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June 29, 2015

National Fisheries Conservation Center
308 Raymond Street
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Attention: Julia Sanders

Subject: Cover Letter
Literature Review & Support Services
Grays Harbor, Washington
File No. 21922-001-00

GeoEngineers has completed the literature search regarding sedimentation within Grays Harbor estuary. The attached letter report and appendices summarize our efforts to gather and evaluate technical information regarding the sedimentation conditions in Grays Harbor, and the corresponding impacts to shellfish.

This literature search was completed in accordance with our signed agreement dated May 5, 2015, and is for the express use of the National Fisheries Conservation Center and its partners in this investigation. We will also provide to you electronic copies of the references contained in the bibliography.

We thank you for the opportunity to support the National Fisheries Conservation Center as you investigate the sedimentation issues in Grays Harbor. We look forward to working with you to develop mitigation strategies that facilitate ongoing shellfish aquaculture in Grays Harbor.

Sincerely,
GeoEngineers, Inc.

Timothy P. Hanrahan, PhD
Senior Fluvial Geomorphologist

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Attachments:

Grays Harbor Literature Review & Support Services Letter Report

- Figure 1. Vicinity Map
- Appendix A. Website Links
- Appendix B. Bibliography

One copy submitted electronically

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LITERATURE REVIEW & SUPPORT SERVICES
GRAYS HARBOR, WASHINGTON
FILE NO. 21922-001-00
JUNE 29, 2015

INTRODUCTION

Grays Harbor has been an important shellfish growing area for decades, supporting many commercial growers using leased subtidal lands from Washington State Department of Natural Resources, as well as other aquaculture land. Since the inception of the Grays Harbor navigation channel dredging project, commercial growers have observed and documented substantial increases in sandy sediment deposition on their shellfish plots. The focal point of this literature review is to search available literature to gain a more robust understanding of sediment sources, distribution and overall circulation of sediment in Grays Harbor that may establish some added insight to reducing the impacts to the shellfish industry.

Following the literature review, various recommendations for reducing and mitigating the sedimentation in Grays Harbor will be developed. GeoEngineers will review those suggestions and provide input and possible alternatives to those suggested mitigation methods in a separate document.

This literature search was completed in accordance with our signed agreement dated May 5, 2015, and is for the express use of the National Fisheries Conservation Center and its partners in this investigation.

SEDIMENTATION IN GRAYS HARBOR ESTUARY

The Grays Harbor estuary is the outlet for the Chehalis Watershed, a basin that includes Water Resource Inventory Areas (WRIA) 22 and 23. The Chehalis Basin encompasses 2,700 square miles and is bounded by the Pacific Ocean to the west, the Deschutes River Basin to the east, the Olympic Mountains to the north, and the Willapa Hills and Cowlitz River Basin to the south. Chehalis Basin elevations range from sea level at Grays Harbor to 5,000 feet in the Olympic National Forest. With only very small areas of significant snow pack in the upper watersheds, the Chehalis Basin water supply relies largely on winter rainfall and groundwater supply. The population density within the Chehalis Basin is relatively low, with a total population of approximately 141,000. Accordingly, urban/industrial land use comprises only 3 percent of the Basin, while agricultural land and forest land make up 8 percent and 87 percent of the Basin, respectively (Chehalis Basin Partnership 2004).

The Grays Harbor estuary (Figure 1) has a long history of human development and the accompanying large-scale engineered modifications to the physical environment. Modifications to the estuary inlet began as early as 1896 with the authorization of navigation improvements to the entrance of the estuary (U.S. Army Corps of Engineers [USACE] 1982). The authorized improvements were meant to prevent the ongoing shifting of the entrance channel, the bar across the inlet, and the channel bottom, all of which deterred regular entry of ships into Grays Harbor. By the early 1900s the entrance bar and channel were stabilized by the construction of a jetty system and dredged channels (USACE 1989). Ongoing reconstruction, navigation channel improvements and expansions have resulted in the present day extensive jetty, groin, and dredged channel system within the Grays Harbor estuary (USACE 2000; 2004; 2011; 2012a; 2012b; 2013; 2014a; 2014b). This system includes twin jetties (17,200 feet and 13,734 feet in length) at the estuary inlet to a deep draft 22-mile-long navigation channel extending from the Pacific Ocean to the city of Aberdeen. Just inside the inlet is the Westport Marina that provides moorage for a fishing fleet and the U.S. Coast Guard station. The navigation channel is 350 feet wide near Aberdeen, extending to 1,000 feet wide over the bar at the estuary inlet, and ranges in depths from approximately 32 feet to 36 feet. Maintaining the navigation channel requires annual dredging of up to 3.2 million cubic yards, and the disposal of this material at one offshore site; three open water sites within the estuary; two nearshore nourishment sites; and one direct beach nourishment site (USACE 2011).

The Grays Harbor estuary is very productive for shellfish, including Pacific oysters. The cultivation of oysters began in the late 1800s. The estuary includes approximately 3,995 acres of tidelands that are owned or leased for commercial shellfish aquaculture (Ecology 2014). The North Bay of Grays Harbor contains 3,088 acres of tidelands that are available for aquaculture, although most of these lands are out of production. The South Bay contains 907 acres of owned or leased tidelands used for aquaculture, with approximately 900 acres currently farmed for commercial oyster and clam production (Ecology 2014). Most of the oysters are raised directly on the tideland substrates, ranging from subtidal elevations to approximately +3.5 feet mean lower low water (MLLW) elevation within the intertidal regions (Ecology 2014).

Sedimentation processes within the Grays Harbor estuary are part of a large system that extends well beyond the estuary. This system includes the coastal sediment dynamics along the southwest Washington coast, sediment delivery to the estuary from the Chehalis Basin, and hydrodynamics within Grays Harbor, particularly near the inlet because of the proximity to South Bay. These sediment dynamics are important to the physical characteristics of the region, including the tidelands used for commercial aquaculture.

Southwest Washington Coastal Sediment Dynamics

Sediment dynamics along the southwest Washington coast are part of the Columbia River littoral cell (CRLC). This coastal sediment system extends from Tillamook Head, Oregon, to Point Grenville, Washington, a distance of approximately 100 miles. In the immediate vicinity of Grays Harbor the CRLC includes the Grayland Plains sub-cell along South Beach and the North Beach sub-cell along North Beach (Gelfenbaum et al. 1999). The beaches and inner shelf along the coast are composed of fine-grained sand from the Columbia River.

The coastal region near Grays Harbor has experienced significant change in the morphology of the dune, beach, shelf and delta landforms, largely due to alterations at the Grays Harbor inlet. Throughout the Holocene period, the larger CRLC responded to a variety of processes driving coastal change, including changing rates of sea-level rise, seismic subsidence events, large regional sediment supply, inter-annual climatic fluctuations and seasonally varying wave climate (Gelfenbaum and Kaminsky 2010). During centuries prior to the 1800s the Grayland Plains and North Beach sub-cells coastal beaches prograded significantly (Kaminsky et al. 2010), with growth rates exceeding 10 feet per year. By the early 20th century human influences on the CRLC included the construction of more than 200 dams in the Columbia River

Basin, dredging of navigation channels, disposal of dredged material, and construction of large inlet jetties to the Columbia River and Grays Harbor. The construction of these entrance jetties has been the dominant driver of coastal change through most of the CRLC over the last hundred years (Gelfenbaum and Kaminsky 2010).

The beaches and shorelines adjacent to the Grays Harbor inlet have experienced both progradation and erosion as a result of jetty construction (Kaminsky et al. 2010). After jetty construction, the shorelines prograded rapidly, including as much as 0.25 miles (Grayland Plains sub-cell) and 1.5 miles (North Beach sub-cell). The shoreline progradation was due to the onshore directed sand transport from the shore-connected sides of the ebb-tidal delta at the inlet to Grays Harbor. Over subsequent decadal time periods, longshore sediment transport dispersed sand northward and southward away from the jetties, modifying the morphology of the shoreline-beach complexes over tens of miles away from the jettied harbor inlet. The rapid shoreline progradation diminished during recent decades as the local source of sand from the ebb-tidal deltas became depleted and the shorelines adjacent to the jetties either stabilized or eroded (Kaminsky et al. 2010; Gelfenbaum and Kaminsky 2010). Jetty construction led to inlet erosion and channel deepening (by design), offshore and northerly migration of the ebb-tidal deltas, and reduction in size of the delta flanks. As a result, Grayland Plains to the south of the inlet has become increasingly separated from the ebb-tidal delta flank, leading to the alteration of the natural sediment-bypassing mechanism of the formerly-shallow shoals (Gelfenbaum and Kaminsky 2010). Before the jetties were constructed, the coasts to the north and south of the inlets were connected across the tidal inlet by shallow, sand-rich shoals. Today the North Beach sub-cell coast is offset by approximately 1.5 miles seaward relative to the coast to the south of the inlet (Grayland Plains). This difference in morphology may be diminishing southerly sediment transport along the shore that is typical during fair-weather conditions. The reduced sediment supply from the north may manifest as depletion of sand supply to the south of the inlet leading to net beach erosion (Gelfenbaum and Kaminsky 2010).

Much of the understanding of coastal dynamics in this region were developed by the Southwest Washington Coastal Erosion Study (URL link in Appendix A). This information is well documented in the sources referenced above, as well as in Peterson et al. (2010a; 2010b), Ruggiero et al. (2010), Twichell et al. (2010), Vanderburgh (2010), and the references cited therein.

Chehalis Basin Sediment Delivery

Sediment delivery from the Chehalis Basin to the Grays Harbor estuary is an important component of the overall sediment budget within the estuary. However, little information is available describing the quantitative estimates of sediment supply to the estuary from the rivers draining the Chehalis Basin. Historical reconstruction of Grays Harbor sedimentation indicates that sea level rise after Pleistocene glaciation drowned the river valley, leading to an infill of the estuary during the Holocene period with coarse-grained sediment of both fluvial (river) and marine origin (Peterson and Phipps 1992). During the mid-20th century total sediment production from the Chehalis Basin was considered low, with an average sediment yield ranging from 50 to 150 parts per million of flow (U.S. Department of Health 1962). This is consistent with the findings of Glancy (1971), who reported that 74 percent of the suspended sediment discharge in the Basin was derived from the Satsop and Wynoochee watersheds, while 24 percent was delivered by the Chehalis River past Porter. More recent evaluations of sediment issues within the Chehalis Basin are limited to areas of the upper watershed and are focused on fish habitat, instream gravel mining, channel migration, forest practices and landslides (Pickett 1992; Sarikhan 2008; Entrix 2009; GeoEngineers and Herrera 2009; Green et al. 2009; Anchor 2012).

Fluvial-derived sediment delivered to the Grays Harbor estuary may be a significant source of sediment in only portions of the estuary. Three zones of sediment origins have been identified within Grays Harbor: marine sediments in the outer estuary, mixed marine-river sediments in the middle estuary, and river-derived sediments in the inner estuary (Figure 21 in USACE 2014b). The Chehalis River is thought to be the major contributor of sediment to the inner estuary (USACE 2011). While high flows from the Chehalis River can control currents in the inner (upper) estuary, the hydrodynamics within Grays Harbor are generally dominated by tidal currents and waves (USACE 2014b).

Grays Harbor Inlet Hydrodynamics

The outer estuary region of Grays Harbor has changed dramatically since the mid-1800s, largely in response to alterations of sediment transport dynamics caused by engineered modifications to the inlet and harbor. The historical evolution of Grays Harbor has been described within six distinct time periods (Epochs) extending from the mid-1800s to present (Kraus and Arden 2003).

Before the shipping channel and jetties were built (Epoch 1) between 1862 and 1898, the entrance to Grays Harbor was comprised of sandy spits (shoals) located more than 2,000 feet east of the current shoreline. During flood tides sediment was transport within flood channels into the estuary to create flood shoals, while during ebb tides sediment was transported out of the estuary resulting in development of an ebb shoal (delta) in the ocean outside of the estuary entrance. Between 1898 and 1916 (Epoch 2), establishment of the shipping channel and construction of the north and south jetties altered these patterns of flood and ebb shoaling processes. By design, tidal and ebb flow currents were concentrated through the inlet, resulting in a deepening of the channel. The ebb shoal delta moved farther out into the ocean, reducing the availability of sand to the inlet. The jetties also reduced storm surge flooding and the amount of shoaling in the navigation channel due to waves and longshore drift, particularly the southward movement of littoral drift and sediment transport. Blockage of the longshore drift resulted in substantial sediment accretion on beaches north and south of the jetties (Kraus and Arden 2003; USACE 2014b).

During the period from 1916 to 1942 (Epoch 3), the jetties deteriorated in elevation and porosity, allowing them to be overtopped by flood tides, transporting sediment into the estuary. The net sediment influx resulted in the creation of Damon Point on the north side of the inlet and Point Chehalis on the south side of the inlet. The net sediment influx to the Damon Point area was significant enough to cause a deepening of the shipping channel and a shifting of the channel to the south. The jetties were rebuilt to 20 feet above MLLW. During the period from 1942 to 1965 (Epoch 4) jetty reconstruction and maintenance reduced the magnitude of sand transport over and through the jetties. The reduced sediment supply to the estuary resulted in erosion and eastward migration of Damon Point and Point Chehalis (Kraus and Arden 2003; USACE 2014b).

Ongoing deterioration of the jetties resulted in additional jetty reconstruction during the period from 1965 to 1987 (Epoch 5). The configuration of the north jetty allowed sediment bypass into the estuary, resulting in rapid southeasterly growth of Damon Point into the harbor. The jetty rehabilitation was focused on the inner portions of the jetties, resulting in the present day structure configuration. The third rehabilitation of the jetties occurred in the early 2000s during Epoch 6 (1987 to present). Maintenance of the jetty structures in their current configuration has resulted in the continued eastward migration of Damon Point and the erosion and eastward migration of Whitcomb Flats (Osborne 2003; USACE 2014b).

The modifications made to the Grays Harbor inlet during Epochs 1 through 6 has altered the sediment budget in the North Beach sub-cell, the Grayland Plains sub-cell and the inlet of Grays Harbor (Buijsman et al. 2003; Osborne 2003). The presence of the north and south jetties, and associated structures, has displaced the bar delta complex further offshore and has increased the amount of sand deposited on the offshore bar. This has likely had the corresponding effect of decreasing the amount of sand moving into Grays Harbor from the outer coast (USACE 2014b). Because of the net export of sand from Grays Harbor, the rate of accretion along north beach and south beach has increased, leading to a westward extension of these beaches from the historic shoreline. Within the Grays Harbor inlet, beaches are receding at Half Moon Bay and Point Chehalis, and the Whitcomb Flats sand island is eroding and migrating eastward (Osborne 2003; USACE 2014b).

Much of the understanding of Grays Harbor inlet hydrodynamics were developed as part of the U.S. Army Corps of Engineers programs to maintain the navigation channel (URL links in Appendix A). This information is well documented in the sources referenced above, as well as in Burch and Sherwood (1992), Cialone and Kraus (2001, Cialone et al. (2002), Demirblek et al., (2010), Hayter et al., (2012), Hughes and Cohen (2006), Kraus and Arden (2003), Li et al., (2013), McDonald and Osborne (2003), Sanchez and Wu (2011), Wamsley et al., (2006), Zundel et al., (2002), USACE (1982, 1989, 2000, 2004, 2011, 2012a, 2012b, 2013, 2014a, 2014b), and the references cited therein.

The Whitcomb Flats sand island has experienced significant morphological changes in response to the changing Grays Harbor inlet hydrodynamics. After reconstruction of the south jetty in the late 1930s, sediment supply to Whitcomb Flats was significantly reduced (Osborne 2003; USACE 2014b). During this same period, Damon Point to the north of the navigation channel continued to expand resulting in a migration of the ebb channel to the south. The resulting changes in hydrodynamics at the inlet caused Whitcomb Flats to erode and migrate eastward at rates ranging from approximately 49 feet per year to 656 feet per year (Osborne 2003; USACE 2014b). Whitcomb Flats migration rates increased dramatically during the period from 1994 to 2001, with average migration rates exceeding 330 feet per year during that timeframe (Osborne 2003). Anecdotal evidence suggests that much of the eroded sand from Whitcomb Flats is transported into South Bay. However, through our literature search we did not discover any reports describing the sediment dynamics of South Bay associated with the larger scale morphodynamics of Grays Harbor.

Grays Harbor Shellfish and Fisheries Resources

Estuary ecosystems support diverse populations of fish and shellfish species. These critically important habitats are nurseries to juveniles, breeding grounds for adults, feeding zones for all users and transportation routes for migratory species. The Grays Harbor estuary, combined with Willapa Bay, produces nearly 25 percent of the national oyster production in the United States (Ecology 2014). There are many production methods for oyster culture—long line, rack-and-bag, suspended, stake, and bottom-set, the most common method. In all cases, stable substrate and clean water are required for successful oyster growing (Wilber and Clarke 2010; Berry et al. 2003).

Two primary issues jeopardize substrate stability in the Grays Harbor estuary. These issues are burrowing shrimp (ghost shrimp, *Neotrypaea californiensis* and mud shrimp, *Upogebia pugettensis*), and sediment instability. Burrowing shrimp destabilize the substrate causing the growing oysters to settle into the overly-softened substrate creating several negative results for oyster growth. This issue is well studied and understood in Grays Harbor estuary and has been a major problem for oyster aquaculture in Washington

State (Washington State Department of Ecology 2015). As oysters settle into the softened sediment, their shell growth shifts toward an elongated morphology to maintain sufficient feeding position. This is termed "compensatory growth" and leads to an undesirable commercial product and may ultimately lead to mortality as oysters slowly sink into the mud. More details on oyster physiology and life history characteristics may be found in Pauley et al. (1988).

Sediment instability also results from excessive erosion of the physical substrate where oyster production is occurring. Loss of physical ground results in lost oyster production. Deposition of sediments on top of culture areas smothers the oysters and disrupts their feeding and respiration capability (Thomsen and McGlathery 2006; Volety and Encomino 2006). Both of these studies showed that accumulations of sediments and drift algae pose adverse impacts on sessile estuarine organisms, causing physiological stress and mortality, reducing richness and abundance. Gonda-King et al. (2010) provides a good assessment of known impacts of sedimentation to oyster growth and survival. Although focused on eastern oysters in Chesapeake Bay, the similarities and basic conditions apply to Grays Harbor estuary. Wilber et al. (2005) is a technical note prepared by the US Army Corps of Engineers that investigates the various impacts of sedimentation associated with dredging on a variety of aquatic organisms. Their investigation demonstrated minor to substantial impact to aquatic ecosystems as a result of dredging induced sedimentation ranging from some impact to direct burial and mortality. Restoration is mandatory to recover productive oyster growing areas following significant habitat loss. This has been documented across the United States (Baggett et al. 2014).

Literature cited by Baggett et al. (2014) identify seven ecosystem services provided by *C. virginica* habitats: (1) production of oysters; (2) water filtration and concentration of pseudofeces; (3) provision of habitat for epibenthic invertebrates; (4) nutrient sequestration; (5) augmented fish production; (6) stabilization of adjacent habitats and shoreline; and (7) diversification of the landscape and ecosystem. A study with emphasis on Pacific Northwest shellfish ecosystem services and economic valuation was completed by Northern Economics, Inc., in 2009. Although placed in context of a monetary valuation process, the same basic ecosystem services are contained in this analysis. This study goes a bit farther to include cultural services related to collection, preparing and consuming shellfish. These literature sources clearly define the importance of oyster production and demonstrate the need for preservation and restoration efforts in all historic oyster producing grounds.

Oyster restoration projects can take many forms and use a variety of construction materials (Brumbaugh et al. 2006). While the aim of some projects is to restore a natural but degraded reef to some former condition, other restoration projects involve constructing an entirely new reef structure, though often at historic reef sites. In all cases, restoration programs are intended to address recovery of all (or as many as possible) ecosystem services associated with targeted locations. Construction materials may include unconsolidated clean shell (cultch), bagged clean shell, limestone or fossil shell, engineered concrete domes, metal shell containment structures filled with loose or bagged oyster shell, or other similar materials. Construction processes range from the direct placement of cultch or other construction materials to form a reef of a specific design and size, to spraying unconsolidated shell off barges across a project area, resulting in a reef with large spatial extent, but varying vertical relief and cultch density. When designing an oyster restoration project, local conditions should be considered in selecting the construction material and reef design. In addition, sites should be chosen to maximize the chance of successful restoration (for site selection considerations see Coen et al., 2004 and 2007; Brumbaugh et al., 2006; Brumbaugh and Coen 2009; CSCC 2010; and http://www.oyster-restoration.org for additional information).

Additionally, restoration projects should be designed so that the appropriate metrics can be assessed and statistical analyses can be performed on the resultant data.

Impacts to oyster production in Grays Harbor estuary related to the navigation channel widening and deepening program by the US Army Corps of Engineers has not been well studied nor documented in the environmental review documents (Stevens 1981; USACE 1982; USACE 1989, Antrim et al., 1992; USACE 2012). Most of the study and investigation to date has centered on impacts to Dungeness crab (*Cancer magister*).

A Dungeness crab mitigation program of substrate enhancement by additions of oyster shell was undertaken for several years. This effort was monitored and found to be an effective method of promoting crab settlement and survival but after only a few years of mitigation efforts, the program was curtailed due to the inability of Washington State Department of Natural Resources to secure shared funding for the oyster shell enhancement program (Armstrong et al. 1991; Visser 2010).

Fisheries resources are substantial in Grays Harbor estuary. Salmon, green sturgeon, baitfish, groundfish and multiple other commercial and non-commercial species are dependent on the ecosystem of Grays Harbor estuary for survival. Sandell et al (2011) provides a good literature view of juvenile fish use and a habitat inventory for Grays Harbor estuary. Similar to oysters, most of the literature produced to evaluate the impact of dredging omit specific detailed investigations of impact to finfish resources.

FUTURE ACTIONS

Following the literature review, several suggestions and ideas have emerged to consider for improving oyster productivity and reducing sedimentation impacts. These are:

1. Prior substrate enhancement with oyster shell proved effective to promote Dungeness crab survival and reproduction. Past studies in Grays Harbor (Armstrong 1991) showed that oyster shell substrate enhancement performed best with live oysters on the substrate. With this backdrop, reinitiating the oyster shell enhancement program with a focus on ultimate enhancement of live oyster beds would prove beneficial for both crab and oyster productivity in Grays Harbor estuary.
2. Hydrodynamic models should be recalibrated and re-run with sediment transport in mind to define the cause and effect of physical manipulations in Grays Harbor estuary specific to oyster ground impact and stability. These same models may identify other areas within Grays Harbor estuary that may be more suitable for oyster production. Models should be crafted to allow insertion of physical improvements (such as sediment curtains, reef construction, sand nourishment within the harbor, structure placement, etc.) to predict sediment distribution and response to possible improvements or mitigation measures.
3. Holistic planning of all activities in the Grays Harbor estuary is required to account for multiple variables and cause/effect relationships tied to ecosystem services and dependent species assemblages. Effective solutions stem from meaningful stakeholder engagement with open access to information and available tools to evaluate alternatives and approaches. Funding must be made available to promote and facilitate this public engagement process.

Our literature search regarding sedimentation in Grays Harbor revealed a substantial amount of information available for the large scale processes and morphodynamics associated with the Grays Harbor estuary and adjacent coast. While there is some information available for understanding smaller scale hydrodynamics within the inlet, there remain several information gaps. The most significant information gaps include:

- Fluvial sediment supply to the estuary from the major tributaries, particularly the sediment supply to South Bay
- The processes and morphodynamic effects at Whitcomb Flats, and the associated fate of sediment eroded from Whitcomb Flats

The information provided by our literature search has furthered our understanding of sedimentation processes within Grays Harbor. We will use this understanding to assist you with a review of risk assessment and mitigation measures for sedimentation conditions that may be affecting the shellfish industry in Grays Harbor.

Notes:

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: Mapbox Open Street Map, 2015 and Aerial from ESRI

Projection: NAD 1983 UTM Zone 10N

Vicinity Map

Grays Harbor Sedimentation Literature Review & Support Services
Grays Harbor, Washington

GEOENGINEERS

Figure 1

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APPENDIX A
Website Links

APPENDIX A
WEBSITE REFERENCES

Southwest Washington Coastal Erosion Study:

http://www.ecy.wa.gov/programs/sea/coast/erosion/study.html

http://www.ecy.wa.gov/programs/sea/swces/index.htm

Coastal Zone Management in Washington: http://www.ecy.wa.gov/programs/sea/czm/prgm.html

USGS monitoring as part of SWCES program (includes data): http://pubs.usgs.gov/ds/2007/260/

Additional USGS for SWCES project, including Corps data: https://walrus.wr.usgs.gov/swces/

USGS, Twichell and Cross, 2001, Holocene evolution of the southern Washington and northern Oregon shelf and coast:

http://pubs.usgs.gov/of/2001/of01-076/index.htm

Grays Harbor County Shoreline Master Program: http://ghcsmp.org/index.html

Grays Harbor Council of Governments: http://www.ghcog.org/index.html

Grays Harbor County Marine Resource Committee: http://www.co.grays-harbor.wa.us/info/pub_svcs/MRC/index.html

Washington DNR Dredged Material Management Program: http://www.dnr.wa.gov/BusinessPermits/Topics/AquaticResources/Pages/aqr_dredged_material_program.aspx

Washington DNR State Owned Aquatic Lands Program: http://www.dnr.wa.gov/BusinessPermits/Topics/ShellfishAquaticLeasing/Pages/aqr_aqua_leasing_aquaculture.aspx

U.S. Army Corps of Engineers, Seattle District, Dredged Material Management Office: http://www.nws.usace.army.mil/Missions/CivilWorks/Dredging.aspx.

U.S. Army Corps of Engineers, Seattle District, Grays Harbor Navigation: http://www.nws.usace.army.mil/Missions/CivilWorks/Navigation/NavigationProjects/GraysHarbor.aspx

Washington State Coastal Atlas (for spatial data viewing): https://fortress.wa.gov/ecy/coastalatlas/.

Chehalis Basin Partnership (CBP): http://www.chehalisbasinpartnership.org/

http://www.co.grays-harbor.wa.us/info/pub_svcs/ChehalisBasin/Index.html

CBP Watershed Management Plan: http://www.chehalisbasinpartnership.org/watershed_plan/watershed_plan.html

APPENDIX B
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APPENDIX B
LITERATURE REVIEW

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