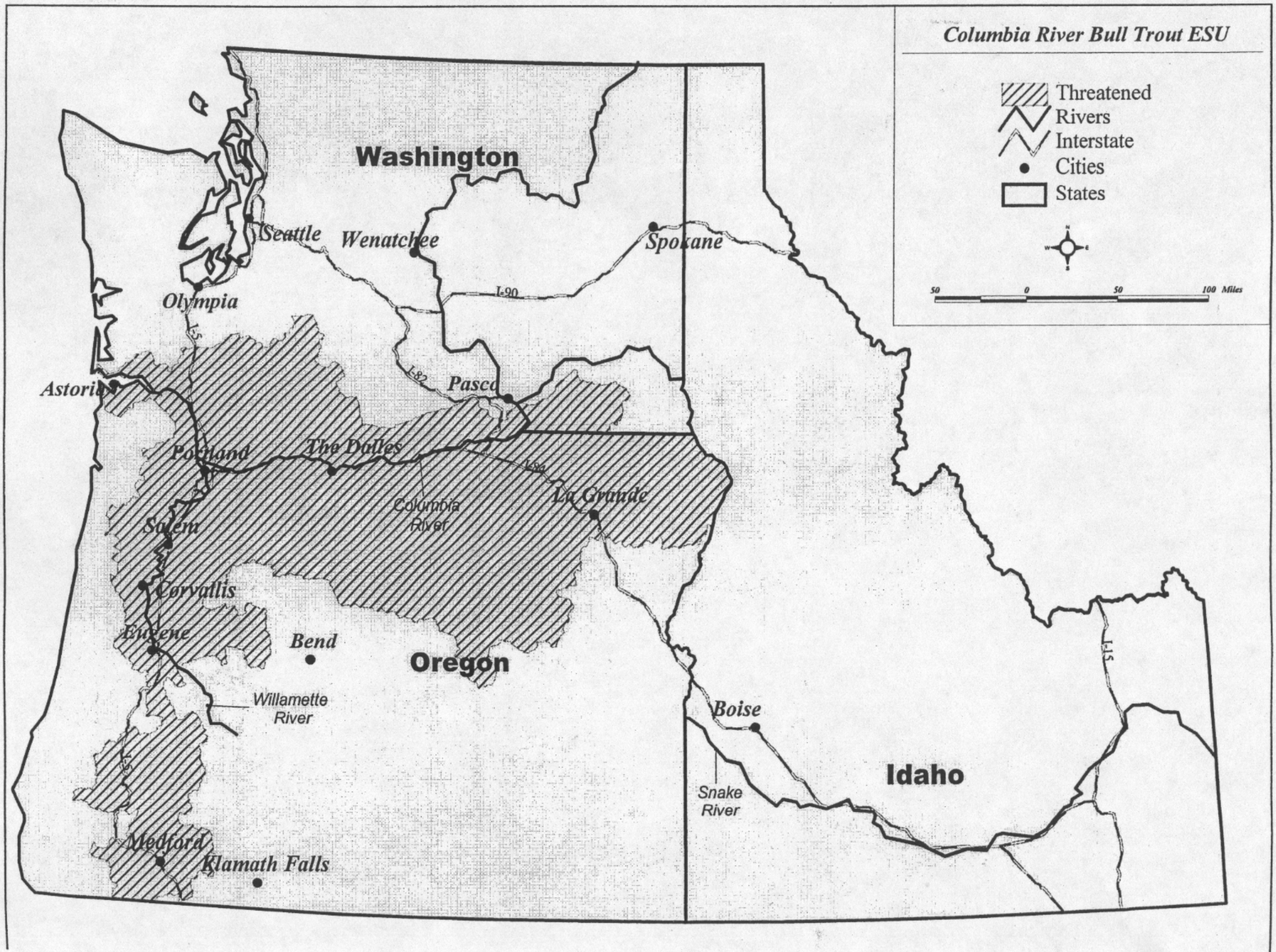

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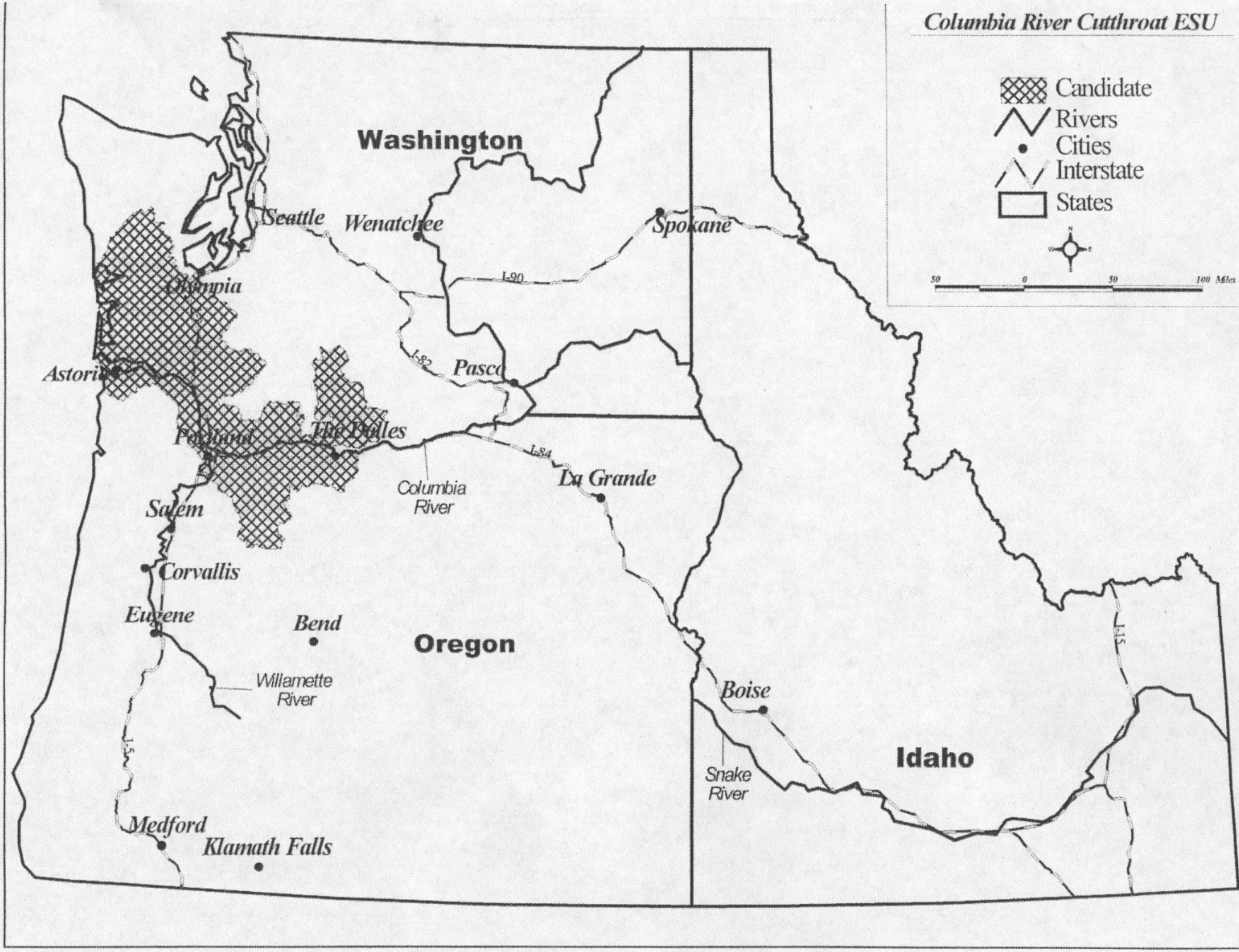
Klamath Falls



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Portland
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Columbia River
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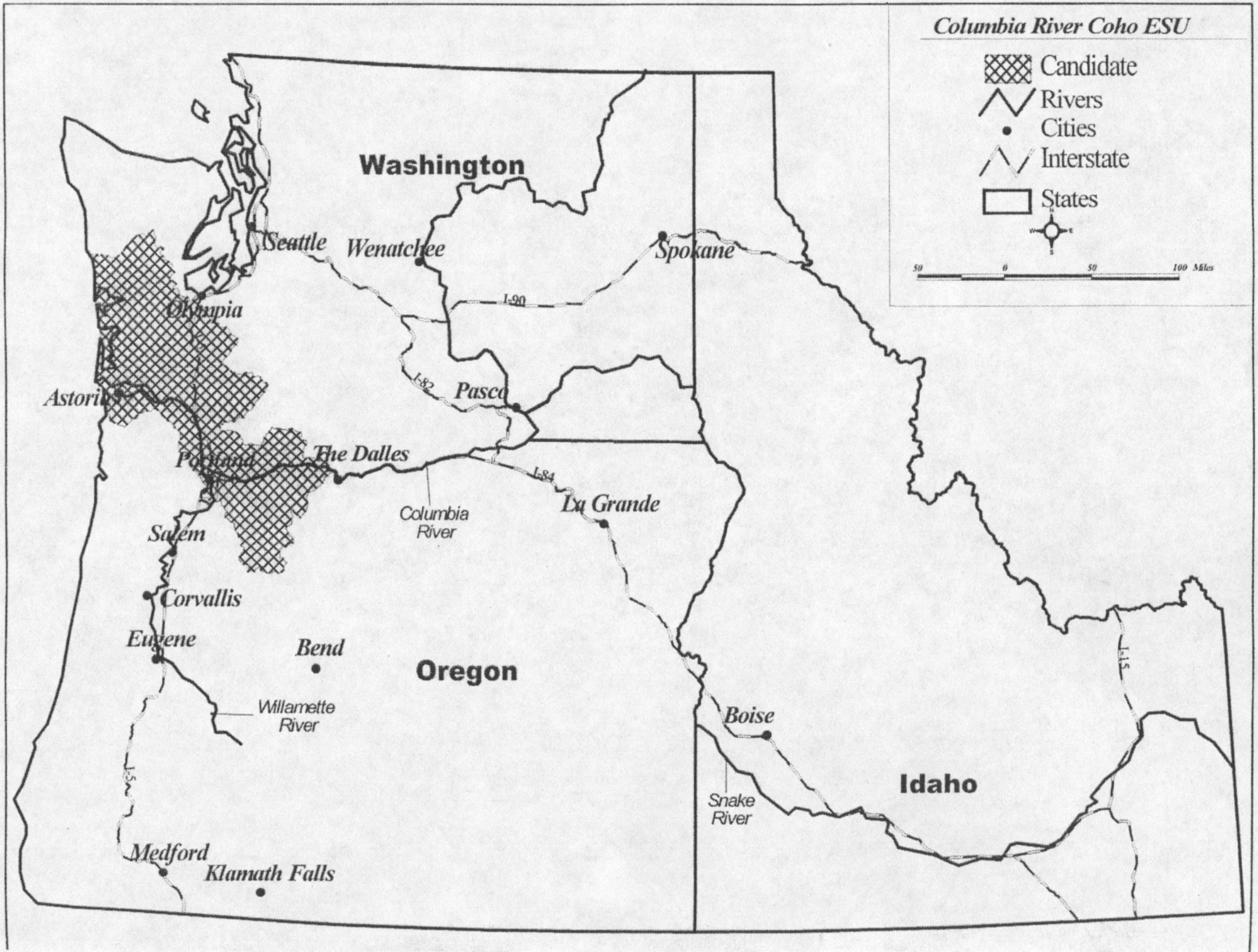

Columbia River Coho ESU
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Astoria
Portland
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Columbia
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La Grande
Salem
Corvallis
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Bend
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Willamette
River
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Medford
Klamath Falls
Boise
Snake
River
Idaho
I-15

D-2 USE AND IMPORTANCE OF THE LOWER COLUMBIA RIVER, ESTUARY, AND OCEAN PLUME TO COASTAL CUTTHROAT TROUT

2.1 Introduction

Coastal cutthroat trout, *Oncorhynchus clarki clarki*, have been studied for many years throughout their geographic range. Regardless, there has never been a concerted effort to obtain for this subspecies the type of information that is commonly collected for management of commercially harvested salmonids. Data on these fish are most often obtained incidentally during studies targeting other salmonids. Interest and concern for coastal cutthroat trout has increased in recent years due to declining numbers in some areas. The Southwest Washington/Columbia River Evolutionarily Significant Unit (ESU) of coastal cutthroat trout was recently proposed for listing as threatened under the Endangered Species Act (Johnson, et al., 1999; National Marine Fisheries Service [NMFS], and U.S. Fish and Wildlife Service [USFWS], 1999). This situation has heightened concerns about the possible effects on this subspecies of proposed routine dredging of the Columbia River shipping channel. Coastal cutthroat trout are known to use the Columbia River's lower reaches and associated marine environs during various stages of their complex life history, however, details of this use are not well understood and available information has not been well synthesized. The purpose of this document, therefore, is to draw together available information about use of the lower Columbia River, estuary, and ocean plume by coastal cutthroat trout to assess the use of this area by this subspecies.

2.1.1 *Objectives:*

- Assemble available literature on this subject from the area of interest and from highly similar areas
- Include, as available, information from phone interviews with fisheries professionals familiar with cutthroat in the lower Columbia or similar ecosystems
- Determine from the information above, describe where, when, how, and why coastal cutthroat use (or used) the area of interest
- Assess deficiencies in existing information and identify other pertinent data that is unpublished
- Suggest future research needs and methods for studying coastal cutthroat trout in the area of interest

The discussion will be summarized by selected key topics important to an understanding of cutthroat trout in the lower Columbia system.

2.2 Background

2.2.1 *Study Area*

The geographical area considered in this paper includes the lower Columbia River and sloughs from the city of Portland to the estuary, the estuary itself, and the plume of reduced salinity water (<26 psu, Pearcy and Fisher, 1990) that extends beyond the river mouth into the ocean (Figure D2-1). The ocean plume varies in size seasonally with ocean currents and river discharge, often extending over 50 km offshore and up and down the coast during spring and summer months (Loch and Miller, 1988; Pearcy, et al., 1990; Pearcy, 1997). The estuary is considered to have three zones that also vary somewhat in size seasonally with river discharge: a high salinity marine zone at the river mouth, an estuarine mixing zone, and a tidally influenced, mainly freshwater zone at the upper end of the estuary, referred to as the lower riverine reach in this document as shown in Figure D2-1 (Bottom, et al., 1984; Simenstad, et al., 1990). The upstream boundary of the lower riverine reach is 75 km (47 miles) from the river mouth, and is about 20 km above the maximum extent of salinity intrusion during the low river flow season (Simenstad, et al., 1990). The portion of the study area upstream from this boundary extends from River kilometer (RKm) 75 to about RKm 170, in Portland, and is referred to here as the upper riverine reach. Both riverine reaches are tidally influenced, and tides normally reverse downstream flow up to 115 km from the river mouth (Dawley, et al., 1986).

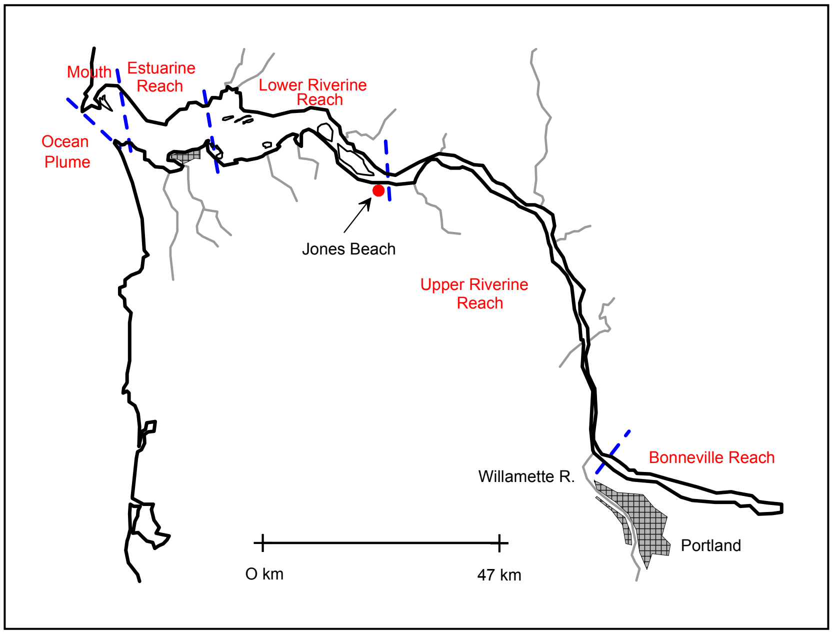

Figure D2-1: Study Area Map Showing the Lower Columbia River, its Estuary, and Ocean Plume, with Principal Subdivision Used in this Document Indicated

The Columbia River in the upper riverine reach (Figure D2-1) is a large, low gradient stream with numerous islands and predominantly fine substrate. It is subject to large seasonal differences in discharge: peak flows typically occur in spring and early summer, with low flows in the fall, and low but variable flows in winter (Sherwood, et al., 1990). Historically, the difference between high and low flows was greater than at present, but dam operations and irrigation withdrawals have damped the hydrograph and reduced mean flow, with greatest changes in both since 1960 (Sherwood, et al., 1990). Winter high flows (November through March) originate mainly from tributaries west of the Cascade Mountains, whereas the spring freshet (April-June) derives mostly from snowmelt in tributary basins east of the Cascade crest (Simenstad, et al., 1990). The study area, which lies entirely west of the Cascade crest, receives inflow from numerous tributaries, of which the largest are the Willamette, Cowlitz, and Lewis Rivers (Figure D2-2).

The Columbia River estuary is a highly dynamic and variable environment with high river flows and strong tidal currents that may limit fish productivity by controlling prey availability and predator's feeding efficiencies (Haertel and Osterberg, 1967; Bottom, et al., 1984; Bottom and Jones, 1990). Variability in the estuary environment is, as in most of the world's large estuaries, both seasonal and annual (Sherwood, et al., 1990; Monoco, et al., 1992). Significant morphological changes to the river and estuary have taken place over the past 150 years, stemming largely from diking, dredging, draining of wetlands, and removal of large woody debris (Maser and Sedell, 1994; Sherwood, et al., 1990). The ocean plume may be affected less directly by human activities, but its environment is also highly dynamic due to influences of river input and variable ocean conditions (McLain, 1984; Lawson, 1993; Pearcy, 1997), and river input is greatly affected by the operation of dams for flood control and hydropower generation (Sherwood et al. 1990).

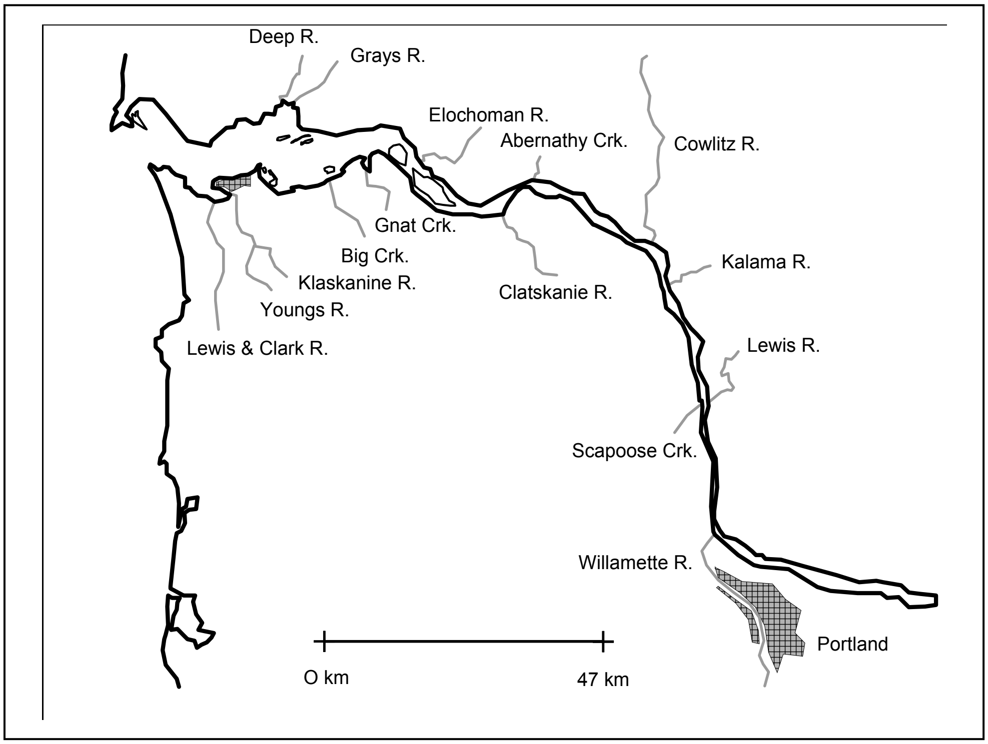

Figure D2-2: Main Tributaries of the Columbia River Within the Study Area (Not all Creeks are Shown)

Outside the study area, but inseparable from it in importance to coastal cutthroat trout, are the numerous tributaries to the lower Columbia River where this subspecies spawns and initially rears (Figure D2-2). Perhaps the most significant change to these streams in the recent past for coastal cutthroat was extensive logging that is thought to have damaged spawning and rearing habitat in many watersheds on the Washington side (Crawford, et al., 1980; Leider, 1997; Blakely, 2000). Similarly, Hooten (1997) attributed probable declines in coastal cutthroat abundance in Oregon tributaries of the lower Columbia to habitat impacts from a variety of land and water-use activities.

2.2.2 Geographical Distribution of Coastal Cutthroat Trout

Coastal cutthroat trout are found in the coastal plains of western North America from southeastern Alaska to northern California (Trotter, 1989). The eastern range of the subspecies rarely extends farther inland than 160 km (usually less than 100 km), and appears to be bounded by the Cascade Mountain Range in California, Oregon, and Washington, and by the Coast Range in British Columbia and southeastern Alaska. This range coincides closely with the coastal temperate rain forest belt defined by Waring and Franklin (1979). The subspecies appears highly adapted to this region. Even when the fish have access beyond the coastal rainforest, as in the Columbia or Stikine rivers, they penetrate only a limited distance inland (Sumner, 1972; Trotter, 1987, 1989).

In Washington and Oregon, coastal cutthroat trout are widespread west of the crest of the Cascade Mountains. Historically, their range may have extended past the Cascade crest into tributaries of the Columbia River as far eastward as the Klickitat River at RKm 290 (Bryant, 1949). At present, freshwater forms (migrants and non-migrants) of coastal cutthroat trout are found at least to the Klickitat River, on the Washington side of the Columbia River east of the study area (Blakely, et al., 2000), and to 15-Mile Creek on the Oregon side (Kostow, 1995). Blakely, et al. (2000), Leider (1997), and Hooten (1997) conclude that current distribution of sea-run fish in the Columbia River appears to be confined to tributaries downstream from Bonneville Dam (RKm 235).

2.2.3 Status of Lower Columbia River Coastal Cutthroat Stocks

NMFS recently completed a comprehensive status review of coastal cutthroat trout populations in Washington, Oregon, and California, which identified six ESUs within this region (Johnson, et al., 1999). Subsequently, a proposal was issued to list the Southwest Washington/Columbia River ESU as threatened under the Endangered Species Act (NMFS and USFWS, 1999), with a final listing decision pending. The Southwest Washington/Columbia River ESU includes cutthroat trout of all streams tributary to Grays Harbor, as well as all populations in Washington coastal streams from Grays Harbor south to the Columbia River, including those of Willapa Bay, and streams entering the lower Columbia River as far east as, but not including, the Deschutes River. Populations in the Willamette River above Willamette Falls comprise a separate ESU.

Abundance of coastal cutthroat trout in the Southwest Washington/Columbia River ESU is considered depressed, particularly in lower Columbia River tributaries. The proposed listing was based on negative abundance trends throughout the ESU, particularly for anadromous forms (NMFS and USFWS, 1999). These declines are mainly attributed to extensive habitat degradation and high potential for negative interactions with hatchery-produced cutthroat and other salmonids, especially coho salmon (NMFS and USFWS, 1999).

2.2.4 Generalized Life History of Coastal Cutthroat Trout with Reference to Columbia River Stocks

Life history forms

Coastal cutthroat trout belong to the same genus as Pacific salmon and steelhead (*Oncorhynchus*), but they are generally smaller, rarely overwinter in the sea, and usually make less extensive oceanic migrations compared to other members of this group. Unlike Pacific salmon, coastal cutthroat trout are capable of spawning in successive years, and adults have been known to spawn each year for more than 6 years (Trotter, 1989). The life history of coastal cutthroat trout is perhaps the most complex of any Pacific salmonid (Northcote, 1997; Johnson, et al., 1999), with four life-history forms widely recognized: resident (non-migratory), adfluvial (lake migrants), fluvial (stream and river migrants), and anadromous or sea-run (saltwater migrants). A trait in common is that all forms tend to spawn in small tributary streams. Resident cutthroat, which complete their entire life cycle in their natal stream, are often found above barriers to anadromous migrations, but they also occur where there is access to the sea (Johnson, et al., 1999). Migratory cutthroat trout juveniles typically rear in small tributary streams for 2-3 years before traveling to either a lake (adfluvial), a river (fluvial), or saltwater (anadromous) on a feeding migration (Northcote, 1997). Multiple forms may occur within a single watershed (Johnston, 1982), and individuals may switch among migratory strategies, skipping seaward migrations in some years (Tomasson, 1978). To a limited extent, resident fish can produce migratory offspring, and visa versa (Johnson, et al., 1999). It is thought that this great behavioral flexibility and life-history diversity may help cutthroat trout respond to changing environmental conditions and allow them to exploit habitats not fully utilized by other salmonids (Johnson, et al., 1999; Johnston, 1982; Northcote, 1997). The following sections pertain to the fluvial and anadromous forms, which may both occur in the study area, but they will focus mainly on the anadromous or sea-run form which is likely the more abundant.

Spawning, incubation, and early rearing

Anadromous cutthroat trout spawn in Washington and Oregon streams from December to May, with peak activity in February (Pauley, et al., 1989; Trotter, 1989). They typically spawn in small, low-order streams, above or slightly overlapping coho salmon and steelhead spawning areas in systems where these species live together (Lowry, 1965; Edie, 1975; Johnston, 1982). Anadromous cutthroat spawn in tributaries with summer low flows often averaging only 0.1 cubic meter per second and seldom exceeding 0.3 cubic meter per second (Johnston, 1982). This choice of locations is believed to have evolved to reduce competition with coho and steelhead for spawning sites and for resources for juvenile rearing (Johnston, 1982; Johnston, et al., 1999). The degree of straying by mature sea- run cutthroat returning to their natal streams has not been clearly defined by studies conducted to date (Johnson, et al., 1999). Early studies of Oregon coastal streams suggested a high rate of straying that may have been real or due to juveniles on feeding migrations to non-natal streams or due to poor imprinting of hatchery fish on the rivers where they were released (Giger, 1972). From their studies of Alaskan and Puget Sound cutthroats, Jones (1976) and Johnston (1982) also believed that fish captured in non-natal streams were mainly immatures on feeding migrations. Campton and Utter (1987) concluded from an analysis of allele frequencies that homing of Puget Sound fish to natal tributaries was highly precise. Tagging data from the lower Columbia River suggest that straying among tributary streams may occur there at an unusually high rate, although this phenomenon remains to be substantiated (Loch, pers. comm., 2001).

Cutthroat eggs typically hatch after 6 or 7 weeks of incubation, and fry emerge from the gravel from March through June, with the peak emergence occurring in mid-April over much of the species range (Trotter, 1997). The fry, which are about 25 millimeters (mm) long at emergence, quickly migrate to channel margins, side channels, and backwaters, collectively referred to as "lateral habitats", where they may remain for several weeks until large enough to cope with higher velocities farther off shore (Glova and Mason, 1976; Moore and Gregory, 1988). Juvenile cutthroat generally remain in small, upper tributary streams for one year before dispersing more widely within their natal river system, if migratory (Trotter, 1997). As discussed in Trotter (1987) and Johnson, et al. (1999), the published literature leaves some uncertainty about habitat preferences of juvenile cutthroat during the growing season once they have left lateral habitats. When cutthroat are the only species present, some workers report that the fry prefer pools (Glova, 1984); others report that the fry prefer low gradient riffles and pool tailouts, while older fish prefer pools with large woody debris and residual depths of at least 0.3 meters (Bisson and Sedell, 1984; Lisle, 1987). Competitive interactions with coho (Glova, 1984) or steelhead (Hartman and Gill, 1968) of similar size usually end in displacement of cutthroat trout from preferred stream habitats. For overwintering, pools near cover from undercut banks and large woody debris are favored habitats of juvenile cutthroat (Bustard and Narver, 1975). Most anadromous cutthroat remain in freshwater for 2 to 4 years before smolting and migrating to saltwater, although the observed range is 1 to 6 years (Giger, 1972a; Lowery, 1975). Young cutthroat grow considerably during this period of freshwater residence, attaining lengths of about 150 to 300 mm before smoltification in streams from Oregon to Alaska as shown in Table D2-1 (Johnston and Mercer, 1976).

Coastal cutthroat trout are opportunistic feeders and generalists during their period of stream residence, usually taking advantage of whatever prey is available (Trotter, 1997). For example, age-0 to age-2 cutthroat coexisting in a Bogachiel River tributary all ate the same diet and switched from aquatic to terrestrial insects as the latter prey became more abundant (Martin, 1984). Aquatic insects are often the most available and therefore the dominant food item in streams (Pauley, et al., 1989; Trotter, 1997); however, age-1 and older cutthroat may eat coho fry less than 50 to 60 mm in length when available (Fransen, et al., 1993). Stream dwelling cutthroats may also feed on salmon eggs at times (Johnston, 1982), although this resource may more often be exploited by Dolly Varden/bull trout (Johnston, pers. comm., 2001).

Table D2-1: Freshwater Growth of Juvenile Sea-Run Cutthroat Trout

Location	Age in Years I	II	III	IV	V
Oregon	107	132	175-234	211-253	280
British Columbia	49-89	84-112	156-183		
Washington			163-189	200	

Source: Johnston and Mercer (1976)

Note: Fork lengths are in millimeters and all data were from the spring of the year references.

Estuarine and marine residence

Emigration to saltwater occurs from March through July, and varies locally. For Washington and Oregon populations, outmigration begins as early as March, peaks in mid-May, and is complete in mid-June (Johnson, et al., 1999). Smolting appears to be more dependent on size than age (Trotter, 1997), and a relationship between age and size at smolting and severity of the saltwater environment that smolts will be entering has been suggested, but not confirmed (Johnston, 1982; Johnston, et al., 1999). In the protected waters of Puget Sound, smolts are mainly age-2 and average about 160 mm (Johnston, 1982). In less hospitable waters of the open coast, smolts are often older and larger. Fuss (1982) found that smolts from Washington coastal streams were predominantly age-3 and age-4, and measured over 200 mm in length. There is some variation in the age at which Columbia River sea-run cutthroat smolts enter the estuary and ocean plume. Chilcote (1980) and Tipping (1981) reported that wild smolts from two lower Columbia tributaries (Kalama and Cowlitz Rivers) were about 65 percent age-2, 35 percent age-3, and a small fraction age-4, with an average length of about 160 mm. From sampling in saltwater, Loch and Miller (1988) and Pearcy, et al. (1990) concluded that most hatchery origin sea-run cutthroat migrated to the Columbia River estuary and ocean plume at one year of age, whereas all wild smolts first entered salt these environments at age-2 or age-3 (Table D2-2).

Table D2-2: Age and Length of Hatchery and Wild Cutthroat Trout Sampled in the Columbia River Estuary and Ocean Plume

Location	Stock	Age	Sample Size	Mean Fork Length (mm)	SD	% Total
Estuary	Hatchery	1.+	88	290.6	28.5	85%
“	“	1.+F+	10	362.9	44.7	10%
“	“	1.+S+	4	393.3	29.6	4%
“	“	1.+F+S+	1	389	-	1%
“	“	Total	103			100%
“	Wild	2.+	6	294.2	45.6	30%
“	“	2.+F+	2	364.5	3.5	10%
“	“	2.+S+	3	387.3	2.5	15%
“	“	2.+S+S+	1	466	-	5%
“	“	2.+F+S+S+S+	1	445	-	5%
“	“	3.+F+	1	410	-	5%
“	“	3.+S+	3	375.3	21.1	15%
“	“	3.+F+S+	2	410	14.1	10%
“	“	3.+F+S+S+S+	1	520	-	5%
	“	Total	20			100%

Plume	Hatchery	1.+	7	260.3	18.9	78%
"	"	1.+F+	2	298	25.5	22%
"	"	Total	9			100%
"	Wild	2.+	6	287.7	41.4	67%
"	"	2.+S+	1	365	-	11%
"	"	2.+F+S+	1	415	-	11%
"	"	3.+S+S+S+	1	470	-	11%
"	"	Total	9			100%

Source: June to September 1980, from Loch, 1982.

Note: Age designation: Number left of decimal is winters in freshwater before smolting; to the right of the decimal each letter indicates one additional season of growth in freshwater (+F) or in the estuary or plume (+S)

The amount of time spent in salt water and distance migrated from the home stream varies among populations. At the extremes, cutthroats spend from 2 to 8 months in salt water before returning to freshwater (Thorpe, 1994). Some populations seldom venture into salt water farther than the estuary of their home stream (Tomasson, 1978; Northcote, 1997). Tipping (1981) thought that cutthroat smolts on their first seaward migration from the Cowlitz River moved no farther than the Columbia estuary. In most systems, cutthroat remain within a few kilometers of shore, do not cross large bodies of open water after reaching salt water, and migrate no more than about 70 km along shore from their home stream (Johnston, 1982; Trotter, 1997). In a few situations, most notably the Columbia River plume, cutthroats migrate to open marine waters with riverine influence over 50 km from shore (Loch and Miller, 1988; Pearcy, et al., 1990; Pearcy, 1997).

While in the estuary and at sea, cutthroats typically feed opportunistically on a variety fish and invertebrates (Pauley, et al., 1989; Trotter, 1997), often foraging in waters no more than a few meters deep (Johnston, 1982), except for populations that use marine waters as noted above (Pearcy, 1997). In sheltered waters, cutthroats seek gammarid amphipods, isopods, shrimp, as well as small fish such as sticklebacks and baitfish in shallow habitats such as sand bars, gravel beaches, creek mouths, eel grass patches, and oyster beds (Giger, 1972; Simenstad and Eggers, 1981; Trotter, 1997). Cutthroats prey in open marine waters commonly includes crab megalops, mysids, euphausids, and small fish such as greenlings, cabezon, and anchovy (Loch and Miller, 1988; Pearcy, et al., 1990; Pearcy, 1997). Other salmonids, such as juvenile pink and chum salmon, are sometimes an important prey of cutthroats in saltwater (Trotter, 1997). Growth in salt water can be rapid. Sea-run cutthroats in the Columbia River plume grow at a rate of about 25 mm per month (Pearcy, et al., 1990). Over their range, sea-run cutthroats are typically about 300 to 330 mm in length on their first return to freshwater, and they reach a maximum length of about 500 mm after multiple migrations (Trotter, 1997).

Return migration to fresh water

Nearly all cutthroat trout overwinter in freshwater after feeding in marine or brackish waters for several months (Trotter, 1997; Johnson, et al., 1999). An exception to this rule occurred in the Squamish River estuary (British Columbia) where Levy and Levings (1978) captured cutthroats in all months except April and May. In most systems, not all fish spawn on their first return because few anadromous cutthroats are sexually mature until their fourth or fifth year of age (Trotter, 1997). In the Cowlitz River, at first return from salt water hatchery and wild females were 62.5 percent and zero percent mature, respectively (Tipping, 1981). The return time of fish to fresh water appears to vary by type of river. Coastal streams with appreciable estuaries, large Puget Sound rivers, and the Columbia River typically have early-entry stocks that return to freshwater July through October, often with peak migrations in September and October (Trotter, 1997). Small streams draining directly into marine waters often have late-entry stocks, which remain in salt water until mid winter (Johnston, 1982). In some systems, anadromous cutthroat feed actively on their return migration to freshwater (Johnston, 1982), while other populations appear to feed little in tidewater areas in the summer and fall, despite abundant food sources Giger (1972). Columbia river cutthroat feed actively on their return to the estuary and tidewater (Loch, 1982).

The published literature contains no data about the overwintering period of sea-run fish in fresh water. Trotter (1997) speculates that instream behavior, habitat choice, and foraging may be similar to that of older pre-migrant juveniles, with fish holding in sheltered habitats such as deep pools with cover. In the Fraser River, a British Columbia stream nearly as large as the Columbia River, many coastal cutthroats greater than 200 mm in length overwinter in lower river freshwater back-channels that they do not typically occupy in the summer (Rempel, 2001a). These are protected pockets during winter low flows that convey high flows during spring freshet. Stomachs from 5 such fish sampled in February and March 2000 contained as a percentage of total stomach volume, plant material (28 percent), Trichoptera nymphs (22 percent), Chironomidae pupae (7 percent), Ephemeroptera nymphs (5 percent), plus other assorted insects and invertebrates (Rempel, 2001b).

2.3 Findings on Selected Key Topics Relative to the Study Area

2.3.1 Occurrence of Cutthroat Trout by Location and Time

Knowledge of where and when cutthroat trout occur in the study area is essential to a basic understanding of their migrations, life history, and living requirements. Additional information about abundance, age, and size of cutthroats is also important for informed management decisions. What is known of these subjects from studies conducted in the area of interest is presented below.

Studies of Columbia River tributaries in Washington show that age-1 juvenile cutthroats migrate downstream from March to June, with peak movement typically occurring in May (Chilcote, 1980; Chilcote, et al., 1980; Blakely, 2000). However, available information does not clearly indicate whether any of these fish rear for any appreciable time in the upper riverine reach of the Columbia River (Figure D2-1) prior to smolting, or if it is used mainly as a migratory corridor. Some cutthroats clearly do not stay in the river for long, as a large fraction of hatchery origin sea-run cutthroat captured in the estuary and ocean plume had reached salt water at age-1, as shown in Table D2-2 (Loch and Miller, 1988; Pearcy, et al., 1990). Wild fish captured in the salt water had spent at least two winters in freshwater, so they may have reared for a time in the upper riverine reach. Loch (pers. comm., 2001) believes that the downstream portion of the upper riverine reach, from about Longview to Jones Beach, may be a transitional zone between river and estuary, where juvenile salmonids feed and complete their adaptation to salt water. Length of stay varies: some do not complete the transition and remain in the river, while others move into the estuary or migrate to sea (ibid.). Out-migrant cutthroat often feed for an extended period in this transitional zone, and many hatchery cutthroats residualize there (ibid.). This behavior has been well documented at Jones Beach were sampling was extensive (Loch, 1982), but data for areas farther upstream are fragmentary and only suggestive. Loch (pers. comm., 2001) believes that portions of the upper riverine reach above Longview may be generally less hospitable to juvenile cutthroat in terms of food and habitat, and may therefore serve more as a migratory corridor than as a long-term rearing area.

Sport fishery catch records show that adult and immature fish returning from the estuary and the sea are captured in the upper and lower riverine reaches, mainly from Jones Beach to the Cowlitz River, mostly from July through September (Schuck, 1980; Melcher and Watts, 1995; Melcher, 1996; Trotter, 1997). The implication of declining catches after September is that the fish have moved to other locations, probably into the tributaries to overwinter and, if mature, to spawn. It is possible that some cutthroats may overwinter in the riverine reaches of the Columbia or in the estuary. Lucas (1997) states that immature sea-run cutthroat trout from lower Columbia tributaries may overwinter in deep tributary pools or in the estuary, but no substantiating data were presented. Dawley, et al. (1985) collected few cutthroats in the lower riverine reach and the estuary during the winter, suggesting that few cutthroats overwintered in those areas. This conclusion is open to question, however, because sampling was scant during this period and did not include all habitats that cutthroats may have used (see sections below). As mentioned previously, in the Fraser River many smolt-size and larger coastal cutthroats overwinter in lower river freshwater back-channels (Rempel, 2001a).

Based on sampling at Jones Beach at the upstream end of the lower riverine reach (Figure D2-1) from 1977 to 1983, Dawley, et al. (1985) reported that coastal cutthroat were in the area March through November, with peak abundance occurring in April through June and in August through September; few fish were present in the winter. These authors did not present age and size information for cutthroat, but they state that the migration of spawned out adults peaked in May (Dawley, et al., 1979 and 1980). An extensive sampling program for sea-run cutthroat and steelhead trout was conducted at Jones Beach as well as several sites in the estuary in 1980 (Loch, 1982). The few cutthroat smolts that were captured during this program were taken in the lower and central estuary from April through June. Adult cutthroat were sampled at Jones Beach and in the estuary from July 8 through the end of August. Catches of adults peaked during the last week of July in the estuary and during the first week of August at Jones Beach, indicating that the fish were migrating riverward. The size of adult fish in the estuary was largest in July, and decreased thereafter, following the often-observed pattern that the largest cutthroat migrate streamward first (Trotter, 1997). At Jones Beach, the size of cutthroat increased over time, however. Loch (1982) determined from scale characteristics that 90 percent of the fish at Jones Beach were age-1+ hatchery stock, and he concluded that they remained in the area and grew throughout the summer (Table D2-2). Age-1+ hatchery fish were also found throughout the estuary, whereas all wild fish examined were older and had spent at least 2 winters in freshwater (Loch, 1982).

Appendix D-3 of this BA is an analysis of beach and purse seine data collected by NMFS between 1967 and 1980 to determine spatial and temporal trends in size and abundance of coastal cutthroat trout in the estuary. Sampling coverage varied greatly from year to year, but some general patterns were suggested by results. In four of five years, cutthroats were captured along the shoreline (beach seine) only in August and September in the lower two-thirds of the estuary (mouth and estuarine reach, Figure D2-1), and from February through September in the upper one-third of the estuary (lower riverine reach). Cutthroats were commonly taken in the deeper channel (purse seine) throughout the estuary from April through August, the whole sampling season for this gear. Somewhat higher catch rates in the middle and upper estuary suggest that cutthroats were more abundant there than in the lower estuary where catch rates tended to be lower. Frequent catches of more than one cutthroat per set, when any were caught at all, indicated that some schooling occurred, but most multiple fish catches were only two to three fish. Trends in size of cutthroat by time of year and portion of the estuary were not clear. The over all mean fork length was 283 mm for beach-seined fish and 285 mm for purse-seined fish, with a range of about 120-530 mm for both gears.

Nearly all sea-run cutthroat that have been captured in marine waters off the Washington and Oregon coasts occurred within the bounds of the Columbia River plume, 10 to 50 km offshore and 55 km up or down coast from the river mouth (Loch, 1982; Loch and Miller, 1988; Pearcy, 1997). These fish tended to drift southward in the plume with prevailing currents, and limited data suggest that they were only present in marine waters from May through August, presumably returning to the estuary afterwards (the last catches of cutthroats were in August, but sampling in the plume was not performed after early September). While in the plume they fed intensively and grew rapidly, about 1 mm per day, and they showed no tendency toward schooling (Pearcy, 1997). Cutthroat trout in the plume were found in waters with a depth of 30 to 134 meters and did not frequent shallower shoreline waters (Dawley, et al., 1985; Pearcy, and Fisher, 1990). Their depth distribution within the water column was not determined, but the nets used over the years fished from the surface to depths ranging from 20 to 60 meters (Pearcy and Fisher, 1990).

2.3.2 Habitat Use and Preferences

Understanding the habitat requirements and preferences of coastal cutthroat trout is important for their preservation and management. Given the complex life history of coastal cutthroat trout and the high degree of scientific uncertainty associated with it, defining specific habitat requirements for this species is difficult (NMFS and USFWS, 1999). Potential cutthroat habitat within the study area constitutes rearing and foraging habitat, and a migratory pathway. Considering the strict requirements of the species for spawning and age-0 rearing, these activities are probably restricted to tributary streams and are very unlikely in the study area.

Information about coastal cutthroat trout habitat use and preferences in upper riverine reach (Figure D2-1) of the Columbia is very limited. Trotter (1987) states that in many streams, returning sea-run cutthroat favor quieter pools, where the water deepens and slows, and that places of this type with added habitat complexity and cover from boulders, log jams, or overhanging brush often attract cutthroats. Available information for the Columbia does not clearly indicate migration path preferences or whether age-1 or older cutthroat rear for extended periods in the upper riverine reach (also see discussion of occurrence by location in previous section). Near the upper end of this area, Ellis (2000) reported a limited catch of cutthroat trout (three fish) in shallow water of the Willamette River near Portland. Loch (pers. comm., 2001) believes that both out-migrant and returning cutthroat trout in the upper riverine reach prefer shoreline areas where food is available and where in-water structure offers protection from rapid flows and cover from predation. He also believes that tributary mouths are important holding areas. In the lower Chehalis River, another large SW Washington/Columbia River cutthroat ESU stream, the reach immediately below one major tributary confluence (Satsop River) was found to be an important area for juvenile and adult cutthroats alike (Wright, 1973). Sea-run cutthroats returning from the estuary held there, apparently awaiting flows and temperatures favorable for continued upstream migration, and age-0 trout, presumed to include both rainbow and cutthroat juveniles, reared there during the growing season (ibid.). In the upper riverine reach, sea-run cutthroat are captured by the sport fishery from July through October, mainly below the Cowlitz confluence. Fishing takes place along relatively shallow bars where cutthroats forage.

Seining at Jones Beach, near the upper extreme of the estuary, at times captured many cutthroat trout, both offshore in the main channel and along the featureless, sandy beach (Dawley, et al., 1985). In both habitats, most cutthroats were captured during the peak seaward (April to May) and upstream (August to September) migrations. Limited sampling from November through March suggests that few cutthroats overwintered at Jones Beach (ibid.). Little information was given about age or size of the cutthroats, except to say that the migration of spawned out adults peaked in May (Dawley, et al., 1979 and 1980). Dawley, et al. (1985) reported that cutthroat catches in the main channel declined during mid-summer months, while shoreline catches remained relatively high, suggesting that cutthroats reared in shallow littoral habitats at Jones Beach during the summer. Results of beach and purse seine sampling at other sites throughout the estuary, reported in Appendix D-3 of this BA, indicated that cutthroats occurred in the channel throughout the estuary during spring and summer. In the shallows, they were present in the upper estuary spring through summer, but were seldom found in the lower two-thirds of the estuary until August and September (ibid.). Loch (pers. comm., 2001) believes that cutthroat smolts and returning adults favor shallow, nearshore habitats of the estuary where they prey opportunistically on invertebrates and small fish. Ledgerwood (pers. comm., 2001) points out that cutthroats were seldom the target species of the aforementioned studies, and that no study in the Columbia estuary to date has attempted to sample all of the shallow habitat types that cutthroats may commonly use. Ledgerwood (ibid.) believes that cutthroats often occur in shallow habitats more structurally complex than can be sampled with beach seines typically used in the estuary. It therefore appears that studies conducted to date do not clearly describe habitat use by adult or juvenile cutthroat trout in the lower Columbia river and estuary (see Recommended Studies and Methods sections for alternatives).

Within the Columbia River plume, most sea-run cutthroat were captured 10 to 50 km off the Washington and Oregon coasts, in waters with an average surface temperature of 13.4 degrees C and a surface salinity of 28.6 psu (Loch and Miller, 1988; Pearcy, et al., 1990). Sea-run cutthroat in protected waters typically remain within a few kilometers of shore (Johnston, 1982), but they were absent from this zone near the Columbia River mouth, for no apparent reason (Dawley, et al., 1985; Pearcy and Fisher, 1990). No cutthroats were captured near shore off the river mouth where the water was less than 30 meters deep, although they were captured in the estuary and in offshore waters of the plume during concurrent sampling (Dawley, et al., 1985; Loch and Miller, 1988; Pearcy, et al., 1990). Their depth distribution within the water column was not determined, but the nets used over the years fished from the surface to depths ranging from 20 to 60 meters (Pearcy and Fisher, 1990).

2.3.3 Food and Feeding

Coastal cutthroat trout are opportunistic feeders throughout their lives, both in streams and in salt water, taking advantage of what ever prey is most abundant, commonly aquatic insects and other invertebrates as well as small fish when available (Loch and Miller, 1988; Trotter, 1997). No information was found in the literature describing cutthroat feeding habits or diet in the upper riverine reach per se (Figure D2-1). However, Tipping (1981) reported that adult cutthroat trout in the mainstem Cowlitz River fed mainly on terrestrial and aquatic insects. At Jones Beach, near the boundary of the lower and upper riverine reaches, the diet of cutthroats varied seasonally (Loch, 1982). In August, cutthroats (mean fork length 291 mm) consumed mainly fish, gammerid amphipods, and insects, and small shad were the dominant prey (89 percent of stomach contents by weight and 29 percent by numbers, ibid.). In September, cutthroats (mean fork length 304 mm) preyed on cladocerans, mysids, fish, and insects, and shad were again the dominant food item (85 percent of stomach contents by weight and 41 percent by numbers, ibid.). Loch (pers. comm., 2001) believes that, in general, outmigrant juvenile cutthroat in the lower Columbia River favor shallow, nearshore habitats where they prey on invertebrates and small fish, as available. As they progress downstream toward the estuary, aquatic and terrestrial insects give way to gammerid amphipods in dietary importance, and gammerids are especially abundant in mudflats and shallow habitats of the lower river.

In most estuaries, smolts and older cutthroats typically travel in small schools, feeding opportunistically on fish and invertebrates, often in waters no more than a few meters deep (Trotter, 1997). The only detailed description of cutthroat food habits available for the Columbia River estuary comes from sampling conducted throughout the estuary in 1980 with beach seine, purse seine, and fyke nets (Loch, 1982). On their seaward migration through the estuary, sea-run smolts fed chiefly on insects and gammerid amphipods (Loch, 1982; McCabe, et al., 1983; Bottom et al., 1984). Adults returning to the lower estuary fed mainly on Pacific herring, threespine stickleback, and bay shrimp (Loch, 1982). Loch (pers. comm., 2001) believes that cutthroat feed extensively in estuarine habitats that support high food production, such as mudflats for amphipods, and on certain bars were fish such as sand lance are abundant. Simenstad and Eggers (1981) collected five cutthroats averaging 260 mm in fork length (standard deviation = 116 mm) from shallow waters of Grays Harbor, the northwest extreme of the Southwest Washington/Columbia River coastal cutthroat ESU. Stomachs of these fish contained pelagic larvae of *Cancer* sp. crabs (44 percent of total IRI), juvenile smelt (34.4 percent), juvenile salmonids (8.3 percent), greenling (5.1 percent), and unidentified fish (7.9 percent).

In marine waters of the Columbia plume, sea-run cutthroat consumed primarily fish and crustaceans (Brodeur, et al., 1987; Loch and Miller, 1988; Pearcy, et al., 1990). Mysids and euphausids (crustaceans) were dominant in numbers in some places at some times, but fish dominated in biomass (Pearcy, et al., 1990). Northern anchovy, kelp greenling, cabezon, and rockfishes were the predominant fish species eaten and other juvenile salmonids were infrequently preyed on by cutthroats (ibid.).

2.3.4 Interspecific Competition

Competition for food and habitat between coastal cutthroat trout and other fish in the study area is likely, although supporting evidence is circumstantial. Coastal cutthroat trout are fairly unspecialized and adaptable in their feeding habits throughout their life history, making them capable of exploiting the prey items most abundant or desirable at a particular time and location (Loch and Miller, 1988; Trotter, 1997). Johnston (1982) describes coastal cutthroat trout as generalists that spend their lives migrating and filling niches other salmonids least prefer. However, when diet and habitat use by cutthroat trout overlap use by other salmonid and non-salmonid species, as they commonly do in the area of interest (Emmett and Stone, 1991), competition is likely if resources are limited. Releases of hatchery-reared salmonids are recognized as a major potential source of competition for lower Columbia River cutthroat trout in all habitats that cutthroat occupy throughout their life history (Lichatowich and McIntyre, 1987; Johnson, et al., 1999).

Although outside the study area, competitive interactions with hatchery fish in tributary streams have undoubtedly affected cutthroat trout in the study area and should therefore be mentioned here (Hooten, 1997; Leider, 1997). In natal streams, cutthroat fry are displaced from preferred habitats by steelhead and coho salmon of similar size, so cutthroat typically avoid competition by spawning and rearing upstream from the coho zone (Johnston, 1982). The formerly common practice of indiscriminately planting juvenile coho into cutthroat rearing areas of natal streams therefore had a strong negative impact on wild cutthroat trout in the lower Columbia watershed (Leider, 1997; Johnston, pers. comm., 2001). Introductions of hatchery-reared rainbow trout have also impacted wild cutthroat populations in spawning and rearing areas through competition for food and space, as well as through interbreeding (Behnke, 1992). Behnke (1992) considers that the lack of basibranchial teeth in some wild coastal cutthroats of Washington and Oregon streams where rainbow trout have been heavily stocked is evidence of hybridization between these species.

Many potential competitors (and predators) of cutthroat are also found in the upper riverine reach of the study area (Figure D2-1). In a fisheries study near Portland, Ellis (2000) sampled cutthroat trout in shallow water habitat along with largemouth and smallmouth bass, yellow perch, American shad, northern pike minnow, and other species that may compete for resources such as food and habitat. Shad and northern pile minnow occur over the entire extent of the upper riverine reach, and both species were seasonally abundant at Jones Beach (Dawley, et al., 1986). As non-native species, many of the fishes mentioned above have not co-evolved to partition resources with cutthroat trout, and are therefore likely to compete with coastal cutthroat trout for when resources are limited.

In the Columbia estuary, amphipods and insects are a dominant prey of juvenile shad (Hamman, 1981) and out-migrating cutthroat smolts (Loch, 1982) and Bottom and Jones (1990) concluded that the diets of juvenile shad and salmonids overlapped appreciably. Marine mammals and birds foraging on baitfish such as Pacific herring, smelt, and anchovy may also compete for these favored prey items with adult cutthroat trout returning from the sea. Cutthroat trout may also experience competition in marine waters. Off the Washington and Oregon coast, dietary overlap of sea-run cutthroat trout with juvenile chinook and coho salmon is sometimes as high as 60 percent (Brodeur and Pearcy 1992), suggesting that these species may sometimes compete for food. Large-scale hatchery releases of fry and fingerling salmon that are common in the Columbia River have the potential to overwhelm food production capacity and increase competition in estuaries and marine waters (Lichatowich and McIntyre 1987).

2.3.5 Predation on Cutthroat Trout

Predation on coastal cutthroat trout by other fish, birds, and marine mammals in the study area may be substantial, although documentation is rare. In portions of the Columbia River where prey and predator behavior has been disrupted by dams, most notably in impoundments and near the dams themselves, bass and northern pikeminnow are at times important predators on juvenile salmonids in general, with smaller fish likely most vulnerable (Beamesderfer, 2000). Juvenile salmonids can comprise one third of the diet of northern pikeminnow in such locations (ibid.) Birds such as cormorants, belted kingfishers, loons, common merganser, heron, grebes, and other piscivors are likely to be major predators of cutthroats in fresh and brackish waters (Palmisano, 1997). Alcid predators, including auklets, murres, murrelets, Guillemots, and puffins, likely feed on salmonids, which may include cutthroats, in nearshore marine waters (Manuwal, 1977). Collis, et al. (1999, 2000) have measure high levels of predation by terns, cormorants, and gulls on juvenile salmonids in the Columbia estuary in recent years. For example, they estimated that these birds consumed from 10 to 30 percent of all salmonid smolts that entered the estuary in 1998. Caspian terns accounted for nearly 60 percent of this consumption and predation was centered around rookeries on Rice and Sand Islands in the lower riverine reach, see Figure D2-1 (ibid.). Relative predation rates were highest on species with the largest smolts (steelhead and coho) in the riverine reach, and it was speculated that large smolt size, longer residence time in the estuary, and occurrence near the water surface may be factors leading to higher predation rates (ibid.). It was also noted that the number of terns and cormorants nesting in the Columbia estuary has been increasing rapidly since the mid 1980s (ibid.). Although no information was reported on predation by birds on cutthroat trout, all trends mentioned suggest the potential for significant predation on this species; for example, large smolt size and long residency in the estuary could lead to high predation rates on cutthroats. Since these fish-eating birds commonly consume steelhead smolts 200 mm in length, sea-run cutthroat smolts that typically average about 160 mm in length (Tipping 1981) are of a size vulnerable to bird predation (Ledgerwood, pers. comm., 2001).

Northwest pinneped populations have been increasing annually by 3 to 12 percent since passage of the Marine Mammal Protection Act in 1972 (NMFS, 1992), increasing the potential for predation on cutthroat trout. Scarring rates on other salmonids, indicative of attacks from marine mammals, have increased markedly at Columbia River dams where scarring incidence is monitored during fish passage (Harmon and Matthews, 1990; Palmisano, 1997). For Alsea River (Oregon) cutthroat trout in the marine environment, spiny dogfish, harbor seals, and adult salmon were identified as the most likely predators (Giger 1972). Giger reported that 58 percent of wild cutthroat trout, and 67 percent of hatchery trout taken from the Alsea River estuary in 1970 had scarring from predatory attacks. In his 1980 sampling of cutthroat trout in the Columbia River estuary, Loch (1982) captured one fish with a bite mark attributed to a seal. Neither Loch and Miller (1988) nor Pearcy (1997) report any predation or attacks on cutthroat trout in the Columbia River plume. Bryen (2000) reports that scarring from pinneped attacks on cutthroats returning to the Beaver Creek hatchery (lower Columbia River, Figure D2-1) was at a record high of 18 percent in 1997-1998, but was only 5 percent in 1998-1999. With steelhead, harbor seals and sea lions preferentially targeted gravid females (ibid.), and it may not be unreasonable to speculate that such behavior occurs toward cutthroats as well. Pearcy (1997) suggests that predation at sea might be intensified during warm ocean conditions. During warm summers when upwelling is weak, the inshore-offshore zone of cool temperatures for salmonids is compressed close to shore, concentrating both predators and prey. In addition, abundance of major Clupeid and Osmerid prey species is typically low during warm conditions with weak upwelling, perhaps intensifying predation on alternate species, such as salmonids.

Fisheries for Cutthroat Trout

There are no commercial fisheries that target coastal cutthroat trout in the study area, although the species is sometimes incidentally captured in commercial salmon fisheries (Blakely, 2000). The extent of this bycatch is unknown, but Tipping (1981) reported that a gillnet fishery in the lower Cowlitz River captured an estimated 230 cutthroat trout, mainly in 5- to 5-7/8 inch stretched mesh sizes, and the largest cutthroat in the population were most vulnerable to harvest.

Sport fisheries for sea-run cutthroat trout are a longstanding tradition in the lower Columbia River and its tributaries. The fishery traditionally begins about July 4 when fish appeared in the lower Columbia, and continues until about the end of October, when the migratory influx ceases (Trotter, pers. comm., 2001). In the riverine reach, nearly all angling effort and harvest are attributed to bank anglers fishing at river bars from Jones Beach to the Cowlitz River (Melcher and Watts, 1995; Melcher, 1996); few cutthroat anglers fish from boats or fish upstream or downstream of the segment described above (Schuck, 1980, Melcher and Watts, 1995; Melcher, 1996; Trotter, pers. comm., 2001). Angling for sea-run cutthroat is also popular in tributaries such as the Cowlitz River (Tipping and Springer, 1980; Tipping, 1981), the Elochoman River (Randolph 1986), and other tributaries (Lavier, 1963). Occasionally, cutthroat trout are captured by anglers trolling from boats in the estuarine reach, but this is believed to be infrequent (Sheehan, pers. comm., 2001).

The literature contains little quantitative information about sport fisheries for sea-run cutthroat trout in the study area. Lucas (1980) conducted a creel survey at two river bars between the Elochoman and Cowlitz Rivers on 14 days from July 19 to November 12, 1977. Over the course of the survey he checked 61 anglers targeting cutthroat trout who had fished 190 angler-hours, with a total catch of zero cutthroat trout. Schuck (1980) surveyed the mainstem sport fishery at several locations (location codes not defined) from July to November and reported fish sizes, but not effort levels. In general, mainstem and tributary fisheries were very productive into the 1980s, after which they declined drastically (Melcher and Watts, 1995, 1996; Hooten, 1997; Leider, 1997). The annual cutthroat harvest in the lower Columbia River for Washington and Oregon anglers combined ranged from 1,405-13,617 fish from 1969-1985 (1975-1985 mean = 4,200), compared with 69 to 503 fish from 1986-1995 (Melcher and Watts, 1995, 1996). This decline in harvest reflects increasingly restrictive harvest regulations as well as decreasing stock abundance (Hooten 1997, Leider 1997). Tipping (1981) reports that a sample of 32 cutthroat trout from the 1980 Cowlitz River sport fishery averaged 34.1 cm in length (range approximately 26 to 40 cm), and that these fish were on average larger and older than cutthroats from a concurrent fishery in the lower Columbia River. Additional unanalyzed sport fishery data exists in agency archives (Sheehan, pers. comm., 2001).

2.3.6 Natural versus Hatchery Stock Composition

Hatcheries have been used to augment wild production of cutthroat trout in the lower Columbia River and its tributaries for many years (Hooten, 1997; Leider, 1997; Johnson, et al., 1999). The main intent of hatchery programs has been to improve recreational fishing opportunities (Hooten, 1997; Leider, 1997). Hatchery supplementation programs in Oregon tributaries of the lower Columbia were discontinued in 1994, but supplementation continues in Washington, with most production from the Cowlitz River facility (Hooten, 1997; Leider, 1997). In 1997, about 200,000 hatchery cutthroat were released into Abernathy and Beaver Creeks and the Coweeman, Cowlitz, and Lewis Rivers (WDFW, 1997).

Despite the many fisheries studies conducted over the years, estimated proportions of hatchery and wild cutthroats in the study area per se were found in only one report. Loch (1982) described stock proportions from fish sampled in the Columbia River estuary and plume for June-September 1980 (Table D2-2). These data indicate that 84 percent of fish sampled in the estuary (103 of 123) were hatchery fish, whereas 50 percent of fish sampled in the plume (9 of 18) were hatchery fish. Similarly, Tipping and Springer (1980) reported that 60 percent of the cutthroat catch in the Cowlitz River was of hatchery origin in 1979.

2.3.7 Data Deficiencies

Many gaps and deficiencies exist in available data about Columbia River coastal cutthroat trout in the various parts of the study area. In general, long-term data sets that quantitatively describe changes in abundance and stock characteristics such as population age and size structure are lacking. Knowledge of cutthroat migrations within the area of interest is also sketchy. Much of the available information about cutthroats in the study area is dated and in some cases may not accurately describe current conditions. These deficiencies are described in greater detail below.

Very little information exists in both published and unpublished literature about cutthroat in the upper riverine reach (Portland to Jones Beach). Results from creel surveys are scant and mainly useful as an indicator of presence/absence and migration timing in the lower portion of this area. Information about cutthroats in the Columbia above the Cowlitz confluence is almost nonexistent. Quantitative data about subjects such as seasonal use by cutthroat, age groups involved, and habitat preferences in this unique large river environment are apparently unavailable, and results from studies conducted in smaller streams may be inapplicable. Some useful unanalyzed and unpublished data may exist in agency archives from tagging and creel surveys (Loch and Sheehan, pers. comm., 2001).

Considerable fisheries work has taken place in the lower riverine reach and the estuary (Jones Beach to the river mouth) since the 1960s. Much of this work appears in the literature with peripheral mention of cutthroat trout as a non-target species, and additional unanalyzed data on cutthroats exists in agency archives (Ledgerwood, pers. comm., 2001). Several published studies (e.g., Dawley, et al., 1980; Loch, 1982; Bottom, et al., 1984) indicate the presence or absence and timing of cutthroat trout in this area, and Loch's work also describes age at smolting, size, and diet. Some available habitats were not sampled in these studies, most notably complex, shallow-water habitats that may be preferred by cutthroat trout, so this work does not accurately portray habitat preferences of this species in the study area (Ledgerwood, pers. comm., 2001). Tagging and tracking studies would offer more direct measures of habitat use and preferences. Predation on cutthroats in the estuary by rapidly increasing populations of birds and marine mammals is a subject of concern that has yet to be studied.

Purse and beach seining in the ocean plume have provided important basic information about use of this habitat by sea-run cutthroat, as well as basic biological information about the species (e.g., size, age, growth, diet, hatchery/wild composition). Studies were conducted according to a design that appeared to sample the whole distribution of cutthroat in the plume for at least most of the time that they were present in the marine environment, and several years of data were collected to evaluate inter-annual variability. Some uncertainty remains about whether any cutthroats overwintered at sea because sampling was only conducted from May through September (absence of cutthroats from the plume in winter months was presumed due to their disappearance from catches after August coupled with other knowledge of cutthroat life history). Other noteworthy questions, such as the effects of changing ocean conditions on cutthroats, may at some time need to be addressed in future studies.

This appendix collects and synthesizes the available scientific and commercial data on cutthroat trout presence in and use of the lower Columbia River, estuary, and ocean plume. In order to make final listing decisions or develop recovery plans for cutthroat trout, it may be necessary to address the data deficiencies and suggested studies identified above. However, the available data collected and reported here provide sufficient information on cutthroat trout's presence in and use of the project area to support the Biological Assessment's analysis of the potential effects of channel improvement on the species.

2.3.8 Suggested Studies and Methods

Marvin Rosenau (BC Ministry of the Environment, Surrey, BC):
Study cutthroat trout migrations in the lower river and estuary using combination radio/sonic tags and strontium analysis of scales or otoliths. Combination tags would be effective in both salt and fresh water.

Richard Ledgerwood (NMFS, Hammond Lab, Oregon):
Use Passive Integrated Transponders (PIT) to tag cutthroats to evaluate their use of side channels and other shallow water habitats in the estuary. Ed Casillas at NMFS is spearheading a program to develop such methods for other salmonids. PIT tags could also be used to assess mortality from predatory birds. This is presently working well for other salmonids, and NMFS has discovered high mortality of steelhead smolts (200 mm and larger fish) this way. Currently, no cutthroat trout are being PIT tagged. Ledgerwood also recommends sonic tags to study migrations in the estuary. This could be piggybacked with methods under development for salmon; e.g., development of a buoy-based monitoring system.

Much useful data resides on paper forms only at the Hammond Lab, and some of it pertains to cutthroat trout. It should be entered to a computer database before people who know the data have retired. The entire task for all species could likely be done in about six months. Ledgerwood might be able to provide some guidance if this task is attempted. Some of this data was entered to computer during a visit to the Hammond Lab by a team led by Doug Young (USFWS) on March 7 and 8, 2001.

John Loch (WDFW):
A basic habitat inventory is needed in the study area and tributaries to identify important habitats such as main food producing areas. Examples would be flats and bars in the estuary where cutthroats feed on amphipods and sand lance, respectively. From this type of basic information more focused questions about the needs of cutthroats could be developed.

Involve universities in the design and execution of the work to keep scientific standards high and for cost effectiveness

Dr. Jim Hall at OSU would be a source of other recommendations for work that is needed.

Mario Solazzi (ODFW):
More work is needed to better define distribution, environmental preferences, and diet of cutthroats in marine waters.

More studies are also needed to determine where cutthroats go, what they are doing, habitat preferences, and critical areas in estuaries. He suggests radio and acoustic tags.

William Pearcy (from the conclusion of his article, "The Sea-Run and the Sea,". Pearcy, 1997). Some key studies and data are needed:
Population estimates are necessary to evaluate the plight of trout in regions of decline.

Sampling should include taking scales so age and size structure and survival rates can be evaluated.

Long-term sampling programs should be maintained so time trends can be recognized.

Some careful comparisons of resident and anadromous cutthroat populations should be made to determine if recent declines in cutthroat populations stem from the freshwater or marine environment.

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D-3 REVIEW OF COLUMBIA RIVER ESTUARY STUDIES INDICATING SIZE AND LOCATION OF COASTAL CUTTHROAT TROUT IN THE COLUMBIA RIVER ESTUARY 1967-1971 AND 1978-1980

3.1 Introduction

Since the 1960s, extensive sampling in the Columbia River estuary has produced a large amount of information about fish using the area. Much of this information has only been thoroughly analyzed for salmon species, and much of it has not been transferred from paper forms to computer files. This technical memo describes how a subset of data for coastal cutthroat trout (Oncorhynchus clarki clarki) was obtained from archival records and analyzed, and presents findings of this analysis. Objectives of the analysis were to:

- Examine occurrence of cutthroat trout in the estuary by month and location
- Examine catch patterns to determine whether cutthroat trout tended to school
- Examine size of cutthroat trout by month and location

3.2 Methods

In March 2001, a USFWS-led crew visited the NMFS Hammond Lab to transcribe data from paper forms to Excel spreadsheets. Only information about cutthroat trout was taken, and only a subset of what is available was obtained. Very little data from Jones Beach was transcribed, as this location has been reported on extensively by Loch (1982); Dawley, et al., (1985); and others. Data obtained included sampling dates, locations, and methods, and number and fork lengths of fish captured. A streamlined data entry format was used to summarize catch and effort by location-time cell (e.g., Puget Island on May 1): if no fish were captured in a cell, one record was entered showing a zero-catch and the total effort for the cell (number of net sets); if at least one fish was captured, one or more records were entered, each showing the catch of one or more net sets and the total effort for the cell. If fish were measured, there was one record per fish. If fish were not measured, a single record often represented the composite catch of more than one net set.

Data were obtained from trawling in 1966 and from beach and purse seine sampling in several years from 1967 to 1980 (Table D3-1). Trawl data were not analyzed due to difficulties identifying sampling location and because of analysis time constraints. Stations extended from the river mouth to Jones Beach at River Mile (RM) 45, including marine, estuarine mixing, and freshwater portions of the estuary (Figures D3-1a; salinity zones according to Bottom, et al.,1984). Data from nearshore and offshore areas of the ocean plume were not included in this analysis due to time constraints. Only lengths from catch cards were analyzed because of uncertainty about length data in "binders." Stations shown in Figures D3-1b and D3-1c closely approximate actual sampling sites. Beach seine locations changed slightly as bars and beaches moved over time (Ledgerwood, pers. comm., 2001). Purse seining sampled offshore areas in the main channel close to the stations indicated in Figure D3-1c. Raw data are included as Attachment D3-1.

In general, fish sampling methods were fairly standardized over the years. A 95- by 5-meter beach seine was used in most cases (Dawley, et al., 1985; Miller, pers. comm., 2001) and a smaller beach seine was occasionally used for exploration (Miller, pers. comm., 2001). For the data presented here, a 229- by 10.7-meter purse seine was used during the 1967-1978 period (Johnsen and Sims, 1973; Miller, pers. comm., 2001), and a larger 305- by 10.7-meter purse seine was used from 1979-1980 (Miller, pers. comm., 2001). Fish sampling methods are described in detail in Johnsen and Sims (1973), Sims and Johnsen (1974), Loch (1982), Dawley, et al. (1985), and others. Varying tides, river flow, and weather conditions were likely the most significant factors affecting gear efficiency (Ledgerwood, pers. comm., 2001). Dawley, et al. (1985), adjusted their salmon passage rates for varying environmental conditions, however, information for making such an adjustment was not available for our analysis. The level of sampling consistency inherent to our data reasonably justifies monthly comparisons between stations or areas for individual gears (Ledgerwood and Miller, pers. comm., 2001). Purse seine data from 1967-1971 and 1979-1980 periods should be compared with caution because of differing net size between the two periods.

Initial data entry and editing were done in MS Excel. Subsequent analysis was performed with Systat 10 and Surfer software.

3.3 Results and Discussion

Data were analyzed from a total of 1,250 beach seine sets from all years of sampling (Table D3-2a). Most data were from March through September, but locations and months sampled were inconsistent over the years; coverage of the whole estuary was best before 1978. Average monthly beach seine catch per unit effort (CPUE) is defined as catch per set and varied from zero to 16.67 over all years (Table D3-2b). Zero catches were quite common (64 percent of all month-area cells), even when an appreciable number of sets were made. CPUE did not exceed 0.5 near the river mouth (areas A-C). Most cutthroats were caught in this area in August and September, except in 1978 when all captures were in May and June (Table D3-2a). Catch rates were higher in the middle estuary (areas D-F), ranging from 0.3 to 2.0, for catches made June through September. In the upper estuary (areas G-J), CPUE was generally in the same range as the middle estuary. Cutthroats were captured in the upper estuary from February through August. In 1967 and 1968, the only years when this area was sampled over a range of months, appreciable catches were made from March through August. The highest catch rate on record (16.7) occurred in July of 1970 in area G.

Data were analyzed from 1,109 purse seine sets from all years sampled (Table D3-3a). Most data were from April through September. Locations and months sampled were inconsistent over the years, and seldom did beach and purse seine samples coincide in time and location. Purse seine coverage of the whole estuary was best in years before 1978. Monthly beach seine CPUE per set varied from zero to 8.33 over all years (Table D3-3b), and zero-catches were common (34 percent of all month-area cells), even when an appreciable number of sets were made. Near the river mouth (areas A-C), cutthroats were captured from April through September over the years. CPUE in this area ranged up to 2.63, and peak rates were seen in May, July, and August (Table D3-3b). Catch rates in the middle estuary (areas D-F) were similar to or higher than those in the lower estuary on comparable dates. Cutthroats were caught in the middle estuary from April through August. Cutthroats were captured in the upper estuary (areas G-J) from April through July at a rate similar to other areas on comparable dates, but no data are available outside that period. Peak catch rates typically occurred in the upper estuary in May, and the highest CPUE on record (8.33) was in May 1968 in area J.

Considering all available data, catch per individual set was available from 61 purse seine sets with non-zero catches. Over half of these sets captured only one cutthroat trout, while the remaining fraction captured 2 to 14 trout (Figure D3-2). These results indicate some schooling, but most multiple catches were only 2 to 3 fish. No beach seine results were available from individual sets.

Fork lengths were available from 154 and 427 cutthroat trout captured by beach and purse seine, respectively (Table D3-4a). A few area-month cells (e.g., beach seine in area H April 1968) accounted for a large proportion of the catch, and catches were small for most other cells. For both gears, fork length ranged from about 120 to 530 millimeters (mm), with distinct modes at about 200 mm, 300 mm, and 500 mm; modes between 300 and 500 mm were more ambiguous (Figure D3-3, Table D3-4b). The overall mean fork length was 283 mm for beach seined fish and 285 mm for purse seined fish, with a range of about 120 to 530 mm for both gears. Length data were pooled by early and late season (March-June, July-September) and by portion of the estuary (lower = areas A-C, middle = areas D-E, upper = areas F-J) to calculate mean and standard deviation of fork length for individual gears. In these comparisons, fork length differed little between gears, except during the March-June period in the middle estuary, when the beach seine caught much smaller fish than the purse seine (Figure D3-4). This difference might suggest that outmigrating smolts in the middle estuary favored nearshore habitats, whereas kelts (adults migrating to the ocean after spawning) or other larger cutthroats favored channel habitats. Alternatively, it may be an artifact of the very small beach seine sample size for this period and portion of the estuary (Table D3-4a). The spread of sizes overlapped considerably across zones and seasons, and trends in length relative to these factors are not clear.

Analysis of the Hammond data presented here suggests several spatial and temporal trends in abundance and size of coastal cutthroat trout in the Columbia River estuary. Cutthroats were taken in the shallows (beach seining) of the upper estuary (freshwater zone, Figure D3-1) and in the channel (purse seining) throughout the estuary for at least April through September, whereas they were seldom taken in the shallows of the lower two-thirds of the estuary (estuarine mixing and marine zones) until May or later. Somewhat higher catch rates in the middle and upper estuary suggest that cutthroats were more abundant there than in the lower estuary where catch rates tended to be lower. Frequent catches of more than one cutthroat per set, when any were caught at all, indicated that occasional schooling occurred. Trends in size of cutthroat by time of year and portion of the estuary were not clear.

These results are more suggestive than definitive. They were influenced by small sample sizes and by the lack of any data at all for many times of year and locations of interest. Also, they were not supported by statistical tests, which were beyond the scope of this memorandum. Statistical testing would certainly require pooling of data (e.g., as for length computations above) to reduce the number of empty cells. The USFWS crew was not able to compensate for weather, flow, and tidal conditions during sampling, which undoubtedly affected catch rates, especially for beach seining. Another potentia l source of error was uncertainty about differentiation of cutthroat trout and steelhead in early years. For this analysis it was assumed that all fish were identified correctly.

3.4 Acknowledgements

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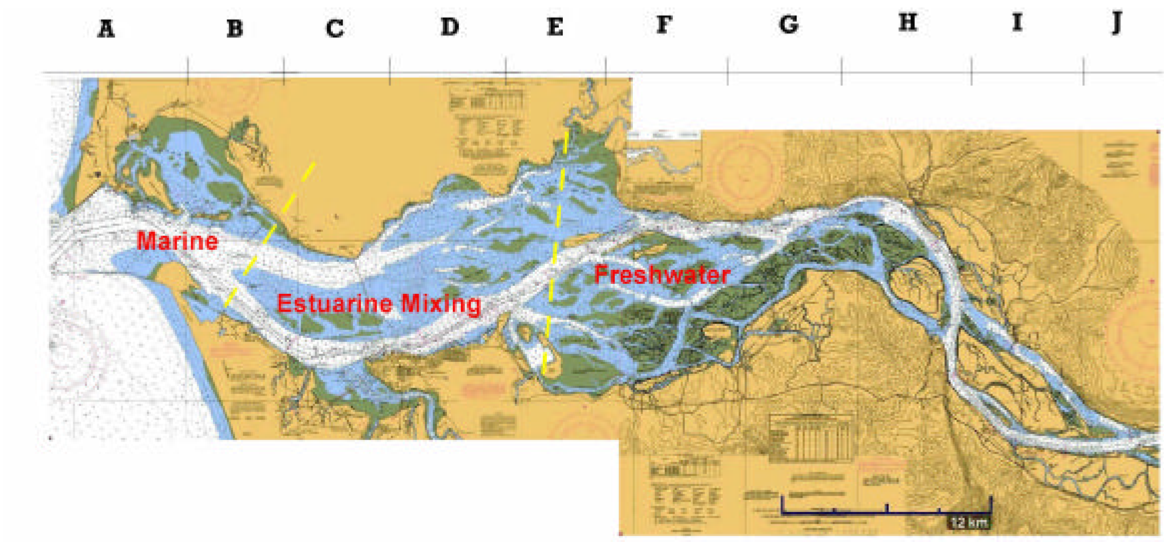
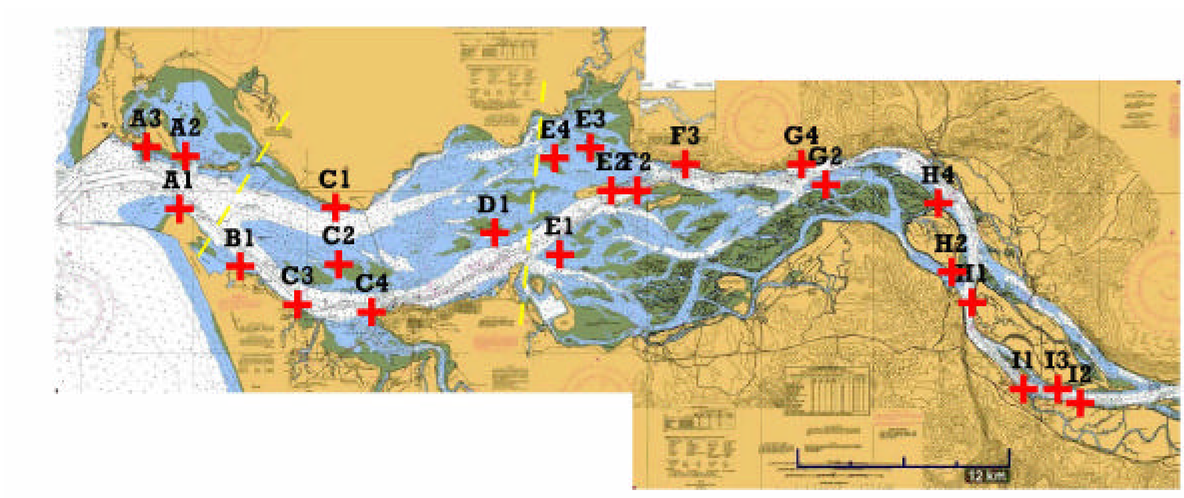


Figure D3-1a: The Columbia River Estuary, Showing Approximate Boundaries of Salinity Zones (from Bottom, et al., 1984) and East-West Analysis Areas A-J



D3-1b: Stations Sampled With Beach Seine, All Years

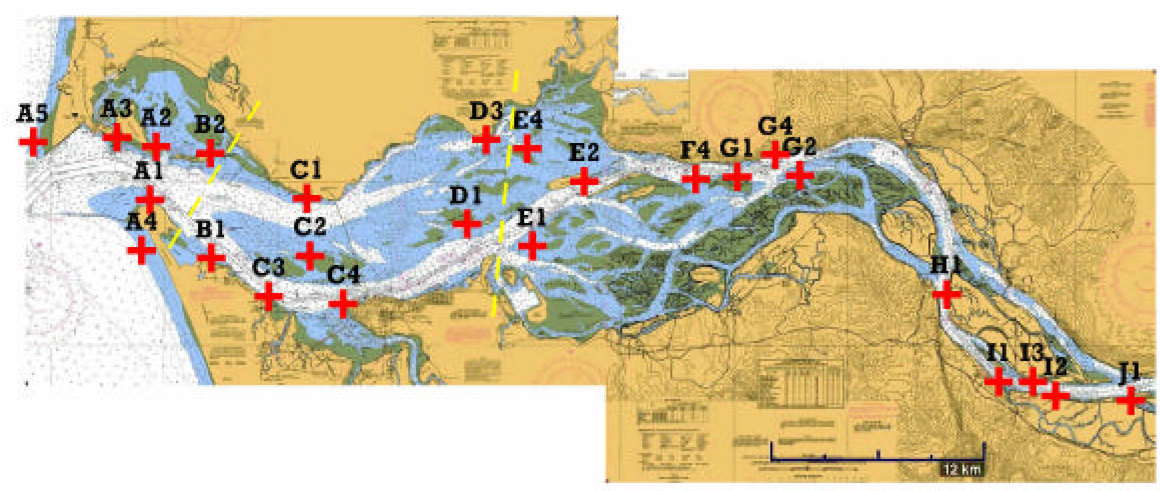


Figure D3-1c:Stations Sampled With Purse Seine, All Years

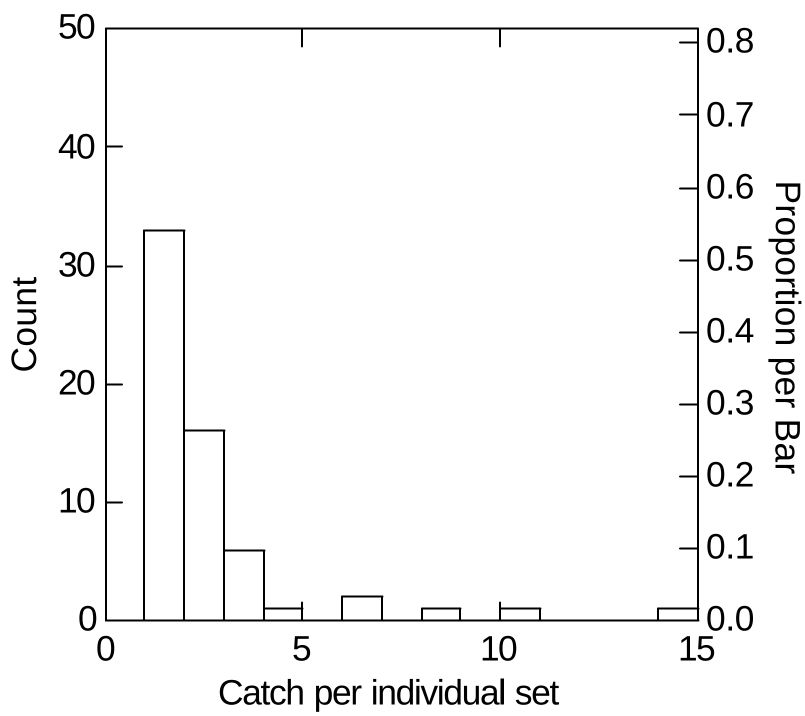


Figure D3-2: Frequency Distribution of Catch Per Purse Seine Set, For All Data Recorded By Individual Set

Note: Data were not available for beach seining

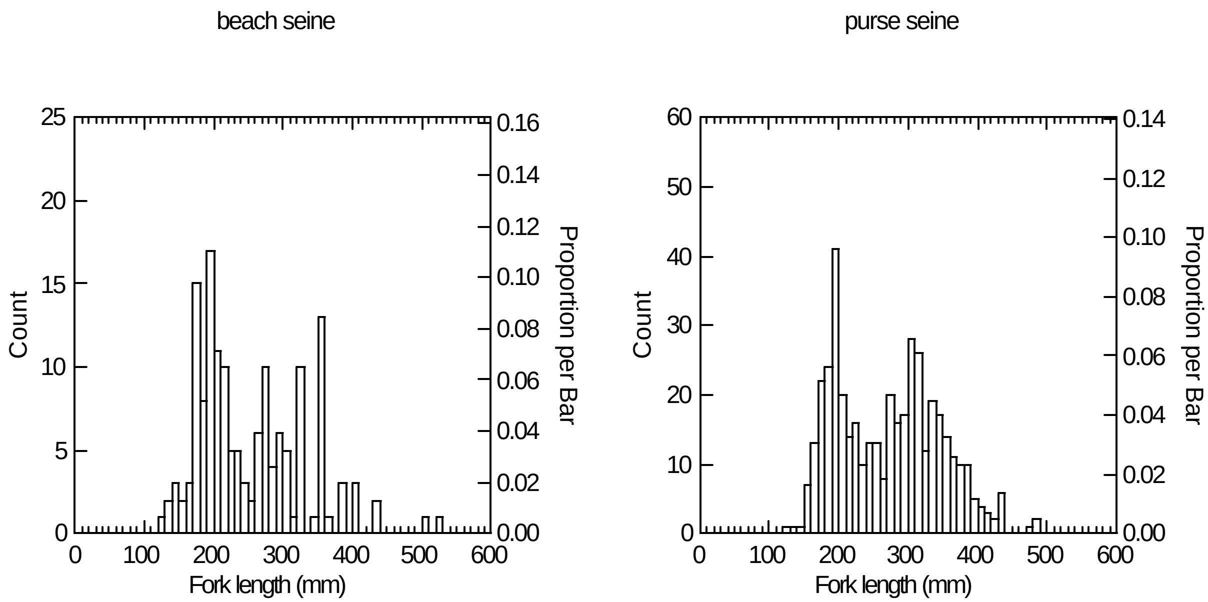


Figure D3-3 Length Frequency Distribution of All Cutthroat Sampled in the Columbia Estuary by Beach and Purse Seine, All Dates and Locations Combined

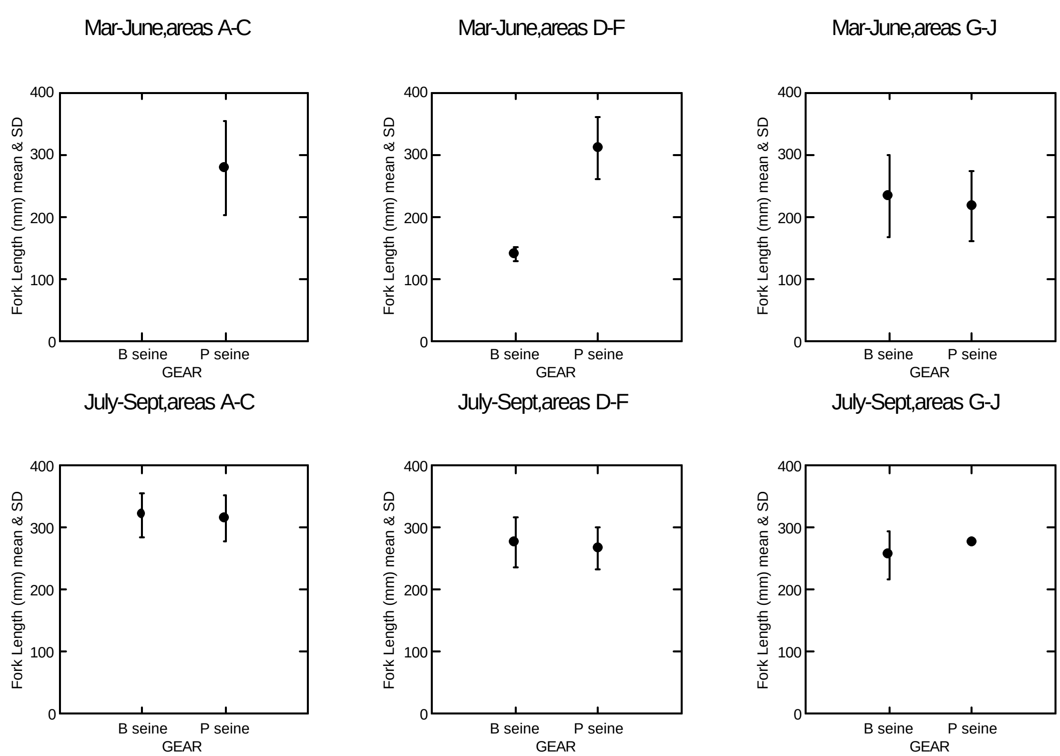


Figure D3-4. Fork Length (mm) of Cutthroat Trout in Beach and Purse Seine Catches in the Columbia River Estuary, Subdivided by Portion of the Estuary and Time of Year

Note: All years of data were pooled for these plots.

Table D3-1 Data About Cutthroat Trout in the Columbia River Estuary, by Year

	Data obtained		
Year	Beach seine	Purse seine	Trawl
1966			x
1967	x	x	
1968	x	x	
1969	x	x	
1970	x		
1971		x	
1972			
1973			
1974			
1975			
1976			
1977			
1978	x	x	
1979		x	
1980		x	

Obtained from Hammond Laboratory Records

Table D3-2a&b Beach Seine Sampling Effort (a) as Sets Per Area Per Month and CPUE (b) as Catch Per Set

			Area										
Gear	Year	Month	A	B	C	D	E	F	G	H	I	J	Total
beach seine	67	Feb		4	2				7	34			47
"	"	Mar								64	13		77
"	"	Apr		1	4	4	3		5	63	12		92
"	"	Aug	42	4	39	11	32	2	4	66	13		213
"	"	Sept	3				3			24			30
"	"	Oct								15			15
"	"	Nov								2			2
"	"	Dec								3			3
"	68	Jan								2			2
"	"	Feb								6			6
"	"	Mar	6				9		5	18	7		45
"	"	Apr			3	4	10	2	4	103			126
"	"	May								11			11
"	"	Aug	14	7	7	2	12	2		8			52
"	"	Sept				2	2						4
"	69	Aug	13		8					10	16		47
"	"	Sept	9	4	7								20
"	"	Oct				9	16						25
"	70	May	13		2								15
"	"	June	119	6				10					135
"	"	July	28	43	3				6	9	4	7	100
"	"	Aug	2										2
"	"	Sept		2									2
"	78	Apr	48										48
"	"	May	61										61
"	"	June	54										54
"	"	July	9										9
"	"	Sept	7										7
		Total	428	71	75	32	87	16	31	438	65	7	1250

			Area										
Gear	Year	Month	A	B	C	D	E	F	G	H	I	J	Mean
beach seine	67	Feb		0.00	0.00				0.00	0.03			0.01
"	"	Mar								0.00	0.00		0.00
"	"	Apr		0.00	0.00	0.00	0.00		0.00	0.22	0.33		0.08
"	"	Aug	0.02	0.00	0.00	0.00	0.31	0.00	0.25	0.35	0.00		0.10
"	"	Sept	0.00				0.00			0.00			0.00
"	"	Oct								0.00			0.00
"	"	Nov								0.00			0.00
"	"	Dec								0.00			0.00
"	68	Jan								0.00			0.00
"	"	Feb								0.00			0.00
"	"	Mar	0.00				0.00		1.00	0.00	0.57		0.31
"	"	Apr			0.00	0.00	0.00	0.00	0.00	0.68			0.11
"	"	May								1.82			1.82
"	"	Aug	0.07	0.00	0.14	0.00	0.67	0.50		0.00			0.20
"	"	Sept				2.00	1.50						1.75
"	69	Aug	0.31		0.50					0.80	0.44		0.51
"	"	Sept	0.00	0.00	0.14								0.05
"	"	Oct				0.00	0.00						0.00
"	70	May	0.00		0.00								0.00
"	"	June	0.00	0.00				0.60					0.20
"	"	July	0.00	0.00	0.00				16.67	0.00	2.00	0.00	2.67
"	"	Aug	0.00										0.00
"	"	Sept		0.00									0.00
"	78	Apr	0.00										0.00
"	"	May	0.18										0.18
"	"	June	0.04										0.04
"	"	July	0.00										0.00
"	"	Sept	0.00										0.00

Table D3-3a&b Purse Seine Sampling Effort (a) as Sets Per Area Per Month and CPUE (b) as Catch Per Set

Gear	Year	Month	Area A	B	C	D	E	F	G	H	I	J	Total
purse seine	67	May							49				49
"	"	June							22				22
"	"	July	27	2	23	5	17		3	37	66		180
"	"	Aug				3							3
"	68	Apr							9	15			24
"	"	May							4	5		3	12
"	"	June							10				10
"	"	Aug			2	18	22						42
"	69	Feb				2							2
"	"	Mar				12							12
"	"	Apr				14			27	2	1		44
"	"	June			22	9			15				46
"	"	July	19		16	5			16				56
"	"	Aug	11										11
"	71	Mar				2	3						5
"	"	Apr			9	20	30		4				63
"	"	May		27	20				8				55
"	"	June		7	70								77
"	78	Apr			25								25
"	"	May			60								60
"	"	June			62								62
"	"	July			24			3					27
"	"	Aug			18								18
"	"	Sept			17								17
"	79	May			7								7
"	"	June			26								26
"	"	July			35								35
"	"	Aug			36	7							43
"	"	Sept			37								37
"	80	July			39								39
		Total	57	36	548	97	72	3	167	59	67	3	1109

Gear	Year	Month	Area A	B	C	D	E	F	G	H	I	J	Mean
purse seine	67	May							2.78				2.78
"	"	June							0.05				0.05
"	"	July	0.00	0.00	0.00	0.00	0.06		0.00	0.00	0.02		0.01
"	"	Aug				0.00							0.00
"	68	Apr							0.22	0.27			0.24
"	"	May							0.75	1.60		8.33	3.56
"	"	June							0.20				0.20
"	"	Aug			0.00	0.44	0.18						0.21
"	69	Feb				0.00							0.00
"	"	Mar				0.00							0.00
"	"	Apr				0.07			0.26	0.00	0.00		0.08
"	"	June			0.09	0.33			0.33				0.25
"	"	July	1.47		0.00	0.00			0.00				0.37
"	"	Aug	0.36										0.36
"	71	Mar				0.00	0.33						0.17
"	"	Apr			0.67	0.70	0.83		0.00				0.55
"	"	May		1.59	1.35				1.50				1.48
"	"	June		0.57	0.59								0.58
"	78	Apr			0.04								0.04
"	"	May			0.37								0.37
"	"	June			0.24								0.24
"	"	July			0.00			0.00					0.00
"	"	Aug			1.00								1.00
"	"	Sept			0.47								0.47
"	79	May			0.00								0.00
"	"	June			0.15								0.15
"	"	July			2.63								2.63
"	"	Aug			2.42	2.14							2.28
"	"	Sept			0.95								0.95
"	80	July			0.44								0.44

Table D3-4a&b Sample Size (a) and Mean Fork Length (b) of Cutthroat Trout from Beach and Purse Seine Sets

Gear	Year	Month	Sample size by sampling area A	B	C	D	E	F	G	H	I	J	Total
beach seine	67	Apr								11	4		15
"	"	Aug	1				10		1	7			19
"	68	Mar							5		4		9
"	"	Apr								61			61
"	"	May								20			20
"	"	Aug	1		2		8	1					12
"	"	Sept				4							4
"	69	Aug	3		4								7
"	"	Sept			1								1
"	70	June						6					6
"	Beach seine total		5		7	4	18	7	6	99	8		154
purse seine	67	May							136				136
"	"	June							1				1
"	"	July					1				1		2
"	68	Apr							2	4			6
"	"	May							3	8		25	36
"	"	June							2				2
"	"	July											2
"	"	Aug				5	4						11
"	69	Apr				1			7				8
"	"	June			2	3			5				10
"	"	July	23										23
"	"	Aug	2										2
"	71	Mar					1						1
"	"	Apr			6	14	25						47
"	"	May		4	1				12				19
"	78	June			2								2
"	"	Aug			9								9
"	"	Sept			8								8
"	79	June			2								2
"	"	July			6								6
"	"	Aug			67								67
"	"	Sept			12								12
"	80	July			14								14
"	Purse seine total		25	4	129	23	31		168	12	1	25	427

Gear	Year	Month	Mean fork length (mm) by sampling area A	B	C	D	E	F	G	H	I	J	Total
beach seine	67	Apr								303	343		323
"	"	Aug	263				281		197	264			251
"	68	Mar							340		374		357
"	"	Apr								228			228
"	"	May								192			192
"	"	Aug	330		305		271	213					280
"	"	Sept				330							330
"	69	Aug	321		333								327
"	"	Sept			350								350
"	70	June						141					141
"	Beach seine total		305		329	330	276	177	269	247	358		283
purse seine	67	May							210				210
"	"	June							218				218
"	"	July					255				275		265
"	68	Apr							254	254			254
"	"	May							310	251		186	249
"	"	June							221				221
"	"	July											249
"	"	Aug				283	249						262
"	69	Apr				330			341				335
"	"	June			200	261			175				212
"	"	July	298										298
"	"	Aug	278										278
"	71	Mar					352						352
"	"	Apr			276	319	329						282
"	"	May		301	298				305				316
"	78	June			268								268
"	"	Aug			305								305
"	"	Sept			315								315
"	79	June			393								393
"	"	July			326								326
"	"	Aug			327								327
"	"	Sept			308								308
"	80	July			352								352
"	Purse seine total		288	301	306	298	296		254	252	275	186	285

Attachment D3-1: Raw Data

Data codes:
Gear types: 1=beach, 2=purse, 3=trawl; 4=unknown.
Missing values: -999 = missing (e.g. fish caught but no lengths recorded), blank = no data (e.g. no lengths from sets with no catch)

Area	StationLocatName	Lon	Lat	Month	Day	Year	Gear	TotSets	SetNum	Count	FkLenmm	LenSource
H	H1PUGET ISL	-123.42710	46.19366	2	7	67	1	8		0		cards
H	H1PUGET ISL	-123.42710	46.19366	2	7	67	1	-999		-999		cards
H	H1500 YDS UP FROM JETTY /PUGET ISL	-123.42710	46.19366	2	10	67	1	6		0		cards
H	H1PUGET ISL	-123.42710	46.19366	2	10	67	1	6		0		cards
H	H2noname	-123.44210	46.20923	2	10	67	1	2		0		cards
H	H2noname	-123.44210	46.20923	2	10	67	1	-999		-999		cards
H	H1PUGET ISL	-123.42710	46.19366	2	14	67	1	6	1	1		cards
H	H1PUGET ISL	-123.42710	46.19366	2	14	67	1	-999		-999		cards
B	B11000 YDS BELOW PNT ADAMS	-123.96482	46.21204	2	20	67	1	4		0		cards
B	B11000 YDS BELOW PNT ADAMS	-123.96482	46.21204	2	20	67	1	-999		-999		cards
C	C1200 YDS DOWN FROM OLD CHRUCH	-123.89520	46.24229	2	20	67	1	2		0		cards
C	C1200 YDS DOWN FROM OLD CHRUCH	-123.89520	46.24229	2	20	67	1	-999		-999		cards
G	G4JIM CROW PNT	-123.55249	46.26457	2	21	67	1	7		0		cards
G	G4JIM CROW PNT	-123.55249	46.26457	2	21	67	1	-999		-999		cards
H	H1PUGET ISL	-123.42710	46.19366	2	24	67	1	4		0		cards
H	H1PUGET ISL	-123.42710	46.19366	2	24	67	1	-999		-999		cards
H	H2BRADWOOD	-123.44210	46.20923	2	24	67	1	2		0		cards

H	H4BRADWOOD	-123.45208	46.24439	2	24	67	1	2		0		cards
I	I2JUST SO. OF WESTPORT SLOUGH ORE. SHORE	-123.34754	46.14202	3	1	67	1	8		0		cards
H	H1PUGET ISL	-123.42710	46.19366	3	2	67	1	4		0		cards
H	H1PUGET ISL	-123.42710	46.19366	3	6	67	1	6		0		cards
I	I2BETWEEN FIRST AND SECOND JETTY ABOVE WESTPORT SLOUGH	-123.34754	46.14202	3	8	67	1	5		0		cards
H	H1LOWER END OF PUGET ISL	-123.42710	46.19366	3	13	67	1	12		0		cards
H	H1PUGET ISL	-123.42710	46.19366	3	15	67	1	7		0		cards
H	H1PUGET ISL	-123.42710	46.19366	3	17	67	1	3		0		cards
H	H1PUGET ISL	-123.42710	46.19366	3	20	67	1	11		0		cards
H	H1LOWER END OF PUGET ISL	-123.42710	46.19366	3	21	67	1	4		0		cards
H	H1LOWER END OF PUGET ISL	-123.42710	46.19366	3	24	67	1	7		0		cards
H	H1PUGET ISL	-123.42710	46.19366	3	28	67	1	6		0		cards
H	H1PUGET ISL	-123.42710	46.19366	3	31	67	1	4		0		cards
G	G4JIM CROW PNT	-123.55249	46.26457	4	3	67	1	5		0		cards
H	H1PUGET ISL	-123.42710	46.19366	4	4	67	1	7		0		cards
B	B1PNT ADAMS	-123.96482	46.21204	4	5	67	1	1		0		cards
C	C1300 YDS DOWN FROM OLD CHRUCH AT MCGOWAN	-123.89520	46.24229	4	5	67	1	4		0		cards
D	D1SOUTH BEACH TAYLOR SANDS?	-123.77808	46.22935	4	6	67	1	4		0		cards
E	E1DOWN STREAM END	-123.73014	46.21813	4	6	67	1	3		0		cards
H	H1PUGET ISL	-123.42710	46.19366	4	7	67	1	3		0		cards
H	H1PUGET ISL	-123.42710	46.19366	4	11	67	1	-999	1	-999	-999	cards
H	H1PUGET ISL	-123.42710	46.19366	4	12	67	1	4	1	1	285	cards
H	H1PUGET ISL	-123.42710	46.19366	4	12	67	1	4	3	1	315	cards

H	H1PUGET ISL	-123.42710	46.19366	4	13	67	1	10		0		cards
H	H1PUGET ISL	-123.42710	46.19366	4	17	67	1	10		0		cards
I	I3UPPER END PUGET ISL SHIP CHANL	-123.36420	46.14923	4	19	67	1	10		0		cards
H	H1PUGET ISL	-123.42710	46.19366	4	20	67	1	9	4	1	406	cards
H	H1PUGET ISL	-123.42710	46.19366	4	20	67	1	9	7	1	355	cards
H	H1PUGET ISL	-123.42710	46.19366	4	20	67	1	9	9	1	355	cards
H	H1PUGET ISL	-123.42710	46.19366	4	20	67	1	9	9	1	355	cards
H	H1PUGET ISL	-123.42710	46.19366	4	21	67	1	3	2	1	355	cards
H	H1PUGET ISL	-123.42710	46.19366	4	21	67	1	3	2	1	305	cards
I	I1WESTPORT ISL	-123.38920	46.14924	4	24	67	1	2	1	1	305	cards
I	I1WESTPORT ISL	-123.38920	46.14924	4	24	67	1	2	1	1	305	cards
I	I1WESTPORT ISL	-123.38920	46.14924	4	24	67	1	2	1	1	355	cards
I	I1WESTPORT ISL	-123.38920	46.14924	4	24	67	1	2	1	1	406	cards
H	H1PUGET ISL	-123.42710	46.19366	4	26	67	1	8	1	1	178	cards
H	H1PUGET ISL	-123.42710	46.19366	4	26	67	1	8	1	1	209	cards
H	H1PUGET ISL	-123.42710	46.19366	4	26	67	1	8	6	1		cards
H	H1PUGET ISL	-123.42710	46.19366	4	26	67	1	8	7	1		cards
H	H1PUGET ISL	-123.42710	46.19366	4	26	67	1	8	8	1		cards
H	H1PUGET ISL	-123.42710	46.19366	4	27	67	1	3	3	1	210	cards
H	H1PUGET ISL	-123.42710	46.19366	4	28	67	1	6		0		cards
H	H1PUGET ISL	-123.42710	46.19366	8	3	67	1	6	5	1	260	cards
H	H2BRADWOOD	-123.44210	46.20923	8	3	67	1	3		0		cards
D	D1TAYLOR SANDS	-123.77808	46.22935	8	4	67	1	2		0		cards

E	E1BRUM BEACH	-123.73014	46.21813	8	4	67	1	7	0	cards
E	E2RICE ISL	-123.69220	46.25096	8	7	67	1	7	0	cards
A	A1SLOUGH	-124.00983	46.24173	8	8	67	1	2	0	cards
A	A1noname	-124.00983	46.24173	8	8	67	1	4	0	cards
A	A2noname	-124.00524	46.26876	8	8	67	1	2	0	cards
C	C1MCGOWAN	-123.89520	46.24229	8	8	67	1	3	0	cards
H	H1PUGET ISL	-123.42710	46.19366	8	8	67	1	3	0	cards
I	I2noname	-123.34754	46.14202	8	8	67	1	5	0	cards
H	H1PUGET ISL	-123.42710	46.19366	8	9	67	1	8	0	cards
A	A1above clatsop spit	-124.00983	46.24173	8	10	67	1	8	0	cards
A	A1SO JETTY BY ROAD	-124.00983	46.24173	8	10	67	1	1	0	cards
D	D1TAYLOR SANDS	-123.77808	46.22935	8	10	67	1	1	0	cards
D	D9TANNY PNT	-999.00000	-999.00000	8	10	67	1	2	0	cards
E	E5GOVT ISL	-999.00000	-999.00000	8	10	67	1	2	0	cards
D	D1TAYLOR SANDS	-123.77808	46.22935	8	11	67	1	2	0	cards
E	E2RICE ISL	-123.69220	46.25096	8	11	67	1	2	0	cards
E	E3NE END RICE ISL	-123.70762	46.27312	8	11	67	1	2	0	cards
E	E4GEORGE ROLLINGS MUD FLAT GRAYS BAY	-123.73388	46.26765	8	11	67	1	2	0	cards
H	H1PUGET ISL	-123.42710	46.19366	8	11	67	1	5	0	cards
A	A2SAND ISL	-124.00524	46.26876	8	14	67	1	2	0	cards
A	A3ILLWACO	-124.03401	46.27350	8	14	67	1	4	0	cards
C	C1MCGOWAN	-123.89520	46.24229	8	14	67	1	2	0	cards
A	A1CLATSOP SPIT	-124.00983	46.24173	8	15	67	1	2	0	cards

B	B1ADAMS PNT	-123.96482	46.21204	8	15	67	1	4		0		cards
C	C1MCGOWAN	-123.89520	46.24229	8	15	67	1	4		0		cards
C	C2MID RIVER OFF BRIDGE	-123.89271	46.21321	8	15	67	1	2		0		cards
D	D1TAYLOR SANDS	-123.77808	46.22935	8	16	67	1	2		0		cards
E	E1BURNS BEACH	-123.73014	46.21813	8	16	67	1	2		0		cards
E	E2RICE ISL	-123.69220	46.25096	8	16	67	1	3	3	1	275	cards
E	E2RICE ISL	-123.69220	46.25096	8	16	67	1	3	3	1	276	cards
E	E2RICE ISL	-123.69220	46.25096	8	16	67	1	3	3	1	431	cards
E	E2RICE ISL	-123.69220	46.25096	8	16	67	1	3	3	1	278	cards
E	E2RICE ISL	-123.69220	46.25096	8	16	67	1	3	3	1	278	cards
E	E2RICE ISL	-123.69220	46.25096	8	16	67	1	3	3	1	281	cards
E	E2RICE ISL	-123.69220	46.25096	8	16	67	1	3	3	1	281	cards
E	E2RICE ISL	-123.69220	46.25096	8	16	67	1	3	3	1	237	cards
E	E2RICE ISL	-123.69220	46.25096	8	16	67	1	3	3	1	218	cards
E	E2RICE ISL	-123.69220	46.25096	8	16	67	1	3	3	1	253	cards
E	E5LITTLE RICE ISL OFF ALTOUNA	-999.00000	-999.00000	8	16	67	1	2		0		cards
H	H1PUGET ISL	-123.42710	46.19366	8	16	67	1	8		0		cards
A	A3ILLWACO ENTRANCE	-124.03401	46.27350	8	17	67	1	8		0		cards
C	C2MID RIVER OFF BRIDGE	-123.89271	46.21321	8	17	67	1	2		0		cards
C	C3WARENTON ENTRANCE	-123.92314	46.19246	8	18	67	1	5		0		cards
C	C4MOUTH OF YOUNG RIVER	-123.86854	46.18872	8	18	67	1	3		0		cards
C	C5DESDEONIA SANDS	-999.00000	-999.00000	8	18	67	1	4		0		cards
A	A1CLATSOP SPIT	-124.00983	46.24173	8	21	67	1	3		0		cards

A	A2ILLWACO CHNL	-124.00524	46.26876	8	21	67	1	2	1	1	263	cards
C	C3WARENTON MOUTH OF SKIPANON RV	-123.92314	46.19246	8	21	67	1	5		0		cards
H	H1PUGET ISL	-123.42710	46.19366	8	21	67	1	11	6	4	-999	cards
H	H1PUGET ISL	-123.42710	46.19366	8	21	67	1	11	6	4	-999	cards
H	H1PUGET ISL	-123.42710	46.19366	8	21	67	1	11	6	4	-999	cards
H	H1PUGET ISL	-123.42710	46.19366	8	21	67	1	11	6	4	-999	cards
C	C1BURNS BEACH	-123.89520	46.24229	8	22	67	1	5		0		cards
D	D1TAYLOR SANDS	-123.77808	46.22935	8	22	67	1	2		0		cards
I	I2noname	-123.34754	46.14202	8	22	67	1	8		0		cards
-999	-9991/4MILE BELOW PNT ELIS SAND BAR BELOW BRIDGE WASHINGTON SIDE	-999.00000	-999.00000	8	23	67	1	2		0		cards
C	C1MCGOWAN	-123.89520	46.24229	8	23	67	1	4		0		cards
F	F2ACROSS FROM ALTOONA	-123.67333	46.25106	8	23	67	1	2		0		cards
G	G4JIM CROW PNT	-123.55249	46.26457	8	23	67	1	2		0		cards
H	H1PUGET ISL	-123.42710	46.19366	8	23	67	1	9	6	1	254	cards
A	A2ILWACO	-124.00524	46.26876	8	24	67	1	6		0		cards
H	H1PUGET ISL	-123.42710	46.19366	8	28	67	1	11	1	1	278	cards
H	H1PUGET ISL	-123.42710	46.19366	8	28	67	1	11	1	1	291	cards
H	H1PUGET ISL	-123.42710	46.19366	8	28	67	1	11	4	1	289	cards
H	H1PUGET ISL	-123.42710	46.19366	8	30	67	1	2	1	1	271	cards
H	H1PUGET ISL	-123.42710	46.19366	8	30	67	1	2	1	1	207	cards
E	E1BURNS BEACH	-123.73014	46.21813	8	31	67	1	3		0		cards
G	G4JIM CROW PNT	-123.55249	46.26457	8	31	67	1	2	1	1	197	cards
H	H1PUGET ISL	-123.42710	46.19366	9	7	67	1	4		0		cards

H	H2BRADWOOD	-123.44210	46.20923	9	7	67	1	4		0		cards
H	H1PUGET ISL	-123.42710	46.19366	9	13	67	1	-999	4	-999	-999	cards
H	H1PUGET ISL	-123.42710	46.19366	9	13	67	1	-999	4	-999	-999	cards
H	H1PUGET ISL	-123.42710	46.19366	9	14	67	1	10		0		cards
A	A3ILWACO CHNL	-124.03401	46.27350	9	18	67	1	3		0		cards
E	E1BURNS BEACH	-123.73014	46.21813	9	18	67	1	3		0		cards
H	H1PUGET ISL	-123.42710	46.19366	9	26	67	1	6		0		cards
H	H1PUGET ISL	-123.42710	46.19366	10	11	67	1	5		0		cards
H	H1PUGET ISL	-123.42710	46.19366	10	19	67	1	5		0		cards
H	H1PUGET ISL	-123.42710	46.19366	10	30	67	1	5		0		cards
H	H1PUGET ISL	-123.42710	46.19366	11	9	67	1	-999	1	-999	-999	cards
H	H1PUGET ISL	-123.42710	46.19366	11	9	67	1	-999	1	-999	-999	cards
H	H1PUGET ISL	-123.42710	46.19366	11	15	67	1	2		0		cards
H	H1PUGET ISL	-123.42710	46.19366	12	1	67	1	3		0		cards
-999	-999NORTH CHNL JUST BEFORE LIGHT #3	-999.00000	-999.00000	4	20	67	2	-999	0	-999		cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	4	25	67	2	-999	0	-999		cards
G	G2noname	-123.53468	46.25398	4	27	67	2	-999	0	-999		cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	4	28	67	2	-999	0	-999		cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	2	67	2	-999	0	-999		cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	3	67	2	2	1	1	174	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	4	67	2	4	1	1	482	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	5	67	2	3	1	1	240	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	5	67	2	3	2	1	355	cards

G	G2WOODY ISL CHNL	-123.53468	46.25398	5	5	67	2	3	2	1	381	cards
E	E2noname	-123.69220	46.25096	5	8	67	2	-999	0	-999		cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	9	67	2	4	?	1	192	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	9	67	2	4	?	1	194	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	10	67	2	3	?	1	200	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	10	67	2	3	?	1	210	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	10	67	2	3	?	1	124	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	10	67	2	3	?	1	232	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	10	67	2	3	?	1	350	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	10	67	2	3	?	1	350	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	10	67	2	3	?	1	365	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	10	67	2	3	?	1	209	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	11	67	2	2	?	1	220	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	11	67	2	2	?	1	230	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	11	67	2	2	?	1	235	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	11	67	2	2	?	1	225	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	11	67	2	2	?	1	220	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	11	67	2	2	?	1	240	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	11	67	2	2	?	1	210	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	12	67	2	3	1	1	200	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	12	67	2	3	1	1	200	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	12	67	2	3	1	1	190	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	12	67	2	3	1	1	195	cards

G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	12	67	2	3	1	1	173	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	12	67	2	3	1	1	215	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	12	67	2	3	1	1	183	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	12	67	2	3	1	1	195	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	12	67	2	3	1	1	190	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	12	67	2	3	1	1	185	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	12	67	2	3	1	1	190	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	12	67	2	3	1	1	165	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	12	67	2	3	1	1	200	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	12	67	2	3	1	1	245	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	12	67	2	3	2	1	190	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	15	67	2	2	1	1	215	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	15	67	2	2	1	1	190	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	15	67	2	2	1	1	188	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	15	67	2	2	1	1	190	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	15	67	2	2	1	1	210	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	15	67	2	2	1	1	175	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	15	67	2	2	1	1	205	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	15	67	2	2	1	1	175	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	15	67	2	2	1	1	178	cards
G	G2UPPER WOODY ISL CHNL	-123.53468	46.25398	5	15	67	2	2	1	1	305	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	16	67	2	3	?	1	355	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	16	67	2	3	?	1	180	cards

G	G2WOODY ISL CHNL	-123.53468	46.25398	5	16	67	2	3	?	1	170	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	16	67	2	3	?	1	210	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	16	67	2	3	?	1	165	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	16	67	2	3	?	1	180	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	16	67	2	3	?	1	210	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	16	67	2	3	?	1	190	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	16	67	2	3	?	1	163	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	16	67	2	3	?	1	175	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	16	67	2	3	?	1	180	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	16	67	2	3	?	1	200	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	16	67	2	3	?	1	180	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	16	67	2	3	?	1	160	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	16	67	2	3	?	1	215	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	16	67	2	3	?	1	190	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	185	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	160	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	203	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	195	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	230	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	221	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	250	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	195	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	205	cards

G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	192	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	168	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	204	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	194	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	190	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	190	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	220	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	215	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	260	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	150	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	224	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	200	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	270	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	190	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	273	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	232	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	304	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	176	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	196	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	160	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	250	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	175	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	17	67	2	2	?	1	245	cards

G	G2WOODY ISL CHNL	-123.53468	46.25398	5	18	67	2	3	?	1	190	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	18	67	2	3	?	1	190	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	18	67	2	3	?	1	190	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	18	67	2	3	?	1	210	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	18	67	2	3	?	1	185	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	18	67	2	3	?	1	180	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	18	67	2	3	?	1	188	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	18	67	2	3	?	1	210	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	19	67	2	5	?	1	201	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	19	67	2	5	?	1	204	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	19	67	2	5	?	1	174	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	19	67	2	5	?	1	260	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	19	67	2	5	?	1	222	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	22	67	2	3	?	1	305	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	22	67	2	3	?	1	330	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	22	67	2	3	?	1	195	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	22	67	2	3	?	1	240	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	22	67	2	3	?	1	180	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	22	67	2	3	?	1	170	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	22	67	2	3	?	1	165	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	22	67	2	3	?	1	162	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	22	67	2	3	?	1	181	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	22	67	2	3	?	1	220	cards

G	G2WOODY ISL CHNL	-123.53468	46.25398	5	22	67	2	3	?	1	195	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	22	67	2	3	?	1	175	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	22	67	2	3	?	1	150	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	22	67	2	3	?	1	230	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	22	67	2	3	?	1	170	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	22	67	2	3	?	1	190	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	22	67	2	3	?	1	170	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	23	67	2	3	?	1	155	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	23	67	2	3	?	1	192	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	23	67	2	3	?	1	183	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	23	67	2	3	?	1	201	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	24	67	2	2	?	1	194	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	24	67	2	2	?	1	200	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	24	67	2	2	?	1	207	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	24	67	2	2	?	1	220	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	24	67	2	2	?	1	178	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	25	67	2	4	?	1	225	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	5	26	67	2	1	1	1	205	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	6	7	67	2	5		0		cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	6	8	67	2	1		0		cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	6	8	67	2	4		0		cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	6	9	67	2	4	?	1	218	cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	6	12	67	2	2		0		cards

G	G2WOODY ISL CHNL	-123.53468	46.25398	6	13	67	2	3		0		cards
G	G2WOODY ISL CHNL	-123.53468	46.25398	6	27	67	2	4		0		cards
H	H1PUGET ISL	-123.42710	46.19366	7	5	67	2	12		0		cards
I	I2HALF MILE UP WESTPORT SLOUGH	-123.34754	46.14202	7	5	67	2	6		0		cards
D	D1noname	-123.77808	46.22935	7	6	67	2	3		0		cards
E	E1noname	-123.73014	46.21813	7	6	67	2	5		0		cards
A	A1CLATSOP SPIT	-124.00983	46.24173	7	7	67	2	5		0		cards
I	I1WESTPORT SLOUGH	-123.38920	46.14924	7	7	67	2	1		0		cards
I	I1WESTPORT SLOUGH	-123.38920	46.14924	7	7	67	2	9		0		cards
I	I2WESTPORT BEACH	-123.34754	46.14202	7	10	67	2	8	?	1	275	cards
I	I3UPPER PUGET ISL ACROSS FROM LIGHT 62	-123.36420	46.14923	7	10	67	2	2		0		cards
H	H1PUGET ISL	-123.42710	46.19366	7	11	67	2	3		0		cards
I	I2HALF MILE UP WESTPORT SLOUGH	-123.34754	46.14202	7	11	67	2	10		0		cards
A	A1CLATSOP SPIT	-124.00983	46.24173	7	12	67	2	4		0		cards
A	A2SAND ISL	-124.00524	46.26876	7	12	67	2	2		0		cards
B	B2PNT ADAMS	-123.96565	46.26531	7	12	67	2	2		0		cards
C	C3WARRENTON ENTRANCE DN RIVER FROM SKIPANON	-123.92314	46.19246	7	12	67	2	2		0		cards
I	I2HALF MILE UP WESTPORT SLOUGH	-123.34754	46.14202	7	12	67	2	10		0		cards
E	E1BURNS BEACH	-123.73014	46.21813	7	13	67	2	5		0		cards
E	E2MILLER SANDS	-123.69220	46.25096	7	13	67	2	4		0		cards
H	H1PUGET ISL	-123.42710	46.19366	7	13	67	2	6		0		cards
C	C1MCGOWAN	-123.89520	46.24229	7	14	67	2	8		0		cards
A	A3ILWACO CHNL	-124.03401	46.27350	7	17	67	2	4		0		cards

I	I21/4 MILE ABOVE WESTPORT SLOUGH	-123.34754	46.14202	7	17	67	2	6		0		cards
H	H1LOWER PUGET ISL	-123.42710	46.19366	7	18	67	2	2		0		cards
I	I2WESTPORT	-123.34754	46.14202	7	18	67	2	10		0		cards
I	I2WESTPORT	-123.34754	46.14202	7	19	67	2	3		0		cards
A	A2SAND ISL	-124.00524	46.26876	7	21	67	2	1		0		cards
C	C1MCGOWAN	-123.89520	46.24229	7	21	67	2	3		0		cards
G	G4JIM CROW PNT	-123.55249	46.26457	7	24	67	2	3		0		cards
A	A1PUGET ISL	-124.00983	46.24173	7	25	67	2	5		0		cards
C	C2MID COLUMBIA ON ISL BEFORE BRIDGE	-123.89271	46.21321	7	25	67	2	2		0		cards
C	C3WARRENTON INLET	-123.92314	46.19246	7	25	67	2	4		0		cards
C	C4LONG SHORE WAREHOUSE	-123.86854	46.18872	7	25	67	2	2		0		cards
H	H1LOWER PUGET ISL	-123.42710	46.19366	7	25	67	2	2		0		cards
D	D1TAYLOR SANDS	-123.77808	46.22935	7	26	67	2	2		0		cards
E	E2RICE ISL	-123.69220	46.25096	7	26	67	2	3	?	1	255	cards
H	H1PUGET ISL ACROSS FROM BRADWOOD	-123.42710	46.19366	7	27	67	2	5		0		cards
A	A1CLATSOP SPIT	-124.00983	46.24173	7	31	67	2	2		0		cards
A	A2SAND ISL	-124.00524	46.26876	7	31	67	2	2		0		cards
A	A3ILWACO CHNL	-124.03401	46.27350	7	31	67	2	2		0		cards
C	C1MCGOWAN BEACH	-123.89520	46.24229	7	31	67	2	2		0		cards
H	H1PUGET ISL	-123.42710	46.19366	7	31	67	2	7		0		cards
I	I2WESTPORT BEACH	-123.34754	46.14202	7	31	67	2	2		0		cards
D	D1TONGUE PNT PIER 3	-123.77808	46.22935	8	1	67	2	1		0		cards
D	D1TONGUE PNT PIER 3	-123.77808	46.22935	8	10	67	2	2		0		cards

H	H1Puget Island	-123.42710	46.19366	1	23	68	1	2		0		cards
H	H1Puget Island	-123.42710	46.19366	2	12	68	1	3		0		cards
H	H1Lower End Puget Island	-123.42710	46.19366	2	29	68	1	3		0		cards
I	I21/4 mi. upriver from Westport Slough	-123.34754	46.14202	3	8	68	1	3	3	0		cards
H	H1W. end Puget Is.	-123.42710	46.19366	3	22	68	1	5		0		cards
I	I2Btwn 1st & 2nd Jetty at Westport	-123.34754	46.14202	3	22	68	1	4	2	1	343	cards
I	I2Btwn 1st & 2nd Jetty at Westport	-123.34754	46.14202	3	22	68	1	4	2	1	368	cards
I	I2Btwn 1st & 2nd Jetty at Westport	-123.34754	46.14202	3	22	68	1	4	2	1	521	cards
I	I2Btwn 1st & 2nd Jetty at Westport	-123.34754	46.14202	3	22	68	1	4	4	1	263	cards
E	E1W. end Burns Beach	-123.73014	46.21813	3	25	68	1	3		0		cards
G	G4Jim Crow Point	-123.55249	46.26457	3	26	68	1	5	1	1	305	cards
G	G4Jim Crow Point	-123.55249	46.26457	3	26	68	1	5	?	1	431	cards
G	G4Jim Crow Point	-123.55249	46.26457	3	26	68	1	5	?	1	266	cards
G	G4Jim Crow Point	-123.55249	46.26457	3	26	68	1	5	?	1	292	cards
G	G4Jim Crow Point	-123.55249	46.26457	3	26	68	1	5	?	1	406	cards
H	H1Puget Island	-123.42710	46.19366	3	27	68	1	8		0		cards
A	A1East of Jetty	-124.00983	46.24173	3	28	68	1	3		0		cards
A	A2Sand Is.	-124.00524	46.26876	3	28	68	1	3		0		cards
E	E1Burns Is. West end	-123.73014	46.21813	3	28	68	1	4		0		cards
E	E2SE Rice Is.	-123.69220	46.25096	3	28	68	1	2		0		cards
H	H1Puget Island West end	-123.42710	46.19366	3	29	68	1	5		0		cards
G	G4Jim Crow Point	-123.55249	46.26457	4	2	68	1	4		0		cards
H	H1Puget Island West end	-123.42710	46.19366	4	2	68	1	5		0		cards

D	D1Taylor Sands East	-123.77808	46.22935	4	3	68	1	4		0		cards
E	E1E. Side Burns Is.	-123.73014	46.21813	4	3	68	1	2		0		cards
E	E2Lone Is. At west end of Rice Is.	-123.69220	46.25096	4	3	68	1	4		0		cards
F	F2Miller Sands	-123.67333	46.25106	4	3	68	1	2		0		cards
C	C3Warrington entrance	-123.92314	46.19246	4	5	68	1	3		0		cards
E	E1Burns Beach	-123.73014	46.21813	4	5	68	1	4		0		cards
H	H1Puget Island	-123.42710	46.19366	4	11	68	1	3		0		cards
H	H2Bradwood Beach	-123.44210	46.20923	4	11	68	1	4		0		cards
H	H1Puget Island	-123.42710	46.19366	4	16	68	1	4	3	1	305	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	17	68	1	4		0		cards
H	H1West End Puget Is.	-123.42710	46.19366	4	19	68	1	5		0		cards
H	H1West End Puget Is.	-123.42710	46.19366	4	22	68	1	6	4	1	209	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	23	68	1	12	2	1	186	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	23	68	1	12	2	1	178	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	23	68	1	12	2	1	198	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	23	68	1	12	2	1	178	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	23	68	1	12	2	1	178	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	23	68	1	12	2	1	200	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	23	68	1	12	2	1	190	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	24	68	1	10	?	1	381	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	24	68	1	10	?	1	381	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	24	68	1	10	?	1	381	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	24	68	1	10	?	1	355	cards

H	H1West End Puget Is.	-123.42710	46.19366	4	24	68	1	10	?	1	355	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	24	68	1	10	?	1	206	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	24	68	1	10	?	1	210	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	24	68	1	10	?	1	209	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	24	68	1	10	?	1	156	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	24	68	1	10	?	1	179	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	24	68	1	10	?	1	198	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	24	68	1	10	?	1	195	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	25	68	1	16	?	1	223	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	25	68	1	16	?	1	170	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	25	68	1	16	?	1	196	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	25	68	1	16	?	1	180	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	25	68	1	16	?	1	279	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	25	68	1	16	?	1	355	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	25	68	1	16	?	1	508	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	25	68	1	16	?	1	208	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	25	68	1	16	?	1	127	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	25	68	1	16	?	1	211	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	25	68	1	16	?	1	208	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	25	68	1	16	?	1	196	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	25	68	1	16	?	1	193	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	26	68	1	12	?	1	330	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	26	68	1	12	?	1	240	cards

H	H1West End Puget Is.	-123.42710	46.19366	4	26	68	1	12	?	1	219	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	26	68	1	12		9		cards
H	H1West End Puget Is.	-123.42710	46.19366	4	29	68	1	11	?	1	238	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	29	68	1	11	?	1	230	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	29	68	1	11	?	1	355	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	29	68	1	11	?	1	209	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	29	68	1	11	?	1	220	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	29	68	1	11	?	1	220	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	29	68	1	11	?	1	210	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	29	68	1	11	?	1	214	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	29	68	1	11	?	1	197	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	29	68	1	11	?	1	185	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	29	68	1	11	?	1	220	cards
H	H1West End Puget Is.	-123.42710	46.19366	4	29	68	1	11	?	1	245	cards
H	H1Puget Island	-123.42710	46.19366	4	30	68	1	11	1	1	175	cards
H	H1Puget Island	-123.42710	46.19366	4	30	68	1	11	1	1	175	cards
H	H1Puget Island	-123.42710	46.19366	4	30	68	1	11	2	1	273	cards
H	H1Puget Island	-123.42710	46.19366	4	30	68	1	11	2	1	214	cards
H	H1Puget Island	-123.42710	46.19366	4	30	68	1	11	2	1	159	cards
H	H1Puget Island	-123.42710	46.19366	4	30	68	1	11	4	1	191	cards
H	H1Puget Island	-123.42710	46.19366	4	30	68	1	11	4	1	181	cards
H	H1Puget Island	-123.42710	46.19366	4	30	68	1	11	5	1	205	cards
H	H1Puget Island	-123.42710	46.19366	4	30	68	1	11	5	1	173	cards

H	H1Puget Island	-123.42710	46.19366	4	30	68	1	11	8	1	170	cards
H	H1Puget Island	-123.42710	46.19366	4	30	68	1	11	11	1	194	cards
H	H1Puget Island	-123.42710	46.19366	4	30	68	1	11	11	1	175	cards
H	H1Puget Island	-123.42710	46.19366	5	1	68	1	11	1	1	211	cards
H	H1Puget Island	-123.42710	46.19366	5	1	68	1	11	2	1	185	cards
H	H1Puget Island	-123.42710	46.19366	5	1	68	1	11	2	1	190	cards
H	H1Puget Island	-123.42710	46.19366	5	1	68	1	11	2	1	182	cards
H	H1Puget Island	-123.42710	46.19366	5	1	68	1	11	3	1	190	cards
H	H1Puget Island	-123.42710	46.19366	5	1	68	1	11	4	1	168	cards
H	H1Puget Island	-123.42710	46.19366	5	1	68	1	11	5	1	199	cards
H	H1Puget Island	-123.42710	46.19366	5	1	68	1	11	7	1	163	cards
H	H1Puget Island	-123.42710	46.19366	5	1	68	1	11	8	1	179	cards
H	H1Puget Island	-123.42710	46.19366	5	1	68	1	11	9	1	191	cards
H	H1Puget Island	-123.42710	46.19366	5	1	68	1	11	9	1	179	cards
H	H1Puget Island	-123.42710	46.19366	5	1	68	1	11	9	1	223	cards
H	H1Puget Island	-123.42710	46.19366	5	1	68	1	11	9	1	235	cards
H	H1Puget Island	-123.42710	46.19366	5	1	68	1	11	10	1	236	cards
H	H1Puget Island	-123.42710	46.19366	5	1	68	1	11	10	1	180	cards
H	H1Puget Island	-123.42710	46.19366	5	1	68	1	11	11	1	200	cards
H	H1Puget Island	-123.42710	46.19366	5	1	68	1	11	11	1	179	cards
H	H1Puget Island	-123.42710	46.19366	5	1	68	1	11	11	1	170	cards
H	H1Puget Island	-123.42710	46.19366	5	1	68	1	11	11	1	190	cards
H	H1Puget Island	-123.42710	46.19366	5	1	68	1	11	11	1	199	cards

H	H1Puget Island	-123.42710	46.19366	8	7	68	1	8		0		cards
A	A1Clatsop Spit Upper	-124.00983	46.24173	8	13	68	1	4		0		cards
A	A3Illwaco Channel	-124.03401	46.27350	8	13	68	1	6		0		cards
B	B1Ft. Stevens	-123.96482	46.21204	8	14	68	1	3		0		cards
C	C2McGowin	-123.89271	46.21321	8	14	68	1	4	1	1	330	cards
C	C2McGowin	-123.89271	46.21321	8	14	68	1	-999	1	-999	279	cards
C	C3Mouth of Skipanon	-123.92314	46.19246	8	14	68	1	3		0		cards
D	D1Taylor Sands	-123.77808	46.22935	8	15	68	1	2		0		cards
E	E1Burns Beach	-123.73014	46.21813	8	15	68	1	4	2	1	292	cards
E	E1Burns Beach	-123.73014	46.21813	8	15	68	1	4	2	1	266	cards
E	E1Burns Beach	-123.73014	46.21813	8	15	68	1	4	2	1	241	cards
E	E1Burns Beach	-123.73014	46.21813	8	15	68	1	4	3	1	292	cards
E	E2Upper Rice Is.	-123.69220	46.25096	8	15	68	1	6	3	1	266	cards
E	E2Upper Rice Is.	-123.69220	46.25096	8	15	68	1	6	3	1	292	cards
E	E2Upper Rice Is.	-123.69220	46.25096	8	15	68	1	6	4	1	187	cards
F	F6Between F-5 and F-6	-999.00000	-999.00000	8	15	68	1	2	?	1	213	cards
A	A2Sand Is.	-124.00524	46.26876	8	16	68	1	4	2	1	330	cards
B	B1Sand Is.	-123.96482	46.21204	8	16	68	1	4		0		cards
E	E1Burns Beach	-123.73014	46.21813	8	16	68	1	2	?	1	330	cards
D	D1Taylor Sands	-123.77808	46.22935	9	9	68	1	2	1	1	330	cards
D	D1Taylor Sands	-123.77808	46.22935	9	9	68	1	2	1	1	330	cards
D	D1Taylor Sands	-123.77808	46.22935	9	9	68	1	2	1	1	330	cards
D	D1Taylor Sands	-123.77808	46.22935	9	9	68	1	2	1	1	330	cards

E	E2Rice Is.	-123.69220	46.25096	9	9	68	1	2	1	2		cards
E	E2Rice Is.	-123.69220	46.25096	9	9	68	1	2	2	1		cards
G	G2Woody Island Channel	-123.53468	46.25398	4	22	68	2	4		0		cards
H	H1Lower Puget Island	-123.42710	46.19366	4	23	68	2	2		0		cards
-999	-999Puget Is. To Jim Crow Pt.	-999.00000	-999.00000	4	24	68	2	5		0		cards
H	H1Channel off H-1	-123.42710	46.19366	4	25	68	2	4	4	1	270	cards
H	H1Channel off H-1, between Bradwood and Cathlamet channel	-123.42710	46.19366	4	26	68	2	6	5	1	308	cards
G	G2Woody Island Channel	-123.53468	46.25398	4	29	68	2	5	?	1	220	cards
G	G2Woody Island Channel	-123.53468	46.25398	4	29	68	2	5	?	1	287	cards
H	H1Channel off H-1, between Bradwood and Cathlamet channel	-123.42710	46.19366	4	30	68	2	3	1	1	251	cards
H	H1Channel off H-1, between Bradwood and Cathlamet channel	-123.42710	46.19366	4	30	68	2	3	3	1	185	cards
H	H1Channel off H-1, between Bradwood and Cathlamet channel	-123.42710	46.19366	5	1	68	2	5	2	1	205	cards
H	H1Channel off H-1, between Bradwood and Cathlamet channel	-123.42710	46.19366	5	1	68	2	5	4	1	217	cards
H	H1Channel off H-1, between Bradwood and Cathlamet channel	-123.42710	46.19366	5	1	68	2	5	4	1	300	cards
H	H1Channel off H-1, between Bradwood and Cathlamet channel	-123.42710	46.19366	5	1	68	2	5	4	1	200	cards
H	H1Channel off H-1, between Bradwood and Cathlamet channel	-123.42710	46.19366	5	1	68	2	5	4	1	431	cards
H	H1Channel off H-1, between Bradwood and Cathlamet channel	-123.42710	46.19366	5	1	68	2	5	5	1	186	cards
H	H1Channel off H-1, between Bradwood and Cathlamet channel	-123.42710	46.19366	5	1	68	2	5	5	1	220	cards
H	H1Channel off H-1, between Bradwood and Cathlamet channel	-123.42710	46.19366	5	1	68	2	5	5	1	245	cards
G	G2Woody Island Channel	-123.53468	46.25398	5	2	68	2	4	1	1	330	cards
G	G2Woody Island Channel	-123.53468	46.25398	5	2	68	2	4	1	1	220	cards
G	G2Woody Island Channel	-123.53468	46.25398	5	2	68	2	4	?	1	381	cards
J	J1Ship Channel from J-1 to I-2	-123.29254	46.13970	5	2	68	2	3	1	1	189	cards

J	J1Ship Channel from J-1 to I-2	-123.29254	46.13970	5	2	68	2	3	1	1	187	cards
J	J1Ship Channel from J-1 to I-2	-123.29254	46.13970	5	2	68	2	3	1	1	170	cards
J	J1Ship Channel from J-1 to I-2	-123.29254	46.13970	5	2	68	2	3	1	1	192	cards
J	J1Ship Channel from J-1 to I-2	-123.29254	46.13970	5	2	68	2	3	1	1	199	cards
J	J1Ship Channel from J-1 to I-2	-123.29254	46.13970	5	2	68	2	3	1	1	165	cards
J	J1Ship Channel from J-1 to I-2	-123.29254	46.13970	5	2	68	2	3	1	1	192	cards
J	J1Ship Channel from J-1 to I-2	-123.29254	46.13970	5	2	68	2	3	1	1	200	cards
J	J1Ship Channel from J-1 to I-2	-123.29254	46.13970	5	2	68	2	3	1	1	355	cards
J	J1Ship Channel from J-1 to I-2	-123.29254	46.13970	5	2	68	2	3	1	1	178	cards
J	J1Ship Channel from J-1 to I-2	-123.29254	46.13970	5	2	68	2	3	2	1	190	cards
J	J1Ship Channel from J-1 to I-2	-123.29254	46.13970	5	2	68	2	3	2	1	192	cards
J	J1Ship Channel from J-1 to I-2	-123.29254	46.13970	5	2	68	2	3	2	1	220	cards
J	J1Ship Channel from J-1 to I-2	-123.29254	46.13970	5	2	68	2	3	2	1	172	cards
J	J1Ship Channel from J-1 to I-2	-123.29254	46.13970	5	2	68	2	3	2	1	150	cards
J	J1Ship Channel from J-1 to I-2	-123.29254	46.13970	5	2	68	2	3	2	1	150	cards
J	J1Ship Channel from J-1 to I-2	-123.29254	46.13970	5	2	68	2	3	2	1	170	cards
J	J1Ship Channel from J-1 to I-2	-123.29254	46.13970	5	2	68	2	3	2	1	170	cards
J	J1Ship Channel from J-1 to I-2	-123.29254	46.13970	5	2	68	2	3	3	1	145	cards
J	J1Ship Channel from J-1 to I-2	-123.29254	46.13970	5	2	68	2	3	3	1	190	cards
J	J1Ship Channel from J-1 to I-2	-123.29254	46.13970	5	2	68	2	3	3	1	173	cards
J	J1Ship Channel from J-1 to I-2	-123.29254	46.13970	5	2	68	2	3	3	1	150	cards
J	J1Ship Channel from J-1 to I-2	-123.29254	46.13970	5	2	68	2	3	3	1	186	cards
J	J1Ship Channel from J-1 to I-2	-123.29254	46.13970	5	2	68	2	3	3	1	197	cards

J	J1Ship Channel from J-1 to I-2	-123.29254	46.13970	5	2	68	2	3	3	1	178	cards
G	G2Woody Island Channel	-123.53468	46.25398	6	12	68	2	4	4	1	250	cards
G	G2Woody Island Channel	-123.53468	46.25398	6	13	68	2	6	6	1	192	cards
-999	-999Lower Columbia	-999.00000	-999.00000	7	14	68	2	3		0		cards
-999	-999Lower Columbia	-999.00000	-999.00000	7	16	68	2	6		0		cards
-999	-999Lower Columbia	-999.00000	-999.00000	7	24	68	2	3	2	1	255	cards
-999	-999Lower Columbia	-999.00000	-999.00000	7	24	68	2	3	2	1	243	cards
E	E2Rice Island	-123.69220	46.25096	8	20	68	2	4		0		cards
E	E22nd Island above Rice Is.	-123.69220	46.25096	8	20	68	2	2		0		cards
-999	-999Between Water Sample Stations 1&2	-999.00000	-999.00000	8	21	68	2	2		0		cards
C	C2Along Desdamona Sands Off Hammond	-123.89271	46.21321	8	22	68	2	1		0		cards
E	E2Rice Island	-123.69220	46.25096	8	22	68	2	3		0		cards
C	C2McGowan	-123.89271	46.21321	8	23	68	2	1		0		cards
D	D1Off Astoria btwn Tongue Pt. & Taylor Sands	-123.77808	46.22935	8	23	68	2	2	?	1	271	cards
E	E2Rice Island	-123.69220	46.25096	8	26	68	2	6		0		cards
-999	-999Buoy #43	-999.00000	-999.00000	8	27	68	2	2	2	1	268	cards
-999	-999Buoy #43	-999.00000	-999.00000	8	27	68	2	1	1	1	240	cards
C	C1Meglar	-123.89520	46.24229	8	27	68	2	-999		-999		cards
D	D1Taylor Sands	-123.77808	46.22935	8	28	68	2	7	2	1	355	cards
D	D1Taylor Sands	-123.77808	46.22935	8	28	68	2	7	5	1	254	cards
D	D1Taylor Sands	-123.77808	46.22935	8	29	68	2	8	1	1	258	cards
D	D1Taylor Sands	-123.77808	46.22935	8	29	68	2	8	4	1	279	cards
D	D1Taylor Sands	-123.77808	46.22935	8	30	68	2	1	1	3		cards

E	E2Rice Island	-123.69220	46.25096	8	30	68	2	7	2	1	248	cards
E	E2Rice Island	-123.69220	46.25096	8	30	68	2	7	3	1	245	cards
E	E2Rice Island	-123.69220	46.25096	8	30	68	2	7	3	1	248	cards
E	E2Rice Island	-123.69220	46.25096	8	30	68	2	7	3	1	253	cards
-999	-999Off Maritime Base	-999.00000	-999.00000	3	28	69	1	1		0		cards
H	H1400 yards up from Ten Is.	-123.42710	46.19366	8	5	69	1	10	2	2		cards
H	H1400 yards up from Ten Is.	-123.42710	46.19366	8	5	69	1	10	1	6		cards
A	A1Clatsop Spit	-124.00983	46.24173	8	11	69	1	3		0		cards
I	I1Puget Island	-123.38920	46.14924	8	12	69	1	8	7	1		cards
I	I1Puget Island	-123.38920	46.14924	8	12	69	1	8	3	2		cards
I	I1Puget Island	-123.38920	46.14924	8	12	69	1	8	1	4		cards
I	I1Puget Island	-123.38920	46.14924	8	14	69	1	8		0		cards
A	A1Clatsop Spit	-124.00983	46.24173	8	20	69	1	4	4	1	279	cards
A	A1Clatsop Spit	-124.00983	46.24173	8	20	69	1	4	3	1	330	cards
A	A1Clatsop Spit	-124.00983	46.24173	8	20	69	1	4	2	1	355	cards
C	C1McGowan	-123.89520	46.24229	8	20	69	1	4	4	1	292	cards
C	C1McGowan	-123.89520	46.24229	8	20	69	1	4	4	1	330	cards
C	C1McGowan	-123.89520	46.24229	8	20	69	1	4	1	1	355	cards
C	C1McGowan	-123.89520	46.24229	8	20	69	1	4	4	1	355	cards
A	A1Clatsop Spit	-124.00983	46.24173	8	21	69	1	1		0		cards
A	A2Sand Island	-124.00524	46.26876	8	21	69	1	4		0		cards
C	C1McGowan	-123.89520	46.24229	8	21	69	1	3		0		cards
A	A1Clatsop Spit	-124.00983	46.24173	8	26	69	1	1		1		cards

C	C1McGowan	-123.89520	46.24229	8	26	69	1	1		0		cards
A	A1Clatsop Spit	-124.00983	46.24173	9	5	69	1	3		0		cards
B	B1Pt. Adams	-123.96482	46.21204	9	5	69	1	1		0		cards
C	C1McGowan	-123.89520	46.24229	9	5	69	1	3	1	1	350	cards
A	A1Clatsop Spit	-124.00983	46.24173	9	12	69	1	4		0		cards
C	C1McGowan	-123.89520	46.24229	9	12	69	1	4		0		cards
A	A1Clatsop Spit	-124.00983	46.24173	9	23	69	1	2		0		cards
B	B1Pt. Adams	-123.96482	46.21204	9	23	69	1	3		0		cards
D	D1Taylor Sands	-123.77808	46.22935	10	2	69	1	4		0		cards
E	E1Between N. Channel and ship channel	-123.73014	46.21813	10	2	69	1	4		0		cards
E	E2Upper Rice Island	-123.69220	46.25096	10	2	69	1	4		0		cards
D	D1Taylor Sands	-123.77808	46.22935	10	24	69	1	3		0		cards
E	E2Rice Island	-123.69220	46.25096	10	24	69	1	3		0		cards
D	D1Taylor Sands	-123.77808	46.22935	10	31	69	1	2		0		cards
E	E1Burns Beach	-123.73014	46.21813	10	31	69	1	5		0		cards
D	D1N. Channel 2 mi. SE of Tongue Pt.	-123.77808	46.22935	2	13	69	2	2		0		cards
D	D1N. Channel 1-3 mi. above Tongue Pt.	-123.77808	46.22935	3	27	69	2	3		0		cards
D	D1Taylor Sands in the shipping channel	-123.77808	46.22935	3	27	69	2	3		0		cards
D	D1N. Channel 1-3 mi. above Tongue Pt.	-123.77808	46.22935	3	28	69	2	3		0		cards
D	D1Taylor Sands in the shipping channel	-123.77808	46.22935	3	28	69	2	3		0		cards
-999	-999Jetty #60	-999.00000	-999.00000	4	3	69	2	1		0		cards
-999	-999Light #37	-999.00000	-999.00000	4	3	69	2	1		0		cards
-999	-999Water Station 10C	-999.00000	-999.00000	4	3	69	2	1		0		cards

H	H1500 yards below Puget Island	-123.42710	46.19366	4	3	69	2	1		0		cards
I	I3Puget Island Bradwood	-123.36420	46.14923	4	3	69	2	1		0		cards
G	G2Woody Is. Channel	-123.53468	46.25398	4	4	69	2	4		0		cards
G	G1Rockland & Woody Is. Channel	-123.58041	46.25334	4	9	69	2	2		0		cards
H	H1Main channel off H-1	-123.42710	46.19366	4	9	69	2	1		0		cards
G	G2Woody Is. Channel	-123.53468	46.25398	4	10	69	2	4		0		cards
G	G2Woody Is. Channel near Miller Sands	-123.53468	46.25398	4	10	69	2	2		0		cards
D	D1N. Channel near Tongue Pt.	-123.77808	46.22935	4	14	69	2	3	2	1	330	cards
D	D1N. Channel near Tongue Pt.	-123.77808	46.22935	4	15	69	2	3		0		cards
D	D1N. Channel near Tongue Pt.	-123.77808	46.22935	4	16	69	2	3		0		cards
D	D1N. Channel near Tongue Pt.	-123.77808	46.22935	4	17	69	2	1		0		cards
D	D1N. Channel near Tongue Pt.	-123.77808	46.22935	4	18	69	2	4		0		cards
G	G2Woody Is. Channel	-123.53468	46.25398	4	23	69	2	5	2	1	317	cards
G	G2Woody Is. Channel	-123.53468	46.25398	4	24	69	2	5	2	1	261	cards
G	G2Woody Is. Channel	-123.53468	46.25398	4	24	69	2	5	3	1	297	cards
G	G2Woody Is. Channel	-123.53468	46.25398	4	24	69	2	5	1	1	381	cards
G	G2Woody Is. Channel	-123.53468	46.25398	4	25	69	2	7	6	1	317	cards
G	G2Woody Is. Channel	-123.53468	46.25398	4	25	69	2	7	1	1	381	cards
G	G2Woody Is. Channel	-123.53468	46.25398	4	25	69	2	7	4	1	431	cards
G	G2Woody Is. Channel	-123.53468	46.25398	6	11	69	2	4	1	1	164	cards
G	G2Woody Is. Channel	-123.53468	46.25398	6	11	69	2	4	2	1	198	cards
G	G2Woody Is. Channel	-123.53468	46.25398	6	12	69	2	4	4	1	159	cards
G	G2Woody Is. Channel	-123.53468	46.25398	6	12	69	2	4	3	1	169	cards

G	G2Woody Is. Channel	-123.53468	46.25398	6	12	69	2	4	4	1	184	cards
C	C1WA side below Astoria Bridge	-123.89520	46.24229	6	13	69	2	3		0		cards
D	D1Tongue Pt. By ship channel	-123.77808	46.22935	6	13	69	2	1		0		cards
C	C1WA side below Astoria Bridge	-123.89520	46.24229	6	16	69	2	3		0		cards
D	D1Tongue Pt.	-123.77808	46.22935	6	16	69	2	1		0		cards
G	G2Woody Is. Channel	-123.53468	46.25398	6	17	69	2	3		0		cards
D	D1Tongue Pt. By ship channel	-123.77808	46.22935	6	19	69	2	3		0		cards
C	C1WA side below Astoria Bridge	-123.89520	46.24229	6	20	69	2	5	1	1	187	cards
C	C1WA side below Astoria Bridge	-123.89520	46.24229	6	23	69	2	3		0		cards
G	G2Woody Is. To Jim Crow Pt. Ship channel	-123.53468	46.25398	6	24	69	2	4		0		cards
D	D1Tongue Pt./Taylor Sands ship channel	-123.77808	46.22935	6	26	69	2	4	4	1	183	cards
D	D1Tongue Pt./Taylor Sands ship channel	-123.77808	46.22935	6	26	69	2	4	3	1	194	cards
D	D1Tongue Pt./Taylor Sands ship channel	-123.77808	46.22935	6	26	69	2	4	1	1	406	cards
C	C1WA side below Astoria Bridge	-123.89520	46.24229	6	27	69	2	4		0		cards
C	C1WA side below Astoria Bridge	-123.89520	46.24229	6	30	69	2	4	3	1	212	cards
G	G2Woody Is. Channel	-123.53468	46.25398	7	2	69	2	4		0		cards
C	C1WA side below Astoria Bridge	-123.89520	46.24229	7	7	69	2	4		0		cards
G	G2Woody Is. Ship channel	-123.53468	46.25398	7	8	69	2	6		0		cards
C	C1WA side below Astoria Bridge	-123.89520	46.24229	7	10	69	2	3		0		cards
C	C1WA side below Astoria Bridge	-123.89520	46.24229	7	11	69	2	3		0		cards
D	D3Gray's Pt.	-123.76390	46.27225	7	11	69	2	3		0		cards
C	C1WA side below Astoria Bridge	-123.89520	46.24229	7	14	69	2	4		0		cards
G	G2Woody Is. Ship channel	-123.53468	46.25398	7	15	69	2	6		0		cards

C	C1WA side below Astoria Bridge	-123.89520	46.24229	7	22	69	2	2		0		cards
D	D1Tongue Pt./Taylor Sands ship channel	-123.77808	46.22935	7	22	69	2	2		0		cards
A	A4South jetty	-124.01583	46.21596	7	25	69	2	6		0		cards
A	A5North jetty	-124.09523	46.27101	7	28	69	2	6	4	1	233	cards
A	A5North jetty	-124.09523	46.27101	7	28	69	2	6	3	1	240	cards
A	A5North jetty	-124.09523	46.27101	7	28	69	2	6	3	1	265	cards
A	A5North jetty	-124.09523	46.27101	7	28	69	2	6	2	1	269	cards
A	A5North jetty	-124.09523	46.27101	7	28	69	2	6	3	1	275	cards
A	A5North jetty	-124.09523	46.27101	7	28	69	2	6	2	1	278	cards
A	A5North jetty	-124.09523	46.27101	7	28	69	2	6	3	1	280	cards
A	A5North jetty	-124.09523	46.27101	7	28	69	2	6	4	1	280	cards
A	A5North jetty	-124.09523	46.27101	7	28	69	2	6	2	1	285	cards
A	A5North jetty	-124.09523	46.27101	7	28	69	2	6	3	1	285	cards
A	A5North jetty	-124.09523	46.27101	7	28	69	2	6	4	1	285	cards
A	A5North jetty	-124.09523	46.27101	7	28	69	2	6	2	1	290	cards
A	A5North jetty	-124.09523	46.27101	7	28	69	2	6	3	1	290	cards
A	A5North jetty	-124.09523	46.27101	7	28	69	2	6	4	1	290	cards
A	A5North jetty	-124.09523	46.27101	7	28	69	2	6	4	1	300	cards
A	A5North jetty	-124.09523	46.27101	7	28	69	2	6	4	1	300	cards
A	A5North jetty	-124.09523	46.27101	7	28	69	2	6	3	1	310	cards
A	A5North jetty	-124.09523	46.27101	7	28	69	2	6	4	1	310	cards
A	A5North jetty	-124.09523	46.27101	7	28	69	2	6	2	1	320	cards
A	A5North jetty	-124.09523	46.27101	7	28	69	2	6	3	1	320	cards

A	A5North jetty	-124.09523	46.27101	7	28	69	2	6	2	1	330	cards
A	A5North jetty	-124.09523	46.27101	7	28	69	2	6	2	1	330	cards
A	A5North jetty	-124.09523	46.27101	7	28	69	2	6	2	1	480	cards
A	A5North jetty	-124.09523	46.27101	7	28	69	2	6	4	2	-999	cards
A	A5North jetty	-124.09523	46.27101	7	28	69	2	6	5	3	-999	cards
A	A4South jetty	-124.01583	46.21596	7	29	69	2	7		0		cards
-999	-999Seaside	-999.00000	-999.00000	7	30	69	2	4		0		cards
A	A4South jetty	-124.01583	46.21596	7	31	69	2	6		0		cards
A	A4South jetty	-124.01583	46.21596	8	1	69	2	6	1	1	-999	cards
A	A4South jetty	-124.01583	46.21596	8	4	69	2	5	3	1	-999	cards
A	A4South jetty	-124.01583	46.21596	8	7	69	2	5	?	1	275	cards
A	A4South jetty	-124.01583	46.21596	8	7	69	2	5	?	1	280	cards
A	A4South jetty	-124.01583	46.21596	8	11	69	2	2		0		cards
A	A1Below Lagoon	-124.00983	46.24173	5	21	70	1	4		0		cards
A	A1Downstream from lagoon	-124.00983	46.24173	5	22	70	1	4		0		cards
A	A1Downstream from lagoon	-124.00983	46.24173	5	25	70	1	1		0		cards
C	C1Magar Church	-123.89520	46.24229	5	26	70	1	2		0		cards
A	A1Below Lagoon	-124.00983	46.24173	5	28	70	1	4		0		cards
A	A1Below Lagoon	-124.00983	46.24173	6	2	70	1	5		0		cards
A	A1Below Lagoon	-124.00983	46.24173	6	3	70	1	5		0		cards
A	A1Below Lagoon	-124.00983	46.24173	6	5	70	1	6		0		cards
A	A1BELOW LAGOON	-124.00983	46.24173	6	8	70	1	-999		-999		cards
A	A1CLATSOP SPIT	-124.00983	46.24173	6	8	70	1	12		0		cards

A	A1CLATSOP SPIT	-124.00983	46.24173	6	9	70	1	11		0		cards
A	A1CLATSOP SPIT BELOW LAGOON	-124.00983	46.24173	6	10	70	1	12		0		cards
A	A1CLATSOP SPIT BELOW LAGOON	-124.00983	46.24173	6	11	70	1	12		0		cards
A	A1CLATSOP SPIT BELOW LAGOON	-124.00983	46.24173	6	12	70	1	8		0		cards
B	B1POINT ADAMS CANNERY	-123.96482	46.21204	6	15	70	1	1		0		cards
A	A1CLATSOP SPIT BELOW LAGOON	-124.00983	46.24173	6	16	70	1	10		0		cards
A	A1CLATSOP SPIT BELOW LAGOON	-124.00983	46.24173	6	17	70	1	8		0		cards
A	A1CLATSOP SPIT BELOW LAGOON	-124.00983	46.24173	6	18	70	1	7		0		cards
A	A1CLATSOP SPIT BELOW LAGOON	-124.00983	46.24173	6	19	70	1	8		0		cards
A	A1CLATSOP SPIT BELOW LAGOON	-124.00983	46.24173	6	22	70	1	5		0		cards
A	A1CLATSOP SPIT BELOW LAGOON	-124.00983	46.24173	6	23	70	1	3		0		cards
F	F3ELLIOT PNT .75 MILE ABOVE ALTOONA	-123.63791	46.26458	6	25	70	1	6	1	1	130	cards
F	F3ELLIOT PNT .75 MILE ABOVE ALTOONA	-123.63791	46.26458	6	25	70	1	6	4	1	135	cards
F	F3ELLIOT PNT .75 MILE ABOVE ALTOONA	-123.63791	46.26458	6	25	70	1	6	1	1	140	cards
F	F3ELLIOT PNT .75 MILE ABOVE ALTOONA	-123.63791	46.26458	6	25	70	1	6	1	1	140	cards
F	F3ELLIOT PNT .75 MILE ABOVE ALTOONA	-123.63791	46.26458	6	25	70	1	6	1	1	140	cards
F	F3ELLIOT PNT .75 MILE ABOVE ALTOONA	-123.63791	46.26458	6	25	70	1	6	2	1	160	cards
F	F3ELLIOT PNT	-123.63791	46.26458	6	26	70	1	4		0		cards
A	A1CLATSOP SPIT (LAGOON)	-124.00983	46.24173	6	29	70	1	7		0		cards
B	B1POINT ADAMS AND CLATSOP SPIT	-123.96482	46.21204	6	30	70	1	5		0		cards
A	A1CLATSOP SPIT (LAGOON)	-124.00983	46.24173	7	1	70	1	4		0		cards
A	A1CLATSOP SPIT (LAGOON)	-124.00983	46.24173	7	2	70	1	4		0		cards
B	B1PNT ADAMS	-123.96482	46.21204	7	2	70	1	3		0		cards

A	A1CLATSOP SPIT (LAGOON)	-124.00983	46.24173	7	6	70	1	4		0	cards
B	B1PNT ADAMS	-123.96482	46.21204	7	6	70	1	2		0	cards
A	A1CLATSOP SPIT	-124.00983	46.24173	7	7	70	1	5		0	cards
B	B1PNT ADAMS	-123.96482	46.21204	7	7	70	1	2		0	cards
B	B1LOWER COLUMBIA POINT ADAMS	-123.96482	46.21204	7	8	70	1	4		0	cards
B	B1PNT ADAMS	-123.96482	46.21204	7	9	70	1	6		0	cards
B	B1PNT ADAMS	-123.96482	46.21204	7	10	70	1	10		0	cards
A	A1CLATSOP SPIT	-124.00983	46.24173	7	13	70	1	4		0	cards
B	B1PNT ADAMS	-123.96482	46.21204	7	13	70	1	6		0	cards
B	B1PNT ADAMS	-123.96482	46.21204	7	14	70	1	10		0	cards
C	C1MCGOWAN	-123.89520	46.24229	7	15	70	1	3		0	cards
A	A1CLATSOP SPIT	-124.00983	46.24173	7	16	70	1	7		0	cards
H	H1LOWER END PUGET SOUND	-123.42710	46.19366	7	21	70	1	7		0	cards
J	J4UPPER END PUGET SOUND	-999.00000	-999.00000	7	27	70	1	7		0	cards
H	H1LOWER PUGET ISL ACROSS FROM BRADWOOD	-123.42710	46.19366	7	28	70	1	2		0	cards
I	I3PUGET ISL ACROSS FOM WEST PORT CHNL	-123.36420	46.14923	7	28	70	1	4	2	8	cards
G	G2LOWER WOODY ISL	-123.53468	46.25398	7	29	70	1	5	4	50	cards
G	G2LOWER WOODY ISL	-123.53468	46.25398	7	29	70	1	5	5	50	cards
G	G2WOODY ISL	-123.53468	46.25398	7	30	70	1	1		0	cards
A	A1CLATSOP SPIT LAGOON	-124.00983	46.24173	8	31	70	1	2		0	cards
B	B1BOAT HOUSE HAMMOND MOOR BASIN	-123.96482	46.21204	9	6	70	1	2		0	cards
D	D1E. Dr(?) Tongue POINT.	-123.77808	46.22935	3	31	71	2	1		0	cards
D	D1OFF TONGUE PNT NE	-123.77808	46.22935	3	31	71	2	1		0	cards

E	E4MARITIME BASIN	-123.73388	46.26765	3	31	71	2	3	2	1	352	cards
D	D1WEST OF TONGUE PNT COST GRD STA	-123.77808	46.22935	4	1	71	2	1		0		cards
E	E4MARITIME BASIN SO&EAST EDGE	-123.73388	46.26765	4	1	71	2	5	2	1	381	cards
E	E4MARITIME BASIN	-123.73388	46.26765	4	2	71	2	6	4	1	433	cards
E	E4MARITIME BASIN	-123.73388	46.26765	4	5	71	2	8	1	1	230	cards
E	E4MARITIME BASIN	-123.73388	46.26765	4	5	71	2	8	5	1	295	cards
E	E4MARITIME BASIN	-123.73388	46.26765	4	5	71	2	8	1	1	296	cards
E	E4MARITIME BASIN	-123.73388	46.26765	4	5	71	2	8	5	1	300	cards
E	E4MARITIME BASIN	-123.73388	46.26765	4	5	71	2	8	1	1	306	cards
E	E4MARITIME BASIN	-123.73388	46.26765	4	5	71	2	8	5	1	306	cards
E	E4MARITIME BASIN	-123.73388	46.26765	4	5	71	2	8	5	1	313	cards
E	E4MARITIME BASIN	-123.73388	46.26765	4	5	71	2	8	3	1	337	cards
E	E4MARITIME BASIN	-123.73388	46.26765	4	5	71	2	8	5	1	371	cards
E	E4MARITIME BASIN	-123.73388	46.26765	4	6	71	2	5	1	1	312	cards
E	E4MARITIME BASIN	-123.73388	46.26765	4	6	71	2	5	1	1	328	cards
E	E4MARITIME BASIN	-123.73388	46.26765	4	6	71	2	5	1	1	470	cards
E	E4MARITIME BASIN	-123.73388	46.26765	4	7	71	2	4	1	1	318	cards
E	E4MARITIME BASIN	-123.73388	46.26765	4	7	71	2	4	1	1	322	cards
E	E4MARITIME BASIN	-123.73388	46.26765	4	7	71	2	4	1	1	337	cards
E	E4MARITIME BASIN	-123.73388	46.26765	4	7	71	2	4	2	1	350	cards
C	C1PNT ELLICE	-123.89520	46.24229	4	12	71	2	1		0		cards
D	D1OFF COAST GUARD BASE AND TONGUE PNT	-123.77808	46.22935	4	13	71	2	2		0		cards
D	D1TONGUE PNT PEIR SO END	-123.77808	46.22935	4	13	71	2	1		0		cards

E	E4NE CORNER MARITIME BASIN	-123.73388	46.26765	4	13	71	2	1	1	1	319	cards
E	E4N SIDE MARITIME BASIN	-123.73388	46.26765	4	16	71	2	1	1	1	190	cards
E	E4N SIDE MARITIME BASIN	-123.73388	46.26765	4	16	71	2	1	1	1	297	cards
E	E4N SIDE MARITIME BASIN	-123.73388	46.26765	4	16	71	2	1	1	1	301	cards
E	E4N SIDE MARITIME BASIN	-123.73388	46.26765	4	16	71	2	1	1	1	343	cards
E	E4N SIDE MARITIME BASIN	-123.73388	46.26765	4	16	71	2	1	1	1	356	cards
E	E4N SIDE MARITIME BASIN	-123.73388	46.26765	4	16	71	2	1	1	1	410	cards
D	D1TONGUE PNT	-123.77808	46.22935	4	19	71	2	2	2	1	342	cards
D	D1TONGUE PNT	-123.77808	46.22935	4	19	71	2	2	2	1	343	cards
D	D1TONGUE PNT	-123.77808	46.22935	4	20	71	2	2		0		cards
D	D1SHIP CHANL SIDE TONGUE PNT	-123.77808	46.22935	4	21	71	2	4	3	1	316	cards
D	D1SHIP CHANL SIDE TONGUE PNT	-123.77808	46.22935	4	21	71	2	4	3	1	324	cards
D	D1SHIP CHANL SIDE TONGUE PNT	-123.77808	46.22935	4	21	71	2	4	1	1	339	cards
G	G2UPPER WOODY ISL CHANL	-123.53468	46.25398	4	22	71	2	4		0		cards
C	C1WASH.SIDE OF COLUMBIA ABOVE AND BELOW ASTORIA BRDG.	-123.89520	46.24229	4	26	71	2	4	4	1	253	cards
C	C1WASH.SIDE OF COLUMBIA ABOVE AND BELOW ASTORIA BRDG.	-123.89520	46.24229	4	26	71	2	4	3	1	270	cards
C	C1WASH.SIDE OF COLUMBIA ABOVE AND BELOW ASTORIA BRDG.	-123.89520	46.24229	4	26	71	2	4	1	1	313	cards
D	D3WASH. SHORE OFF GRAYS PNT	-123.76390	46.27225	4	26	71	2	1	1	1	278	cards
-999	-999INSIDE BAR MIDDLE OF RV & OF COAST GUARD STA	-999.00000	-999.00000	4	27	71	2	2		0		cards
-999	-999OFF OF MOUTH OF SKIPANON RV	-999.00000	-999.00000	4	27	71	2	1		0		cards
-999	-999WASH.SIDE TO BAR THEN BACK TO OR SIDE	-999.00000	-999.00000	4	27	71	2	2	2	1	182	cards
-999	-999WASH.SIDE TO BAR THEN BACK TO OREGON SIDE	-999.00000	-999.00000	4	27	71	2	2	2	1	225	cards
D	D1Tongue Pnt area	-123.77808	46.22935	4	29	71	2	7	7	1	186	cards

D	D1Tongue Pnt area	-123.77808	46.22935	4	29	71	2	7	3	1	292	cards
D	D1Tongue Pnt area	-123.77808	46.22935	4	29	71	2	7	3	1	302	cards
D	D1Tongue Pnt area	-123.77808	46.22935	4	29	71	2	7	4	1	324	cards
D	D1Tongue Pnt area	-123.77808	46.22935	4	29	71	2	7	3	1	331	cards
D	D1Tongue Pnt area	-123.77808	46.22935	4	29	71	2	7	7	1	348	cards
D	D1Tongue Pnt area	-123.77808	46.22935	4	29	71	2	7	6	1	364	cards
D	D1Tongue Pnt area	-123.77808	46.22935	4	29	71	2	7	6	1	372	cards
C	C1WASH SIDE WEST OF ASTRIA BRDG	-123.89520	46.24229	4	30	71	2	4	3	1	139	cards
C	C1WASH SIDE WEST OF ASTRIA BRDG	-123.89520	46.24229	4	30	71	2	4	4	1	339	cards
C	C1WASH SIDE WEST OF ASTRIA BRDG	-123.89520	46.24229	4	30	71	2	4	3	1	342	cards
G	G2WOODY ISL CHANL UPPER END	-123.53468	46.25398	5	3	71	2	4	1	1	169	cards
G	G2WOODY ISL CHANL UPPER END	-123.53468	46.25398	5	3	71	2	4	1	1	241	cards
G	G2WOODY ISL CHANL UPPER END	-123.53468	46.25398	5	3	71	2	4	1	1	340	cards
G	G2WOODY ISL CHANL UPPER END	-123.53468	46.25398	5	3	71	2	4	1	1	345	cards
G	G2UPPER WOODY ISL CHANL	-123.53468	46.25398	5	4	71	2	4	4	1	192	cards
G	G2UPPER WOODY ISL CHANL	-123.53468	46.25398	5	4	71	2	4	4	1	224	cards
G	G2UPPER WOODY ISL CHANL	-123.53468	46.25398	5	4	71	2	4	2	1	333	cards
G	G2UPPER WOODY ISL CHANL	-123.53468	46.25398	5	4	71	2	4	3	1	335	cards
G	G2UPPER WOODY ISL CHANL	-123.53468	46.25398	5	4	71	2	4	3	1	343	cards
G	G2UPPER WOODY ISL CHANL	-123.53468	46.25398	5	4	71	2	4	3	1	346	cards
G	G2UPPER WOODY ISL CHANL	-123.53468	46.25398	5	4	71	2	4	3	1	371	cards
G	G2UPPER WOODY ISL CHANL	-123.53468	46.25398	5	4	71	2	4	1	1	419	cards
-999	-999WASHINGTON	-999.00000	-999.00000	5	10	71	2	5	2	1	406	cards

C	C1ASTORIA MEGLER BRDG -AREA	-123.89520	46.24229	5	11	71	2	7	1,2,4,6	5		cards
C	C1MEGLAR	-123.89520	46.24229	5	12	71	2	5	1,2,4	1	298	cards
C	C1MEGLAR	-123.89520	46.24229	5	12	71	2	5	1,2,4	1	110	binder
C	C1MEGLAR	-123.89520	46.24229	5	12	71	2	5	1,2,4	1	110	binder
C	C1MEGLAR	-123.89520	46.24229	5	12	71	2	5	1,2,4	1	190	binder
C	C1MEGLAR	-123.89520	46.24229	5	12	71	2	5	1,2,4	1	215	binder
C	C1MEGLAR	-123.89520	46.24229	5	12	71	2	5	1,2,4	1	220	binder
C	C1MEGLAR	-123.89520	46.24229	5	12	71	2	5	1,2,4	1	235	binder
C	C1MEGLAR	-123.89520	46.24229	5	12	71	2	5	1,2,4	1	250	binder
C	C1MEGLAR	-123.89520	46.24229	5	12	71	2	5	1,2,4	1	255	binder
-999	-999BELOW ASTORIA BRDG	-999.00000	-999.00000	5	13	71	2	9	1,2,3	9	318	cards
B	B1HAMMOND	-123.96482	46.21204	5	14	71	2	7	2,3,4,5,6,7	1	230	cards
B	B1HAMMOND	-123.96482	46.21204	5	14	71	2	7	2,3,4,5,6,7	1	267	cards
B	B1HAMMOND	-123.96482	46.21204	5	14	71	2	7	2,3,4,5,6,7	1	310	cards
B	B1HAMMOND	-123.96482	46.21204	5	14	71	2	7	2,3,4,5,6,7	1	395	cards
B	B1HAMMOND	-123.96482	46.21204	5	14	71	2	7	2,3,4,5,6,7	1	180	binder
B	B1HAMMOND	-123.96482	46.21204	5	14	71	2	7	2,3,4,5,6,7	1	190	binder
B	B1HAMMOND	-123.96482	46.21204	5	14	71	2	7	2,3,4,5,6,7	1	200	binder
B	B1HAMMOND	-123.96482	46.21204	5	14	71	2	7	2,3,4,5,6,7	1	200	binder
C	C1WASH MEGLER BRDG	-123.89520	46.24229	5	25	71	2	8	1, 2, 3, 6,7, 8	1	110	binder
C	C1WASH MEGLER BRDG	-123.89520	46.24229	5	25	71	2	8		1	145	binder
C	C1WASH MEGLER BRDG	-123.89520	46.24229	5	25	71	2	8		1	155	binder
C	C1WASH MEGLER BRDG	-123.89520	46.24229	5	25	71	2	8		1	185	binder

C	C1WASH MEGLER BRDG	-123.89520	46.24229	5	25	71	2	8		1	190	binder
C	C1WASH MEGLER BRDG	-123.89520	46.24229	5	25	71	2	8		1	190	binder
C	C1WASH MEGLER BRDG	-123.89520	46.24229	5	25	71	2	8		1	195	binder
C	C1WASH MEGLER BRDG	-123.89520	46.24229	5	25	71	2	8		1	200	binder
C	C1WASH MEGLER BRDG	-123.89520	46.24229	5	25	71	2	8		1	210	binder
C	C1WASH MEGLER BRDG	-123.89520	46.24229	5	25	71	2	8		1	215	binder
C	C1WASH MEGLER BRDG	-123.89520	46.24229	5	25	71	2	8		1	235	binder
C	C1WASH MEGLER BRDG	-123.89520	46.24229	5	25	71	2	8		1	240	binder
C	C1WASH MEGLER BRDG	-123.89520	46.24229	5	25	71	2	8		1	250	binder
B	B1HAMMOND	-123.96482	46.21204	5	26	71	2	6		0		cards
B	B1HAMMOND	-123.96482	46.21204	5	27	71	2	7	1,3,4,5,6,7	1	185	binder
B	B1HAMMOND	-123.96482	46.21204	5	27	71	2	7		1	185	binder
B	B1HAMMOND	-123.96482	46.21204	5	27	71	2	7		1	190	binder
B	B1HAMMOND	-123.96482	46.21204	5	27	71	2	7		1	195	binder
B	B1HAMMOND	-123.96482	46.21204	5	27	71	2	7		1	195	binder
B	B1HAMMOND	-123.96482	46.21204	5	27	71	2	7		1	200	binder
B	B1HAMMOND	-123.96482	46.21204	5	27	71	2	7		1	205	binder
B	B1HAMMOND	-123.96482	46.21204	5	27	71	2	7		1	210	binder
B	B1HAMMOND	-123.96482	46.21204	5	27	71	2	7		1	210	binder
B	B1HAMMOND	-123.96482	46.21204	5	27	71	2	7		1	215	binder
B	B1HAMMOND	-123.96482	46.21204	5	27	71	2	7		1	215	binder
B	B1HAMMOND	-123.96482	46.21204	5	27	71	2	7		1	225	binder
B	B1HAMMOND	-123.96482	46.21204	5	27	71	2	7		1	230	binder

B	B1HAMMOND	-123.96482	46.21204	5	27	71	2	7		1	240	binder
B	B1HAMMOND	-123.96482	46.21204	5	27	71	2	7		1	250	binder
B	B1HAMMOND	-123.96482	46.21204	5	27	71	2	7		1	260	binder
B	B1HAMMOND	-123.96482	46.21204	5	27	71	2	7		1	260	binder
B	B1HAMMOND	-123.96482	46.21204	5	28	71	2	7	3,4,5,6	1	155	binder
B	B1HAMMOND	-123.96482	46.21204	5	28	71	2	7	3,4,5,6	1	170	binder
B	B1HAMMOND	-123.96482	46.21204	5	28	71	2	7	3,4,5,6	1	185	binder
B	B1HAMMOND	-123.96482	46.21204	5	28	71	2	7	3,4,5,6	1	195	binder
B	B1HAMMOND	-123.96482	46.21204	5	28	71	2	7	3,4,5,6	1	200	binder
B	B1HAMMOND	-123.96482	46.21204	5	28	71	2	7	3,4,5,6	1	200	binder
B	B1HAMMOND	-123.96482	46.21204	5	28	71	2	7	3,4,5,6	1	200	binder
B	B1HAMMOND	-123.96482	46.21204	5	28	71	2	7	3,4,5,6	1	210	binder
B	B1HAMMOND	-123.96482	46.21204	5	28	71	2	7	3,4,5,6	1	210	binder
B	B1HAMMOND	-123.96482	46.21204	5	28	71	2	7	3,4,5,6	1	215	binder
B	B1HAMMOND	-123.96482	46.21204	5	28	71	2	7	3,4,5,6	1	215	binder
B	B1HAMMOND	-123.96482	46.21204	5	28	71	2	7	3,4,5,6	1	215	binder
B	B1HAMMOND	-123.96482	46.21204	5	28	71	2	7	3,4,5,6	1	220	binder
B	B1HAMMOND	-123.96482	46.21204	5	28	71	2	7	3,4,5,6	1	220	binder
B	B1HAMMOND	-123.96482	46.21204	5	28	71	2	7	3,4,5,6	1	225	binder
B	B1HAMMOND	-123.96482	46.21204	5	28	71	2	7	3,4,5,6	1	240	binder
B	B1HAMMOND	-123.96482	46.21204	5	28	71	2	7	3,4,5,6	1	240	binder
B	B1HAMMOND	-123.96482	46.21204	5	28	71	2	7	3,4,5,6	1	250	binder
C	C1MCGOWAN BEACH	-123.89520	46.24229	6	3	71	2	7	5	1	180	binder

C	C1MCGOWAN BEACH	-123.89520	46.24229	6	3	71	2	7	5	1	255	binder
C	C1MCGOWAN BEACH	-123.89520	46.24229	6	3	71	2	7	5	1	275	binder
C	C1PNT ELLICE	-123.89520	46.24229	6	4	71	2	7	4,5,6	1	170	binder
C	C1PNT ELLICE	-123.89520	46.24229	6	4	71	2	7	4,5,6	1	175	binder
C	C1PNT ELLICE	-123.89520	46.24229	6	4	71	2	7	4,5,6	1	185	binder
C	C1PNT ELLICE	-123.89520	46.24229	6	4	71	2	7	4,5,6	1	200	binder
C	C1PNT ELLICE	-123.89520	46.24229	6	4	71	2	7	4,5,6	1	225	binder
B	B1HAMMOND	-123.96482	46.21204	6	7	71	2	7	3,4,5,7	1	165	binder
B	B1HAMMOND	-123.96482	46.21204	6	7	71	2	7	3,4,5,7	1	170	binder
B	B1HAMMOND	-123.96482	46.21204	6	7	71	2	7	3,4,5,7	1	210	binder
B	B1HAMMOND	-123.96482	46.21204	6	7	71	2	7	3,4,5,7	1	215	binder
C	C1PNT ELLICE	-123.89520	46.24229	6	8	71	2	7	1,2,4,6	1	155	binder
C	C1PNT ELLICE	-123.89520	46.24229	6	8	71	2	7	1,2,4,6	1	160	binder
C	C1PNT ELLICE	-123.89520	46.24229	6	8	71	2	7	1,2,4,6	1	160	binder
C	C1PNT ELLICE	-123.89520	46.24229	6	8	71	2	7	1,2,4,6	1	165	binder
C	C1PNT ELLICE	-123.89520	46.24229	6	8	71	2	7	1,2,4,6	1	165	binder
C	C1PNT ELLICE	-123.89520	46.24229	6	8	71	2	7	1,2,4,6	1	195	binder
C	C1PNT ELLICE	-123.89520	46.24229	6	8	71	2	7	1,2,4,6	1	205	binder
C	C1PNT ELLICE	-123.89520	46.24229	6	8	71	2	7	1,2,4,6	1	340	binder
-999	-999WASH SIDE	-999.00000	-999.00000	6	9	71	2	8	1,3,5,6,8	6		cards
-999	-999WASH SIDE	-999.00000	-999.00000	6	9	71	2	8	1	1	431	cards
C	C1MCGOWAN BEACH	-123.89520	46.24229	6	10	71	2	7	3	1	170	binder
C	C1MCGOWAN BEACH	-123.89520	46.24229	6	10	71	2	7	3	1	195	binder

C	C1MCGOWAN BEACH	-123.89520	46.24229	6	11	71	2	7	2,3,4,7	1	155	binder
C	C1MCGOWAN BEACH	-123.89520	46.24229	6	11	71	2	7	2,3,4,7	1	170	binder
C	C1MCGOWAN BEACH	-123.89520	46.24229	6	11	71	2	7	2,3,4,7	1	175	binder
C	C1MCGOWAN BEACH	-123.89520	46.24229	6	11	71	2	7	2,3,4,7	1	180	binder
C	C1MCGOWAN BEACH	-123.89520	46.24229	6	11	71	2	7	2,3,4,7	1	180	binder
C	C1MCGOWAN BEACH	-123.89520	46.24229	6	11	71	2	7	2,3,4,7	1	210	binder
C	C1MCGOWAN BEACH	-123.89520	46.24229	6	14	71	2	7	1,2,6,7	1	150	binder
C	C1MCGOWAN BEACH	-123.89520	46.24229	6	14	71	2	7	1,2,6,7	1	150	binder
C	C1MCGOWAN BEACH	-123.89520	46.24229	6	14	71	2	7	1,2,6,7	1	180	binder
C	C1MCGOWAN BEACH	-123.89520	46.24229	6	14	71	2	7	1,2,6,7	1	185	binder
C	C1MCGOWAN BEACH	-123.89520	46.24229	6	15	71	2	7	1,5	3	185	binder
C	C1MCGOWAN BEACH	-123.89520	46.24229	6	16	71	2	8	3,4,7,8	1	150	binder
C	C1MCGOWAN BEACH	-123.89520	46.24229	6	16	71	2	8	3,4,7,8	1	155	binder
C	C1MCGOWAN BEACH	-123.89520	46.24229	6	16	71	2	8	3,4,7,8	1	160	binder
C	C1MCGOWAN BEACH	-123.89520	46.24229	6	16	71	2	8	3,4,7,8	1	165	binder
C	C1MCGOWAN BEACH	-123.89520	46.24229	6	16	71	2	8	3,4,7,8	1	170	binder
C	C1MCGOWAN BEACH	-123.89520	46.24229	6	16	71	2	8	3,4,7,8	1	175	binder
C	C1MCGOWAN BEACH	-123.89520	46.24229	6	16	71	2	8	3,4,7,8	1	175	binder
C	C1MCGOWAN BEACH	-123.89520	46.24229	6	17	71	2	6	5,6	1	165	binder
C	C1MCGOWAN BEACH	-123.89520	46.24229	6	17	71	2	6	5,6	1	180	binder
C	C1MCGOWAN	-123.89520	46.24229	6	18	71	2	7	1	1		cards
A	A1Clatsop spit	-124.00983	46.24173	4	6	78	1	-999		-999		unspec
A	A2Sand Isle	-124.00524	46.26876	4	7	78	1	-999		-999		unspec

A	A1Clatsop spit	-124.00983	46.24173	4	10	78	1	7		0	cards
A	A2Sand Isle	-124.00524	46.26876	4	11	78	1	6		0	cards
A	A2Sand Isle	-124.00524	46.26876	4	14	78	1	9		0	cards
A	A1Clatsop spit	-124.00983	46.24173	4	17	78	1	9		0	cards
A	A2Sand Isle	-124.00524	46.26876	4	18	78	1	-999		-999	unspec
A	A1Clatsop spit	-124.00983	46.24173	4	19	78	1	-999		-999	unspec
A	A2Sand Isle	-124.00524	46.26876	4	25	78	1	8		0	cards
A	A1Clatsop spit	-124.00983	46.24173	4	27	78	1	9		0	cards
A	A2Sand Isle	-124.00524	46.26876	5	2	78	1	9		0	cards
A	A1Clatsop spit	-124.00983	46.24173	5	4	78	1	9	7	1	unspec
A	A1Clatsop spit	-124.00983	46.24173	5	4	78	1	9	6	2	unspec
A	A1Clatsop spit	-124.00983	46.24173	5	9	78	1	9		0	cards
A	A2Sand Isle	-124.00524	46.26876	5	11	78	1	9		0	cards
A	A1Clatsop spit	-124.00983	46.24173	5	18	78	1	7	1	1	unspec
A	A1Clatsop spit	-124.00983	46.24173	5	18	78	1	7	2	2	unspec
A	A1Clatsop spit	-124.00983	46.24173	5	18	78	1	7	4	3	unspec
A	A1Clatsop spit	-124.00983	46.24173	5	24	78	1	9	6	2	unspec
A	A2Sand Isle	-124.00524	46.26876	5	24	78	1	-999		-999	unspec
A	A2Sand Isle	-124.00524	46.26876	5	30	78	1	9		0	cards
A	A1Clatsop spit	-124.00983	46.24173	6	6	78	1	9		0	cards
A	A2Sand Isle	-124.00524	46.26876	6	9	78	1	9		0	cards
A	A1Clatsop spit	-124.00983	46.24173	6	13	78	1	9		0	cards
A	A2Sand Isle	-124.00524	46.26876	6	15	78	1	9	3	2	unspec

A	A2Sand Isle	-124.00524	46.26876	6	27	78	1	9		0	cards
A	A1Clatsop spit	-124.00983	46.24173	6	29	78	1	9		0	cards
A	A2Sand Isle	-124.00524	46.26876	7	10	78	1	-999		-999	unspec
A	A1Clatsop spit	-124.00983	46.24173	7	13	78	1	9		0	cards
A	A2Sand Isle	-124.00524	46.26876	7	19	78	1	-999		-999	unspec
A	A1Clatsop spit	-124.00983	46.24173	7	31	78	1	-999		-999	unspec
A	A1Clatsop spit	-124.00983	46.24173	9	6	78	1	7		0	cards
C	C1Astoria Meglar Bridge	-123.89520	46.24229	4	4	78	2	-999		-999	unspec
C	C1Astoria Meglar Bridge	-123.89520	46.24229	4	20	78	2	6		0	cards
C	C1Astoria Meglar Bridge	-123.89520	46.24229	4	21	78	2	5		0	cards
C	C1Astoria Meglar Bridge	-123.89520	46.24229	4	24	78	2	4		0	cards
C	C1Astoria Bridge	-123.89520	46.24229	4	26	78	2	4		0	cards
C	C1Astoria Bridge	-123.89520	46.24229	4	28	78	2	6	4	1	unspec
C	C1Astoria Bridge	-123.89520	46.24229	5	1	78	2	6	1	1	unspec
C	C1Astoria Bridge	-123.89520	46.24229	5	3	78	2	5	1	1	unspec
C	C1Astoria Bridge	-123.89520	46.24229	5	5	78	2	4		0	cards
C	C1Astoria Bridge	-123.89520	46.24229	5	8	78	2	4		0	cards
C	C1Astoria Bridge	-123.89520	46.24229	5	10	78	2	4		0	cards
C	C1Astoria Bridge	-123.89520	46.24229	5	12	78	2	5		0	cards
C	C1Astoria Bridge	-123.89520	46.24229	5	15	78	2	2		0	cards
C	C1Astoria Bridge	-123.89520	46.24229	5	16	78	2	5		0	cards
C	C1Astoria Bridge	-123.89520	46.24229	5	17	78	2	5	2	1	unspec
C	C1Astoria Bridge	-123.89520	46.24229	5	17	78	2	5	1	3	unspec

C	C1Astoria Bridge	-123.89520	46.24229	5	19	78	2	5	1	1		unspec
C	C1Astoria Bridge	-123.89520	46.24229	5	19	78	2	5	2	1		unspec
C	C1Astoria Bridge	-123.89520	46.24229	5	22	78	2	3	3	2		unspec
C	C1Astoria Bridge	-123.89520	46.24229	5	22	78	2	3	2	3		unspec
C	C1Astoria Bridge	-123.89520	46.24229	5	23	78	2	4	4	2		unspec
C	C1Astoria Bridge	-123.89520	46.24229	5	23	78	2	4	3	3		unspec
C	C1Astoria Bridge	-123.89520	46.24229	5	23	78	2	4	2	4		unspec
C	C1Astoria Bridge	-123.89520	46.24229	5	25	78	2	4		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	5	26	78	2	4		0		cards
C	C1Astoria Meglar Bridge	-123.89520	46.24229	6	1	78	2	4	1	2		unspec
C	C1Astoria Meglar Bridge	-123.89520	46.24229	6	2	78	2	4	1	1		unspec
C	C1Astoria Meglar Bridge	-123.89520	46.24229	6	2	78	2	4	3	1		unspec
C	C1Astoria Bridge	-123.89520	46.24229	6	5	78	2	4	1	1		unspec
C	C1Astoria Bridge	-123.89520	46.24229	6	5	78	2	4	2	2		unspec
C	C1Astoria Bridge	-123.89520	46.24229	6	7	78	2	4	2	1		unspec
C	C1Astoria Bridge	-123.89520	46.24229	6	8	78	2	3		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	6	12	78	2	5	2	1	345	cards
C	C1Astoria Bridge	-123.89520	46.24229	6	14	78	2	5	5	1	190	cards
C	C1Astoria Bridge	-123.89520	46.24229	6	16	78	2	5	4	2		unspec
C	C1Astoria Bridge	-123.89520	46.24229	6	17	78	2	5	5	1		unspec
C	C1Astoria Bridge	-123.89520	46.24229	6	17	78	2	5	4	2		unspec
C	C1Astoria Bridge	-123.89520	46.24229	6	21	78	2	5		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	6	22	78	2	5		0		cards

C	C1Astoria Bridge	-123.89520	46.24229	6	24	78	2	5		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	6	27	78	2	5		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	6	30	78	2	3		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	7	3	78	2	1		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	7	5	78	2	5		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	7	7	78	2	3		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	7	21	78	2	5		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	7	24	78	2	5		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	7	26	78	2	5		0		cards
F	F4Pillar Rock & Vicinity	-123.61083	46.25219	7	28	78	2	3		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	8	1	78	2	5	2	1		unspec
C	C1Astoria Bridge	-123.89520	46.24229	8	1	78	2	5	3	2		unspec
C	C1Astoria Bridge	-123.89520	46.24229	8	1	78	2	5	1	6		unspec
C	C1Astoria Bridge	-123.89520	46.24229	8	7	78	2	5	3	1	280	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	7	78	2	5	3	1	300	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	7	78	2	5	4	1	305	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	7	78	2	5	5	1	310	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	7	78	2	5	4	1	330	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	23	78	2	3		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	8	31	78	2	5	2	1	255	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	31	78	2	5	2	1	300	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	31	78	2	5	1	1	330	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	31	78	2	5	1	1	335	cards

C	C1Astoria Bridge	-123.89520	46.24229	9	7	78	2	6	1	1	295	cards
C	C1Astoria Bridge	-123.89520	46.24229	9	7	78	2	6	2	1	300	cards
C	C1Astoria Bridge	-123.89520	46.24229	9	7	78	2	6	3	1	300	cards
C	C1Astoria Bridge	-123.89520	46.24229	9	7	78	2	6	1	1	310	cards
C	C1Astoria Bridge	-123.89520	46.24229	9	7	78	2	6	3	1	310	cards
C	C1Astoria Bridge	-123.89520	46.24229	9	7	78	2	6	2	1	320	cards
C	C1Astoria Bridge	-123.89520	46.24229	9	7	78	2	6	2	1	325	cards
C	C1Astoria Bridge	-123.89520	46.24229	9	7	78	2	6	4	1	360	cards
C	C4Youngs Bay N entrance	-123.86854	46.18872	9	8	78	2	3		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	9	11	78	2	-999		-999		unspec
C	C1Astoria Bridge	-123.89520	46.24229	9	15	78	2	4		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	9	20	78	2	-999		-999		unspec
C	C1Astoria Bridge	-123.89520	46.24229	9	29	78	2	4		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	10	2	78	2	-999		-999		unspec
C	C1Astoria Bridge	-123.89520	46.24229	10	18	78	2	-999		-999		unspec
C	C3Tansy Pt.	-123.92314	46.19246	5	30	79	2	1		0		cards
C	C4Young's Bay	-123.86854	46.18872	5	30	79	2	5		0		cards
C	C3Tansy Pt.	-123.92314	46.19246	5	31	79	2	1		0		cards
C	C1Bridge Purse	-123.89520	46.24229	6	4	79	2	4		0		cards
C	C1Bridge Purse	-123.89520	46.24229	6	7	79	2	3	2	1	365	cards
C	C1Bridge Purse	-123.89520	46.24229	6	11	79	2	3	1	1	-999	cards
C	C1Bridge Purse	-123.89520	46.24229	6	11	79	2	3	3	1	-999	cards
C	C1Bridge Purse	-123.89520	46.24229	6	14	79	2	3		0		cards

C	C1Bridge Purse	-123.89520	46.24229	6	15	79	2	3		0		cards
C	C1Bridge Purse	-123.89520	46.24229	6	18	79	2	3		0		cards
C	C1Bridge Purse	-123.89520	46.24229	6	22	79	2	3	3	1	420	cards
C	C1Bridge Purse	-123.89520	46.24229	6	25	79	2	4		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	7	2	79	2	4		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	7	4	79	2	4		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	7	11	79	2	4	4	2	375	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	13	79	2	4	2	1	290	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	13	79	2	4	4	1	350	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	13	79	2	4	1	3	280	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	17	79	2	4	2	2	-999	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	17	79	2	4	3	3	-999	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	17	79	2	4	4	7	-999	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	18	79	2	3	3	3	-999	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	18	79	2	3	2	4	-999	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	19	79	2	4	2	1	-999	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	19	79	2	4	3	1	-999	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	19	79	2	4	1	2	-999	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	19	79	2	4	4	2	-999	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	20	79	2	4	4	1	-999	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	20	79	2	4	3	4	-999	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	20	79	2	4	2	7	-999	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	20	79	2	4	1	24	-999	cards

C	C1Astoria Bridge	-123.89520	46.24229	7	31	79	2	4	4	11	340	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	31	79	2	4	3	13	320	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	3	79	2	4		0		cards
D	D1Tongue Pt.	-123.77808	46.22935	8	6	79	2	3		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	8	7	79	2	4	3	6	-999	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	7	79	2	4	4	6	-999	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	7	79	2	4	2	9	435	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	8	79	2	4	2	1	255	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	8	79	2	4	1	1	270	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	8	79	2	4	1	1	270	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	8	79	2	4	2	1	280	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	8	79	2	4	3	1	285	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	8	79	2	4	2	1	295	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	8	79	2	4	2	1	305	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	8	79	2	4	2	1	305	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	8	79	2	4	2	1	310	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	8	79	2	4	3	1	310	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	8	79	2	4	2	1	315	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	8	79	2	4	4	1	360	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	8	79	2	4	2	1	390	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	8	79	2	4	2	1	405	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	13	79	2	4		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	8	14	79	2	2		0		cards

C	C1Bridge Purse	-123.89520	46.24229	8	20	79	2	5	2	1	270	cards
C	C1Bridge Purse	-123.89520	46.24229	8	20	79	2	5	2	1	305	cards
C	C1Bridge Purse	-123.89520	46.24229	8	20	79	2	5	1	1	275	cards
C	C1Bridge Purse	-123.89520	46.24229	8	20	79	2	5	1	1	285	cards
C	C1Bridge Purse	-123.89520	46.24229	8	20	79	2	5	1	1	295	cards
C	C1Bridge Purse	-123.89520	46.24229	8	20	79	2	5	1	1	300	cards
C	C1Bridge Purse	-123.89520	46.24229	8	20	79	2	5	1	1	305	cards
C	C1Bridge Purse	-123.89520	46.24229	8	20	79	2	5	1	1	315	cards
C	C1Bridge Purse	-123.89520	46.24229	8	20	79	2	5	1	1	355	cards
C	C1Bridge Purse	-123.89520	46.24229	8	20	79	2	5	1	1	360	cards
D	D1Tongue Pt.	-123.77808	46.22935	8	22	79	2	4	1	1	-999	cards
D	D1Tongue Pt.	-123.77808	46.22935	8	22	79	2	4	3	4	-999	cards
D	D1Tongue Pt.	-123.77808	46.22935	8	22	79	2	4	4	4		cards
D	D1Tongue Pt.	-123.77808	46.22935	8	22	79	2	4	2	6	-999	cards
C	C1Bridge Purse	-123.89520	46.24229	8	24	79	2	-999	?	1	260	cards
C	C1Bridge Purse	-123.89520	46.24229	8	24	79	2	-999	?	1	270	cards
C	C1Bridge Purse	-123.89520	46.24229	8	24	79	2	-999	?	1	295	cards
C	C1Bridge Purse	-123.89520	46.24229	8	24	79	2	-999	?	1	295	cards
C	C1Bridge Purse	-123.89520	46.24229	8	24	79	2	-999	?	1	310	cards
C	C1Bridge Purse	-123.89520	46.24229	8	24	79	2	-999	?	1	315	cards
C	C1Bridge Purse	-123.89520	46.24229	8	24	79	2	-999	?	1	325	cards
C	C1Bridge Purse	-123.89520	46.24229	8	24	79	2	-999	?	1	330	cards
C	C1Bridge Purse	-123.89520	46.24229	8	24	79	2	-999	?	1	345	cards

C	C1Bridge Purse	-123.89520	46.24229	8	24	79	2	-999	?	1	345	cards
C	C1Bridge Purse	-123.89520	46.24229	8	24	79	2	-999	?	1	355	cards
C	C1Bridge Purse	-123.89520	46.24229	8	24	79	2	-999	?	1	360	cards
C	C1Bridge Purse	-123.89520	46.24229	8	24	79	2	-999	?	1	375	cards
C	C1Bridge Purse	-123.89520	46.24229	8	24	79	2	-999	?	1	380	cards
C	C1Bridge Purse	-123.89520	46.24229	8	24	79	2	-999	?	1	390	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	27	79	2	4	4	1	275	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	27	79	2	4	3	1	285	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	27	79	2	4	4	1	285	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	27	79	2	4	4	1	290	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	27	79	2	4	3	1	300	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	27	79	2	4	3	1	300	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	27	79	2	4	4	1	305	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	27	79	2	4	3	1	310	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	27	79	2	4	3	1	310	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	27	79	2	4	4	1	310	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	27	79	2	4	4	1	315	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	27	79	2	4	3	1	335	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	27	79	2	4	4	1	335	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	27	79	2	4	3	1	340	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	27	79	2	4	4	1	345	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	27	79	2	4	4	1	350	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	27	79	2	4	4	1	360	cards

C	C1Astoria Bridge	-123.89520	46.24229	8	27	79	2	4	4	1	360	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	27	79	2	4	3	1	370	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	27	79	2	4	4	1	370	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	27	79	2	4	4	1	375	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	27	79	2	4	3	1	380	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	27	79	2	4	3	1	385	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	27	79	2	4	3	1	395	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	27	79	2	4	4	1	395	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	29	79	2	4	2	1	335	cards
C	C1Astoria Bridge	-123.89520	46.24229	8	31	79	2	5	4	1	375	cards
C	C1Astoria Bridge	-123.89520	46.24229	9	5	79	2	4	2	1	300	cards
C	C1Astoria Bridge	-123.89520	46.24229	9	5	79	2	4	1	1	305	cards
C	C1Astoria Bridge	-123.89520	46.24229	9	5	79	2	4	2	1	315	cards
C	C1Astoria Bridge	-123.89520	46.24229	9	5	79	2	4	2	1	330	cards
C	C1Astoria Bridge	-123.89520	46.24229	9	5	79	2	4	2	1	335	cards
C	C1Astoria Bridge	-123.89520	46.24229	9	5	79	2	4	2	1	340	cards
C	C1Astoria Bridge	-123.89520	46.24229	9	5	79	2	4	3	1	-999	cards
C	C1Astoria Bridge	-123.89520	46.24229	9	5	79	2	4	3	1	-999	cards
C	C1Astoria Bridge	-123.89520	46.24229	9	5	79	2	4	3	1	-999	cards
C	C1Astoria Bridge	-123.89520	46.24229	9	6	79	2	6	1	1	275	cards
C	C1Astoria Bridge	-123.89520	46.24229	9	6	79	2	6	1	1	285	cards
C	C1Astoria Bridge	-123.89520	46.24229	9	6	79	2	6	1	1	290	cards
C	C1Astoria Bridge	-123.89520	46.24229	9	6	79	2	6	1	1	300	cards

C	C1Astoria Bridge	-123.89520	46.24229	9	6	79	2	6	3	6	-999	cards
C	C1Astoria Bridge	-123.89520	46.24229	9	6	79	2	6	2	7	-999	cards
C	C1Astoria Bridge	-123.89520	46.24229	9	6	79	2	6	4	7	-999	cards
-999	-999Upriver	-999.00000	-999.00000	9	10	79	2	4		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	9	11	79	2	5	5	1	275	cards
C	C1Astoria Bridge	-123.89520	46.24229	9	11	79	2	5	4	1	340	cards
C	C1Astoria Bridge	-123.89520	46.24229	9	13	79	2	5		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	9	14	79	2	6		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	9	17	79	2	5		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	9	19	79	2	6		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	7	2	80	2	2	2	1	365	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	6	80	2	2	2	1	280	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	9	80	2	5		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	7	10	80	2	4		0		cards
C	C1Astoria Bridge	-123.89520	46.24229	7	11	80	2	5	2	1	-999	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	14	80	2	4	1	1	365	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	15	80	2	4	1	1	420	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	15	80	2	4	2	1	380	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	15	80	2	4	2	1	235	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	15	80	2	4	3	1	400	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	16	80	2	4	2	1	410	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	16	80	2	4	4	2	-999	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	17	80	2	5	2	1	350	cards

C	C1Astoria Bridge	-123.89520	46.24229	7	17	80	2	5	2	1	385	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	17	80	2	5	2	1	370	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	17	80	2	5	5	1	276	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	18	80	2	4	1	1	259	cards
C	C1Astoria Bridge	-123.89520	46.24229	7	18	80	2	4	2	1	435	cards

D-4 ECOLOGY AND BEHAVIOR OF COLUMBIA RIVER SALMONIDS

4.1 Salmonids In Highly Modified River

The lower Columbia River and its estuary are part of a highly modified river system. The modifications have resulted in a number of the salmon stocks being officially listed as threatened or endangered under the Endangered Species Act (ESA). Modifications began during the 1860s and 1870s when commercial fishing became sufficiently intense to essentially eliminate some stocks of salmon (Gilbert and Evermann, 1894). Subsequent modifications to the physical and biological characteristics of the river basin have resulted in the official listing of 14 evolutionarily significant units (ESUs) and distinct population segments (DPSs), or species for the Columbia River. These alterations and their potential impacts were identified in R. M. Thom's white paper (2001) on a conceptual model for the Columbia River Navigation Channel Improvements Project (the Project).

Thom's white paper identifies 14 species of concern and presents information describing their basic habitat needs during the periods they occupy the lower Columbia River in the area potentially affected by the channel deepening project. A brief description of the species (ESUs and DPSs) is followed by a summary of information describing the habitat characteristics identified in the existing literature as important to the life stages of ESUs and DPSs as they move through the lower Columbia River and similar areas of the Pacific Northwest.

Nearly all the information available to describe the biological processes related to listed species in the Columbia River was obtained after the river system's biological and physical characteristics had been highly modified. Thus, our understanding of how the system functions is derived from this modified system. We have only inferential logic and sketchy information to describe how the river system most likely functioned naturally before it was modified.

In the following discussion, the term "salmon" refers to various life stages of the chinook, chum sockeye, and steelhead ESUs and DPSs. The term "salmonid" refers to each of these salmon ESUs as well as the anadromous forms of the cutthroat trout and bull trout DPSs.

4.1.1 Objective

The purpose of this document is to describe the known biological characteristics of the listed species pertinent to the action area and the proposed Project.

The discussion in this paper is restricted to information describing biological processes only in the project area, other than a brief description of each ESUs spawning and rearing areas, and how they influence timing and habitat use within the project area. The information provided has been developed both from the lower Columbia River and from other Pacific Northwest estuarine areas that support the fish species listed in the project area. The assembled information is appropriate for interpretation of potential impacts of the proposed navigation channel deepening project on listed species. This purpose of this information is twofold: (1) to help avoid impacts to habitat supporting listed species, and (2) to potentially identify how the project can support recovery of the species.

4.1.2 Habitat Conditions In Project Area

The Project encompasses an area that essentially all juvenile salmon and returning adults use as a migratory corridor. Their use of habitat within the action area varies with life stage and species, primarily related to size of the fish when they migrate through the action area.

Juvenile rearing and migrations

Young salmon are likely present in at least small numbers through out the year; however, substantial numbers of juveniles first appear in the project area in middle to late March. These young chinook and chum are fish produced in the lower river area, including tributaries within the Bonneville Dam area and possibly within the Willamette River basin. Commonly these very young chinook and chum are the smallest migrants passing through the project area. Other subyearling chinook migrating later in the year from upstream locations tend to be somewhat larger, with the largest subyearlings reaching the lower river from the upstream reaches in the autumn. Consequently, several different size groups of sub-yearling salmon that account for some juveniles in the lower Columbia River appear in substantial numbers from March through about October.

Smaller juvenile salmon tend to rear and move relatively slowly through the lower river, primarily in shallow water habitat. Older subyearlings and smolts tend to move faster through the lower river, with less dependence on shallow water habitat; they also tend to be surface-oriented.

Juvenile cutthroat and bull trout are present within the Columbia River estuary during the spring and early summer at the same time as the young salmon. However, the young trout tend to be the size of salmon smolts and larger. These fish are relatively rare in fish collections; therefore information on their habitat requirements in the lower Columbia River is limited.

Adult migrations

Adult salmon return through the lower Columbia River from early spring through early autumn. Spring chinook begin entering the lower river in March or April, with the majority moving through the area in middle to late April or early May. They are sequentially followed by summer chinook and fall chinook, with chum, steelhead, and cutthroat and bull trout moving upstream during the same general period. During their upstream migrations through estuaries and lower rivers, the adult salmon are not oriented to any specific habitats. They generally tend to remain relatively close to the surface but also use greater depths at times. The National Marine Fisheries Service (NMFS) has designated two basic reproductive ecotypes of steelhead, depending on the time they migrate upstream—ocean-type (winter run) and stream-type (summer run). Stream-maturing steelhead enter the lower river in a sexually immature condition, requiring several months of residence within the river prior to spawning.

4.2 ESUs and DPSs

The listed species (ESUs and DPSs) shown in Table D4-1 pass through the lower Columbia River both as juvenile downstream migrants and as sub-adults or adults on return migrations. Some individuals of the steelhead, cutthroat, and bull trout species may pass through the lower Columbia River more than once because they survive to spawn more than one time.

Table D4-1: Listed ESUs and DPSs for the Columbia River System

SPECIES (Evolutionarily Significant Unit)	STATUS	JUVENILE LIFE STATE IN PROJECT AREA	DATE LISTED
CHINOOK			
Snake River spring/summer	Threatened	Yearling	April 22, 1992
Snake River fall	Threatened	Subyearling	April 22, 1992
Lower Columbia River	Threatened	Subyearling	March 24, 1999
Upper Columbia River spring	Endangered	Yearling	March 24, 1999
Upper Willamette River	Threatened	Yearling	March 24, 1999
SOCKEYE			
Snake River	Endangered	Smolt	November 20, 1991
STEELHEAD			
Snake River	Threatened	Smolt	August 18. 1997
Lower Columbia River.	Threatened	Smolt	March 19, 1998
Middle Columbia River	Threatened	Smolt	March 25, 1999
Upper Columbia River	Endangered	Smolt	August 18, 1997
Upper Willamette River	Threatened	Smolt	March 25, 1999
CHUM			
Columbia River	Threatened	Subyearling	March 25, 1999
BULL TROUT			
Columbia River	Threatened	Smolt or larger	June 10, 1998
CUTTHROAT TROUT			
Southwestern Washington/Columbia River	Threatened	Smolt or larger	October 25, 1999

4.3 Three Guilds of Columbia River ESUs

Each of the Columbia River ESUs and DPSs has some unique life history characteristics that help to separate it from adjacent populations of the same species. However, for consideration of the Project, these ESUs and DPSs can be aggregated into several general life history types. The salmon tend to follow one of two life history types—ocean type and stream type—that provide different size fish with substantially different habitat requirements. A portion of the cutthroat and bull trout populations are anadromous and follow a third life history form, as do some wild steelhead. Characteristics of each of the life history types are listed below.

Ocean type

- Rear only weeks to months in fresh water
- Are small (30 to 80 centimeters [cm])
- Use shallow water/shoreline habitat (0.1 to 2 meters deep, current less than 0.3 meters per second)
- Prolonged rearing in lower river (weeks to months)
- Include fall chinook, chum, and pink (few listed)

Stream type

- Rear more than 1 year in fresh water prior to downstream migration
- Are large (10 to 30 cm or larger)
- Generally move in open water
- Move relatively quickly through lower river (days to weeks)
- Include spring chinook, coho, sockeye, steelhead, bull trout, and cutthroat trout

Trout

- Rear 2 to 3 years in fresh water streams
- Migrate as very large juveniles (14 to 30 cm) or as adults
- Rear throughout the late spring and summer in estuarine or ocean areas
- Are scarce in scientific collections, which implies they are not commonly found in shallow water habitats or are adept at escaping sampling gear

A question raised during this process was whether or not the 14 ESUs and DPSs can be grouped into guilds or if they require individual species analyses. The first step in answering this question is to identify a common definition of a guild. The guild concept was defined by Root (1967):

> "A guild is defined as a group of species that exploit the same class of environmental resources in a similar way."

According to Jaksi (1981), the term guild should be reserved for co-occurring, interacting species in a particular habitat. The salmonid ESUs and DPSs in the Columbia River fit this requirement for at least a portion of their life cycles.

In the lower Columbia River and its estuary, several general classes of environmental resources are exploited or used by salmon, including:

- Shallow water (less than 6 feet deep) beaches and tideflats composed of fine-grained sediment, and having low current velocities (less than 0.3 foot per second)
- Near surface (within 20 feet of surface) water column areas not associated with specific substrate types or specific current velocities
- The entire water column

Because various members of the ocean-type and stream-type groups tend to use the lower river's environmental resources in a similar way, they tend to fit the definition of a guild.

Ocean-type salmon fry migrate through the lower estuary slowly, remaining in shallow water most of the time. These small fish undergo a rearing migration that provides substantial growth prior to their entry into ocean conditions. In the lower river, ocean-type chinook are present as several different size groups ranging from small fry [~35 millimeters (mm)] to much larger late summer migrants (~80 to 100 mm).

Stream-type salmon migrate relatively rapidly through the lower river and estuary in a directed migration that takes only days to weeks. During this migration, they remain surface oriented but occupy a greater depth range and areas of higher current velocity than do the smaller ocean-type fish. These larger juveniles tend to be water-column-oriented rather than substrate-oriented like the smaller ocean-type juveniles. Because of their larger size, the stream-type juveniles are generally ready to meet ocean conditions by the time they enter the project area.

Adult and sub-adult salmon form a separate guild. Adult fish, which include the chinook, steelhead, and sockeye ESUs and DPSs enter the project area on their upstream migration as sexually maturing fish nearly ready to spawn. These fish generally have ceased feeding by the time they enter estuarine areas. The adults actively swim within the water column, occupying a wide range of depths but commonly within about 50 feet of the surface. At times the adult salmon are found near the bottom, but do not appear to use the substrate in any specific manner. Adults appear to be consistently milling or actively migrating.

Anadromous trout juveniles and adults may rear within the estuary; however, little factual information is available to document this occurrence. Apparently their numbers are sufficiently small and their capacity to avoid sampling gear is sufficiently great that little information data has been generated regarding the characteristics of the estuarine habitat they use. Brown (1992), Kraemer (1994), and Smith and Slaney (1980) provide what information is known about the anadromous form of bull trout. Most juveniles migrate at 2 to 3 years of age. Surviving anadromous adults also migrate back to saline conditions following spawning to undergo additional rearing in the saline environment. Downstream migration occurs during the spring, with rearing in either the estuary or the ocean during the summer, and return migration in the autumn. Some adults return upstream as early as April in some streams, migrating much as adult salmon with little or no feeding. Cutthroat trout appear to have similar life-history characteristics. Sumner (1962), Lowry (1965), Giger (1972), and Johnson (1981) provide information on the life history characteristics of the anadromous form of coastal cutthroat trout. Most migrate to the estuary or ocean during the spring for several months of rearing, returning to their natal streams as sub-adults or adults. These trout may migrate to high salinity areas and return to spawn several times.

4.4 Salmonid Habitat Requirements

Habitat supporting a species or a life stage of a species generally makes up only part of an ecosystem. This discussion focuses on defining those aspects of the lower Columbia River and estuary portion of the ecosystem that provide habitat for the listed fish species.

The quality or suitability of habitat meeting the needs of an organism of concern is determined by a variety of factors. These include the physical characteristics of the environment that are important to the organism, biological production yielding food sources for the organism, and populations of other organisms that are either competitors or predators

Water depth, water velocity, and substrate type are basic physical characteristics determining the suitability of the habitat for young and adult salmon. Water temperature, salinity and turbidity are secondary physical factors that influence the suitability of the habitat. Salmon appear to find relatively wide ranges acceptable for these secondary factors.

4.4.1 Physical Habitat Characteristics of Lower Columbia River Guilds

Each of the three guilds or groups of salmon moving through the lower Columbia River project area has substantially different habitat requirements. Ocean-type juveniles appear to have the most restrictive requirements for physical habitat characteristics. Stream-type juvenile salmon have somewhat less rigid habitat preferences. Adult salmon appear to be relatively none specific in the physical characteristics they are willing to accept. The following information on the habitat characteristics important to young salmon is derived primarily from Weitkamp (2001a) except where otherwise noted.

Ocean-Type Juvenile Salmon

Ocean-type subyearlings require specific physical characteristics in the habitat they commonly use. Apparently, because of their small size, they are unable or unwilling to use much of the habitat that larger juveniles find suitable.

Water Depth: These small fish are generally found within 1 meter of the water surface. Because they are shoreline oriented, this commonly means they occupy shallow water habitat with depths of 0.3 to 2 meters (1 to 7 feet).

Water Currents: The small ocean-type juveniles are not capable of dealing with substantial current velocities; consequently, they tend to occupy areas with current velocities of 9 centimeters per second (0.3 foot per second) or less.

Substrate Type: Subyearling salmon actually are found associated with a wide range of substrate types throughout their range, extending from mud flats to rock cliffs. However, because they are both strongly shoreline oriented and require weak current speeds to remain within the habitat, they are most frequently found in areas with fine grain substrates of silt and sand.

Salinity: Ocean-type juveniles occupy a substantial range of salinities. Although they all begin their rearing migration in freshwater, they appear to have the capacity to readily enter moderate to high salinity conditions within hours to a day. Wagner et al. (1969) found that all fall chinook alevins tested were able to tolerate 15 to 20 parts per thousand (ppt) salinity immediately following hatching. Ellis (1957) found ocean-type fall chinook fry (3 grams) adapted rapidly to high salinity, with high survival to adult returns after only 5 days of incremental adaptation to saltwater with 25 to 75 percent salinity (~ 9 to 25 ppt). Tiffan, et al. (2000) determined that once active migrant fall chinook passed McNary Dam, 470 kilometers upstream from the Columbia River's mouth, 90 percent of the subyearlings were able to survive challenge tests in 30 ppt seawater at 18.3°C. Clark and Shelbourn (1985) determined that very small chinook fry of 1.5 grams and larger could survive and grow in seawater.

Water Temperature: Subyearling salmon commonly experience a wide range of temperatures during their rearing migration through the lower Columbia and other rivers. Because these fish remain in shallow water and migrate in the spring through early summer, they are exposed to water with temperatures raised to near the upper end of their range. Tidal fluctuations cause water to flow over flats heated by the sun resulting in temperatures that frequently reach 15 to 20° C for brief periods, only to be replaced within hours by much cooler river or estuarine water. The lethal temperature for young salmon is about 22° C for fish acclimated to cold water (Brett, 1956; Lee and Rinne, 1980). These studies have shown that young salmon can survive substantially higher temperatures when acclimated to moderate temperatures (10 to 15°C), and can tolerate higher temperatures for brief periods of time (hours) (Brett, 1956; Elliott, 1981).

Sublethal effects can occur at temperatures well below lethal limits. Exposure to high but sublethal temperatures for prolonged periods can have a broad range of effects on various fish functions . Brett (1971) identified 25 physiological responses in sockeye. Two general response patterns have been identified. The response (e.g., standard metabolic rate, active heart rate, gastric evacuation) can either increase continuously with increased temperature, or the response (e.g., growth rate, swimming speed, feeding rate) can increase with temperature to maximum values at optimum temperatures and then decrease as temperature continues to increase (Brett, 1971; Elliott, 1981). At or near 22°C salmonids tend to cease feeding. Growth rates tend to be highest for salmonids between 10 and 18°C when adequate food rations are available. At lower food availability growth decreases at higher temperatures (Brett et al., 1969). At low food rations growth is very low or ceases at temperatures above about 15°C.

Turbidity: Turbidity and suspended sediment are a natural part of the habitat occupied by young and adult salmon. Although they these two parameters are often used interchangeably, they refer to different properties. Turbidity refers to light attenuation by materials in the water, while suspended sediment refers to the amount of mineral particles suspended in the water column.

Turbidity at moderate levels of about 25 to 110 nephelometric turbidity units (NTUs) is common in rivers with migrating salmon. Turbidity can decrease predation on young salmonids. Gregory and Levings (1998) found that young salmon are less likely to be eaten by piscivorus fish at higher turbidities. Turbidity can also reduce the feeding efficiency of young salmonids. Gregory (1988) reported the reaction distance of young chinook to benthic prey decreased greatly between 0 and about 50 NTUs. However, from 50 to 250 NTUs there was little change in reaction distance, in part because the fish were only reacting to prey within about 8 cm at 50 NTUs. Berg and Northcote (1985) demonstrated a similar decrease in the reaction distance of juvenile coho to pelagic prey at turbidities of 30 and 60 NTUs as compared to zero NTU. Growth of young steelhead and coho was reduced by chronic turbidity in the range of 20 to 50 NTUs in freshwater rearing (Sigler et al., 1984). However, turbidity in the range of 30 to 60 NTUs is common in natural rivers such as the Columbia.

Direct survival of young salmonids is can be affected at high suspended sediment loads. Noggle (1978) defined the lethal concentration 50 (LC_{50}) for turbidity (the amount expected to cause death in 50 percent of the exposed population) under summer conditions (the most sensitive) as near 1.2 grams per liter (g/L) for young coho. Smith (1978) determined the LC50 for chum to be greater than 2.5 g/L.

In the lower Columbia River turbidity is important in relation to the zone of the turbidity maximum. Relatively high turbidity is a characteristic of the intermixing of fresh and saltwater where high biological productivity occurs. However, Jones et al. (1990) concluded that, in the lower Columbia River, the standing stocks of benthic infauna were highest in the protected tidal flat habitats, while those of epibenthic and zooplanktonic organisms were concentrated within the estuary mixing zone.

Stream-Type Juvenile Salmon

Because of their relatively large size and rapid migration, stream-type juveniles have somewhat different habitat requirements in the lower Columbia River and its estuary than the subyearlings. These relatively large smolts have the physical capacity to deal with a much larger range of conditions than the subyearlings.

Water Depth: These larger juveniles have been found over a substantial range of water depths although they appear to have some propensity to remain near the water surface. Because they are not shoreline-oriented, they are found throughout a substantial portion of the near-surface water column at depths of 0.3 to 10 meters.

Water Currents: The larger stream-type juveniles are capable of resisting substantially greater current velocities than subyearlings. They are found throughout a wide range of current speeds as they move downstream, generally avoiding low velocity areas except during brief periods when they tend to hold position against tidal or river currents.

Substrate Type: Salmon smolts generally are not associated with river or estuarine substrate types. Because they tend to be more water column oriented than the subyearlings, the smolts are found in areas having a wide range of substrate types.

Salinity: Stream-type juveniles commonly begin the process of smoltification prior to initiating their downstream migration. Salinity challenge tests have routinely shown they are capable of residing in moderate to high salinities long before they reach the saline water of the estuary. Sims (1970) reported that young chinook in the Columbia River that were marked one day in a fresh water area were found the next day in a high salinity area 43 kilometers downstream. Even subyearling salmon migrating from upstream areas are generally able to tolerate immediate exposure to the high salinity conditions of sea-water challenge tests by the time they reach McNary Dam, far upstream from the estuary (Tiffan, et al., 2000).

Movement from fresh water to saline water apparently does not place high metabolic demands on young salmon. Bullivant (1961) found young chinook had no significant difference in oxygen consumption rates when in fresh water, dilute sea water, or sea water (35.4 ppt). He interpreted this lack of difference in oxygen consumption as an indication that the energy expended on osmoregulation was a small portion of the total energy consumption.

Water Temperature: These habitat characteristics are the same for the stream-type guild as for the ocean-type guild.

Turbidity: These habitat characteristics are the same for the stream-type guild as for the ocean-type guild.

Adult Salmonids

Adult salmon have much less restrictive habitat requirements as they migrate through estuarine and lower river areas as compared to juveniles.

High concentrations of suspended sediment can influence the homing of adult salmon. Whitman, et al. (1982) found adult chinook tended to avoid Mount St. Helens ash at about 650 milligrams per liter (mg/L), but ash at average concentrations of 3.4 g/L in the Toutle River did not appear to influence homing performance.

Generally adult salmon are not exposed to temperatures in a lethal range because of their capacity to avoid high temperatures together with their propensity to remain in relatively open water until they reach spawning areas. However, high temperatures can delay their migrations. In 1941, extremely high water temperatures (22 to 24° C) apparently resulted in chinook, sockeye and steelhead adults congregating in small cold streams near the Bonneville and Rock Island Dams (Fish and Hanavan, 1948). At the Okanogan River Major and Mighell (1967) observed that temperatures greater than 21°C blocked sockeye migrations, while stable or even rising temperatures below 21°C did not block migration.

Trout

Considerable information regarding trout habitat was previously presented to the Sustainable Ecosystems Institute (SEI) Science Panel by Doug Young (USFWS) during the initial workshop held in March 2001. Published and other information on cutthroat trout was recently assembled by Trotter (1989) and again for Appendix D-2 of this document. Previously Sumner (1962), Lowry (1965), and Giger (1972) have provided information on anadromous forms of cutthroat trout in Oregon coastal streams, although not the Columbia River. Likewise, available information on anadromous forms of bull trout comes primarily from areas other than the Columbia River. As stated above, the characteristics of habitat used by cutthroat trout and bull trout in estuarine areas are not well defined, but can be inferred from the available information.

Most likely the trout move relatively rapidly through the lower Columbia River to the estuary or ocean. Cutthroat trout generally make up a small portion of the salmonid collections that have been obtained in the lower river, while char (bull trout/Dolly Varden) have been absent. Substantial numbers of adult cutthroat trout have been taken at times in relatively shallow water along shallow bars by sport fishers. Cutthroat have also been collected in the lower Columbia River at a number of estuarine locations (Loch, 1982) and just upstream from the estuary at Jones Beach (Dawley, 1985). Downstream migration of juvenile and adult cutthroat appears to occur in April and May, peaking in early May (Dawley, et al., 1979 and 1980). Johansen and Sims (1973) captured cutthroat in small numbers in purse seines in the channels of the lower river and estuary. Most of the trout were yearling fish collected in April to June.

In other areas, anadromous bull trout appear to move quickly through the lower river and estuarine areas during both smolt out migrations and adult spawning migrations based on their complete absence in most scientific collections. No information is available indicating holding, feeding, or other extended use of the lower Columbia River by either juvenile or returning adult bull trout. Anadromous bull trout most likely feed where forage fish are present, but not near the bottom in subtidal areas or near the shorelines, which do not provide habitat for forage fish. Anadromous bull trout have been found in Puget Sound in areas where Pacific herring, surf smelt, and Pacific sand lance spawn occur (Kraemer, 1994) apparently following concentrations of prey species.

Because bull trout are a relatively long-lived iteroparous species (spawn multiple times), the potential exists for the anadromous forms to make several outmigration and spawning runs through the lower Columbia River. Upstream migrations of bull trout spawners typically occur in early summer (late June and July) when water temperatures are relatively cool (Rieman and McIntyre, 1993), most likely in moderate to low velocity areas. Bull trout are not known to use shoreline habitat in the lower Columbia River.

4.4.2 Juvenile Salmonid Prey Resources

No information is available on prey resources historically used by young salmon before the substantial modification of the lower river and its estuary. Studies of the prey consumed by young salmon began long after the river system had become highly modified, providing information about how the system currently supports their survival, but not necessarily how it naturally supported their survival prior to modification.

Prey consumed by young salmon in the lower Columbia River with modified conditions and in other estuarine areas includes a variety of organisms (Table D4-2). As stated in Higgs, et al. (1995, p. 262), "…all Pacific salmon species are opportunistic in their food habits. Frequently, their daily diet consists of many food items. Moreover, prey selection is directed generally at the most commonly encountered species (available and abundant) that are organoleptically acceptable based on previous experience, visible, unable to escape readily, and of appropriate actual or perceived size relative to the size of the fish (Hyatt, 1979)."

In an early study of juvenile salmon food habits in the lower Columbia River, Craddock, et al. (1976) found they consume primarily insects in the spring and fall, while Daphnia is the major prey—selected more than other planktonic organisms—from July to October. Dawley et al. (1986) found that young salmon in the lower Columbia River consume diptera, hymenoptera, coleoptera, tricoptera, and ephemeroptera in the upstream portion of the area. Downstream their diet changes to diptera, cladocerans, and amphipods (*Corophium salmonis*, *Corophium spinicorne*, *Eogammarus confervicolus*). Many yearlings passing through the lower river were found by Dawley, et al. (1986) to have empty or less than full stomachs. Considerable overlap occurred in the diets of the salmon species, with dipterans being most important for coho. More recently, Bottom and Jones (1990) reported young chinook ate primarily *Corophium*, *Daphnia*, and insects, with *Corophium* being the dominant prey species in winter and spring, and *Daphnia* the dominant prey species in summer.

Corophium is commonly discussed as a primary prey item of juvenile salmon in the lower Columbia River. *Corophium salmonis* is a euryhaline species tolerating salinities in the range of 0-20 ppt (Holton and Higley, 1984). As shown by the above investigations, it is one of several major prey species consumed by juvenile chinook under existing conditions. Data from other estuaries indicates *Corophium* can be a substantial portion of the dietary intake for young salmon, but it is not included in most estuarine habitats. Data are not available that indicate its historic role in the diet of Columbia River salmon prior to substantial modification of the river system. *Corophium* may not be a highly desirable food source for young salmon. According to Higgs, et al. (1995), gammarid amphipods are high in chitin and ash and low in available protein and energy relative to daphnids and chironomid larvae. This may be in part why daphnids and chironomid larvae are commonly a major portion of the prey consumed by juvenile salmonids in the upper portions of estuaries where these organisms are generally available.

Table D3-2: Prey Consumed by Young Chinook in Estuarine Habitats (Weitkamp, 2001)

PREY CONSUMED	LOCATION	REFERENCE
Neomysis, Corophium, and insects	Sacramento-San Joaquin, CA	Sasaki, 1966
Primarily copepods, amphipods, and fish larvae within the inland delta.	Sacramento-San Joaquin, CA	Kjelson, et al., 1982
Insects in spring and fall. Daphnia is major prey, selected more than other planktonic organisms, from July to October.	Columbia R. OR-WA	Craddock, et al., 1976
Subyearlings at Jones Beach (RKm 75) were in a feeding transition zone from insects (diptera, hymenoptera, coleoptera, tricoptera, ephemeroptera) upstream to diptera, cladocerans, and some amphipods (*Corophium salmonis, C. spinicorne, Eogammarus confervicolus*) downstream. Many yearlings passing through the estuary had empty or less than full stomachs. Considerable overlap of the salmon species occurred, with dipterans most important for coho.	Columbia R. OR-WA	Dawley, et al., 1986
Chinook ate *Daphnia, Corophium* and insects, with major prey being *Corophium* in winter and spring and *Daphnia* in summer.	Columbia R. OR-WA	Bottom and Jones, 1990
Corophium, gammarids, mysids, cumacea, crangonids, and crab predominant prey.	Chehalis R. WA	Herrmann, 1970
Insects, gammarids, and mysids consumed in constructed and natural sloughs (also coho). Lower stomach content fullness in constructed sloughs.	Chehalis R. WA	Miller and Simenstad, 1997
Fry fed almost exclusively on chironomid larvae in Capitol Lake until August, when they began to feed on *Daphnia* and *Epischura.*	Deschutes R. WA	Engstrom-Heg, 1968
Dipterans, gammarids, decapod larvae, calanoids, euphausids, mysids, and fish.	Nisqually R. WA	Fresh, et al., 1978
Diptera, mysids and gammarids.	Nisqually R. WA	Pearce, et al., 1982
Copepods and harpacticoids in general area. Primarily crab larvae and gammarids in Hylebos waterway.	Commencement Bay, WA	Meyer, et al., 1981
Observed feeding under piers. Appeared to acquire less food than natural shorelines.	Commencement Bay, WA	Simenstad, et al., 1985
Ate crab larvae, and drift insects; ate chum and consumed harpacticoids in highly modified shorelines with little eelgrass or macrophytes.	Commencement Bay, WA	Simenstad, Cordell, et al., 1985
Tended to select chironomid larvae (epibenthic) in March-May in constructed wetlands, but ate few harpacticoids and nematodes although these were dominant in wetlands. In river fed on adults (neuston) as well as plecoptera, dipterans, *Daphnia, Corophium, Eogammarus*, and cyclopoids.	Puyallup R.WA	Shreffler, et al., 1992a

Gammarids, chironomids, and calanoids. Ate more marine prey at downstream locations. Near shorelines ate epibenthic. In deeper water ate pelagic prey.	Duwamish R. WA	Meyer, et al., 1980
Consumed insects, gammarid amphipods, cumacea, *Corophium*, and mysids (in order of numerical abundance); gammarids (28 percent), insects (27 percent), and fish (19 percent) were the most important by weight.	Snohomish R. WA	Conley, 1977
Chinook consumed fish larvae and gammarids along beaches, with some insects and cumacea. In deeper water they ate fish larvae, barnacle larvae, crab larvae, insects, and gammarids.	Snohomish R. WA	Parametrix, Inc., 1985
Fry consumed *Corophium*, harpacticoids, and insect larvae in marsh area.	Skagit R. WA	Congleton and Smith, 1976
Fed on copepods (50 percent) and chironomids (26 percent) eaten by fry (40-95 mm) in high saline waters.	San Juan Is. WA	Annan, 1958
Juvenile chinook and chum were found to prey on larval and juvenile baitfish.	Birch Bay Marina north Puget Sound WA	Cardwell, et al., 1980
Crab larvae, herring, sand lance larvae, and polychaetes eaten by smolts (118 mm) near shore. Offshore ate herring, euphausids, gammarids, and mysids.	Puget Sound,	Fresh, et al., 1981
Chinook preferred euphausids along with fish in spring, and crab larvae and fish during the summer. During fall they ate a variety of euphausids, amphipods, crab larvae, and fish. Offshore, chinook, chum, and coho juveniles preyed on the same food sources with different preferences.	Puget Sound	Beamish, et al., 1998
Ate pelagic prey, insects, calanoids, juvenile fish, and polychaetes in August.	San Juan beaches, WA	Simenstad, et al., 1977
Ate primarily adult insects, cumacea, and *Neomysis*. Dominant organisms varied with time of day on Fraser R. tide flat.	Fraser R. BC	Levings, 1982
Ate chironomids, cladocera, *Anisogammarus, Corophium, Neomysis*, and insects.	Fraser R. BC	Dunford, 1975
Ate harpacticoids, chironomids, adult insects, and amphipods. Diets varied considerably over time, location/habitats within, & different among years, indicating opportunistic feeders.	Fraser R. BC	Healey, 1980b
At Nanaimo, fed mainly on decapod larvae, mysids, and adult insects in the inner estuary, and larval herring in the outer estuary (1978, 1979). In 1972 their diet included more amphipods and harpacticoids. At Nitinat, fed primarily on adult insects, gammarids, and crab larvae, and occasionally on cladocera; showed seasonal shift in prey items with cladocera and fish larvae becoming important later in migration period.	Fraser R. BC Nanaimo R. BC Nitinat R. BC	Healey, 1982b
Large fry (57 to 69 mm) fed on epibenthic prey at low rates in high turbidity (370 to 810 NTU) and clear water, and at highest rates in intermediate turbidity (18 to150 NTU) present in tidal channels). Small fry (49 to 50 mm) fed at highest rates in low turbidity; planktonic prey consumed at highest rates in low turbidity for both sizes.	Fraser R. BC laboratory	Gregory, 1994
Harpacticoids important prey in March-early April, decapod larvae and amphipods in April-May, and mysids and insects in May-July. Ate fish as they moved offshore. Diets varied considerably over time, location/habitats within, & different among years, indicating opportunistic feeders.	Nanaimo R. Vancouver Is, BC	Healey, 1980b
Fed on *Anisogammarus* found in periphyton on logs and near bank substrates in Inlet having steep intertidal. Also fed on chironomids when nearshore, but fish larvae, euphausids, decapod larvae, copepods, cladocerans, chaetognaths, barnacle	Somas R., Alberni Inlet, Vancouver Is. BC	Kask and Parker, 1972

larvae, polychaete larvae, and cephalopods when in open water.		
Fed on zooplankton, not harpacticoids. Diets varied considerably over time, location/habitats within, & different among years, indicating opportunistic feeders .	Nitinat R. BC	Healey, 1980b
Ate benthic estuarine organisms along with fish in estuary in March-May, and primarily juvenile herring during July-September, along with decapod larvae.	Cowichan R. BC	Argue, et al., 1985
Ate *Anisogammarus* and *Neomysis ragii*, plus benthic invertebrates (chum and coho ate same).	Squamish R, BC	Goodman and Vroom, 1972
Neomysis and insects (June-July).	Squamish R, BC	Levy and Levings, 1978
Wild chinook consumed *Bosmina* and insects, shifted to *Neocalanus* & *Cumella* at outer estuary locations (chum same).	Campbell R. BC	MacDonald, et al., 1986

Adult salmon have generally ceased feeding by the time they enter estuarine areas. Chinook, sockeye, and steelhead have acquired food reserves in the ocean environment that sustain them through their migration according to Burgner (1991). "Salmon usually cease feeding before entering their natal streams and depend on their energy reserves for migration, maturation of gonads, spawning, and redd (nest) defense until death."

Only one investigation of the estuarine prey eaten by bull trout was identified. Narver and Dahlberg (1965) found that juvenile bull trout ate predominantly on Pacific sand lance, caplin, greenling, sculpin, and juvenile sockeye, together with Gammarus and eupahusids. Feeding by cutthroat trout and bull trout during their upstream migration through the lower river has not been defined. It is likely these fish continue to feed to some degree as they commonly retain a functional digestive system and return to saltwater following spawning.

4.4.3 Time Present in Project Area

Subyearlings

Chinook and chum fry from the lower Columbia spawning areas appear in the project area by late March. Most likely chum and the early chinook rear in the project area through late April or early June, based on the residence time of these fry in other Pacific Northwest estuaries (Weitkamp, 2001).

Yearling Smolts

Chinook, sockeye, and steelhead smolts (second to third year of life) migrate through the project area primarily from April through August.

Adults

Adult salmonids are present in the project area throughout much of the year. Generally upstream migration begins with spring chinook migrating to upstream portions of the watershed in March or April. These early chinook are followed by summer and fall run chinook that form a nearly continuous run of upstream migrants through September.

Trout

Downstream migration of juvenile and adult cutthroat appears to occur in April and May, peaking in early May (Dawley et al., 1979 and 1980). Johansen and Sims (1973) captured cutthroat in small numbers in purse seines in the channels of the lower Columbia River and estuary. Most of the trout were yearling fish collected in April to June.

Upstream migrations of bull trout spawners typically occur in early summer (late June and July) when water temperatures are relatively cool (Rieman and McIntyre, 1993), most likely in moderate to low velocity areas.

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APPENDIX E

DESCRIPTION OF THE CONCEPTUAL MODEL FOR LOWER COLUMBIA RIVER JUVENILE SALMONIDS

1 INTRODUCTION

Appendix E describes an ecosystem-based conceptual model for juvenile salmonid production in the lower Columbia River. Development of a conceptual model was initially proposed at the first Sustainable Ecosystems Institute (SEI) Science Panel Workshop for the Columbia River Navigation Channel Improvements Project (the Project) (March 17-18, 2001). The model emphasizes juvenile salmonids, which are also the emphasis of the reconsultation process. This approach was proposed in response to the SEI Science Panel's suggestion that it would be helpful to present the ecological relationships for the lower Columbia River in a systematic framework.

The purpose of this conceptual model is to organize the available information on the lower Columbia River ecosystem that pertains to rearing and outmigration of juvenile salmonids. It was thought that organizing the information into a model would help the science panel and members of the interagency consultation and management teams to visualize how various components of the ecosystem connect and function together, and how actions associated with the navigation improvement project may affect the ecosystem as a whole. The model is also a tool to help guide discussions on the most appropriate mitigation (if required), monitoring strategies, and adaptive management.

A substantial amount of information about the lower Columbia River ecosystem and the proposed project has been developed; however, it is contained primarily in lists and extensive text from unrelated sources. The model provides a simple set of diagrams that illustrate the relationships among the various components of the ecosystem; its selected components highlight the more important linkages for the model output, which is successful juvenile salmonid migration to the ocean. In addition to graphically displaying the ecosystem, the model provides a guide for determining what types of data may be most important in understanding long-term component relationships and could be gathered during a monitoring program.

The model, which was developed over a period of approximately 6 months is based on published information and consultation with experts on the lower Columbia River ecosystem. Staff from Battelle Marine Science Laboratories prepared the model with assistance by staff from Parametrix, Inc., and the Port of Portland. Also, individuals from several organizations provided critical review and input, including the Port District of the U.S. Army Corps of Engineers, Port of Portland, National Marine Fisheries Service, U.S. Fish and Wildlife Service, Parametrix, Inc., Limno-Tech, Inc., University of Washington, and Battelle Marine Sciences Laboratory. The SEI Science Panel also provided comments on various versions of the model during the SEI Science Panel Workshops.

Definition of a Conceptual Model

Huggett (1993) describes a conceptual model as follows:

> "…a conceptual model expresses ideas about components and processes deemed to be important in a system, and some preliminary thoughts on how the components and processes are connected. In other words, it is a statement about the system form and system function."

Huggett also makes the following points regarding conceptual models:

> "Conceptual models are expressed in several ways: as pictures, as box-and-arrow diagrams, as matrix models, as computer flow charts, and in various symbolic languages…the old saw is generally true, one picture is worth a thousand words….

> "Conceptual models help to clarify loose thoughts about how a system is composed and how it operates…they are often the foundation for the construction of mathematical models…it is the most important step in the entire process of mathematical modeling."

Conceptual models have been used widely in ecology to depict ecosystems and food webs (e.g., Odum, 1988; Odum and Hornbeck, 1997; Jackson, et al., 2001; McIntire and Colby, 1978). The conceptual model developed here is what Huggett (1993) terms a box-and-arrow model. In this type of model, boxes stand for system components and arrows depict important links and relations between the components.

Purpose of the Conceptual Model

In general, a conceptual model is developed to ensure a shared vision of the relationship between components of the ecosystem. A conceptual model functions as a formulation tool, a communications tool, and an assessment tool. Properly constructed, a conceptual model enhances stakeholder participation and minimizes ecological risk. Furthermore, combining the conceptual model with a decision process and framework enables a planning team to deal with risk and uncertainties in a systematic way.

The lower Columbia River conceptual model is used to identify the connection between the actions associated with the Project and the physical and biological reactions to such actions, based on the best available information on qualitative and conceptual relationships. The model provides an integrated picture of the major ecosystem components and those factors that affect ecosystem structure and functioning relative to juvenile salmon. It represents the consensus among the reconsultation stakeholders about how the lower river ecosystem operates. Finally, this conceptual model with its linked submodels representing major ecosystem pathways is a "living" concept that can be refined and revised as new insight and interpretation become available.

Objectives of the Model

The specific objectives of the lower Columbia River model are to:

- Identify links among physical-chemical and biological components and processes
- Aid in the identification of ecosystem and salmon vulnerabilities and potential effects of the project
- Inform decision-making about the proposed project effects by providing a system-level scientific perspective
- Provide a framework for monitoring and adaptive management

Approach to Model Development

The model was developed through a synthesis of published and unpublished information, as well as expert input, coupled with the application of ecosystem principles. There is both a general belief that the Columbia River estuary is important, if not critical, to juveniles of some salmon species and a lack of fundamental information proving this. According to Bottom, et al. (2001, page 152), "…the intrinsic assumption that food or predation in the estuary may limit juvenile salmon productivity, or that there are carrying capacity limitations for juvenile salmon in the Columbia River estuary, has never been rigorously tested." In the opinion of Bottom, et al. (2001) the complex relationships among the many factors affecting salmon, together with the primary producers in the food web, prey production and availability, and salmonid vulnerability to predators, make modeling difficult. This degree of complexity became clear in the development of the model. However, the estuary ecosystem theoretically can be visualized in a conceptual manner that is useful sorting out key ecological interactions.

The primary publications used in developing the conceptual model are listed below. These publications represent both primary reports of new research as well as synthesis documents. The white papers and presentations developed for the reconsultation process were also consulted.

An Ecological Characterization of the Pacific Northwest Coastal Region: Volume One—Conceptual Model and Volume Three—Characterization Atlas, Zone and Habitat Descriptions (Proctor, et al., 1980). This set of publications is a comprehensive compilation of information on estuarine and outer coastal systems in the Pacific Northwest. The presentation is organized by conceptual models of the various ecosystems in the region.

A Review of the Effects of Dams on the Columbia River Estuarine Environment, with Special Reference to Salmonids (Weitkamp, 1994). This report contains a food web diagram that includes juvenile salmon.

Changes in Fluxes in Estuaries: Implications from Science to Management (Dyer and Orth, editors, 1994). This book contains several papers on the Columbia River estuary prepared by the team conducting research on the estuarine turbidity maximum (ETM).

Columbia River: Estuarine System (Small, 1990). This special publication in Progress of Oceanography contains papers summarizing research conducted as part of the Columbia River Estuary Data Development Program (CREDDP) program in the 1980s.

Salmon at River's End: The Role of the Estuary in the Decline and Recovery of Columbia River Salmon (Bottom, et al., 2001), unpublished. A comprehensive compilation and treatment of the factors contributing to changes in the role the estuary plays in juvenile salmon production.

Scientific Issues Relating to Temperature Criteria for Salmon, Trout, and Char Native to the Pacific Northwest (Water Temperature Criteria Technical Workgroup, 2001). A summary report to the Policy Workgroup of EPA Region 10 Water Temperature Criteria Guidance Project.

Chinook Capacity to Adapt to Saltwater (Weitkamp, 2001a, unpublished). A summary of data on salinity and juvenile salmonids.

Prey Consumed in Estuaries (Weitkamp, 2001b, unpublished). A summary of information on prey eaten by juvenile Pacific salmon in estuaries.

Variability of Pacific Northwest Marine Ecosystems and Relation to Salmon Production (Bottom, et al., 1998). Comprehensive description of the pelagic life history of salmon and factors in the system that may affect salmon populations.

Variability of Estuarine and Riverine Ecosystem Productivity for Supporting Pacific Salmon (Wissmar and Simenstad, 1998). A companion paper to Bottom, et al. (1998) that addresses the river and estuary life history of salmon and factors in the system that may affect salmon populations.

Changes in Columbia River Estuary Habitat Types over the Past Century (Duncan W. Thomas, 1983). This report systematically compares present day (i.e., 1970s) benthic habitat areas with information from surveys conducted in 1868-1873.

Upstream: Salmon and Society in the Pacific Northwest (National Research Council, 1996). A comprehensive review by a panel from the National Academy of Sciences of salmon stocks and issues related to salmon decline and recovery in the Northwest.

2 LOWER COLUMBIA RIVER AND ESTUARY MODELS

Several models have been developed to illustrate how various components of the Lower Columbia system function. Proctor, et al. (1980) provide a series of illustrations that can be used to summarize the fundamental picture of the Columbia River estuarine systems. The relative composition of some of these systems has changed over the past 100 years so that emergent wetlands and above-tide estuarine wetlands have been lost, and deep water habitats, tidal flats and channels have increased in area (Thomas, 1983).

The successional development of these habitats depends on several processes. Through physical processes of deposition, erosion, stabilization, and siltation, vegetation changes occur and the land surface elevation increases, gradually forming forested wetlands and upland habitats (Proctor, et al., 1980). Human-induced alterations of this successional process in the Columbia River estuary include diking, grazing, dredging, and changes in flow (Sherwood, et al., 1990). Elevation and hydrology are key factors that control the types of habitats and functions each habitat performs. Therefore, altering primary and secondary rate controlling factors – either by restricting hydrology (through diking or changing elevation by filling or dredging) or by changing erosional and deposition processes through alterations in river flow or sediment supply – will result in a modification of habitat distribution and function.

Sherwood, et al. (1990) summarized the changes that have occurred in the estuary. Their study reported that the tidal prism had been reduced approximately 15 percent and there had been a net increase in sediment in the estuary. Sediment had eroded from the entrance and been deposited on the continental shelf. Reduced river flow resulted in less mixing, increased stratification, altered response to tidal forcing, and decreased salinity intrusion length and transport of salt into the estuary. There had been an estimated 82 percent reduction in emergent wetland production and a 15 percent reduction in benthic microalgae production. Riverine detritus derived from freshwater phytoplankton production had increased to partially compensate for this loss. This increase caused a shift in the food web from macrodetritus from emergent marshes to more labile microdetritus from allocthonous phytoplankton. The shift favored suspension-feeding copepods associated with the ETM, such as Eurytemora affinis and the harpacticoid copepod Scottolana canadensis. Sherwood, et al. (1990) postulated that production of these species over benthic deposit-feeding invertebrates resulted in a fundamental shift from support of a benthic-feeding to a pelagic-feeding fish fauna. Estuarine-dependent juvenile salmon feed primarily on benthic prey, and this fundamental shift in the food web may have affected the quality and quantity of prey available to these fish.

The decrease in flows caused by flow regulation has resulted in less variation in the location of both the toe of the salt wedge and the ETM. Extensive research on the ETM by Simenstad, et al. (1994) and others indicates that the position of the ETM and the excursion of salty water are driven by tides and river flow. The ETM and salinity may play an important role in the food web as well as in structuring the benthic community (including important salmonid prey such as *Corophium*).

Weitkamp (1994) describes a food web for the estuary that highlights the sources of prey to salmonids in the estuary, including *Daphnia*, insects, mysids and *Corophium*. The latter three taxa are supported by marsh carbon, whereas *Daphnia* is supported by the resident phytoplankton and freshwater microdetritus pathway. The microdetritus pathway supports a set of piscivorous birds and mammals known to prey on juvenile salmon in the estuary. The degree to which this shift in the food web has affected salmonid production and survival is not quantified.

Salmonids exhibit several life-history strategies, which are believed to maximize the ability of the species to withstand variation in the system. For ocean-type chinook salmon, there may be as many as 35 potential life-history strategies (Wissmar and Simenstad, 1998). Of relevance to the estuary is that chinook are known to spend time ranging from brief periods (days) to extended periods (6 months) rearing and feeding in the estuary. The net effect is that there may be populations of juvenile chinook in the estuary throughout much of the year. Because of seasonal changes in habitats and prey resources, caused by changes in forcing factors, the salmon use a seasonally varying array of habitat conditions and prey resources. Consequently, the support provided by the estuary for survival, growth, smolting, and passage varies.

According to Wissmar and Simenstad (1998), juveniles that are highly estuarine dependent are known to feed on a variety of prey, including insects and amphipods. However, the author caution that the food web pathway can be highly variable because of differential pulses of organic matter and the heterogeneous distributions of living and detrital food sources across estuarine habitats. This variability may explain dramatically different trophic support of salmon, especially when salmon localize their rearing and migrations in a specific estuarine region or habitat. Furthermore, production at lower trophic levels may not be a realistic indicator of estuarine production support for salmon because of this variability.

Bottom, et al. (2001) proposed two criteria for evaluating the "opportunity for subyearling, ocean-type, salmon to use habitat for their benefit." Their review of information on use of estuarine habitats in the Pacific Northwest indicated that depth and velocity were potentially useful in defining the areas most frequently utilized. These salmonids generally were found in the depth zone of 0.1 to 2.0 meters (m) in the water column and in areas where current velocities were on the order of 30 centimeters per second (cm/s) or less. These life-history types were generally oriented toward shallow channels and marsh edges where benthic prey are abundant. Based on these criteria, Bottom, et al. (2001) showed that habitat opportunity was altered by bathymetry and flow changes in the system when compared to pre-dam conditions. In combining their findings related to large-scale alterations in flow characteristics with the knowledge that marshes have been lost and changes in carbon sources have occurred, they concluded that the productive capacity of the estuary has likely declined over the last century.

The relationship between changes in the Columbia River and its estuary are complex. Bottom, et al. (2001) present a comprehensive assessment of large-scale historical changes in the estuary relative to salmon. However, evaluation of smaller-scale changes, such as those relevant to the channel improvements project, is being approached from a variety of directions by various agencies. Some key issues that need to be included in this latter assessment are:

- Availability of specific (especially shallowwater) habitats used during rearing and outmigration through the estuary
- Effects of physiochemical and biological conditions on estuarine residence times, growth, and survival
- Food chain relationships among juvenile salmon, invertebrate prey, and vertebrate predators
- Differences in these estuarine habitat needs and ecological relationships among salmon species, life-history types, and source populations

2.1 General Model Overview

The general form of a conceptual model is typically formatted to flow from the general to the specific, as shown below:

Controlling Factors →
Ecosystem Structure →
Ecosystem Function

This form assumes that ecosystem functions are determined by ecosystem structure and that ecosystem structure is controlled by physical and chemical processes. The model form can be applied to the Columbia River Navigation Channel Improvement Project reconsultation process by defining the historical, present (i.e., project baseline), and potential state of the ecosystem relative to the project. Figure E-1 illustrates a conceptual matrix for the ecosystem state. It is assumed that there is a positive relationship between structure of an ecosystem and function of that ecosystem, and that the natural climax or optimal structure of an ecosystem has a corresponding and predictable functional condition.

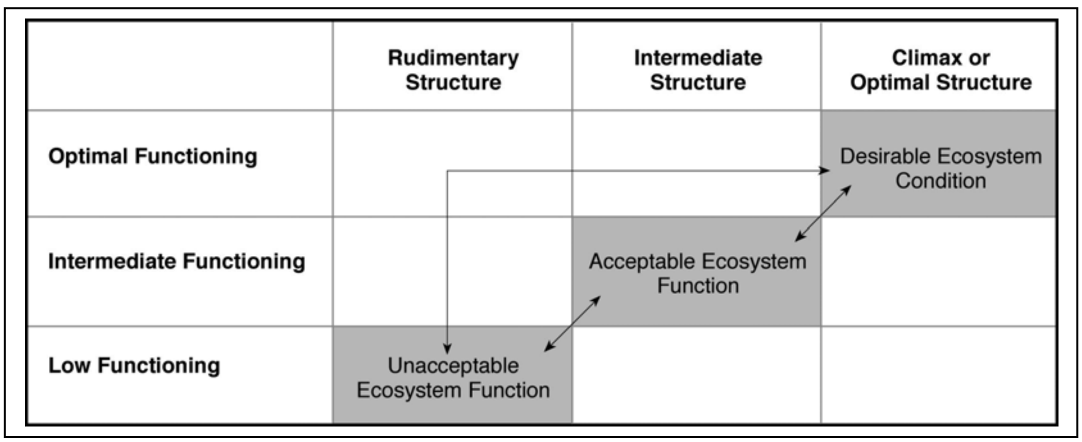


Figure E-1 Conceptual Ecosystem State

As shown, system structure and function are divided into three levels: low, moderate, and high conditions. The values (e.g., acreage) used to quantify the structural condition (e.g., the size of the pond-wetland interface) and the functional conditions (e.g., the number of ducks nesting at this interface) can occupy a range (e.g., from 80 to 100 square meters of pond-wetland area). Using a range of values acknowledges two primary sources of uncertainty:

- Present understanding of the relationship between structural and functional ecosystem components
- Natural variability associated with structural conditions and functional conditions target (Shreffler and Thom, 1993; Hobbs and Norton, 1996; Thom, 2000)

As noted by Bottom, et al. (2001, 1998); and Wissmar and Simenstad (1998), the Columbia River salmon populations have been subjected to variations in climate and other factors and have, to a certain degree, adapted their life-history strategies to deal with these variations. Prior to human influence, the Columbia system underwent extensive variability in the ecosystem conditions that form the structural aspects of habitats used by salmon. Flow regulation has reduced variability in river discharge, which is potentially a major influence on habitats and their use by salmon (Bottom, et al., 2001). Flow regulation and tidal wetland and swamp loss have been identified as two of the most important changes in the lower Columbia River relative to salmonids. Because of these two major changes, the lower Columbia River ecosystem is likely in an altered state. Whether that state is acceptable depends on the interpretation of the situation. As with other system states, natural variation in ecosystem conditions within this altered state is expected and will not shift the system condition to a lower or higher state.

The conceptual model for the lower Columbia River ecosystem, which is described in the remaining sections, illustrates the relationships among the structural and functional conditions of the system. In addition, the model is a summary of what is understood about controlling factors responsible for the formation of the structural and functional aspects of the ecosystem. The conceptual model, coupled with the general matrix shown in Figure E-1, provides a framework by which the effects of changes in structure, function, and controlling factors on salmon can be assessed.

2.2 Conceptual Model Description

This section begins with a brief discussion of migratory patterns for juvenile and adult salmon, but focuses on juvenile salmon outmigration. The integrated model and component pathways are emphasized.

Major Migratory Behaviors

Juvenile salmon use the lower Columbia River system for a variety of purposes; adults primarily use the system to move upstream to spawning grounds but may also feed in it. At some point in their first or second year, juvenile salmon begin their outmigration from their natal stream down through the estuary to the open ocean. Success in reaching the ocean depends on their ability to:

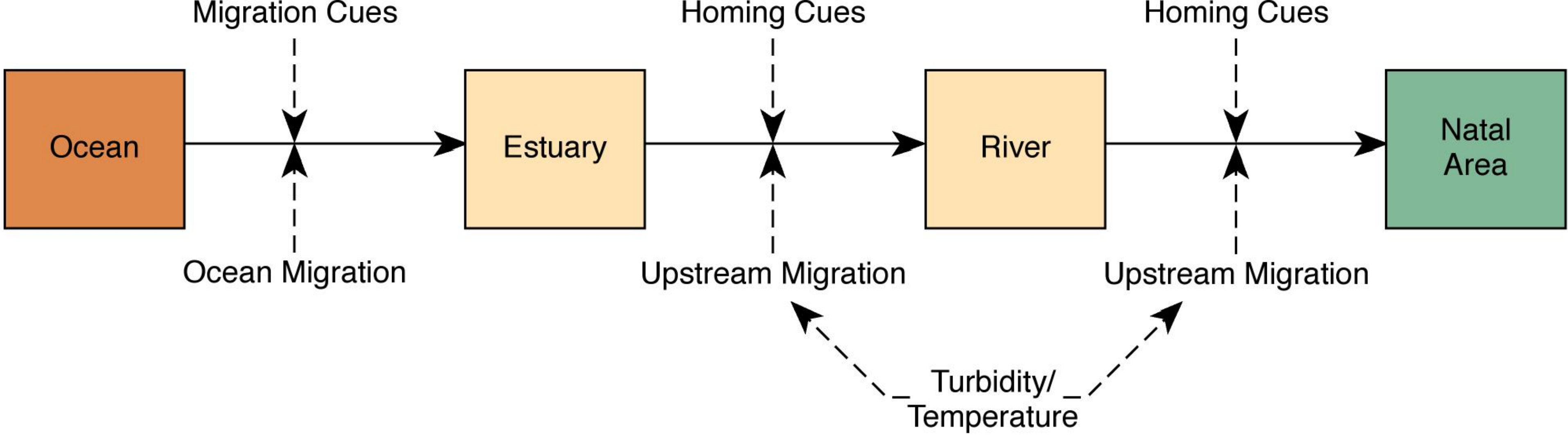
- Easily move between the various zones within the migratory corridor
- Transition physiologically between fresh and salt water environments
- Feed and grow substantially
- Avoid predation

(Wissmar and Simenstad, 1998; Brodeur, et al., 2000; Bottom, et al., 2001),

During return migration, adult salmon rely on various homing cues to relocate the mouth of the river as well as their natal spawning grounds (Figure E-2) Migration to their spawning grounds depends on an open connection between the ocean and the natal area as well as the ability of the fish to find its way. According to a report by the National Resource Council (NRC, 1996) both extreme temperatures and increased turbidity may affect the ability of fish to find their way or may restrict the upstream rate of movement. Higher temperatures, combined with lower levels of dissolved oxygen in the water, may stop migration until conditions improve. Bottom, et al. (1998) and the NRC (1996) concluded that salmon survival is affected by ocean conditions and that variability in ocean conditions strongly influences salmon abundance.

Integrated Conceptual Model for Juvenile Salmon

The Integrated Conceptual Model illustrates the major components of the estuarine ecosystem relative to juvenile salmon (Figure E-3). The output from the model is juvenile salmon production and ocean entry. According to a similar model in Brodeur, et al. (2000), salmon production and ocean entry depend on several functions, including the development of habitats, production of food to fuel the food web, and ability to access and use these habitats. The culmination of these functions results in growth and survival of fish and their ultimate entry into the ocean.



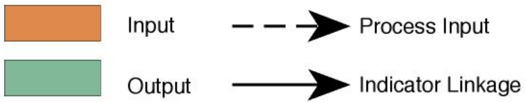


Figure E-2
Adult Salmonid Migration Returning to their Natal Stream

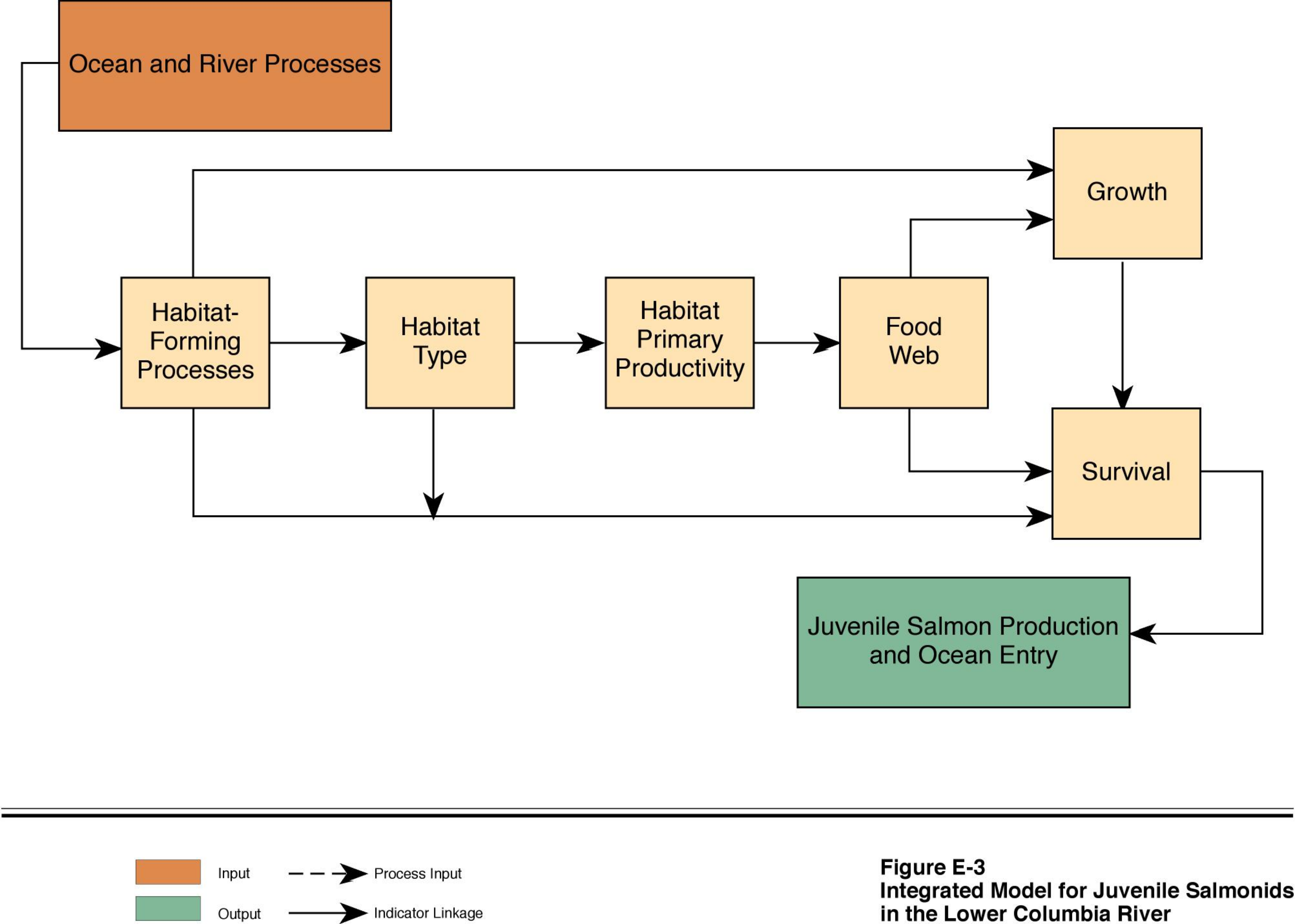


Figure E-3
Integrated Model for Juvenile Salmonids in the Lower Columbia River

Taken as whole, the model highlights the complexity of the factors supporting juvenile salmonid production and ocean entry. Benefits provided to salmonids in the lower Columbia can be summarized as the ability of salmonids to access habitats (i.e., habitat opportunity) and the amount of food available within these habitats (i.e., habitat capacity), as discussed in Bottom, et al., 2001. In turn, opportunity and capacity depend on the development and functioning of viable habitats. These habitats are formed and maintained by physical and chemical forcing factors. Significant interactions affect the development of habitat as well as its support to salmonids. These interactions include habitat succession rates and patterns, disturbance regimes, landscape connectivity, and salmonid life-history diversity.

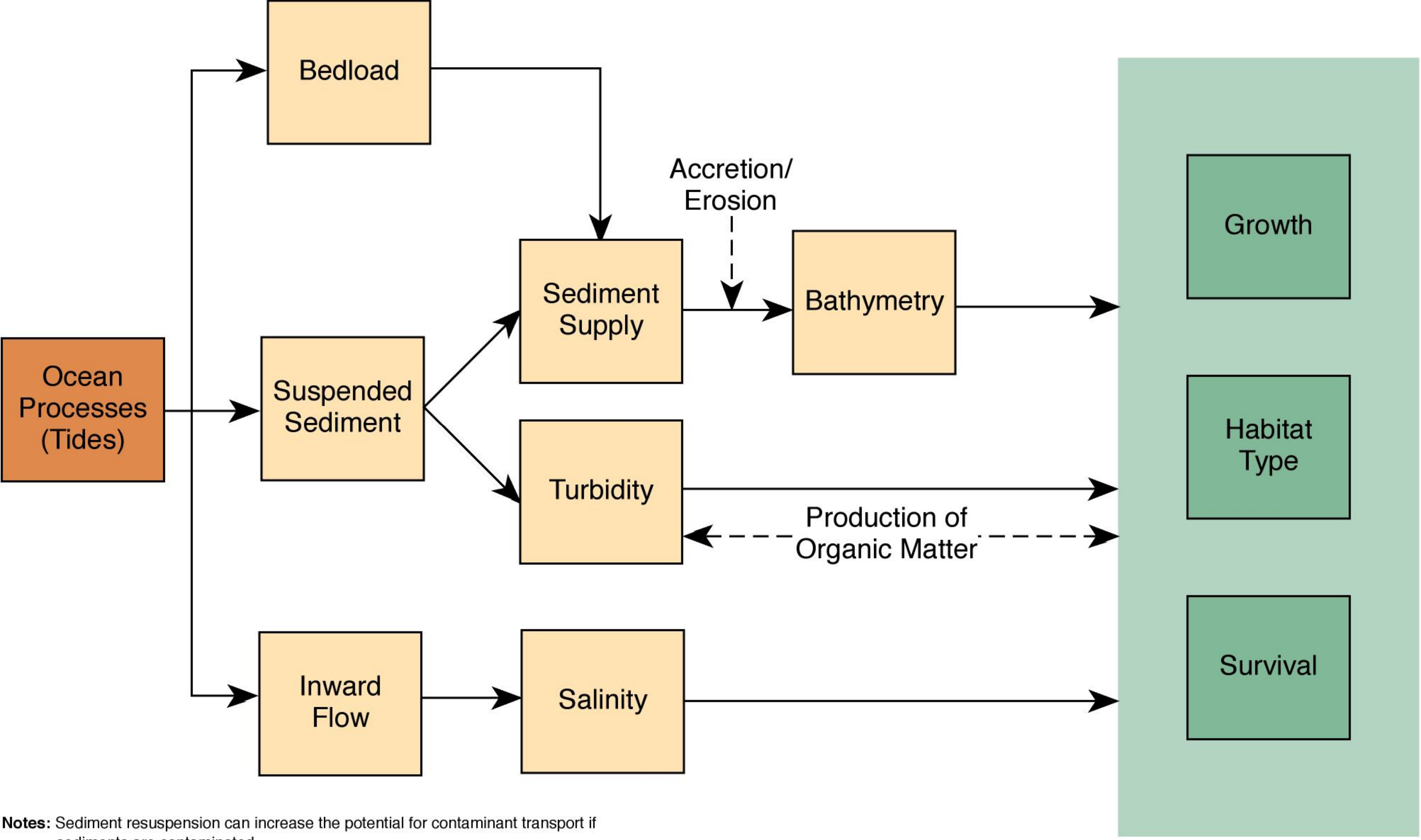
Salmon can be grouped into river type and ocean type. The river type is more dependent on the lower Columbia for migration and water column feeding opportunities, whereas the ocean type spends more time in the estuary and feeds in shallow water habitats. Each type is believed to have several variations in life-history strategies. For ocean-type chinook, this number may be as high as 35 (Wissmar and Simenstad, 1998). The variation among life-history strategies occurs in the timing and relative length of time spent in the estuary. Theoretically, evolution of a diverse set of strategies guards against complete elimination of a species because of large natural variations in the system. Both ocean and river types undergo physiological changes to acclimate to salt water while in the estuary. Each type can be subject to predation as well as contaminants and other stressors. Bottem, et al. (2001) believe that an important point for transition occurs in the oligohaline zone.

Habitat-Forming Processes

The Habitat-Forming Processes Pathways illustrate the factors and interactions involved in the formation and maintenance of lower Columbia River habitats (Figures E-4a and E-4b). The main factors affecting or "explaining" habitat development include salinity and bathymetry (i.e., elevation). Woody debris is a special case of a distinct habitat that enters into the estuary from upstream sources. Turbidity and contaminants also affect habitat quality. Contaminants may affect the quality and quantity of food available for salmonids as well as salmonid health.

Habitats are formed primarily by hydrological processes: flow rates, volumes, and dynamics. In the lower Columbia, the river and the ocean influence the hydrodynamics. River flow rates and volumes are regulated by precipitation, temperature (e.g., freeze and thaw), and dam operations. Ocean processes, including tidal action and waves, interact in the lower Columbia with river hydrodynamics. The net result is deposition (accretion) of sediment to form flats and carving (erosion) to form shallow and deep channels. Where sediments form stable islands, marsh and swamp vegetation can develop. These marshes and swamps are dissected by shallow channels, which provide access for fish to the edges of the vegetated areas. Broad intertidal sand flats and mud flats form where sediments are somewhat unstable and where the elevation is not high enough for marshes to develop.

Large woody debris is also deposited on the flats, in channel edges, and in marshes and swamps. Woody debris creates a vertical structure to which fish often orient, as well as small "micro" habitats that can trap organic matter and be rich in invertebrate animals. The relative role of woody debris as a habitat for salmonids in the Columbia River estuary or any other estuary in the Pacific Northwest is not well studied (Simenstad, pers. comm., 2001). Anecdotal observations show that salmonids will congregate near large woody debris, and feeding may be enhanced because of the deposition of organic matter and the production of small benthic prey animals.



Notes: Sediment resuspension can increase the potential for contaminant transport if sediments are contaminated.
Habitat-forming processes are affected by natural disturbance regimes including: 1) extreme hydrological events, 2) vertical land movement, and 3) storms.

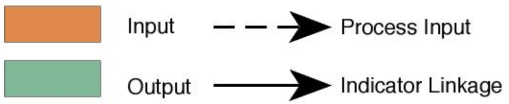
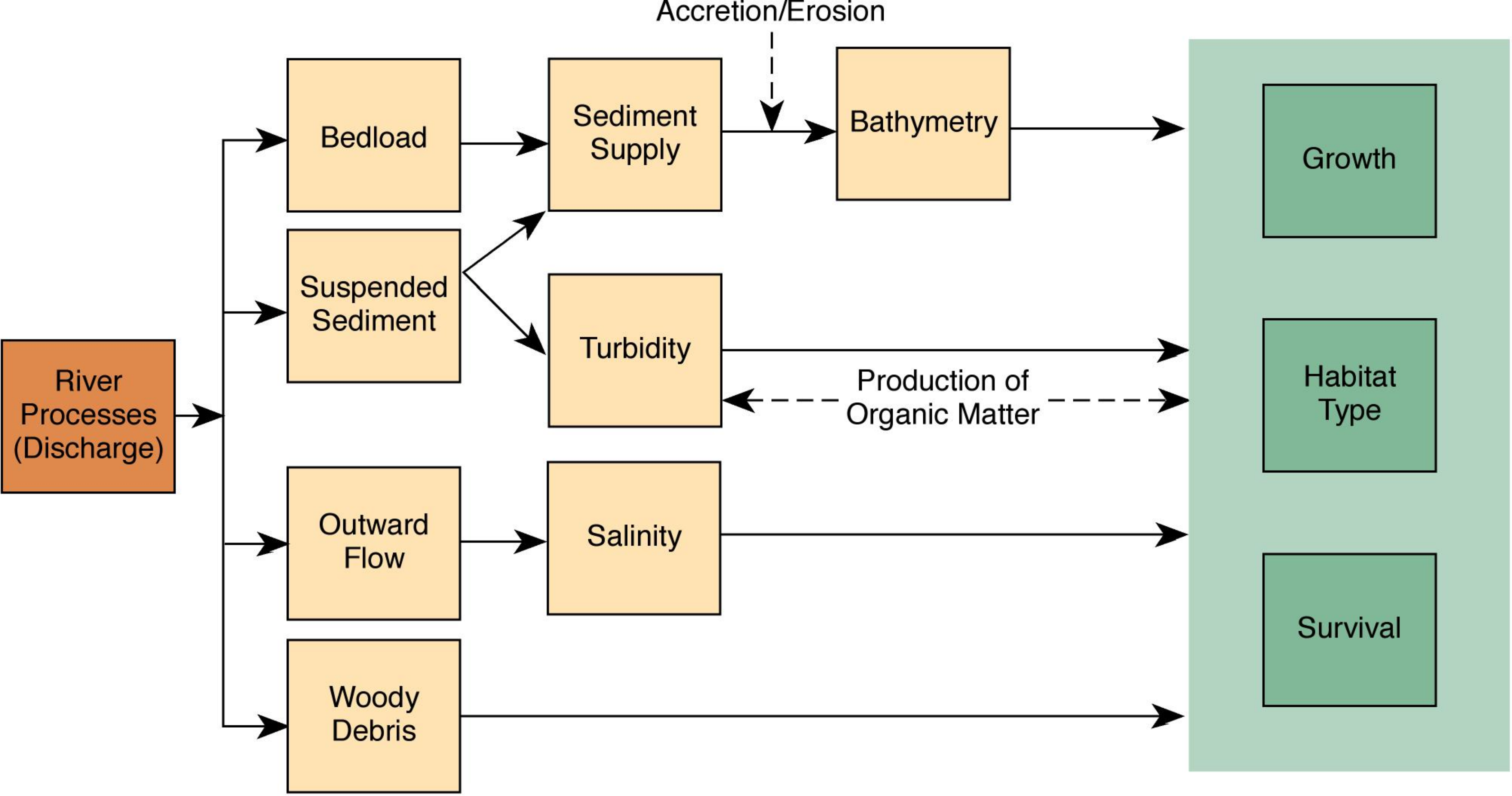


Figure E-4a
Habitat-Forming Process Pathway – Ocean



Notes: Sediment resuspension can increase the potential for contaminant transport if sediments are contaminated.
Habitat-forming processes are affected by natural disturbance regimes including: 1) extreme hydrological events, 2) vertical land movement, and 3) storms.

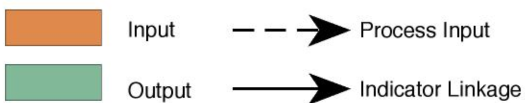


Figure E-4b
Habitat-Forming Process Pathway – River

Because plants and animals prefer certain ranges of salinity, the level, seasonal, and spatial patterns of salinity strongly influence where species occur in the lower Columbia. Mixing of fresh and salt water in the Columbia estuary results in a gradient in salinity in the estuary. The zone of mixing varies dramatically (i.e., tens of miles) in location, depending on river flow and tides. The salt wedge forms a zone of intense mixing, breaks up phytoplankton produced upstream, and results in increased microbial activity and turbidity (Simenstad, et al., 1994).

Salinity ranges that occur in estuaries are grouped into the categories shown in Table E-1. The oligohaline zone (the zone where juvenile salmonids go through a physiological transition to a saltwater environment) is of particular relevance to salmon. Animals may spend a considerable period of time in the oligohaline zone, where they require adequate food supplies and refuge from predators to survive and grow.

Table E-1 Salinity Zones

Zones	Salinity Range (ppt)
Hyperhaline	> 40
Euhaline	30.0 – 40
Mixohaline (brackish):	0.5 – 30
Polyhaline	18.0 – 30
Mesohaline	5.0 – 18
Oligohaline	0.5 – 5
Fresh	< 0.5

Source: Modified from Cowardin, et al., 1979.

The zone of intense biological activity and physical interactions where this mixing occurs is the ETM. As in many estuaries, turbidity from suspended sediment and plankton is moderate to high in the lower Columbia. High river flows and heavy wind and wave activity can increase turbidity dramatically. Because plants need light to grow, turbidity affects how deep plants can grow below the water surface. Higher turbidity means that plants can grow only very near the surface of the water. Rooted aquatic plants such as eelgrass (*Zostera marina*) are generally limited to very shallow depths in the estuary because of turbid water.

As shown in the Habitat Forming Processes Pathways (Figures E-4A and E-4b), all of these dynamics and interactions culminate in the creation of habitat types important to salmon in the lower Columbia. The functions of the types of habitats created are further developed in the Habitat Type Pathway (Figure E-5), and the Habitat Primary Productivity Pathway (Figure E-6).

Habitat Types

The habitats most directly linked to salmonids in the lower Columbia River include the water column, the flats, and the tidal marshes (including swamps). Physical processes active in the river and ocean form these habitats. Because the project area is physically dynamic, the locations and functions of the habitats are adapted for this situation and also exhibit dynamic features.

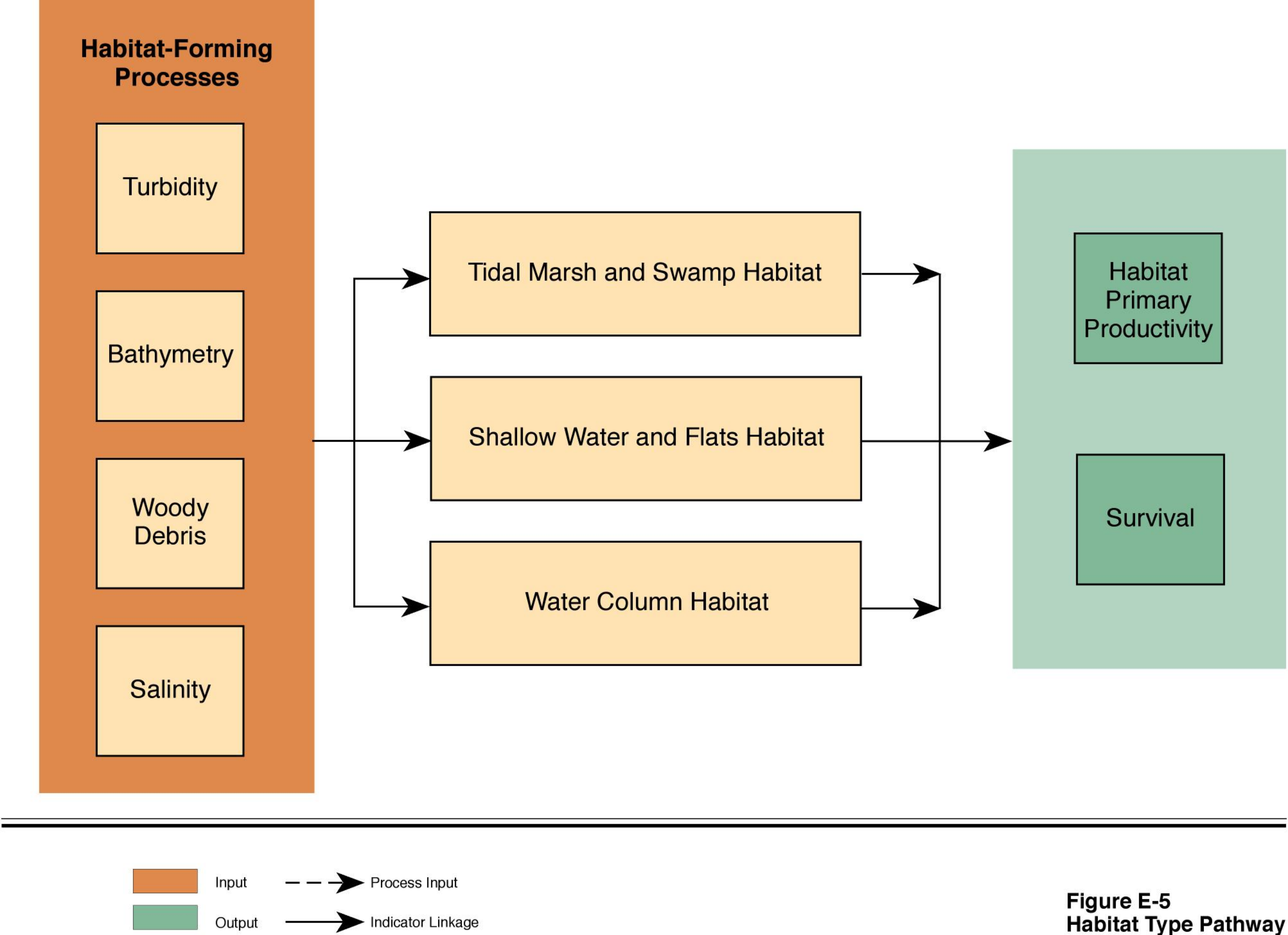


Figure E-5
Habitat Type Pathway

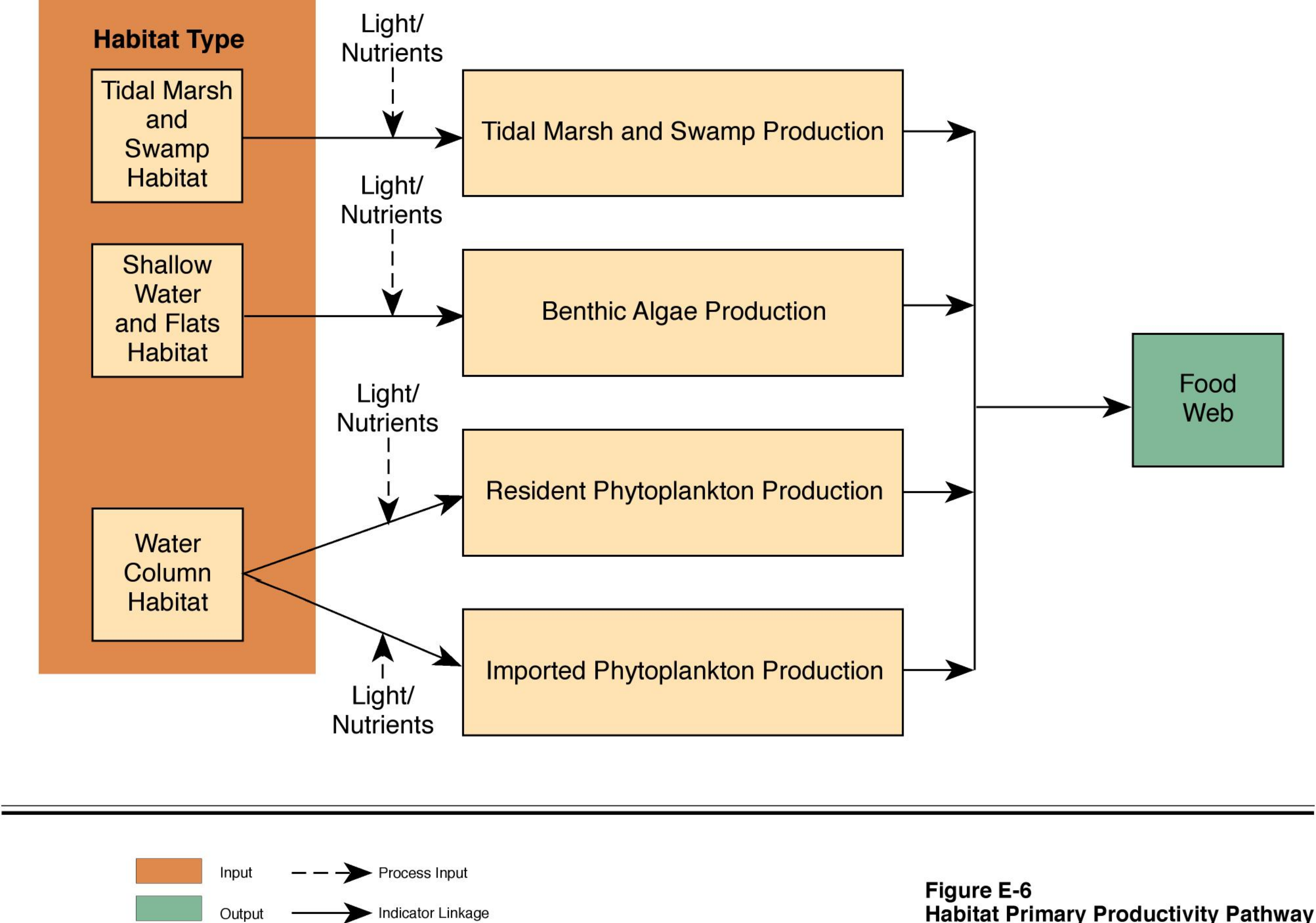


Figure E-6
Habitat Primary Productivity Pathway

Habitat types are generally restricted to specific elevation ranges (Figure E-7). Marshes and swamps occur from about mean high water to above. Flats occur throughout the intertidal zone and into the shallow subtidal zone. Water column vegetation can be stratified by depth. For example, the upper 1 to 3 meters of the water column can have a very different community than deeper zones. This stratification is caused by both the salinity variation and the light penetration by depth. The elevation gradient is driven by tolerances of the plants to withstand immersion as well as drying (desiccation) and light. For example, the depth to which eelgrass can grow is limited by light penetration (Thom, et al., 1998). The upper limit is controlled by plant intolerance to drying during low tides.

At a given elevation, there is an overriding influence of salinity in development of these habitat types. Tidal marshes can be divided into saltwater marshes and freshwater marshes, each characterized by a distinctive vegetation type. There are extensive tidal freshwater marshes in the lower Columbia, in particularly those in Cathlamet Bay. Benthic algae, largely benthic diatoms, develop on tidal flats and in the shallow subtidal zone in the system. The water column habitat is essentially the location of phytoplankton and floatable organic matter. Both phytoplankton and zooplankton respond to changes in salinity. Freshwater plankton dominates the fresh and oligohaline portion of the system, and plankton tolerant of greater salinity dominates the estuary and the mouth of the system.

There is a growing understanding that juvenile salmon use the edges of tidal marshes to feed and the edges of channels as low-tide refuge and feeding areas (Simenstad and Cordell, 2000). Consequently, access to the edges at high tide and development of low-tide refuge areas near or within marshes are important. Channel order (the number and width of channels) and channel depth are a function of marsh area. Although there are no empirical data on this relationship for the Columbia River, smaller marshes would provide limited salmonid access and only limited nearby low-tide refuge areas. Large marshes provide access to a much greater amount of edge and provide low-tide refuge.

A major function of the habitats is to produce food used by the ecosystem. Food production is driven by the growth of plants, which is termed *primary productivity*. Habitat-specific primary productivity is described in the following subsection.

Habitat Primary Productivity

The food consumed by young salmon in the lower Columbia derives its energy from a variety of sources. The detrital food web supported by plant material from marshes, benthic algae, and the water column is particularly important. All of the habitats are described in the Habitat Type Pathway. Plants in these three habitats make up the bulk of the primary production, or plant growth, in the system. They not only produce organic matter within plant tissue but also export dissolved organic matter to the ecosystem (McIntire, 1984).

Primary productivity is driven by light, and the growth of the plants is supported by inorganic nutrients (e.g., nitrate, phosphate). Inorganic nutrients enter the system from the river and the ocean and also from cycling of organic matter in the system. Factors that affect the distribution of the plants within the system include the habitat-forming processes of sedimentation, erosion, salinity, and turbidity (Section 5, Figures 5-2a and 5-2b). As turbidity increases, light in the water column is reduced. This reduction in light can result in less phytoplankton growth as well as limit the depth of submerged plants.

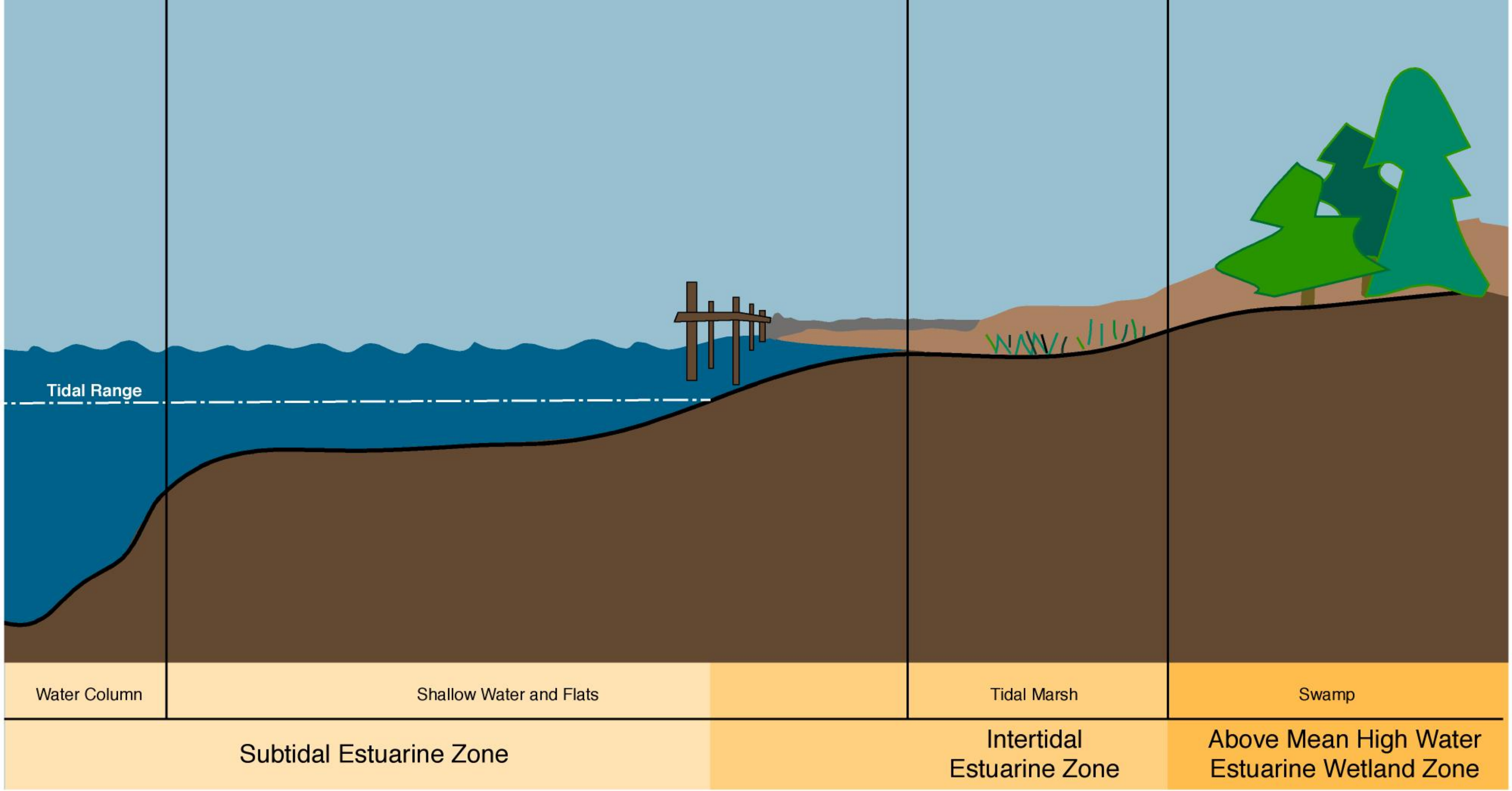


Figure E-7
Major Habitat Types in the System

The plants in the system can be divided into resident and imported. Resident refers to the phytoplankton, benthic algae, and marsh vegetation produced within the lower Columbia River. Imported material, primarily phytoplankton and floating organic matter, enters the system at Bonneville Dam; it is largely produced in the reservoirs upstream of Bonneville Dam. The material produced in the lower Columbia and imported to the system includes material in various stages of disintegration and decay. It has become customary to describe larger particles of organic matter as macrodetritus and very small particles as microdetritus. Small animals that shred the larger plant matter and microbes, such as bacteria, protozoa, and fungi, facilitate the breakdown of the detritus. Besides making the organic matter useful to the food web, the breakdown process results in the recycling of inorganic nutrients needed by the plants.

As illustrated in the Food Web Pathway in the next section (Figure E-8), the live plant material and detritus are the primary sources of organic matter in the food web used by salmonids in the lower Columbia River.

2.3 Food Web

Along with the functions of refuge, rearing, and reproduction, feeding is a key function of estuaries to salmonids. A food web is an illustration of who eats what in an ecosystem. The importance of constructing a food web is to develop a complete understanding of the ways in which a member of the food web obtains its food. The food web can be used to provide insight about what food items might be absent, potentially limiting the growth of members of the food web.

As illustrated in the Food Web Pathway (FigureE-9), juvenile salmonids are members of a complex food web in the lower Columbia. The model represents only the salmonid portion of the total food web for the system, which is far more complex (Weitkamp, 1994). The energy sources at the base of this web as shown at the left side of Figure E-9, are derived from the Habitat Primary Productivity Pathway (Figure E-6). Live plants can be eaten directly or decaying material (detritus) can be incorporated into the food web through the detritivores (animals that eat dead and decaying plants and animals) (Jones, et al., 1990).

Although the Food Web Pathway does not show the relative amounts of food derived from each primary producer type, it does illustrate that salmonids can and do use prey species supported by resident and imported plankton and detritus as well as resident marsh plant material. The relative amount of food depends on the abundance of each resident habitat type (e.g., tidal marshes) and the input of nonresident material from upstream sources. The latter input is controlled primarily by production in the reservoirs behind the dams as well as flow rates from Bonneville Dam.

Invertebrates that salmonids consume occur in the water column and on the river bottom. Among the most abundant species found in the stomachs of salmonids are a benthic amphipod (*Corophium salmonis*) and a planktonic cladocera (crustacean), *Daphnia*. Subyearling chinook feed primarily on the bottom while they are in the lower Columbia, whereas older (yearling) fish of all species feed primarily on zooplankton in the water column.

Floating insects (larvae and adults) appear to be important in the diet of most of the species and age classes. Many of these insects feed on live tidal marsh plants.

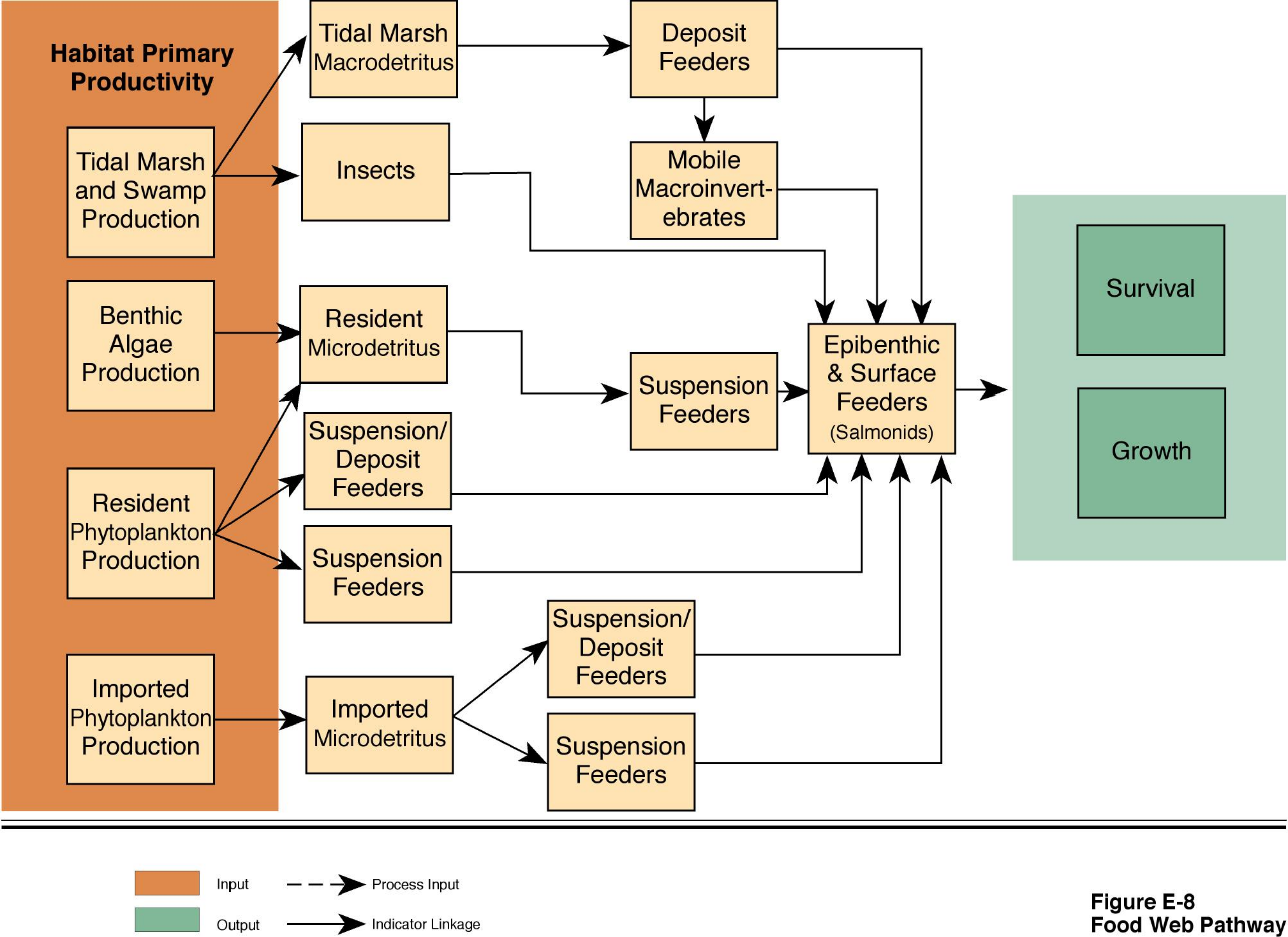


Figure E-8
Food Web Pathway

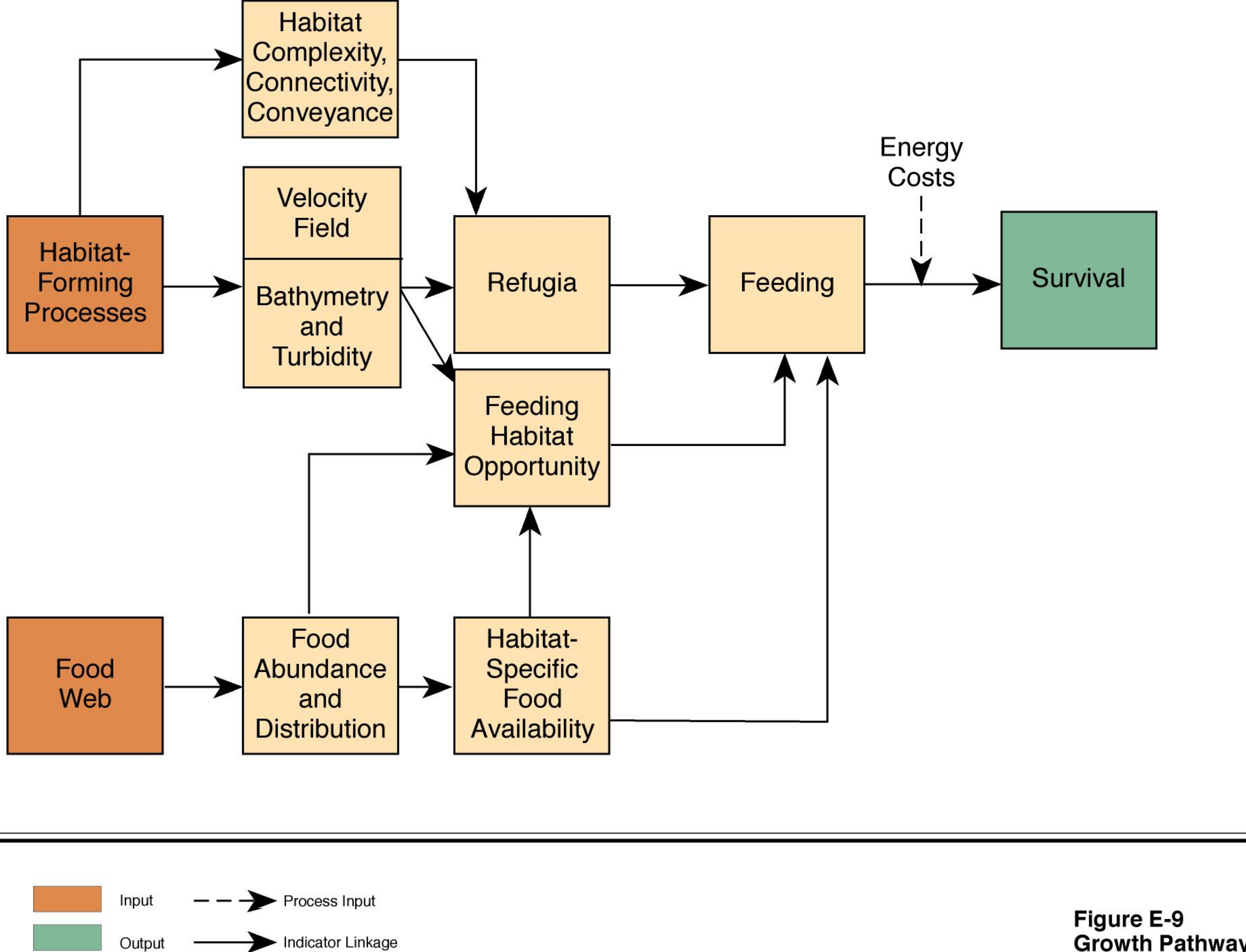


Figure E-9
Growth Pathway

The location of these prey species' production is important. Because outmigrating juvenile salmon are often found in the upper 2 meters of the water column, they probably are not using benthic (bottom-dwelling) prey in deeper parts of the estuary. For this reason, the primary range of feeding depths for salmon feeding on benthic prey is the intertidal zone down to a depth of about 2 meters below Extreme Lower Low Water. Insects, *Corophium*, and mysids located in shallow habitats such as tidal marshes, tidal channels, and flats are more available to salmonids at higher tides. Planktonic prey such as *Daphnia* and copepods are available at any stage of the tide.

Salmonid feeding results in growth of the animals in preparation for their outmigration to the North Pacific. The Growth Pathway (Section 5, Figure 5-10) incorporates feeding as well as other factors that are involved in producing salmonid growth in the lower Columbia.

2.4 Growth

The pathways leading up to the Growth Pathway (Figure E-9) show the progression from physical factors involved in creating habitats in the lower Columbia River through the ways in which these habitats work to produce food for salmonids. The Growth Pathway highlights the factors involved in producing the amount of, and access by fish to, productive feeding areas.

The characteristics of the food web, such as the abundance of insects versus the biomass of nonresident microdetritus, and where this material is distributed are important in the relative contribution of the material to growth of salmonids. The "Food Abundance & Distribution" and "Habitat-Specific Food Availability" boxes in the Growth Pathway (See Figure E-9) illustrate this line of logic. The actual locations and structure of feeding habitats are important because the fish must first be able to access feeding habitat and then be able to find the prey items.

Salmonids are adapted for using a complex mosaic of habitats during their residence in estuarine systems in the Northwest. Therefore, they require the opportunity to feed within the set of habitats, combined with habitat-specific food production. Simenstad and Cordell (2000) identified the following elements as relevant to habitat use opportunities for juvenile salmon:

- Tidal elevation, which is directly related to frequency and duration of tidal flooding
- Extent of geomorphic features, such as total edge and penetration of tidal channels
- Proximity to disturbance
- Actual or perceived refuge from predation
- Strength of cues that might attract salmon

Most fish live primarily in very shallow water, especially the subyearling chinook. They benefit most from prey produced in tidal marshes, in marsh channels, on the edges of deeper channels, and on flats. Fish move up over flats and into tidal marsh systems as the water level rises and falls with the tide and with river flow (Figure E-10). When water level is low, fish are thought to congregate at the edges of deeper channels and pools (low-tide refuges). Longer channels provide deeper penetration of fish into a marsh, and thereby access to more marsh-edge habitat. This mosaic of available habitats is called habitat complexity. An absence or reduction in the natural complexity of habitats available to the fish may have an impact on their ability to reach food resources needed for growth.

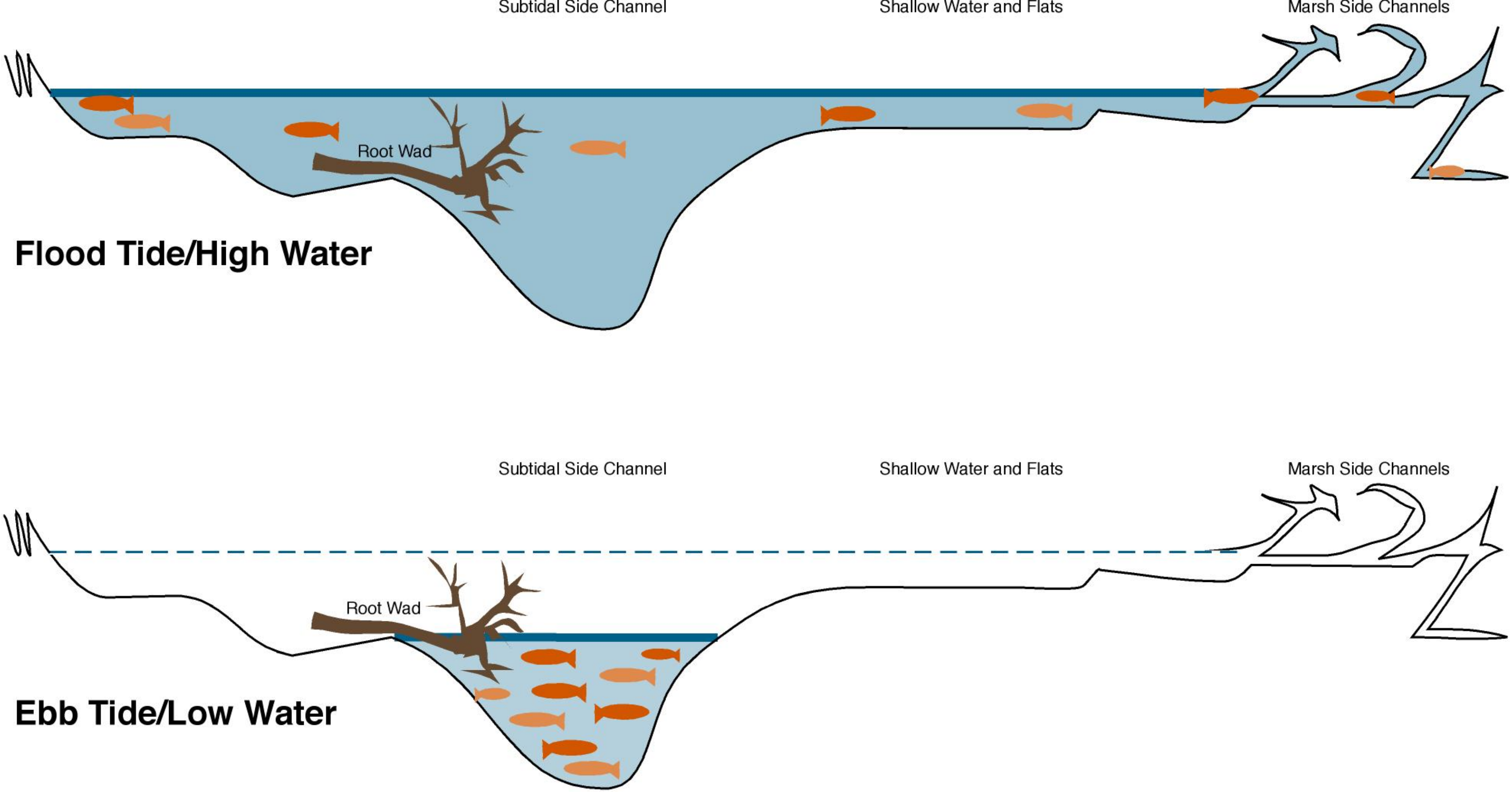


Figure E-10
General Pattern of Lower Columbia River Use by Juvenile Salmonids

Connectivity refers to the connections between habitats in the mosaic. In the lower Columbia, this refers to the connection between viable feeding and refuge habitats along the migratory corridor. Blockages or interruptions of corridors may limit access to productive feeding habitats. For example, a culvert may block fish access to tidal marsh behind a river levee. Large numbers of over water structures may restrict the ability and migration habits of fish traveling along the shoreline. Because fish are adapted for use of a wide but linked set of habitats, maintenance of free access among habitat types is an important component of feeding habitat opportunity. This concept is illustrated in the Growth Pathway (See Figure E-9).

Still, shallow areas provide productive feeding areas for salmonids. Because juveniles are small and have relatively weak swimming capabilities, feeding is most effective in areas where current velocities are slow. Although not well understood or studied, velocities of 30 cm/s or less are considered best for optimal foraging opportunity (Bottom, et al., 2000). Because salmonids are visual predators, turbid waters may limit their ability to see prey. Again, little is understood about this phenomenon in the context of Northwest estuarine systems. Velocity field, shallow bathymetry, and turbidity are illustrated in boxes at the left of the Growth Pathway (See Figure E-9).

Finally, each individual animal expends energy to feed. These energy costs include those associated with locating prey, feeding behavior, avoiding predators, and processing energy from the prey consumed. In general, fish prefer high-energy food, which provides the most energy per unit of effort. Anything less will, theoretically, produce suboptimal growth rates.

Besides growth, a variety of interacting factors affect the ultimate survival of salmonids in the lower Columbia River. The Survival Pathway (Figure E-11) describes what is understood about these factors.

2.5 Survival

Salmonid survival depends on an ability to grow and migrate through the lower Columbia River system (see Figure E-11). As shown in the previous pathways, a complex set of factors controls or affects growth and migration. The Survival Pathway is a summary of these key factors.

Factors that can negatively affect survival include contaminants, predation, suspended solids, temperature and salinity extremes, stranding, and competition. In addition, fish may be entrained during dredging operations.

Contaminants include those chemicals that affect the health of fish. They can be taken up directly through the water column and indirectly through contaminated prey throughout the food web. The prey of juvenile salmon may obtain contaminants via their food sources. For example, contaminants deposited on the bottom along with organic matter may be ingested by deposit-feeding animals, which are in turn ingested by salmon. Contaminants can affect the health (physiological integrity) of fish, with a net effect of impaired health from disease as well as a reduced ability to physiologically adapt to salt water, avoid predators, forage effectively, and seek and find shelter.

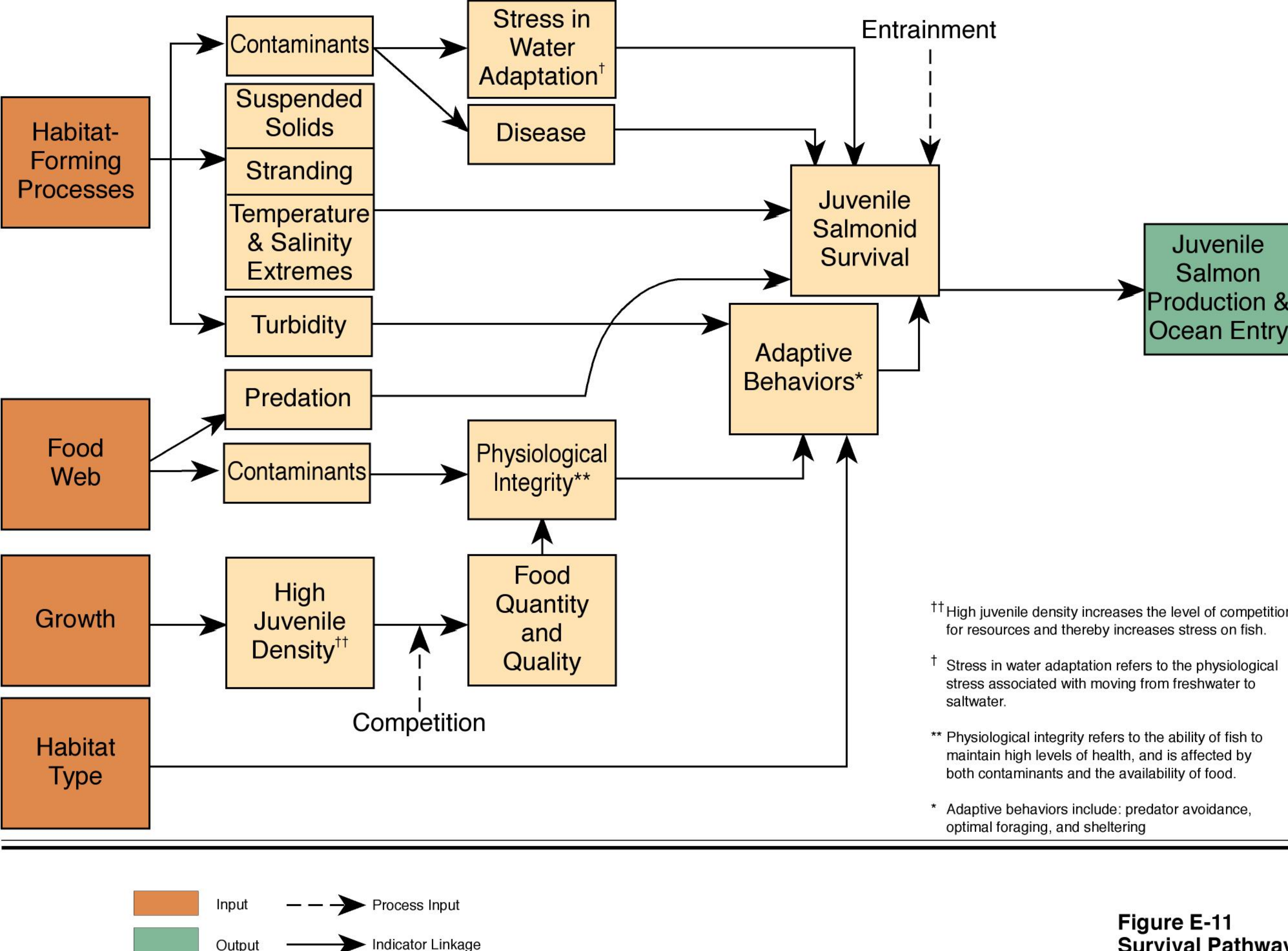


Figure E-11
Survival Pathway

Predation is a major factor affecting fish survival in the lower Columbia River. Birds, such as western grebes, cormorants, gulls, terns, and great blue herons, are known to prey on small fish, which may include young salmon. Surprisingly, few fish that prey on juvenile salmon have been verified by actual examination of the gut contents of the suspected predators. In a review of existing information, Simenstad, et al. (1999) found a relatively long list of potential predators, but only two species (Pacific staghorn sculpin and Cutthroat trout) were verified as preying on juvenile salmon.

Suspended solids, which can be a major contributor to turbidity, affect migratory ability by reducing the fish's ability to see prey. Data indicate that the threshold concentration for survival of ocean type salmonids is on the order of 1 gram per liter (Weitkamp, 2001).

Both abnormally high temperatures and high salinity will stress fish. These conditions can occur during extreme low flow conditions in summer, with shallow flats and channels being the zones of most intense heating.

Stranding can occur when fish are washed up onto higher ground by waves or boat wakes, or if they are caught for extended periods of time in a shallow pool during an extended low tide. Observations by fisheries biologists in the system indicate that some stranding does occur.

Competition among members of the outmigrating population may play a role in survival; however, little is understood or documented regarding the effects of competition in a system such as the lower Columbia.

Entrainment refers to the uptake of fish by the dredge during dredging. Because dredging takes place primarily at the deepest portions of the channel, bottom-dwelling fish are more susceptible to entrainment. Surface-oriented fish such as salmonids may be less susceptible.

Adaptive behavior improves the probability that fish will survive. The adaptive behaviors of predator avoidance, optimal feeding (foraging) in the system, and ability to find refuge are all enhanced if fish are healthy. As described earlier, fish health depends on the physiological integrity of the fish as well as the availability and quality of habitats.

3 SUMMARY DISCUSSION

The conceptual model represents the current understanding of the lower Columbia River ecosystem relative to juvenile salmon. It has aided in the identification of links among the physical and biological structures and processes in the estuary. The model indicates that flow, depth, salinity, temperature, and sediment appear to be driving the structure and function of the estuary ecosystem in terms of supporting the essential needs of juvenile salmon for survival, growth, saltwater adaptation, and passage.

The actual organization of the model changed several times during its development as a result of both corrections and refinement. The need to make the model understandable to as many people as possible, without sacrificing technical accuracy, was also important; consequently, much of the process involved simplifying the model. For example, the food web developed by Weitkamp (1994) was simplified considerably to include only the major taxa directly linked to juvenile salmon. An additional effort was made to link the Pathways to one another to ensure that anticipated changes in physical conditions could be followed through the entire model to their links with biological components.

The model highlights those connections most relevant to assessing the effects of navigation channel improvements on juvenile salmon. Once these effects have been identified, more in-depth analysis can be undertaken, which may include the development of a numerical model. For example, because possible changes in salinity were of concern, numerical modeling was used to evaluate the effects that a deeper channel could have on salinity intrusion (Weitkamp, 2001; Reed, et al, 1994). The modeling results were then used as input to the conceptual model in order to assess the impacts that changing the locations of feeding and physiological transition would have on salmonids.

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APPENDIX F

Oregon Health & Sciences University Modeling Results

Appendix F

APPENDIX G

Waterways Experiment Station Modeling Results

The U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory (CHL) completed a salinity intrusion analysis regarding the Project in 1996 (Corps, 1999a). As a result of the SEI panel comments, a limited additional analysis was performed to assess the potential impacts at 70,000 cfs, a very low river discharge. Issues included in the analysis were deepening impacts on salinity, velocity, and depth as revealed in the existing CHL numerical model (ECHL) of the Columbia River Estuary.

Model development and verification for the ECHL model of the Columbia River Estuary are explained in the Corps' FEIS (Corps, 1999a). The same model was used to compute results for the 70,000-cfs inflow case requested by the SEI panel. The results for project impacts to salinity intrusion, current velocities, and water surface elevations are presented in this appendix in Figures 1-20.

Based on the WES RMA-10 modeling, the 70,000 cfs low flow condition resulted in the largest impacts on salinity intrusion. As with the analysis for 120,000 cfs and 134,000 cfs (USACE, 1999a), the salinity concentration increases were predicted to be larger at the bottom of the water column than at the surface. For this base versus plan comparison, the model predicts that deepening the channel would increase surface salinity in the estuary by a maximum of 0.15 ppt (Figure 2). In particular, the 0.1-0.15 ppt range of increase shows up in shallow areas of Cathlamet Bay and Grays Bay (figure 10). Bottom salinity increases in the range of 1.0-1.5 ppt are predicted to occur at the bottom of the navigation channel in the vicinity of Tongue Point and back through the Miller Sands channel (Figure 3). Bottom salinity concentrations increases of 0.3 to 0.4 ppt are predicted in the deeper channels of Cathlamet Bay, near Tongue Point (Figure 12).

The WES model indicates that the impact of channel deepening on surface water elevation is minimal. Differences between base and plan are estimated to range between –0.02 feet and 0.02 feet for all locations between the mouth and the upper estuary (Figure 4).

Velocity changes predicted as a result of the deepening are also very small, with the most change generally occur along the navigation channel (Figures 6 and 8). Velocity changes in the shallow water areas of Cathlamet and Grays Bays are predicted to be near zero (Figure 17).

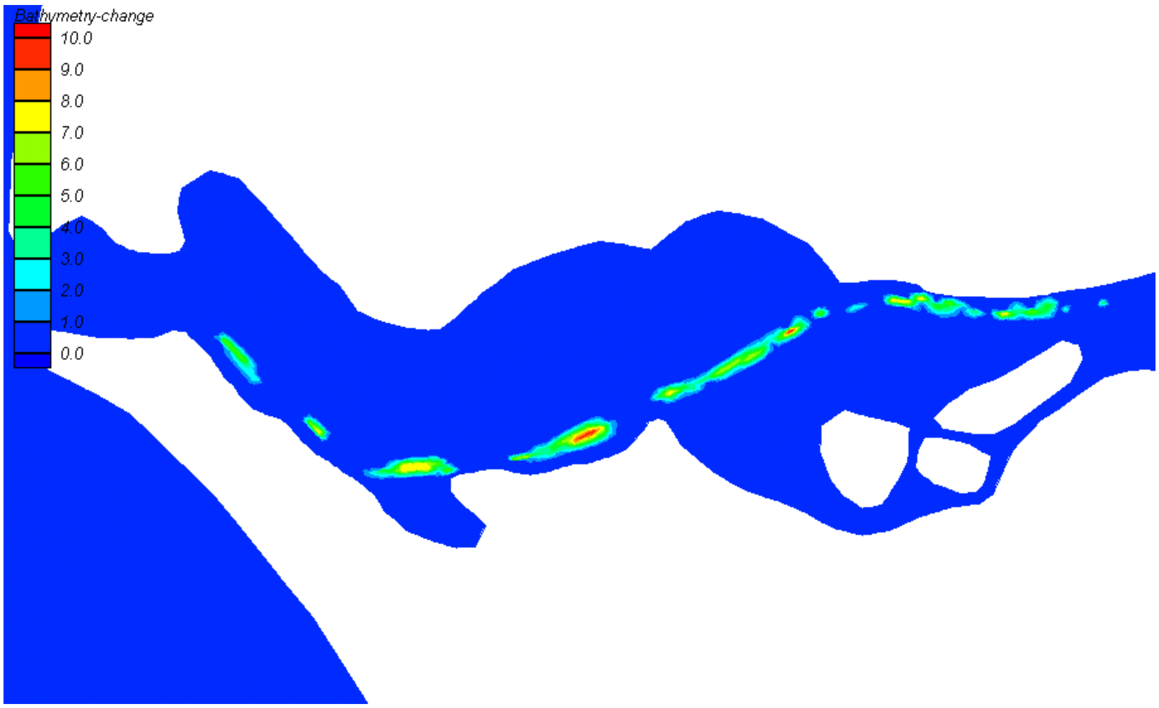

Figure 1. Bathymetric differences between plan and base. (10 ft changes indicated are at channel edges only.)

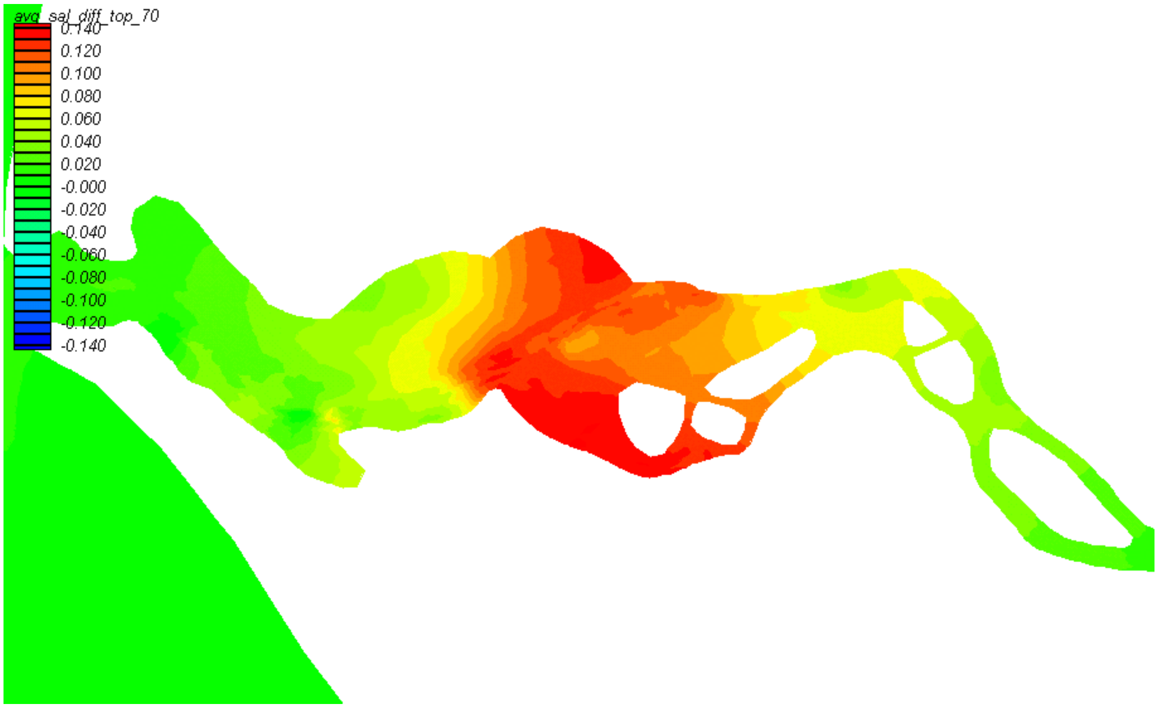

Figure 2. Average surface salinity differences. 70k flow.

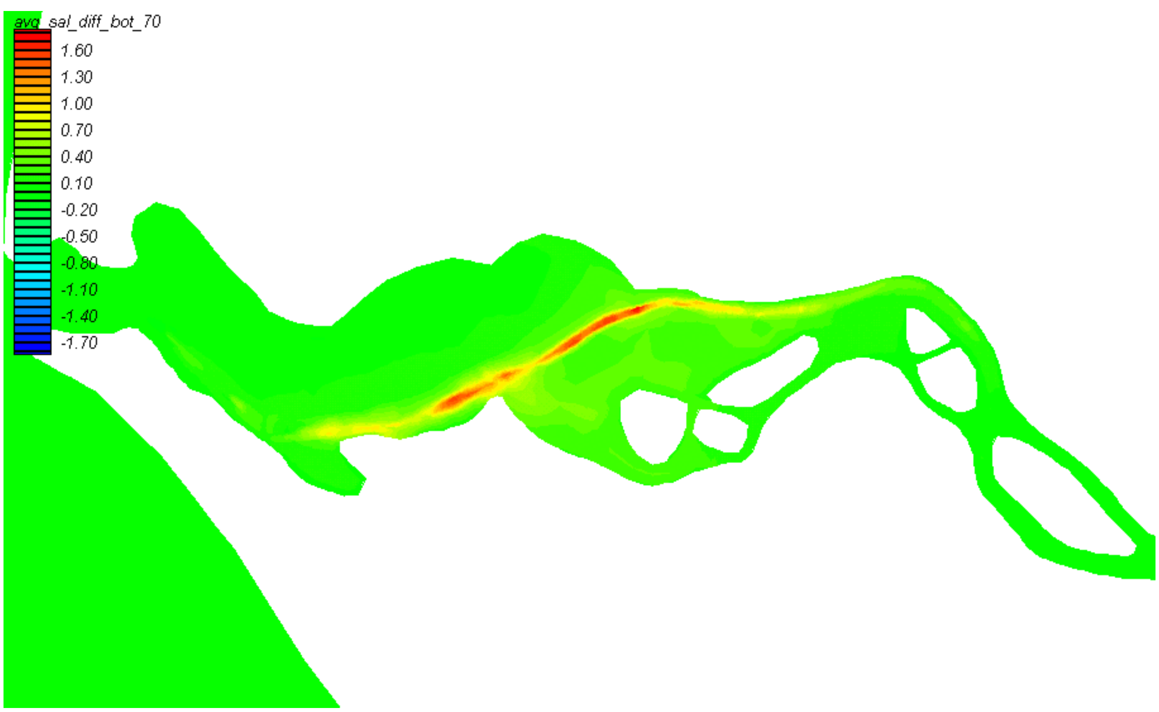

Figure 3. Average bottom salinity differences. 70k flow.

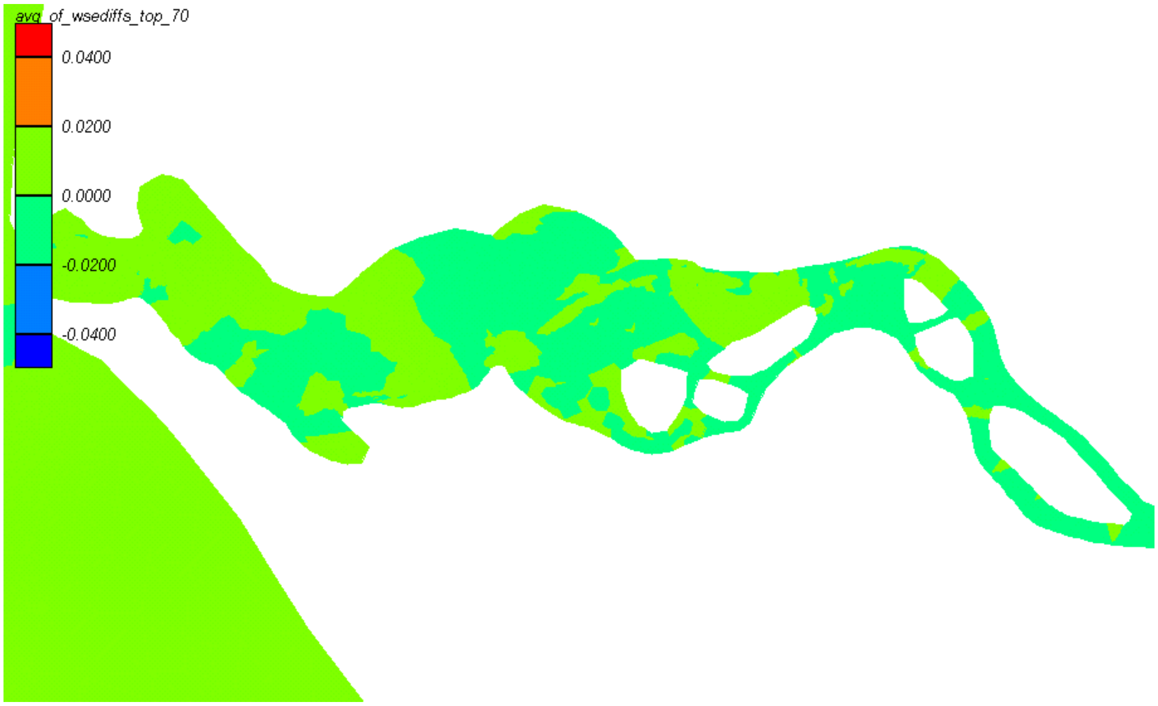

Figure 4. Average water surface elevation difference (ft). 70k flow.

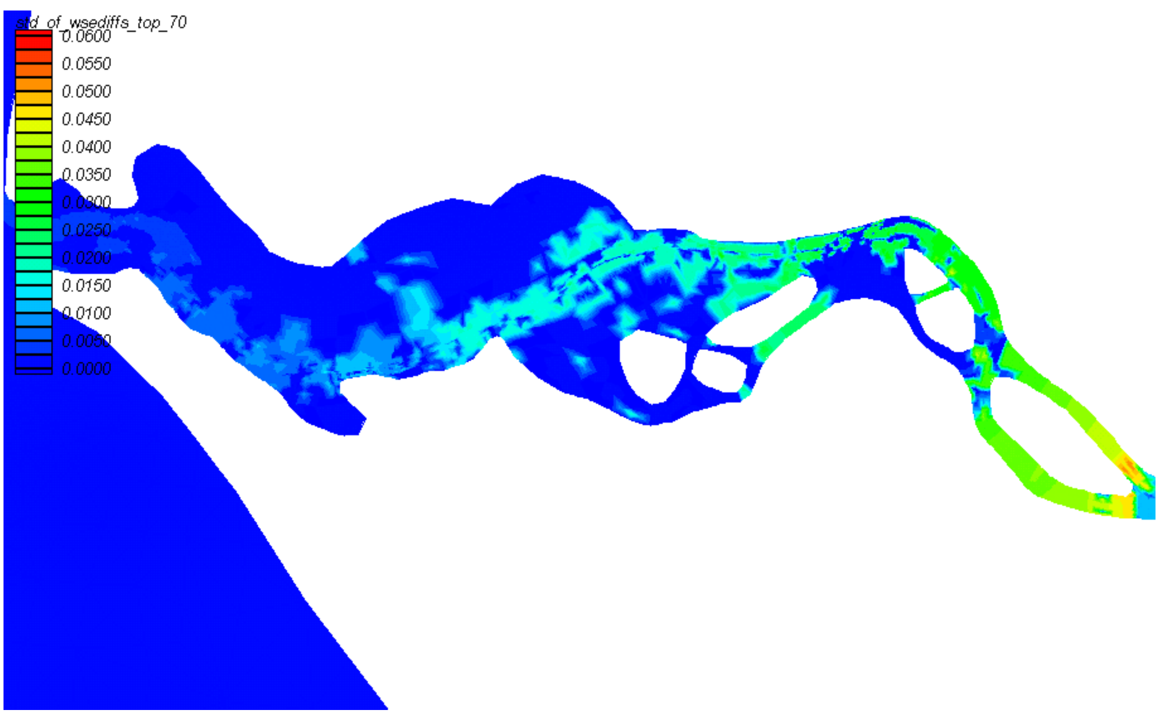

Figure 5. Standard deviation of water surface elevation differences (ft). 70k flow

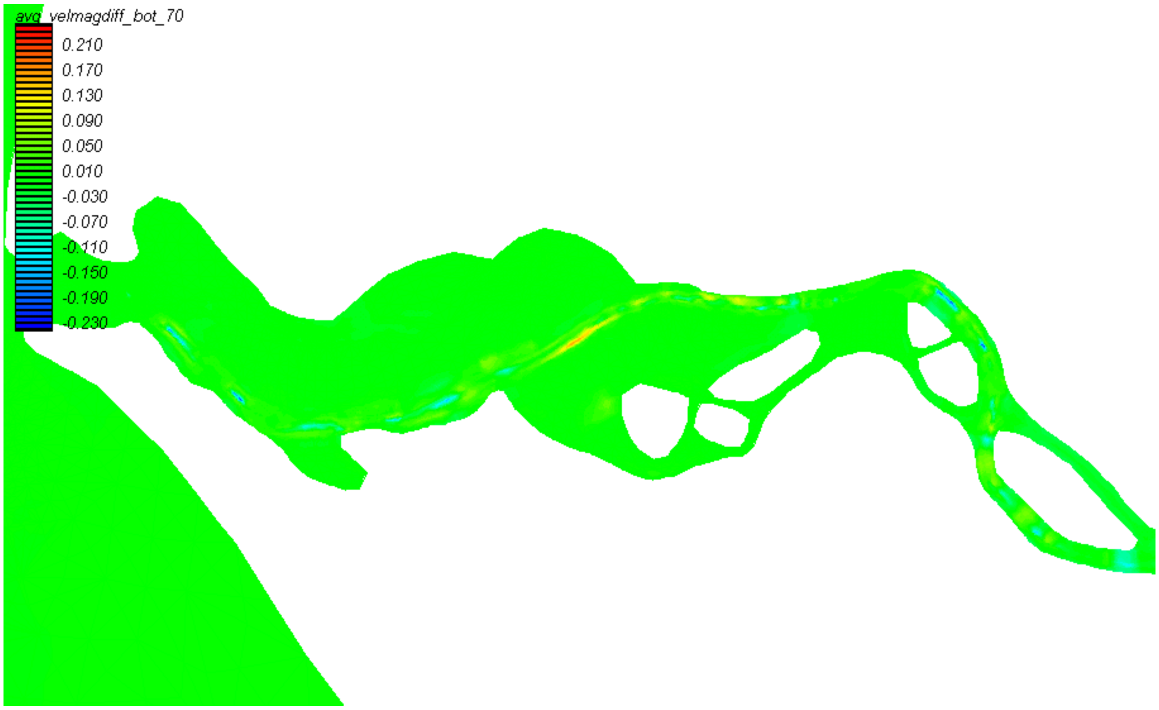

Figure 6. Average bottom velocity magnitude difference (ft/sec). 70k flow.

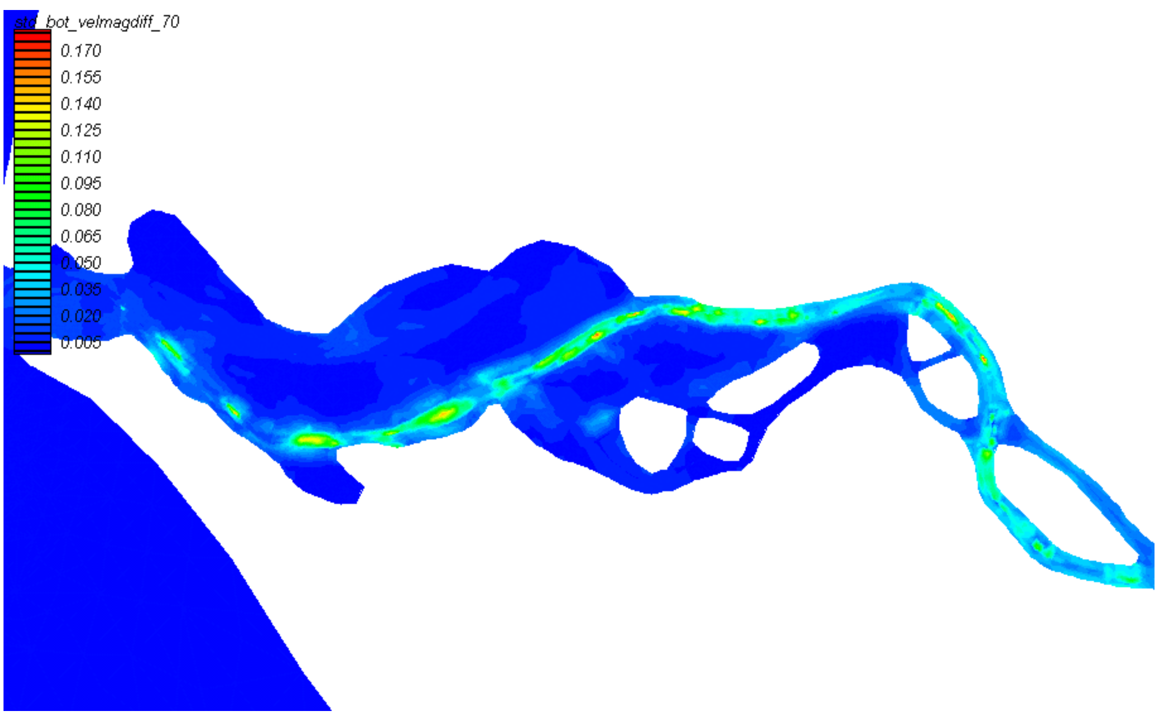

Figure 7. Standard deviation of bottom velocity magnitude difference (ft/sec). 70k flow

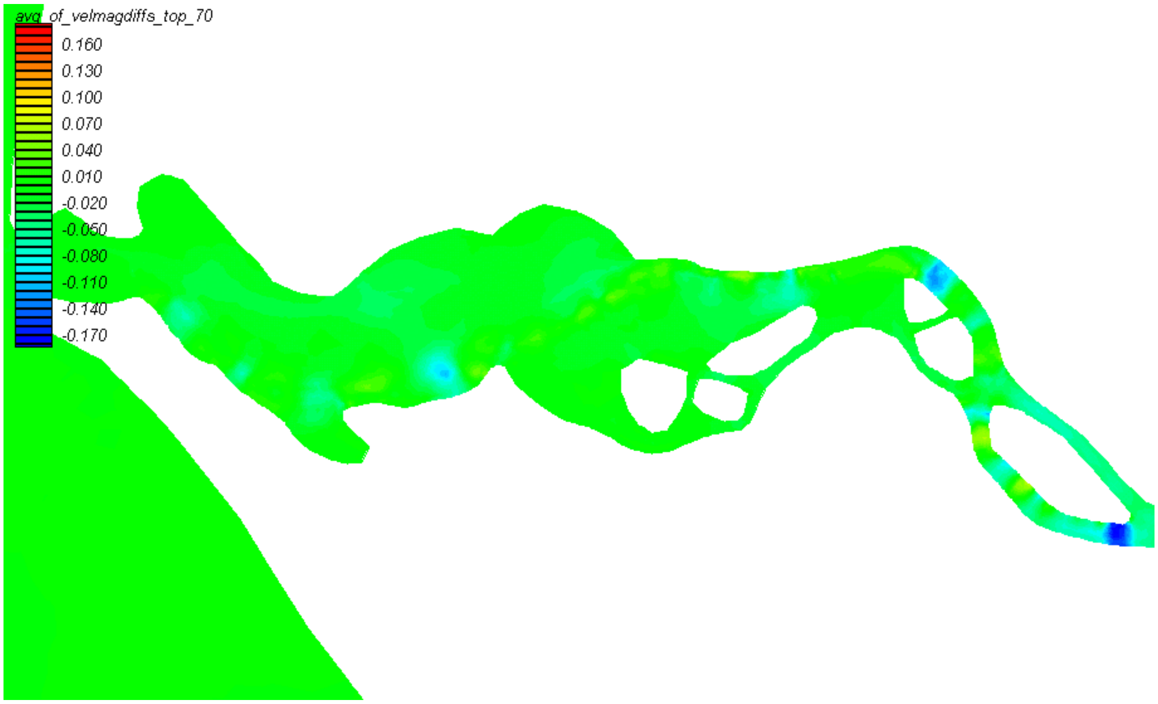

Figure 8. Average surface velocity magnitude differences (ft/sec). 70k flow.

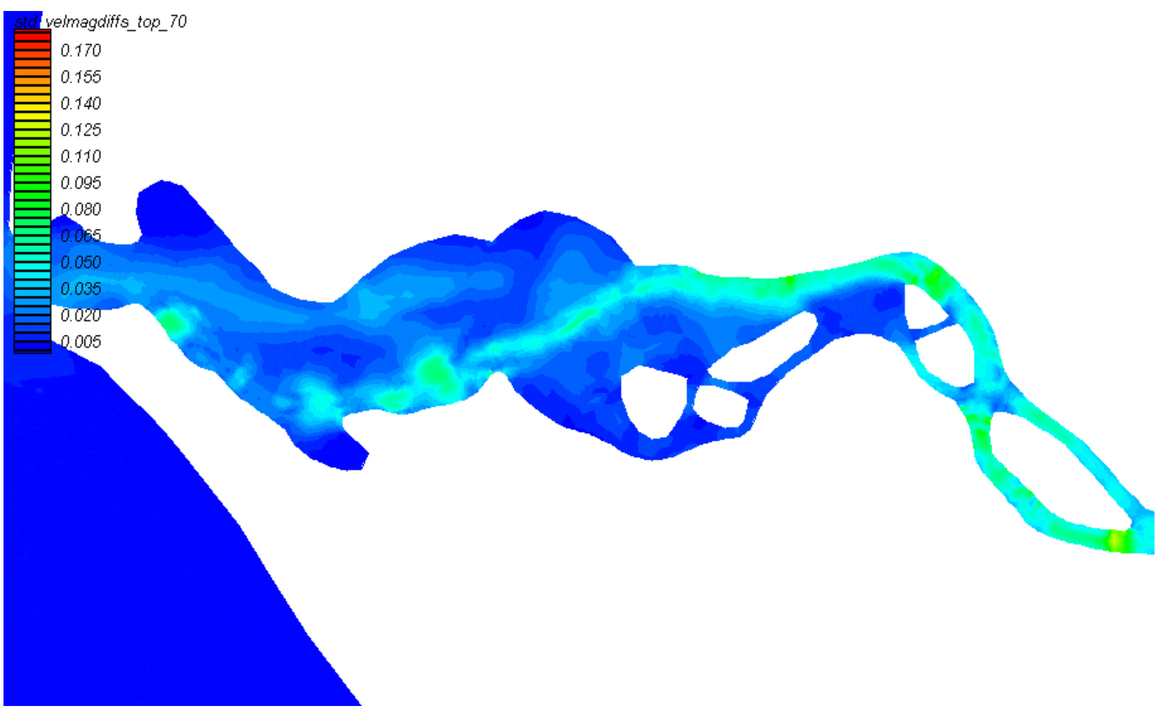

Figure 9. Standard deviation of surface velocity magnitude differences (ft/sec). 70k flow.

Figure 10. Cathlamet Bay average surface salinity differences. 70k flow.

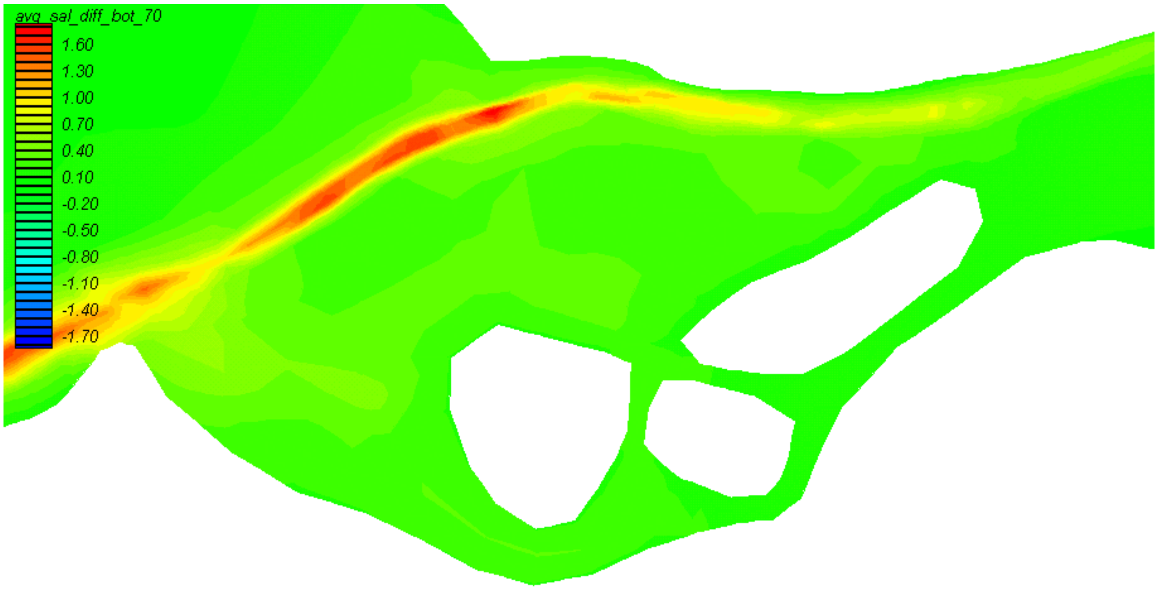

Figure 11. Cathlamet Bay average bottom salinity differences. 70k flow.

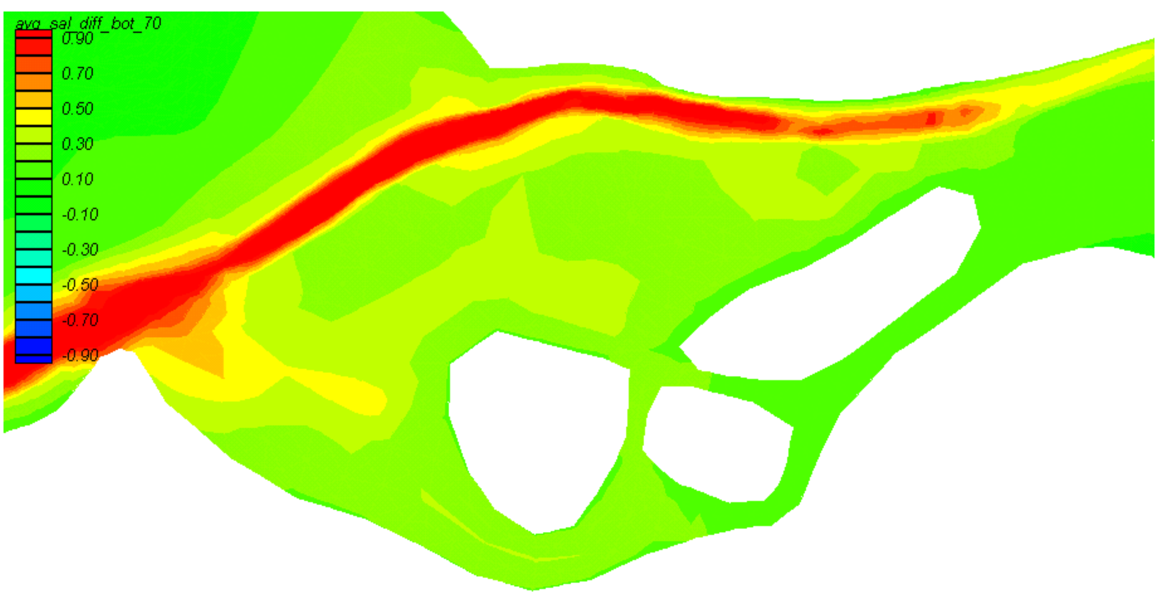

Figure 12. Cathlamet Bay average bottom salinity differences. 70k flow. Finer scale.

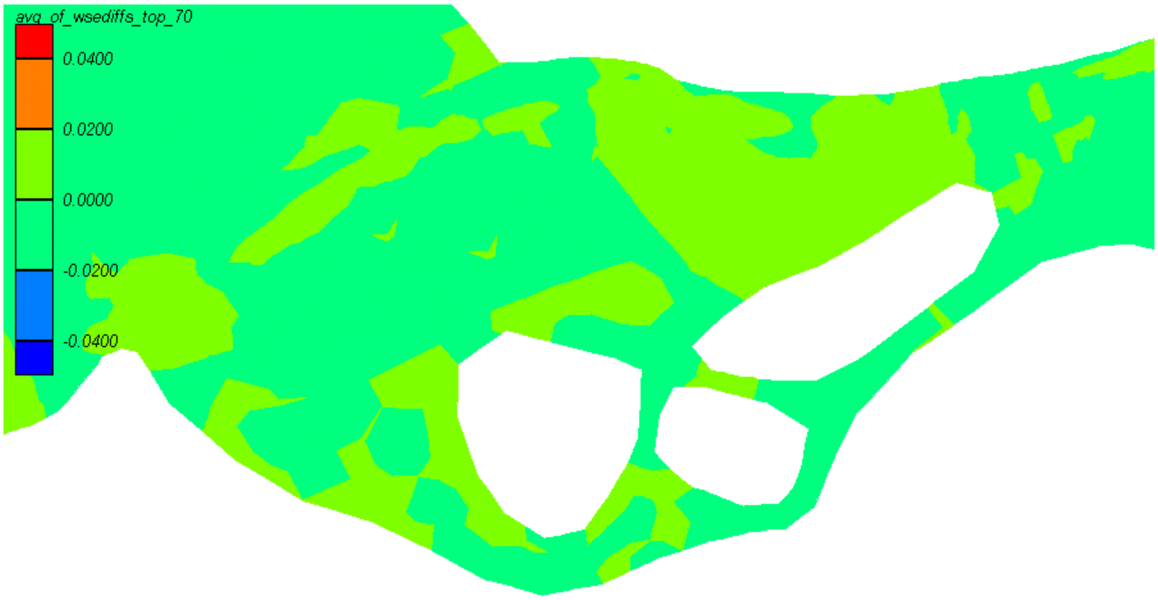

Figure 13. Cathlamet Bay average water surface elevation difference (ft). 70k flow.

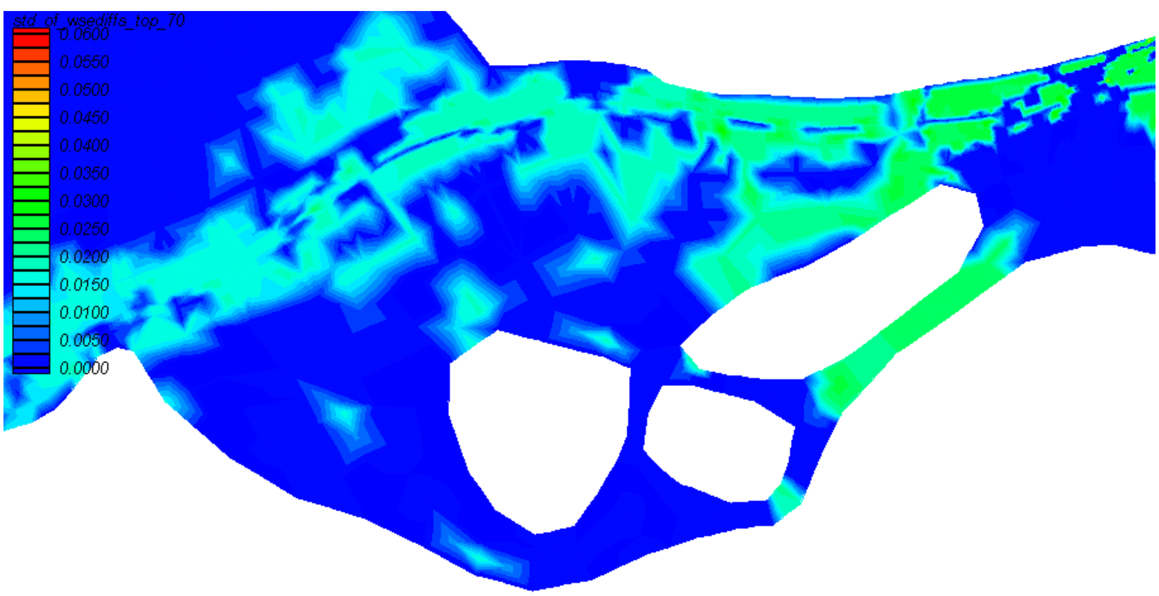

Figure 14. Cathlamet Bay standard deviation of water surface elevation differences (ft). 70k flow.

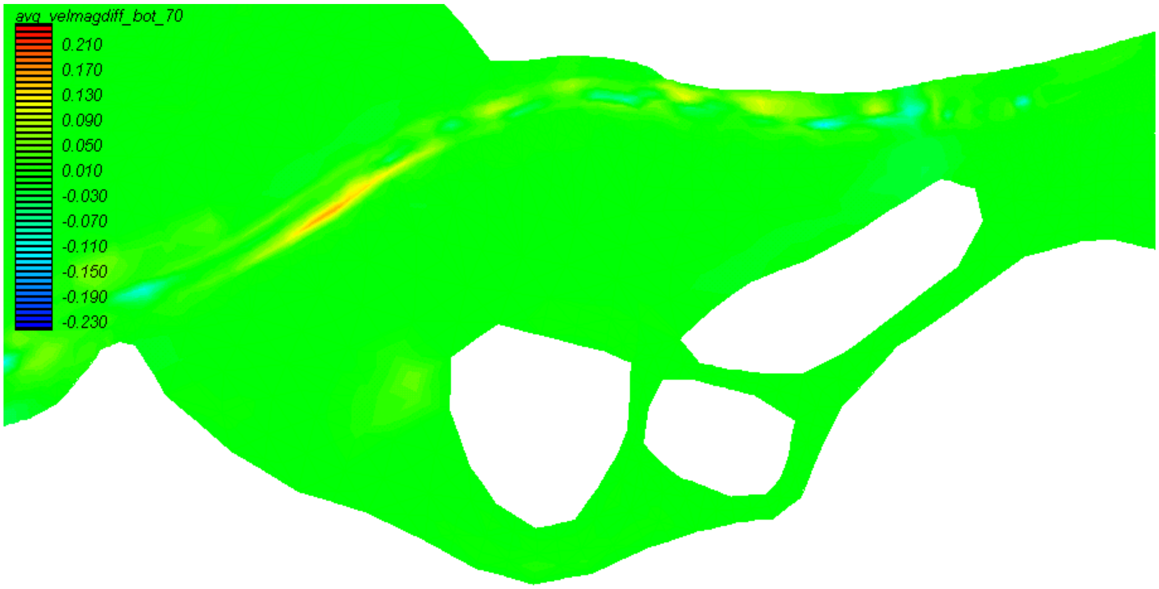

Figure 15. Cathlamet Bay bottom velocity magnitude difference (ft/sec). 70k flow.

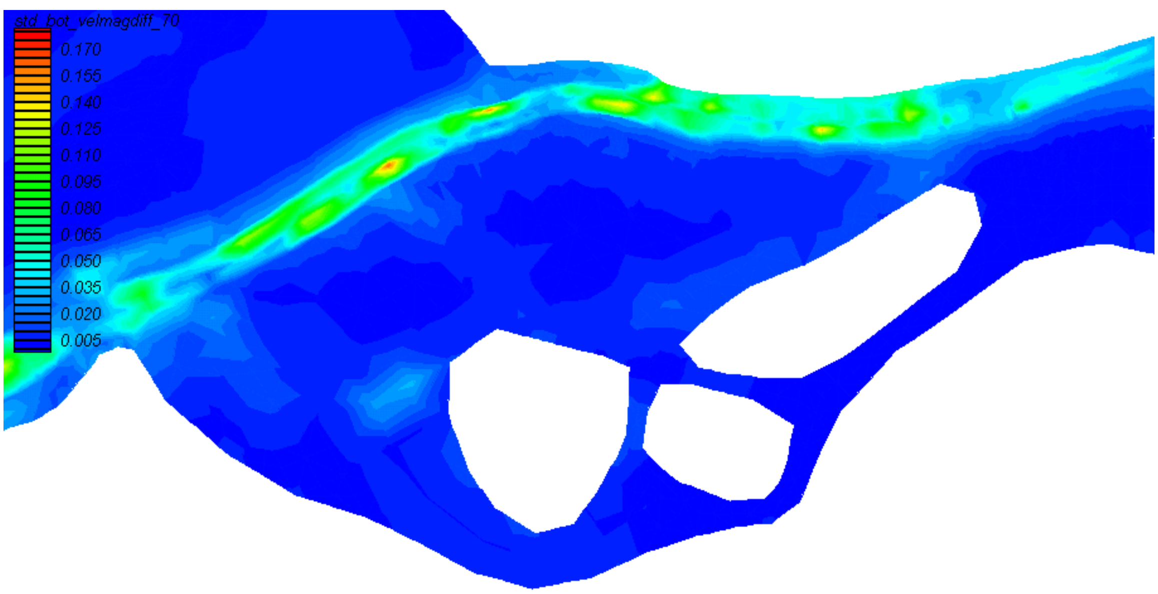

Figure 16. Cathlamet Bay standard deviation of bottom velocity magnitude difference (ft/sec). 70k flow.

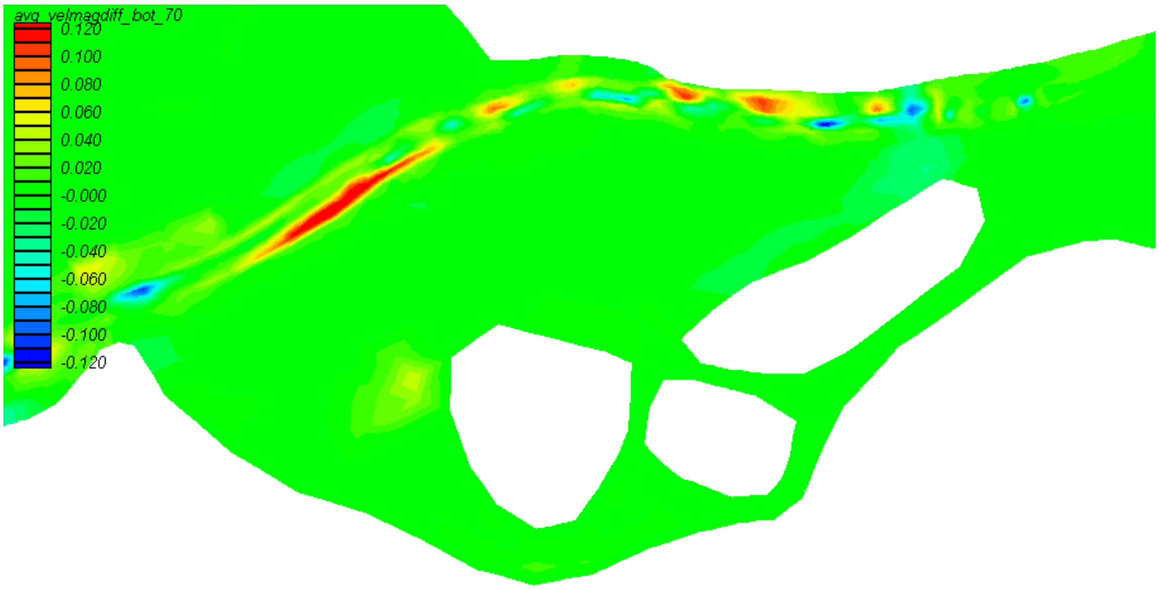

Figure 17. Cathlamet average bottom velocity magnitude difference (ft/sec). 70k flow. Finer scale.

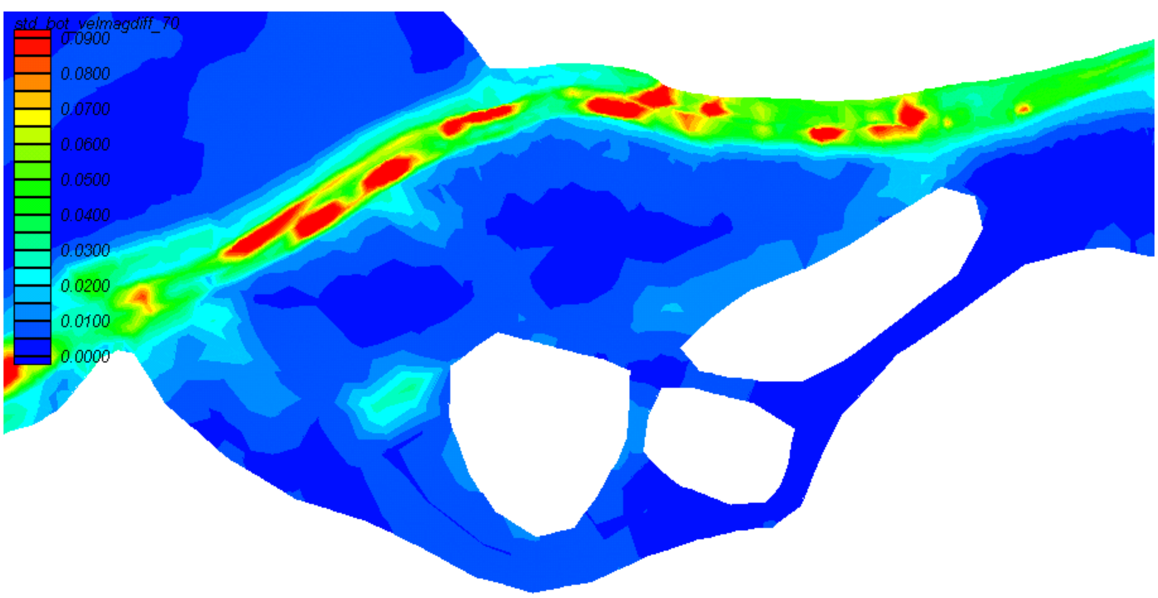

Figure 18. Cathlamet Bay standard deviation of bottom velocity magnitude differences (ft/sec). 70k flow. Finer scale.

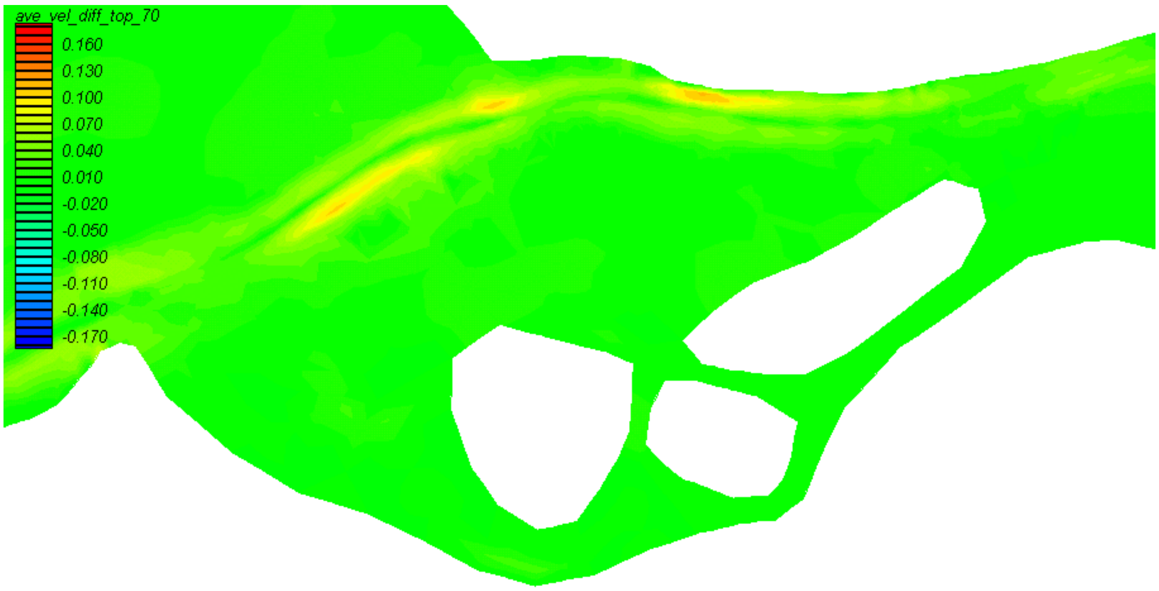

Figure 19. Cathlamet Bay average surface velocity magnitude differences (ft/sec). 70k flow.

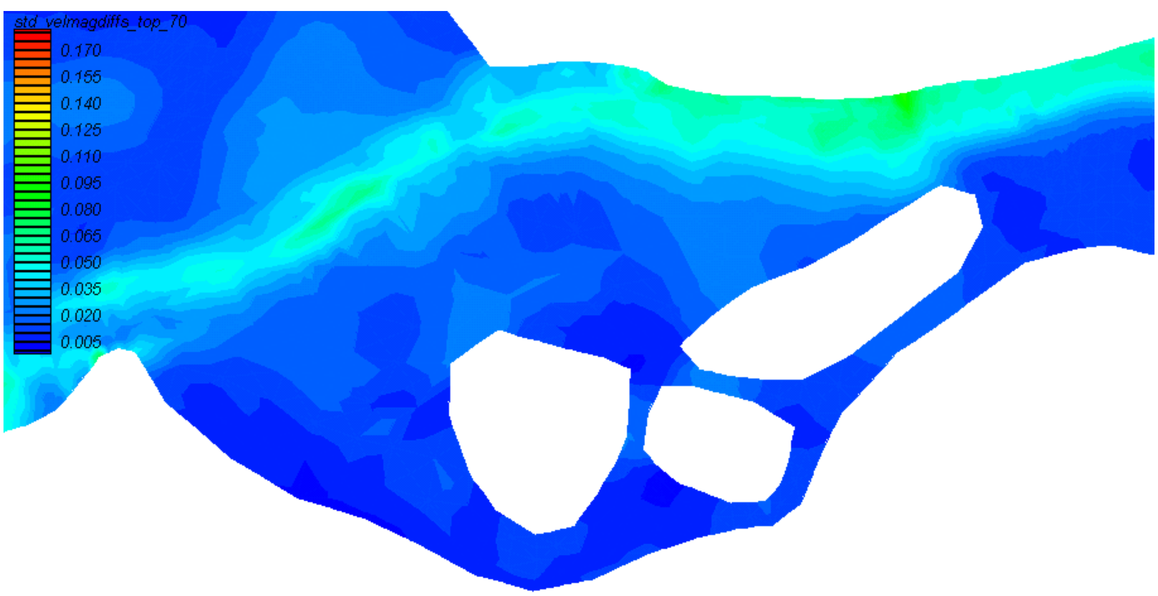

Figure 20. Cathlamet Bay standard deviation of surface velocity magnitude differences (ft/sec). 70k flow.

APPENDIX H

TOWARDS THE UNDERSTANDING OF CHANNEL DEEPENING IMPACTS

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1 CONTEXT AND OBJECTIVES

This investigation was conducted in the context of the Columbia River Channel Improvement Reconsultation Project, by the joint request of the U.S. Army Corps of Engineers (contracting agency), National Marine Fisheries Service, U.S. Fish and Wildlife Service, and Port of Portland.

The investigation sought to address, in a limited period of time, the following questions:

> Q1: Is there evidence to reasonably challenge the conclusion of the Waterways Experiment Station that the impact of channel deepening on salinity intrusion is small?
>
> Q2: Is there evidence to anticipate that channel deepening will significantly impact estuarine habitat opportunity?
>
> Q3: Is there evidence to anticipate that water temperature will be increased by channel deepening during Summer months?

The supporting technology consists of best available CORIE ([1], [2]) models and sensors. The use of CORIE technology is done with understanding of all parties that:

- Use is parallel to on-going code and model refinements.
- Use precedes a rigorous one-year "estuary modeling certification" research project for CORIE (now on-going, with separate funding).
- Some sub-optimal modeling choices are required to meet the time constraints of the reconsultation.

The investigation was conducted in coordination with the project managers of the four agencies listed above. Most of the results contained herein were presented and discussed in one of the following forums:

Aug. 15, 2001:	Project managers meeting
Aug. 28, 2001:	Public workshop, organized by the Sustainable Ecosystems Institute as an element of the Columbia River Channel Improvement Reconsultation Project
Sep. 27, 2001:	Project managers meeting

2 FINDINGS

Q1: Is there evidence to reasonably challenge the conclusion of the Waterways Experiment Station that the impact of channel deepening on salinity intrusion is small?

We found no evidence to challenge the conclusion that the impact of channel deepening on salinity intrusion in the estuary will be characterized by generally small numerical values (e.g., Figs. 1-6,8, 9-10). In particular, we found no evidence of significant impact on salinity intrusion upstream of Tongue Point.

Within the framework of generally small numerical differences between base and plan, spatial patterns of impact are identifiable. In particular, the plan appears to increase salinity propagation in the navigation channel, with a decrease of salinity in Grays Bay and some areas of the North Channel (e.g., Figs. 3, 6, 9-10).

Differences between base and plan may, in some small pockets within the navigation channel, reach large values (e.g., Fig. 9-10). This is generally consistent with earlier findings of the Waterways Experiment Station.

Impacts on salinity intrusion depend on prevailing conditions of river discharge. The trends described above seem to apply across the low, moderate and high river discharge conditions considered in the simulations (Fig. 12), and across a range of associated stratification regimes, although specifics of the impact will vary.

Patterns such as those of Figs. 3,6,9-10 may be used to guide management decisions, including evaluation of need and/or design of mitigation or restoration efforts, but only if model uncertainty is further reduced.

Q2: Is there evidence to anticipate that channel deepening will significantly impact estuarine habitat opportunity?

We find modest, but numerically detectable, changes in physical habitat opportunity in the estuary between base and plan. Habitat opportunity is defined as in [3], with extensions described in Figs. 13-15. Changes can have either sign (e.g., Fig. 16-21).

No credible net negative impact larger than a few hours per week was detected for the average habitat opportunity in any of the six regions (Fig. 22) considered in the analysis of [3].

- Spatial patterns of change are easier to detect for the velocity and salinity criteria than for the depth criterion.

- Based on the salinity criterion, the largest negative impacts are in the navigation channel, with the area of Grays Bay often experiencing beneficial impacts.

- Based on the velocity criterion, negative impacts are typically found in the navigation channel, while beneficial impacts are often found in the lateral bays.

The analysis of habitat opportunity was conducted only for the estuary.

Patterns such as those of Figs. 16-21 and 23 may be used to guide management decisions, including evaluation of need and/or design of mitigation or restoration efforts, but only if model uncertainty is further reduced. Fig. 23 illustrates remaining model uncertainties, representative of mid-range and high discharge conditions.

Q3: Is there evidence to anticipate that water temperature will be increased by channel deepening during Summer months?

During the Summer, ocean water is cooler than river water (e.g., Fig. 24). Any increased penetration of ocean water due to channel deepening will therefore tend to reduce rather than increase the temperature of estuarine waters.

Negative impacts of channel deepening on temperature could in theory occur in:

- regions where penetration of ocean water is inhibited in the plan(e.g., where there is a beneficial salinity habitat opportunity impact).

- shallow regions where flushing is inhibited (e.g., where there is a beneficial velocity habitat opportunity impact).

However, simulations for August 1999 do not reveal any significant impact on the maximum temperatures (Fig. 25).

3 PROCESS

The project involved, often through leverage of other on-going CORIE projects, the following inter-related steps:

- Model development and benchmarking (Section 3.1)
- Bathymetry development and analysis (Fig. 26)
- Grid generation (Fig. 27)
- Creation of plan bathymetry (Figs. 28-29)
- Gathering of input/control data from CORIE and external observations

- Computer resources expansion (4 independent 667 MHz DEC Alphas, with a shared on-line storage of 0.5 TB, were used to support this investigation)
- Limited model calibration and validation (Section 3.2)
- Creation of the simulation database (Section 3.2)
- Development of metrics of impact (Figs. 13-15)
- Assessment of model uncertainty (Section 3.2)
- Assessment of impact based on multiple metrics (Section 2)

3.1 Model development and benchmarking

The numerical model used in this project is ELCIRC ([4] and modifications thereof). ELCIRC solves the 3D shallow water equations using a Eulerian-Lagrangian finite volume method inspired on [5].

ELCIRC is a recent model, still undergoing enhancements and benchmarking through funding from the National Marine Fisheries Service, U.S. Fish and Wildlife Service, Office of Naval Research and National Science Foundation. Several significant changes were introduced to ELCIRC during the period of this project, often influenced by the experience acquired by the present model application. A partial list of key modifications includes:

- Version 3.0: (a) Redefinition of the location of definition of several primary variables within the elements. Variables are now defined as follows: horizontal velocities at side centers; vertical velocity, salinity, temperature and water levels at element centers. Benefit: internal consistency, mass conservation. (b) Multiple representations of vertical mixing were added, including [6] and [7]. Benefit: physical realism, conditional to appropriate parameterization.

- Version 3.1: Solution of the transport equation for salinity and temperature was changed from an interpolation Eulerian-Lagrangian method (ELM) to an integration ELM. Benefit: mass conservation (e.g., see discussion in [8]);

- Version 3.6: An ITPAK solver was adopted to solve linear systems of equations. Benefit: robustness, efficiency.

- Version 3.9: (a) Boundary conditions were imposed to the momentum equation prior to substitution in the 3D continuity equation. Benefit: preservation of horizontal fluxes, via minimization of lateral leakage. (b) Incorporation of water-air exchanges in the heat budget, including links to global models. Benefit: improved representation of temperature.

Consistently with the principle of adapting best-available technology at any given time, several different versions of ELCIRC were used to produce simulations. There are enough differences between ELCIRC3.9 and ELCIRC3.1 that the two model versions should have been calibrated separately. However, because of time constraints, only ELCIRC3.1 was systematically calibrated.

3.2 Model application

3.2.1 Simulation database

In addition to a large number of specific-purpose runs, four versions of the simulation database were developed. Each version covered a different sub-set of the target runs, and differed from the others by the ELCIRC version and/or computational choices made for the simulations. A summary follows:

Version	Grid	Coverage	Δt (min)	Heat balance
1	Multiple	May 97, May 01, Jul 01 (all partial)	7.5, 15	no
2	Production/Longview	May 97, May 01, Jul 01 (comprehensive)	7.5	no
3	Production/Longview	May 97, Aug 99 (first week of each month)	2.5	no
4	Production/complete	May 97, Aug 99 (first week of each month)	7.5	Only for Aug 99

3.2.2 Modeling choices

Version 1 of the simulation database was designed to explore sensitivities to various choices of domain, numerical parameters, and physical parameters. Results led to the following modeling choices in subsequent versions of the database, often reflecting concessions to the time constraints of the reconsultation process:

- The *production* grid was chosen over the *fine* grid (Fig. 27) for versions 2-4 of the simulation database. While the level of resolution of the *fine* grid is preferable from a numerical viewpoint, the fine grid was prohibitively expensive for this project.

- Longview, rather than Bonneville and Willamette Falls, was the default upstream boundary of the computational domain (Fig. 27). This choice was initially dictated by a deficiency in the bathymetric database (Fig. 26), but was retained through versions 1-3 of the simulation database, for considerations including: (a) the need to keep computational costs low, (b) lack of time for an appropriate calibration of the levels and flows upstream of Longview, and (c) concerns on lateral flow leakage in narrow, coarsely resolved parts of the domain (resolved in ELCIRC3.9, see latter part of this section).

- We chose a default time step of 7.5 minutes. This choice, coupled with the choice of the production grid, limited our ability to represent strong stratification. In version 3 of the simulation database, we used a smaller time step (2.5 minutes) to enable stratification to develop more realistically.

- Different representations of friction were used downstream of the Astoria-Megler Bridge and upstream of Tongue Point. We typically used drag coefficients of 0.0025 downstream the bridge, and 0.0045 or 0.0065 upstream of Tongue Point, with a linear transition in-between. This approach is consistent with Hamilton (reference), although he used a lower coefficient (0.0011) downstream. Hamilton's rationale for a bi-modal representation is based on known differences in bottom characteristics.

- We chose a simplified parameterization of the vertical mixing, inspired in [7].

A thorough calibration and validation of the model was beyond the time constraints of this project. Limitations of our calibration include (a) lack of differentiation of friction coefficients between channels and shallow or intertidal regions, and (b) simplistic parameterization of local vertical mixing, (c) lack of optimization of the grid based on internal error metrics of the model, and (d) lack of significant recalibration after replacement ELCIRC3.1 by ELCIRC3.9 (in version 4 of the simulation database).

Figs. 31a-h show comparisons between simulations and observations at multiple CORIE stations (Fig. 30), for July 2001 (week 27), one of the low flow conditions. These figures are illustrative of the best matches obtained between simulations and observation data. Fig. 32 illustrates, for a higher river discharge condition (1999, week 31) the type of match that was considered acceptable under more strongly stratified conditions.

Three key factors appear to be necessary for this type of match: correct local fluxes, low vertical noise, and adequate parameterization of friction. The first factor appears to be inherently guaranteed in ELCIRC3.9 (but not in ELCIRC3.1). Taming the vertical noise requires, for the production grid, very small time steps (version 3 of the database) – a better optimized grid is a more effective alternative, but out of the scope of this project. Adequate parameterization of friction is a straightforward process, successfully done for critical simulations in version 2 (including the simulation shown in Figs. 31a-h).

Modeling choices have direct implications on modeling error and uncertainty. Key examples are:

- The grid resolution was insufficient to avoid artificial vertical mixing at the tidal inlet, for the default time step of 7.5 minutes. Stratification was therefore under-represented in most runs, with the exception of version 3 simulations (where the time step was 2.5 minutes) – Figs. 33a-c.

- Setting the upstream boundary conditions at Longview was limiting in two ways. First, we lost strict control of the actual river discharge, because the only condition that could be realistically imposed there were water levels. Second, because the deepening extends to Longview, imposing the same levels for base and plan do not assure the same river discharges. Versions 1 and 3 of the simulation database are substantially affected by this problem. The problem was minimized in version 2 (by forcing the same depth in base and plan in the immediate vicinity of Longview) and solved in version 4 (by using Bonneville dam and Willamette Falls as upstream boundary conditions).

Algorithmic details in the numerical codes also have direct implications on modeling error and uncertainty. A key example is the imposition of land boundary conditions in the momentum equation prior to (rather than after) its substitution into the continuity equation. Prior imposition (as in ELCIRC3.9) leads to excellent mass and flux preservation, while posterior imposition (as in ELCIRC3.1) allows resolution-dependent water leakage through complex lateral boundaries. In the latter case, mass balances are respected, but flux preservation is controlled by spatial and temporal resolution.

It is relevant to note that, although the absolute model results changed with the different modeling choices (boundary conditions, time step, etc.), the resulting negative impacts of the plan remained consistently of small numerical magnitude across modeling choices. In a context of small-magnitude differences, spatial patterns of difference between base and plan are, however, sensitive to the actual modeling choice, in particular when stratification is underestimated (e.g., Fig. 23).

3.2.3 Computational costs

All simulations were conducted in four independent 667 MHz DEC alpha workstations. Using a time step of 7.5 minutes, computational costs per week of simulation were 29h, 33h and 49 h, respectively, for the production grid cut at Longview, the complete production grid, and the fine grid cut at Longview. Costs increased essentially linearly by reducing the time step from 7.5 minutes to 2.5 minutes.

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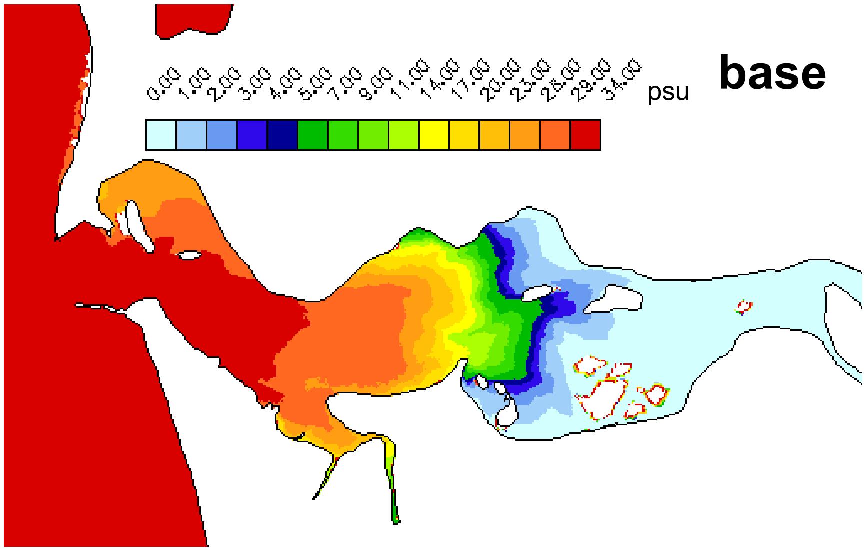
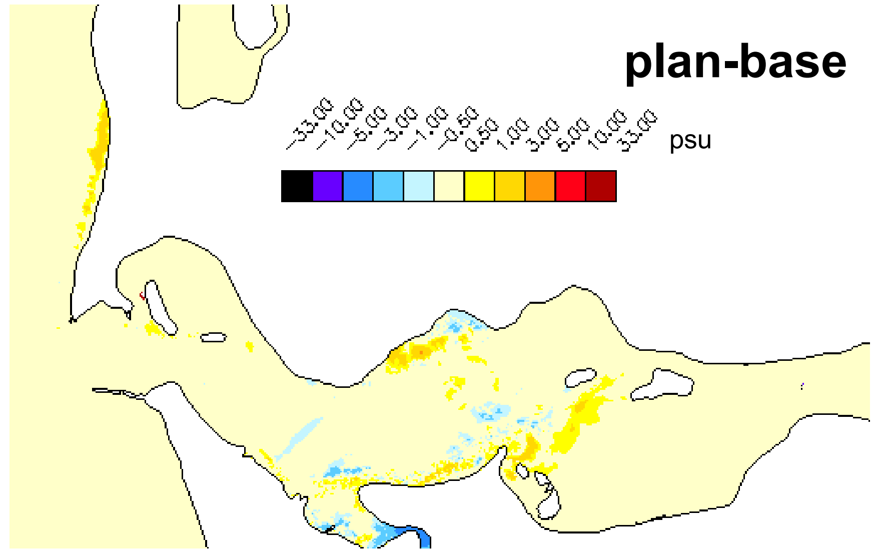
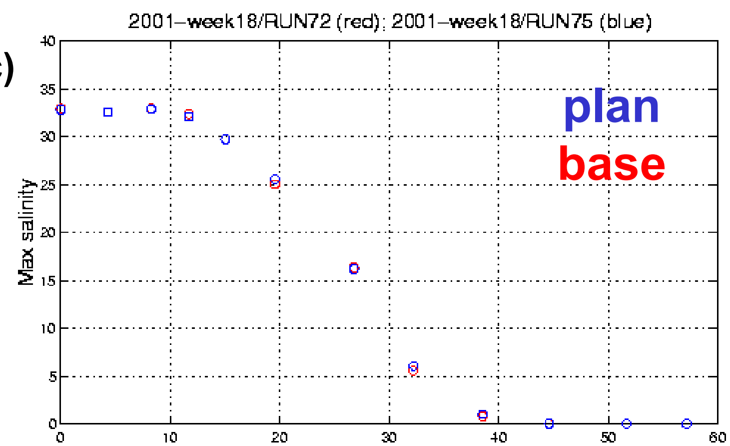
(a)



(b)



(c)



Distance along navigation channel from estuary mouth (km)
(see Fig. 28a for location)

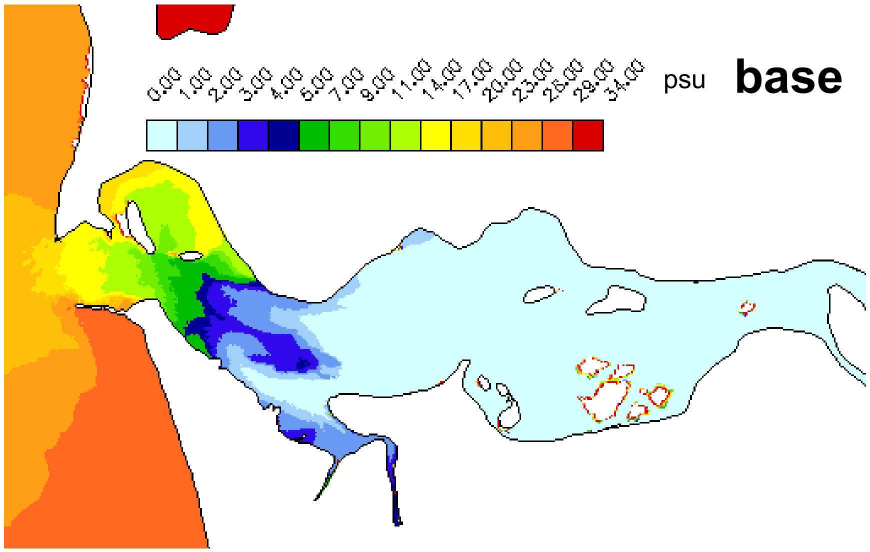
2001 – week 18

(May)

Version 2 of simulation database

Fig. 1: (a) Maximum salinity (psu) for base conditions. (b) Difference between maximum salinities: plan minus base. (c) Maximum salinities along the navigation channel, for base and plan.

(a)



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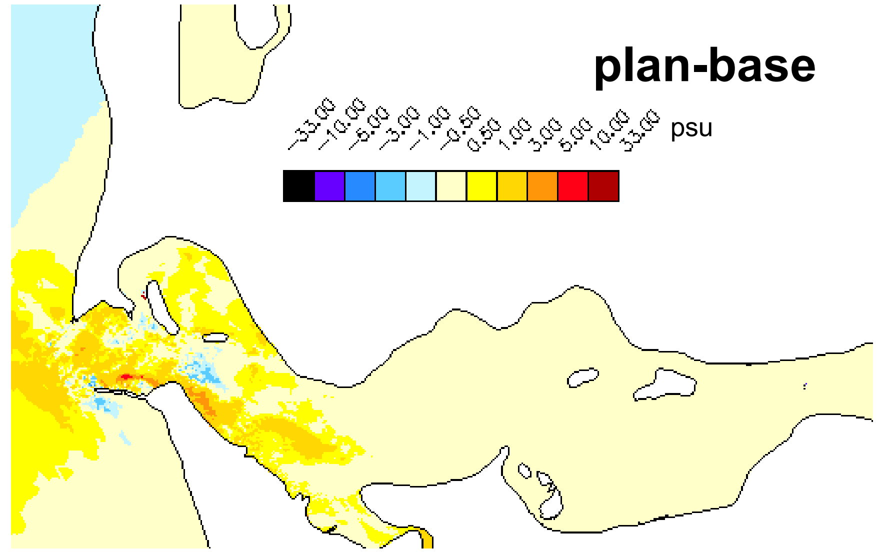
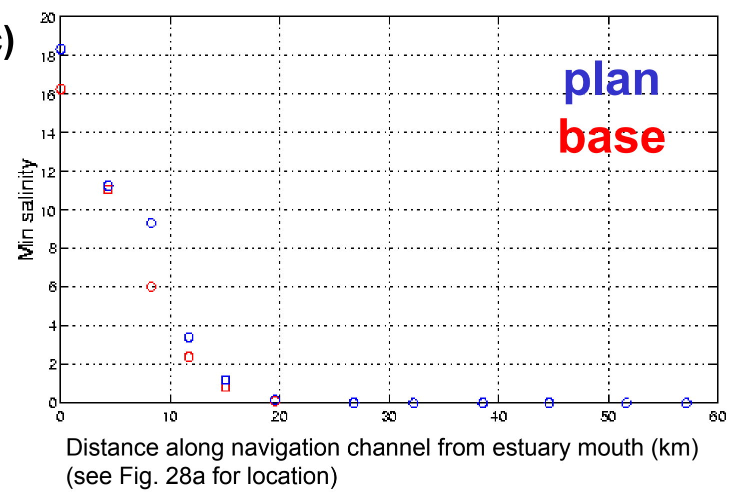


(c)



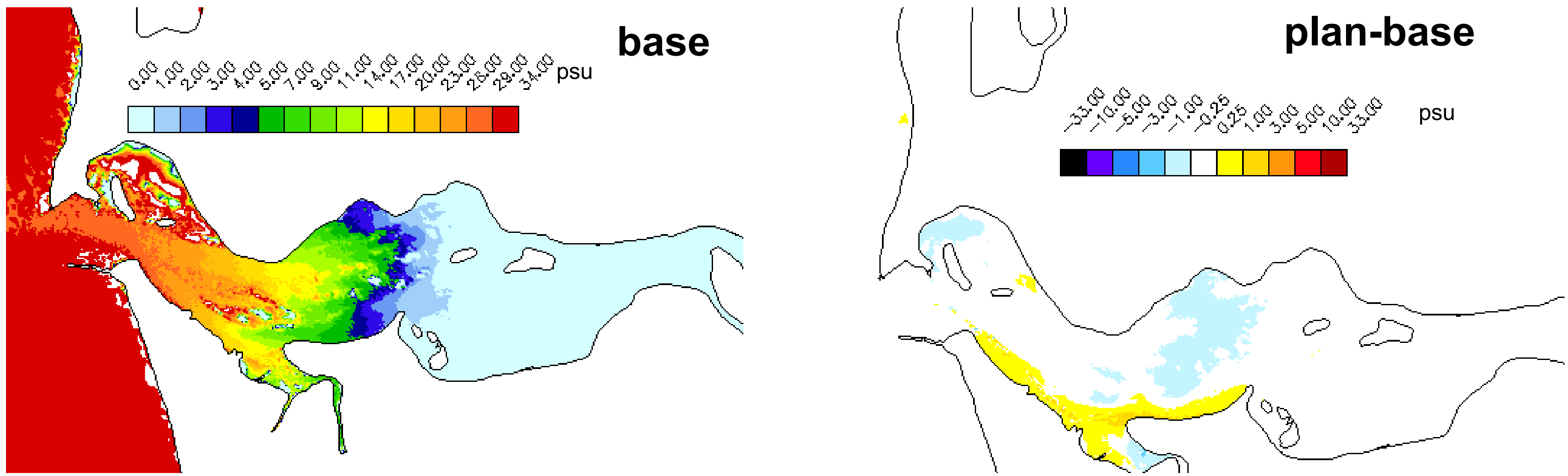
2001 – week 18

(May)

Version 2 of simulation database

Fig. 2: (a) Minimum salinity (psu) for base conditions. (b) Difference between minimum salinities: plan minus base. (c) Minimum salinities along the navigation channel, for base and plan.

(a) (b)



$$S_{ac} = \frac{\iint_{D,T} s(t,z)\,dz\,dt}{D_{MSL}T}$$

2001 – week 18

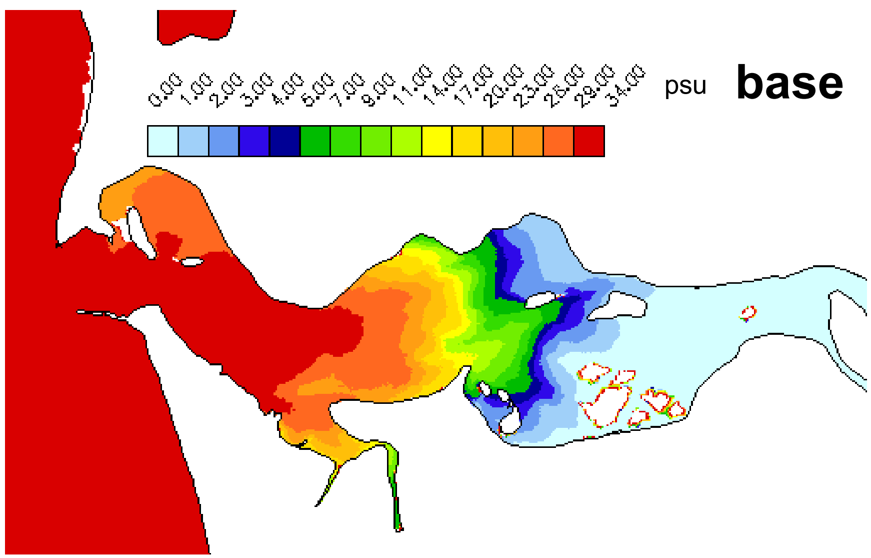
(May)

Version 2 of simulation database

Fig. 3: (a) Salinity accumulation, S_{ac} (psu), for base conditions. (b) Difference between salinitiy accumulations: plan minus base. While differences are numerically small, a clear spatial pattern of differences can be observed.

Note: Unlike maximum and minimum salinities, salinity accumulation filters out numerical noise and episodic events. Hence, S_{ac} may be a more representative metric than maximum or minimum salinity.

(a)



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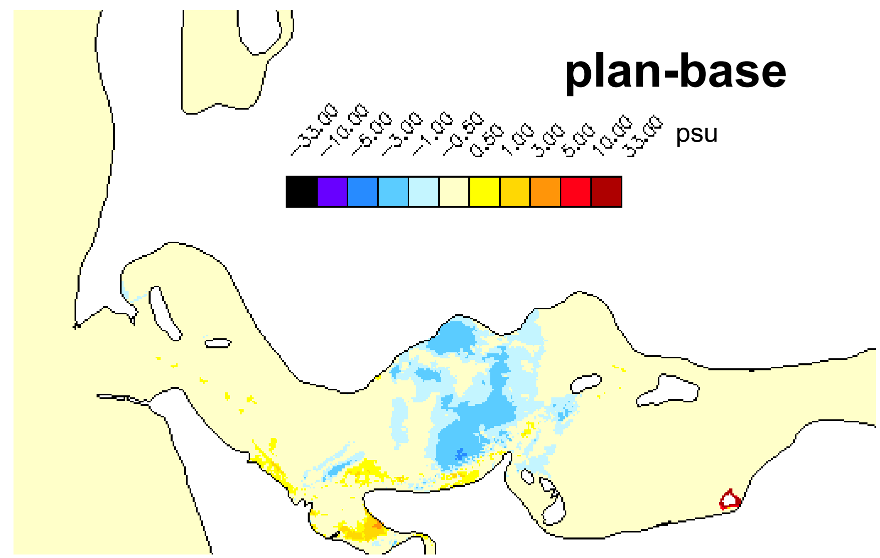

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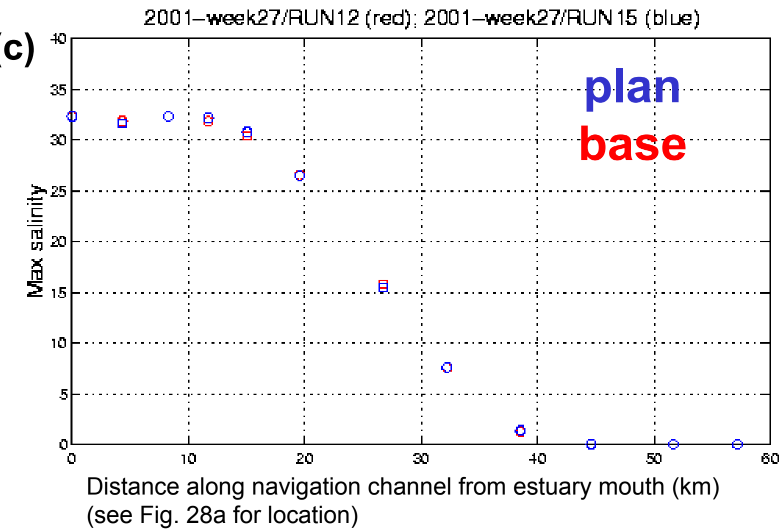
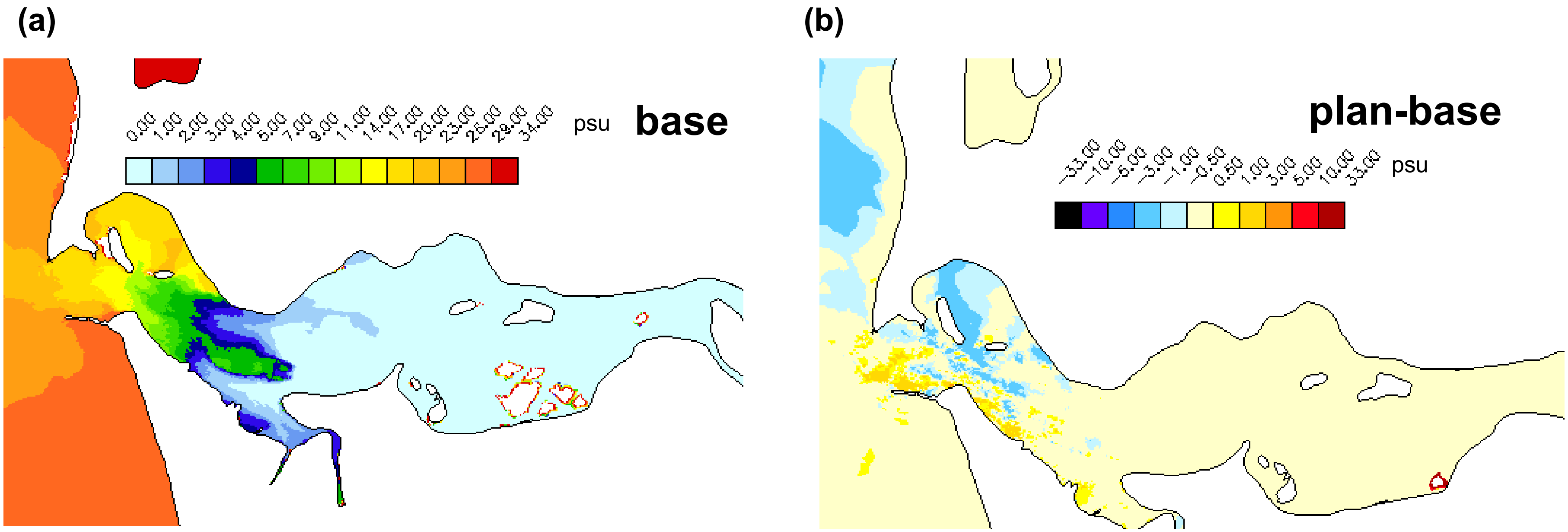


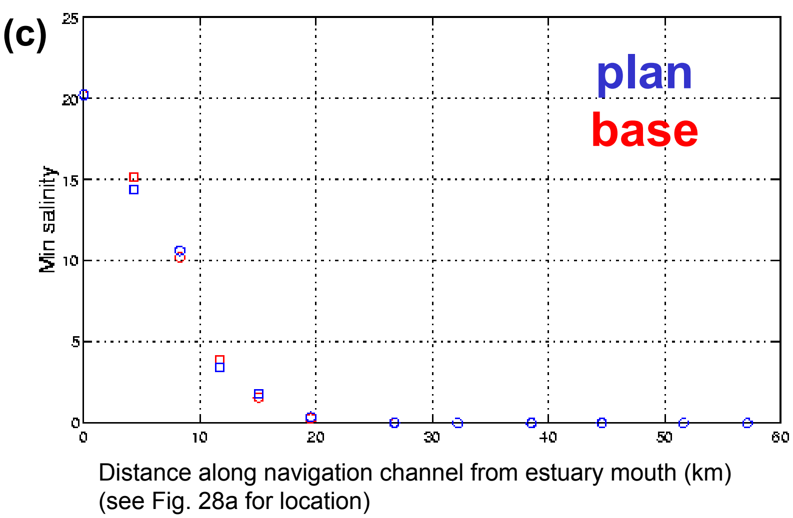
2001 – week 27

(July)

Version 2 of simulation database

Fig. 4: (a) Maximum salinity (psu) for base conditions. (b) Difference between maximum salinities: plan minus base. (c) Maximum salinities along the navigation channel, for base and plan.



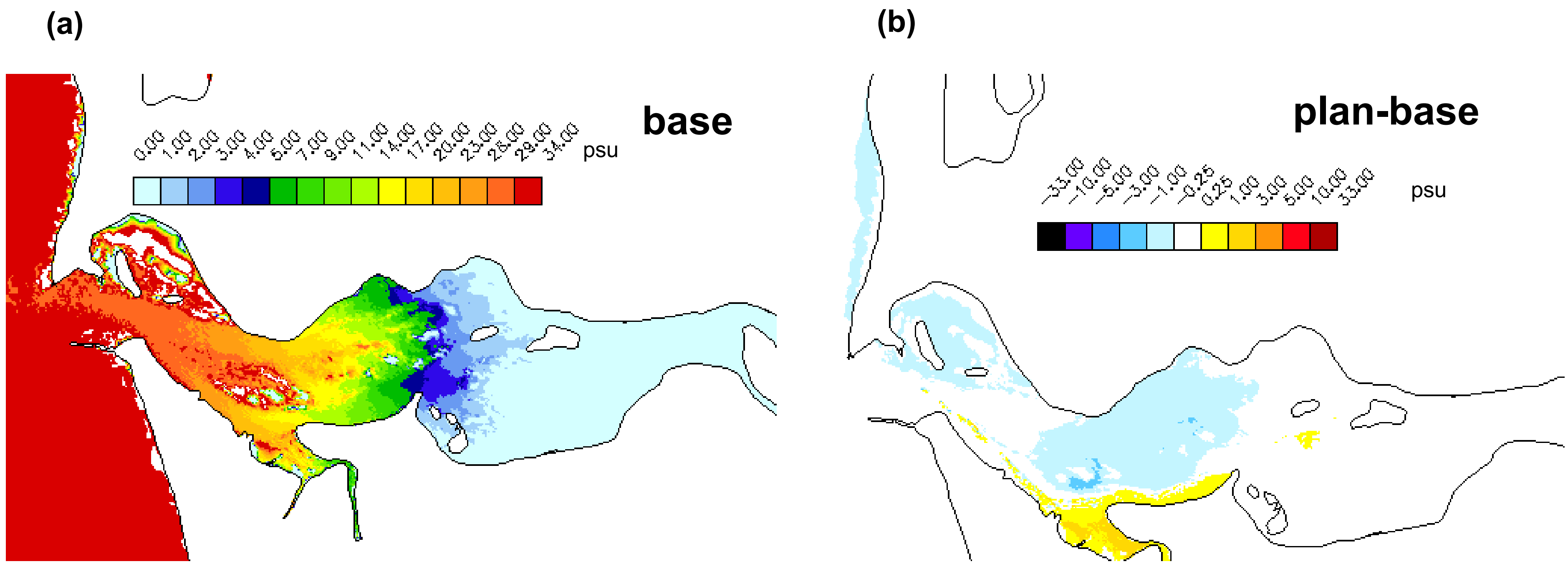


2001 – week 27

(July)

Version 2 of simulation database

Fig. 5: (a) Minimum salinity (psu) for base conditions. (b) Difference between minimum salinities: plan minus base. (c) Minimum salinities along the navigation channel, for base and plan.



2001 – week 27

(July)

Version 2 of simulation database

$$S_{ac} = \frac{\iint\limits_{D,T} s(t,z)\,dz\,dt}{D_{MSL}T}$$

Fig. 6: (a) Salinity accumulation, S_{ac} (psu), for base conditions. (b) Difference between salinitiy accumulations: plan minus base. While differences are numerically small, a clear spatial pattern of differences can be observed.

Note: Unlike maximum and minimum salinities, salinity accumulation filters out numerical noise and episodic events. Hence, S_{ac} may be a more representative metric than maximum or minimum salinity.

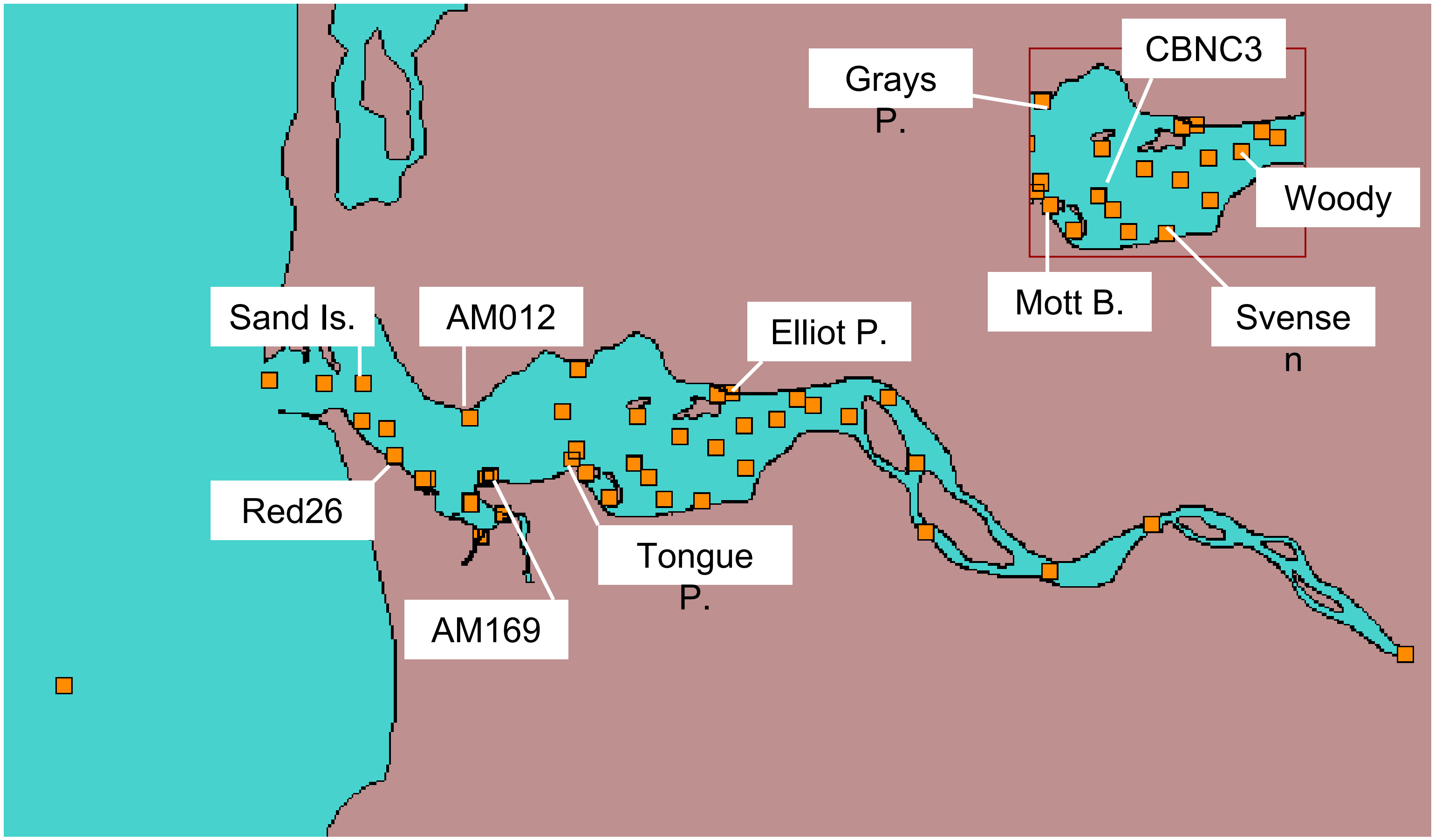


Fig. 7: Time series of water level and of salinity were compared for base and plan at multiple locations in the estuary, shown above as orange squares. Comparisons at representative stations (names shown above) are presented in Figs. 8(a- k), for week 27 of 2001.

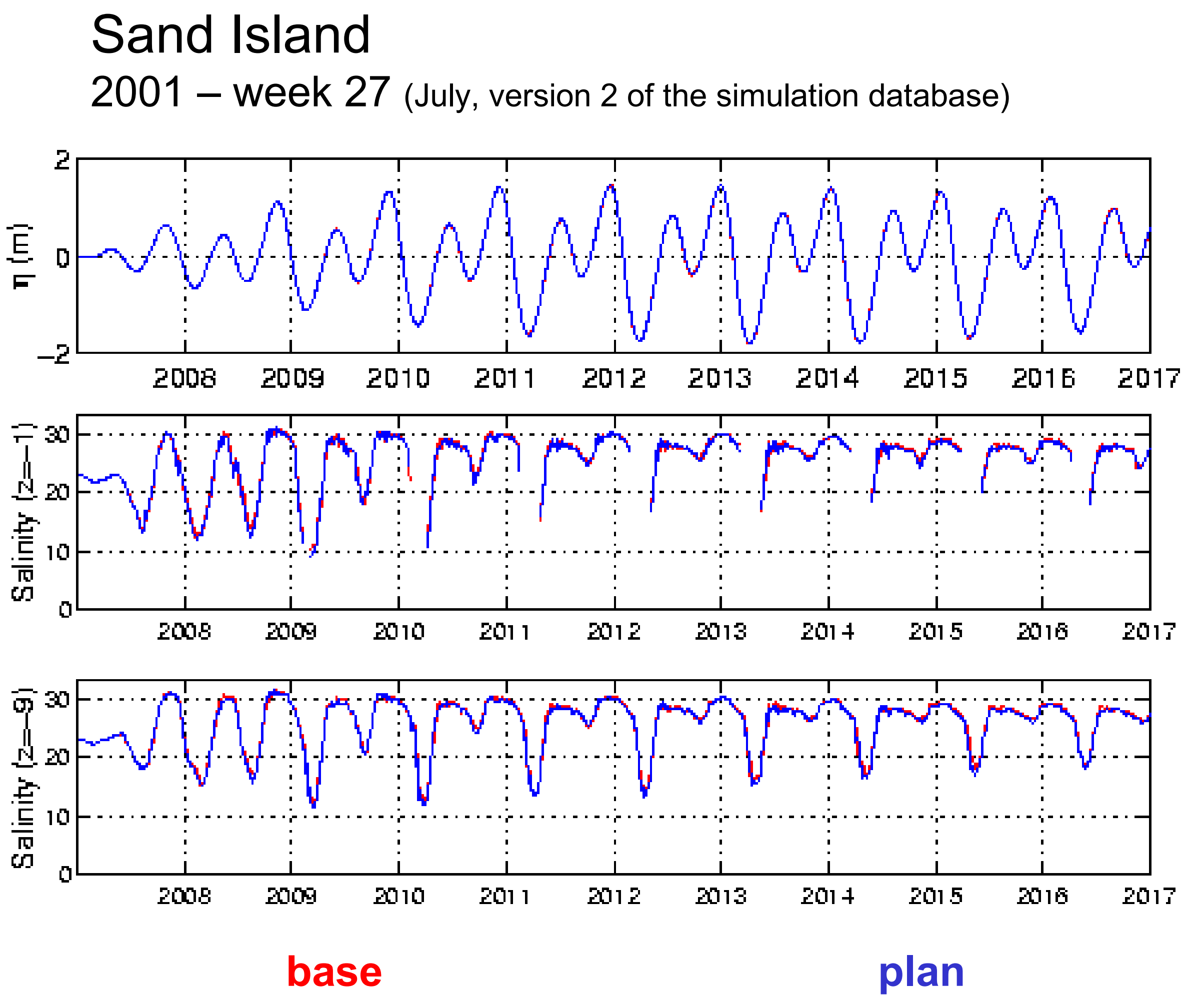


Fig. 8a: Time series of water level (η, top panel) and of salinity near the water surface (middle panel) and near the bottom (bottom panel) for base and plan, respectively. See Fig. 7 for station location. Time is in *CORIE days* (origin: January 1, 1996). The first three days represent a warm-up phase.

RED26

2001 – week 27 (July, version 2 of the simulation database)

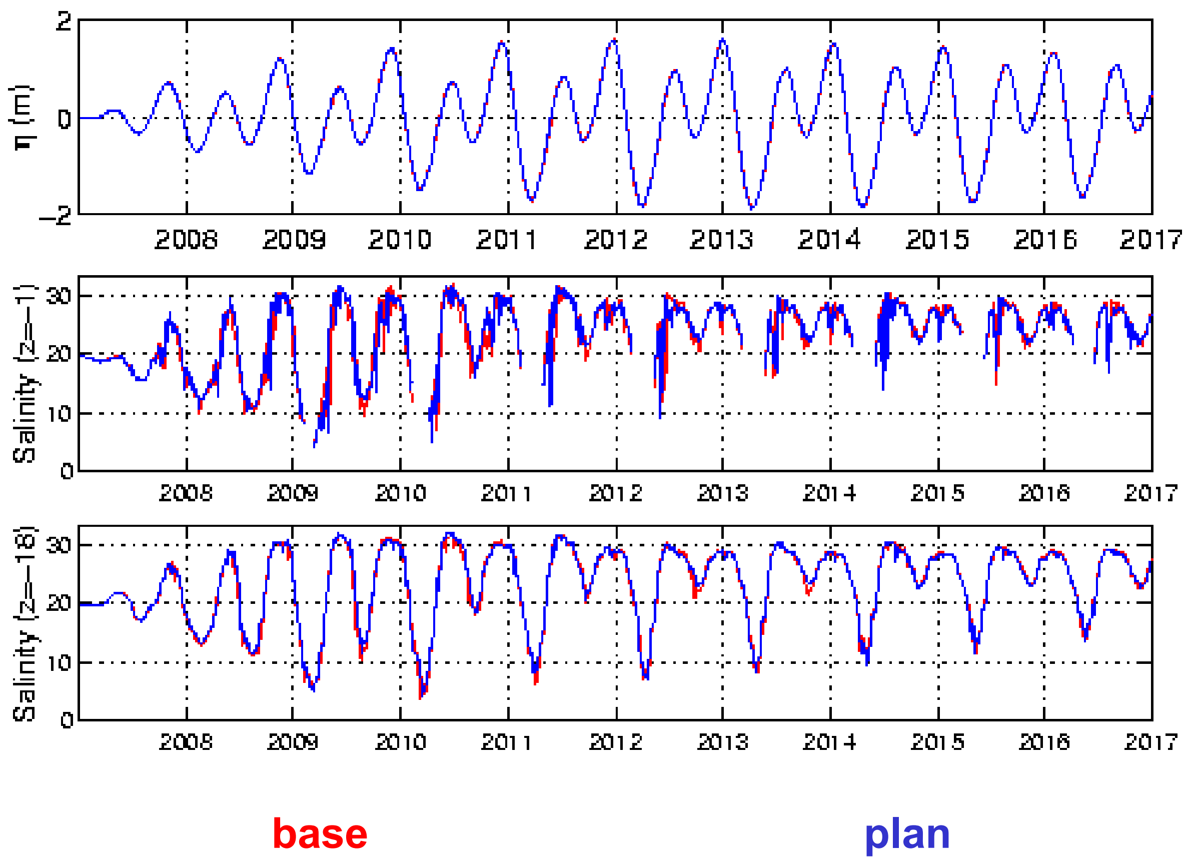
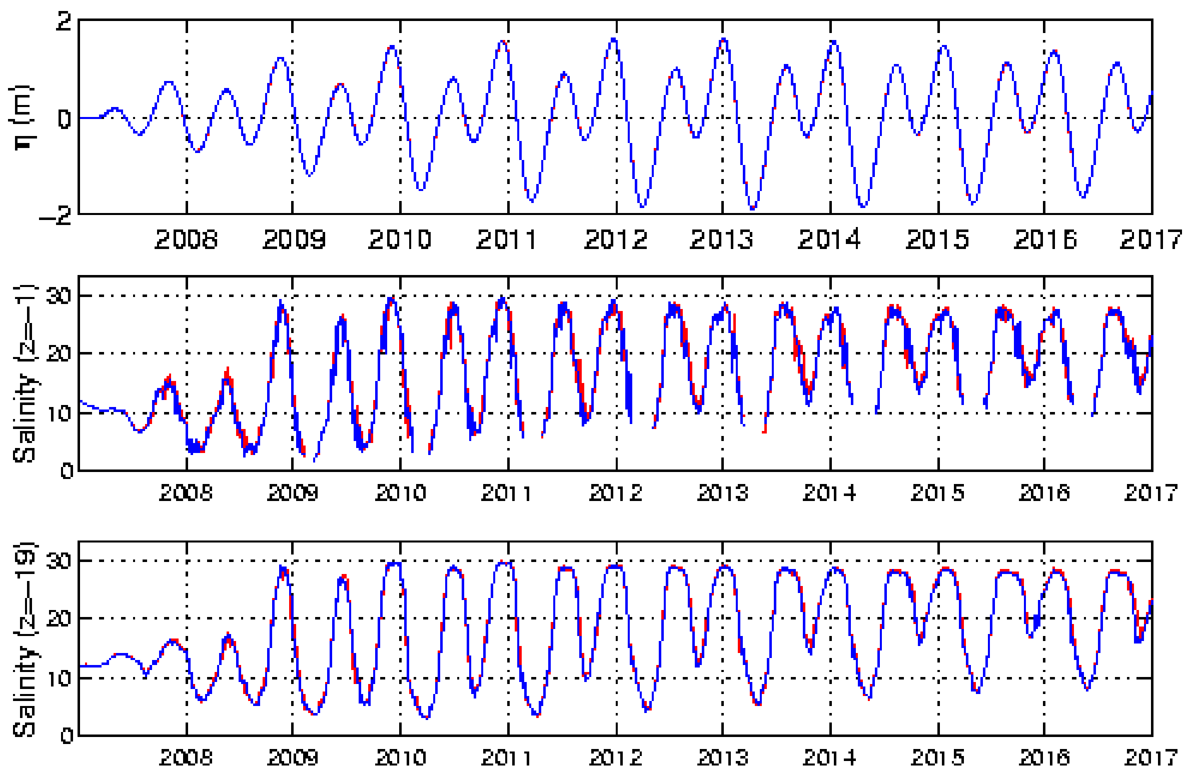


Fig. 8b: Time series of water level (η, top panel) and of salinity near the water surface (middle panel) and near the bottom (bottom panel) for base and plan, respectively. See Fig. 7 for station location. Time is in *CORIE days* (origin: January 1, 1996). The first three days represent a warm-up phase.

AM012

2001 – week 27 (July , version 2 of the simulation database)



base **plan**

Fig. 8c: Time series of water level (η, top panel) and of salinity near the water surface (middle panel) and near the bottom (bottom panel) for base and plan, respectively. See Fig. 7 for station location. Time is in *CORIE days* (origin: January 1, 1996). The first three days represent a warm-up phase.

Tongue Point

2001 – week 27 (July, version 2 of the simulation database)

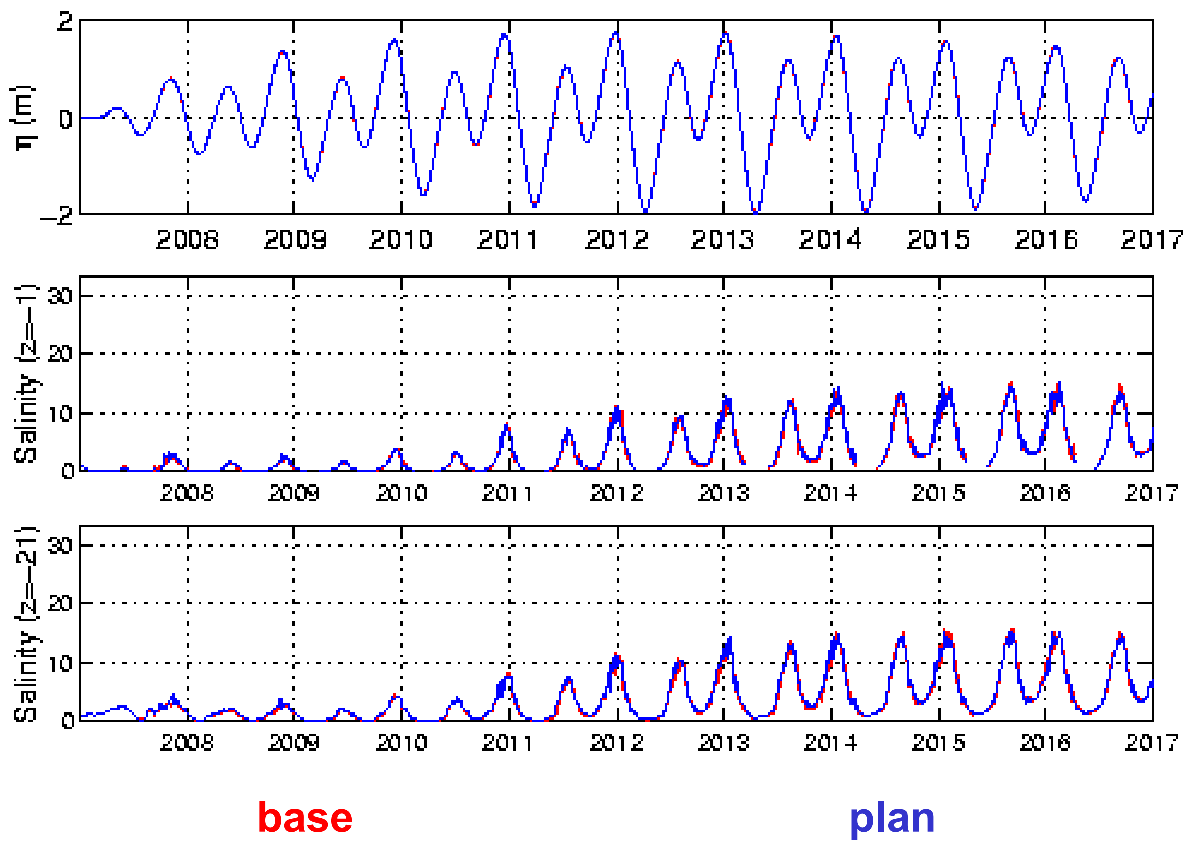


Fig. 8d: Time series of water level (η, top panel) and of salinity near the water surface (middle panel) and near the bottom (bottom panel) for base and plan, respectively. See Fig. 7 for station location. Time is in *CORIE days* (origin: January 1, 1996). The first three days represent a warm-up phase.

Elliot Point

2001 – week 27 (July, version 2 of the simulation database)

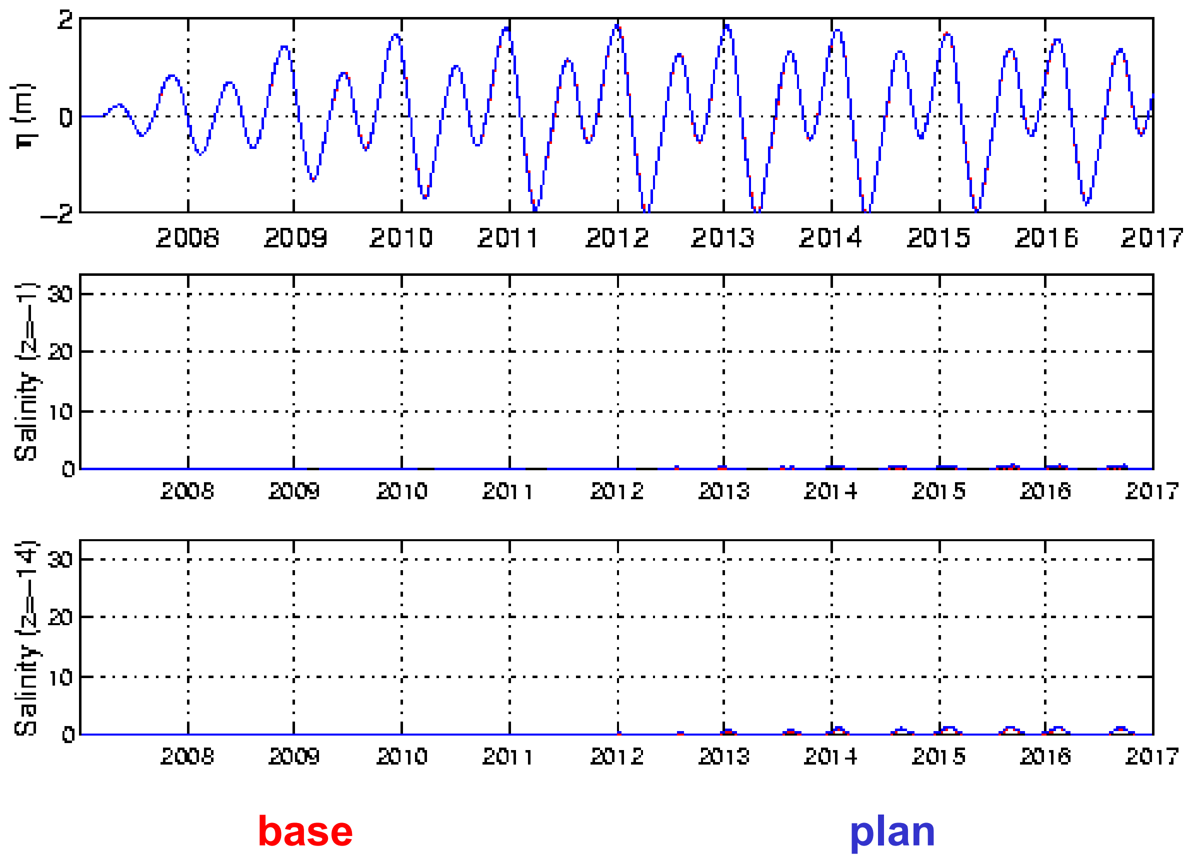


Fig. 8e: Time series of water level (η, top panel) and of salinity near the water surface (middle panel) and near the bottom (bottom panel) for base and plan, respectively. See Fig. 7 for station location. Time is in *CORIE days* (origin: January 1, 1996). The first three days represent a warm-up phase.

AM169

2001 – week 27 (July, version 2 of the simulation database)

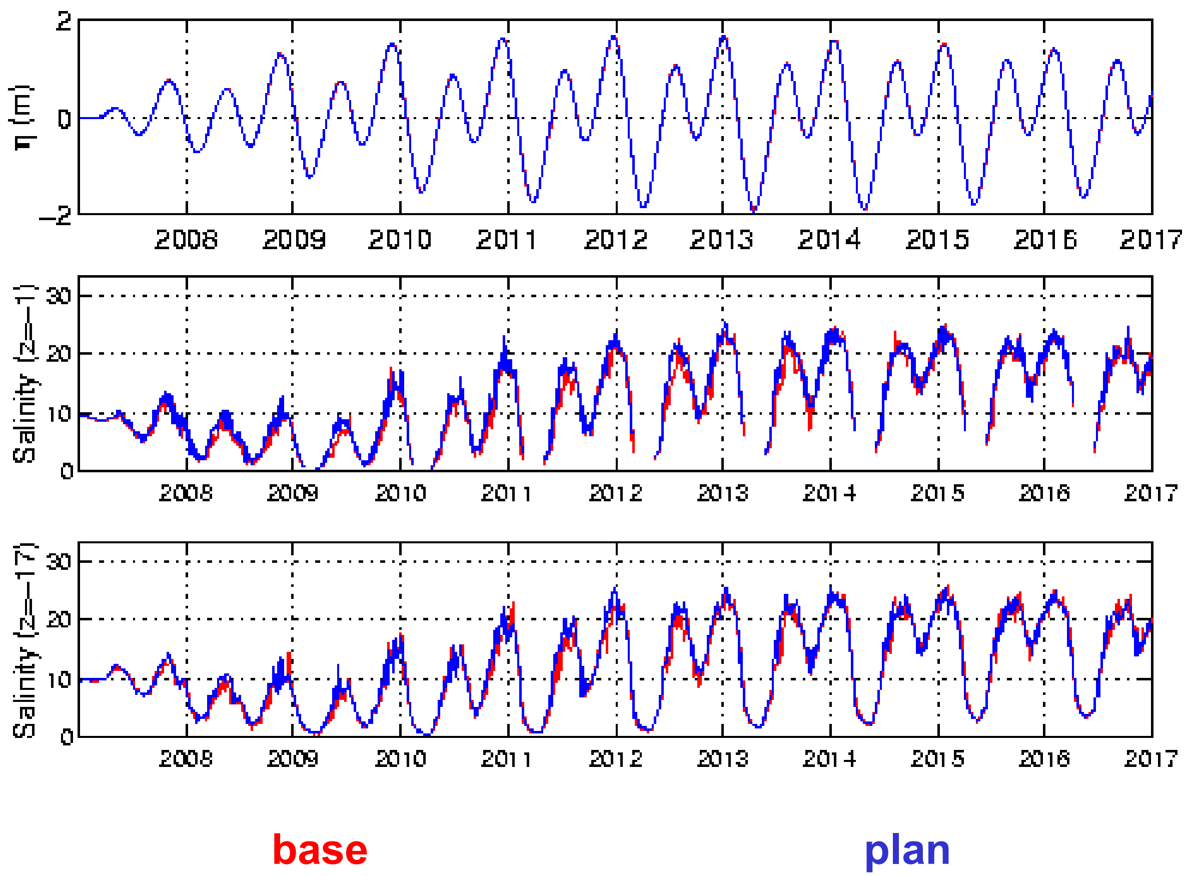


Fig. 8f: Time series of water level (η, top panel) and of salinity near the water surface (middle panel) and near the bottom (bottom panel) for base and plan, respectively. See Fig. 7 for station location. Time is in *CORIE days* (origin: January 1, 1996). The first three days represent a warm-up phase.

Grays Point

2001 – week 27 (July, version 2 of the simulation database)

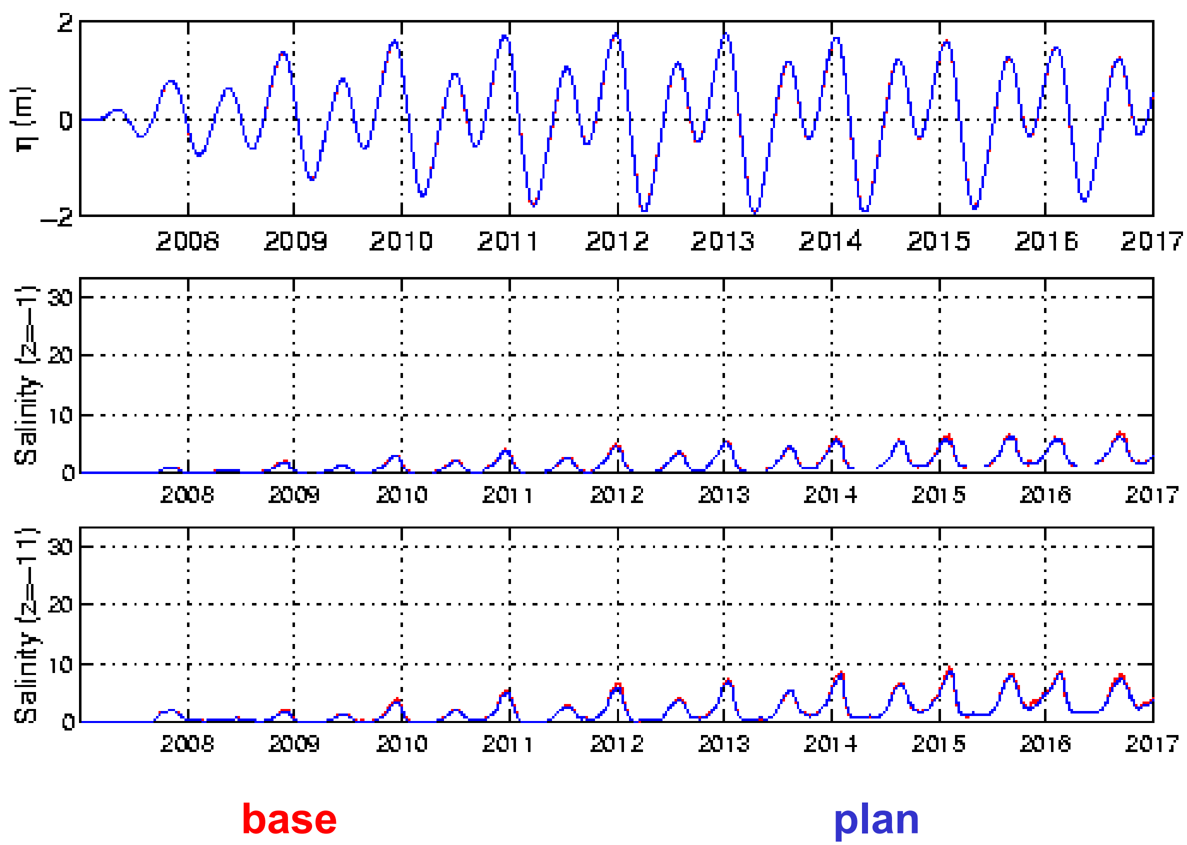


Fig. 8g: Time series of water level (η, top panel) and of salinity near the water surface (middle panel) and near the bottom (bottom panel) for base and plan, respectively. See Fig. 7 for station location. Time is in *CORIE days* (origin: January 1, 1996). The first three days represent a warm-up phase.

Mott Basin

2001 – week 27 (July, version 2 of the simulation database)

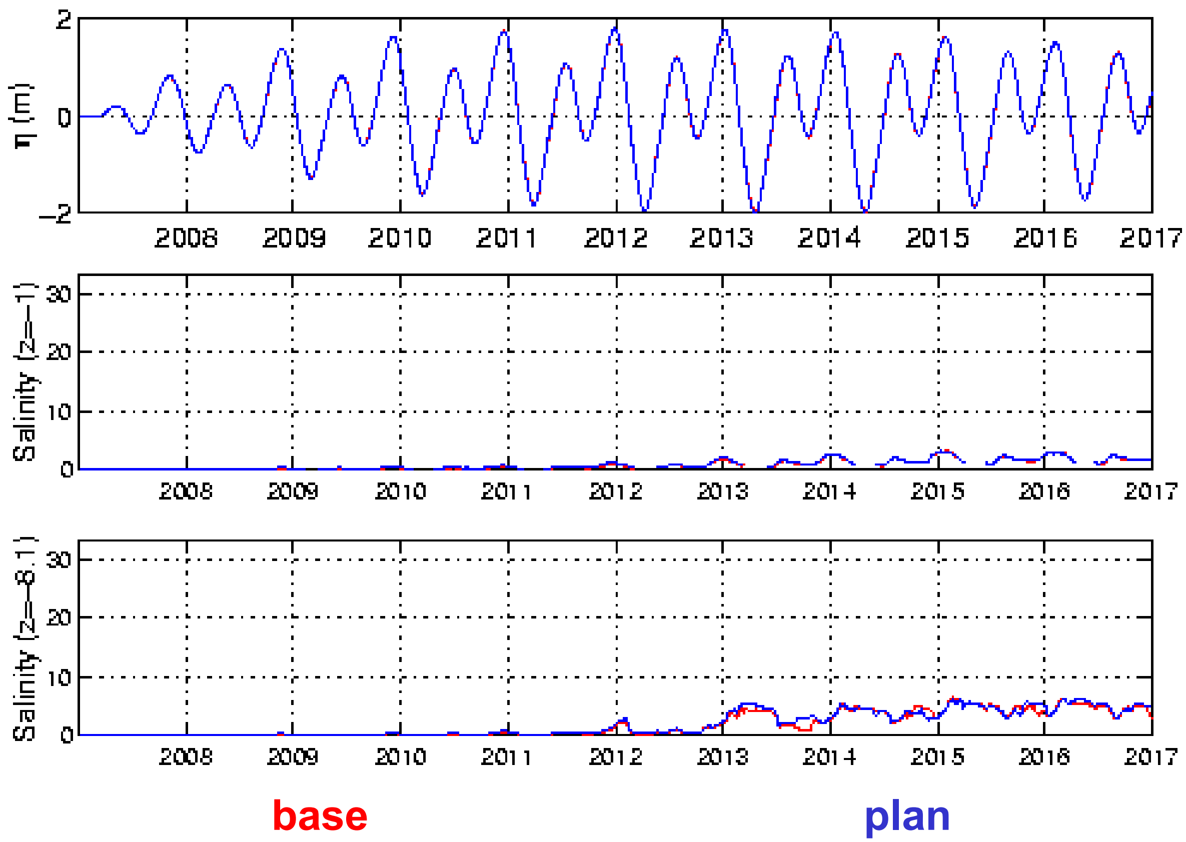


Fig. 8h: Time series of water level (η, top panel) and of salinity near the water surface (middle panel) and near the bottom (bottom panel) for base and plan, respectively. See Fig. 7 for station location. Time is in *CORIE days* (origin: January 1, 1996). The first three days represent a warm-up phase.

CBNC3

2001 – week 27 (July, version 2 of the simulation database)

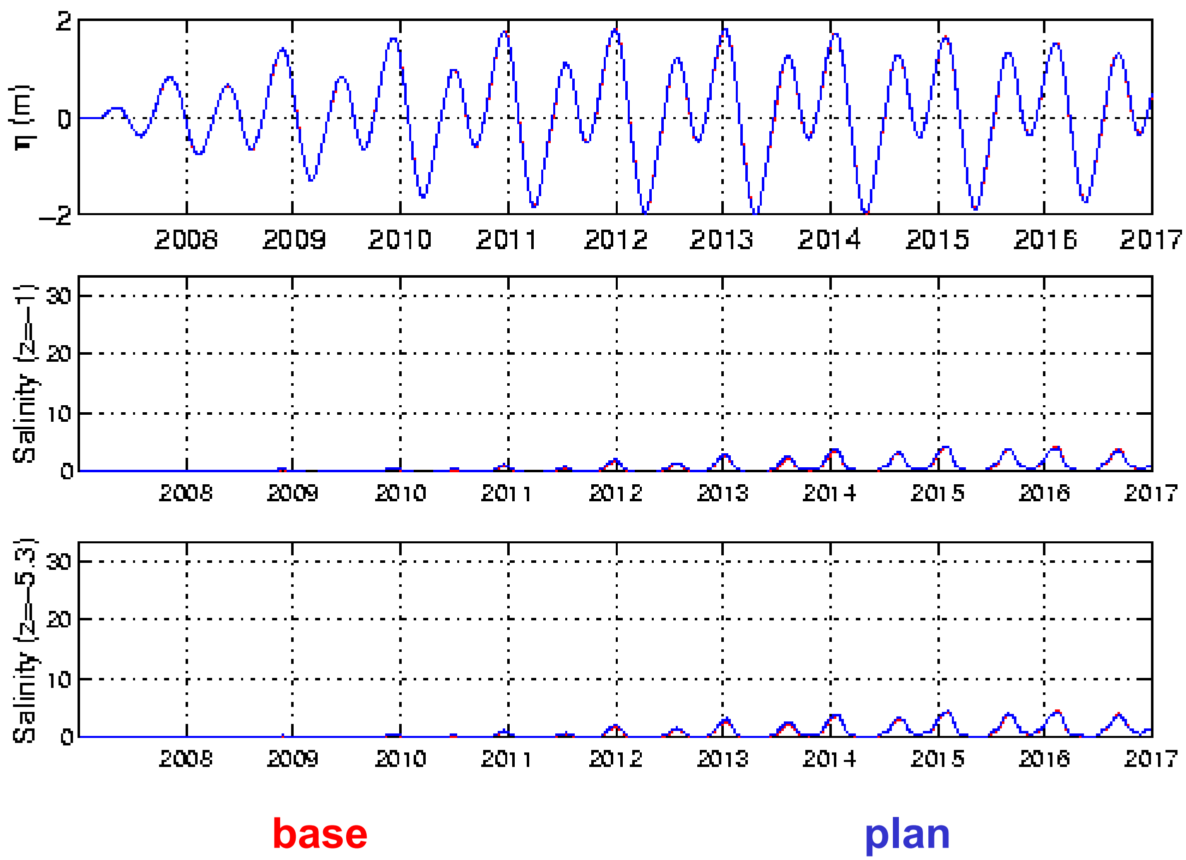


Fig. 8i: Time series of water level (η, top panel) and of salinity near the water surface (middle panel) and near the bottom (bottom panel) for base and plan, respectively. See Fig. 7 for station location. Time is in *CORIE days* (origin: January 1, 1996). The first three days represent a warm-up phase.

Woody Island

2001 – week 27 (July, version 2 of the simulation database)

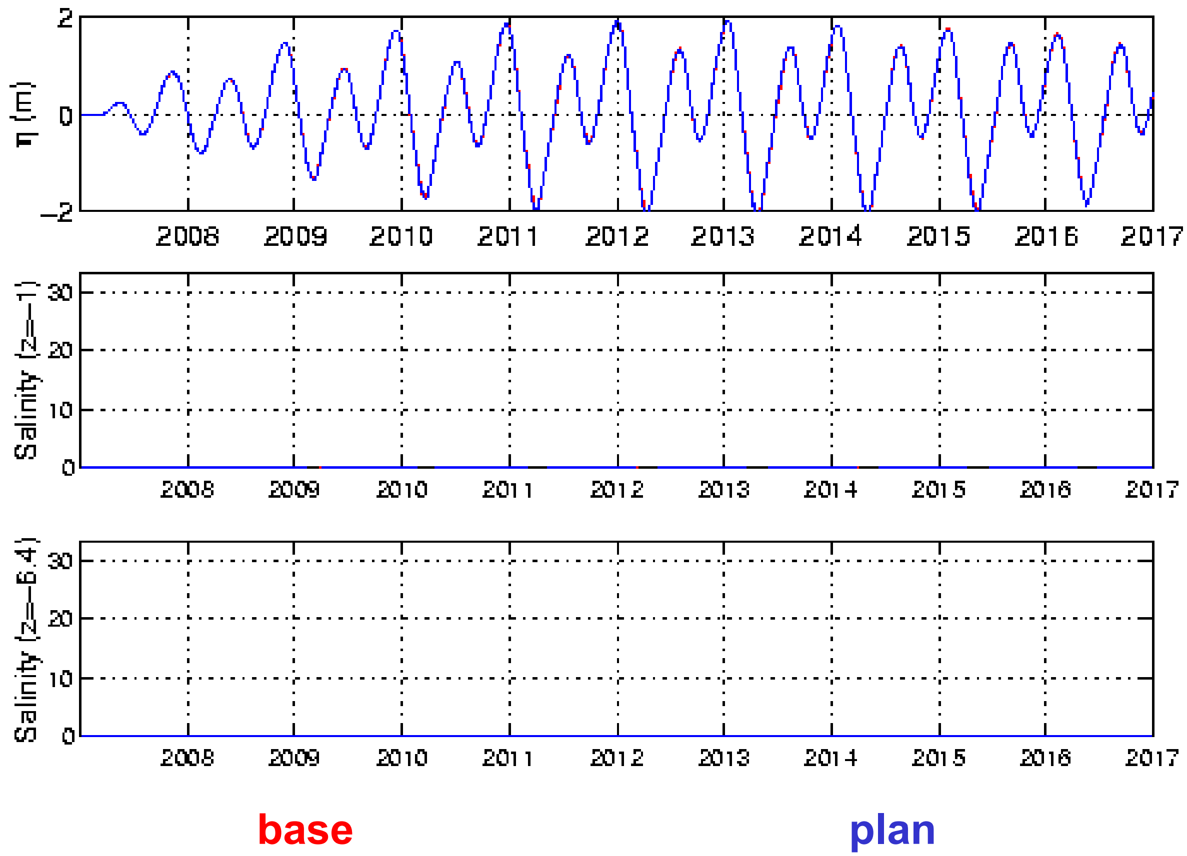


Fig. 8j: Time series of water level (η, top panel) and of salinity near the water surface (middle panel) and near the bottom (bottom panel) for base and plan, respectively. See Fig. 7 for station location. Time is in *CORIE days* (origin: January 1, 1996). The first three days represent a warm-up phase.

Svensen Island

2001 – week 27 (July, version 2 of the simulation database)

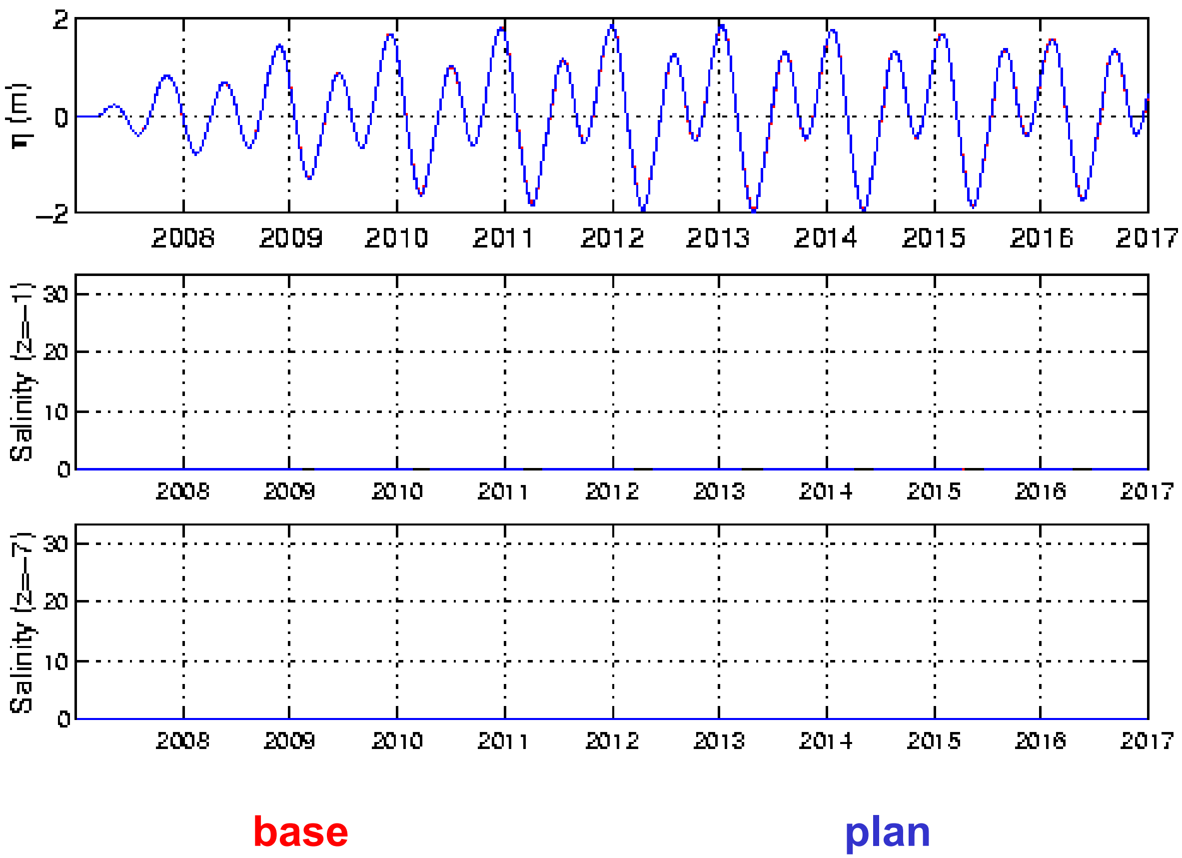
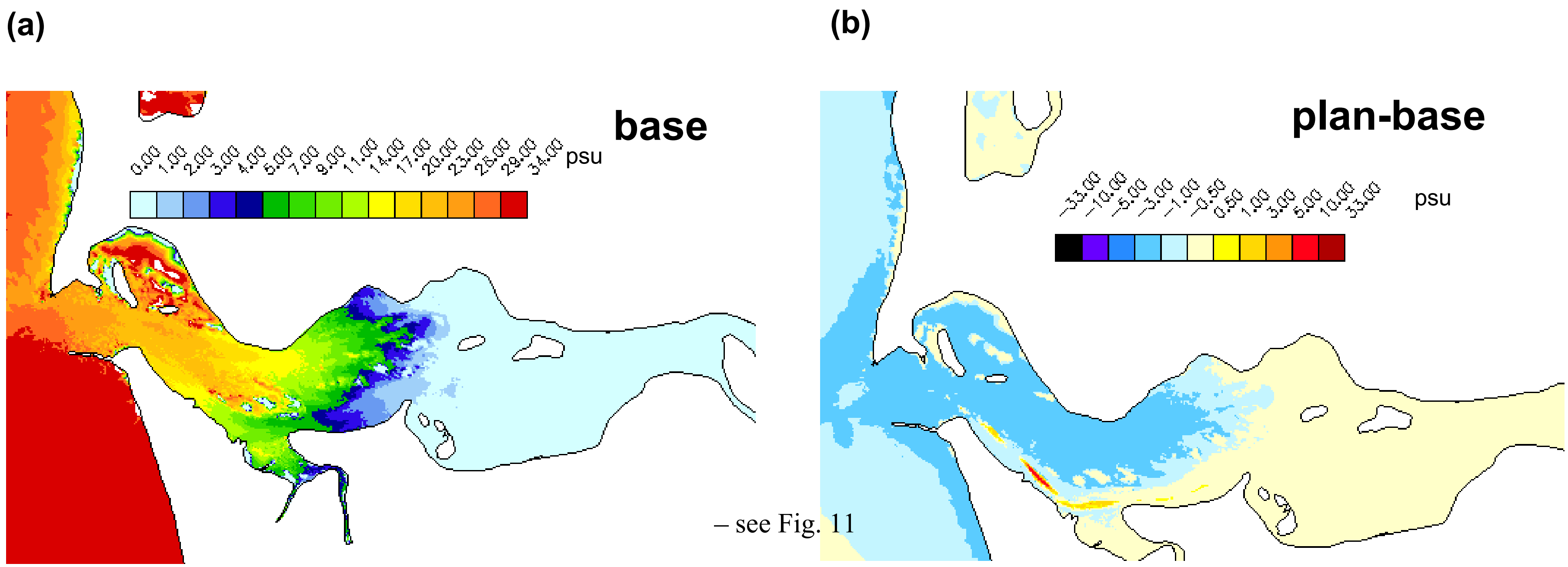


Fig. 8k: Time series of water level (η, top panel) and of salinity near the water surface (middle panel) and near the bottom (bottom) for base and plan, respectively. See Fig. 7 for station location. Time is in *CORIE days* (origin: January 1, 1996). The first three days represent a warm-up phase.



1997 – week 18

(May)

Version 3 of simulation database

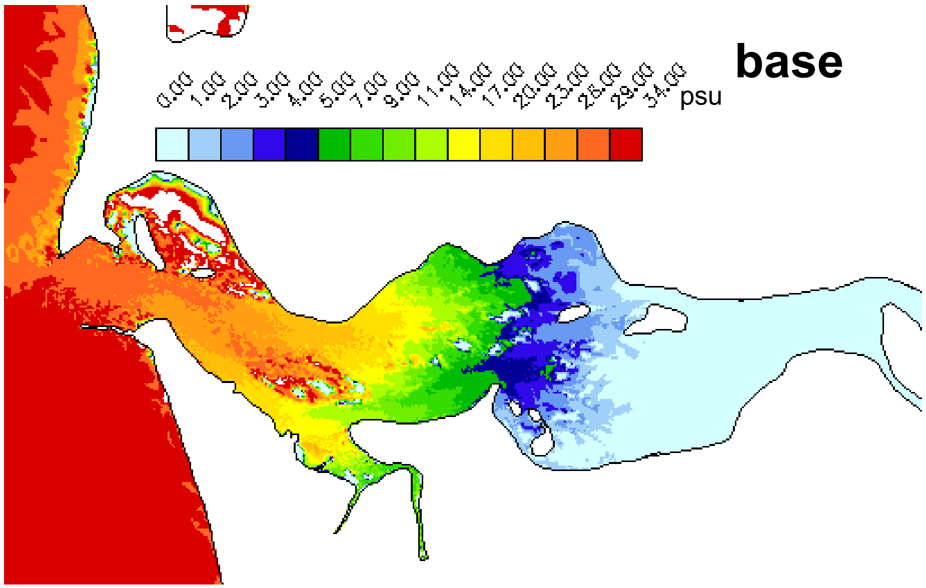
$$S^*_{ac} = \frac{\iint\limits_{D,T} s(t,z)\,dz\,dt}{D^{\text{base}}_{MSL} T}$$

Fig. 9: (a) Salinity accumulation, S^*_{ac} (psu), for base conditions. (b) Difference between salinitiy accumulations: plan minus base. While differences are numerically small, a clear spatial pattern of differences can be observed.

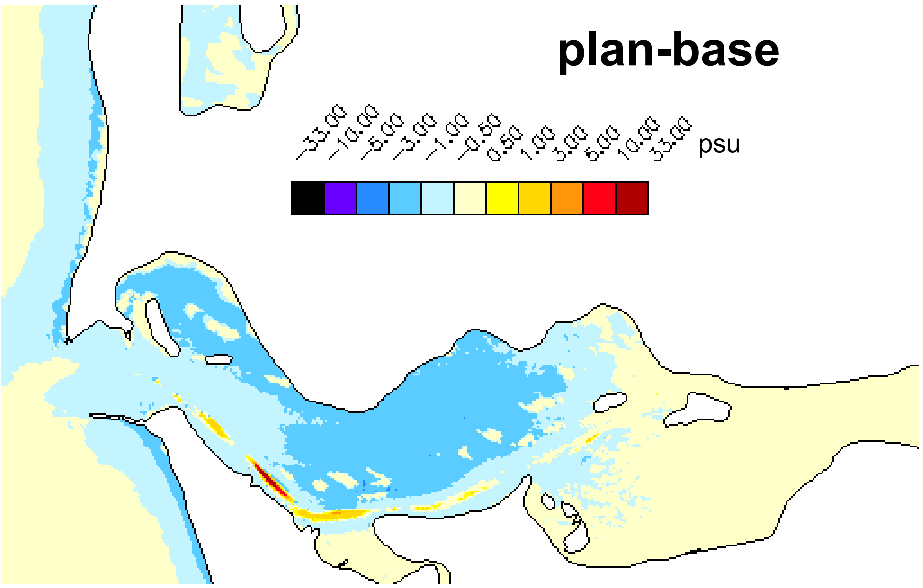
Note: definition of S^*_{ac} is, for plan, slightly different than in Figs 3 and 6 (scaling is based on the pre-deepening depth of the channel, arguably a better measure of impact – see Fig. 11)

Note: Differences between base and plan may be underestimated, because of difficulty in controlling upstream discharges in version 3 of the simulation database.

(a)



(b)



1999 – week 31

(August)

Version 3 of simulation database

$$S_{ac}^{*} = \frac{\iint\limits_{D,T} s(t,z)\,dz\,dt}{D_{MSL}^{\text{base}}\,T}$$

Note: definition of S^*_{ac} is, for plan, slightly different than in Figs 3 and 6 (scaling is based on the pre-deepening depth of the channel, arguably a better measure of impact – see Fig. 11)

Fig. 10: (a) Salinity accumulation, S^*_{ac} (psu), for base conditions. (b) Difference between salinitiy accumulations: plan minus base. While differences are numerically small, a clear spatial pattern of differences can be observed.

Note: Differences between base and plan may be underestimated, because of difficulty in controlling upstream discharges in version 3 of the simulation database.

AM169: 1997 – week 18 (version 3 of the simulation database)

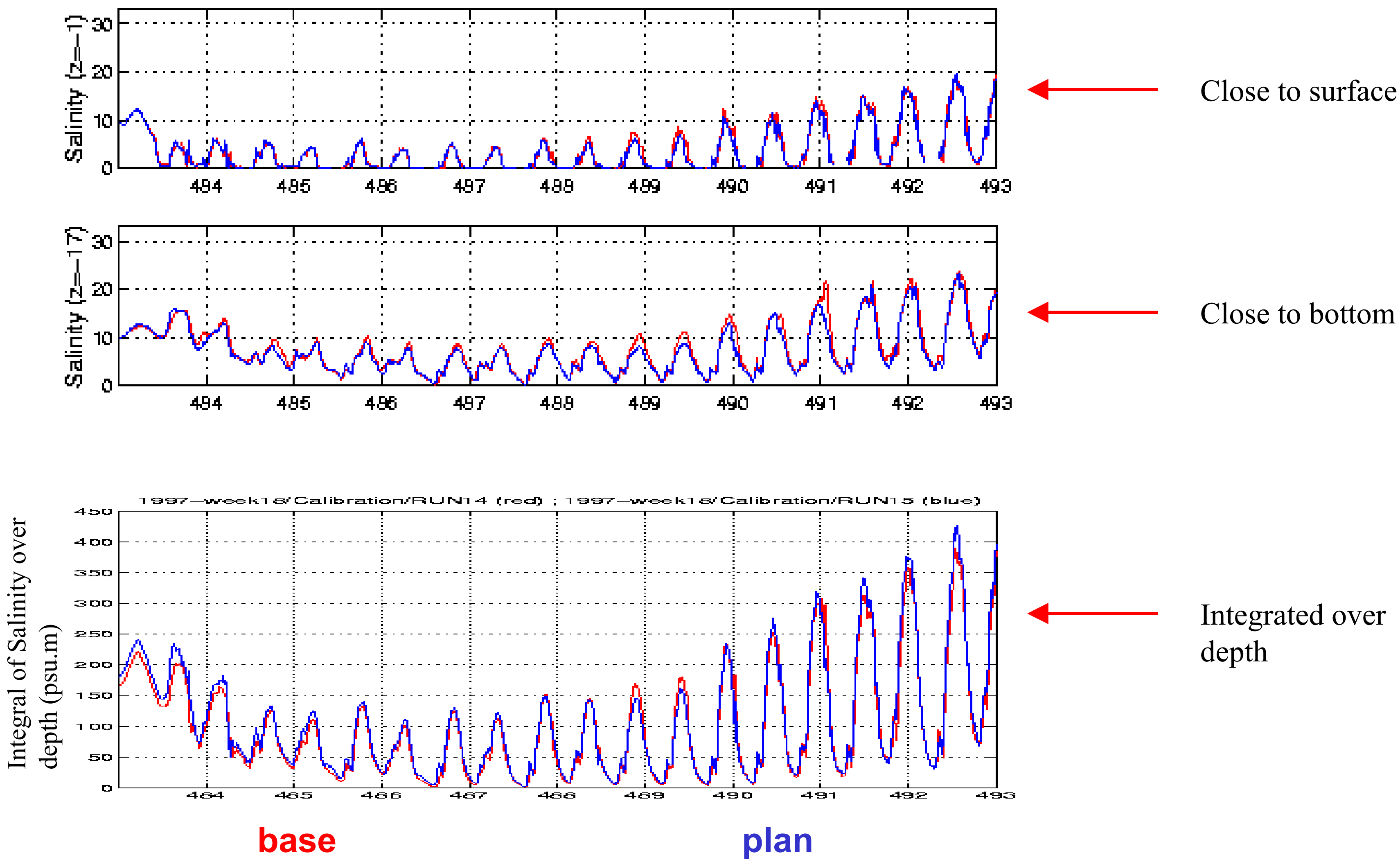


Fig. 11: Because channel is deeper for plan than for base, integration of salt over depth may show larger amount of salt for plan even when salinities are lower at a given depth. This suggests that S^*_{ac} may be preferable to S_{ac} as a metric of impact. Note also that spring-neap transition modulates base-plan differences, an effect best seen when (as in version 3 of the simulation database) stratification is realistically represented.

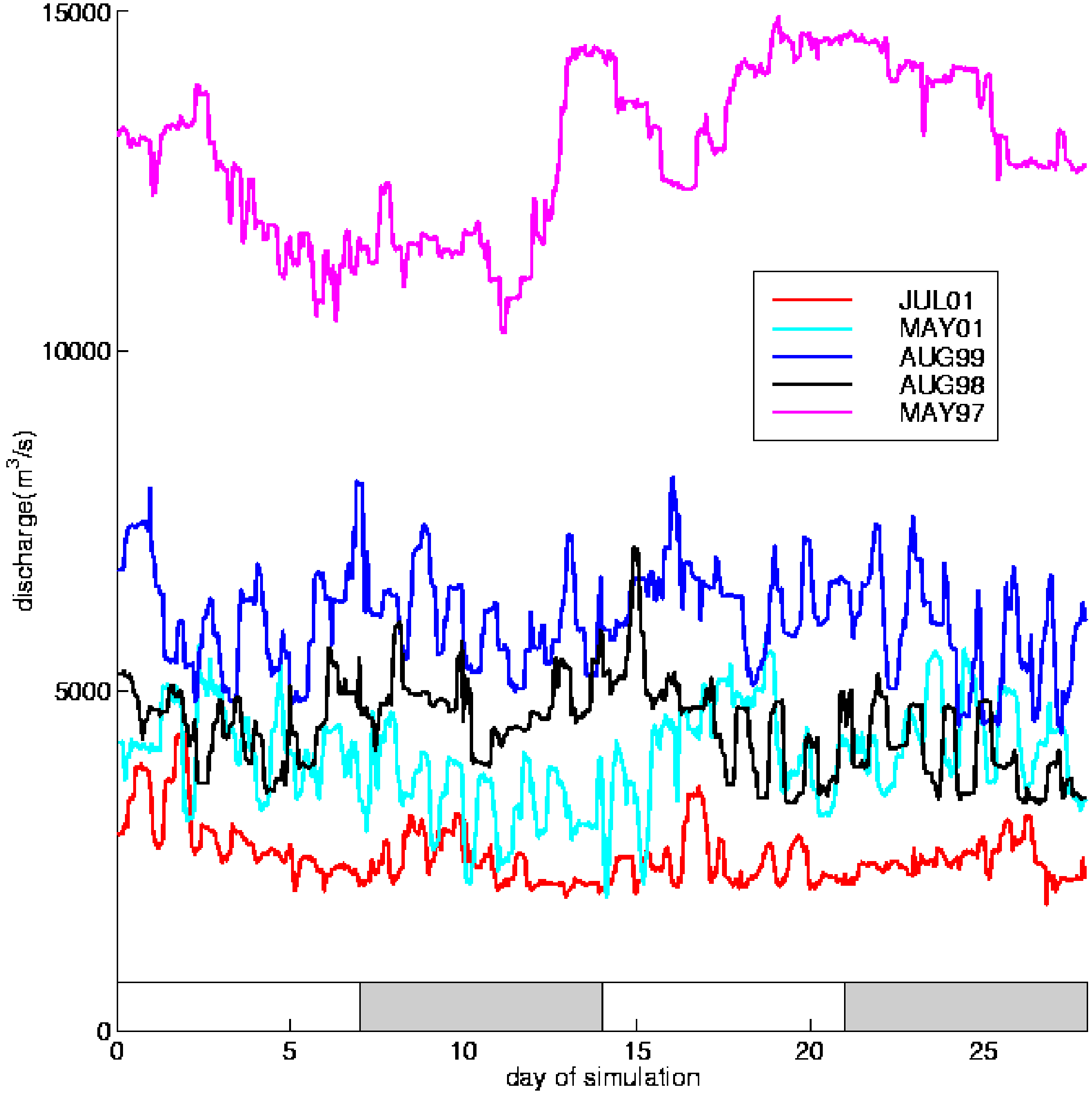


Fig. 12: River discharges at Bonneville, for the various periods considered in this project.

Note:

Month	Refers to …
'May'	Weeks 18-21 of the year (week 18 includes days in late April)
'July'	Weeks 27-30 (week 27 includes days in late June)
'Aug'	Weeks 31-34 (week 31 includes days in late July)

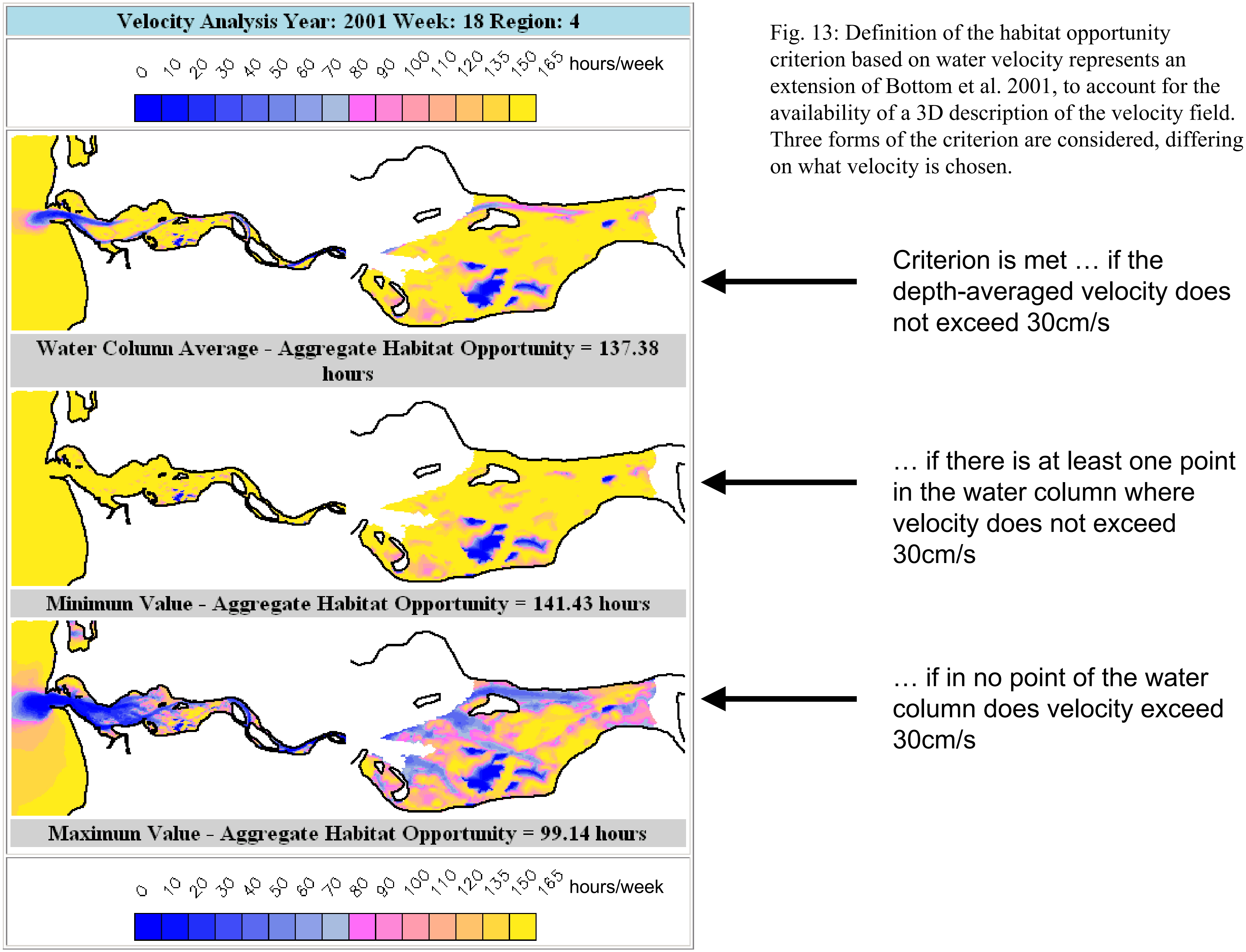


Fig. 13: Definition of the habitat opportunity criterion based on water velocity represents an extension of Bottom et al. 2001, to account for the availability of a 3D description of the velocity field. Three forms of the criterion are considered, differing on what velocity is chosen.

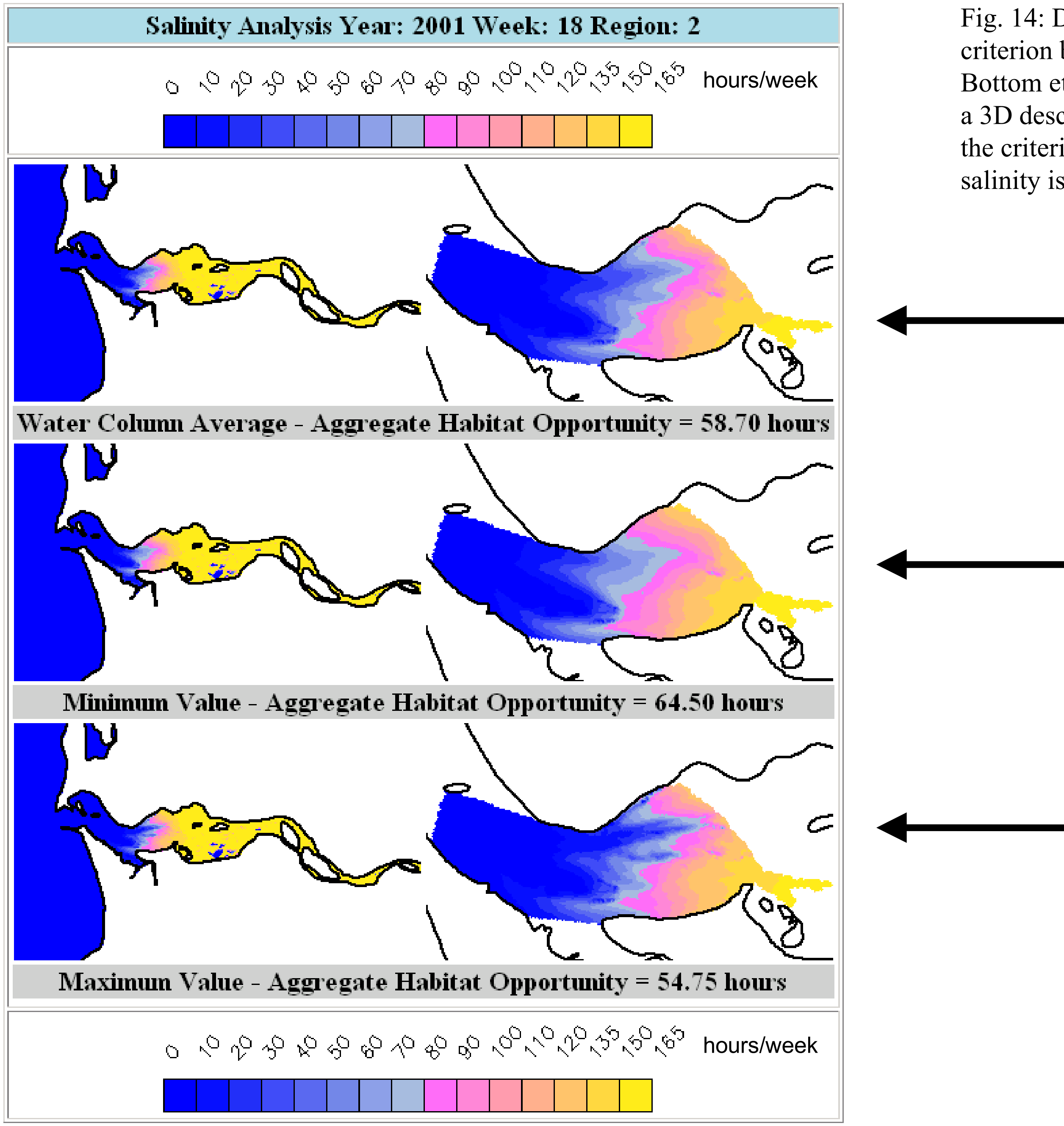


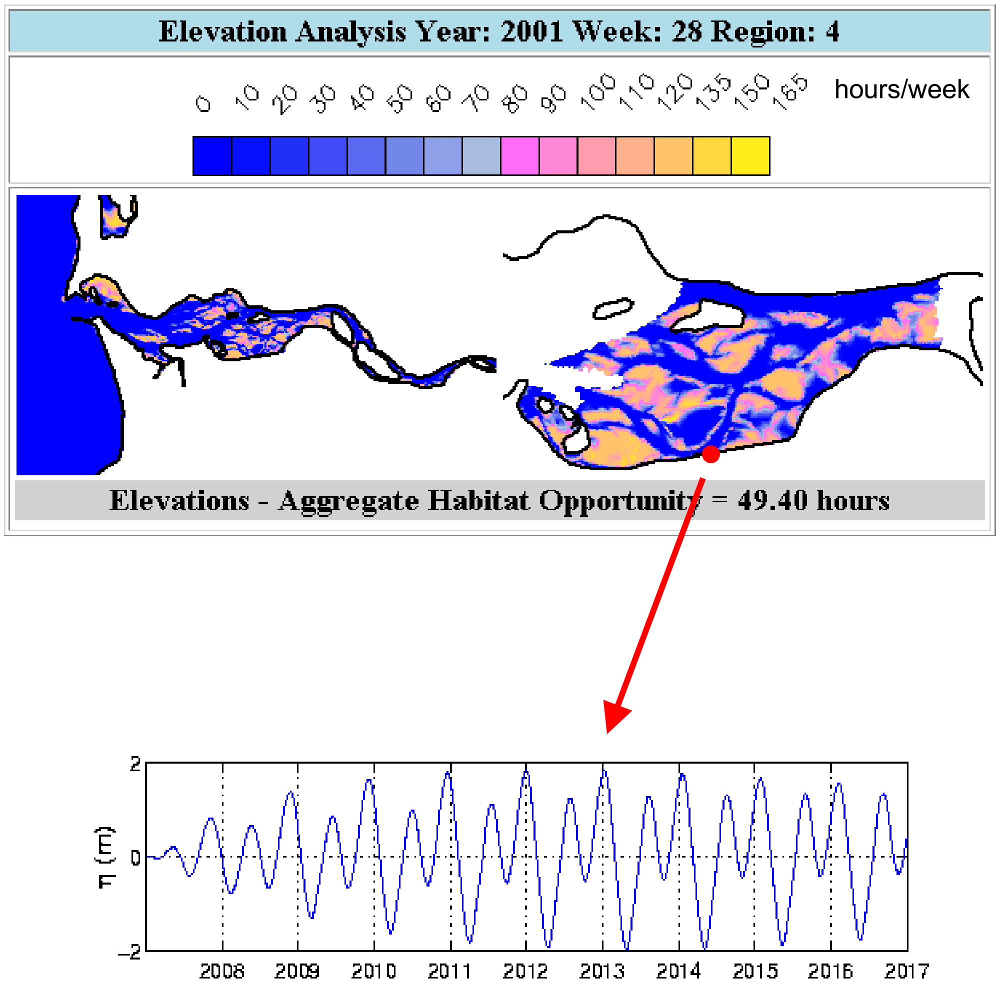
Fig. 14: Definition of the habitat opportunity criterion based on salinity represents an extension of Bottom et al. 2001, to account for the availability of a 3D description of the salinity field.. Three forms of the criterion are considered, differing on what salinity is chosen.

Criterion is met … if the depth-averaged salinity does not exceed 5 psu

… if there is at least one point in the water column where salinity does not exceed 5 psu

… if in no point of the water column does salinity exceed 5 psu

Fig. 15: Definition of the habitat opportunity criterion based on water depth is the same as in Bottom et al. 2001.



Criterion is met if the water depth is between 10cm and 2m

Note: Tidal fluctuation controls much of the opportunity in regions like Cathlamet Bay

Salinity criteria
2001 – week 18
(May)
Version 2 of simulation database

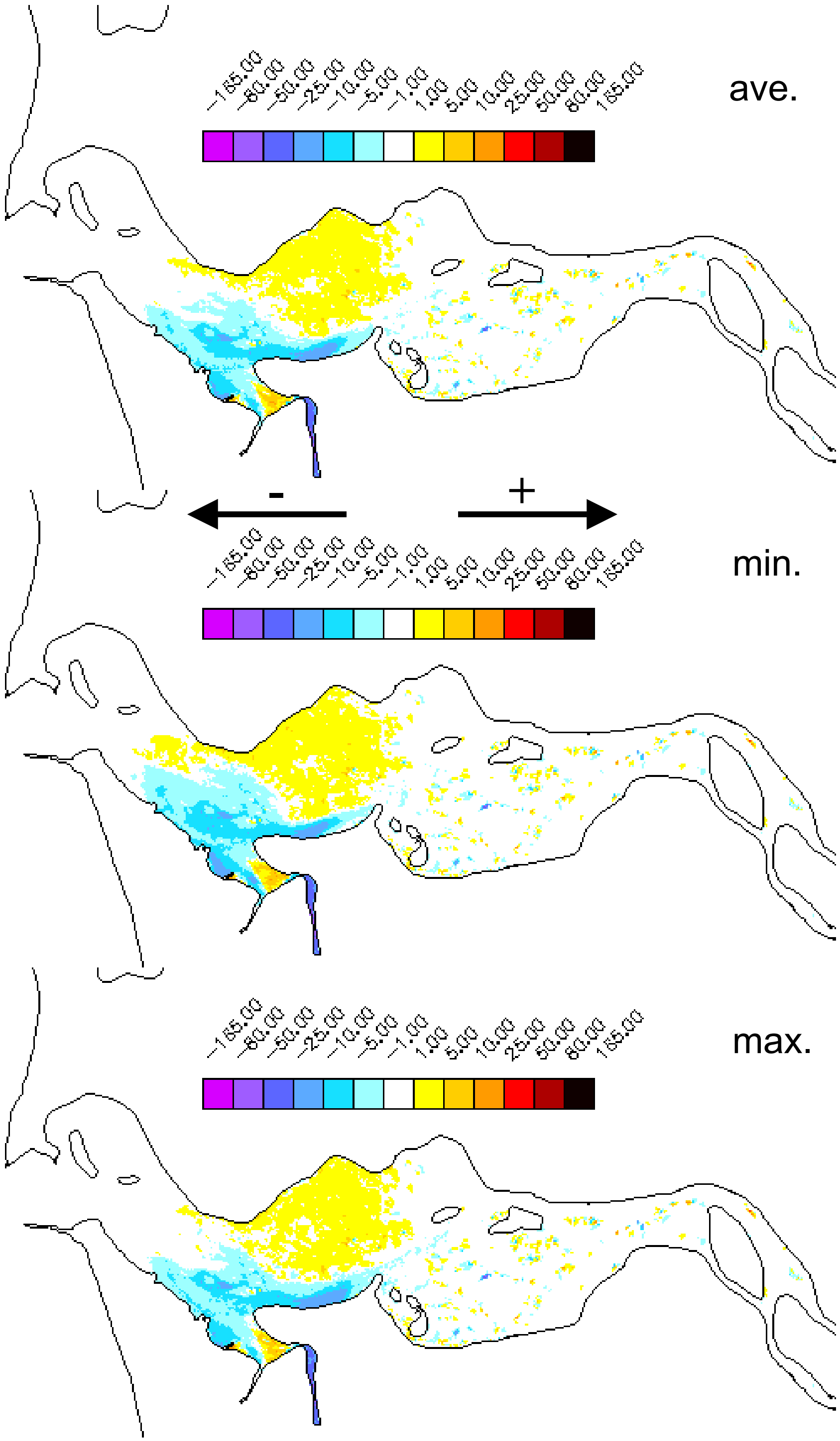
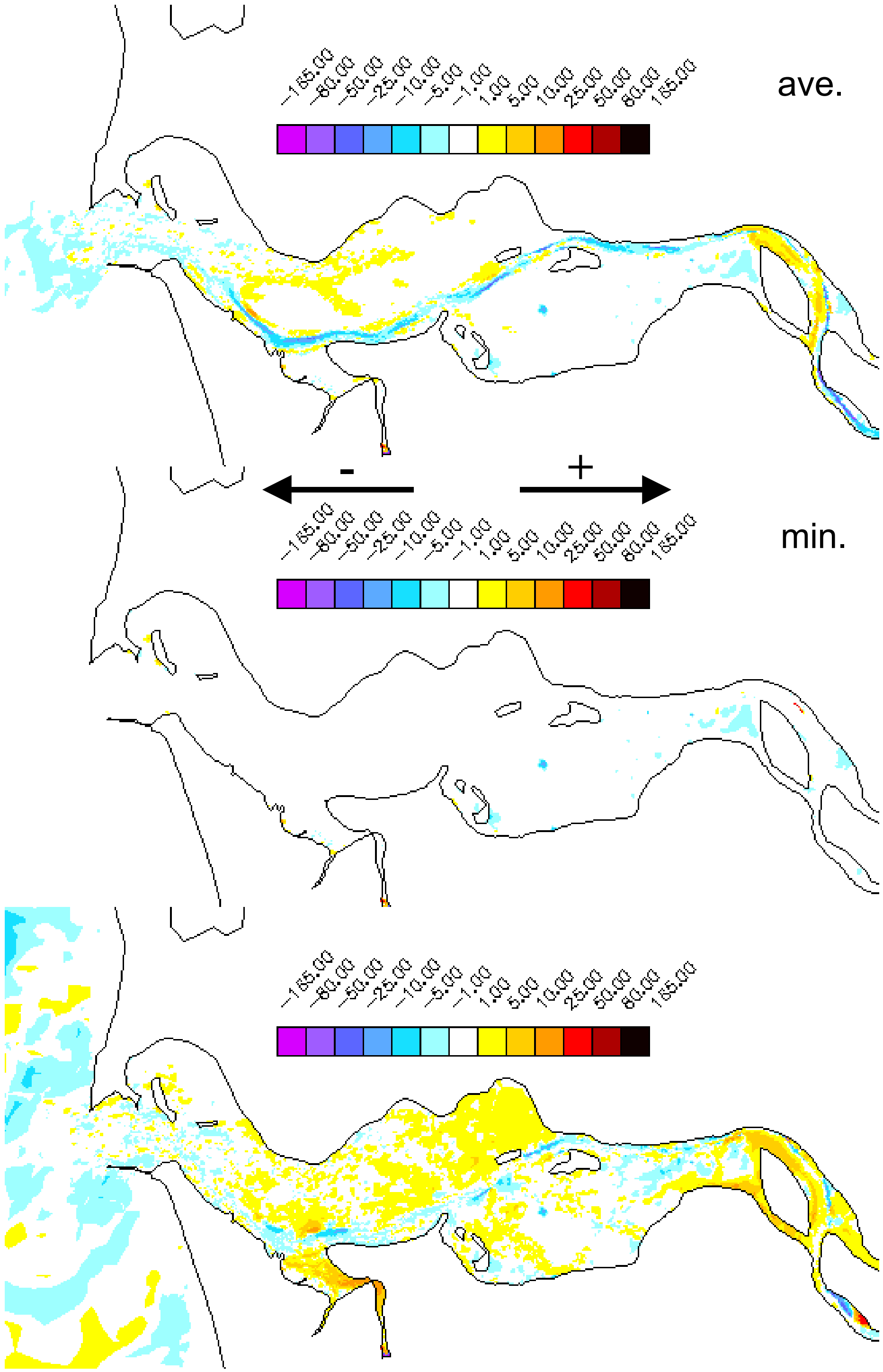


Fig. 16: Impact of the plan on habitat opportunity, in hours/week, based on: (top panel) depth-averaged salinity; (middle panel) minimum salinity over depth; and (bottom panel) maximum salinity over depth.

Note:

- ❑ Positive values indicate higher habitat opportunity for plan (thus a beneficial impact)
- ❑ Negative values indicate higher habitat opportunity for base (thus a negative impact)



Velocity criteria 2001 – week 18

(May)

Version 2 of simulation database

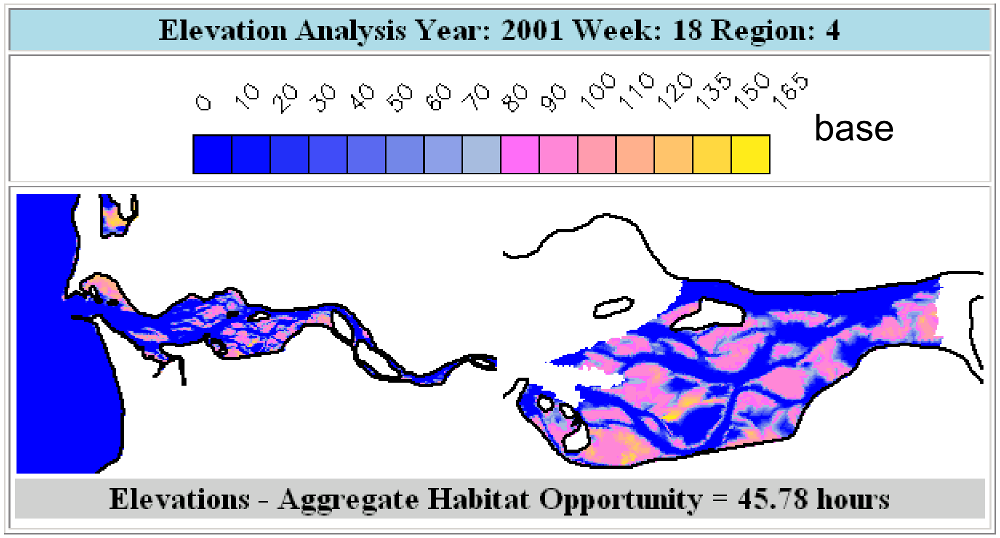
Fig. 17: Impact of the plan on habitat opportunity, in hours/week, based on: (top panel) depth-averaged velocity; (middle panel) minimum velocity over depth; and (bottom panel) maximum velocity over depth.

Note:

- Positive values indicate higher habitat opportunity for plan (thus a beneficial impact)
- Negative values indicate higher habitat opportunity for base (thus a negative impact)

Depth criterion
2001 – week 18
(May)

Version 2 of simulation database



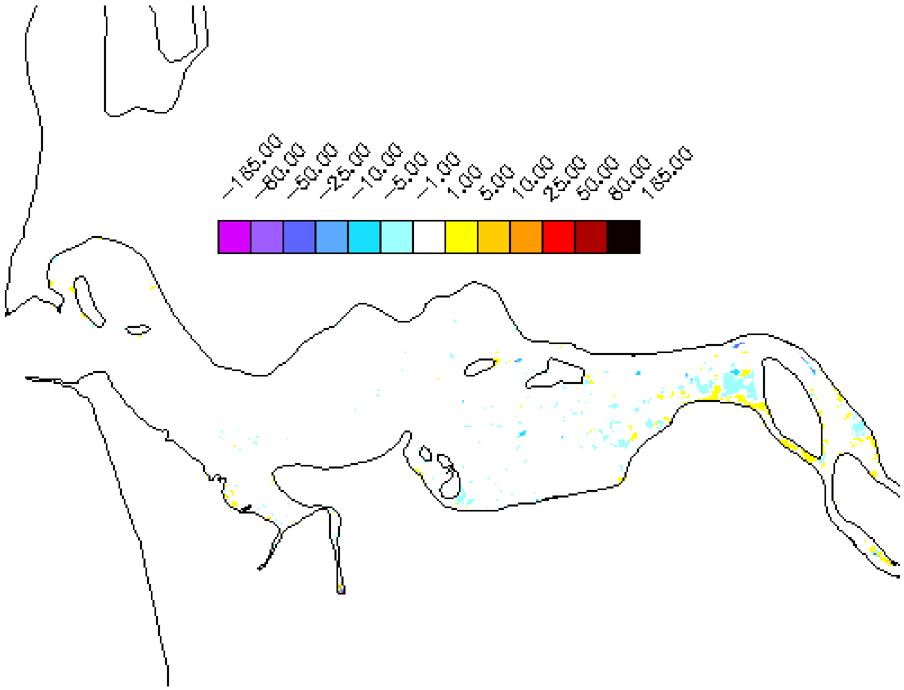
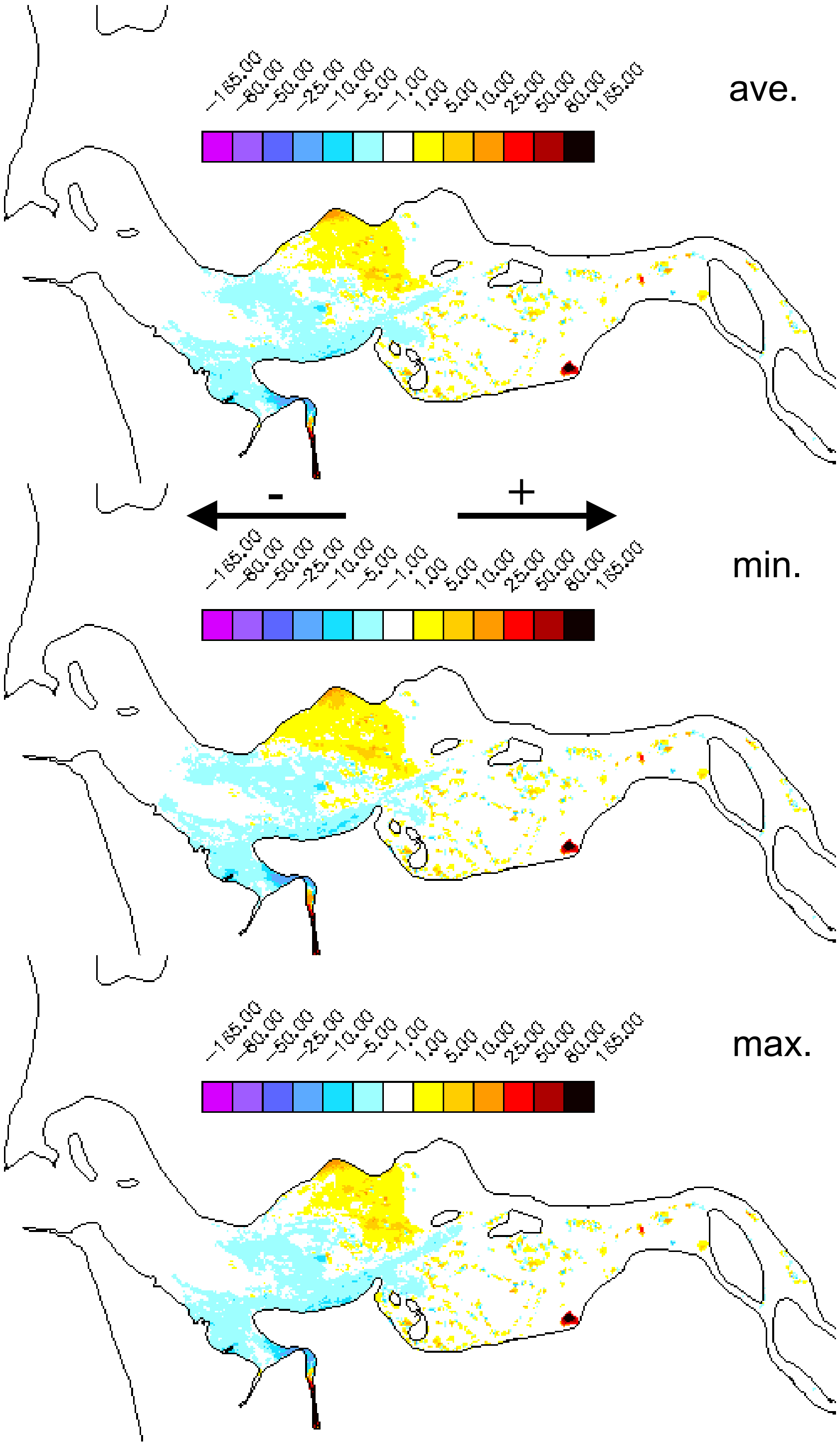


Fig. 18: (top panel) Habitat opportunity, for base conditions; (bottom panel) impact of the plan on habitat opportunity, based on depth. Units are in hours/week.

Note: In bottom panel,

- Positive values indicate higher habitat opportunity for plan (thus a beneficial impact)
- Negative values indicate higher habitat opportunity for base (thus a negative impact)

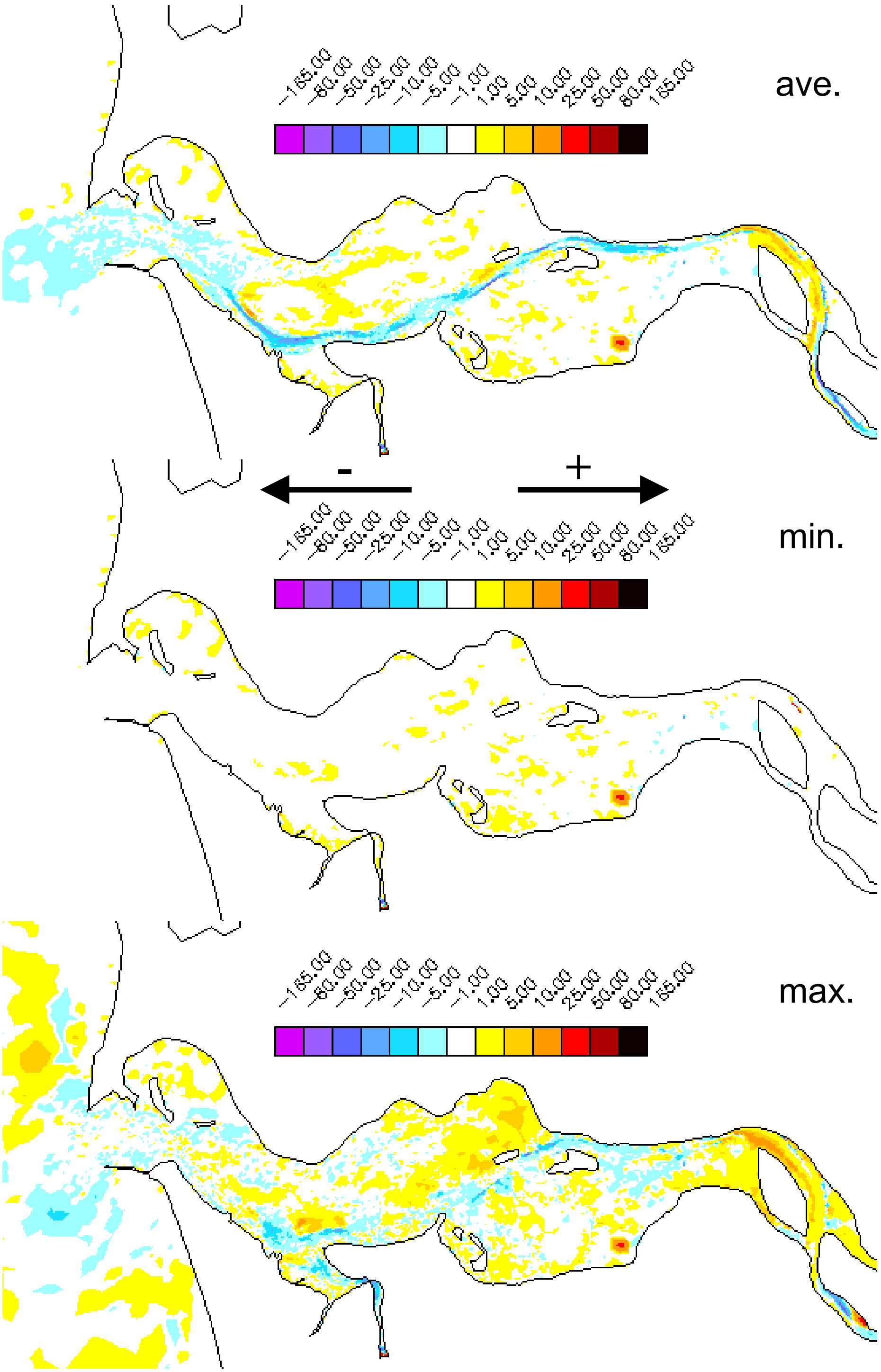


Salinity criteria
2001 – week 27
(July)
Version 2 of simulation database

Fig. 19: Impact of the plan on habitat opportunity, in hours/week, based on: (top panel) depth-averaged salinity; (middle panel) minimum salinity over depth; and (bottom panel) maximum salinity over depth.

Note:

- ❑ Positive values indicate higher habitat opportunity for plan (thus a beneficial impact)
- ❑ Negative values indicate higher habitat opportunity for base (thus a negative impact)



Velocity criteria
2001 – week 27

(July)

Version 2 of simulation database

Fig. 20: Impact of the plan on habitat opportunity, in hours/week, based on: (top panel) depth-averaged velocity; (middle panel) minimum velocity over depth; and (bottom panel) maximum velocity over depth.

Note:

- ❑ Positive values indicate higher habitat opportunity for plan (thus a beneficial impact)
- ❑ Negative values indicate higher habitat opportunity for base (thus a negative impact)

Depth criterion
2001 – week 27
(July)
Version 2 of simulation database

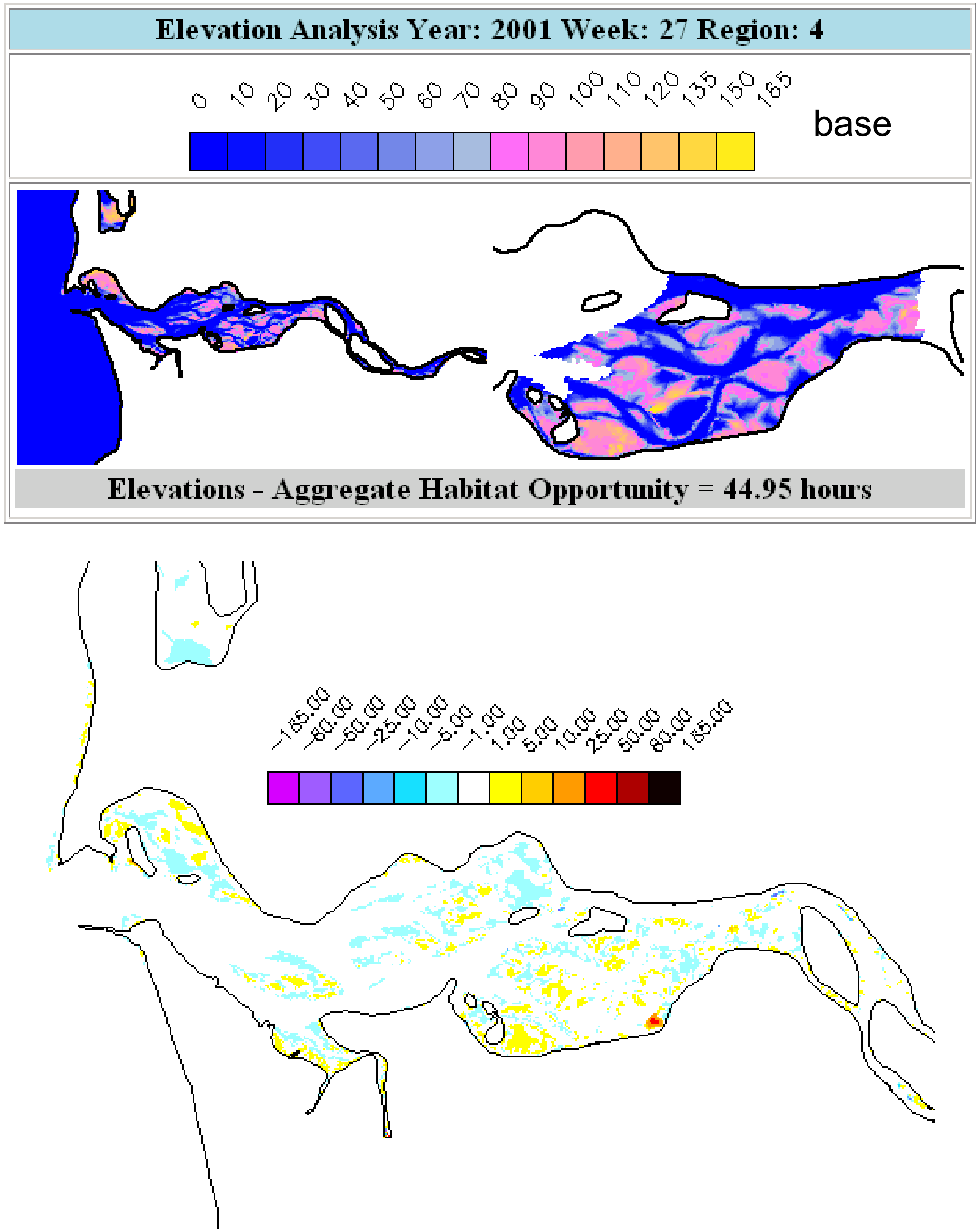


Fig. 21: (top panel) Habitat opportunity, for base conditions; (bottom panel) impact of the plan on habitat opportunity, based on depth. Units are in hours/week.

Note: In bottom panel,
- Positive values indicate higher habitat opportunity for plan (thus a beneficial impact)
- Negative values indicate higher habitat opportunity for base (thus a negative impact)

$$H = \sum_{\text{elements}} y_e . A_e \, / \sum A_e$$

H – weighted average hours in which criterion is met over a specific period of time (a 720h month in Bottom et al. 2001; a 165h week in this study)

y_e – hours in which criterion is met (average over element)

A_e – area of element

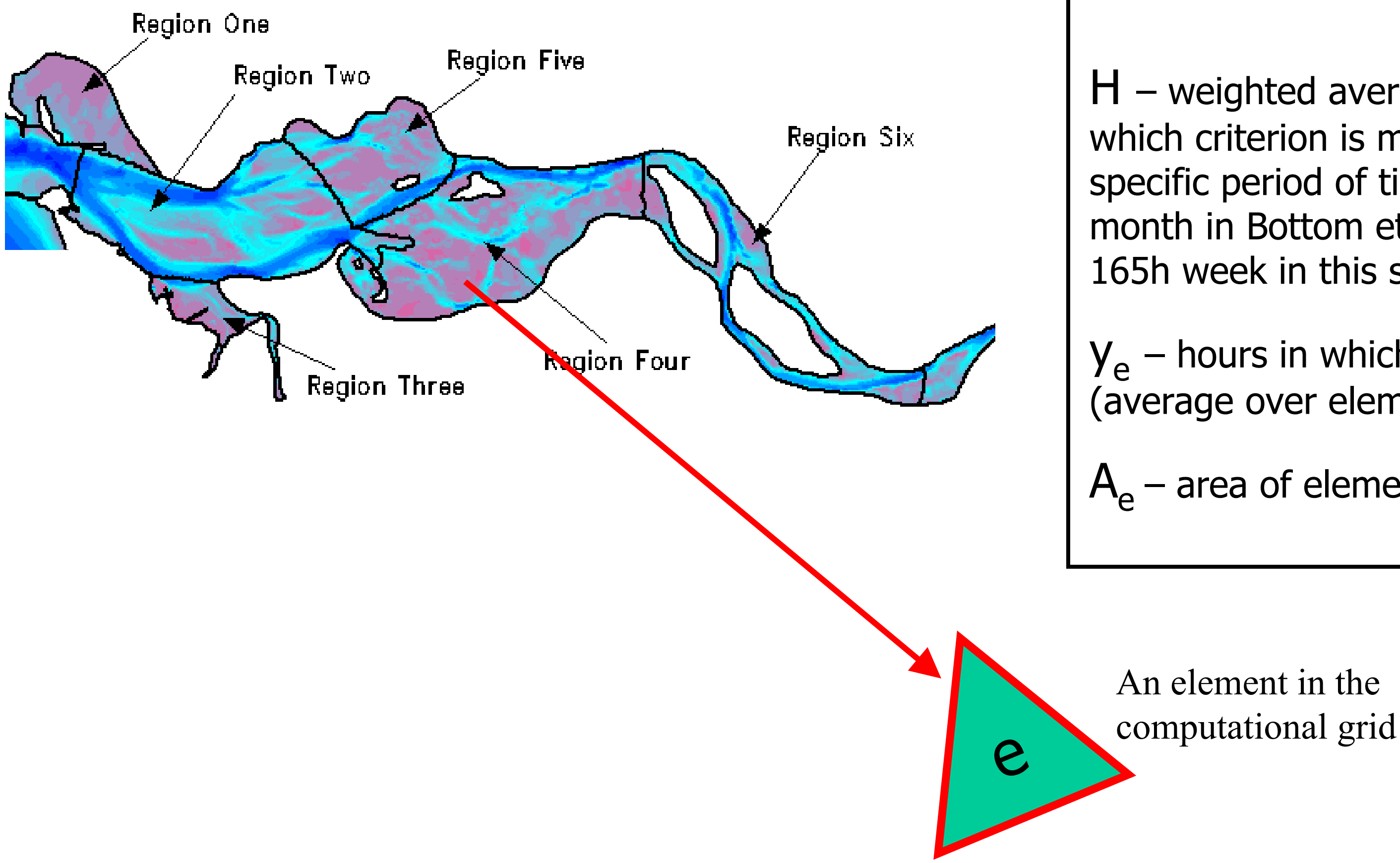


Fig. 22: The analysis of habitat opportunity in Bottom et al. 2001 concentrated in the domain and regions represented above. For each region, an average habitat opportunity can be computed as shown in the panel. In this report we typically emphasized the analysis of the domain over individual regions.

Salinity criteria: 1999 – week 31 (August, versions 3 [left] and 4 [right] of the database)

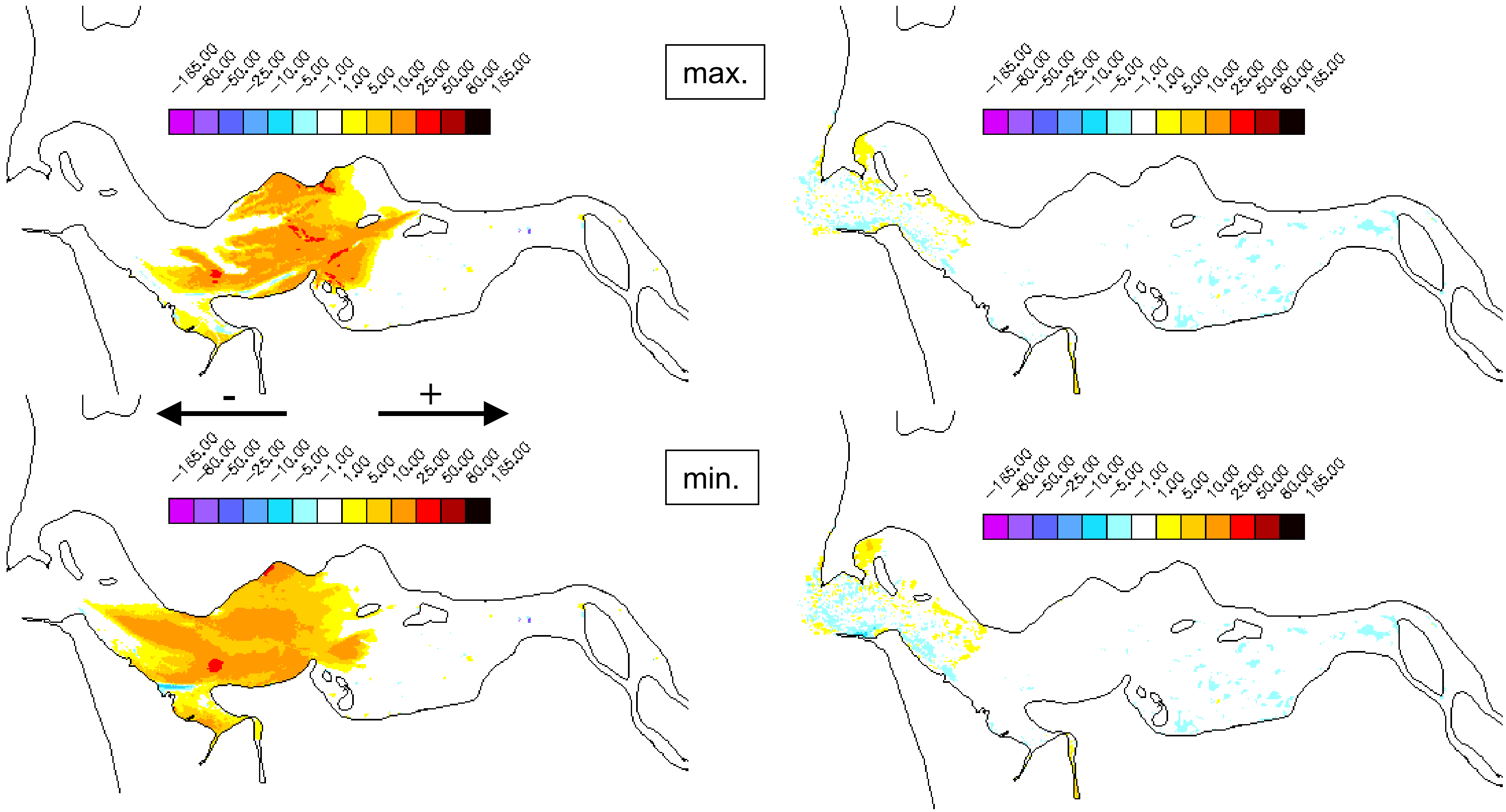


Fig. 23: Impact of the plan on habitat opportunity for: (top panels) maximum salinity; (bottom panels) minimum salinity.

Note: The differences between left and right panels illustrate the effect of remaining model uncertainties on predicted impacts. Left panels are computed from version 3 of the database, where stratification is realistic but *plan* discharges are slightly exaggerated relative to *base*; we observe significant differences between top and bottom panels, and consider impacts of the plan under-estimated but with reasonable spatial patterns (qualitatively consistent with Figs. 16 and 19). Right panels are computed from version 4 of the database, where stratification is under-estimated but *plan* and *base* discharges are consistent; we do not observe significant differences between top and bottom panels, and impacts are much more neutral (reflecting both consistency of discharges and underestimation of salinity penetration in both *base* and *plan*).

Note: Positive values indicate higher habitat opportunity for plan (thus a beneficial impact). Negative values indicate higher habitat opportunity for base (thus a negative impact).

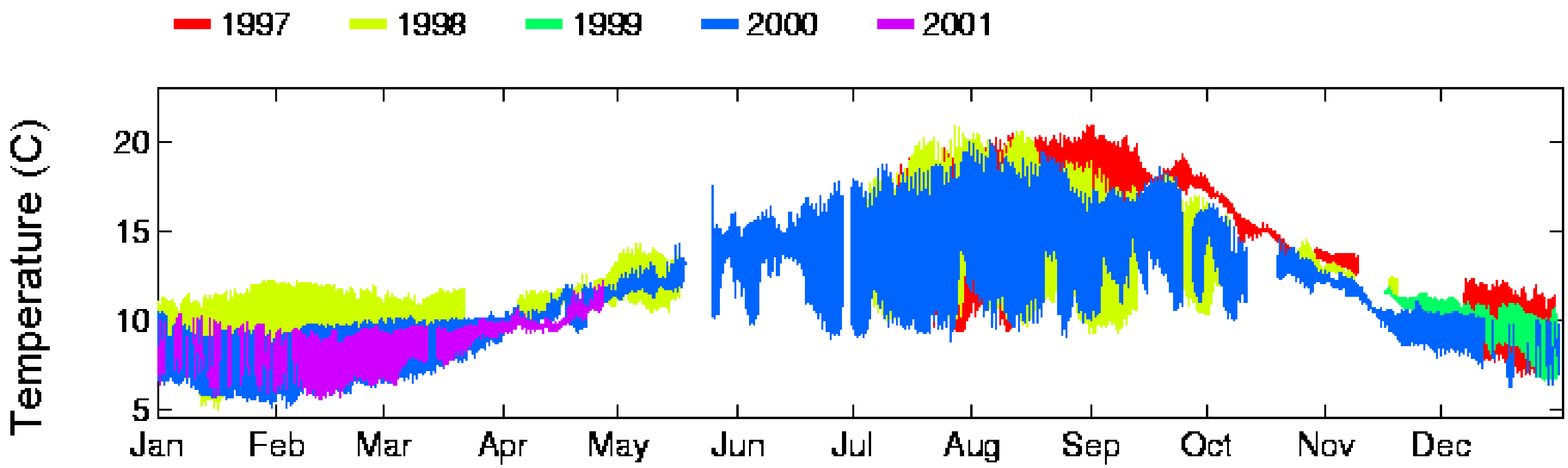


Fig. 24: Annual variation of temperature at Sand Island (raw data, from sensor installed low in the water column), for 1997-2001. River (ocean) water roughly represents the upper (lower) envelope of the temperature curve at Sand Island during the Summer, and the upper (lower) envelope during the Winter.

(a)

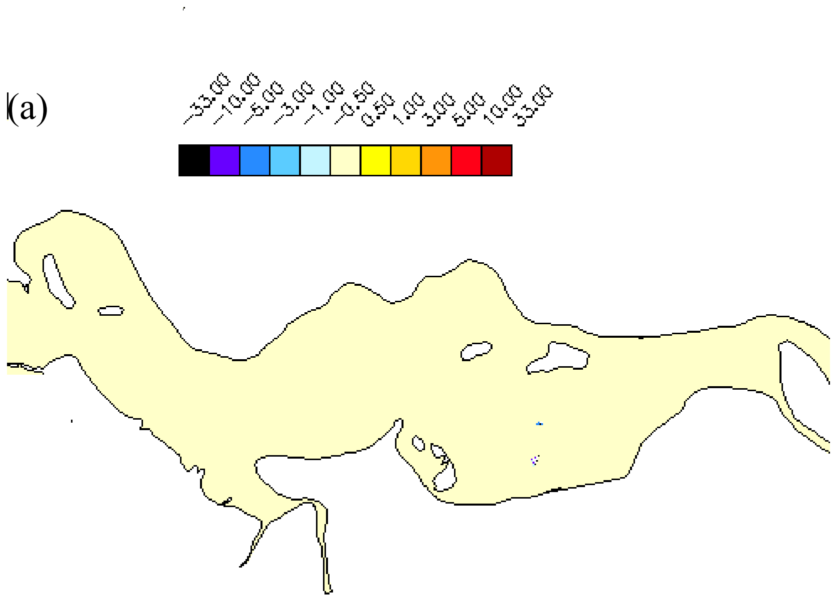
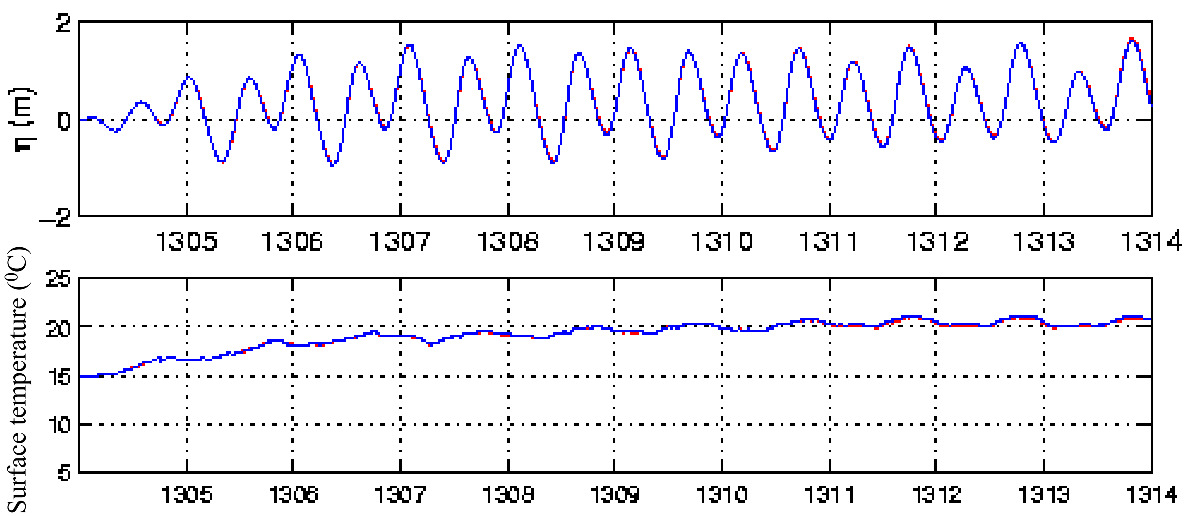


Fig. 25: (a) Differences in maximum temperature between base and plan. (b) Time series of water elevation and temperature at Svensen Island (see Fig. 7 for location). The red line corresponds to base and the blue line to plan.

Note: Time is in *CORIE days* (origin: January 1, 1996). The model is allowed to freely adjust to air-water heat exchanges (adjustment can be seen in the form a significant warm-up during the first 3-4 days).

(b)



1999 – week 31

(August)

Version 4 of
simulation database

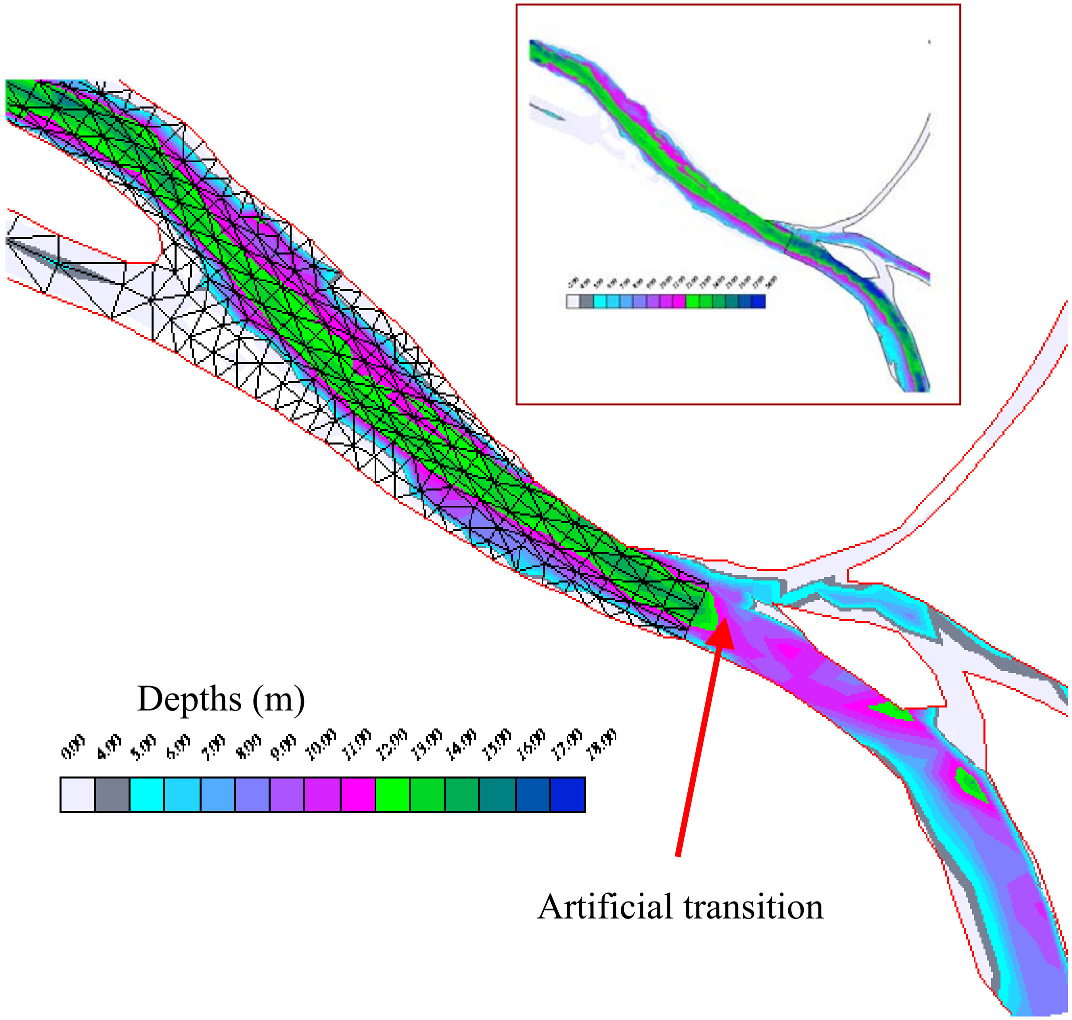
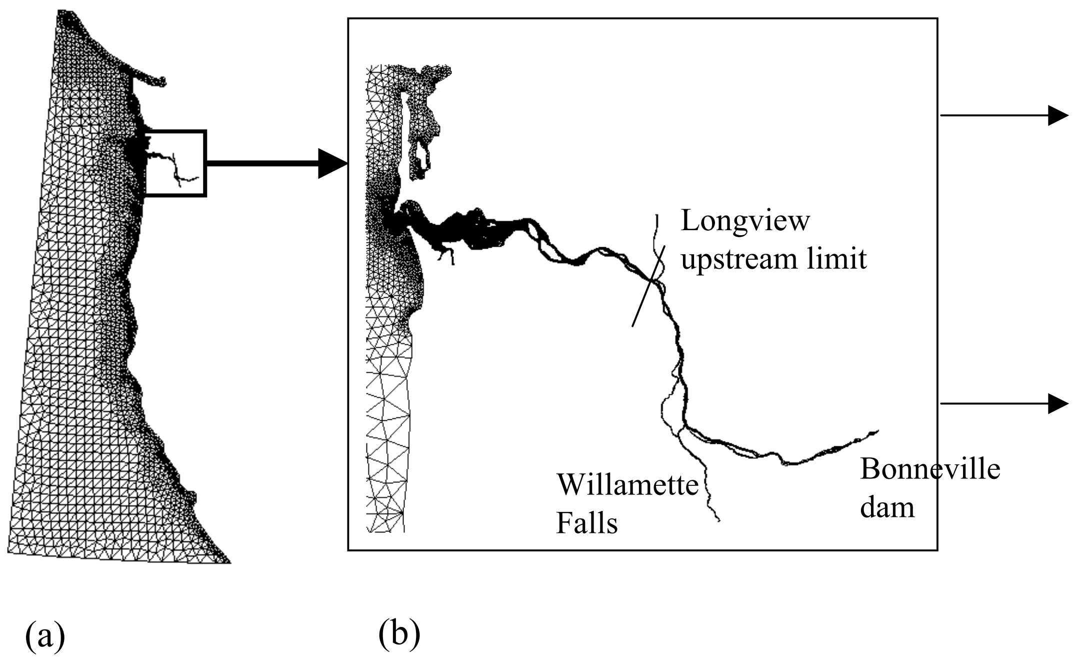
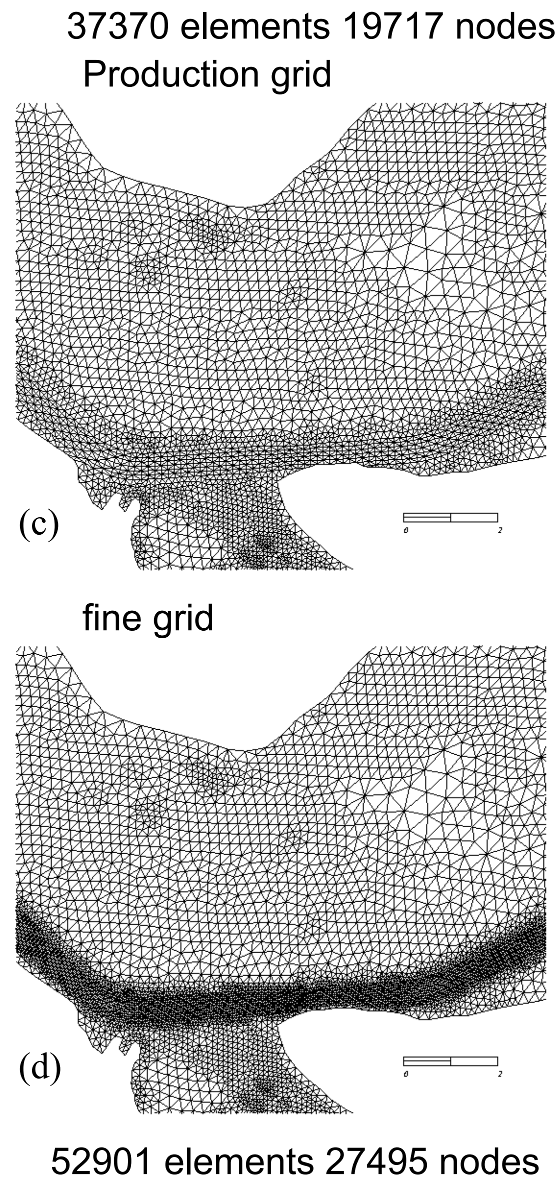


Fig. 26: A detailed analysis of the bathymetry available to us at the beginning of the project revealed an artificial, brusque transition of channel depths downstream and upstream of Longview (main figure). The problem was solved (inset) with bathymetry provided by the Corps of Engineers, but influenced early choice of grid domain (Fig. 27)

Fig. 27: Several grids were considered in this project. (a) All grids extended oceanward beyond the continental slope, north to British Columbia and south to California. (b) Most simulations were conducted with grids extending upstream only to Longview. Version 4 and selected version 1 simulations were conducted with *complete* grids, extending upstream to Bonneville dam and to Willamette Falls. (c) Most simulations were conducted with *production* grids, characterized by moderate spatial resolution. (d) Selected version 1 simulations were conducted with a *fine* grid, with twice the spatial resolution. Both fine and production grids became coarser upstream of Longview.





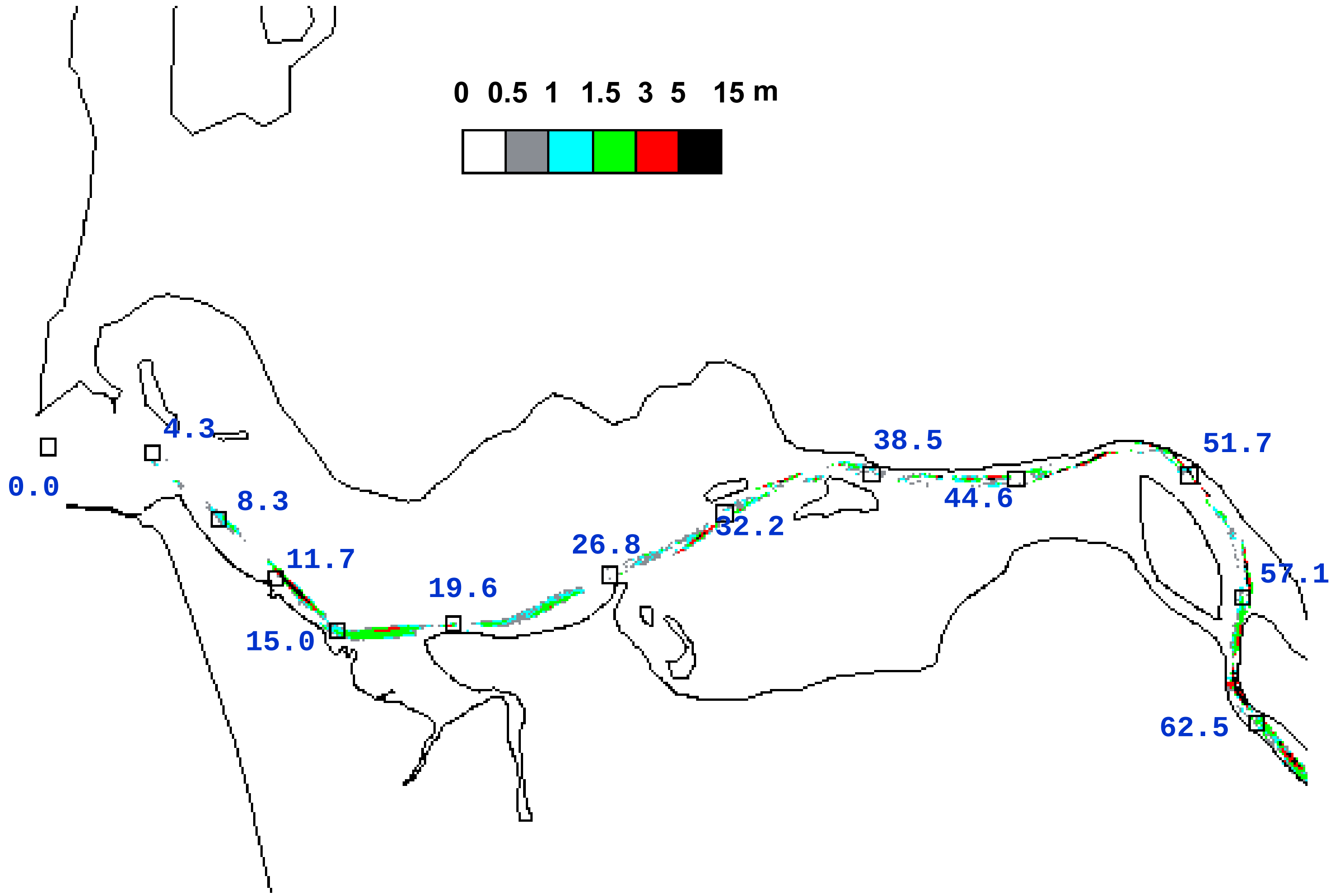


Fig. 28a: Depth differences between base and plan (general view). Numerical values represent kilometers of distance to the entrance of the estuary, measured along the navigation channel.

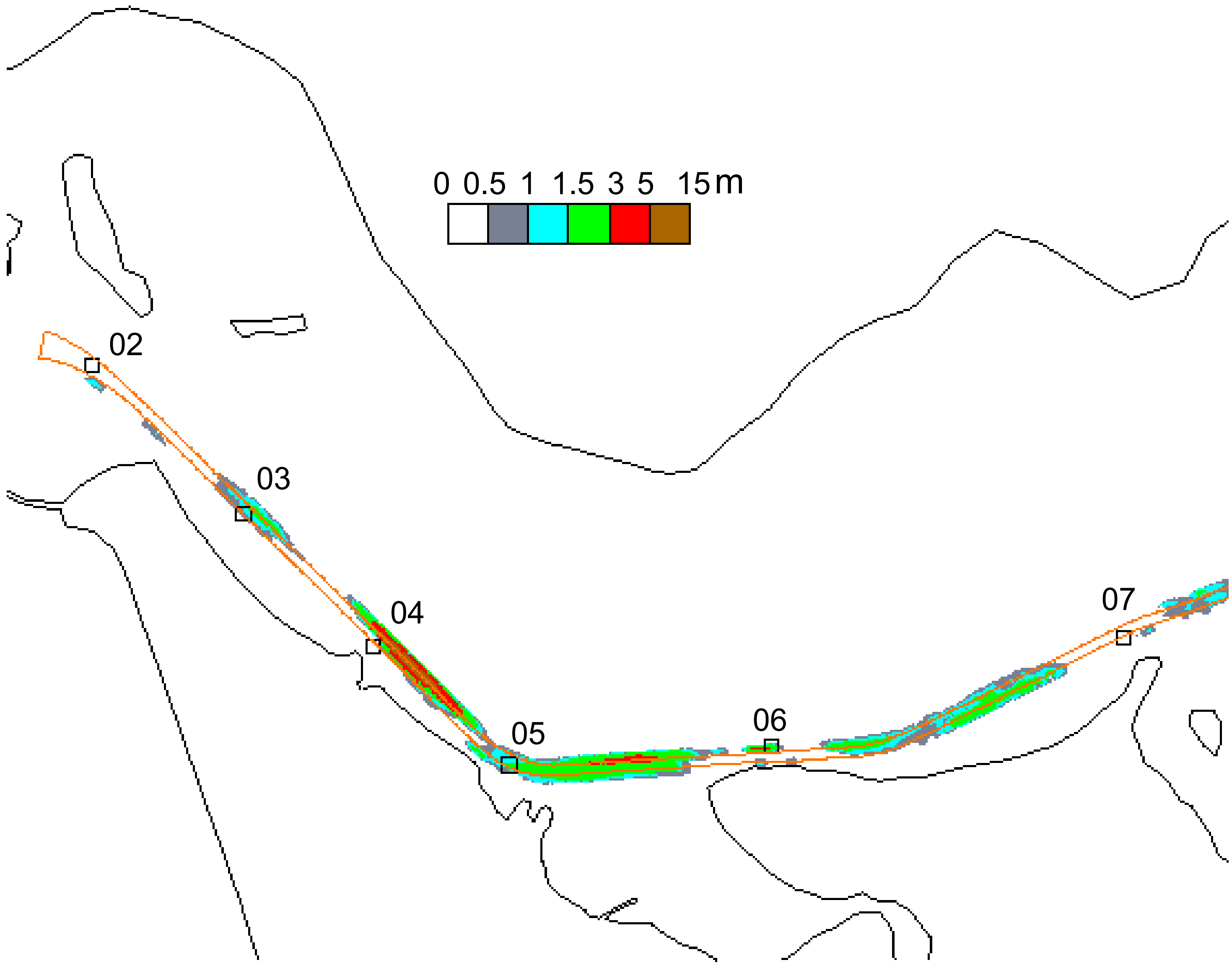


Fig. 28b: Depth differences between base and plan (detail). Numbers refer to the cross sections shown for illustrative purposes in Fig. 29.

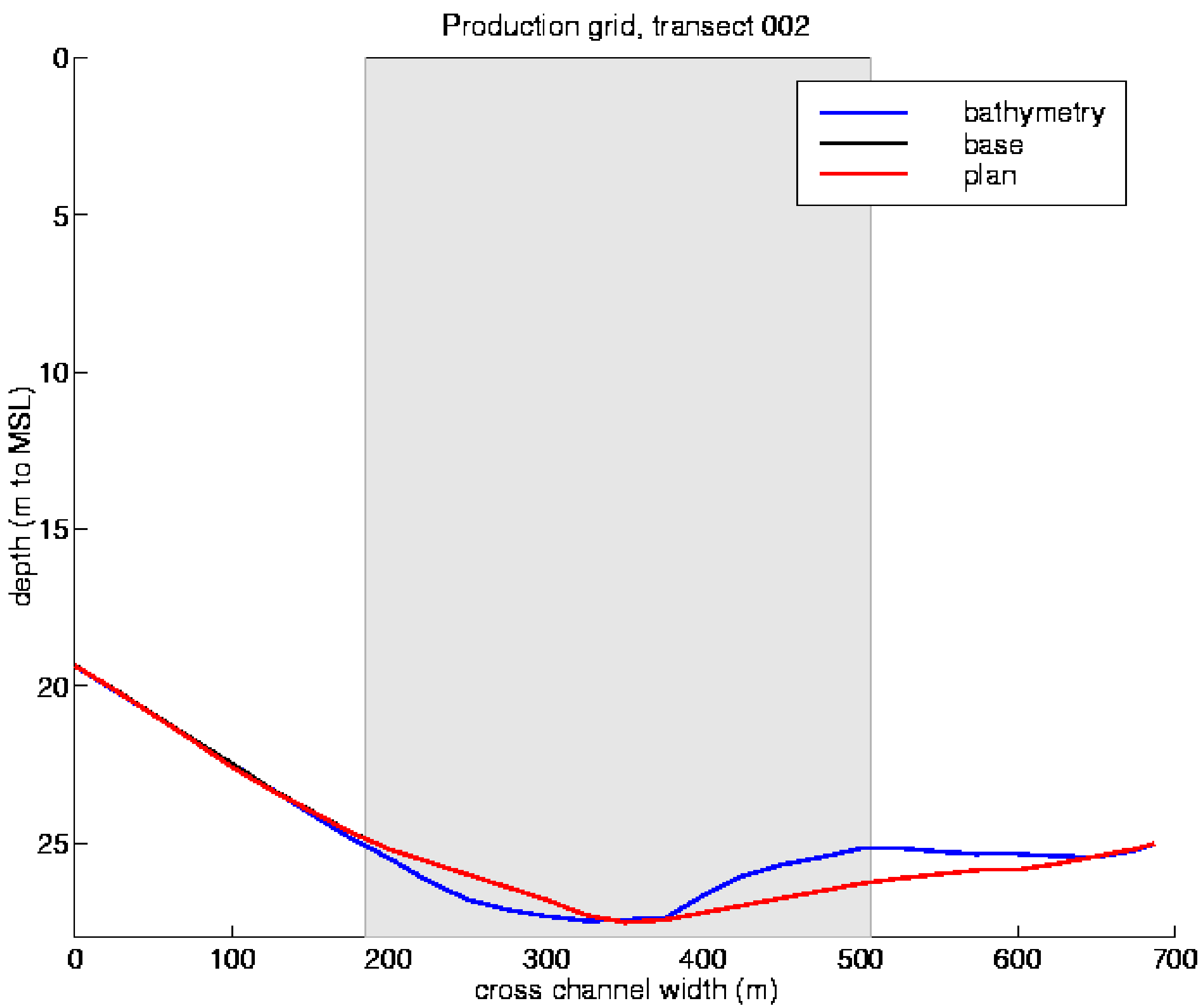


Fig. 29a: Depth at cross-section 02 (see Fig. 28b for location). Different curves represent the cross-section as 'viewed' by either: the detailed grid representing bathymetric data (*bathymetry*), the production grid with base bathymetry (*base*), or the production grid with bathymetry modified to account for channel deepening (*plan*). Shaded area represents the core channel.

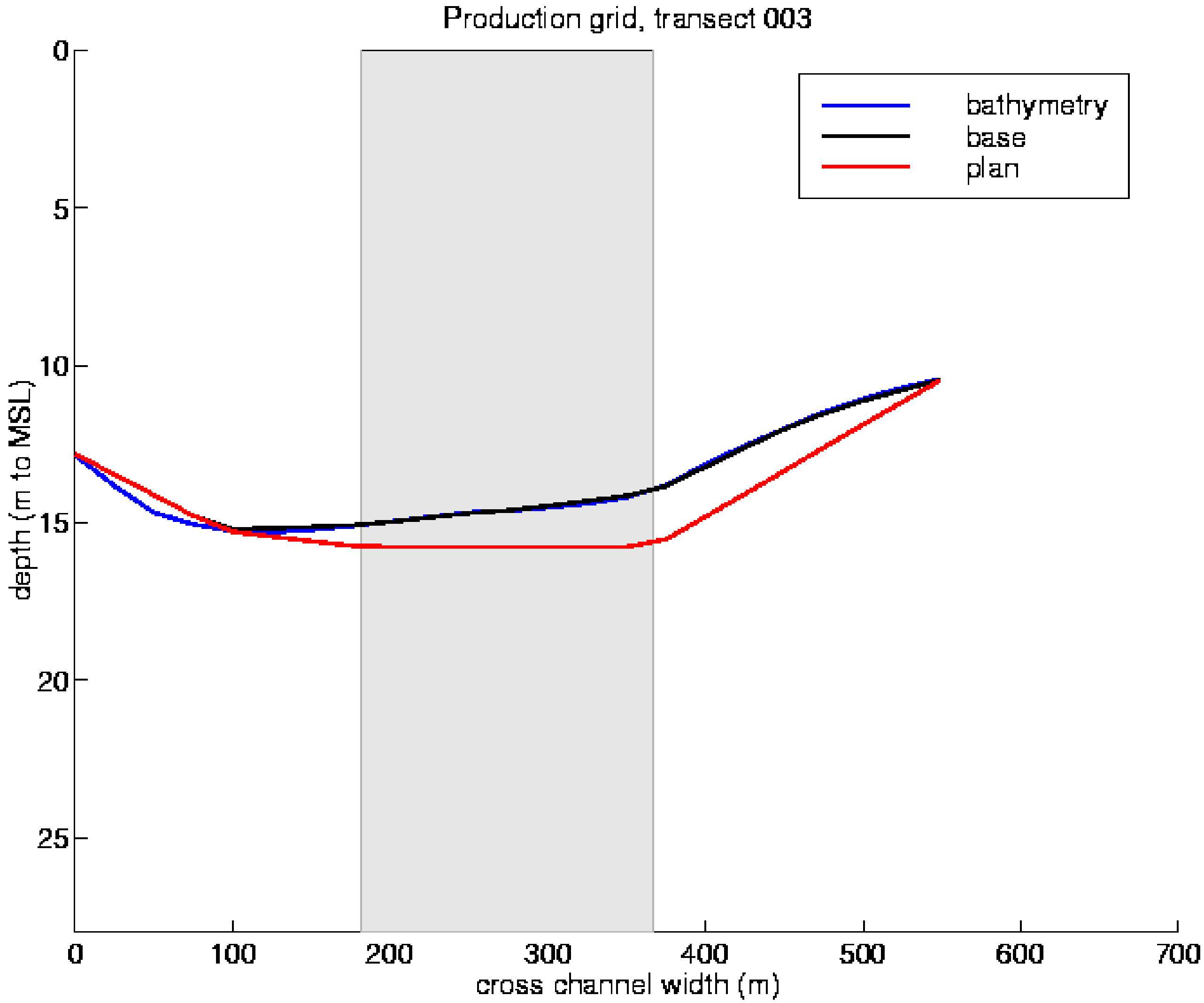


Fig. 29b: Depth at cross-section 03 (see Fig. 28b for location). Different curves represent the cross-section as 'viewed' by either: the detailed grid representing bathymetric data (*bathymetry*), the production grid with base bathymetry (*base*), or the production grid with bathymetry modified to account for channel deepening (*plan*). Shaded area represents the core channel.

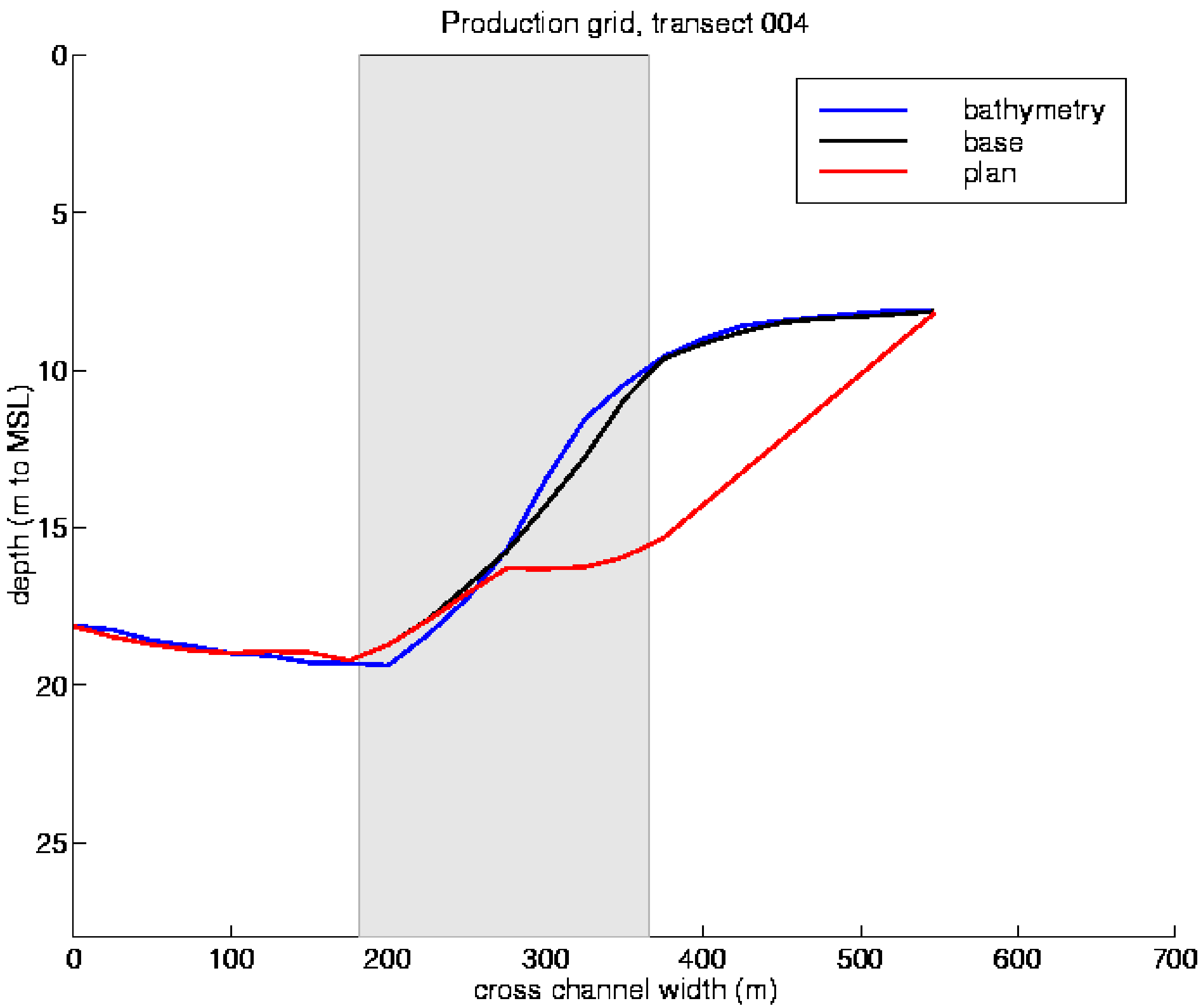


Fig. 29c: Depth at cross-section 04 (see Fig. 28b for location). Different curves represent the cross-section as 'viewed' by either: the detailed grid representing bathymetric data (*bathymetry*), the production grid with base bathymetry (*base*), or the production grid with bathymetry modified to account for channel deepening (*plan*). Shaded area represents the core channel.

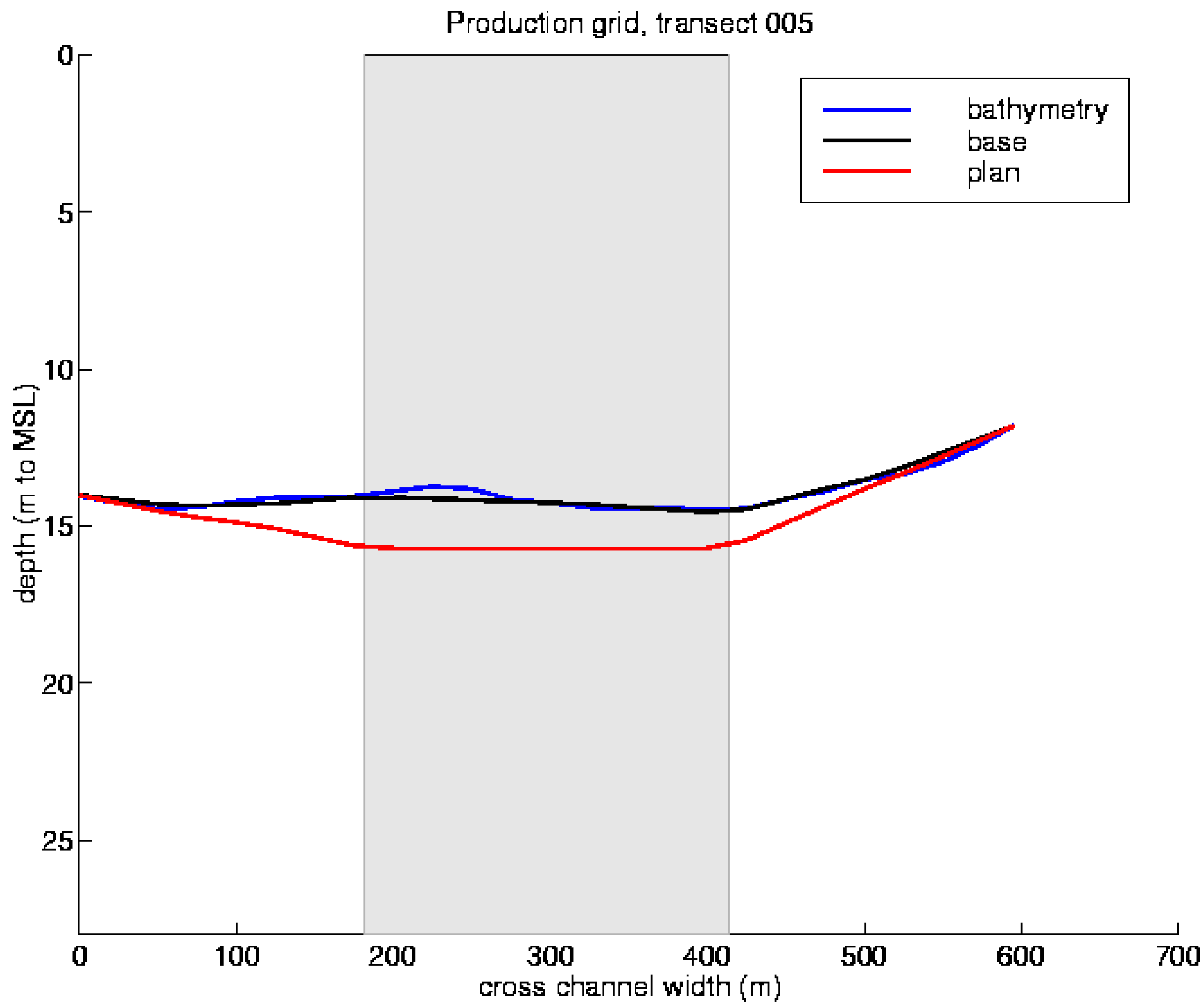


Fig. 29d: Depth at cross-section 05 (see Fig. 28b for location). Different curves represent the cross-section as 'viewed' by either: the detailed grid representing bathymetric data (*bathymetry*), the production grid with base bathymetry (*base*), or the production grid with bathymetry modified to account for channel deepening (*plan*). Shaded area represents the core channel.

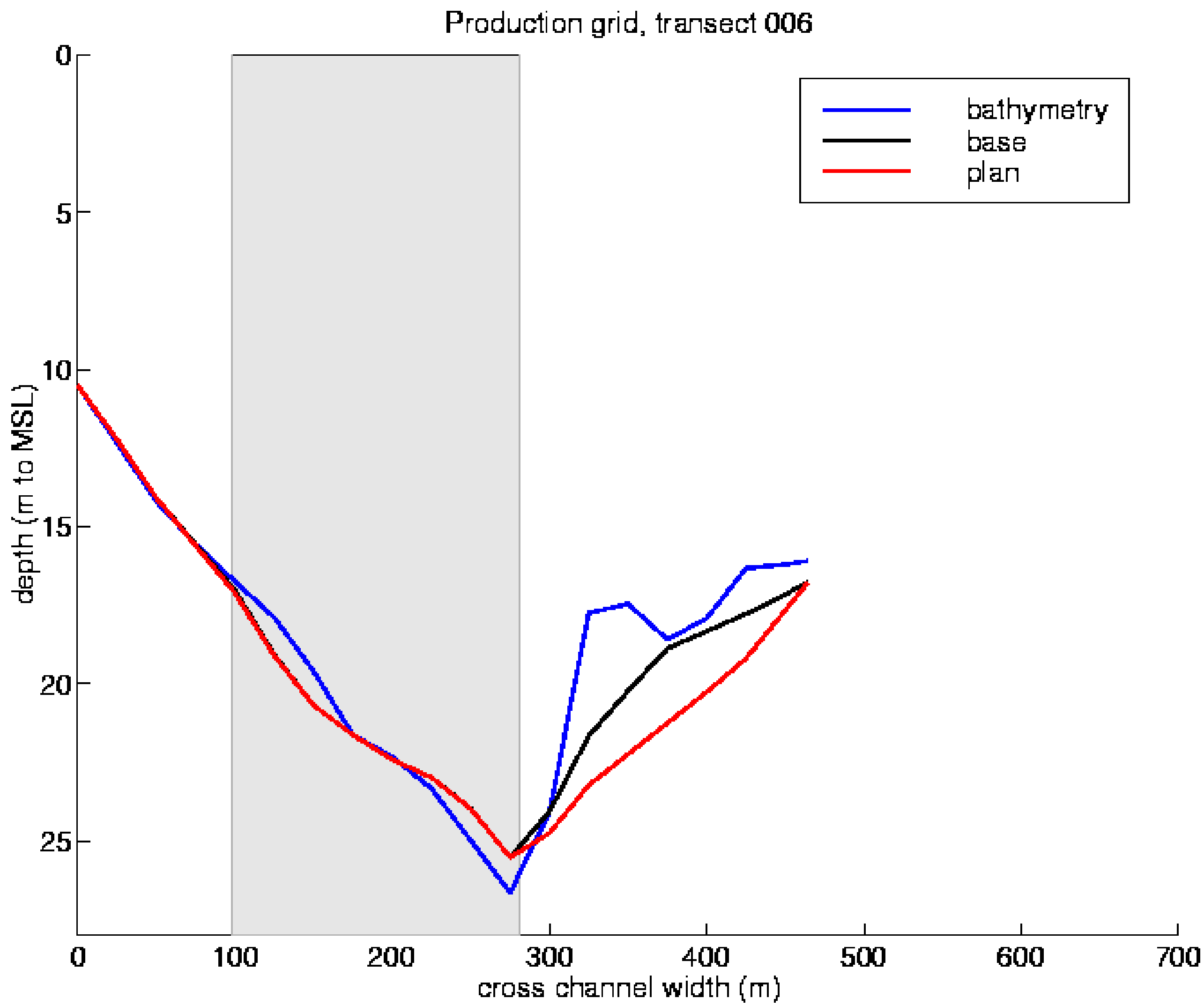


Fig. 29e: Depth at cross-section 06 (see Fig. 28b for location). Different curves represent the cross-section as 'viewed' by either: the detailed grid representing bathymetric data (*bathymetry*), the production grid with base bathymetry (*base*), or the production grid with bathymetry modified to account for channel deepening (*plan*). Shaded area represents the core channel.

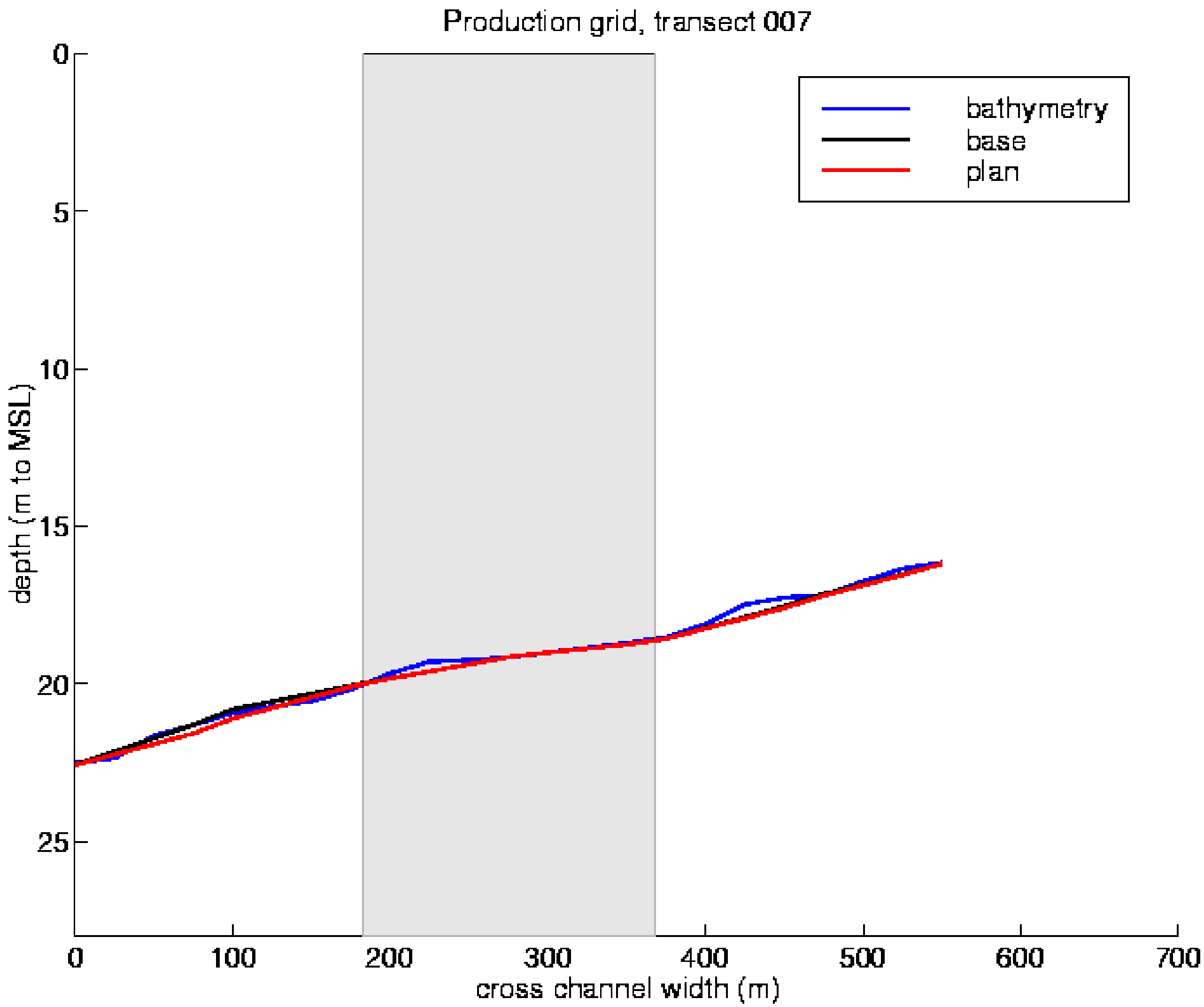


Fig. 29f: Depth at cross-section 07 (see Fig. 28b for location). Different curves represent the cross-section as 'viewed' by either: the detailed grid representing bathymetric data (*bathymetry*), the production grid with base bathymetry (*base*), or the production grid with bathymetry modified to account for channel deepening (*plan*). Shaded area represents the core channel.

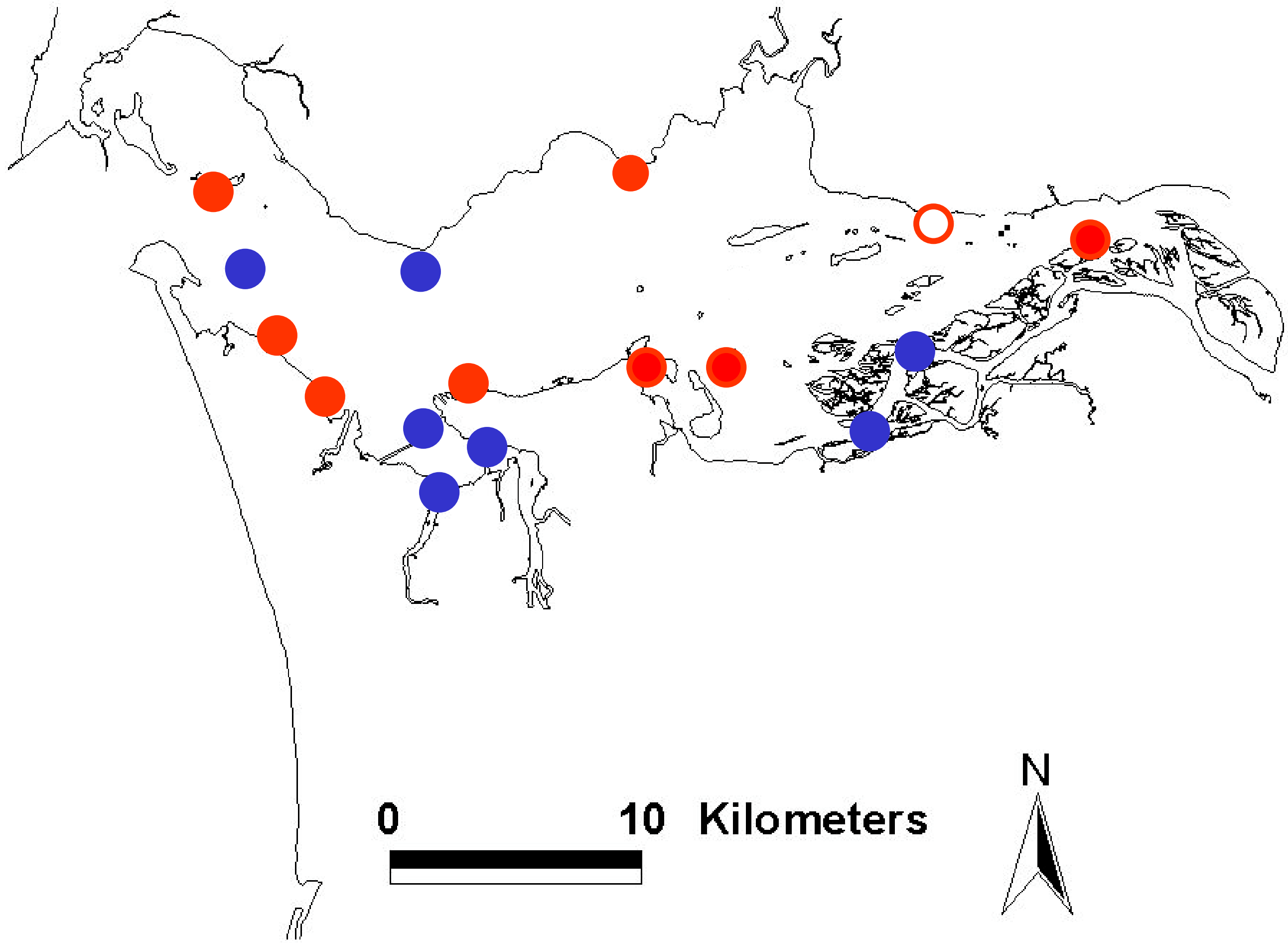


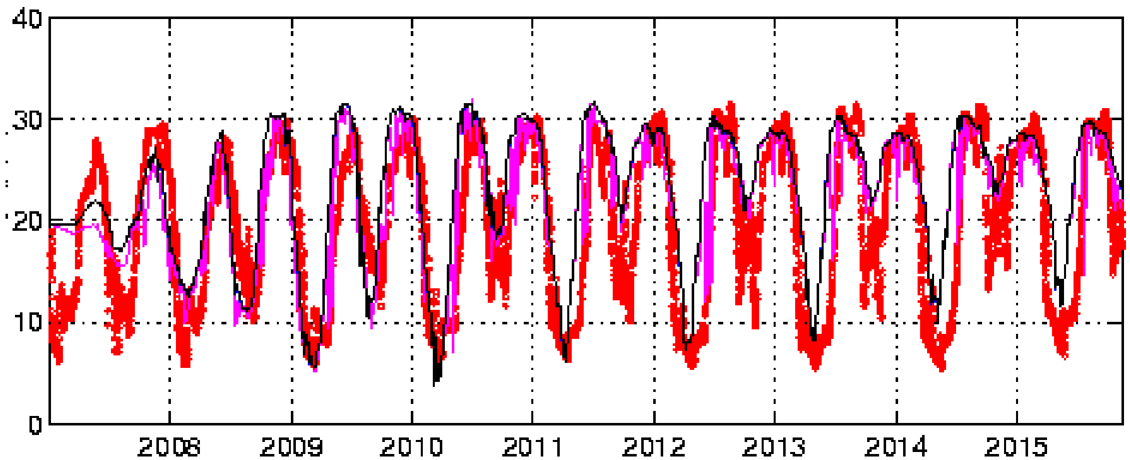
Fig. 30: Red circles represent the CORIE stations with salinity data available for model comparison in week 27 of 2001 (July). Model-data comparisons are shown in Fig. 31a-h. Blue circles represent CORIE stations for which data are not available for the period.

2001 – week 27

(July)

Version 2 of simulation database

Salinity (psu)



CORIE days

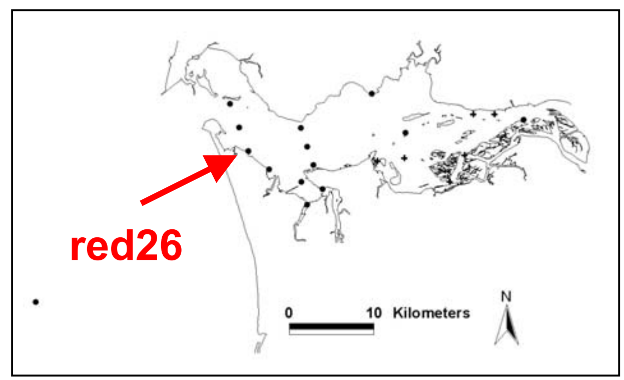


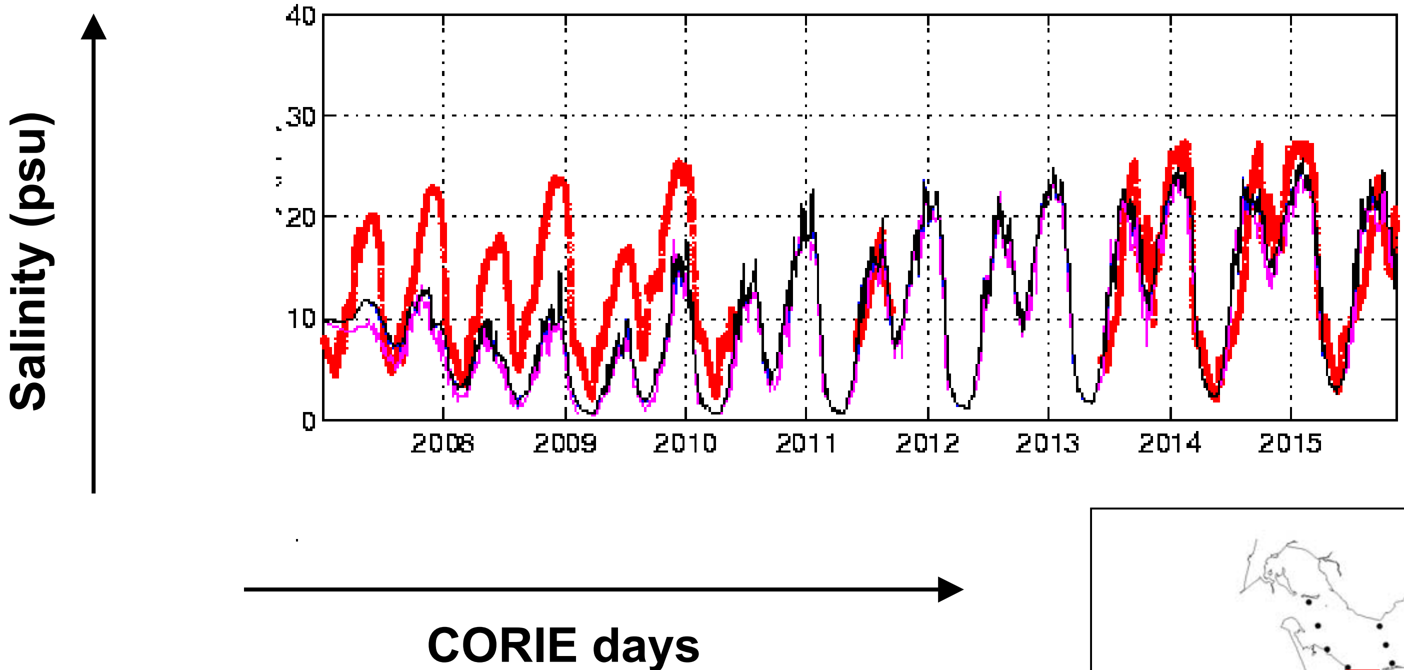
Fig. 31a: Model-data comparisons for the period and CORIE station shown. Data is in red, model at comparable depth is in purple. Model at other depths in black and blue.

Note: The first three days correspond to a warm-up period.

2001 – week 27

(July)

Version 2 of simulation database



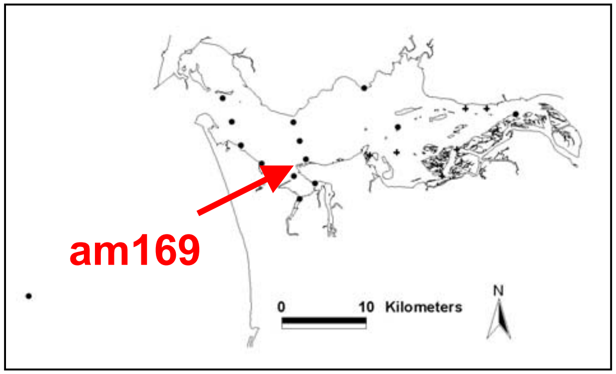


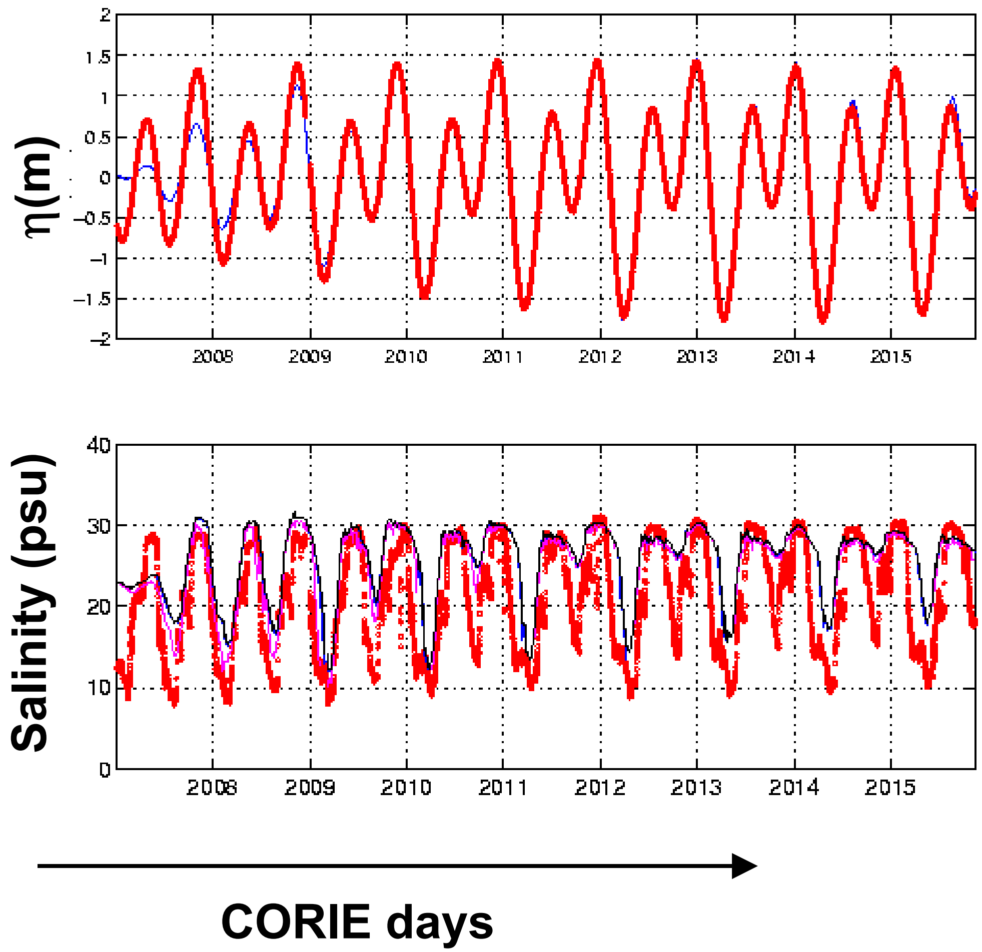
Fig. 31b: Model-data comparisons for the period and CORIE station shown. Data is in red, model at comparable depth is in purple. Model at other depths in black and blue.

Note: The first three days correspond to a warm-up period.

2001 – week 27

(July)

Version 2 of simulation database



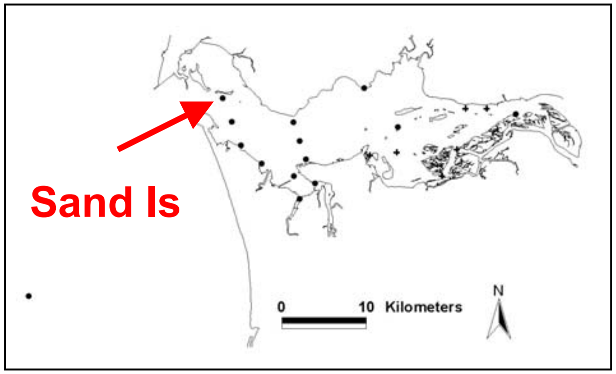


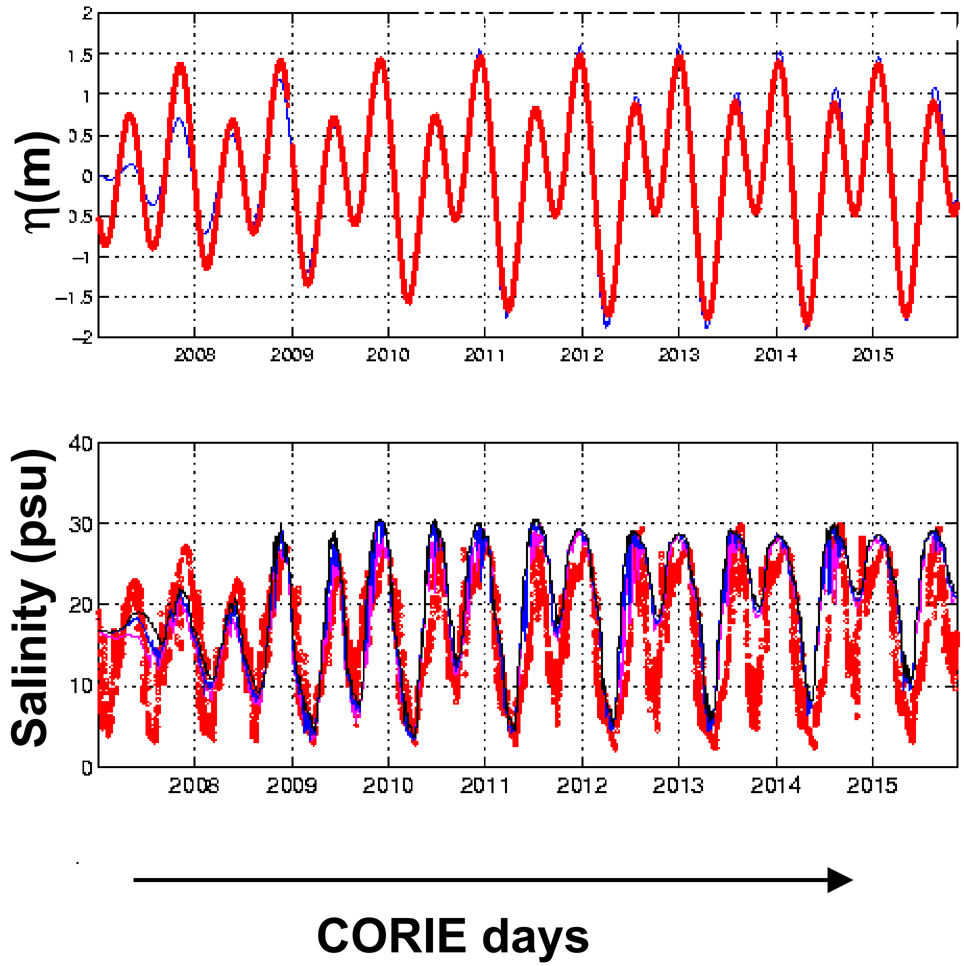
Fig. 31c: Model-data comparisons for the period and CORIE station shown. Water elevation: data in red, model in blue. Salinity: data in red, model at comparable depth in purple; model at other depths in black and blue.

Note: The first three days correspond to a warm-up period.

2001 – week 27

(July)

Version 2 of simulation database



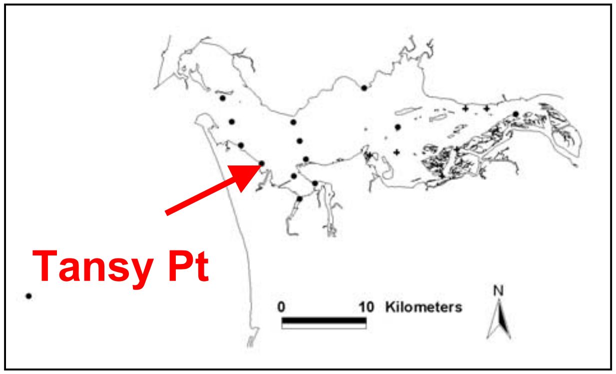


Fig. 31d: Model-data comparisons for the period and CORIE station shown. Water elevation: data in red, model in blue. Salinity: data in red, model at comparable depth in purple; model at other depths in black and blue.

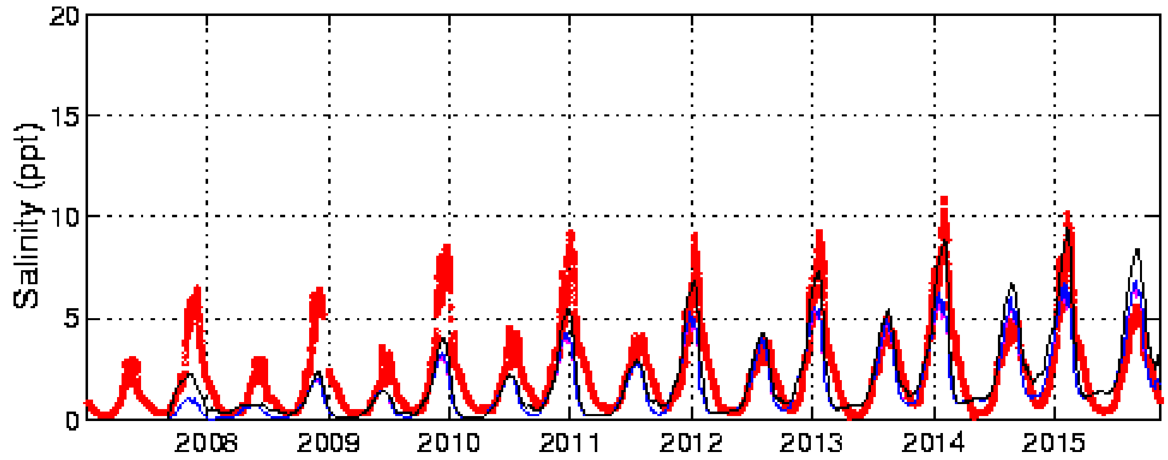
Note: The first three days correspond to a warm-up period.

2001 – week 27

(July)

Version 2 of simulation database

Salinity (psu)



CORIE days

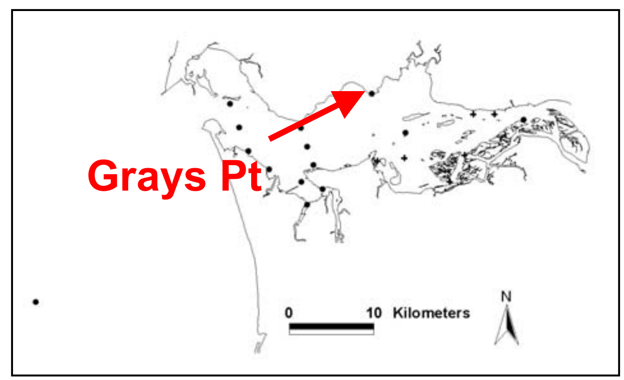


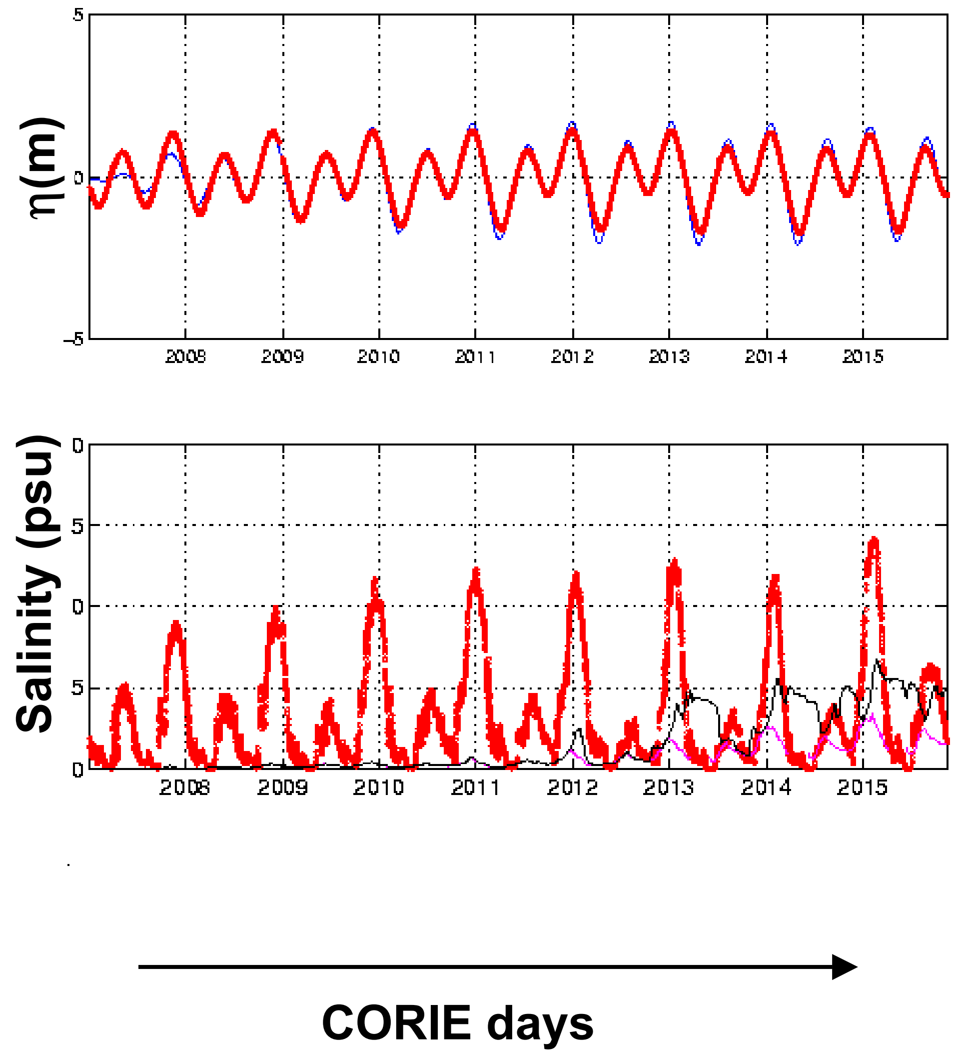
Fig. 31e: Model-data comparisons for the period and CORIE station shown. Data is in red, model at comparable depth is in purple. Model at other depths in black and blue.

Note: The first three days correspond to a warm-up period.

2001 – week 27

(July)

Version 2 of simulation database



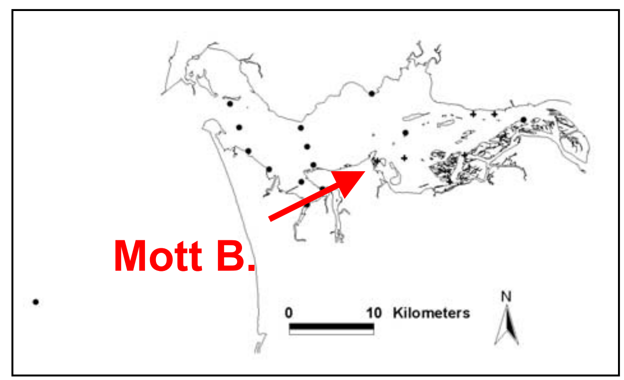


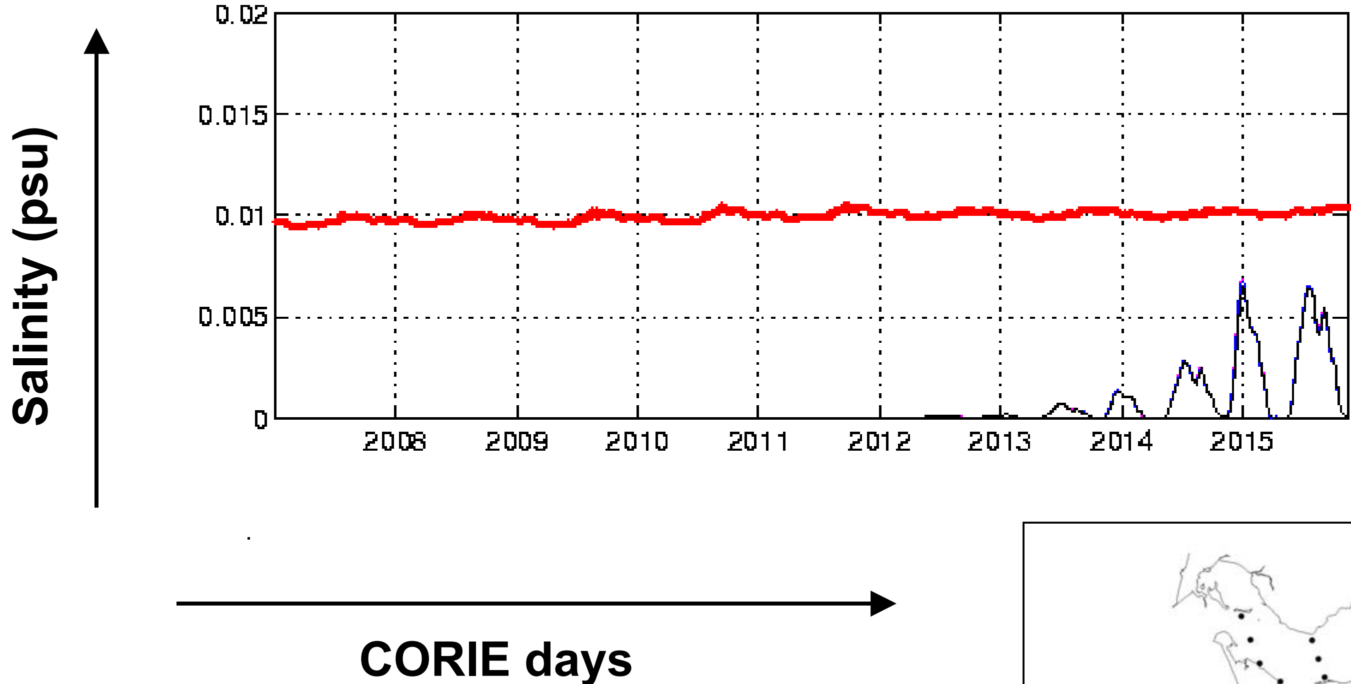
Fig. 31f: Model-data comparisons for the period and CORIE station shown. Water elevation: data in red, model in blue. Salinity: data in red, model at comparable depth in purple; model at other depths in black and blue.

Note: The first three days correspond to a warm-up period.

2001 – week 27

(July)

Version 2 of simulation database



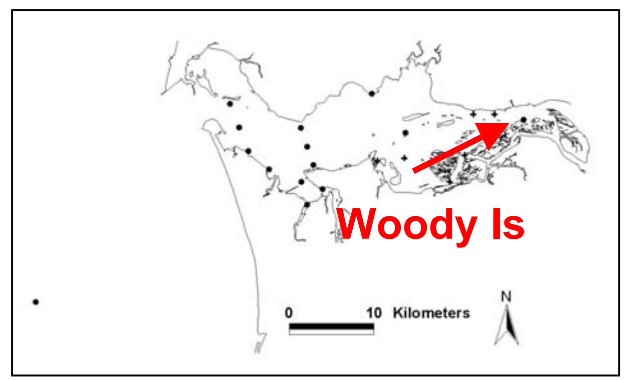


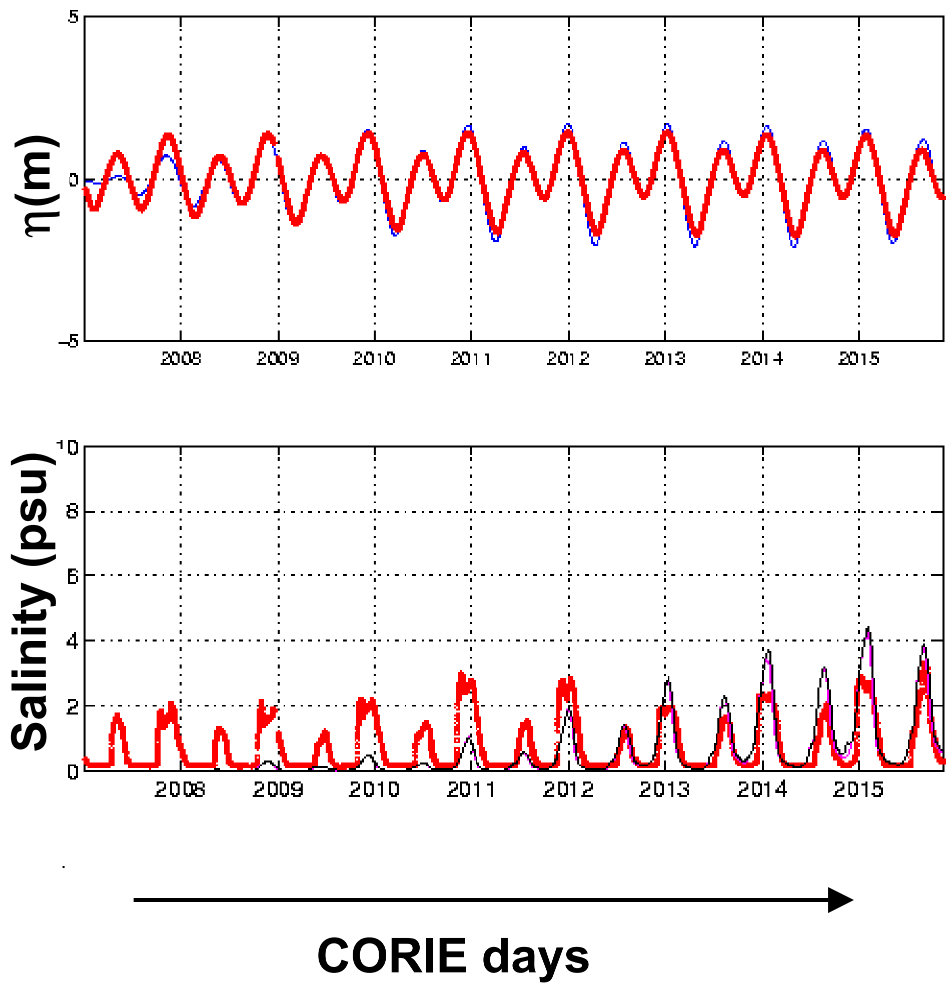
Fig. 31g: Model-data comparisons for the period and CORIE station shown. Data is in red, model at comparable depth is in purple. Model at other depths in black and blue.

Note: The first three days correspond to a warm-up period.

2001 – week 27

(July)

Version 2 of simulation database



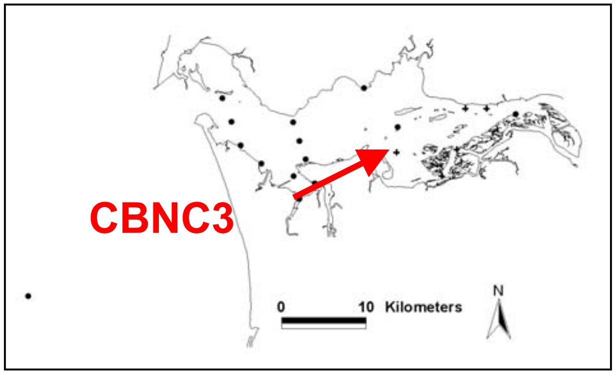


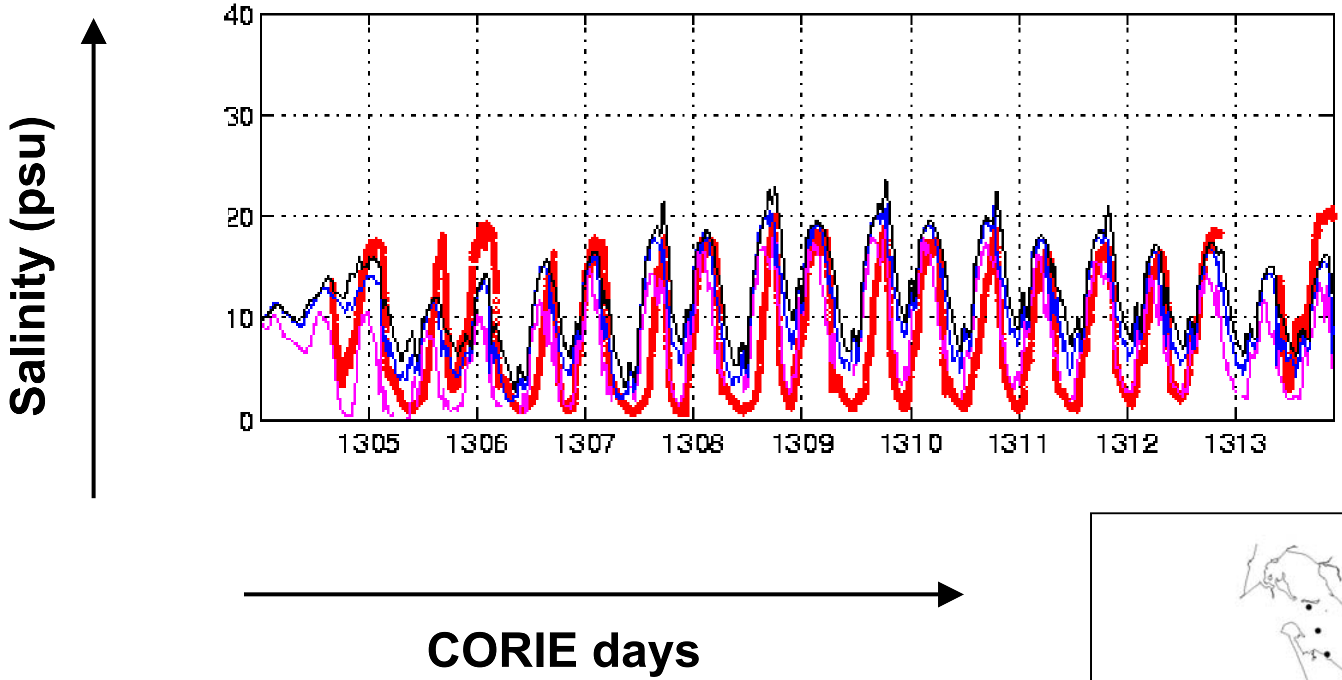
Fig. 31h: Model-data comparisons for the period and CORIE station shown. Water elevation: data in red, model in blue. Salinity: data in red, model at comparable depth in purple; model at other depths in black and blue.

Note: The first three days correspond to a warm-up period.

1999 – week 31

(August)

Version 3 of simulation database



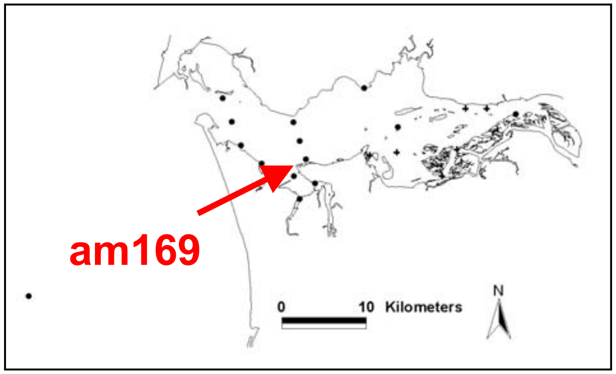


Fig. 32: Model-data comparisons for mid-range river discharges, with stratification represented by the model. Data is in red, model at comparable depth is in purple. Model at other depths (closer to bottom) in black and blue.

Note: The first three days correspond to a warm-up period.

1997 – week 18

(May)

Sand Island

Version 2
Version 3

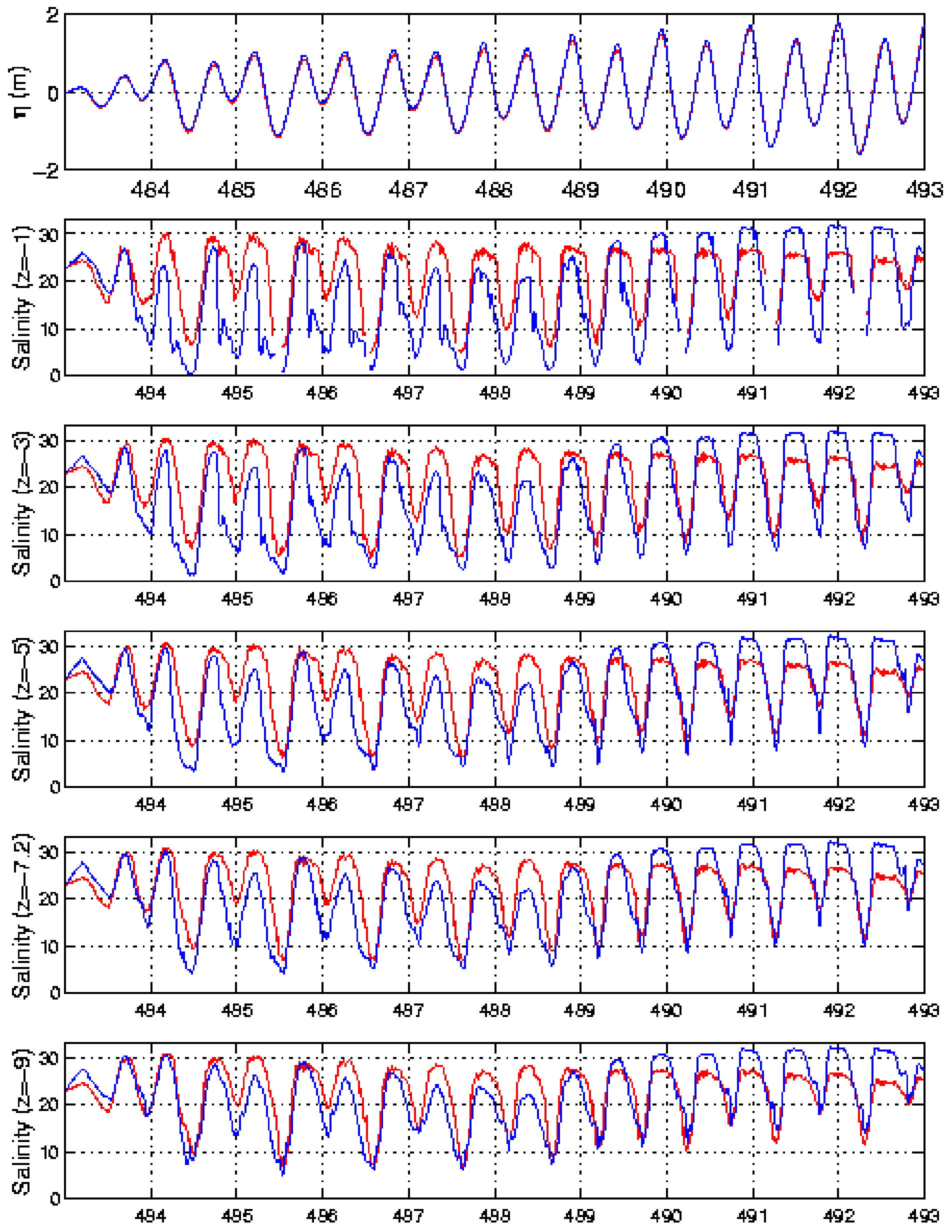
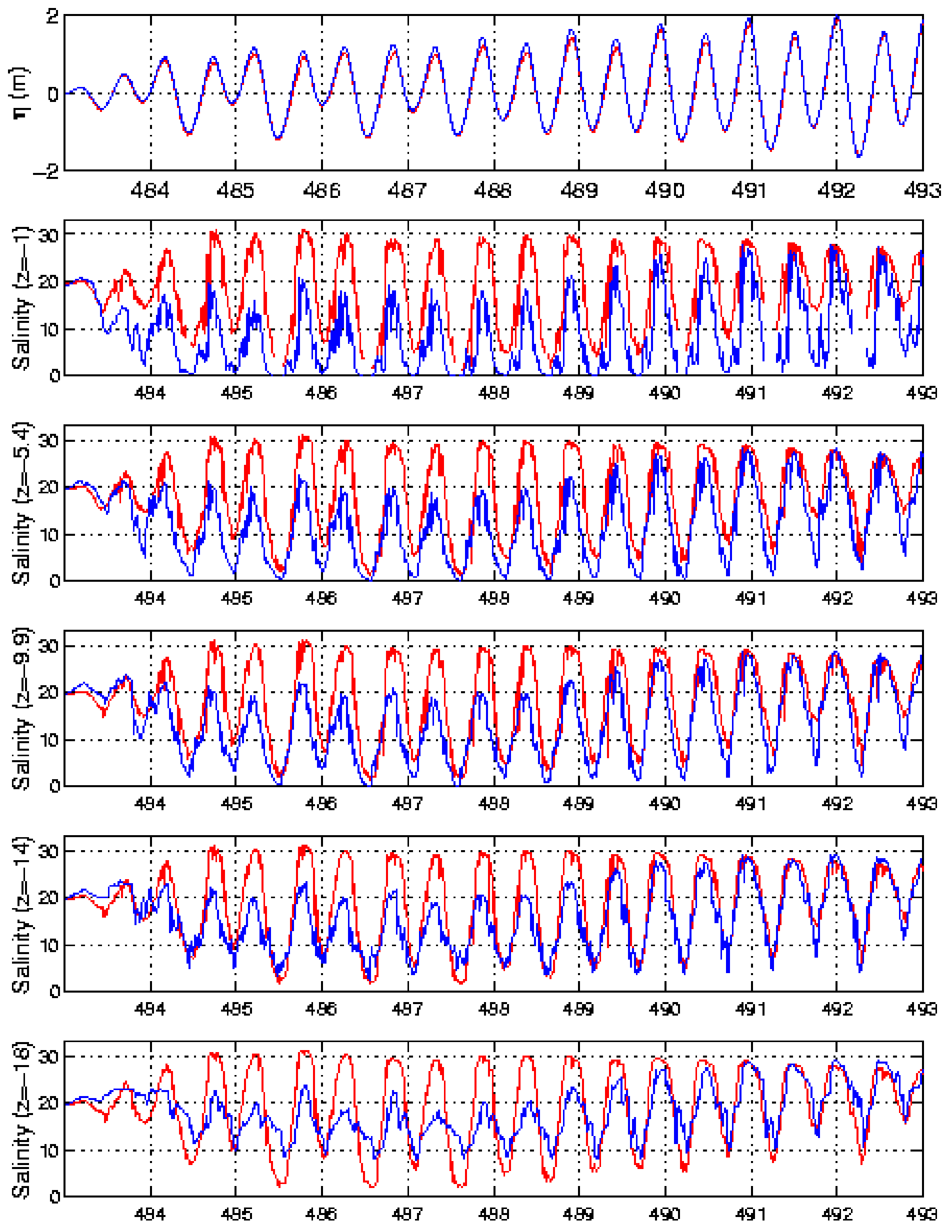


Fig. 33a: Model-model comparisons for high river discharges, with stratification underestimated (version 2) and more realistically represented (version 3). Version 2 and 3 differ on the time step used (7.5 versus 2.5 minutes).

Note: The first three days correspond to a warm-up period.



1997 – week 18

(May)

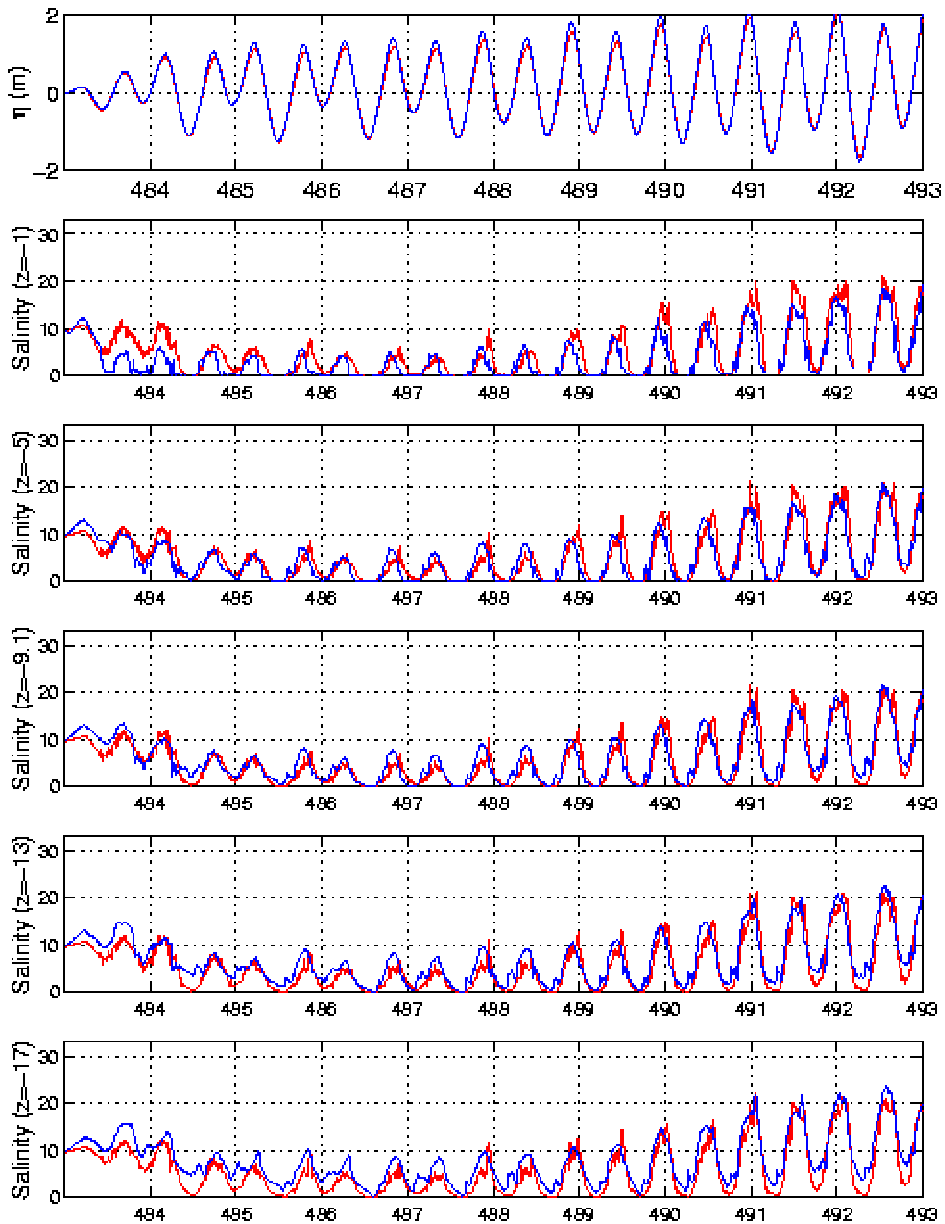
Red26

Version 2

Version 3

Fig. 33b: Model-model comparisons for high river discharges, with stratification underestimated (version 2) and more realistically represented (version 3). Version 2 and 3 differ on the time step used (7.5 versus 2.5 minutes).

Note: The first three days correspond to a warm-up period.



1997 – week 18

(May)

AM169

Version 2
Version 3

Fig. 33c: Model-model comparisons for high river discharges, with stratification underestimated (version 2) and more realistically represented (version 3). Version 2 and 3 differ on the time step used (7.5 versus 2.5 minutes).

Note: The first three days correspond to a warm-up period.