City of Aberdeen

Critical Areas Ordinance

Best Available Science Review

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Revision History

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Acronyms

AMC	Aberdeen Municipal Code
BAS	Best Available Science
BFE	Base Flood Elevation
BMP	Best Management Practice
CAO	Critical Areas Ordinance
CARA	Critical Aquifer Recharge Area
CFR	Code of Federal Regulations
cfs	Cubic Feet Per Second
CMZ	Channel Migration Zone
CTED	Washington State Department of Community, Trade and Economic Development
DMMP	Dredged Material Management Program
DPS	Distinct Population Segment
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Maps
ft	Feet
FWHCA	Fish and Wildlife Habitat Conservation Areas
GHDMEP	1995 Dredged Material Evaluation Procedures and Disposal Site Management Manual, Grays Harbor and Willapa Bay, Washington
GMA	Growth Management Act
HCA	Habitat Conservation Areas
HGM	Hydrogeomorphic Classification System
HMP	Hazard Mitigation Plan
LID	Low Impact Development
LWD	Large Woody Debris
NFIP	National Flood Insurance Program
NGVD	National Geodetic Vertical Datum
NMFS	National Marine Fisheries Servcie
NOAA	National Oceanic and Atmospheric Administration – Fisheries Service
NWI	National Wetlands Inventory
PCE	Primary Constituent Elements
PHS	Priority Habitat and Species
ppt	Parts Per Thousand

RCW	Revised Code of Washington
RM	River Mile
SEPA	State Environmental Policy Act
SMA	Shoreline Management Act
SPTH	Site Potential Tree Height
TAG	Technical Advisory Group Members
TBT	tri-n-butyl tin
TESC	Temporary Erosion and Sediment Control Plan
USACE	United States Army Corps of Engineers
USDA	U.S. Department of Agriculture
USEPA	United States Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	United States Geological Survey
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington Department of Natural Resources
WHSRN	Western Hemisphere Shorebird Reserve Network
WRIA	Water Resource Inventory Area
YOY	Young of the Year

1 Introduction

1.1 Report Background and Purpose

Under the Washington State Growth Management Act (GMA) all counties and cities are required to protect certain natural resources within their boundaries called "critical areas". Although Aberdeen is not required to plan under the GMA, the city is still required to designate and protect critical areas through a Critical Areas Ordinance (CAO). This ordinance must be adopted by December 1, 2008.

In 1995, the Washington State Legislature amended the GMA to require that local governments include Best Available Science (BAS) in designating and protecting critical areas (RCW 36.70A.172(1)). Washington Administrative Code 365-196-900 gives the background and purpose of the best available science rule followed by five sections on criteria (WAC 365-195-905 to 925). These criteria guide local governments on how to recognize and locate sources of valid scientific information and use that information in their decision making process. In addition, in 2000 the Department of Community Trade and Economic Development (CTED) adopted procedural guidance to implement these changes to the GMA, and provided guidance for identifying BAS (CTED 2004).

BAS means current scientific information derived from research, monitoring, inventory, survey, modeling, assessment, synthesis, and expert opinion that are:

- Logical and reasonable
- Based on quantitative analysis
- Peer reviewed
- Used in the appropriate context
- Based on accepted methods
- Well referenced.

This document summarizes the BAS for the city of Aberdeen critical areas as part of the administrative record and provides recommendations for policies and Critical Areas Ordinance (CAO) requirements.

As directed by RCW 36.70A.050, this document addresses the following critical areas:

- Geologically hazardous areas;
- Frequently flooded areas;
- Critical aquifer recharge areas (CARAs);
- Wetlands (both freshwater and estuarine); and
- Fish and wildlife habitat conservation areas (HCAs) including habitat requirements and management needs for anadramous fish.

The information contained in this document is a summary of scientific studies related to designating and protecting critical areas, including habitat for anadramous fish species, as defined by the GMA. The information is intended to provide a collective BAS

information set as a basis for development of the city of Aberdeen's Critical Areas Ordinance. It is not intended to provide an exhaustive summary of all science available for all critical areas. Information for this review was selected, to the extent possible, on its relevance to the natural conditions found in Aberdeen. It should be understood that it is possible that applicable and relevant work was overlooked because of the immense volume of available information. An exhaustive review and incorporation of all relevant and applicable scientific information is beyond the scope of this project.

This report contains BAS findings for each of the critical areas for Aberdeen to consider within the CAO development process. In many cases, the information presented for one critical area may overlap, complement, or be applicable to another type of critical area because these areas function as integrated components of the ecosystem. The chapters also summarize the GMA requirements for protection of these areas.

In developing the CAO, the city has to ensure that:

- Critical areas are not exempted or excluded from designation
- All designated areas are protected using specific criteria and standards
- The values and functions of critical areas are protected, that "no net loss" of these values and functions occurs, and that adverse impacts are prevented or mitigated.

In some cases the GMA is very specific about the type of protection that is required for a critical area. In others, the city will have options to choose from. Local governments must balance Critical Areas protection with other public values, such as preserving public health and safety, economic development and protecting environmentally sensitive areas.

While local governments can adopt CAOs that may result in localized impacts on some critical areas or even the loss of some critical areas, there must be no net loss of the structure, value, and functions of the natural systems. A county or city must provide a detailed and reasoned justification based on best available science for any designated critical area.

The city is required to integrate critical areas protection into all of its permitting and regulation activities, including: zoning regulations, clearing and grading provisions, stormwater management requirements, subdivision regulations and other applicable regulations, plans and policies.

1.2 City Setting

The city of Aberdeen is an 11.7 square-mile municipality of 16,450 residents located in Grays Harbor County, Washington (OFM 2005; Aberdeen 2001). The city limits span the north and south banks of the mouth of the Chehalis River where it discharges into Grays Harbor. The Wishkah River flows south through eastern Aberdeen and discharges into the Chehalis River. Figure 1 illustrates the city boundaries and the study area for this BAS review.

Insert Figure 1-1

The city began to develop in the late 1800s, with initial residential and commercial development undertaken in the inner harbor and river flood plain areas. These flood plain areas originally contained forested wetlands. Over time these areas were filled with wood waste from the forest product industries.

The land uses are those typically found in Washington State coastal communities with resource-based economies. The economy of the city is based primarily on the forest product industry, the fishing industry and to a lesser extent the sport fishing/recreation industry. All of these industries are seasonal, heavily cyclical and depend on a worldwide export economy. The recreation industry depends on a regional clientele who are primarily interested in sports fishing (Aberdeen 2003).

The topography within the city can be generally divided into two areas: the low lying flood plains surrounding Grays Harbor and the Chehalis and Wishkah Rivers, and higher elevations in the northwest and northeast portions of the city.

Land use in the higher elevations to the northeast and northwest is limited to single family residential, and major institutional uses. The lower flood plain areas of the city concentrate various types of residential, commercial and industrial land uses (Aberdeen 2001).

In North Aberdeen the flood plain extends approximately one-half mile inland in a northern and southern direction from the Chehalis River and 800 feet on either side of the meander of the Wishkah River. Land uses within the northern flood plain of the Chehalis River are primarily industrial and commercial. They include the Grays Harbor port area and extensive log storage facilities. The water front areas are located within land use zoning districts that permit heavy industrial activities, such as timber processing and shipping. These areas are supported by railroad and highway transportation systems designed to serve commerce. The Aberdeen Central Business District, which is the primary business district for the County, is located at the confluence of the Wishkah and Chehalis Rivers and extends west approximately 6 blocks along the Chehalis River and 4 blocks along the Wishkah. Land uses in the remainder of the northern flood plain are primarily residential with scattered commercial.

The southern flood plain of the Chehalis River is less intensively developed than the northern flood plain. Because of the flat topography it extends considerably further inland. The 100-year flood plain, which follows the 10’ contour, encompasses virtually all of South Aberdeen. Industrial areas, scattered along the waterfront, consist of log storage and related forest product facilities. The rest of South Aberdeen is residential with some commercial development including the South Shore Mall constructed on dredge spoils in 1981. Undeveloped areas in South Aberdeen are predominantly wetlands.

The flood plain of the Wishkah River accommodates some commercial use in the vicinity of the Chehalis River. Upstream the land use is primarily residential with some undeveloped area.

In addition to the Wishkah and Chehalis Rivers, major creeks within city boundaries include Fry Creek, Stewart Creek, Wilson Creek, Charley Creek, and Newskah Creek. Aberdeen is located in Water Resource Inventory Area (WRIA) 22, Lower Chehalis.

1.3 References

City of Aberdeen. 2001. Comprehensive Land Use Plan Biological Evaluation.

City of Aberdeen. 2003. Hazard Mitigation and Preparedness Plan.

CTED (Washington State Department of Community Trade and Economic Development). 2004. Review Guidelines for use of Best Available Science in Critical Areas Ordinances.

Ecology (Washington State Department of Ecology). 2007. WRIA 22 Lower Chehalis [Online]. Available: http://www.ecy.wa.gov/apps/watersheds/wriapages/22.html

OFM (Washington State Office of Financial Management). 2005. Census Data.

2 Fish and Other Aquatic Species

This analysis is focused on fish and other aquatic species and their habitats on non-federal lands in the city of Aberdeen, with special emphasis on anadromous salmonids. State Growth Management Act (GMA) guidelines (Ousley et al. 2003) suggest the following habitat types that should be designated as fish and wildlife habitat conservation areas (FWHCAs) in accordance with the GMA procedural criteria for adopting development regulations (WAC 365-190):

- Areas where state or federally listed species (endangered, threatened, or sensitive) have a primary association. The U.S. Fish and Wildlife Service (USFWS) and National Oceanic and Atmospheric Administration Fisheries Service (NOAA Fisheries) are responsible for designating federal special status. The Washington Department of Fish and Wildlife (WDFW) is responsible for designating state special status species and maintains the current list of these species (Ousley et al. 2003). These three agencies maintain current lists for protected species.
- State priority habitats and areas associated with state priority species. The Priority Habitats and Species (PHS) database is updated on a regular basis with input from WDFW field biologists and other scientists, and represents the best available science on the distribution of special status wildlife species and habitats in Washington. The PHS habitats identified by WDFW are considered a priority for conservation and management due to their high fish and wildlife species density and/or diversity, important habitat functions, importance to priority species, limited distribution or rarity, vulnerability, or their cultural value (e.g., commercial or recreational) (Ousley et al. 2003; WDFW 2004). WDFW has designated 18 priority habitats statewide, 15 of which occur in northwestern Washington. Of the 15 priority habitats found in northwestern Washington, those most associated with fish species include instream habitats, riparian habitat, freshwater wetlands/fresh deepwater, marine/estuary shorelines, estuary/estuary-like habitats, and vegetated marine/estuarine areas (eelgrass, kelp, turf algae).
- Habitats and species of local importance. These could include a seasonal range or habitat elements with which a given species has a primary association, and which, if altered, may reduce the likelihood that the species will maintain and reproduce over the long-term. Examples are areas of high relative density or species richness, breeding habitats, winter ranges, movement corridors, and habitats that are of limited availability or high vulnerability to alteration, such as riparian areas, wetlands, and shorelines. Local jurisdictions may designate habitats and species of local importance because of their value to the local environment (Ousley et al. 2003).
- Commercial and recreational shellfish areas. Commercial and recreational shellfish areas include public, tribal and private tidelands that support shellfish harvest (Ousley et al. 2003).
- Kelp and eelgrass beds, Pacific sand lance, and herring and smelt spawning areas. Kelp and eelgrass beds are highly productive ecosystems that provide essential rearing and foraging habitat for a variety of important food and bait fish including rockfish, salmon, smelt and herring as well as Dungeness crab (WAC 365-190-080; WAC 220-110-250; Murphy et al. 2000).
- Naturally occurring ponds under twenty (20) acres. Naturally occurring ponds and ponds created for wetland/critical areas mitigation may provide fish and wildlife

habitat and other wetland functions. These ponds do not include other manmade ponds such as farm ponds and detention ponds (Ousley et al. 2003).

- Waters of the State. Waters of the state include surface waters and watercourses within state jurisdiction as defined in WAC 222-16-030 or WAC 222-16-031 (Ousley et al. 2003).
- Lakes, ponds, streams, and rivers planted with game fish by a government or tribal entity. These waters provide a valuable public recreational and commercial resource.
- State natural area preserves and natural resource conservation areas. Natural area preserves and natural resource conservation areas, owned and administered by the Washington State Department of Natural Resources (WDNR), represent unique or high quality undisturbed ecosystems and habitats (WDNR 2004).
- Land essential for preserving connections between habitat blocks and open space. Maintaining habitat connectivity for fish and wildlife species is necessary to sustain population viability. Habitat connectivity enables individuals to move between habitat patches in obtaining requisite resources, the dispersal of individuals, and genetic exchange between populations. Isolated populations are at greater risk of extinction due to natural population fluctuations, random events, and inbreeding (Morrison et al. 1998; Lemkuhl et al. 2001).

2.1 Inventory of Species and Habitats

2.1.1 Overview

The aquatic habitats of the city of Aberdeen support a number of special status species and priority habitats and species. The Chehalis River system is the largest river system in Grays Harbor County draining 2,660 square miles. The Chehalis system supports chinook salmon, coho salmon, chum salmon, steelhead trout, bull trout, coastal cutthroat trout, longfin smelt, and green sturgeon (WDFW 2007). The principal aquatic priority habitats on non-federal lands in the County are found along the Chehalis River and its major tributaries, the Wishkah River and its major tributaries, the Wynoochee River and along the marine shoreline, and at Aberdeen Lake (WDFW 2004). Further discussion of the city of Aberdeen's FWHCAs with respect to fish species and aquatic habitat is provided below.

2.1.2 Species and Habitats

Federally Listed Species and Habitats

Only two federally listed aquatic species are present in the project area: bull trout and green sturgeon. The Coastal-Puget Sound population of bull trout (*Salvelinus confluentus*) is listed as a threatened species (64 CFR 58910; November 1, 1999). The southern Distinct Population Segment (DPS) of green sturgeon (*Acipenser medirostris*), is listed as threatened (final rule published in 71 FR 17757, April 7, 2006). Migrating individual green sturgeon may use portions of estuaries along the west coast of Washington for migration and foraging but critical habitat for this species has not been designated as of the writing of this report.

State Priority Habitats and Species

The Washington Administrative Code (WAC 365-190-080 designates priority habitats and priority species as separate categories of fish and wildlife conservation areas. Priority species require protective measures for their perpetuation due to their population status, sensitivity to habitat alteration, and/or recreational, commercial, or tribal importance. Priority habitats are those habitat types or elements with unique or significant value to a diverse assemblage of species. A priority habitat may consist of a unique vegetation type or dominant plant species, a described successional stage, or a specific structural element (WDFW 2007a). Priority species include State Endangered, Threatened, Sensitive, and Candidate species; animal aggregations considered vulnerable; and those species of recreational, commercial, or tribal importance that are vulnerable.

According to WDFW (2007b), the following priority habitats and species are found within the city of Aberdeen:

Priority Habitats:

- Wetlands

Priority anadromous fish species:

- Fall, Spring and Summer Chinook salmon (*Onchyrynchus tshawytscha*);
- Fall Chum salmon (*Onchyrynchus keta*);
- Coho salmon (*Onchyrynchus kisutch*);
- Winter and Summer Steelhead trout (*Oncorhynchus mykiss*);
- Bull Trout (*Salvelinus confluentus*);
- Coastal cutthroat trout (*Oncorhynchus clarki*);
- Green Sturgeon (*Acipenser medirostris*)

Priority resident fish species:

- Resident cutthroat trout (*Oncorhynchus clarki*);

Salmon are also associated with other types of priority habitats and species, particularly in relation to riparian areas, so the protection of salmonid habitats serves to protect other species dependent on similar or associated habitats. Other priority habitats and fish species occur in estuarine and nearshore areas and may be present in the city of Aberdeen. Species include Pacific herring, Pacific sand lance, surf smelt, longfin smelt, and green sturgeon (Table 2-1b).

Habitats and Species of Local Importance

The city of Aberdeen Comprehensive Plan (Aberdeen 2001) designates critical areas including wetlands, frequently flooded areas, and fish and wildlife conservation areas as areas that require special consideration.

In addition to these critical areas, the Grays Harbor estuary was designated in 1995 as a hemispheric significant reserve by the Western Hemisphere Shorebird Reserve Network (WHSRN). This habitat in the reserve generally includes intertidal mudflats that may be

used by shorebird flocks that feed in this area during their northern migration in the spring (WHSRN 2007). The WHSRN completed an inventory of available habitat for shorebirds within the Grays Harbor estuary and a portion of this designated area lies within the city limits.

Shellfish Conservation Areas (if there are any)

There are no shellfish conservation areas within the city of Aberdeen.

Kelp and Eelgrass Beds

Kelp and eelgrass beds are found in the Grays Harbor estuary, outside of the city of Aberdeen limits. Washington Department of Natural Resources ShoreZone Inventory states that only 5% of the estuary contains eelgrass and less than 1% of the shoreline contains kelp (WDNR 2001). Kelp and eelgrass beds are important rearing and feeding habitats for juvenile salmonids, particularly during the first year after entry into saltwater, and prior to entering the open ocean. Eelgrass beds provide food and cover for a variety of other organisms including crabs and clams (Kozloff 1973). Diatoms and other microscopic plants that live on eelgrass leaves are an important component of the food chain. Kelp and eelgrass beds may occur in portions of the Grays Harbor estuary that lie within the city of Aberdeen.

Naturally Occurring Ponds

There are no naturally occurring ponds within the city of Aberdeen. Lake Aberdeen is a 64 acre reservoir and is classified as a shoreline of the state under WAC 173-20-300.

Waters of the State

"Waters of the state" includes lakes, river, ponds, streams, inland waters, underground water, salt waters, estuaries, tidal flats, beaches, and lands adjoining the seacoast of the state, sewers, and all other surface waters and watercourses within the jurisdiction of the state of Washington (WAC 173-183-100).

Waters of the state within the city of Aberdeen include the Chehalis and Wishkah Rivers, Elliott Slough, Aberdeen Lake and Van Winkle Creek, Fry Creek, Wilson Creek, Newskah Creek, Mill Creek, Charley and Alder Creeks, Stewart and Bear Creek, and all unnamed tributaries to these rivers and creeks.

Waters with Planted Game Fish

Information on water bodies that have been planted with game fish is not available in the Priority Habitat and Species (PHS) database. A small hatchery is located on Alder Creek, a tributary to the Chehalis River (LLID 1238000469544). This hatchery is operated by Grays Harbor College.

2.1.3 Aquatic Habitats

The most basic functions of an aquatic area are the storage, purification, or transport of water. They also function as habitat for a large number of plants and animals. Specific types of aquatic habitats in the city of Aberdeen include rivers, streams, reservoirs,

wetlands, estuaries, and marine nearshore areas. These habitats and the species that use them are integrated parts of an aquatic ecosystem that has developed, and continues to develop, due to many climatic, geologic, and plant and animal interactions. Human development of land and water often affects this ecosystem in significant ways, ultimately affecting the type and abundance of species that exist. This review focuses primarily on the formation and habitat functions of aquatic and riparian areas, and factors that influence those functions. Much of this discussion focuses on salmonids and their habitats because of their ecosystem, social, and commercial importance. Their wide-spread distribution and sensitivity to environmental change also makes them good indicators of habitat impacts and of the effectiveness of protection measures for aquatic systems and other aquatic species.

The following section has been divided into freshwater habitats and marine habitats to reflect the different processes and functions of these two types of aquatic areas. Detailed information in the following sections was obtained from the Limiting Factors Analysis Report for Water Resource Inventory Areas 23 and 24 Salmon and Steelhead Habitat Limiting Factors, Chehalis basin and Nearby Drainages, Water Resource Inventory Areas 22 and 23 (Smith and Wenger 2001).

Freshwater Habitats

Chehalis River Estuary and Small Tributary Streams

General Conditions

The Chehalis River drains an area of approximately 2,660 square miles (Chehalis River Council 2007). The river begins near the town of Pe Ell in western Washington, and flows to the north and west to end in Grays Harbor estuary and the Pacific Ocean. Major tributaries to the Chehalis River include the South Fork Chehalis, Newaukum, Skookumchuck, Black, Satsop, Wynoochee, and Wishkah Rivers (Phinney and Bucknell 1975). Numerous smaller tributaries also contribute to the Chehalis River.

The Chehalis River Estuary has numerous tributaries within the city of Aberdeen. These include the Wishkah River, Van Winkle Creek, Fry Creek, Wilson Creek, Newskah Creek, Alder Creek, Mill Creek, Elliott Slough, and Charley Creek and three unnamed tributaries.

Fish Passage

Currently, there are no dams or other human-made structures that block the upstream or downstream movement of salmonids in the mainstem of the Chehalis River (Phinney and Bucknell 1975). Van Winkle Creek was dammed to form Aberdeen Lake, which is the primary reservoir for the primary water supply for the city of Aberdeen.

Riparian Buffers

Within the city of Aberdeen, riparian buffers along the Chehalis River are limited. The inner harbor has been developed with residential, commercial, and industrial facilities. Some riparian wetlands are present along Charley Creek. Narrow riparian areas with natural vegetation and slope characteristics remain along some of the city's small streams. A narrow band of native vegetation is present from approximately Filmore

Road northeast to the SR 105 Bridge. East of the bridge, commercial and industrial development extends to the waterline. Overall, canopy cover on the lower Chehalis River and estuary is largely absent, and the riparian conditions are rated as "poor" (Phinney and Bucknell 1975).

Streambank Conditions

Streambanks of the Chehalis River and its estuary within the city of Aberdeen are largely developed. A relatively small (but still significant) exception is the riparian wetlands located at the confluence of Charley Creek with the Chehalis River. Developed streambanks are largely protected with artificial structures such as rip-rap.

Floodplain Connectivity

Channel incision is not documented in the lower reach of the Chehalis River. Considerable areas of estuarine wetland have been filled, which is known to have an effect on floodplain connectivity; however the extent of this filling has not been documented (Phinney and Bucknell 1975). Floodplain condition in the lower Chehalis River is composed of natural floodplain in "good" condition (Phinney and Bucknell 1975).

Substrate Embeddedness

Substrate in the Lower Chehalis River has been greatly disturbed by dredging operations to facilitate commercial shipping traffic. Sediment quality in the Lower Chehalis River has been degraded by increasing sediment loads from upstream tributaries. A relative absence of large woody debris (Phinney and Bucknell 1975) results in higher rates of embeddedness. As a result, the lower Chehalis River is rated "poor" for sediment quality (Phinney and Bucknell 1975).

Large Woody Debris

Large Woody Debris (LWD) in the Chehalis River Estuary was common prior to logging and settlements, but is now believed to be relatively infrequent (Smith and Wenger 2001). Estuarine LWD creates firm substrates in a fine sediment environment and serves as cover for juvenile salmonids (Martin and Dieu 1997). Measurements of LWD levels have not been made within most of the mainstem Chehalis River, but Technical Advisory Group (TAG) members have indicated that levels appear to be low, resulting in a poor rating (Phinney and Bucknell 1975).

Pool Quality and Quantity

No data is available about pool quality and quantity in the Chehalis River in vicinity of the city (Smith and Wenger 2001).

Off-Channel Habitat

Between river mile (RM) 1 (east of Aberdeen) and RM 11 (just west of the Wynoochee River), the lower Chehalis River comprises a large, fairly undeveloped floodplain complex with numerous sloughs and canals (Ralph et al. 1994). These are under strong tidal influence with nearby vegetation that is dominated by older conifers and hardwoods (Ralph et al. 1994). Juvenile coho salmon have been documented in several of these

sites (Moser et al. 1991; Simenstad et al. 1992) and it is likely that other species of salmonids are using this habitat as well. This large, undeveloped estuarine floodplain habitat is a good candidate for preservation, as it is one of the few areas within the basin that is in a relatively natural state.

Water Quality

Many reaches of the Chehalis River mainstem are listed on Washington State Department of Ecology 303(d) list. Temperature, dissolved oxygen, and fecal coliform levels exceed the thresholds for acceptable water quality. The 1998 303 (d) list listed sections of the lower Chehalis and inner Grays Harbor exceeding temp and fecal coli.

Water Quality/Flow Regime

The mean annual discharge from the Chehalis River and all its tributaries is estimated at 14,000 cubic feet per second. Peak discharges occur during winter following storm events rather than from snowmelt.

The Chehalis River has a high sediment load, which is a factor in the frequency of dredging. Kehoe (1982) found that three Chehalis sub-basins, the Wynoochee, Middle Fork Satsop, and West Fork Satsop, discharged suspended sediments at an extremely high annual rate compared to other watersheds in western Washington and Oregon. The balance of the Chehalis sub-basins contributed sediments to the system at moderate to low annual rates. For example, at the time of Kehoe's study, annual sediment discharge for the West Fork Satsop (1500 tons/square mile/year) was 5 times that of the highest discharge non-problem Chehalis sub-basin (the Wishkah, 300 tons/square mile/year). It was thought that a combination of steep topography, high rainfall, and deeply weathered surface soils make the problem sub-basins inherently susceptible to erosion and subsequent high sediment discharge levels, and that these natural conditions had been aggravated by forestry practices (Kehoe 1982).

Biological Processes

No data is available regarding biological processes for the Chehalis River (Smith and Wenger 2001). The level of Spartina invasion has been kept to a minimum, resulting in a "good" rating for biological processes in the Chehalis River Estuary (Smith and Wenger 2001).

Wishkah River

General Conditions

The Wishkah River drains a 102 square mile area with its mainstem (Smith and Wenger 2001), but only a small portion of this area is within the city of Aberdeen. The lower 7 miles of the Wishkah River are tidally influenced. The Wishkah River has two main tributaries (East and West Forks), and numerous smaller tributaries. The East and West Forks originate in the foothills of the southern Olympic Mountains, and converge upstream of the city of Aberdeen. Within the city of Aberdeen study area, the Wishkah River had two named tributaries (Stewart Creek and Bear Creek), and numerous smaller, unnamed tributaries. The Limiting Factors Analysis Report for Water Resource Inventory Areas (WRIA) 23 and 24 (Smith and Wenger 2001) describes the lower 3

miles of the Wishkah River as “exclusively commercial or residential lands, with only small areas containing streamside vegetation”, however, maps of the area show a large wetland near the confluence of the Wishkah River and Stewart Creek within the city of Aberdeen, and the presence of these wetlands was verified in the late summer of 2007.

Fish Passage

The mainstem of the Wishkah River is known to be accessible to anadromous salmon at least up to the Wishkah River Falls at RM 29.4, and steelhead are known to pass the falls during high flows, using the habitat in the river up to Malinowski Dam at RM 32.2 (Smith and Wenger, 2001). These data would tend to support the hypothesis that significant barriers to fish passage are not present in the lower reach of the Wishkah River mainstem. Some dikes have been erected in the lower reach of the Wishkah River, and County officials have reported the presence of undersized culverts in the Wishkah basin, but the exact locations of these facilities have not been reported (Smith and Wenger 2001).

Riparian Buffers

Riparian conditions in the lower three miles of the Wishkah River are rated as “poor” (Smith and Wenger 2001). However, areas of natural vegetation can be found along the Wishkah River in three locations within the City of Aberdeen. The first is a relatively wide (approximately 300 feet) band of riparian forest on the east bank of the Wishkah River, extending approximately one half mile from North Chehalis Street northwards to Gladys Way. A second location is located on the west bank of the Wishkah River, and is dominated by a mixture of trees and shrubs and begins roughly at Steward Road and continues northwards to the city limits. A third area of relatively undisturbed riparian forest extends along the east bank of the Wishkah River from Johnson Street northwards beyond the confluence of Bear Creek and the Wishkah River. These three areas provide potential for recruitment of large woody debris to the Wishkah River.

Riverbank Conditions

Riverbanks of the Wishkah River within the city of Aberdeen are largely developed with commercial and residential properties. Developed riverbanks are largely protected with artificial structures such as rip-rap.

Floodplain Connectivity

Floodplain condition in the Wishkah River is rated as “poor” (Smith and Wenger 2001). This rating is the result of a number of factors, including significant loss of estuarine wetlands, conversion of vegetation to impervious surface, a decrease in large woody debris, confinement of the floodplains by dikes, roads, and commercial and residential development, and long term impacts resulting from splash dams created during logging operations conducted in the past (Smith and Wenger 2001).

Substrate Embeddedness

Stream sediment data is not available for the lower Wishkah River. Road densities in the lower Wishkah River sub-basin are calculated as 4.9 miles/square mile. Densities

greater than three miles/square mile of watershed are rated “high”, and areas with high road densities are prone to deliver fine sediments to streams (Smith and Wenger 2001).

Large Woody Debris

LWD levels are estimated to be low in the Wishkah basin. Areas where LWD surveys have been conducted indicated that LWD levels are low and the near-term recruitment potential is also low because of the hardwood dominated riparian corridor (Smith and Wenger 2001). The developed nature of much of the lower reach of the Wishkah River would indicate limited potential for large woody debris recruitment within the city of Aberdeen boundaries.

Pool Quality and Quantity

No data is available regarding pool quality and quantity for the Wishkah River (Smith and Wenger 2001).

Off-Channel Habitat

While there are several smaller tributaries to the Wishkah River within the city of Aberdeen, floodplains are largely developed (Smith and Wenger 2001), and therefore off-channel habitat is somewhat limited.

Water Quality

Water quality for the Wishkah River is listed as “good” in the limiting factors analysis (Smith and Wenger 2001), however limited data are available for sediment quality and other factors affecting water quality in the lower Wishkah River (Smith and Wenger 2001).

Water Quality/Flow Regime

Water quantity in the lower reach of the Wishkah River is rated “poor” in the limiting factors analysis (Smith and Wenger 2001); however significant data gaps are present.

Biological Processes

No data is available regarding biological processes for the Wishkah River (Smith and Wenger 2001).

Habitats for Anadromous Salmonid Species

All anadromous salmonid species in Grays Harbor County are considered priority species by WDFW. Habitats for anadromous salmonid species include both fresh and marine waters. Habitat use is dependent on the lifestage and species, but in general there is considerable overlap in the range of habitat variables used by different salmonid species. Freshwater streams provide spawning and early-rearing habitat for all anadromous fish species, whereas marine waters are where anadromous fish grow to maturity prior to returning to freshwaters to spawn. Freshwater salmonid life stages require cold-water streams having complex structural habitat and clean gravels free of fine sediment. Upon hatching, juveniles spend varying lengths of time (from days to

more than 2 years depending on species and stock) in freshwater prior to migrating to sea. After entering the estuary, juvenile salmonids typically spend a period of time inhabiting and foraging among coastal and estuary shoreline habitats.

Streams in the city of Aberdeen provide habitat for spawning and rearing habitat for the early life stages of anadromous salmonids. The mainstem of the Chehalis River provides spawning and rearing habitat for chinook salmon, and sloughs and side channels provide important migration and rearing habitat for chinook, coho, and chum salmon and steelhead trout. The estuary areas of the Chehalis River and tributaries provide important habitat for salmonids while they physiologically adjust to the saltwater environment.

The Wishkah River supports fall chinook, coho, and fall chum salmon, and winter steelhead trout (summer steelhead are not supported). Chinook salmon spawning in the Wishkah River is concentrated in the mainstem (WDFW and WWTIT 1994), with additional distribution into the upper reaches of the West and East Forks (WDFW 2000). Fall chinook in the Wishkah watershed are described as "native" (WDFW and WWTIT 1994). Since 1985, the stock has been supplemented by the Long Live the Kings native broodstock hatchery located on the upper mainstem near RM 26 (WDFW and WWTIT 1993; Smith and Wenger 2001). Fall chum salmon are distributed throughout the floodplain reaches of the river up to the Wishkah River Falls at RM 29.4 (Raines et al. 1992). Although Chum populations are believed to have declined significantly in the Wishkah River over the last 40 years, the Wishkah River and its tributaries are believed to have among the largest chum runs in this area (Smith and Wenger 2001).

Other smaller drainages within the city of Aberdeen, independent of the large watershed also support anadromous salmonid populations. Table 2-1a and 2-1b below present detailed information about the presence of salmonids within the city of Aberdeen watercourses. Table 2-1b also contains information on Pacific herring, Pacific sand lance, and smelt.

Table 2-1a. Fish Species & Life History Present Within City of Aberdeen Water Courses

	Coho			Fall Chinook			Spring/ Summer Chinook			Fall Chum			Coastal Cutthroat Trout			Winter Steelhead Trout			Summer Steelhead Trout			Bull Trout	Green Sturgeon
	Presence	*Spawning*	*Rearing*	***Presence***	*Spawning*	*Rearing*	***Presence***	*Spawning*	*Rearing*	***Presence***	*Spawning*	*Rearing*	***Presence***	*Spawning*	*Rearing*	***Presence***	*Spawning*	*Rearing*	***Presence***	*Spawning*	*Rearing*	***Presence***	***Presence***
Wishkah River	X			X						X			X			X						X	X
Stewart Creek	X	X	X										X	X	X								
Bear Creek	X									X	X		X			X							
Chehalis River	X			X			X			X			X			X			X			X	X
Elliott Slough	X			X									X			X			X			X	X
Wynoochee River	X	X		X	X					X	X		X			X	X		X			X	
Van Winkle Creek	X												X						X				
Newskah Creek	X		X										X			X		X					
Charley Creek	X												X			X							
Fry Creek	X						X						X										
Alder Creek	X	X	X										X										
Mill Creek	X	X	X										X										
Wilson Creek	X	X	X										X	X	X								

Table 2-1b. Habitat Associations and Distribution of Priority and Listed Fish Species in the City of Aberdeen

Fish Species	Federal and State Status	General location, distribution and habitat occupied
Fall/Spring/Summer Chinook salmon (Coastal/Puget Sound ESU) *Oncorhynchus tschawytscha*	Priority Species	**Habitat:** Juveniles and adults require cold, well-oxygenated water. Spawning generally occurs in riffle areas with clean gravel and cobble substrates. Fall Chinook use the mainstem of rivers, spring Chinook select the upper reaches of tributaries and summer Chinook use the mouths of the tributaries for spawning. Juveniles use pool habitat and instream cover such as LWD, spaces among cobbles, and undercut banks as resting areas and/or for refuge from predators. Cobble substrate and off-channel habitats such as secondary channels, backwaters, or ponds provide important refuge from flows for overwintering juveniles. After river entry, adults on spawning migration use resting pools, which provide refuge from river currents and high water temperatures that are often encountered in the summer and early autumn. Nearshore marine areas are important for feeding and refuge for juveniles after entering the ocean. **Distribution:** Fall, spring and summer Chinook salmon are found in the waters of the city of Aberdeen. **When habitats are occupied:** Spring and summer Chinook adults return to freshwater systems in preparation for spawning much earlier than fall Chinook. However, all Chinook stocks spawn in the fall, with spring Chinook spawning first, followed by summer Chinook, and then fall Chinook. Spring and summer Chinook adults migrate and are in streams from February to October and spawn from July to October. Fall Chinook adults migrate and are in streams from June to November and spawn from October to early December. Chehalis spring Chinook stock spawning generally occurs in the upper watershed from early September to mid-October, peaking in late September. Spawning takes place throughout the Chehalis basin upstream from the Satsop River for the Chehalis fall stock. Most spawning for the Wishkah fall stock takes place in the mainstem Wishkah River with peak spawning occurring in late October to early November. Most spawning for the Wynoochee fall stock takes place in the mainstem Wynoochee River above RM 10.5 Juveniles of all stocks can be found rearing in streams year-round.
Coho salmon *Oncorhynchus kisutch*	Priority Species	**Habitat:** Coho spawn in a variety of stream-types, including small coastal streams, large rivers, and remote tributaries. They will spawn just about anywhere that suitable gravel (15 cm or smaller in diameter) is present. Coho are visual feeders and prefer food moving in suspension or on the surface. They rarely feed on non-moving food or along the stream bottom. The juveniles usually rear in slower sections of the stream that allow them to capture prey with a minimum of effort. Small streams are the most productive coho areas because they provide more marginal slack water habitat than large streams. The midstream portion of large streams is generally unsuitable for juvenile coho; therefore, any food drifting through this area is unavailable (Sandercock 1998). Juveniles use pool habitat and instream cover such as LWD, spaces among cobbles, and undercut banks as resting areas and/or refuge. Juvenile coho salmon overwinter in freshwater so overwinter habitat such as deep pools and off-channel habitats are of particular importance for survival, especially in coastal streams subject to high fall and winter flows. Outmigration generally peaks in May, with most movement occurring at night. The fish grow rapidly in the nearshore waters of the estuary, feeding on invertebrates. **Distribution:** The Chehalis River and nearby drainages produce more coho smolts (575,000 in 1999) than any other system along the Washington Coast (Smith and Wenger 2001). In 1999, the Chehalis River was the third largest producer of wild coho smolts in Washington State (Seiler 2000). Wishkah coho spawning takes place in the Mainstem and East and West Forks of the Wishkah River. Spawning also occurs in accessible tributaries such as Bear, Big, Cedar, Raney and Hopper Creeks. Chehalis coho spawn in all available tributaries such as Van Winkle Creek, and Elliott Slouch. South Bay coho spawn in Newskah Creek and other creeks draining the south shore. Wynoochee coho stock spawn in the upper tributaries of the Wynoochee River basin.

Fish Species	Federal and State Status	General location, distribution and habitat occupied
		When habitats are occupied: Coho salmon adults migrate and are in streams from July to as late as February, and spawn from October to as late as February. Juveniles can be found rearing in streams year-round. There are two run timings particular to the Chehalis basin. "Normal" coho are the most numerous and spawn in December throughout the basin (Hiss and Knudsen 1992). "Late" coho salmon spawn from January through February and have been observed in the Wishkah River, and the upper Wynoochee River. Wishkah stock spawning generally occurs from late October through mid-February. Wynoochee coho stock spawning generally occurs from late October through February. Chehalis coho stock spawning generally occurs from November through February. South Bay coho stock spawning generally occurs late October through mid-February.
Fall Chum salmon *Oncorhynchus keta*	Priority Species	**Habitat:** Chum salmon rear in freshwater for only a few days to weeks before migrating downstream to saltwater, therefore juveniles have limited habitat needs in freshwater. Migrating spawning adults require cold well-oxygenated water, resting pools, and clean gravel spawning substrate. They prefer to spawn immediately above turbulent areas or in areas of groundwater upwelling. Chum have adapted to spawn in shallower water depths and slower velocities than some of the other members of the genius Oncorhynchus. Late chum stocks often select spawning sites near springs above 4ºC (~ 39ºF), protecting the eggs from freezing and resulting in relatively consistent emergence timing from year to year. Intertidal spawning provides a similar benefit because the redd is warmed by marine waters during each tidal cycle (Kuttel 2002). Chum are second only to Chinook in their dependence upon estuaries. The timing of entry to sea water is often correlated with warming of nearshore waters and the associated plankton blooms. The juveniles feed primarily on zooplankton including copepods and amphipods. The fry feed extensively over submerged tide flats. This allows them to exploit both freshwater and marine food webs. **Distribution:** Chehalis chum spawn in WRIA 22 and 23 streams outside of the Humptulips subbasin. This includes the Chehalis, Wishkah, and Wynoochee, Rivers, as well as some smaller streams (Smith and Wenger 2001). Most spawning takes place in the mainstem Wishkah, and Wynoochee, rivers. Fewer spawners are observed in Cloquallum Creek and the lower mainstem Chehalis River (Smith and Wenger 2001). **When habitats are occupied:** Chum salmon adults migrate and are in streams from August to February, and spawn from October to February. Spawning generally occurs from late October through mid-December. Fall chum enter the Wynoochee River in October and spawn during late October to early November (WDFW and WWTIT 1994). Fry can be found in streams from February to July, but fry migrate seaward shortly after hatching and there is no juvenile rearing in freshwater.
Bull trout *Salvelinus confluentus*	Federally Threatened, Priority Species	**Habitat:** Similar general instream habitat requirements as other salmonids except that bull trout require much colder water temperatures than other salmonid species, and require relatively pristine habitats. Bull trout spawn in the fall after water temperatures drop below 48°F, in streams with cold, unpolluted water, clean gravel and cobble substrate, and gentle stream slopes. The eggs incubate for four to five months, hatching in late winter or early spring. Migratory forms of bull trout inhabit lower river reaches and use nearshore marine habitats for migration, rearing, and feeding. **Distribution:** Some bull trout may live near areas where they were hatched, while others may migrate to lakes, reservoirs, or salt water. Coastal migratory bull trout migrate to salt water. A literature search performed by the USACE found three accounts of either migratory Dolly Varden or bull trout in Grays Harbor (Simenstad 1981). A recent native char utilization study (R2 Consulting 2006) documented more occurrences of bull trout in the Lower Chehalis/ Grays Harbor area. The study indicated that the native char were least likely to be present in the lower Chehalis River/ Grays Harbor area from July 16 through the end of February. The Chehalis River upstream to

Fish Species	Federal and State Status	General location, distribution and habitat occupied
		and including the Satsop River, and portions of the Wishkah, Wynoochee, and Humptulips Rivers used by salmon and steelhead, have been identified as either current or suspected bull trout foraging, migration, and overwintering habitat important for bull trout recovery in the Olympic Peninsula **When habitats are occupied:** Anadromous bull trout smolts move downstream in April through June, and adults migrate from the marine environment to freshwater spawning grounds during May, June, and July (Kraemer and Curtis 1994). The Coastal/Puget Sound Distinct Population Segment (DPS) of the bull trout population may migrate past the city of Aberdeen on their way upstream to spawn, and as juveniles migrate to the Pacific Ocean.
Winter/Summer Steelhead *Oncorhynchus mykiss*	Priority Species	**Habitat:** Similar general instream habitat requirements as other salmonids. Adult winter steelhead generally enter freshwater from November through March. Spawning usually takes place within four months of freshwater entry. The majority of returning adult steelhead are three to four years of age. These fish typically display three distinct life histories: Two years in freshwater and one year at sea (about 50%), Two years in freshwater and two years in saltwater (about 30%), and Three years in freshwater and one year at sea (about 10%) Survival of steelhead to first spawning improves with increased juvenile size at outmigration, hence the prevalence of two or three years of freshwater rearing in the three major life histories. Small groups of adult steelhead enter the stream as water levels rise following storms. The fish generally migrate upstream during daylight hours. Spawning sites are typically located near the head of a riffle (pool tailout) (Kuttel 2002). Juvenile steelhead have a diverse suite of life histories, with fish migrating downstream from young-of-the-year (YOY) to four years of age. The bulk of downstream migration takes place in the spring and summer. Young-of-the-year through age two juveniles make up the bulk of downstream migrants with age three and four fish representing only a small proportion of the outmigration. The typical life history involves migration to the ocean at two years of age, but environmental conditions and sexual development can cause changes in the behavior pattern. Age one and YOY juveniles often remain in the lower portion of the stream or estuary for an additional year prior to migrating to the ocean. Age two and older fish typically migrate to the ocean immediately. The saltwater feeding habits of steelhead are likely similar to coho, with small fish feeding on invertebrates and larger fish feeding on fish (Shapovalov and Taft 1954). Summer steelhead adults enter the river from about May through October with spawning from about February through April. They enter the river in an immature state and require several months to mature (Burgner et al 1992). Summer steelhead usually spawn farther upstream than winter stocks (Withler 1966) and dominate inland areas such as the Columbia Basin. However, the coastal streams support more winter steelhead populations. Juvenile steelhead can either migrate to sea or remain in freshwater as rainbow or redband trout. In Washington, those that are anadromous usually spend 1-3 years in freshwater, with the greatest proportion spending two years (Busby et al. 1996). Because of this, steelhead rely heavily on the freshwater habitat and are present in streams all year long. **Distribution:** Four winter-run stocks in the Wishkah, Wynoochee, South Bay Tributaries, and Chehalis (all spawn upstream of the confluence of the Satsop River) (WDFW and WWTIT 1994). Chehalis winter steelhead spawning takes place in the mainstem Chehalis, East and West Fork Chehalis rivers and in tributaries. South Bay winter steelhead spawn in Newskah Creek. Wishkah winter steelhead spawning takes place in the mainstem and in the west and east forks of the Wishkah River. Wynoochee winter steelhead spawning takes place in the mainstem Wynoochee River. There is an unknown summer stock in the Chehalis basin with wild production. Specific spawning locations are unknown and spawning timing is unknown. A native stock originally returned to the Chehalis River system, but now there is uncertainty about natural production by hatchery summer steelhead

Fish Species	Federal and State Status	General location, distribution and habitat occupied
		spawning in the wild. **When habitats are occupied:** Resident rainbow trout are found in freshwaters year-round. Summer steelhead adults are potentially found in streams year-round, but spawning occurs from February to April, with surviving adults outmigrating to the ocean shortly thereafter. Winter steelhead are found in streams from October to July, and spawning may occur from December to July. Chehalis and South Bay winter steelhead spawning generally occurs from mid-February through mid-June. Wishkah and Wynoochee winter steelhead spawning generally occurs from mid-February through June. Juveniles of both life-history forms rear in freshwaters year-round prior to outmigrating to the ocean.
Coastal Cutthroat Trout *Oncorhynchus clarki*	Priority Species	**Habitat:** Cutthroat trout have similar general requirements as all salmonids and display varying degrees of migratory behavior, often moving out to nearshore marine waters and estuaries to feed in the summer and migrating freshwater streams to overwinter prior to spawning in the spring. Coastal cutthroat spawn from late winter through late spring in low gradient reaches of small tributary streams or the lower reaches of larger streams. During the summer months, young-of-the-year (Age-0) cutthroat prefer to rear in pools and other slow-water habitats. However, if coho juveniles are present, cutthroat are often displaced into riffles. Coho emerge earlier and at a larger size than cutthroat. They are able to outcompete cutthroat because of their larger size, aggressive behavior, and body morphology is better adapted to pool habitat. Juvenile steelhead may displace juvenile cutthroat from riffles in a similar fashion. Steelhead are more aggressive with a body better adapted to riffle habitat than cutthroat. Interactions between young-of-the-year coho, steelhead, and cutthroat during the summer rearing period may set a natural limit on cutthroat production in streams where all three species are present. Stream-rearing juvenile coastal cutthroat may be feeding generalists, consuming whatever prey is available. The juveniles overwinter in deep pools associated with large woody debris and undercut banks, as well as boulders and cobbles that provide interstitial cover. Off-channel pools, side channels, and lakes are also used where available (Trotter 1997). Puget Sound coastal cutthroat typically smolt at age 2 with an average length of 160 mm (~ 6 inches). Seaward migration begins as early as March and continues through mid-July, with a peak in late May to early June. **Distribution:** Coastal cutthroat trout are widely found in virtually all perennial tributaries and mainstem reaches of all of the city of Aberdeen streams in one or more of their life history forms. **When habitats are occupied:** The life-history of coastal cutthroats is highly variable. The anadromous and fluvial forms inhabit mainstem and accessible tributary reaches. The resident form exists both above anadromous barriers and below where they mix with anadromous fish. Anadromy is not well developed in coastal cutthroat trout. They spend little time in saltwater and often remain in the tidewater and estuarine reaches of their home streams. While in saltwater, cutthroat generally travel along the shoreline within 50 km (~ 31 miles) of the home stream and are reluctant to cross deep open water. Coastal cutthroat seldom over winter in salt water. They often return to freshwater the same year they migrated to sea, but not all of these fish are spawners. In large streams fish enter freshwater from July through November with a peak in September and October. In small streams that flow directly to saltwater, cutthroat enter freshwater from December through March with a peak in December and January. Spawning by anadromous and fluvial life history forms occurs from January through mid-March. Adfluvial fish spawn from March through mid-April, and resident fish spawn from February through mid-March. Coastal cutthroat survive spawning quite well (Trotter 1997). Kelts return to saltwater from late March through early April, about one month earlier than cutthroat smolt

Fish Species	Federal and State Status	General location, distribution and habitat occupied
		outmigration. This timing places the adults in position to feed on outmigrating juvenile salmonids, particularly pink and chum salmon (Trotter 1997).
Green Sturgeon *Acipenser medirostris*	Federally Threatened, Priority Species	**Habitat:** Green sturgeon are the most broadly distributed, wide ranging, and most marine-oriented species of the sturgeon family. Green sturgeon are believed to spend the majority of their lives in nearshore waters and estuaries. Early life-history stages (< 4 years old) reside in fresh water, with adults returning to freshwater (early spring) to spawn (late spring to early summer) when they are more than 15 years of age and greater than 4 feet (130 cm) in length. Southern green sturgeon spawn in the Sacramento River, California, while northern green sturgeon spawn in the Klamath and Rogue Rivers. There is no evidence of current spawning in the Chehalis Rivers or other tributaries of Grays Harbor. (NMFS 2005; NMFS 2007a-c). **Distribution:** The green sturgeon ranges from Mexico to at least Alaska in marine waters, and forages in estuaries and bays ranging from San Francisco Bay to British Columbia. (Moyle et al. 1992; NMFS 2005). The only feeding data recorded for adult green sturgeon indicate that they consume benthic invertebrates such as shrimp, mollusks, amphipods, and even small fish (Moyle et al. 1992). Green sturgeon are migratory, utilizing the open ocean to travel vast distances between freshwater rivers. Genetic and tagging data indicate the stocks co-mingle in the Columbia River estuary, Willapa Bay, and Grays Harbor during the summer as sub-adults and adults. Recent studies indicate that tagged individuals released in the Sacramento River have been captured as far north as Willapa Bay, Washington, and tagged individuals released in the Columbia River have been captured as far north as Vancouver Island, British Columbia, and as far south as the Sacramento River. Green sturgeon tagged with radio transmitters in the Rogue River have been documented near Vancouver Island, British Columbia (NMFS 2005). **When habitats are occupied:** Both green sturgeon distinct population segments are known to congregate during summer months in coastal estuaries such as Grays Harbor, Willapa Bay, and the Columbia River estuary, indicating probable offshore migration along the Washington coast (ODFW 2005). Moser and Linkley (2007) suggested that green sturgeon enter Washington estuaries during summer when water temperatures are more than 2°C warmer than adjacent coastal waters. In order to confirm this green sturgeon migration pattern along the West Coast, one hundred and sixty-eight green sturgeons were tagged with acoustic tags in both spawning areas (Rogue and Klamath rivers and San Pablo Bay) and mixed stock areas (Columbia River and Willapa Bay) during 2002, 2003, and 2004 (NMFS 2005). This study documented movement of green sturgeon from all spawning areas to Willapa Bay (NMFS 2005).
Pacific Herring *Clupea pallasi*	Species of Concern	**Habitat:** Most spawning occurs in shallow sub-tidal zones from 0 to -10 ft in tidal elevation. Eggs are deposited on vegetation or other shallow water substrate. Most of the spawn deposition in Grays Harbor appears to occur in the South Bay/Elk River estuary area. **Distribution:** Herring are abundant throughout the northeast Pacific Ocean. Spawning concentrations are found in Western Grays Harbor. **When habitats are occupied:** Pacific herring spawn from February through March in Grays Harbor.
Pacific sand lance *Ammodytes hexapterus*	Priority Species	**Habitat:** Pacific sand lance deposit their eggs in sand-gravel substrates between the mean high tide line and about +5 ft in tidal elevation. Eggs incubate in beach substrate for about one month before emerging. Larvae are a common component of the nearshore plankton. Incubating sand lance eggs occur in the same substrate with the eggs of surf smelt spawning populations, both species using the same stretches of beach for spawning at the

Fish Species	Federal and State Status	General location, distribution and habitat occupied
		same times of year. **Distribution:** The Pacific sand lance is found from southern California around the north Pacific Ocean. It is common in nearshore marine waters throughout Washington state. Spawning areas are scattered along nearshore areas in South Arbor (Smith and Wenger 2001). **When habitats are occupied:** Sand lance inhabit marine near-shore areas year-round, with spawning in intertidal areas occurring annually from November 1 through about February 15.
Surf smelt *Hypomesus pretiosus*	Priority Species	**Habitat:** Similar spawning and nearshore habitat requirements as the Pacific sand lance. Surf smelt have an entirely marine/estuarine life history (Bargmann 1998). **Distribution:** The surf smelt occurs from southern California to central Alaska and are widespread in Washington. Surf smelt are found in similar areas as Pacific sand lance. **When habitats are occupied:** Surf smelt inhabit marine near-shore areas year-round, and spawning may occur year-round.
Longfin smelt *Spirinchus thaleichthys*	Priority Species	**Habitat:** Longfin smelt are anadromous and spawn in freshwater streams. Spawning substrate is sand and gravel similar to that used by surf smelt in nearshore areas. **Distribution:** Spawning populations occur locally throughout western Washington, but the species is poorly understood or studied. Spawning is known to occur in the lower Chehalis River, but actual spawning sites have not been identified (Bargmann 1998). **When habitats are occupied:** The longfin smelt spawning season in the lower reaches of the Chehalis River is thought to only occur from November until as late as April.

Primary sources: Bargmann (1998), (Smith and Wenger 2001), WDFW (2007)

Marine Habitats

General Conditions

The Limiting Factors Analysis Report for Water Resource Inventory Areas (WRIA) 23 and 24 (Smith and Wenger 2001) describes that Grays Harbor is at the mouth of the Chehalis river on the southwestern coastline of Washington, approximately 110 miles south of the entrance to the Strait of Juan de Fuca and 45 miles north of the Columbia River's outfall. Fresh water inflow to the estuary comes predominantly from the Chehalis, Hoquiam, and Humptulips Rivers.

The predominant physical feature of the Harbor is the expansive mudflats that cover 63% of the Harbor's surface area at low tide; the water surface ranges from about 94 square miles at mean high tide to 38 square miles at low tide. Numerous shallow channels have been cut into the mudflat areas of the North, South, and East Bays by ebbtide flows and discharge from the Humptulips, Elk, and Chehalis Rivers. Harbor sediments are composed of ocean-borne sands in the outer estuary and river-borne silts near river outfalls in the North, South, and East Bays. A mixed transition zone lies between the outer estuary and river outfalls in a broad band.

Riparian Buffers

Between RM 1 (east of Aberdeen) and RM 11 (just west of the Wynoochee River), there is a large floodplain complex with numerous sloughs under strong tidal influence and well buffered by older conifers and hardwoods (Ralph et al. 1994 as cited by Smith and Wenger 2001). There is also a large floodplain complex on the right bank of the Wishkah River upstream of the confluence of Stewart Creek. Significant shoreline acreage along the outer Harbor remains undeveloped. A narrow, fringing band of estuarine emergent vegetation is present along much of this shoreline. In a few areas, such as Oyehut, Bowerman Basin, and eastern Westport, rather extensive marsh stands occur.

Bank Conditions

Since the development of the Chehalis Basin's logging industry, extensive intertidal wetland acreage in the inner Harbor has been filled and/or diked. Dredged material, as well as sawdust and bark from sawmills was placed in tidelands to create much of downtown Aberdeen and Hoquiam (Hiss and Knudsen 1993). The portion of the estuary between Moon Island and Cosmopolis is highly developed and industrialized; fourteen wharves, used primarily for the transport of log or wood products, are located along this area of the waterfront. Diking has been extensive in the lower Wishkah and Hoquiam Rivers, as well as near Montesano (Smith and Wenger 2001), and much of the shoreline along the developed portions of the inner Harbor has been hardened.

Portions of the lower Chehalis and the outer Harbor remain relatively undeveloped and likely serve as refugia for salmonids, particularly juveniles.

Substrate

Sediment is a physical-chemical aspect of the estuarine environment that has a substantial effect on the biological structure of the estuaries. The ecological role of sediment contaminants has been extensively discussed in recent literature (Arkoosh et

al. 1998). Sediment sampling by Ecology in 1998 indicated that chemical concentrations in sediments were generally low, with a few localized problem areas (Norton 1999 as cited by Smith and Wenger 2001). Standards for 4-methylphenol, a degradation product of wood materials, were exceeded near the Grays Harbor Paper Mill. Concentrations of bis(2-ethyl hexyl) phthalate near Westhaven Cove were high enough to elicit concern. Of 16 other sites sampled, six violated Washington sediment standards.

Large Woody Debris

Large woody debris (LWD) was more common in the Chehalis River Estuary prior to logging, where it provided cover for juvenile salmonids and a firm substrate for macroalgal production.

Eelgrass Beds

The areal extent and density of Grays Harbor's eelgrass beds may change from year to year as old beds are uprooted and new ones established. Long-term trends in the extent of eelgrass beds have not been monitored.

Salinity

The dominant features of estuaries are that they have variable salinity and a salt wedge or interface between salt and fresh water where the heavier salt water is deeper than the lighter freshwater. Salinities in Grays Harbor, like other estuaries, are characterized by a high degree of spatial and temporal variability. This variability is driven by meteorological conditions, river flows, and tide stage. Rivers feeding Grays Harbor have very little drainage area extending into the higher elevations of the Olympic Mountains, so river flows closely follow precipitation. Average salinity gradients vary by season and location, for example at the entrance the average is 20 parts per thousand (ppt) during the winter and 30 ppt in the summer; at Sterns Bluff 15 ppt in winter and 25 ppt in summer; at Hoquiam 5 ppt in winter and 20 ppt in summer; and at Elliot Slough 0 ppt in winter and 10 ppt in summer. Salinity is lower at low tide than at high tide and this difference increases from the Harbor entrance towards Cosmopolis, reflecting increasing influence of the Chehalis River (Loehr and Collias 1981).

Vertical salinity gradients in the Harbor are also variable, depending on tidal stage and river flow conditions. Vertical mixing is generally enhanced during periods of low freshwater flow. At the mouth of the Chehalis River, the vertical salinity profile typically displays a salt wedge below a less saline lens of fresh river water. Of four other sites surveyed, this type of profile regularly occurred only at Searns Bluff, suggesting that the predominant river flow directed through the north channel is well mixed, while marine and riverine waters in the south channel are typically well stratified (Kinney et al. 1981).

Water Quality

In the past, water quality in Grays Harbor has been a problem which was thought to contribute to a bottleneck in Chehalis River salmon production (Smith and Wenger, 2001). Bioassays showed that discharges from the Weyerhaeuser and ITT-Rayonier pulp mills were toxic to oyster larvae and rainbow trout. By 1990, Weyerhaeuser began to reduce their discharge of chemicals into the inner Harbor and the ITT-Rayonier mill was no longer in operation.

At present time, both the inner and outer Harbors are on Washington's 303(d) list for fecal coliform. Recent sampling in various areas of the Harbor indicate that water temperature, dissolved oxygen, and pH standards are sometimes violated, but that these problems may be the result of natural conditions (e.g., solar heating of shallow water) or nutrient enrichment attributed to wastewater treatment plant effluent.

Water Quality/Contaminants

Potential point and nonpoint sources of contaminants in Grays Harbor are associated with past and existing land uses adjacent to the estuary. Land uses are residential (housing), commercial, municipal (city outfalls and drains), industrial (paper mill, timber and wood products industries, marine vessel moorage and repair, fish processors), maricultural (oyster beds), agricultural (cranberry bogs), and recreational (parks and waterways).

One of two pulp mills that operated in the vicinity of Cow Point closed in the early 1990s. The Weyerhaeuser pulp mill, located in Aberdeen, is still in operation, but Grays Harbor Paper now occupies the facilities that once housed ITT Rayonier in Hoquiam. Grays Harbor Paper produces uncoated free sheet paper used in copying and printing.

Other potential sources of contaminants may originate from city outfalls located near the Federal Navigation channel in Aberdeen and Hoquiam. Paints, petroleum products, and antifoulants (i.e., tri-n-butyl tin (TBT)) may exist in sediments near marinas and boat docks located at Westport, the Hoquiam River in Hoquiam, the Wishkah River in Aberdeen, and smaller creeks surrounding the harbor. Boatyards (Westport Shipyard, The Boatyard and Pakonen & Son), located in Westport, Aberdeen and Hoquiam, respectively, may generate contaminants associated with marinas and sandblast grit (i.e., metals, paint chips, TBT). The requirements for determining the suitability of dredged material in Grays Harbor for unconfined, open-water disposal are documented in the 1995 *Dredged Material Evaluation Procedures and Disposal Site Management Manual, Grays Harbor and Willapa Bay, Washington* (the GHDMEP).The GHDMEP checks for the presence of these contaminants in the standard suite of chemical tests, and TBT analysis is requested on a case-by-case basis in areas located near marinas and boatyards.

Seafood processors (crabs and oysters), oyster mariculture, and cranberry processors are located in South Bay near Westport. The pesticide sevin (carbaryl), was also routinely tested in the GHDMEP because it is used by the oyster culture industry to exterminate the burrowing shrimp that cause oysters to sink and perish. Since 1990, the principal sources of dioxin as a result of pulp mill processing have been reduced or eliminated through Ecology actions. Dioxin concentrations are either present in low concentrations or are not detected and are no longer monitored as part of the Grays Harbor dredged material characterization process. The analysis of sevin has also been eliminated from the GHDMEP because this chemical has not been detected in Grays Harbor dredged material characterizations. Guaiacol and resin acids will continue to be monitored in Grays Harbor, considering the high volume of raw logs and wood products handled by local entities.

The most recent sampling took place in July 2000, and characterized approximately 620,000 cubic yards from the upstream portion of the navigation channel, including Cow Point, Aberdeen and South Aberdeen reaches. Eighty-two sediment grab samples were

composited per an agency-approved sampling plan for eleven analyses. There were no exceedances of the inter-agency Dredged Material Management Program (DMMP) screening levels for any chemicals of concern, including those found in the 1998 Ecology study. Bioassays of two representative composites showed no effects. Though a suitability determination has yet to be signed by the DMMP agencies, this data indicates that all material is suitable for open-water disposal at any of the proposed disposal sites or nearshore nourishment sites.

Since these standards are designed to be protective of organisms that come into contact with sediments, concentrations and bioavailability of contaminants in sediments suspended during dredging are expected to be below levels that may cause harm to juvenile or adult salmonids.

2.2 Aquatic Habitat Functions and Values

Productive salmonid habitat is necessarily complex owing to the myriad requirements of various lifestages. Salmonids require cold clean waters, silt-free substrates, natural flow conditions, and structurally complex habitat suitable for spawning, rearing, and migration. The aquatic habitat features important for supporting salmonid populations include riparian condition, LWD recruitment, fish passage, floodplain connectivity, channel migration, bank stability, pools, off-channel habitat, substrate/fines, water quality, and hydrology.

Riparian areas are the zones where aquatic and terrestrial ecosystems interact. Riparian vegetation provides habitat for many species of wildlife, and streamside or shoreline vegetation provides habitat functions for streams, and fish such as shade, bank stability, sediment/nutrient filtering, and organic nutrient input. In addition, riparian vegetation interacts with natural erosional and depositional processes of streams as channels migrate across valley bottoms to form instream habitat. As channels move back and forth through this channel migration zone (CMZ), instream pools and riffles are formed. Channel migration also promotes floodplain connectivity and recruitment of LWD, which can be a primary factor influencing channel formation by the creation of pools, riffles and off-channel habitats that are essential to support all life stages of anadromous salmonids (May 2000).

Historically, natural riparian corridors in the Pacific Northwest were nearly continuous and the importance of riparian continuity is widely recognized (May et al. 1997; Naiman and Bilby 1998; Wenger 1999). Riparian corridor continuity is particularly important in smaller headwater streams because smaller streams generally make up most of the stream length within a watershed, and the influence of riparian vegetation on some stream habitat functions is greater for small streams (Binford and Bucheneau 1993; Wenger 1999; Beschta et al. 1987). Such areas upstream of fish-bearing waters help determine water quality, the magnitude and timing of flows, stream temperature, sediment, nutrients, and prey production in downstream waters.

Along marine and lake shorelines, riparian vegetation is also a key element of ecological function and has a significant influence on the habitat value of the riparian zone, and in adjacent aquatic and terrestrial areas (Zelo and Shipman 2000). Though not as well defined as for riverine systems, both marine and freshwater shoreline riparian zones serve many of the same functions (e.g. LWD, shading, organic matter production,

sediment filtration, microclimate), as well as some additional functions unique to shorelines (Gregory et al. 1991; Naiman et al. 1992).

2.2.1 Freshwater Aquatic Habitat Functions and Values

Channel Migration Zones (CMZ)

The importance of protecting the CMZ is well-documented (Knutson and Naef 1997; May 2000; WDNR 1999, 2003; Smith 2002). As stream channels migrate across valley bottoms, riparian vegetation interacts with natural erosional and depositional processes, which promotes floodplain connectivity, LWD recruitment potential and the formation of instream habitat (May 2000).

The definition of CMZs varies. Knutson and Naef (1997) state "the channels of some streams, particularly larger streams and rivers in broad, alluvial valleys, may migrate across the valley as a result of natural erosional and depositional processes; the area over which the channel is expected to migrate is called the channel migration zone". The Washington Forest Practices Board (WDNR 1999) defined CMZs as "...the area that streams have recently occupied (in the last few years or less often decades), and would reasonably be expected to occupy again in the near future." However, the Forests and Fish Report (WDNR 1999) provided the following guidance for defining CMZs:

"Operationally, the CMZ should be equivalent to the area that a stream is expected to occupy in the time period it takes to grow a tree of sufficient size to provide geomorphic/ecological functions in the channel. On smaller streams, it may be appropriate to be concerned where the stream could move within 100 years or less. However, larger wood is needed to function in larger, high-energy channels. To be functional, recruitment trees must be very large, with root wads attached. As a consequence, on a larger stream, it may be necessary to include areas in the CMZ that the stream could occupy in the next 200 years or more."

Regardless of the time frame used to define a CMZ, what ultimately determines the presence of a CMZ is physical evidence of channel migration such as inactive channels, old meander bends, sloughs, oxbows, or floodplain terraces. By definition, such features only occur within CMZs and any classification system of channel migration potential can only be derived from such evidence of channel migration. In general though, channel migration can be expected to occur in lower gradient streams and rivers having broad valleys (that were often formed by such channel migration processes over long periods of time), which are typical of those reaches designated as "Shorelines of the State" (i.e. having a mean annual flow ≥ 20 cubic feet per second (cfs)) in the city of Aberdeen. However, CMZs often occur in smaller streams and reach specific delineations must be conducted to determine the presence and extent of CMZs. Additional details and protocols for identifying and delineating CMZs can be found in WDNR (2003).

LWD Recruitment

The important role of fallen trees and tree parts as structure-forming elements in stream channels is well known. LWD in streams influences coarse sediment storage, creates hydraulic heterogeneity, moderates flow disturbances, provides cover, and contributes to overall channel complexity. LWD traps and accumulates sediment, small woody debris, and other organic matter (Bilby 1981). The complex, submerged structure formed by

LWD and entrapped smaller woody debris provides flow refugia and essential cover in which salmonids conceal themselves from predators and competitors and find profitable feeding positions, as inferred from observations under both natural and laboratory conditions (McMahon and Hartman 1989; Fausch 1984). The removal of riparian forest reduces woody debris in streams, which in turn leads to adverse changes in channel and habitat-forming processes (Bilby 1984; Heifetz et al. 1986; McDade et al. 1990; Van Sickle and Gregory 1990; Bilby and Ward 1991).

Riparian buffer widths of 100 to 200 feet (equal to about 1 site potential tree height or SPTH) generally provide adequate LWD recruitment potential, depending on site conditions such as stream size, channel confinement, gradient, and buffer vegetation characteristics (i.e. type, maturity, and density) (Murphy and Koski 1989; Robison and Beschta 1990; McDade et al. 1990; Thomas et al. 1993). With respect to stream size, the role of LWD varies, with riparian vegetation generally exerting a greater influence on smaller streams (Knutson and Naef 1997). Large woody debris is not easily transported in small streams, regardless of gradient, thus individual pieces (logs, root wads, etc) can greatly influence channel morphology, instream cover, food resources, and sediment transport. As stream size increases, the influence of riparian vegetation and individual pieces of LWD decreases, and more substantial logjams are needed to affect instream structural complexity. Larger buffer widths (>200 ft) may be required for long-term natural recruitment of woody material (FEMAT 1993; May 2000). Humans can “import” woody debris to streams and rivers, but these artificial recruitment efforts provide limited short-term, benefits to stream habitat (e.g., fish cover, localized hydraulic complexity). Therefore, human installation of LWD is not an adequate substitute for the natural recruitment potential of healthy riparian areas, nor does it provide many other important long-term benefits provided by native vegetation buffers. Artificially introduced LWD can provide some habitat benefits in the absence of riparian buffers and natural recruitment (e.g. highly managed agricultural areas), or as an interim measure while existing or newly established riparian buffers mature.

LWD is a natural component of marine shorelines. LWD accumulates in backshore areas at high tides, and serves to help stabilize the shoreline by absorbing wave energy, and trap sediment as is seen in riverine and freshwater lake shorelines where current and wave action would otherwise cause erosion (Zelo and Shipman 2000). LWD is also a source of organic matter and nutrients as with freshwater systems. LWD along shorelines supports a variety of habitats for aquatic species such as foraging, refuge, and spawning substrate for fishes and invertebrates (Brennan and Culverwell 2004).

Shading and Temperature

Thermal benefits of shading by riparian vegetation in summer are obvious (Hall and Lantz 1969; Brown and Krygier 1970; Newbold et al. 1980; Beschta et al. 1987; Holtby 1988). Aside from summer cooling, riparian forest cover also exerts winter-insulating effects (Murphy and Meehan 1991).

As was reviewed in GEI (2002), thermal modeling results indicate that stream temperature in any given location is primarily dependent on the temperature of water directly upstream, or the input water temperature. Riparian vegetation generally serves to reduce solar heating and maintain water temperatures. Under undisturbed conditions, stream temperatures are maintained because the surface and groundwaters that comprise streamflow are thermally protected by upland and riparian vegetation and soils.

As forested area in a watershed is removed, thermal protection is removed and the ratio of surface to groundwater in a stream increases. Combined with loss of thermal protection, stream temperatures increase. Therefore, actions in upper watersheds can lead to increased water temperatures in lowland areas, but adequate shading is required in lowland areas to prevent further solar heating.

The value of riparian buffers in moderating stream temperatures is well-established, but the effectiveness of different buffer widths varies depending on site conditions. Several authors (Beschta et al. 1987) have concluded that buffer strip widths of 100 feet or more generally provide the same level of shading as that of an old growth forest in the Pacific Northwest while several authors have recommended a minimum buffer width of 30 feet (Davies and Nelson 1994). In forested areas, harvest treatments that leave overstory vegetation buffers adjacent to streams have been shown to have no significant impact on stream temperature (Lee and Samuel 1976; Rishel et al. 1982; Lynch et al. 1984; Sugimoto et al. 1997). In coastal British Columbia, Gomi et al. (2003) conducted a 6-year field experiment to evaluate the effects of riparian buffer widths on stream and riparian ecosystems, including stream temperature response. Treatments included no timber harvesting, harvesting with 33-ft and 100-ft wide riparian buffers, and clear-cut harvesting with no buffer. The results indicated that water temperature in the streams with 33 -ft and 100-ft wooded buffers did not exhibit statistically significant warming. Todd (2000) examined various buffer functions and found that smaller riparian buffers (as narrow as about 40 feet) are required to protect water temperature and food web functions, and Johnson and Ryba (1992) recommend a similar buffer width of from 30 to 100 feet to effectively protect stream temperature. However, Brown and Kryier (1971) noted that on very small streams, adequate shade may be provided by brush species.

Along lake and marine shorelines, shading from vegetation reduces light levels and helps regulate heating of the nearshore areas or the upper intertidal zone. Shading also reduces mortality and stress to insects, marine invertebrates, as well as fish eggs deposited in intertidal areas, including those of sand lance and surf smelt (Pentilla 2000). Juvenile anadromous salmonids rely upon shallow-water habitats, especially those vegetated with algae and eelgrass, for prey resources and shelter from predation, making shallow nearshore habitats critical for the survival of these species (Healey 1982; Simenstad et al. 1982; Johnson et al. 1997).

Bank Stabilization and Habitat Formation

The effectiveness of riparian vegetation is well known to naturally stabilize stream banks while providing structural habitat for salmonids. The vegetation also influences water current and shoreline shape in other ways that benefit salmonid habitat. As reviewed in Spence (1966), roots bind streambank soils, and stems, branches, and projecting roots slow water currents that bear against riparian areas. The cover of healthy, native-plant communities generally perform this function more beneficially for salmonid habitat than do artificial reinforcements made of rock or other hard, non-living materials.

The riparian vegetation that protects shorelines also provides structural habitat for aquatic organisms, such as many salmonid microhabitats in live vegetation and in woody debris. This material, most important being tree roots and brush that drapes into the water, creates positions that are concealed from predators and give shelter from water velocity but are near fast currents that bring food (Bossu 1954; Fausch 1984; Fausch and White 1986). Vegetation resists shoreline erosion but generally not as drastically as

do rock riprap, concrete bulkheads, steel sheet-piling, and the like. Diverse native vegetation can be expected to moderately retard shoreline erosion while maintaining their dynamism, letting channels flex, thus forming and reforming salmonid habitat features. Reeves (et al. 1995) described the dynamism of salmonid-producing ecosystems in the Pacific Northwest and put forth ideas for managing them so as to accommodate disturbance regimes.

Filtering of Sediment, Nutrients, and Chemicals

Uptake of dissolved chemicals and filtration of sediments from overland-runoff and flood water is an important riparian function (Lowrance et al. 1984; Cummins et al. 1994). Spence (1966) reviewed evidence for these processes and for alteration of the flux of these materials through stream systems.

Literature analysis indicated that healthy riparian zones greater than 200 feet from the edge of the floodplain probably remove most sediment from overland flow (FEMAT 1993). The chemicals that constitute plant nutrients may be largely incorporated in the riparian zone's biomass. This and deposits of sediment contribute to the building of "new land" involved in channel or shoreline migration. Any action, such as clearing, that degrades the integrity of the riparian zone will hamper its functions of chemical filtering, uptake, and of land-building.

Organic Input and Nutrient Source

Riparian trees and other vegetation furnish water bodies with a "litter fall" of plant particles (leaves, pollen grains, etc.), as well as with terrestrial insects. These organic materials compose a major energy source for food webs that sustain production of salmonids, particularly in small (low- and mid-order) streams (Gregory et al. 1991; Naiman et al. 1992; Cummins et al. 1994). Along smaller stream channels, litter fall from healthy stands of riparian vegetation (an allochthonous source) is a relatively more important basis for the aquatic food web than is within-channel (autochthonous) production of algae, which tends to predominate as the basis for the aquatic food web in wider, less shaded streams and in standing waters (Vannote et al. 1980).

Clearing and certain other subsequent actions obviously reduce or destroy the nutrient providing function of riparian vegetation.

Microclimate

Less obvious but perhaps no less important are the microclimatic influences of the riparian forest on air that passes through on its way to a stream or pond. These include humidity, temperature, and wind speed, as reviewed in Pollack and Kennard (1998). Brosofske et al. (1997) documented that riparian microclimate is important to consider in management because it affects plant growth, therefore influencing ecosystem processes such as decomposition, nutrient cycling, plant succession, and plant productivity. Thus microclimate alterations can affect structure of the riparian forest, the waters within it, and the well-being of many animals, including fish.

2.2.2 Marine Aquatic Habitat

Estuarine and Nearshore Habitats

Estuaries are aquatic areas where rivers and streams meet the marine environment. Estuaries are defined as semi-enclosed bodies of seawater measurably diluted with fresh water (Hobbie 2000). Natural or undisturbed estuaries also have large areas of shallow, turbid water overlying mud flats or salt marshes. Estuaries are coastal areas where juvenile fish including anadromous fish, rear. The functions of the riparian zone in the estuarine environment have not been well studied however several conclusions can be drawn based on this limited work. Juvenile salmonids are known to eat terrestrial insects in estuaries; therefore, the riparian zone contributes food to the estuarine environment (Brennan et al. 2004). Additionally, the shallow water near the shoreline of estuaries functions as refuge habitat from predators. The overhanging vegetation provided by riparian vegetation can increase cover or refuge for aquatic species, thus protecting these species from avian predators. LWD that falls into the riparian areas also provides refuge and contributes to habitat forming processes within the estuarine environment as mentioned above.

In marine nearshore and estuarine environments, woody debris diffuses the energy of tides and waves, thereby modifying on-shore sediment transport and helps to produce habitats ranging from muddy bays to gravel or bedrock beaches. The trapping of sediment from the woody debris can promote vegetation growth (Maser et al. 19988). Additionally, where water energy is very low, woody debris increases the amount, diversity and quality of cover for resting, foraging, and predator avoidance.

Grays Harbor contains many intertidal mudflats, which are dissected by several channels. The largest channels include North Channel and South Channel. Forty-two percent of Grays Harbor is intertidal, consisting primarily of intertidal mud and sand flats.

Sub- and intertidal mudflat habitat radiates from the mouths of major rivers emptying into the estuary. Extensive mudflats are present to the west of the city of Aberdeen. The productive mudflats are riddled with burrow openings, revealing the presence of numerous organisms belonging principally to three groups: polychaete annelids, bivalve mollusks, and crustaceans (Kozloff 1973). Epibenthic green and blue-green algae and diatoms are the predominant flora, while zooplankton is dominated by copepods and mysids. Softshell clams (*Mya arenaria*), bent-nose clams (*Macoma nasuta*), and polychaete worms dominate the benthos. Mudflats support a wide variety of avian species, such as the western sandpiper, sanderling, yellowleg, dunlin, dowitcher, curlew, western grebe, scoter, cormorant, and great blue heron. Benthic invertebrates are important to shorebirds (Albright and Smith 1976), and juvenile salmonids that feed in estuaries during their outmigration (Simenstad 1997).

Eelgrass (*Zostera spp*.) is an important nearshore resource that is an indicator of estuarine health and provides a suite of ecological functions. As a primary producer, it generates oxygen to support marine organisms, provides habitat for numerous flora and fauna and sustains complex food webs. Eelgrass habitat occurs in areas with moderate current velocities and substrates composed of a mix of sand and silt. In Grays Harbor, eelgrass is generally limited to areas that lie below 3 feet of the mean lower low water line because of high turbidity. Areal extent and density may change from year to year as old beds are uprooted and new ones established. Eelgrass habitat provides food,

shelter, and substrate for an abundance of marine organisms, thus increasing the biological productivity and diversity of the estuary. Benthic fauna include nereid worms, clams, nematodes, and burrowing anemones. Eelgrass blades support isopods, amphipods, hydroids, bryzoa, harpacticoids, snails, limpets, protozoa, ciliates, and nudibranchs. Juvenile salmonids, striped sea perch, pipefish, and blennies find food and cover in eelgrass beds. Flatfish, crabs, and moon snails can be found in the epibenthos. Eelgrass is also an important food item for waterfowl, particularly the black brant and widgeon.

Emergent vegetation fringes the estuary in areas of tidal influence and low-energy wave conditions. Small patches of estuarine intertidal emergent marshes are located on the south shore of the Chehalis River Estuary. Characteristic marsh flora include three-square bullrush (*Scirpus americanus*), arrowgrass (*Triglochin moritimum*), spike rush (*Eleocharis macrostachya*), sand spurry (*Spergularia marina*), salt grass (*Distichlis spicata*), bulrush (*Scirpus validus*), and Lyngby's sedge (*Carex lyngbyei*). Grays Harbor marsh habitats have been extensively modified during the past century, although losses slowed substantially after 1972. Salt marshes of this type are important to waterfowl, which graze on seacoast bulrush and Lyngby sedge (Cooke 1997).

Current Patterns

Tides, currents, wave action, and intermixing of salt with freshwater create a complex physical environment situated at the juncture between land and water. Tidal currents dominate the current regime in Grays Harbor, except in the upper estuary during periods of high Chehalis River flows. Freshwater from river runoff forms a low salinity, low density upper layer which tends to move seaward. High density currents of seawater tend to move towards the head of the estuary (or river mouth) in the lower water column. This general pattern is less pronounced in the outer harbor, where the water column is well mixed. Other spatial variations are briefly described in the following section on salinity. Flood currents are stronger along the North Jetty, while ebb tide currents dominate along the South Jetty. The mean diurnal tidal range varies from 8.5 feet at the Harbor's mouth to 10.1 feet at Aberdeen. High wind conditions can alter tidal patterns significantly; strong offshore or onshore winds affect both the magnitude and duration of tide stages. Nearshore ocean currents are also strongly influenced by tidal flows into and out of the estuary. The bathymetry off Grays Harbor refracts deep water waves towards the Harbor mouth, concentrating wave energy in the entrance and outer bar channels. Ocean swells, which most commonly approach the coast from the west-south-west or west, often pass between the North and South Jetties and enter the mouth of the estuary. Tidal flows result in significant wave transformation in the bar and entrance areas; ebb flows result in wave steepening and peaking, while the opposite occurs during flood tide.

Salmonids

Estuaries are important to anadromous fish because they provide a highly productive rearing habitat where young salmon grow rapidly prior to entering marine waters and undergo their physiological transition from fresh water to saltwater. The growth they undergo during their estuarine residence is important to their survival as the young fish enter the marine environment where increased size helps them avoid predation. Salmonids utilize distinctly divergent prey species in Grays Harbor and their diets are typically associated with the predominant epibenthic or neritic habitats in which they are

found. Juveniles occupying nearshore habitats feed predominately upon epibenthic crustaceans, primarily harpacticoid copepods, cumaceans, and gammarid amphipods. Salmonids in deeper neritic habitats tend to be somewhat larger and feed upon more pelagic prey such as larval fish (particularly northern anchovy) and adult insects. As a general rule, juvenile salmonids feed upon epibenthic crustaceans upon their initial entry into the estuary and upon some growth convert to neritic zooplankton (Buechner et al. 1981).

Primary Producers

Among the estuary's primary producers, eelgrass represents the greatest source of organic carbon, followed by benthic algae, marsh vascular plants, and phytoplankton (Thom 1981). Relative contributions of organic carbon to the estuary vary spatially and temporally. Eelgrass and sediment-associated microalgal production is more important in regions with broad tidal flats, while macroalgal production is greatest in areas where hard substrata (e.g., logs, roots, cobble) exists in the intertidal zone. In the spring and summer benthic and planktonic are the primary carbon sources, while autumn vascular plant die-offs results in the primary input of particulate organic carbon to the estuary during early winter.

Forage Fish

Forage fish are an important and abundant fish species in Washington, significant due to the critical part they play as the prey base for a large variety of other marine organisms. Simenstad (1981) found seven species of forage fish to occur in Grays Harbor: Pacific herring (*Clupea harengus pallasi*), Pacific sand lance (*Ammodytes hexapterus*), northern anchovy (*Engraulis mordax*), surf smelt (*Hypomesus pretiosus*), longfin smelt (*Spirinchus thaleichthys*), whitebait smelt (*Allosmerus elongatus*), and American shad (*Alosa sapidissima*). Northern anchovy were the most ubiquitously distributed species and were represented in all life history stages. Surf smelt were the most common species in the lower estuary, while longfin smelt appeared to be restricted to the upper reaches of the estuary. Juvenile Pacific herring were also abundant. Simenstad (1981) found the occurrence of forage fish in Grays Harbor to be highly transitory and typically related to influxes of fish into the estuary from offshore sources. The residence time of forage fish appeared to be somewhat dependent upon physical processes (e.g., passive transport via intrusion of oceanic water masses into the Harbor due to coastal upwelling). Only adult and juvenile northern anchovy, juvenile Pacific herring, and juvenile longfin smelt were consistently abundant over Simenstad's sampling period.

Exotic Species

There is currently a great effort underway by the Washington State Departments of Agriculture and Fish & Wildlife to prevent the spread of the invasive marsh cordgrass (*Spartina alterniflora*) into Grays Harbor and neighboring Willapa Bay. *Spartina* forms thick clumps that trap sediments and converts tideflats into wet meadows, often displacing eelgrass. Although *Spartina* was introduced to Willapa Bay about 100 years ago, it was not documented in Grays Harbor until 1992. Since that time, *Spartina* has been documented and eradicated at several sites in Grays Harbor, including Grass Creek, Bowerman Basin, the Johns River estuary, Damon Point, near the Westport Coast Guard Station, Grass Island, Bottle Beach, Pirates Cove, and the Elk River estuary (Smith and Wenger 2001). Since 1997, some specimens of the non-indigenous

green crab (*Carcinus maenas*) have been found in Grays Harbor. However, there are indications that the spread of the crab in the estuary, at least for the present, is being kept in check by natural forces. Green crab have only been found in the upper intertidal area of the estuary among marshy vegetation. It is thought that native crab species are able to out-compete green crabs in mudflat, oyster bed, and channel habitats.

Marine Riparian Habitats

Riparian areas are the transition zones between aquatic habitats and upland areas such as banks and bluffs. Although much is known about the importance of riparian areas in freshwater systems, relatively little research has been conducted on the functions and values of riparian vegetation in marine systems. The function of riparian areas in the estuarine environment is that the overhanging vegetation in the riparian area provides cover and shade for aquatic species as well as a source of food in the form of terrestrial insects. However, estuaries are commonly very broad areas with most of the habitat a considerable distance from the riparian zone. Another function of riparian areas is that they provide stormwater management by filtering overland runoff that would enter the estuary directly. Water quality is not generally a concern in estuaries due to flow through the riparian areas since most of the water, nutrient input, and contaminant sources come from other sources, both upstream and downstream (due to tidal action).

Shoreline Condition and Habitat Diversity

Shoreline modifications have limited native vegetation to small pockets scattered along the shoreline and has resulted in isolating the intertidal flats from inputs of sediment, nutrients, and organic matter (i.e., woody debris) from upland riparian vegetation zones. This isolation degrades the habitat quality of these flats (Battelle et al. 2001). The overwater structures shade shallow and intertidal habitats, alter microclimates, and inhibit growth of plant communities, further degrading nearshore habitats for native fauna (Battelle et al. 2001).

Portions of the lower Chehalis and the outer Harbor remain relatively undeveloped and likely serve as refugia for salmonids, particularly juveniles. In a few areas, such as Oyhut and eastern Westport, rather extensive marsh stands occur. Large woody debris (LWD) was more common in the estuary prior to logging, where it provided cover for juvenile salmonids and a firm substrate for macroalgal production. The areal extent and density of Grays Harbor's eelgrass beds may change from year to year as old beds are uprooted and new ones established. Long-term trends in the extent of eelgrass beds have not been monitored, however. Light attenuation limits the depth to which Zostera spp. can grow by impeding photosynthesis. Seagrass populations can survive increased turbidity for short periods of time, but prolonged increases in light attenuation result in loss or damage of the population. Habitat diversity can be classified as not properly functioning in the inner Harbor, and properly functioning in the outer Harbor.

Small patches of estuarine intertidal emergent marshes are located on the south shore of the inner Harbor in the Chehalis River estuary, in the southeast section of the city of Aberdeen and in the southwest section of the city, east of Newskah Creek (also along tidally influenced section of the Newskah Creek) and north of the dike along the Chehalis River Estuary.

2.3 Human Activity and Aquatic Habitat Functions

Grays Harbor streams and rivers once flowed through dense forested areas and broad vegetated floodplains. These streams had natural flow regimes, excellent water quality, and complex instream cover. Today, healthy riparian areas are scarce or inadequate, and streams and rivers are frequently confined or controlled, or are realigned to accommodate agricultural or development activities. Human activities have had similar effects on nearshore and estuarine habitats. The effects of human activities on aquatic habitats are summarized in Table 2-2.

Table 2-2. General effects of Different Human Activities on Aquatic Habitats

Activities	Effects
Removing riparian vegetation	Reduced channel complexity, simplified channel morphology, increased stream velocities, loss of pools for holding and rearing, loss of spawning gravel, loss of side channels, loss of wood recruitment, loss of connectivity with floodplain and riparian zone, reduced shade and cover; increased solar radiation; increased erosion and sedimentation, elevated water temperatures and reduced leaf litter.
Introducing invasive non-native vegetation	Altering native riparian habitat functions including associated wildlife refuge, insect litter, replacement of coniferous shade producing trees, etc.
Creating impervious surfaces, filling and draining of wetlands, and increasing water allocations	Altered flow regimes (timing and magnitude of flows), degraded water quality/increased stream temperatures, increased stormwater runoff, and altered instream habitat
Streambank modifications	Loss of natural meander/habitat-forming processes, disconnected floodplains and subsequent loss of floodplain processes
Discharging sewage effluent	Degraded water quality, altered water temperatures, reduced dissolved oxygen concentrations, and increased contaminant levels
Constructing culverts, pipes, and ditches	Obstructed upstream passage of fish and reducing the downstream movement of wood and gravel
Filling/altering estuarine and nearshore habitats	Reduced availability of freshwater to saltwater smolt transition habitat (including cover and food production), and staging and holding habitats for adult salmon
Constructing bulkheads and docks	Increased habitat for predators, altered nearshore currents and gravel movement
Construction activities	Increased erosion, turbidity and inputs of fine sediment during construction and prior to revegetation
Recreational activities	Degraded water quality, and increased contact with listed species

2.3.1 Freshwater Riverine Habitats

The Chehalis River from Cosmopolis downstream to Highway 101 bridge is predominantly channelized and confined between riprap levees with increased industrialization and commercial development. Downstream of the Highway 101 bridge, the Chehalis River estuary is comprised of a broader channel and exposed to increased wave action from Grays Harbor estuary.

2.3.2 Nearshore and Estuarine Habitats

The primary disturbances to nearshore and estuarine habitats are estuarine habitat loss, shoreline modifications, overhead structures, and impacts on water/sediment quality. The condition of the estuarine and nearshore habitat in the city of Aberdeen varies considerably depending on location. Estuary habitat loss has been documented in Chehalis River Estuary (Phinney and Bucknell 1975). Shoreline modifications such as bulkheads, rip-rap, and fills are common along the Aberdeen waterfront (Phinney and Bucknell 1975). Areas of shoreline modification typically have poor riparian or shoreline vegetation, which reduces or eliminates the function of shoreline vegetation. Major overwater structures such as docks also impact eelgrass beds by shading out sunlight, and can alter salmonid behavior and survival. Inner Grays Harbor contains numerous contaminated sediment sites. Detected toxins such as mercury, arsenic, and PCBs can cause tumors and suppress immune systems in salmonids, and be lethal for organisms that are food resources for salmonids. Creosote-treated materials and oil spills are also important water quality concerns within nearshore areas of the city of Aberdeen (Phinney and Bucknell 1975).

The Chehalis Basin Limiting Factors Report assessed several aspects of the Grays Harbor estuary (Phinney and Bucknell 1975). There has been a loss of at least 30% of historic estuary, which is relatively low compared to other losses in Washington State and this resulted in a fair rating. The level of Spartina invasion has been kept to a minimum, resulting in a good rating for biological processes. Predation has not been documented as excessive, and this contributes to the good rating for biological processes. However, chemical input and fecal coliform problems persist, resulting in poor rating for water quality. The lack of LWD in the estuary has resulted in a poor rating for this category. Lastly, the nearshore environment was rated fair because of the loss of gravel recruitment from the Columbia River. There is also concern about seawall impact leading to greater erosion, but this is a highly localized problem and is not widespread.

All of the above alterations are anthropogenic in nature and are associated with industrialization and population growth. For example, loss of LWD can be attributed to logging acitivity, loss of gravel recruitment can be attributed to construction of large dams on the Columbia River, and poor water quality can be attributed to local water quality treatment and industrial growth in the estuary.

2.4 Habitat Management and Protection Tools

2.4.1 Designation, Rating, and Classification

The city of Aberdeen does not designate or classify streams according to any stream typing system. New water types have been established in WAC 222-16-030. As excerpted from WAC 222-16-030, new water types are as follows:

Type S Water - all waters, within their bankfull width, as inventoried as "shorelines of the state" under chapter 90.58 RCW and the rules promulgated pursuant to chapter 90.58 RCW including periodically inundated areas of their associated wetlands.

Type F Water - segments of natural waters other than Type S Waters, which are within the bankfull widths of defined channels and periodically inundated areas of their

associated wetlands, or within lakes, ponds, or impoundments having a surface area of 0.5 acre or greater at seasonal low water and which in any case contain fish habitat.

Type Np Water - means all segments of natural waters within the bankfull width of defined channels that are perennial nonfish habitat streams. Perennial streams are waters that do not go dry any time of a year of normal rainfall. However, for the purpose of water typing, Type N Waters include the intermittent dry portions of the perennial channel below the uppermost point of perennial flow.

Type Ns Water - means all segments of natural waters within the bankfull width of the defined channels that are not Type S, F, or Np Waters. These are seasonal, nonfish habitat streams in which surface flow is not present for at least some portion of a year of normal rainfall and are not located downstream from any stream reach that is a Type Np Water. Ns Waters must be physically connected by an above-ground channel system to Type S, F, or Np Waters.

2.4.2 Buffers

Appropriate buffer sizes will depend on the area necessary to maintain the desired riparian or stream functions for the given suite of land-use activities. A wider buffer may be desired to protect streams from impacts resulting from activities such as unpermitted ad hoc trail construction, recreation, pets, garbage, and tree removal for unpermitted view improvements and hazard reduction. These concerns are associated more with areas of high-intensity land use and thus wider buffers, or restrictions (such as building setbacks) that keep a potential hazard from occurring, may be needed, while narrower buffers may suffice in areas of low-intensity land use (May 2000). It should be noted though that opportunities for protection or improvement of buffer conditions in areas of high-intensity land use are often effectively foreclosed by existing development, or the existing habitat conditions are already highly altered. Under such conditions, establishing buffers wide enough to provide an effective full-range of riparian functions is likely unattainable, and other actions may be required to improve habitat conditions beyond what riparian buffers are able to provide. In addition, buffer vegetation type, diversity, condition, and maturity are equally as important as buffer width, and the best approach to providing high-quality buffers is to strive for establishing and maintaining mature native vegetation communities (May 2000).

The following discussion is a review of major riparian functions and the level of functionality afforded by riparian buffers of varying widths as reported in the literature. Tables 2-3, 2-4, and 2-5 summarize the conclusions and recommendations for riparian buffer widths in frequently cited literature reviews of riparian buffer functions. These tables are not intended to be prescriptive, but do serve to illustrate the wide range of effective buffer widths reported in the literature, and also provide recommendations based on providing a reasonable level of habitat functionality under most conditions. However, it must be recognized that a single prescription is not necessarily appropriate or warranted for all situations. Buffer recommendations and functionality are frequently expressed in terms of site-potential tree height (SPTH), which is the height of mature trees that a given site can be expected to support.

Following the tables, further discussion of riparian functionality and considerations for determining buffer effectiveness is provided. In addition, riparian functions for reservoir and marine shorelines are included in the discussion where appropriate.

There is no consensus in the scientific literature regarding single buffer widths for particular functions, or to accommodate all functions. However, neither does the literature indicate that buffers are not needed, nor that riparian buffers beyond the equivalent of several site potential tree heights (SPTHs) are needed. One SPTH, the maximum height a tree will attain given the existing geology, soils, and other site conditions, ranges from 50 to 250 feet, depending on species, for a tree at least 300 years old in western Washington forests. A buffer width equal to one SPTH would provide for a broad range of riparian functions important for sustaining salmonids. The concept of scaling riparian buffer widths to the potential height of a tree was first proposed by the Federal Ecosystem Management Team who was assessing riparian protections for national forest lands (FEMAT 1993). They reasoned that trees were a logical scaling factor because (1) they are a dominant factor in determining habitat conditions and (2) when left unmanaged, their size (height) reflected inherent productivity and constraints of a given site. As a result of this logic generalized curves using scientific data and professional judgment were developed to help rate buffer effectiveness for a variety of ecological functions, including shade, litter fall (e.g. leaves, branches), root strength and coarse woody debris inputs.

Table 2-3. Stream Riparian Functions and Appropriate Widths Identified by May (2000)

Function	Range of Effective Buffer Widths	Minimum Recommended	Width Notes On Function
Large Woody Debris	10 to 100 m (33 to 328 ft)	80 m (262 ft)	1 SPTH based on long-term natural levels
Water Temperature	11 to 43 m (36 to 141 ft)	30 m (98 ft)	Based on adequate shade
Sediment removal and erosion control	8 to 183 m (26 to 600 ft)	30 m (98 ft)	For 80% sediment removal
Pollutant Removal	4 to 262 m (13 to 860 ft)	30 m (98 ft)	For 80% nutrient removal
Microclimate	45 to 200 m (148 to 656 ft)	100 m (328 ft)	Optimum long-term support

May (2000) recommendation for an overall minimum buffer width is 30 m (98 ft), with the understanding that full effectiveness may not be achieved for some functions such as LWD, wildlife habitat, and microclimate.

Table 2-4. Stream Riparian Functions and Appropriate Widths Identified by Knutson and Naef (1997)

Function	Range of Effective Buffer Widths (ft)
Large Woody Debris	100 to 200
Water Temperature	35 to 151
Erosion Control	100 to 125
Sediment filtration	26 to 300
Pollutant Removal	13 to 600
Microclimate	200 to 525

Table 2-5. Riparian Functions and Appropriate Widths Identified from FEMAT(1993)

Function	Number of SPTH Equivalent	Equivalent (Based on SPTH of 200 ft (m))
Shade	0.75	150 ft (46 m)
Microclimate	up to 3	up to 600 ft (183 m)
Large Woody Debris	1.0	200 ft (61 m)
Organic Litter	0.5	100 ft (30 m)
Sediment Control	1.0	200 ft (61 m)
Bank Stabilization	0.5	100 ft (30 m)
Wildlife Habitat	-----	98 - 600 ft (30 - 183 m)

Riparian buffer literature cited above is derived primarily from work pertaining to streams, rivers and wetlands. Few data exist on the marine-riparian interface in the Pacific Northwest (Levings and Jamieson 2001). However, in many ways the needs of marine nearshore habitats are similar to those of streams and rivers and thus the buffer widths recommended for riverine habitats are also applicable to marine nearshore habitats. For example, as with streams, riparian areas can contribute significant amounts of food for marine fish. Duffy et al. (2002) found that terrestrial invertebrates made up a large contribution of the diet of fishes in north Puget Sound. A study of marine fishes along King County shorelines also found terrestrial insects were a significant part of the diet of juvenile salmon. Also, marine shorelines can be viewed as similar to riverine shorelines because of energy from tides, waves and currents, i.e., their condition is influenced by energy that scours, transports and deposits sediment and woody debris. Woody debris in marine nearshore environments is derived both from onsite vegetation and transported from offsite locations subject to longshore currents. Marine nearshore woody debris also contributes nutrients to nearshore environment, and is a major component in forming and maintaining shoreline structural habitat (Everett and Ruiz 1993).

With respect to the value of buffers for temperature and shading in the marine nearshore environment, Levings and Jamieson (2001) note that the temperature of surficial and interstitial water emanating from marine riparian areas and flowing into marine nearshore habitats may be affected by shading. Pentilla (2001) found that reduced survival of surf smelt eggs was related to reduced shade from trees overhanging marine nearshore spawning habitats. Freshwater aquifers emanating from underneath a riparian forest can discharge into the intertidal zone, creating localized fresh and brackish water habitats.

As with marine nearshore, little has been written about the riparian needs of estuaries (Williams et al. 2001). Subject to tidal fluxes, their erosive energy is somewhat higher than for lakes and ponds and less than for streams, rivers, and marine shorelines, thus the hydraulic function of woody debris in estuaries would likely also be rather modest. However, estuaries often have areas of intense mixing either as a result of geomorphic constraints that focus tidal flow exchanges or due to extreme tidal fluxes during storms (Simenstad et al. 2000). Under such conditions, woody debris would play a similar hydraulic role as it does in more dynamic aquatic areas. Also, as with other habitats, woody debris plays a major role in providing estuarine habitat structure and contributes nutrients to estuarine ecosystems. Temperature regulation contributed by riparian vegetation on estuarine shorelines is probably less important than for streams and rivers, because overall estuarine temperatures are influenced primarily by marine and riverine inflows, depending on the type of estuary. However, as with the other aquatic

areas, estuaries are likely to have seeps and other localized cool areas that may be affected by the extent and type of riparian habitat. Other functions, such as terrestrial food supply, overhead shade (for hiding cover rather than temperature moderation), bank stability, and pollutant removal (see Williams et al. 2001) are similar to those affecting other aquatic areas.

2.4.3 Timing Restrictions

Timing restrictions for conducting in-water work are necessary to protect habitat and life-stage requirements that differ by species and time of year. Windows for conducting work within the OHWM of freshwater and marine systems have been established by state and federal resource management agencies. The approved freshwater fish work windows for most Grays County streams is from July 1 to October 15. For the Chehalis River from the mouth to Porter Creek, the work window is extended to begin earlier on June 1. Work windows vary by species of interest in marine or estuarine waters. Marine work windows are established for salmon (June 14 to March 1), bull trout (July 16 to March 1), Pacific herring (year-round), sand lance (year-round), and surf smelt (year-round). Green sturgeon are known to congregate during summer months in Grays Harbor, but a marine work window for green sturgeon has not yet been proposed or designated.

2.4.4 Mitigation

The definition for mitigation are the actions that shall be required or recommended to avoid or compensate for impacts to fish and other aquatic resources from a proposed project. Mitigation shall be considered and implemented, where feasible, in the following sequential order of preference. Use of the word “mitigation” is comprehensive of all three parts of the following sequence and is not to be considered as synonymous with compensatory mitigation. Complete mitigation is achieved when these mitigation elements ensure no net loss of ecological functions, wildlife, fish and aquatic resources:

- Avoiding the Impact altogether by not taking a certain action or parts of an action.
- Minimizing Impacts by limiting the degree or magnitude of the action and its implementation.
- Compensating for the Impact by replacing and providing substitute resources or environments through creation, restoration, enhancement or preservation of similar or appropriate resource areas.

Regulators and applicants need to look at the watershed ecosystem as a whole when considering impacts and the use of preservation, mitigation banking, and off-site or out-of-kind mitigation as tools for salmon and watershed recovery. Despite the agreed upon benefits of a watershed-based approach, guidance has not been in place to assist regulators and developers with the selection and evaluation of mitigation proposals for alternative watershed-based approaches.

It has been decided by the permitting agencies that, in some cases, protecting high-functioning, irreplaceable areas at substantially higher ratios may be the best ecological choice and acceptable for compensatory mitigation, as long as there is no overall loss of habitat functions. There is value gained in protecting sites that are already providing high quality functions necessary for watershed health and salmon recovery efforts. For

example, protecting aquatic habitat high in the watershed serves to protect downstream resources from erosion and degradation.

Preservation may be beneficial in some circumstances because; a) larger mitigation areas can be set aside due to the higher preservation mitigation ratios; b) can ensure protection for high quality, highly functioning aquatic systems that are critical for the health of the watershed and aquatic resources that may otherwise be adversely affected; and c) preservation of an existing system removes the uncertainty of success inherent in a creation or restoration project.

Stormwater management is a critical issue in implementing salmon recovery and watershed improvement efforts of the state. The emphasis for stormwater management should be on prevention of impacts to aquatic resources through appropriate development regulations, and best management practice applications for erosion control, water quantity and water quality treatment. The guiding principal should be to do no further harm to aquatic resources and to build into projects and plans the incremental improvements necessary to protect, restore and enhance the beneficial uses and functions of the state's water bodies

Refer to section 4.5.1 for wetland mitigation.

2.4.5 Protection and Management of Anadromous Species

The protection and recovery of anadromous salmonids species is a primary focus in Grays Harbor County as a whole. The County, resource agencies, Tribes, and private interests have coordinated protection and management efforts for anadromous species in Grays Harbor County. Existing habitat conditions, salmon & steelhead habitat limiting factors, and proposed protection measures for anadromous salmonids in Grays Harbor County have been presented in several completed or ongoing management documents such as the Chehalis Basin Salmon Habitat Restoration and Preservation Work Plan for WRIA 22 and 23 (Chehalis Basin Partnership 2005; Smith and Wenger 2001). These documents have been developed with the intent of identifying specific habitat issues throughout the Chehalis River watershed and other waters of the city of Aberdeen, and proposing protections and strategies for conserving anadromous salmonid populations. Protection measures and goals that have been identified within and outside of the Chehalis River watershed include:

- Improve riparian conditions throughout Grays Harbor Country watersheds.
- Reduce bank hardening and investigate areas for dike removal and reconnection of the floodplain. High impact areas include the mainstem Wishkah River, the Chehalis River estuary, and the lower reaches of all the small streams entering inner Grays Harbor. These areas are frequently dominated by residential, and municipal land-uses.
- Prevent further loss of wetlands, which can contribute to improved water quality, groundwater recharge, instream flows, and other floodplain functions.
- Prevent further loss of native riparian and wetland buffers (freshwater, marine & estuarine) through the aggressive elimination and/or management of non-native invasive plants.
- Reconnect tidal floodplains, marsh, and wetlands.

- Improve passage barriers, particularly in Fry Creek and at identified high priority culverts.
- Increase LWD by adding to streams and estuary, or preferably by improving natural LWD recruitment in the long-term.
- Reduce pollution runoff from urban, and industrial sources.

Table 2-6 summarizes the federally listed species that may be in the vicinity of the city of Aberdeen based on these agency lists and database searches of agency websites. To determine which species were relevant to the action area, a list of species for the entire county (USFWS, http://www.fws.gov/westwafwo/se/SE_List/GRAYSHAR.htm) was compiled. WDFW PHS data specific to the action area was obtained and compared to the county list. Other species were included in this assessment if they 1) had critical habitat somewhere in the Grays Harbor vicinity, 2) were marine or anadromous species, or 3) were on the 2005 action area USFWS list for this project.

Table 2-6. Listed Species That May Occur in the Vicinity of the City of Aberdeen, Washington

Species (fish)	Scientific Name	Federal Status
Bull trout	Salvelinus confluentus	Threatened (USFWS)
Coastal/Puget Sound population		
Green Sturgeon	Acipenser medirostris	Threatened (USFWS/NMFS)

2.5 GMA Requirements and Regulatory Options

2.5.1 GMA Requirements

The basic requirements for the protection of critical areas are found in the following statute (RCW 36.70A):

- The GMA requires designation and protection of Critical Areas (RCW 36.70A.170)
- Counties and cities shall give special consideration to conservation or protection measures necessary to preserve or enhance anadromous fisheries (RCW 36.70A.172(1)).

2.5.2 Inventory and Classification Options

Classification systems should ideally be biologically and physically relevant to the fisheries resource, while also providing for ease of public understanding and straightforward implementation. Potential classification systems for use in the CAO include the following types:

- DNR Water Typing System – A combination physical/biological based classification system using simplified stream types (S, F, and N)

- Fish Species and Lifestage Stream Classification System - A biologically based classification for stream or stream reaches based on salmonid use including both species presence and life stage utilization (e.g. spawning, rearing, and migration)

- Aquatic Habitat Quality Based Classification System – A habitat based classification system for streams or stream reaches based on existing aquatic habitat condition and previously identified limiting factors

- Combination Classification System – A habitat classification system that combines elements from several of the above methods.

  For any classification system, there will be streams that are not currently classified due to lack of available information (e.g. fish presence) or where a stream is incorrectly classified. In some cases this will require a special study to document the habitat features.

2.5.3 Buffer Options

There is a variety of direction on use of buffers for protecting resources both from the Washington Administrative Code (WAC) Guidelines and Growth Management Hearings Board decisions. For protection of instream salmonid habitat conditions, a wide range of recommended riparian buffer widths exists (see previous discussion of riparian buffer functions). Variation in recommendations or buffer effectiveness is frequently due to variation in site conditions such as sideslope angle, stream type, geology, climate, etc. However, no studies recommend zero width, nor do the studies recommend the equivalent of more than several site potential tree heights. Design of riparian buffers must consider the ecological, cultural, and economic values of the resource, land use characteristics, and existing riparian quality throughout watersheds in order to address the cumulative impacts on stream functions and the resources being protected (Johnson and Ryba 1992; Castelle et al. 1994; Wenger 1999).

Pollack and Kennard (1998) recommended buffer widths of 250 ft on all perennial streams. Buffer widths of one SPTH would reasonably provide for a full range of riparian functions, and therefore, not contribute significantly to the loss of salmonid habitat. May (2000) and other extensive reviews provide detailed summaries of buffer width sizes necessary to achieve stream and riparian functions (Knutson and Naef 1997; FEMAT 1993). The conclusions of those reviews are presented in Tables 2-3, 2-4, and 2-5. However, as was previously discussed, these recommended buffer widths are largely driven by providing adequate long-term LWD recruitment potential, and are not necessarily inclusive of all situations. For example, along highly managed streams such as in agricultural, residential, or commercial areas, some functions normally provided (at least in part) by riparian buffers, such as flow attenuation or filtration of pollutants, can be provided by application of appropriate BMPs in combination with smaller buffers.

2.6 Aquatic Species Findings and Code Recommendations

2.6.1 Recommended Stream Classification and Buffer Systems

According to Best Available Science, a buffer width of about 100 feet would reasonably provide for most stream riparian habitat functions important to fish populations. However, smaller or larger buffer widths may be necessary to provide adequate protections depending on site conditions and watercourse condition. Buffer width regulations tiered to existing or potential habitat functions (i.e., providing greater protection where appropriate) would allow regulatory flexibility and provide for stream functions that can reasonably be expected on a given site. The buffer width recommendations in this report

should be implemented unless it can be demonstrated that some other buffer width would be adequate or necessary to maintain existing stream and riparian functions. It is recommended that the following DNR water types and **minimum** buffer widths be included in the city of Aberdeen Code:

- Type S waters: Shorelines of the State: **150 ft**
- Type F waters (non-shorelines having fish and fish habitat: **100 ft**
- Type N (Type Np and Ns waters -non-fish-bearing natural waters whether connected or not connected to Type S or F waters:) **50 ft**

The DNR classification system is recommended as the system currently available that best meets the needs of the city of Aberdeen and the public. Appropriate buffer sizes will depend on the area necessary to maintain the desired riparian or stream functions for the given suite of land-use activities. A wider buffer may be desired to protect streams from impacts resulting from activities such as unpermitted ad hoc trail construction, recreation, pets, garbage, and tree removal for unpermitted view improvements and hazard reduction. These concerns are associated more with areas of high-intensity land use and thus wider buffers, or restrictions (such as building setbacks) that keep a potential hazard from occurring, may be needed, while narrower buffers may suffice in areas of low-intensity land use (May 2000). It should be noted though that opportunities for protection or improvement of buffer conditions in areas of high-intensity land use are often effectively foreclosed by existing development, or the existing habitat conditions are already highly altered. Under such conditions, establishing buffers wide enough to provide an effective full-range of riparian functions is likely unattainable and other actions may be required to improve habitat conditions beyond what riparian buffers are able to provide. In addition, buffer vegetation type, diversity, condition, and maturity are equally as important as buffer width, and the best approach to providing high-quality buffers is to strive for establishing and maintaining mature native vegetation communities (May 2000).

It is also recommended that a minimum buffer width, or proportion of existing buffer width be retained, in cases of standard buffer adjustments to promote buffer continuity. For example, in cases of buffer averaging, ensure that the buffer is no less than 75 percent of the required buffer width in any given location to maintain buffer continuity while retaining the overall area of required buffer unless it can be demonstrated that other options will not result in loss of riparian functionality.

Definitions, performance and reporting standards must be included in city of Aberdeen Code to ensure that allowable activities within critical areas undergo a review, approval, and monitoring process. This will help ensure that activities will either not adversely impact aquatic habitats, or that loss of habitat functions are appropriately mitigated.

Accepting performance standards as those required in the HPA process, or implementing accepted strategies such as those described in documents such as the Ecology stormwater manual are good approaches to ensuring that proposals are reviewed and approved on a consistent basis.

Illustration of Recommended Buffer Widths

As described in more detail above, buffer widths would depend on the quality of the aquatic habitat in water bodies and .the presence of fish or their critical habitat.

During the city's ordinance adoption process, citizens will be interested in knowing what the potential impact of establishing buffers around streams may mean to their current and future property use. Without classifying all of the streams within the city, these types of questions can not be specifically and accurately answered.

Nevertheless, to assist the city's decision making process, and to inform its citizens, several examples of buffers were illustrated around a few of the city's streams and waterbodies.

It is important to note that actual delineation and classification of these wetlands was not performed – the areal extent of the streams was estimated based on existing wetlands data available from the WDFW and the U.S. Fish and Wildlife Service. Furthermore, buffers only extend up to existing man-made breaks. For example a buffer to a wetland would not extend beyond an existing road or structure that separates that buffer from the remainder of the landscape. Illustrated buffers were not reduced to take into account such existing breaks.

Figures 2-1a and b respectively illustrate possible buffers around streams lying within the city boundaries as a whole, and focusing on streams located near the confluence of the Wishkah and Chehalis Rivers, and show the extent to which existing land uses may lie within them. Existing uses could be impacted if located within these buffers. A number of these uses would be non-conforming. Existing uses could continue, but expansion of existing uses or new uses would require critical areas review.

Insert Figure 2-1a

Insert Figure 2-1b

2.6.2 Recommended Estuarine Classification and Buffer Systems

Few data exist on the marine-riparian interface in the Pacific Northwest (Levings and Jamieson 2001). However, in many ways the needs of marine nearshore habitats are similar to those of streams and rivers and thus the buffer widths recommended for riverine habitats are also applicable to marine nearshore habitats. Tiering buffers to the State system per recommendations in this document would provide a standard shoreline buffer width of 150 feet unless it can be demonstrated that that some other buffer width would be adequate or necessary to maintain shoreline functions.

2.6.3 Recommended Provisions for Non-Conforming Lots and Structures

In some cases, existing parcels are too small to provide for the recommended buffers. Generally, “reasonable use” and “variance” procedures are provided for those situations. In the case of a city, such as Aberdeen, where parcels have been created over a long period without consideration of current buffer requirements, it is recommended that a streamlined process be designed to provide for development of up to 2 500 square feet on a parcel under contiguous ownership, with buffer areas provided in the remaining portion of the site.

2.6.4 Recommended Provisions for Mitigation

Mitigation refers to the avoidance or minimization of project related impacts to critical areas. Mitigation may also include the restoration or enhancement of existing fish and wildlife habitat or the creation of new habitat. Where required, mitigation often includes the approval of a mitigation plan, monitoring of the mitigation site for a specified period (about 5 to 10 years), and the posting of a mitigation bond. Specific guidelines should be established for the mitigation of impacts to shorelines, rivers, streams and their buffers. A habitat management plan may also be required when a proposed project may affect a FWHCA. The plan should include measures to mitigate for impacts to FWHCA based on WDFW management recommendations and should be developed by consulting with WDFW biologists.

2.6.5 Recommended Provisions for Piped Streams

One of the most significant impacts to streams and creeks in Aberdeen is that a number of waterways have been piped or culverted in significant length as they flow through urbanized areas. In some cases, the purpose of these actions was to protect public health when sewer systems were not well developed and septic systems or sewage ponds leaked into creeks. In other cases, the natural flow of creeks conflicted with desired transportation infrastructure or development patterns. Nevertheless, some of these highly impacted stream systems still provide fish passage for anadromous species and connectivity to upstream fish habitat.

The GMA authorizes the protection of existing habitat in critical areas, but does not require restoration of habitat. Nevertheless, piped and culverted streams represent an area where mitigation efforts can be focused at some time in the future. Daylighting of these creeks could be a restoration effort that the city may want to plan for.

In a first step, it is recommended that the city prevent new permanent structures from being built over these piped and culverted streams, with exemptions for transportation

and utility uses. No critical habitat area buffers would be required for sections of streams that are piped or culverted, but typical building setbacks would continue to apply. In the future the city could provide greater incentives for property owners to daylight creeks, especially when these actions represent a fiscally and ecologically sound method to improve aquatic health.

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3 Terrestrial Wildlife Habitat Conservation Areas

3.1 Overview of Inventory

3.1.1 Species and Habitats

Fish and wildlife habitat conservation is defined as land management for maintaining species in suitable habitats within their natural geographic distribution so that isolated subpopulations are not created (WAC 365-190-080). Such areas are considered critical among counties and cities in a region and require cooperative and coordinated land use planning (Ousley et al. 2003). Because terrestrial species also depend on aquatic habitats and wetlands, primarily in riparian and wetland buffer areas, the protection strategies for terrestrial wildlife overlap with protection of aquatic species and wetlands. Aquatic species and wetlands are addressed in Sections 2 and 4 of this document.

This section focuses on terrestrial wildlife species and habitats in Aberdeen. The GMA established a goal of no net loss of habitat functions and values. The CTED GMA guidelines recommend that Fish and Wildlife Habitat Conservation Areas (FWHCA) include the following:

- Areas with which state or federally listed species (endangered, threatened, candidate, or sensitive) have a primary association. Under the Endangered Species Act (ESA), the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) are responsible for federally listed species and should be consulted for current listing status. The Washington Department of Fish and Wildlife (WDFW) are responsible for designating state special-status species and maintains the current list of these species (Ousley et al. 2003).

- State priority habitats and areas associated with State priority species. The Priority Habitats and Species (PHS) database is continuously updated as new information on distribution of wildlife species and habitats in Washington are provided by local biologists and other scientists. The WDFW designates priority habitats based on eight criteria including wildlife density, diversity, habitat availability, and importance as seasonal ranges or movement corridors.

  Priority species are wildlife species requiring protective measures for their perpetuation due to their population status, sensitivity to habitat alteration, and/or recreational importance. Priority species include all state Threatened, Sensitive, and Candidate species (WDFW 1999).

- Habitats and species of local importance. Habitats and species of local importance identified by the city may include a seasonal range or habitat element with which a given species has a primary association and which, if altered, may reduce the likelihood that the species will maintain and reproduce over the long term. For example, areas of high relative density or species richness, breeding habitat, winter range and movement corridors, and habitats that are of limited availability or high vulnerability to alteration such as cliffs, talus and wetlands could be considered as habitats of local importance. Species of local importance are those species that are of local concern due to their population status or their sensitivity to habitat manipulation or that are game species (Ousley et al. 2003).

- Naturally occurring ponds under 20 acres. Naturally occurring ponds and ponds include those artificial ponds created from dry areas for wetland and critical areas mitigation, which may provide fish and wildlife habitat. Naturally occurring ponds do not include canals, detention facilities, wastewater treatment facilities, farm ponds, temporary construction ponds, and landscape amenities, unless they were created for mitigation (Ousley et al. 2003).

- Waters of the state. Waters of the sate include surface waters and watercourses as defined in WAC 222-16-030 or WAC 222-16-031 (Ousley et al. 2003).

- State natural area preserves and natural resource conservation areas. Natural area preserves and natural resource conservation areas, owned and administered by the Washington State Department of Natural Resources (WDNR), represent unique or high quality undisturbed ecosystems and habitats (WDNR 2004).

- Areas critical for habitat connectivity. In highly developed landscapes where natural habitats are likely fragmented and isolated; scattered habitat patches and interconnecting corridors are especially valuable for terrestrial species, especially for those species that become separated within fragments of remaining habitat (Lowell 1994; Beissinger and Osborne 1982; Lee et al. 1987).

  Isolated populations are considered to be at greater risk of extinction from local catastrophes, demographic variability, and genetic deterioration. Habitat connectivity allows wildlife species to move between habitat patches and can help reduce the risk of the isolated sub-population by immigration or re-colonization (Lemkuhl et al. 2001).

The PHS database provides the best available information for most priority habitats and wildlife species including their presence and distribution. The PHS database should be requested through WDFW every six months for site-specific evaluations as WDFW regularly updates the PHS database (WDFW 2007a).

Federally and State Listed Species

The PHS data provided by WDFW show the locations of priority species presence and habitat in the city of Aberdeen. Table 3-1 identifies the habitat requirements of the federally and state listed species that are known to occur in Aberdeen. There were no occurrences and habitat of federally-listed terrestrial wildlife species within the city of Aberdeen boundary. The only listed species identified in the city of Aberdeen is the peregrine falcon (Falco peregrinus), listed as a Federal species of concern and a state sensitive species. A peregrine falcon occurrence is documented within city boundaries east of the Wishkah River**.** Another peregrine falcon sighting is documented just outside of the city boundary. These sightings are probably resting individual birds and not nesting pairs. Peregrine falcon nests are usually found on cliff faces that are not accessible to terrestrial predators, such as foxes or weasels. Peregrine falcons are known to winter and breed in Washington State and known nests are present along the northern sections of the Pacific coast of Washington state.

Three other species are identified by the USFWS as listed species that are known to occur outside of the study area. These species include: marbled murrelet (*Brachyramphus marmoratus*), bald eagle (*Haliaeetus Leucocephalus*), and purple

martin (*Progne subis*). Marbled murrelet is Federally-listed as a threatened species and has been observed circling above a tree canopy or flying through by the Powell Creek watershed. Marble murrelet nest in forests near the coast, and tend to prefer larger stands of mature to old growth trees. These conditions are not present within the city of Aberdeen study area.

Bald eagle is a federally-listed species of concern and state-listed as a threatened species. They are commonly found along aquatic ecosystems such as rivers, lakes, and coastal shorelines where they prey upon fish, waterfowl, and seabirds (Stalmaster 1987). Typical nesting habitat for bald eagles is in mature forests that contain large dominant trees for nesting such as Douglas-fir, Sitka spruce, or black cottonwood trees near water bodies with a sufficient food supply (Anthony et al 1982). Nesting usually occurs from January 1 through August 15. There are no known bald eagle nest sites within the city of Aberdeen study area. The PHS data indicate a total of six bald eagle nest sites in the vicinity of the city boundary.

Purple martin are seasonal residents of Washington. They are not Federally-listed, but are state-listed as a species of concern. Purple martin are small, swallow-like birds that nest in cavities, such as abandoned woodpecker nests and they tend to nest in colonies near water. They feed on flying insects and have been shown to readily accept artificial nest boxes. Purple Martin have been observed within the shoreline areas of the city of Aberdeen study area but no known nesting colonies have been identified.

Table 3-1. Habitat Requirements for Listed, Sensitive, and Candidate Species Known to Occur in Aberdeen

Species	Status[1]	Habitat Requirements and Distribution
Marbled murrelet	FT, ST	Year-round resident on coastal waters, nests on coniferous forests within 42 miles of marine shoreline.2b Occurrence outside the city boundary.
Bald eagle	FCo, ST	Numerous breeding territories and foraging areas in rivers, lakes, and coastal shorelines of western Washington. 2a Occurrences along Chehalis River
Peregrine falcon	FCo, SS	Year-round resident, nests on cliffs (> 150 ft in height) near water and feeds on smaller birds especially shorebirds and waterfowl. 2a Occurrences along Chehalis River
Purple martin	None, SC	Nests in natural and artificial cavities preferably by water. Foraging habitats include open areas, often located near moist to wet sites, where flying insects are abundant.

1. FT = federal threatened, FCo = federal species of concern, ST = state threatened, SS = state sensitive, SC = state candidate (WDFW 2007)

2a. Larsen et al. (2004)

2b. Rodrick and Milner (1991)

State Priority Habitats and Species

According to WDFW, priority habitats and habitats associated with state priority species include areas associated with high recreational value or relatively rare species (1999). Areas mapped as priority habitats in Aberdeen include palustrine wetland habitats, estuarine wetland habitats as well as habitats associated with priority species described above. The only area identified as priority habitat for priority species within the city boundary is the steep bluff area described above for peregrine falcon. In Washington, there are 18 priority habitats designated by WDFW, and 2 of them have been identified in Aberdeen. These habitats are described by habitat type in Table 3-2.

Table 3-2. WDFW Priority Habitats in Aberdeen

Habitat Type or Element	Description and Criteria for Designation
Estuary/Estuary-like	Deepwater tidal habitats and adjacent tidal wetlands, usually semi-enclosed by land but with open, partly obstructed or sporadic access to the open ocean, and in which ocean water is at least occasionally diluted by freshwater runoff from the land. The salinity may be periodically increased above that of the open ocean by evaporation. Along some low-energy coastlines there is appreciable dilution of sea water. Estuarine habitat extends upstream and landward to where ocean-derived salts measure less than 0.5% during the period of average annual low flow. Includes both estuaries and lagoons. Criteria: High fish and wildlife density and species diversity, important breeding habitat, important fish and wildlife seasonal ranges and movement corridors, limited availability, high vulnerability to habitat alteration.
Freshwater Wetlands and Fresh Deepwater	Wetlands: Lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. Wetlands must have one or more of the following attributes: the land supports, at least periodically, predominantly hydrophytic plants; substrate is predominantly undrained hydric soils; and/or the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year. Deepwater: Permanently flooded lands lying below the deepwater boundary of wetlands. Deepwater habitats include environments where surface water is permanent and often deep, so that water, rather than air, is the principal medium within which the dominant organisms live. The dominant plants are hydrophytes; however the substrates are considered nonsoil because the water is too deep to support element vegetation. These habitats include all underwater structures and features (e.g., woody debris, rock piles, caverns). Criteria: Comparatively high fish and wildlife density and species diversity, important fish and wildlife breeding habitat, important fish and wildlife seasonal ranges, limited availability, high vulnerability to habitat alteration

Source: WDFW 1999.

Habitats and Species of Local Importance

In 1995, the Grays Harbor Estuary was designated as a Site of Hemispheric Significance by the WHSRN. Sites that qualify for this, the highest ranking designation, are sites that are visited by at least 500,000 shorebirds annually, or provide habitat for at least 30% of the biogeographic population of a species. Approximately 500,000 shorebirds are estimated to visit the Grays Harbor Estuary annually (WHSRN 2007).

The WHSRN completed an inventory of available habitat for shorebirds within the Grays Harbor estuary. A portion of this designated area lies within the city limits and is shown in the city of Aberdeen Critical Areas Map 5. This habitat generally includes intertidal mudflats that may be used by shorebirds flocks that feed on their northern migration in the spring (WHSRN 2007).

Naturally Occurring Ponds under 20 acres

Naturally occurring ponds less than 20-acres can provide important habitat for aquatic and terrestrial species. They are called out specifically for protection because they would not fall under the Shoreline Management criteria for ponds greater than 20- acres, and they may not qualify as wetlands.

There are no naturally occurring ponds less than 20 acres found throughout the city of Aberdeen.

Waters of the State

Waters of the state within the city limits include Chehalis River and its tributaries, Lake Aberdeen, and wetlands.

State Natural Area Preserves and Natural Resource Conservation Areas.

There are no state natural area preserves or natural resource conservation areas found within the city of Aberdeen.

Areas Critical for Habitat Connectivity

City of Aberdeen has not identified or designated any areas essential for habitat connectivity as recommended in the Critical Areas Assistance Handbook (Ousley et al. 2003). The relative abundance of wildlife species that are observable in and around the city of Aberdeen is due to the rural nature of the surrounding landscape, the abundant forestland in the vicinity, the extensive estuary that connects Aberdeen to the Pacific Ocean and the upstream resources of the Chehalis River and its tributaries. The city environs are largely developed, and because of this the habitats present within the city are generally not conducive to facilitating wildlife movement. The best remaining avenues of connecting habitat within the city of Aberdeen occur along the river and stream channels in the city. Remaining wetlands, especially large wetlands that are adjacent to streams or rivers also help facilitate wildlife movement through the city.

Often referred to as riparian areas, these streamside habitats provide linear strips of vegetation along the sinuous stream routes through the developed landscape. Many species are known to travel along stream corridors, such as raccoon, beaver, mink, and insectivorous migratory songbirds. Other species that are primarily associated with forest habitats located at higher elevations, such as cavity-nesting ducks, marbled murrelets, and songbirds tend to follow stream courses as they navigate to and from their breeding sites.

Most riparian corridors along mainstem of Chehalis River and lower 3 miles of Wishkah River within the city limits have been already developed (Smith and Wenger 2001), but some good habitat connectivity still remains in areas along those two rivers where wetlands are present. Riparian areas along smaller tributaries of Chehalis River provide habitat connectivity as well.

3.2 Habitat Functions and Values

Habitat is a place where animals and plants reside, find foods, water, and cover, grow, and reproduce. A habitat includes the physical and biotic resources to sustain and support fish and wildlife over space and through time. Wildlife habitat is typically classified by the predominant vegetation conditions and structures, but other environmental factors influence and affect wildlife species and their habitats as well (McComb 2001; O'Neil et al. 2001).

Typical habitat functions include the ability to provide food (foraging habitat), shelter from the weather and predators, and allowing for successional reproduction (breeding habitat) as well as migration (Lemkuhl et al. 2001; McComb 2001; O'Neil et al 2001).

3.2.1 Habitat Functions

The PHS data identified estuarine/estuary-like and wetland as priority habitats in the city of Aberdeen. Although not identified on the PHS maps as priority habitats, riparian areas are considered to be priority habitats and these areas are present along selected stream channels within the city. Other portions of streams are piped or have very little stream-side riparian habitat, because the area has been developed.

Riparian habitat functions are described below. Detailed descriptions of riparian habitat functions, estuarine functions, and wetland functions are also addressed in Sections 2 and 4 of this document.

Estuary/estuary-like Habitat

An estuary is a partially enclosed waterbody where seawater is at least occasionally diluted with freshwater derived from land drainages (Armantrout 1998). Estuaries are considered unique and complex for their variable salinity level, nutrient richness, habitat complexity, and moderate microclimate, and estuary habitat provides shallow refuge, rearing, feeding areas, and migration corridors for wildlife species (King County 2001).

The estuary identified in the city of Aberdeen is a part of the Grays Harbor estuary which includes subtidal, intertidal, rocky shore, intertidal emergent (salt marsh and scrub/shrub), and palustrine forested and emergent (WHSRN 2007). The estuarine area within the city limits is mostly intertidal mudflats providing foraging areas for shorebirds, herons, raccoons, otter, mink, and other organisms.

Wetland Habitat

Wetlands are among the most productive ecosystems in the world and support a great diversity of species, many of which are unique and rare (Mitsch and Gosselink 2000; Sipple 2002). Similar to estuaries, wetlands contribute species richness and abundance by providing structural complexity, connectivity with other ecosystems, abundant food source and available water, and moist and moderate microclimate (Knutson and Naef 1997). Physical and chemical characteristics in a wetland such as climate, topography, geology, nutrients, and hydrologic regime can influence what plants and animals inhabit the wetland (Adamus et al. 1991; Mitsch and Gosselink 2000).

Wetlands identified in the city of Aberdeen support various wildlife species of amphibians (frogs, salamanders, etc.), reptiles (snakes, lizards, turtles, etc.), birds (shorebirds, waterfowls, songbirds, herons, etc.), and mammals (beaver, mink, raccoon, etc.).

Riparian Habitat

Riparian habitats are areas adjacent to aquatic systems with flowing water and contain both aquatic and terrestrial ecosystems (Knutson and Naef 1997). Many vertebrates depend on riparian habitat for at least a part of their lifecycles (O'Connell et al. 1993). Examples of these species include Pacific giant salamander, tailed frog, great blue heron, beaver, and river otter. Riparian habitats also provide breeding for wildlife species, especially migrant birds (Andelman and Stock 1994).

Additionally, riparian habitats function as habitat connectors for terrestrial species and are often used for daily movements, seasonal migration, and dispersal of young (Forman and Gordon 1986; Noss 1993; Thomas 1979). Riparian habitat generally exhibits structural complexity, connectivity with other ecosystems, abundant food source and available water, and moist and moderate microclimate for species diversity and abundance (Knutson and Naef 1997).

As mentioned above, most riparian areas along mainstem of Chehalis River and lower portion of Wishkah River have been converted into residential and commercial lands. Only a small portion of riparian habitats exists along Chehalis River and Wishkah River (Smith and Wenger 2001). Small tributaries of Chehalis River located within the city limits have relatively good riparian condition. Dominant vegetation of typical riparian habitat in Aberdeen is red alder (*Alnus rubra*) and salmonberries (*Rubus spectabilis*).

Third-growth Forest

Forests provide forage and cover for a wide variety of wildlife species. Young forests contain less vertical complexity and fewer canopy gaps than old-growth forests (McCleary and Mowat 2002), but young forests still provide habitat functions to wildlife species, especially to some songbirds who depend on early successional habitat including young forests. The third-growth coniferous forest located north of Aberdeen contains Western hemlock (*Tsuga heterophylla*), Douglas fir (*Pseudotsuga menziesii*), and Western red cedar (*Thuja plicata*).

3.2.2 Habitat Values

The value of habitat for wildlife depends on several factors including habitat types, size, configuration, and the structural complexity. Species diversity and rarity are also another ways to measure the quality of habitat. Every wildlife species has different needs for their habitat. For example, snow geese or wintering trumpeter swans prefer agricultural fields as their foraging habitat (Pacific Flyaway Council 2006) whereas other wildlife species prefer foraging in forested areas.

3.3 Human Activity and Terrestrial Habitat Functions

For wildlife, disturbance may include a behavioral and an ecological component. The behavioral aspect of disturbance may be defined as any action, such as human presence or noise from machinery that alters the behavior of an animal (Dahlgren and Korschgen 1992; Martin 2001). The ecological effect of human disturbance includes the alteration of habitat structure and distribution on the landscape through human activities. Disturbances may include special and temporal components and direct and indirect effects. Factors such as the magnitude of the disturbance, the time of year at which the disturbance occurs, and the duration of the disturbing activity help determine the effect on wildlife species. Many wildlife species vary their tolerance for disturbance and habitat modification over the course of any given year (Martin 2001; McComb 2001).

3.3.1 Ecological Disturbance

Habitat modifications may be temporary, like clear cutting a forest, or permanent, like converting a habitat area to a residential development. Temporary modifications may alter habitat structure, like logging mature trees which essentially converts a forest habitat to a shrub habitat. They may change vegetation composition, like selectively logging conifer trees and leaving an open deciduous forest. And they may result in fundamental changes to ecological processes by introducing invasive species, or by

disrupting nutrient cycling processes. Habitat fragmentation, the isolation of habitat patches from one another, is a type of disturbance that may affect habitat suitability at sites well beyond the site of the disturbance that caused the fragmentation. For some very sensitive wildlife species, the presence of a road may represent a barrier to dispersal, fragmenting the habitat and rendering otherwise suitable habitat on the far side of the road inaccessible (Claar et al. 1999; Lemkuhl et al. 2001). Habitat alteration may change the vegetation community and structural elements of a site, which can then affect the density or configuration of wildlife species assemblages that use a site (McComb 2001). Generally, as the size of the habitat area increases the number of species and individual animals the area can sustain also increases. The maximum number of individual animals of a given species that a particular area can support is referred to as a site's carrying capacity (Robinson and Bolen 1984). Habitat alterations may decrease or increase a site's carrying capacity. Another factor affecting wildlife use of smaller patch sizes is the relatively greater amount of edge habitat that may harbor predatory species, or represent a change in habitat type. These smaller patch sizes and increase in edge habitat has a particularly negative affect on species that rely on continuous habitat or specific habitat elements that only develop within continuous stands, like the northern spotted owl, or species that tend to range over large areas to meet their life history needs, like the grizzly bear.

Even though the city of Aberdeen has been developed for many decades, large patches of habitat, dominated by native plants and displaying structural elements important for wildlife are present within the city limits. These large habitat areas are wetlands and especially wetlands connected to one of the many streams and rivers in the city. The Wishkah River and the Chehalis River represent major wildlife corridors that provide a migratory reach for anadromous fish and the wildlife that rely on these resources. Larger patches of scrub-shrub wetlands and forested wetlands also provide a significant habitat element for migratory songbirds during migration, and for breeding.

Other wetlands, third-growth forests, and undeveloped land have been altered by development within the city. Undeveloped land north and south of the city limits provides the core habitat for forest dependent species and the increased habitat fragmentation that has occurred within the city limits habitat functions for most species of wildlife. The State Route 12 highway and U.S. 101 and State Route 105 are heavily used roads that are a significant barrier to wildlife movements, especially for terrestrial mammals, such as deer and elk, but also for small mammals and furbearers. Bridges over the Wishkah River and the Chehalis River help mitigate this barrier effect. Busy roads such as these also represent a source of wildlife mortality.

Table 3-3. Effects of Disturbance and Habitat Alteration on Wildlife

Activity	Habitat Effect	Sensitive Species	Areas at Risk in Aberdeen
Clearing	Changes in habitat composition, complexity, and structure; Loss of snags and large trees; Habitat fragmentation; Alteration of local hydrology; Potential introduction of non-native species	Snag dependent species (pileated woodpecker, cavity-nesting ducks, flying squirrel), Forest interior and old-growth associated species (fisher, northern goshawk). Large trees in riparian/shoreline areas important for bald eagle and great blue heron nest and perch sites	Forest habitats throughout the city; Forested wetlands near the Wishkah and Chehalis Rivers;
Grading	Loss of soil organic layer; Potential soil compaction; Alteration of local hydrology Increased sedimentation of local waters; Potential for landslides and mass wasting on slopes	Aquatic and wetland dependent species (bull trout, juvenile salmonids, amphibians)	Land near steep-sided drainages on north side of the city; Low-lying portions of the city adjacent to major waterbodies
Urbanization	Loss of open space, breeding feeding, cover and dispersal habitat; Loss of unique habitats and species diversity; Habitat fragmentation; Potential increased prevalence of introduced species; Increased wildlife injury/mortality from vehicle collisions, domestic animals; Increased behavioral disturbance from human/domestic animal presence	Species intolerant of human activities or with large home ranges (gray wolf, spotted owl) Ground-nesting birds (Mountain quail, dark-eyed junco) Species associated with unique habitats (rare plants, butterflies) Species that require unobstructed flight corridors	Undeveloped parcels throughout the city Large tracts of undeveloped land near urban fringe Large tracts of land near major waterbodies Intertidal mudflats could be affected by tall, obstructions nearby
Introduction of non-native species	Potential loss of breeding, feeding, cover and dispersal habitat; Displacement and extirpation of native species; Food web simplification	Insects dependent on rare plants; Aquatic or wetland associated species (marsh wren, beaver) Neotropical migrant songbirds	Riparian systems throughout the city
Increased Noise/Light	Interference with courtship, breeding and foraging behaviors; Potential increased susceptibility to predation	Species intolerant of human activities (marbled murrelet, spotted owl); Nesting songbirds	Larger undeveloped parcels throughout the city
Human presence recreational activities	Interference with courtship, breeding and foraging behaviors; Potential increased susceptibility to predation	Species intolerant of human activities (marbled murrelet, spotted owl);	Larger undeveloped parcels throughout the city

3.3.2 Behavioral Disturbance

Increased human activity can affect where wildlife species feel safe and how well wildlife are able to cope with their environment. Direct effects of behavioral disturbance on wildlife can include interruption of activity, flushing, and abandonment of a site or young. Indirect effects may include weight loss due to insufficient time foraging and reduced food intake, or long-term population decline resulting from lower breeding success rates (Castelle et al. 1992). Human presence may disturb some species of wildlife while others may be very tolerant of human activities. The time of year may also influence the sensitivity of wildlife to disturbance. Some species may be highly tolerant of human activities while foraging, but be highly sensitive to human disturbance during courtship, breeding or while rearing young (McComb 2001; Stinson et al. 2001; Quinn and Milner 2004). Activities such as the use of heavy equipment, blasting, or pile driving may disturb species for up to 0.25 mile beyond the source of the noise (Ruediger et al. 2000; Watson and Rodrick 2002; Kennedy 2003). Recreational activities can be a significant source of disturbance in breeding and wintering habitat (Claar et al. 1999; Stinson et al. 2001). Bird watching, wildlife viewing and dog walking have also been shown to induce behavioral effects on wildlife populations (Watson and Pierce 1998; Stinson et al. 2001; Banks and Bryant 2007).

The city of Aberdeen possesses an enviable mix of urban and rural land use and a relatively high abundance of wildlife. As human activity increases this is expected to lead to greater levels of noise and activities that disturb the behavior of wildlife. Concentration of this growth and activity and segregating important wildlife areas is one of the goals of the Growth Management Act and the Critical Areas Ordinance. Federal and state rules prohibit the intentional disturbance of wildlife.

3.4 Terrestrial Species and Habitat Protection and Regulation

Protection and management of FWHCAs requires protection of individual species, species groups, and populations; as well as protection of habitats that provide the life stage needs of the target species. Appropriate identification, mapping, of species and habitats, development of buffers and development best management practices that address wildlife disturbance and enforcing timing restrictions on disturbing activities and the development of habitat restoration and mitigation strategies are effective tools for accomplishing these goals.

3.4.1 Acquisition, Designation, Rating, and Classification

Terrestrial wildlife may be protected through the purchase and ownership of property by private parties, non-profit organizations (The Nature Conservancy, The Trust for Public Land), and natural resource agencies such as the National Park Service, The USFWS, The WDNR, the WDFW, or the city of Aberdeen. Protection can also be achieved by classification or designation through state or federal laws or through a local land use ordinance. For instance, the USFWS may designate critical habitat for federally-listed species. Land uses within designated critical habitat usually are restricted and proposed work in these areas requires coordination with the resource agency. The WDFW PHS Program may identify Priority Habitat areas. Management recommendations for these areas or for species that inhabit specific areas may limit timing or the extent of land use actions. Public agencies may designate their lands for the management of terrestrial wildlife habitat or condition land use practices through rules and permitting requirements.

The CTED Critical Areas Handbook recommends that local jurisdictions use Priority Habitats and Species data in designating FWHCAs and, when possible, large, round or square blocks of habitat should be prioritized for FWHCAs over smaller or linear open space tracts.

3.4.2 Buffers

Buffers are vegetated lands that separate critical areas from more intensive land uses and are generally intended to reduce potential impacts to the critical area from activities beyond the buffer (O'Connell et al. 2000; Sheldon et al. 2003; Castelle et al. 1992). Land use regulations have required buffers adjacent to wetlands and streams for a number of years and buffers have been the subject of numerous scientific studies and reviews (Castelle et al. 1992; Knutson and Naef 1997; O'Connell et al. 2000; Kauffman et al. 2001; Sheldon et al. 2003)

For Wildlife, the principle benefits provided by vegetated buffers are as additional habitat (feeding, cover, breeding); as travel corridors; microclimate moderation; organic input; and to ameliorate the impacts associated with human disturbance (light, noise activity) (Castelle et al. 1992; Kauffman et al. 2001; Sheldon et al. 2003). Since buffers often include the riparian zone, they often contain a higher diversity of wildlife (Castelle et al. 1992; Knutson and Naef 1997; O'Connell et al. 2000; Kauffman et al. 2001). The habitat suitability of buffers for wildlife is related to the width and floristic composition of the buffer (Castelle et al. 1992; Knutson and Naef 1997; O'Connell et al. 2000; Kauffman et al. 2001). Generally, wider buffers with more diverse vegetation and structural habitat components provide better habitat, and better protect core wildlife functions.

Buffers provide habitat for a significant proportion of wildlife in Washington from invertebrates to large mammals (Castelle et al.1992; Knutson and Naef 1997; Kauffman et al. 2001). Because amphibians require moist conditions protected from temperature extremes, they are closely associated with wetland and riparian buffers. Many species of neotropical migrant songbirds are also closely associated with riparian buffers because their main food source (invertebrates) is more abundant within deciduous forests and fast-growing riparian plants (Knutson and Naef 1997). Waterfowl, particularly dabbling ducks, require upland buffer areas near aquatic habitats for breeding.

As travel and dispersal habitat, buffers are preferred habitat for a number of wildlife taxa including amphibians, birds, small mammals, large mammals and furbearers. Because small mammals and amphibians often have relatively small home ranges and have a limited ability to travel long distances, buffers provide critical cover and microclimate reserves for these species as they access water bodies and wetlands (Knutson and Naef 1997; Kauffman et al. 2001; Sheldon et al. 2003).

Buffer width requirements for providing effective habitat are highly dependent on the wildlife species of interest (Table 3-4). For many forest birds and deer and elk, riparian buffers should be at least 200 feet in width (Knutson and Naef 1997). To maintain neotropical migrant birds, Keller et al. (1993) and Hodges and Krementz (1996) recommend buffers of at least 328 feet (as cited in Knutson and Naef 1997).

Table 3-4 Recommended Riparian Buffer Widths to Provide Effective Wildlife Habitat

Wildlife Taxa	Buffer Width (feet)
Invertebrates	100
Reptiles and Amphibians	100 to 312
Forest dwelling birds	200
Neotropical migrant birds	328
Bald eagle	164 to 656
Great blue heron	328 to 984
Small mammals	39 to 305
Large mammals	200 to 328

Source: Knutson and Naef 1997

3.4.3 Timing Restrictions

Some species of wildlife may be particularly sensitive to disturbance during their breeding seasons, on their wintering grounds, or during migration. Providing restrictions on when highly disturbing types of activity may occur when proposed near sensitive habitat areas is another way to protect habitat and help maintain species use of these areas. The WDFW management recommendations for bald eagles, for example, recommend restricting activities within 880 feet of an active bald eagle nest between January 1 and August 15 (Watson and Rodrick 2002). The WDFW, USFWS and NMFS have developed timing restrictions for work that may impact other listed species of fish and wildlife.

3.4.4 Habitat Mitigation

Mitigation refers to a series of steps that project proponents can employ to first locate and avoid impacting sensitive species and habitats and then minimizing the effects of a project and ultimately compensating for any unavoidable impacts. Mitigation may result in restoration and compensatory mitigation of wildlife habitat that results in better and better functioning habitat. Where required, mitigation often includes the approval of a mitigation plan, and the posting of a mitigation bond. The mitigation plan usually includes a monitoring plan and a requirement for the project proponent to monitor the mitigation site for a given period of time. The plan should include measures to mitigate for impacts to FWHCA based on WDFW management recommendations and should be developed by consulting with WDFW biologists.

3.4.5 Recommendations

The basic requirements for the protection of critical areas are found in the following statutes and guidelines:

- The GMA requires designation and protection for critical areas (RCW 36.70A.170).
- In designating and protecting critical areas under this chapter, counties and cities shall include best available science in developing policies and development regulations to protect the functions and values of critical areas. (RCW 36.70A.172(1)). Criteria for determining best available science are contained in WAC 365-195-900 through 925.
- In addition, counties and cities shall give special consideration to conservation or protection measures necessary to preserve or enhance anadromous fisheries (RCW 36.70A.172(1)).

Many Growth Management Hearings Board decisions and court cases have also provided clarification on what is meant by protection of critical areas (Parametrix 2006).

By implementing the following recommendations, the city of Aberdeen would ensure that its protection of terrestrial species and habitats conforms with the requirements of the GMA:

- Designation, Rating, and Classification: It is recommended that the city use WDFW's Priority Habitats and Species data in designating FWHCAs and, when possible, large, round or square blocks of habitat should be prioritized for FWHCAs over smaller or linear open space tracts. The city should designate FHWCAs associated with species designated by USFWS or WDFW for protection. At the time of the inventory conducted for development of this BAS document, there were no state or federally protected habitats present within the City of Aberdeen, and only one species occurrence was noted. Other species however have been documented using areas in vicinity of the city.
- Buffers: Buffer width requirements for providing effective habitat are highly dependent on the wildlife species of interest. It is therefore recommended that the city require buffer widths identified in WDFW's management recommendations for individual species.
- Timing Restrictions: The WDFW, USFWS and NMFS have developed timing restrictions for work that may impact other listed species of fish and wildlife. It is recommended that the city adopt these restrictions as they apply to the individually protected species.
- Habitat Mitigation: As noted in Section 2 of this document, it is recommended that the City incorporate requirements for mitigating habitat losses associated with riparian and wetland areas. In addition, the city should require habitat mitigation if habitats of state or federally protected species are impacted. The mitigation should follow the appropriate federal and state habitat management guidelines for the individual species.
- Species and Habitats of Local Importance: It is recommended that the city of Aberdeen designate those portions of the Site of Hemispheric Significance that have been inventoried by the Western Hemisphere Shorebird Reserve Network (WHSRN) as a habitat of local importance. If the City wishes to prioritize protection for additional habitat areas

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4 Wetlands

The USACE (Federal Register 1982), the Environmental Protection Agency (EPA) (Federal Register 1985), the Shoreline Management Act (SMA), and the Growth Management Act (GMA) all define wetlands as "areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions."

Wetlands generally include swamps, marshes, bogs, and similar areas but do not include those artificial wetlands such as irrigation and drainage ditches, grass-lined swales, canals, detention facilities, wastewater treatment facilities, farm ponds, and landscape amenities, or those wetlands created after July 1, 1990, that were unintentionally created as a result of the construction of roadways. Mitigated wetlands that are created from upland areas may be included (WAC 173-22-030).

All of the following criteria must be met for an area to be defined as a wetland:

1. Hydrophytic vegetation. Hydrophytic vegetation is defined as vegetation adapted to growing in wetland conditions (Reed 1997).
2. Wetland hydrology. Wetland hydrology criteria are considered to be satisfied if the soil was seasonally inundated or saturated to the surface for a consecutive number of days greater than or equal to 12.5% of the growing season (Ecology 1997).
3. Hydric soils. Hydric soil is formed when soils are saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions.

Detailed description of wetland delineation methods are found in the Washington State Wetlands Identification and Delineation Manual (Ecology 1997).

4.1 Wetland Inventory

Wetlands within the city of Aberdeen were identified by two steps: reviewing existing information and limited reconnaissance-level fieldwork. These two steps are discussed in detail below.

4.1.1 Document Review

The following information was reviewed to determine the presumed presence of wetlands in the study area:

- National Wetland Inventory (NWI) maps (online at http://wetlandsfws.er.usgs.gov/wtlnds/launch.html)
- The NWI map identified wetlands in the city of Aberdeen based on the USFWS wetland classification system (Cowardin et al. 1979). The USFWS wetland classification system, also called as the Cowardin classification system, characterizes wetlands according to water sources and vegetation types.
- Soil Survey for Grays Harbor County (Pringle 1986)
- Aerial photographs (City of Aberdeen 2005)

- City of Aberdeen Comprehensive Land Use Plan (City of Aberdeen 2001)

4.1.2 Field Investigation

Qualified wetland scientists conducted field reconnaissance surveys in September and October 2007 to verify the wetlands identified by document review.

4.1.3 City of Aberdeen Wetlands

Wetlands in the city of Aberdeen have been largely displaced by urbanization and agriculture activities in the past. Existing wetlands in the city of Aberdeen are primarily associated with streams including the Chehalis River, the Wishkah River, Stewart Creek, and their tributaries. According to the USFWS Cowardin system, common wetlands found within the city limits are palustrine and riverine wetlands (Cowardin et al. 1979) and are shown in The City of Aberdeen Critical Areas Map 1. Many existing wetlands are located adjacent to residential and commercial properties. In south Aberdeen, lower elevation areas behind the flood control levee system contain scrub-shrub wetlands. Low-lying areas throughout the city may be influenced by groundwater because the elevations are very close to normal tidal elevations, and these areas were probably part of the floodplain of the Chehalis River prior to the development in the area.

Estuarine wetlands within the City of Aberdeen are limited to the fringe wetlands that occur along the Chehalis River shoreline, waterward of the flood control levee system. Estuarine wetlands may have been much more extensive prior to settlement, and there still are large tracts of estuarine wetland within the Grays Harbor Estuary in the Johns River and Humptulips River delta areas. The flood control levees limit the intrusion of tidal waters and fresh water is pumped to the river. Three large tidally-influenced wetland systems are present within the City of Aberdeen. These wetlands occur within the lower Wishkak River floodplain, adjacent to Mill Creek on the border of Aberdeen and Cosmopolis, and adjacent to Elliot Slough in the east part of Aberdeen. These three wetland areas represent large relic tracts of tidal, spruce dominated forested wetlands. These areas provide important wildlife habitat and the dendritic channels and riparian habitats that these wetland possess may be used as rearing habitat for anadromous fish, including salmon.

Other wetlands in the city are supported by heavy precipitation (close to 100 inches per year) and the generally moist maritime climate.

4.2 Wetland Functions and Values

Wetlands potentially perform a variety of unique physical, chemical and biological functions which are beneficial for both the human and biological environment (NRC 1995; Brinson and Rheinhardt 1996). These functions include flood storage and retention, stream base flow maintenance and groundwater support, improving water quality, shoreline protection, and biological support for fish and wildlife habitat (Null et al. 2000; Adamus et al. 1987; Hruby et al. 1999). Because of their unique combination of water and biodiversity, wetland areas are also used for a broad range of recreational, educational, and aesthetic activities including bird watching and hunting.

Factors affecting wetland function include size of wetlands, location, vegetation diversity, and the level of disturbance. Not all wetlands perform all functions, nor do they perform

all functions equally (Novitzski et al. 1995). The following sections describe how palustrine and estuarine wetlands identified in Aberdeen perform these functions.

4.2.1 Flood Water Attenuation and Flood Peak Desychronization

Wetlands control stormwater flow by capturing and slowly releasing surface water runoff that would otherwise flow directly downstream and cause more severe flooding (Reinelt and Horner 1995). Wetlands in the upper watershed with constricted outlets or closed basins are generally important in capturing and detaining floodwaters. Other wetland characteristics that contribute to flood storage and desynchronization include broad floodplains and plant communities consisting of low and dense vegetation (Hruby 2004).

The effectiveness of reducing flooding by wetlands increases with:

- An increase in wetland area;
- Proximity of the wetland to flood waters;
- Location of the wetland (along a river, lake, or stream);
- Amount of flooding that would occur without the presence of wetlands; and
- The lack of other storage areas (Mitsch and Gosselink 2000).

In the city of Aberdeen, levees were built along riverbanks of the Chehalis River to protect adjacent land from flooding. As a result of separation from the floodplain, wetlands along the Chehalis River may not provide this function. The position of the City of Aberdeen low in the watershed of both the Wishkah River and the Chehalis River limits the ability for its wetlands to affect flood behavior. Wetlands higher in a watershed are better able to desynchronize flood flows and protect downstream resources. Wetlands located upstream on the Wishkah River, and the Chehalis River and their tributaries may contribute to reduce flooding downstream within the City of Aberdeen.

4.2.2 Stream Baseflow Maintenance and Ground Water Support

Wetlands function as both recharge and discharge areas for groundwater by retaining large volumes of water and slowly releasing it to streams and groundwater (Mitsch and Gosselink 2000; Reinelt and Horner 1995). This function contributes to stream baseflow and groundwater recharge (Mitsch and Gosselink 2000). Although these factors have been documented to occur, little information is available on deep aquifer recharge by wetlands. Site-specific studies indicate that some wetlands have more groundwater recharge systems occurring than in others (Carter et al. 1979; Novitzki 1979; Carter and Novitzki 1988).

Wetlands have been assumed to enhance base flows in streams during drier seasons because of their ability to store water. However, recent studies indicated that wetlands in Washington may contribute to reduce baseflow because of water loss through evapotranspiration (Adamus et al. 1991; Bullock and Acreman 2003). Wetlands on alluvial soils unlikely hold water long enough into the dry season to support baseflow because alluvial soils are permeable. On the other hand, wetlands with organic and peat soils would hold water but not release very much of it because of the low hydraulic conductivity. As a result of these studies, wetlands are not considered to maintain low flows in streams in Washington (Sheldon et al. 2005).

Groundwater recharge typically occurs around the edges of depressional and riverine wetland systems that impound and hold surface water (Mitsch and Gosselink 2000; Novitzki 1979; Hruby 2004). No wetlands that may provide groundwater recharge have been documented in the city of Aberdeen since the city is located in the lower watershed. Wetlands within the city limits are most likely fed by surface water from rivers and streams, precipitation, and runoff. Wetland complexes with this function may be found in upstream stream headwater areas outside of the city limits.

4.2.3 Water Quality Improvement

Wetlands help improve water quality by removing organic and inorganic nutrients and toxic materials before they reach open water (Mitsch and Gosselink 2000). Processes of removing contaminants in wetlands involve settling, chemical reactions in and with the soils, and biotransformations. Major contaminants that can enter wetlands include sediments, nitrogen and phosphorous compounds, hydrocarbons, heavy metals, pathogens, pesticides, and herbicides (Hammer 1989; Moshiri 1993; Kadlec and Knight 1996). Wetlands may perform well on improving water quality with the following characteristics:

- Are located downstream from sources of pollutants (agriculture, urban development);
- Contain 80 percent or more vegetative cover
- Experience low velocity stormwater flows
- Have a restricted outlet; and
- Attenuate 50 percent or more of overland flow (Ecology 1996).

Herbaceous and woody wetland vegetation can physically trap and filter suspended sediments that are deposited in wetlands from surrounding areas (Adamus et al. 1991; Sipple 2002). Gilliam (1994) suggested that 85 to 90 percent of sediment from runoff remained trapped by wetland vegetation. Wetland vegetation also provides extensive attachment surfaces for bacteria, which are primary mechanism for nitrogen and phosphorous removal (Hruby 2000).

Metals and toxic organic compounds entering wetlands are generally removed through sedimentation, adsorption, chemical precipitation, plant uptake, and biodegradation (Adamus et al. 1991). Certain toxins can be broken down by plant metabolic processes, and other toxins remain within the plants' biomass until the plants decompose (Gambrell and Trace 1994; Sheldon et al. 2005).

Wetlands that contain organic or clay soils can also perform removing metals and toxic compounds from surface and groundwater. Metals and toxic compounds entering wetlands bind to the negatively ionized surface of clay particles, precipitate as inorganic compounds, form a complex with humic materials, and adsorb or occlude to precipitated hydrous oxides (Gambrell and Trace 1994).

Generally, all wetlands in western Washington have the potential to remove toxic metals and organic compounds based on their soil composition. However, wetlands are considered to be very effective on removing nutrient and toxic compounds if they:

- Contain diverse and dense, persistent vegetative classes;
- Contain organic or clay soils
- Are in the depressional class; and

- Have seasonally ponded areas (Sheldon et al. 2005).

Wetlands within the City of Aberdeen may play a significant role in the treatment of untreated stormwater prior to discharge to the Grays Harbor Estuary. Wetlands that occur behind the flood control levees slow the water and this allows time for microorganisms to interact with chemicals dissolved in the water and it allows time for small particles to settle within the wetlands and become part of the wetland soil, instead of the estuary mud. This function may be limited by the heavy amount of precipitation, and regular flooding.

4.2.4 Erosion/Shoreline Protection

Wetlands located nearby water bodies such as lakes, rivers, and bays help protect shorelines and stream banks against erosion by decreasing the velocity of water flowing downstream (Sheldon et al. 2005). The ability of wetlands for reducing water flow depends on the presence of woody vegetation, the configuration of the wetland, and the substrate type (Adamus et al. 1991; Sheldon et al. 2005)

Vegetated depressional wetlands with no outlet are most effective of reducing erosion since they store all surface waters. Riverine wetlands with riparian vegetation also provide erosion protection by decreasing the water velocity. The riverine wetland that is wider than the channel width allows water to spread out; thus slows down the water flow (Sheldon et al. 2005; Hruby et al. 1999). Wetlands with dense vegetation along relatively undeveloped shorelines and banks may also reduce erosion providing high shoreline protection during high-water periods (Adamus et al. 1991).

Shoreline protection is provided by riparian wetlands throughout the City of Aberdeen, particularly by the large riparian wetlands located along the lower Wishkah River.

4.2.5 Biological Support and Fish and Wildlife Habitat

As described in Sections 2 and 3 of this document, wetlands support various species by providing sources of food, shelter, and refuge. Different vegetation communities within wetland boundaries can support a higher diversity of invertebrates by adding more structure complexes and creating more edge habitat (Dvorak and Best 1982; Lodge 1985). Diversity of wildlife species increases when wetlands are connected to undisturbed natural upland habitat or aquatic ecosystems. These connections provide corridors for migration and dispersal of many wildlife species (Mitsch and Gosselink 2000; Kauffman et al. 2001).

Moist and moderate microclimate is one of the characteristics of the wetland habitat that contribute to species richness and abundance (Knutson and Naef 1997). Wetlands with the wet and moist microclimate condition and organic rich soils contribute to high production of plant materials, which increases in the number of invertebrates. Leper and Taylor (1998) indicated that small seasonal wetlands can support more than 700,000 animals per square meter. Increase in invertebrates provides more species diversity since larger predators including amphibians, reptiles, fish, birds, and mammals feed on these invertebrates as a part of the food web (Sipple 2002).

Washington State priority wildlife areas documented in wetlands within the city of Aberdeen include habitat for shorebird concentration and breeding wood ducks.

Wetlands associated with streams in the city of Aberdeen may be used by coho, steelhead, and resident cutthroat. Some of these areas are used seasonally and others are used year around. Other priority species that are associated with wetlands habitats outside of Aberdeen include Olympic mudminnow, reticulate sculpin, purple martin, and great blue heron.

4.2.6 Recreation, Education, Cultural Resources, and Open Space

Because of their unique characteristics, wetlands support a wide range of recreational activities including swimming, fishing, and hunting. Wetlands and surrounding areas also provide other activities such as hiking, wildlife viewing, and nature study. The quality of these recreational activities depends on the health of the wetland. Within urbanized and suburbanized settings, wetlands are also important by providing open space for aesthetic enjoyment to local communities (Stevens and Vanbianchi 1993).

In Aberdeen, some wetlands are located in the city parks or along trails that are used for meeting, walking, birdwatching, and other recreational activities. Parks in the urban area such as Pioneer Park and Garley Park are mostly open space and have limited recreational uses in the wetlands. Wetlands in Steward Park and Morrison Riverfront Park are located nearby waterway providing some habitat for birds and fish; therefore these wetlands are likely used for wildlife viewing and other recreational and educational activities.

4.3 Human Activity and Wetland Habitat Functions

Human activities may alter wetland functions and values that could have both positive and negative effects. For example, logging, agriculture, mining, urbanization, and construction of utilities, in-water structures, and roads could have negative impacts whereas restoration, enhancement, dam removal, and control of invasive species could result in beneficial effects on wetlands (Mitsch and Gosselink 2000; Booth 2000; Sheldon et al. 2005).

Different types of human activities can affect wetland functions and values at various levels. The most extreme impacts caused by human activities are filling or de-watering a wetland, and these activities remove all the wetland functions (Sheldon et al. 2005). In the city of Aberdeen, urbanization is considered to be the major human disturbance identified within the city limits that could influence wetland functions and values. Following sections describe how wetland functions are likely to be affected by different types of human disturbances.

4.3.1 Flood Water Attenuation and Flood Peak Desychronization

Dredging, filling, and channelization (i.e., dikes, levees) alter the wetland's storage capacity and flood control functions by separating the wetland from the floodplain and vegetation removal (Mitsch and Gosselink 2000). Roads, culverts, and other outlet also affect flood control by regulating flow rate (Taylor 1993; Taylor et al. 1995). Changing the water flow and storage capacity in wetlands could increase rates and volumes of the stormwater as well as the timing of stormwater entering aquatic systems (Mitsch and Gosselink 2000; Sheldon et al. 2005).

The loss of the flood control function in urban basins cause to increase in discharge to wetlands changing the pattern of water level fluctuations. Increase in water level fluctuations can reduce biological diversity and native plant cover in wetlands (Reinelet et al. 1998; Azous and Horner 2001). Additionally, increase in stormwater runoff could result in sediment loading to a wetland, which could introduce higher levels of contaminants, increase in stream bank erosion, and disturb aquatic habitat (Richter 2001; Azous and Horner 2001).

Because of the levee constructed along the Chehalis River and intensive development within the city limits in the past, wetlands that affect streamflow have been separated from the streams, drained, or filled. Although wetlands that provide this function are limited in Aberdeen, wetlands that are associated with upstream portions of the Wishkah River, Elliott Sloughs, and their tributaries may still contribute to flood attenuation.

4.3.2 Stream Baseflow Maintenance and Ground Water Support

Surface and groundwater movement are affected by changes in land uses and vegetation communities such as agricultural conversion and urban development. Increase in impervious surface or extensive groundwater pumping may remove or alter wetlands that provide groundwater support (Sheldon et al. 2005; Gersib 2001). As mentioned above, recent studies show that wetlands do not necessary provide stream baseflow; therefore this particular function is not discussed further.

No documents have identified human activities altering or reducing groundwater support function in wetlands in the city of Aberdeen. There may be headwater wetlands that are considered important in ground and surface water recharge outside of the city limits.

4.3.3 Water Quality Improvement

Wetlands maintain the water quality of receiving waters through biofiltration and infiltration. Human land uses such as urbanization, agricultural conversion, and forest practices could alter the physical properties of a wetland and affect the water quality enhancement function of the wetland by the loss of wetlands areas or persistent vegetation and changes in hydroperiod. Typical human disturbances include filling, draining, vegetation removal, compacting surface soils, and creating impervious surfaces (Sheldon et al. 2005; Ecology 1996).

Clearing vegetation causes the rate of surface runoff to increase, which limits suspended sediments and contaminants to settle and react with the soils. Denitrification and phosphorus retention processes are likely restricted by severe water fluctuations (Ecology 1996). Additionally, some studies showed that flowing water across the ground surface tends to collect dissolved nutrients and toxics sending them downstream (Reinelt and Horner 1995; Azous and Horner 2001; Sheldon et al. 2005).

The impact of human activity and development on water quality varies widely between wetlands of different urbanization levels. In general, increase in impervious surfaces would likely change the frequency and the magnitude of surface runoff (Booth and Reinelt 1993). However, there are few studies available addressing the impacts of surface water runoff on water quality in wetlands since many studies have focused more on the effectiveness of wetlands for water treatment. Azous and Horner (2001) studied 28 wetlands in the lower Puget Sound area and found that pollutants concentrations

tended to be higher in urban wetlands, but these concentrations were still within Ecology's water quality standards. Alterations to water quality of a wetland by hydrologic changes, such as low dissolved oxygen, high turbidity, and pollutant levels, may negatively affect plants and animals as well (Adamus et al. 2001).

The majority of the remaining wetlands in Aberdeen likely provide some water quality functions to surface and ground water. However, future urban development would likely increase the level of flow and pollutants and exceed the level of treatment that the existing wetlands can provide. To prevent further disturbance to wetland water quality functions, stormwater systems are generally recommended.

4.3.4 Erosion/Shoreline Protection

Human activities can affect erosion and shoreline protection functions by removing vegetation, compacting soils, and increasing the peak flow. Vegetation removal in wetlands that are located nearby lakes, rivers, or bays may increase in the downstream erosion and flooding by increasing the water velocity (Sheldon et al. 2005).

This function is especially important in urban watersheds with frequent flooding, but many studies suggested that urbanization is the major cause of erosion due to the increase in the movement and deposition of sediments (Azous and Horner 1997; Sheldon et al. 2005). Construction activities especially affect erosion since soil surfaces are often disturbed and exposed during construction.

Major shorelines in Aberdeen such as the Chehalis River have been diked for flooding protection and separated from existing wetlands. As a result, these wetlands unlikely provide protection for erosion. On the other hand, wetlands located upstream of the Wishkah River and its tributaries contain some vegetation complexes and may help stabilize riverbanks during high-water periods. Minimizing shoreline alterations and restoration activities will help maintain erosion and shoreline protection functions.

4.3.5 Biological Support and Fish and Wildlife Habitat

Wetlands develop both aquatic and terrestrial environments when hydrologic conditions are suitable for supporting a wide variety of aquatic and terrestrial species. However, as urbanization or changes in land use occurs, habitats of these species might be lost. Direct impact may be caused by filling, draining or outlet modification whereas indirect impacts include increased or decreased quantity and reduced quality of water flow (Azous and Horner 1997).

Most aquatic and terrestrial species are influenced by types of plants growing in a wetland; therefore altering vegetation communities in the wetland may cause the loss or degradation of habitat for many fish and wildlife species, especially sensitive species in Washington State (Sheldon et al. 2005). Vegetation clearing also contributes to introduction of invasive species, which affects habitat diversity by lowering vegetation diversity. Some examples of vegetation clearing include mowing, burning, and plowing.

Although each species are impacted in a different way, changes in hydrology and hydroperiod can generally affect the distribution and richness of aquatic and terrestrial species. For example, breeding of amphibians can be greatly influenced by altering hydroperiod (Rowe and Dunson 1993; Richter et al. 1991). Reducing water levels of a

wetland through ditching, draining, or pumping may provide less habitat for fish and bird species (Adamus et al. 2001; David 1994; DeAngelis et al. 1997). Changes in wetland vegetation communities are also observed by increase or decrease in water levels (Sheldon et al. 2005).

Human activities such as urbanization, agriculture, and mining can also increase the amounts of pollutants that are released into wetlands by surface water runoff and suspended sediments (Sheldon et al. 2005). Urban development is often associated with increased export of sediment to water bodies, especially affecting aquatic invertebrates and fish species (Sheldon et al. 2005; Euliss and Mushet 1999). Pollutants including heavy metals, pesticides, herbicides, and oil can cause either acute or chronic toxicity to aquatic and terrestrial species. The response of individual species to pollutants vary depending on other environmental factors such as characteristics of wetlands, but many studies have reported that pollutants change community structure of wetlands over time (Sheldon et al. 2005).

Loss of wetlands by conversion and riparian habitat degradation caused a decline in overall habitat diversity and an increase in habitat fragmentation in Aberdeen. Urban development in the city has resulted in wetland loss, changes in wetland hydrologic regimes, and decrease in water quality. For instance, wetlands along main channels used to provide rearing habitat for fish species. However, commercial and residential development including construction of levee along the Chehalis River and other streams has changed their hydrology by disconnecting wetlands from the main channels. As a result of these cumulative impacts to wetlands, habitat diversity of many wetlands in developed areas of Aberdeen is somewhat degraded. On the other hand, some wetlands located upstream of the Wishkah River and along Elliott Slough still remain undisturbed; therefore they may provide important habitat for terrestrial and aquatic species.

4.3.6 Recreation, Education, Cultural Resources, and Open Space

Opportunities for recreation, education, and open space in wetlands can be limited by direct human activities such as filling, draining, or alteration of wetlands. Wetlands surrounded by development are often valued as open space or green space by homeowners who live nearby. The Aberdeen Comprehensive Plan (2001) addresses that open spaces must be provided for quality of life in Aberdeen as the city grows.

Human activities can lower the recreational values of wetlands by impacting fish and wildlife species richness and abundance. Most recreational activities in wetlands in Aberdeen are influenced by wildlife use of the site such as viewing. Proper management is essential for recreational activities since wetland ecosystems can be impacted by recreational activities themselves (Sheldon et al. 2005).

4.4 Wetland Protection and Regulation

Wetlands in Aberdeen are currently regulated at the federal and state levels. Under Section 404 of the Clean Water Act, the USACE regulates discharges of dredged or fill materials into waters of the United States, including wetlands. Additionally, Section 401 of the Clean Water Act requires that any activities permitted under Section 404 meet water quality standards regulated by state and tribal governments. Wetlands for all farm

program participants are regulated by U.S. Department of Agriculture (USDA) under the Food Security Act.

The city can require protection of wetlands through its SEPA authority on a case by case basis. The GMA requires cities and counties to designate critical areas including wetlands by adopting development regulations (RCW 36.70A.130). This best available science document is being prepared in the context of the city of Aberdeen adopting such regulations. The following sections describe the regulatory options for protecting wetlands, and the recommendations for Aberdeen.

Four-Step Framework for Protecting and Managing Wetlands

Ecology's publication, *Wetlands in Washington State Volume 2: Guidance for Protecting and Managing Wetlands* (Granger et al. 2005) outlines a framework for managing wetlands. The framework consists of four steps, and these four steps are briefly summarized and described below:

Step 1: Analyzing the landscape and its wetlands
Step 2: Prescribing solutions
Step 3: Taking actions
Step 4: Monitoring results

Step 1 involves a landscape analysis at different scales that influence wetland resources and the processes that occur on the site. A landscape analysis provides important information that forms the basis of a program to protect wetlands. This information provided by the landscape analysis could be used to develop or update comprehensive plans. The goal of this step is to develop an understanding of where landscape processes occur and where they are particularly sensitive to human disturbances. Understanding the environmental factors in the landscape is essential to plan land use designations in the future.

Information generated from the landscape analysis can also protect some landscape processes by assisting development of regulations. Although beneficial at larger scales, this is best done at a sub-basin or subarea scale, where specific regulations can be developed to prevent degradation of landscape processes and to target protection of connected habitats (Granger et al. 2005).

Step 2 describes the process by which local governments develop solutions to protect and manage wetlands within their jurisdiction. The goal is to identify means for incorporating the results of the landscape analysis in Step 1 into effective planning, regulatory, and non-regulatory tools. This is the step in which Smart Grow planning approaches, such as Green Infrastructure or Alternative Futures, can be applied and when comprehensive plans, critical area ordinance, shoreline management plans, restoration plans, and incentives for conservation are typically developed.

Step 3 ensures that the solutions developed and adopted in Step 2 are effectively implemented through taking actions at the different geographic scales. Examples of taking actions could include:

- Implementing regional, subarea, or community plans on the ground

- Applying critical areas and clearing and grading ordinances at specific wetland sites when a development is proposed
- Restoring or preserving wetlands identified in a restoration plan through a landscape analysis
- Providing tax relief for landowners with wetlands

Step 4 applies monitoring to determine whether cumulative impacts have been minimized during Step 3. Local jurisdictions cannot determine whether their solutions are actually protecting wetlands without collecting data that monitor the success of their approach. Monitoring whether adequate protection has been achieved, followed by any needed corrective action, is especially critical. Much of the information collected to date and reviewed indicates that there is still continued loss of wetlands and their functions and values (i.e. cumulative impacts).

Adaptive Management is based upon the information collected through Step 4 and can be used to determine what changes are necessary to improve protection when the identified goals are not met. Using adaptive future management, policies, and regulations can be more effective in protecting the wetland resource (Washington State Joint Natural Resource Cabinet 1999).

4.4.1 Wetland Delineation, Classification, Rating, and Reporting

Wetland Delineation

Wetlands are those areas that meet the state definition of "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas." Wetlands are identified in accordance with the Washington State Wetlands Identification and Delineation Manual (Ecology 1997). All areas within the city that meet the definition are designated as critical areas. Wetland boundaries are identified by a wetland delineation process. Typically, a qualified professional conducts a site visit gathering data on hydrology, vegetation, and soils. In the State of Washington, local jurisdictions are required to use the Washington State Wetlands Identification and Delineation Manual for delineating wetlands (RCW 36.70A.175, Chapter 173.22.080 WAC).

Wetland Classification

There are two commonly used wetland classification systems: the Cowardin classification system and the Hydrogeomorphic classification system (HGM). The Cowardin system classifies wetlands based on landscape position, vegetation cover, and hydrologic regime. This system is hierarchical and includes several layers of detail for wetland classification including:

- Water flow
- Substrate type
- Vegetation types
- Dominant plant species

The Cowardin system is useful for developing wetland inventories from aerial photographs and incorporates some landscape factors, but it is not designed to help understand how functions differ among wetlands (Sheldon et al. 2005).

The HGM classification was developed by Brinson (1993) to categorize wetlands into groups that function in similar ways. This classification method was chosen by the statewide wetland technical committee that guided the development of the Washington wetland function assessment methods (Hruby et al. 1999). The HGM classification system characterizes wetlands based on:

- Geomorphic setting (topographic location)
- Water source and its transport (precipitation, surface, groundwater)
- Hydrodynamics (direction and strength of flow)

The categories are divided by classes, and the highest class is established based on the geomorphic setting of the wetland (Brinson 1993). Within a region, subclasses for each of these wetland classes can be defined by local wetland experts. Table 4-1 lists the general classes and subclasses of HGM wetland types within the lowlands of Western Washington.

Table 4-1. Classes and Subclasses of HGM Wetland Types in Western Washington Lowlands[1] (Hruby et al. 1999)

Class	Subclass
Riverine	Impounding Flow-through
Depressional	Outflow Closed
Slope	ND[2]
Flats	ND[2]
Lacustrine (Lake) Fringe	ND[2]
Estuarine Fringe	Tidal Freshwater Tidal Saltwater

1. Hruby et al. (1999)
2. ND signifies a classification system that has not yet been developed.

Both Cowardin and HGM classification systems are important to identify wetland functions and are helpful when assessing a wetland by providing detailed information. It is recommended that wetland mitigation projects require this information as the baseline information of the site. This information helps regulatory agencies to determine whether or not the proposed mitigation is the best and most appropriate option for the type of wetland.

Wetland Rating

The Washington State Department of Community, Trade and Economic Development (CTED) recommends cities and counties to use a wetland rating system for identifying the relative function, value, and uniqueness of wetlands in their jurisdiction. As a tool to develop a rating system, the CTED suggests local jurisdiction consider:

- the Washington state four-tier wetlands rating system;
- Wetlands functions and values;
- Degree of sensitivity to disturbance;
- Rarity; and
- Ability to compensate for destruction or degradation.

The most recommended option by the CTED is the Washington state rating system, which is supported by scientific literatures and provides continuity between local and state permit decisions. Local jurisdictions can choose not to use the Washington state rating system and develop their own system that is appropriate for their local conditions. However, the rational for that decision needs to be included in the legal record (Ousley et al. 2003).

Ecology has developed a wetland rating system for ranking wetlands according to their relative importance in terms of functions and special characteristics. This rating system is described in *the Washington State Wetland Rating System for Western Washington* (Hruby 2004), which is a revised version of the system developed in 1993. With this system, wetlands with higher functions or large high quality are generally considered high priority for protection than wetlands with lesser functions and lower quality.

Points are also assigned to wetlands based on their sensitivity to disturbance, rarity, the functions they provide, and whether they are replaceable or not. The maximum number of points a wetland can score is 100. The Ecology's rating system rates wetlands into four distinct categories, from Category I to Category IV (Table 4-2). This rating system was designed to be used for developing standards for protecting and managing the wetlands and wetland buffer areas. However, it does not replace a full wetland functional assessment for compensatory mitigation projects.

Table 4-2. Wetland Rating System[1]

Category	Criteria
I	Category I wetlands are those that: 1). Represent a unique or rare wetland type; or 2). Are more sensitive to disturbance than most wetlands; or 3). Are relatively undisturbed and contain ecological attributes that are impossible to replace within a human lifetime; or 4). Provide a high level of functions. Specific wetlands that meet the Category I criteria include: • Relatively undisturbed estuarine wetlands over one acre in size; or • Natural Heritage Wetlands, specifically, Wetlands identified by the Washington Natural Heritage Program/DNR as high quality relatively undisturbed wetlands; and Wetlands that support state-listed threatened or endangered plants; • Bogs; • Mature and old-growth forested wetlands over one acre in size; • Wetlands in coastal lagoons; and • Wetlands that perform many functions very well, as indicated by a score of 70 or more points out of 100 on the Ecology wetland rating form.
II	Category II wetlands provide high levels of some functions. Specific wetlands that meet the Category II criteria include: 1. Estuarine wetlands less than one acre in size, or disturbed estuarine wetlands larger than one acre; 2. Interdunal wetlands greater than one acre; and 3. Wetlands scoring between 51 and 69 points out of 100 on the wetland rating form.
III	Category III wetlands are: 1. Wetlands scoring between 30 and 50 points out of 100 on the wetland rating form; and 2. Interdunal wetlands between 0.1 acre and 1.0 acre in size.
IV	Category IV wetlands have the lowest levels of functions and are often heavily disturbed. Specific wetlands that meet the Category IV criteria include wetlands scoring less than 30 points out of 100 on the wetland rating form.

1. Hruby 2004

Wetland Exemptions

A review of best available science data indicates that wetlands, regardless of their size, provide some type of important physical, chemical, or biological functions (Sheldon et al. 2005; Granger et al. 2005). In the past, regulatory agencies have often exempted certain wetlands from regulatory requirements or mitigation based on their small size. For example, a jurisdiction may allow filling wetlands that are between 1,000 square feet and 2,500 square feet without mitigation.

Ecology has provided informal guidance regarding potential exemption of small wetlands that allows local jurisdictions to consistently determine what protection measures are required. It states that wetlands less than 1,000 square feet or smaller may be exempt from regulatory requirements when they meet the following criteria:

- They are not associated with a riparian corridor;
- They are not part of a wetland mosaic; and
- They do not contain habitat identified as essential for local populations of priority species identified by Washington Department of Fish and Wildlife.

However, the scientific literature does not provide support for such exemptions because the loss of wetlands may possibly cause cumulative impacts such as fragmentation or exceeding thresholds of ecosystem viability on the landscape (Granger et al. 2005). Therefore, understanding the potential cumulative impacts (e.g., how many acres of wetlands would be affected, what functions would be most affected, how such impacts would be compensated, etc.) and considering and documenting the potential implications are critical to protect wetland functions.

Ecology also suggests that local jurisdictions may limit the exemption to certain areas (such as Urban Growth Areas or specific sub-basins), to certain wetland types (e.g., Category IV wetlands, those with non-native species), which will help minimize the risk of losing important wetland functions. Additionally, it may be important to limit the total acreage of wetlands exempted on a project basis or within a sub-basin (Granger et al. 2005).

Wetland Reporting

Local jurisdictions can choose and specify what needs to be included in a wetland report (Granger et al. 2005). Ousley et al. (2003) provides some guidance for requirements in the preparation of a typical report in Appendix A of their handbook. These requirements include but are not limited to:

- Be prepared by a qualified professional;
- Use scientifically valid methods and studies in the preparation of the report;
- Contain minimum contents for the report, which set the threshold for determining whether it is complete;
- Describe geographic limits of the study area; and

- Outline requirements for compensation, performance standards, construction plans, monitoring and maintenance, contingency plans, financial guarantees, and other details.

Some projects may result in minor impacts which may not require a full detailed wetland report. In that case, jurisdictions can choose to implement a two-tiered process to segregate projects that have different levels of reporting requirements; thereby limiting the need for comprehensive review of all permits that are submitted. Ecology and WDFW recommend including these requirements for wetland reports in critical areas code or administrative rules adopted for implementing the code (Granger et al. 2005).

Regulatory Recommendations

As stated above, once Aberdeen adopts regulations to protect wetland critical areas, the prospective applicant will be required to seek approvals or permits from several layers of government. Both the USACE and Ecology have established a coordinated framework for assessing impacts to wetlands and mitigation of such impacts (Ecology et al 2006a; Ecology et al 2006b) It is recommended that Aberdeen adopt regulations that are as consistent as possible with this state and federal framework. This will ensure that a prospective applicant will develop their projects in a manner that meets the requirements of all three levels of jurisdiction, and that city approvals will be consistent with state and federal approvals, thereby minimizing conflicting requirements for the permittee.

The following requirements would therefore be incorporated into the city's regulations:

- Wetland delineation: the city would require that wetlands be delineated in accordance with the Washington State Wetlands Identification and Delineation Manual for delineating wetlands (RCW 36.70A.175, Chapter 173.22.080 WAC).
- Wetland rating: It is recommended that the baseline information regarding wetlands being impacted or created be described in terms of both the Cowardin and HGM classification systems. The Washington Department of Ecology Wetland Rating System for Western Washington, 2004 is recommended for the City of Aberdeen. This rating system incorporates elements of wetland functional assessment and is useful in development of appropriate avoidance and mitigation measures.
- Wetland exemptions: In order for the city to allow exemptions based on wetland size, the city would need to limit these exemptions to areas in certain subbasins, and to ensure that these losses are limited, or that the city establish areas where such smaller losses are actively re-captured through pre-planned mitigation projects. Given the limited number of basins available to chose from in Aberdeen, exemptions based on wetland size are not recommended for inclusion in the ordinance.

  If the city chooses to exempt small wetlands, such exemptions should be limited to wetlands 1,000 square feet or smaller when the wetlands meet the following criteria:

  - They are not associated with a riparian corridor;
  - They are not part of a wetland mosaic; and
  - They do not contain habitat identified as essential for local populations of priority species identified by Washington Department of Fish and Wildlife

- Wetland reporting: It is recommended that the city require documentation that aligns as closely as possible with the requirements of Ecology and the USACE (Ecology et al 2006b). This will simplify the permitting procedure across local state and federal requirements for the prospective applicant.

4.4.2 Wetland Buffers

Wetland Buffers Values and Functions

Buffers are relatively undisturbed, vegetated areas adjacent to wetlands that can reduce impacts through physical, chemical, and/or biological processes. Buffers generally provide habitats for wildlife species, but primary function of buffers is to protect and maintain many functions and values of wetlands described above. The scientific literature provides considerable guidance on buffer characteristics and effectiveness of providing functions (Sheldon et al. 2005).

Wetland buffers typically provide the following functions to protect and maintain wetland functions:

- Removing sediment;
- Removing excess nutrients (phosphorus and nitrogen)
- Removing toxics (bacteria, metals, pesticides);
- Influencing the microclimate;
- Maintaining adjacent habitat critical for the life needs of many species that use wetlands;
- Screening adjacent disturbances (noise, light, etc.); and
- Maintaining habitat connectivity

A review of scientific literature also indicates that buffer functions are determined by site-specific factors of a buffer. These factors include landscape position of the buffer, vegetation characteristics (composition, density, and roughness), percent slope, soil type, and buffer widths and lengths (adjacent to the source of impacts) (Sheldon et al. 2005).

Determining appropriate buffer widths for a wetland has been a subject of numerous studies and is challenging because of a wide variety of the physical settings of the research. Much of the research focuses on how buffers influence water quality, with fewer studies looking at the influence of a buffer's physical characteristics on attenuating surface water flow rates. Some reports indicated that appropriate buffer widths for a wetland depend on the environmental settings and functions to be achieved by the buffer (Castelle et al. 1992; Castelle and Johnson 2000; Desbonnet et al. 1994). The most recent literature review specific to wetland buffers in western Washington is included in *Freshwater Wetlands in Washington State Volume 1: A Synthesis of the Science* (Sheldon et al. 2005).

Ecology's recent published guideline describes the use of appropriate wetland buffer widths based on wetland functions and characteristics and adjacent land uses (Granger

et al. 2005). Larger buffers are recommended when the adjacent land use intensity is high from commercial and residential development and the quality of the buffer is low.

Buffers play the following roles in protecting and maintaining specific wetland functions:

Flood Water Attenuation and Flood Peak Desychronization

Buffers help reduce water level fluctuations in wetlands by infiltrating flood water. Wetland buffer widths between 50 and 300 feet are considered to moderate water level fluctuations within a wetland by slowing and detaining surface runoff and slowly releasing it to the wetland. This is especially effective on buffers with vegetation (Dunne 1978). Buffers also provide floodwater storage and control for the basin (Wong and McCuen 1982). However, in high-density urban watersheds, buffers have a minimal or insignificant effect on moderating water level fluctuations within wetlands due to high levels of impervious surface. In general, reducing or minimizing the amount of impervious surface would be more effective at controlling storm flows (Azous and Horner 2001; McMillan 2000; Booth 2000).

Stream Baseflow Maintenance and Ground Water Support

When wetlands provide this function, wetland buffers may add to a wetland's ability to provide stream baseflow maintenance and groundwater support by infiltrating, retaining, and slowly releasing stormwater flows to wetlands.

Water Quality Improvement

Wetlands that are located in low areas of the landscape are generally susceptible to sediment loading from upland sources (Brown and Schaefer 1987). Vegetated buffer areas help improve the water quality of wetlands by removing sediments, nutrients, pesticides, and other pollutants that may be present in surface runoff (Ecology 1996). Reducing sediment and pollutant discharge to wetlands also prevents alterations to plant and animal communities in wetlands.

The effective buffer widths for water quality functions range from 15 to 125 feet in width. Greater buffer widths are suggested on slopes for effective functions (Castelle et al. 1992; Knutson and Naef 1997). The buffer's ability to remove sediments depends on site-specific conditions and buffer type, but some studies showed that buffers of 100 feet could remove 75 to 100 percent of suspended sediment (Wong and McCuen 1982; Castelle 1994). However, the long-term effectiveness of buffers providing this function is not well documented in the literature, thus requiring further research.

Erosion/Shoreline Protection

Upland buffers can enhance the wetland's function to control erosion/shoreline by allowing infiltration and slowing sheet flow. Vegetated buffers with fine roots are most effective on preventing erosion by trapping the soil (Karr and Schlosser 1977). Wetlands and buffers that extend 200 to 600 feet from lake shorelines and stream banks may be considered to provide the most effective erosion control (Cooke Scientific Services 2000).

Biological Support and Fish and Wildlife Habitat

Wetland buffers are important for maintaining and protecting habitat for a variety of fish and wildlife species. Wildlife species that use wetlands for a portion of their life cycle depend on adjacent upland buffer areas for food, water, shelter, and/or migration (Johnson and O'Neil 2001). A variety of wildlife species utilize the edge habitat between wetlands and uplands in many different ways. For example, waterfowl primarily feed in wetlands, but they generally nest on dry ground to avoid flooding their nest. Amphibians such as the Pacific chorus frog cannot complete their life cycle without uplands. Breeding of many wetland-associated mammals occurs in uplands as well (Castelle et al. 1992).

Most studies regarding on biotic inputs of buffers for fish habitat are focused on riparian habitat along streams. However, the studies can be applied to wetlands, particularly to open water wetlands. Riparian buffers maintain fish habitat by providing shade regulating water temperature and dissolved oxygen level. Vegetation also provides food source through leaf litter and insect drop and shelter through deposition of large organic debris (Brown 1985; Groffman et al. 1991; Riparian Habitat Technical Committee 1985; Young 1989).

Upland habitats in adjacent to wetlands can also help reduce the impacts of human activities by separating wetland habitat and human disturbance. These human activities can disrupt wildlife species in the form of noise, light, and human motion/presence (Sheldon et al. 2005).

It is difficult to determine appropriate buffer widths for wetland's habitat functions due to many variables in the literature including the objectives of the research, the species studied and their varied life-history needs, and the methods of the research. Some studies reached similar conclusions of buffer widths to range from 100 to 300 feet if the buffer areas contain a diversity of native trees and shrubs, but this recommendation still depends on the type of wildlife species, life-history stage, intensity of adjacent land use, and surrounding landscape (McMillan 2000; Groffman et al. 1991; Castelle et al. 1992; Desbonnet et al. 1994; Semlitsch 1998).

Recreation, Education, Cultural Resources, and Open Space

Wetland buffers can directly increase opportunities for recreation, education, cultural resource protection, and open space by expanding the area available for these pursuits. Buffers also assist these recreational activities by supporting and maintaining other wetland functions such as fish and wildlife habitat, water quality, and shoreline protection.

Wetland Buffer Width Alternatives

Granger et al. (2005) outlines four different alternatives that local jurisdictions could choose to determine standard wetland buffer widths (Buffer Alternatives 1, 2, 3, and 3A). A summary of each alternative is described in the following. The buffer widths presented below are Ecology's recommended buffer widths, but the city of Aberdeen can revise the buffer widths based upon BAS, land-use designations, and additional protection measures outlined below. Ecology provides basic assumptions regarding the guidance

for each of the buffer alternatives described below. Recommended buffer alternatives assume that:

- The wetland has been categorized using the Washington State Wetland Rating System for Western Washington-Revised (Hruby 2004).
- The buffer is vegetated with native plant communities that are appropriate for the *ecoregion* or with a plant community that provides similar functions. Ecoregions denote areas of general similarity in ecosystems and in the type, quality, and quantity of environmental resources. The U.S. Environmental Protection Agency maintains updated maps of ecoregions that are available at http://www.epa.gov/naaujydh/pages/models/ecoregions.htm . Ecoregions currently mapped for Washington are: Coast Range, Puget Lowland, Cascades, Eastern Cascades Slopes and Foothills, North Cascades, Columbia Plateau, Blue Mountains, and Northern Rockies.
- If the vegetation in the buffer is disturbed (grazed, mowed, etc.), proponents planning changes to land use that will increase impacts to wetlands need to rehabilitate the buffer with native plant communities that are appropriate for the ecoregion, or with a plant community that provides similar functions.
- The width of the buffer is measured along the horizontal plane.
- The buffer will remain relatively undisturbed in the future within the width specified.

Buffer Alternative 1

Buffer alternative 1 defines the wetland buffer width based upon the category of the wetland. This alternative is the simplest way to regulate wetland buffers but provides the least amount of flexibility because it does not distinguish between different types of wetlands and human activities. Table 4-3 shows recommended buffers for this alternative.

For example, not all Category I wetland may require a 300-foot buffer as some of the Category I wetlands do not provide the highest level of habitat and water quality functions. Buffer widths are established to protect the wetland from proposed adjacent land uses that have the most significant impacts on the wetland. This system has the advantage of simplicity, but does not reflect the range of wetland functions and the range of potential impacts from proposed land uses.

Table 4-3. Example Buffer Widths using Buffer Alternative 1

Category of Wetland	Proposed Buffer Widths
IV	50 feet
III	150 feet
II	300 feet
I	300 feet

Buffer Alternative 2

Buffer alternative 2 derives wetland buffer widths based upon intensity of the proposed land uses. This alternative provides three levels of proposed land use intensity (high, moderate, and low) and includes the concept that not all proposed changes in land uses have the same level of impact.

Table 4-4 shows recommended buffer widths for this alternative. Types of proposed land uses are shown in Table 4-5.

Table 4-4. Example Buffer Widths using Buffer Alternative 2

Category of wetland	Buffer Widths		
	Low Impact Land Use	Moderate Impact Land Use	High Impact Land Use
IV	25 feet	40 feet	50 feet
III	75 feet	110 feet	150 feet
II	150 feet	225 feet	300 feet
I	150 feet	225 feet	300 feet

Table 4-5. Example Types of Proposed Land Uses

Level of Impact from Proposed Change in Land Use	Types of Land Uses
Low	• Forestry • Low-intensity open space (hiking, bird-watching, preservation of natural resources, etc) • Unpaved trails • Utility corridor without maintenance road and little to no vegetation management
Moderate	• Residential (1 unit/acre or less) • Moderate-intensity open space (parks with biking, jogging, etc.) • Conversion to moderate-intensity agriculture (orchards, hay fields, etc.) • Paved trails • Building logging roads • Utility corridor or right-of-way shared by several utilities and including access/maintenance road
High	• Commercial • Urban • Industrial • Institutional • Retail sales • Residential (more than 1 unit/acre) • Conversion to high-intensity agriculture (dairies, nurseries, green houses, growing and harvesting crops requiring annual tilling, raising and maintaining animals, etc.) • High-intensity recreation (golf courses, ball fields, etc.) • Hobby farms

Buffer Alternative 3

Buffer alternative 3 is the most complicated option but offers the most flexibility in concept by basing the buffer widths on three factors: the wetland category; the intensity of the proposed impacts (Table 4-5), and the functions or special characteristics of the wetland. Table 4-6 shows recommended buffer widths on the three factors. As compared to Alternatives 1 and 2, this system provides reduction in wetland buffers with lower habitat values, given the same wetland classification and land use intensity.

Table 4-6. Recommended Buffer Widths using Alternative 3

Wetland Characteristics	Buffer Width by Impact of Proposed Land Use	Other Measures Recommended for Protection
Category IV Wetlands (For wetlands scoring less than 30 points or more for all functions)		
Score for all 3 basic functions is less than 30 points	Low – 25 ft Moderate – 40 ft High – 50 ft	No recommendations at this time[1]
Category III Wetlands (For wetlands scoring 30-50 points or more for all functions)		
Moderate level of function for habitat (score for habitat 20-28 points)	Low – 75ft Moderate – 110ft High – 150 ft	No recommendations at this time[1]
Not meeting above characteristic	Low – 40 ft Moderate – 60 ft High – 80 ft	No recommendations at this time[1]
Category II Wetlands (For wetlands that score 51-69 points or more for all functions or having the "Special Characteristics" identified in the rating system)		
High level of function for habitat (score for habitat 29-36 points)	Low – 150 ft Moderate – 225 ft High – 300 ft[2]	Maintain connections to other habitat areas.
Moderate level of function for habitat (score for habitat 20-28 points)	Low – 75ft Moderate – 110ft High – 150 ft	No recommendations at this time[1]
High level of function for water quality improvement and low for habitat (score for water quality 24-32 points; habitat less than 20 points)	Low – 50 ft Moderate – 75 ft High – 100 ft	No additional surface discharges of untreated runoff
Not meeting above characteristic	Low – 50 ft Moderate – 75 ft High – 100 ft	No recommendations at this time[1]
Category I Wetlands (For wetlands that score 70 points or more for all functions or having the "Special Characteristics" identified in the rating system)		
Natural Heritage Wetlands	Low – 125 ft Moderate – 190 ft High – 250 ft	No additional surface discharges to wetland or its tributaries. No septic systems within 300 ft of wetland. Restore degraded parts of buffer.
Bogs	Low – 125 ft Moderate – 190 ft High – 250 ft	No additional surface discharges to wetland or its tributaries. Restore degraded parts of buffer.
Forested	Buffer width based on score for habitat functions or water quality functions	If forested wetland scores high for habitat, need to maintain connections to other habitat areas.
High level of function for habitat (score for habitat 29-36 points)	Low – 150 ft Moderate – 225 ft High – 300 ft	Restore degraded parts of buffer. Maintain connections to other habitat areas
Moderate level of function for habitat (score for habitat 20-28 points)	Low – 75ft Moderate – 110ft High – 150 ft	No recommendations at this time[1]
High level of function for water quality improvement (24-32 points) and low for habitat (less than 20 points)	Low – 50 ft Moderate – 75 ft High – 100 ft	No additional surface discharges of untreated runoff
Not meeting above characteristics	Low – 50 ft Moderate – 75 ft High – 100 ft	No recommendations at this time[1]

1. No information on other measures for protection was available at the time the document was written. Ecology will continue to collect new information future updates to this document.

2. Fifty of the 122 wetlands used to calibrate the rating systems for western Washington were Category II. Of these 50, only five (10%) would require 300-ft buffers to protect them from high-impact land uses. The maximum buffer width for the remaining 45 wetlands would be 150 ft.

Buffer Alternative 3A

Buffer alternative 3A bases wetland buffer widths on a graduated scale for habitat function. The graduated scale is derived from habitat scores received using the 2004 Ecology's habitat function worksheet (Publication #04-06-025). Three grouping of scores (0-19, 20-28, 29-36) are used with this system.

As a result, a one-point difference between 28 and 29 could result in a 150-foot increase in buffer width. Because a one-point increase in habitat score may be contentious, Ecology states that jurisdictions may reduce the increments in buffer widths by developing a more graduated (but inherently more complicated) scale on the scores for habitat. For example, buffer width can increase by 20 feet for every one point increase in the habitat score between 22 and 31 points (Table 4-7). This type of graduated scale allows for decrease in buffer widths for wetlands with higher scores in function, which are typically Category I and II wetlands. Table 4-7 compares Ecology's example of a graduated scale for wetland buffers with Alternative 3 buffer widths.

Wetland Buffer Width Adjustment

The recommended buffer widths are based on the assumptions stated above. Changes (i.e., increases, reductions, or enhancements) in the proposed buffer widths could be required or allowed if proper mitigation or conditions were present. For example, Increase in buffer widths may be required if the buffer is unvegetated, sparsely vegetated, or vegetated with invasive species that do not perform necessary functions. The buffer should either be planted with native plants or widened to ensure that adequate functions of the buffer are provided. Generally, improving the vegetation is considered to be more effective than widening the buffer.

If a buffer is to be rated based on the score for its ability to improve water quality instead of habitat or other criteria, then the buffer should be increased by 50 percent if the slope is greater than 30 percent. Similarly, if the buffer is used by a species that might be sensitive to human disturbance, buffer widths should be increased to provide additional protection. Consultation through WDFW may be necessary to determine the appropriate buffer widths for wildlife protection.

Table 4-7. Comparison of Buffer Alternative 3 with Buffer Alternative 3A

	Points for Habitat from Wetland Rating Form																	
Alternative	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Alternative 3	100	150	150	150	150	150	150	150	150	150	300	300	300	300	300	300	300	300
Alternative 3A	100	100	100	120	140	160	180	200	220	240	260	280	300	300	300	300	300	300

Buffer Width Averaging

Buffer averaging may be allowed if averaging improves the wetland protection functions, or if it is the only way to allow for reasonable use of a parcel. Averaging to improve wetland functions may be permitted when all of the following conditions are met:

- The wetland has significant differences in characteristics that affects its habitat functions, such as a wetland with a forested component adjacent to a degraded emergent component or a "dual-rated" wetland with a Category I area adjacent to a lower rated area
- The buffer is increased adjacent to the higher-functioning area of habitat or more sensitive portion of the wetland and decreased adjacent to the lower-functioning or less sensitive portion
- The total area of the buffer after averaging is equal to the area required without averaging
- The buffer at its narrowest point is never less than ¾ of the required with.

All of the following must be met to allow averaging for reasonable use of a parcel:

- There are no feasible alternatives to the site design that could be accomplished without buffer averaging
- The averaged buffer will not result in degradation of the wetland's functions and values as demonstrated by a report from a qualified wetland professional
- The total buffer area after averaging is equal to the area required without averaging
- The buffer at its narrowest point is never less than ¾ of the required width.

Buffer Width Reduction with Impact Mitigation

The buffer widths could be lessened by reducing impacts of a proposed project using mitigation measures. These measures are shown in Table 4-8. These measures can reduce glare, nose, surface water discharge, and other proximity impacts. Table 4-9 shows the possible buffer widths for Alternative 3 and 3A when appropriate mitigation activities are implemented. Buffer widths can be reduced by 25 percent by using the mitigation measures identified in Table 4-8.

Table 4-8. Examples of Measures to Reduce Impacts to Wetlands from Adjacent High Impact Land Use Actions

Examples of Disturbance	Activities and Uses that Cause Disturbances	Examples of Measures to Minimize Impacts
Lights	• Parking lots • Warehouses • Manufacturing • Residential	• Direct lights away from wetland • Plan a dense screen of native evergreen trees at the perimeter of the buffer
Noise	• Manufacturing • Residential	• Locate activity that generates noise away from wetlands
Toxic runoff*	• Parking lots • Roads • Manufacturing • Residential areas • Application of agricultural pesticides • Landscaping	• Route all new, untreated runoff away from wetlands while ensuring the wetland is not dewatered • Establish covenants limiting use of pesticides within 150 ft of wetland • Apply integrated pest management.
Stormwater runoff	• Parking lots • Roads • Manufacturing • Residential areas • Commercial • Landscaping	• Retrofit stormwater detention and treatment for roads and existing adjacent development • Prevent channelized flow from lawns that directly enters the buffer
Change in water regime	• Impermeable surfaces • Lawns • Tilling	• Infiltrate or treat, detain, and disperse into buffer new runoff from impervious surfaces and new lawns
Pets and human disturbance	• Residential areas	• Use privacy fencing; plant dense vegetation to delineate buffer edge and to discourage disturbance using vegetation appropriate for the eco-region; place wetland and its buffer in a separate tract
Dust	• Tilled fields • Construction sites	• Use best management practices to control dust
Lack of native vegetation in buffer	• Previous land use	• Assure minimum vegetation density or plant to 300 stems

Table 4-9. Comparison of Buffer Alternative 3 with Buffer Alternative 3A for Land Use with High Impacts if Impacts are Mitigated

Alternative	Points for Habitat from Wetland Rating Form																	
	19	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**
Large steps Alternative 3 (w/o mitigation)	100	150	150	150	150	150	150	150	150	150	300	300	300	300	300	300	300	300
Alternative 3 (w/ mitigation)	75	110	110	110	110	110	110	110	110	110	225	225	225	225	225	225	225	225
Small Steps Alternative 3A (w/o mitigation)	100	100	100	120	140	160	180	200	220	240	260	280	300	300	300	300	300	300
Alternative 3A (w/ mitigation)	75	75	75	90	105	120	135	150	165	180	195	210	225	225	225	225	225	225

Examples of Buffer Widths

As described in more detail above, buffer widths can be refined by taking into account the quality of the functions that the wetland performs in the landscape, and the land uses and land use intensity adjacent to the wetland. Nevertheless, the combination of these two factors allows for a wide array of buffer widths for a single wetland category.

During the city's ordinance adoption process, citizens will be interested in knowing what the potential impact of establishing buffers around a wetlands landscape may mean to their current and future property use. Without delineating and classifying all of the wetlands within the city, these types of questions can not be specifically and accurately answered.

Nevertheless, to assist the city's decision making process, and to inform its citizens, several examples of buffers were illustrated around a few of the city's wetlands complexes.

It is important to note that actual delineation and classification of these wetlands was not performed – the areal extent of the wetlands was estimated based on existing wetlands data available from the National Wetlands Inventory and the U.S. Fish and Wildlife Service. Land use intensity was not taken into account. Furthermore, buffers only extend up to existing man-made breaks. For example a buffer to a wetland would not extend beyond an existing road or structure that separates that buffer from the remainder of the landscape. Illustrated buffers were not reduced to take into account such existing breaks.

Figures 4-1a, b and c respectively illustrate possible buffers around category I, II and III wetland complexes, and show the extent to which existing land uses may lie within them. Because of the size of some of these wetland areas, existing uses could be impacted along the fringes of the wetlands. This would mean that depending on the buffer requirements adopted by the city, and on the site specific conditions, a number of these uses would be non-conforming. Existing uses could continue, but expansion of existing uses or new uses would require critical areas review.

Low Impact Development

Low impact development (LID) is a stormwater management approach with a basic principle that is modeled after nature. LID is used for describing development techniques and can benefit wetlands and buffers directly and indirectly by preserving wetlands and the hydrologic system that wetlands depend on. LID consists of a variety of design and construction practices to preserve the functions of natural soils and vegetation, reduce peak stormwater runoff, and improve water quality.

LID focuses on several levels of design and construction by addressing measures for site planning standards, minimizing effective impervious surfaces and stormwater runoff through building design and construction features, and improving stormwater management standards.

Insert Figure 4-1A

INSERT FIGURE 4-1B

INSERT FIGURE 4-1C

Recommendations

- Buffers for wetland critical areas: In order to protect the values and functions of wetland critical areas, BAS clearly recommends the implementation of buffers around wetlands. Prospective permittees would be required to evaluate the impact of their projects on both wetlands and wetland buffers and implement best management practices in both of these types of areas. Buffers should be consistent with those recommended by Ecology in the Wetlands in Washington State. Volume 2: Guidelines for Protecting and Managing Wetlands (Granger et al. 2005) with incorporation of mitigation impacts in site design and buffer screening.
- Buffer widths: Of the options described in section 4.4.2.2 above, Alternative 3 is recommended. Although more complex in its application, it allows more flexibility to take into account landscape conditions and uses in the direct vicinity of the project. The critical areas ordinance can allow the Planning Director to consider additional adjustments according to Alternative 3A on a case by case basis.
- Buffer width adjustment: It is recommended that the city allow changes (i.e. increases, reductions, or enhancements) in the proposed buffer widths if proper mitigation or conditions are present.
- Low impact development and stormwater management: It is recommended that the city encourage projects that implement low impact development techniques, since these techniques benefit many types of critical areas. The city may wish to consider requiring stormwater management practices that are approved by Ecology's Western Washington Storm Water Management Manual (Ecology 2005). These practices would benefit protection of many types of critical areas and would ensure protection of water quality resources. Requirements of consistent guidelines would also streamline approvals.

4.5 Wetland Mitigation

Mitigation is a sequential process to avoid, minimize, or compensate for the loss of functions and values of wetlands from the proposed impacts. When the proposed project has the potentially to adversely affect a wetland, the federal and state government agency generally require the mitigation sequencing to be used for addressing impacts to wetlands. According to the Washington State Environmental Policy Act (WAC 197-11-768), mitigation sequencing is defined as:

1. Avoiding the impact all together by not taking a certain action or parts of an action;
2. Minimizing impacts by limiting the degree of magnitude of the action and its implementation, by using appropriate technology, or by taking affirmative steps to avoid or reduce impacts;
3. Rectifying the impact by repairing, rehabilitating, or restoring the affected environment;
4. Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action;
5. Compensating for the impact by replacing, enhancing, or providing substitute resources or environments; and/or
6. Monitoring the impact and taking appropriate corrective measures.

The majority of local jurisdictions in Washington implement these guidelines through local critical area regulations. Local jurisdictions generally require compensatory mitigation as the fifth mitigation element, only after the first four have been addressed. Compensatory mitigation is required when wetlands and/or their buffers are impacted from development or associated activities. Types of compensatory mitigations include creation, rehabilitation, enhancement, and preservation (Gwin et al. 1999; Sheldon et al. 2005). The different types of compensatory mitigation take place either on-site or offsite but are typically applied within the same basin.

4.5.1 Compensatory Mitigation Success and Failure

Several studies have been conducted to determine how successful the compensatory mitigation projects are. Evaluation of various projects indicated that most compensatory wetland mitigation projects in Washington have not been successful in both regulatory compliance and functional replacement. Many projects have resulted in lost acreage, wetland types, and wetland functions (Castelle et al. 1992; Ecology 2001; Mockler et al. 1998). Studies conducted by Ecology (Bill 1990; Castelle et al. 1992) also found that 50 percent or more of the compensatory mitigation projects did not comply with permit requirements. Common problems include:

- Inadequate design;
- Lack of proper maintenance, site infestation by exotic species;
- Grazing by geese or other animals
- Destruction by floods, erosion, fires or other catastrophic events;
- Failure to maintain water levels and failure to protect projects from on-site and off-site impacts such as sediment and pollutant loading; and
- Off-road vehicles.

When compensatory mitigation fails to produced the targeted wetland area and/or function, it can take as long as 20 years to more than 100 years for a newly created or restored wetland to perform some functions (Granger et al. 2005).

Ecology also analyzed 24 freshwater wetland compensatory mitigation sites and indicated that mitigation success has improved in the last 10 years, yet there is much room for improvement (2001). The Ecology's study had the following findings:

- 29 percent of the projects were achieving all of their specified measures.
- 84 percent of the total acreage of mitigation was actually established.
- 65 percent of the total acreage of lost wetlands was replaced with new wetlands.
- 54 percent of the projects were found to be minimally successful or not successful.
- Wetland enhancement as a type of mitigation performed poorly, compared to creation (50 percent of enhancement sites provided minimal or no contribution to overall wetland functions; 75 percent of sites provided minimal or no contribution to general habitat function). Over half of the wetland creation sites provided at least moderate functions for water quality, quantity, and wildlife habitat.

- Publicly funded mitigation projects tended to fail at a higher rate than privately funded mitigation (71 percent of private projects were deemed moderately or highly successful compared with 35 percent of public projects).
- 60 percent of created wetlands were moderately or fully successful and provided significant contribution to water quality and quantity functions.

Compensatory mitigation has been more successful for some wetland types, including emergent and open water wetlands (Castelle et al. 1992). Other wetland types have been very difficult to replicate due to their complex systems or sensitivity. These wetland types include matured forest or bog systems or wetlands that contain habitat for sensitive wildlife species.

Restoration of prior wetlands is often recommended for compensation since it is often found easier to achieve. Restoration is more likely to succeed than other types of mitigation because the site will benefit from restored hydrology, and seed sources from the original wetland that may be present and viable. However, Morgan and Roberts (1999) suggested that mitigation projects in urban settings may be difficult to find restoration opportunities.

In the past, on-site mitigation was considered desirable and most likely to be successful at replacing lost wetland functions, but it is now recognized that taking a watershed or landscape approach to mitigation is more likely to result in ecological benefits and sustainable mitigation projects (NRC 2001). Greater functional benefit may be reached through a larger mitigation project that is established within the context of landscape level assessment where optimum location to meet the "needs" of the hydrologic and ecological system can be determined (Kusler 1992; Ecology 2001; Bedford 1996).

4.5.2 Location of Mitigation

Previously, mitigation activities were required to be performed on-site, but recent studies have concluded that this requirement has often forced applicants to fit a mitigation project into an area that makes little ecological sense and is not suitable (Johnson et al. 2000; Johnson et al. 2002). Mitigation standards should emphasize a site where the target functions can be performed and sustained. Location of compensatory mitigation should be a site that best matches the type of existing wetland (i.e. geomorphic setting and hydroperiod). Further, mitigation wetlands should not create exaggerated morphology or require a berm or other engineered structures to hold back water (Granger et al. 2005).

4.5.3 Performance Standards

Site-specific project goals or standards are one of the critical components of wetland mitigation plans (Granger et al. 2004; Sheldon et al. 2005). Performance standards are observable or measurable attributes used to determine how effective a compensatory mitigation meets regulatory requirements. These standards need to be measurable in the field and achievable by the methods and timeframe selected for monitoring the site. Granger et al. (2004) provides a detailed explanation of how to develop performance standards for measuring success in wetland mitigation projects.

4.5.4 Replacement Ratios for Restoration and Creation

Replacement ratio reflects the acreage of a particular type of compensatory mitigation (creation, restoration, and enhancement) needed to make up for the loss of an acre of wetland (King et al. 1993; McMillan 1998). For example, a loss of 1 acre may be permitted to compensate with 4 acres of enhancement; thus requiring a 4:1 replacement ratio. They also compensate for temporal loss of function and the potential risk of unsuccessful replacement of lost wetland acreage (Sheldon et al. 2005; Castelle et al. 1992; King et al. 1993).

Required replacement ratios vary from one jurisdiction to another based on the type of compensation proposed and project specific circumstances. The literature review indicated that the wetland functions and acreage achieved by using replacement ratios were less than what was required. In some cases, less than 1:1 replacement of acreage resulted in a net loss of wetland acreage and function on the landscape.

Ecology has recently developed new criteria for determining recommended wetland mitigation ratios based on wetland categories and characteristics with the types of mitigation proposed (i.e. creation, restoration, enhancement, or a combination of these) (Sheldon et al. 2005). Ecology's recommended ratios vary as shown in Table 4-10. Some wetlands including natural heritage sites or Category I bogs should not be considered for impacts because they are measured to be irreplaceable and cannot be replaced or compensated through mitigation.

Table 4-10. Recommended Replacement Ratios for Compensatory Mitigation

Wetland Category	Creation	Rehabilitation Only[1]	Re-establishment or Creation (R/C) and Rehabilitation (RH)[1]	Re-establishment or Creation (R/C) and Enhancement (E)[1]	Enhancement Only[1]
IV	1.5:1	3:1	1:1 R/C and 1:1 RH	1:1 R/C and 2:1 E	6:1
III	2:1	4:1	1:1 R/C and 2:1 RH	1:1 R/C and 4:1 E	8:1
II (Estuarine)	On a case-by-case basis	4:1 Rehabilitation of an estuarine wetland	On a case-by-case basis	On a case-by-case basis	On a case-by-case basis
II (Interdunal)	2:1 compensation has to be interdunal wetland	4:1 Compensation has to be interdunal wetland	1:1 R/C and 2:1 RH compensation has to be interdunal wetland	Not recommended[2]	Not recommended[2]
II	3:1	6:1	1:1 R/C and 4:1 RH	1:1 R/C and 8:1 E	12:1
I (forested)	6:1	12:1	1:1 R/C and 10:1 RH	1:1 R/C and 20:1 E	24:1
I (based on score for functions)	4:1	8:1	1:1 R/C and 6:1 RH	1:1 R/C and 12:1 E	16:1
I (Natural Heritage)	Not recommended[3]	6:1 restoration of a Natural Heritage site	R/C not recommended[3]	R/C not recommended[3]	On a case-by-case basis

Wetland Category	Creation	Rehabilitation Only[1]	Re-establishment or Creation (R/C) and Rehabilitation (RH)[1]	Re-establishment or Creation (R/C) and Enhancement (E)[1]	Enhance ment Only[1]
I (Coastal Lagoon)	Not recommende d[3]	6:1 rehabilitation of a coastal lagoon	R/C not recommended[3]	R/C not recommended[3]	On a case-by-case basis
I (Bog)	Not recommende d[3]	6:1 rehabilitation of a bog	R/C not recommended[3]	R/C not recommended[3]	On a case-by-case basis
I (Estuarine)	On a case-by-case basis	6:1 rehabilitation of an estuarine wetland	On a case-by-case basis	On a case-by-case basis	On a case-by-case basis

1. These ratios are based on the assumption that the rehabilitation or enhancement actions implemented represent the average degree of improvement possible for the site. Proposals to implement more effective rehabilitation or enhancement actions may result in a lower ratio, while less effective actions may result in a higher ratio. The distinction between rehabilitation and enhancement is not clear-cut. Instead, rehabilitation and enhancement actions span a continuum. Proposals that fall within the gray area between rehabilitation and enhancement will result in a ratio that lies between the ratios for rehabilitation and the ratios for enhancement.
2. Due to the dynamic nature of interdunal systems, enhancement is not considered an ecologically appropriate action.
3. Natural Heritage sites, coastal lagoons, and bogs are considered irreplaceable wetlands because they perform some functions that cannot be replaced through compensatory mitigation. Impacts to such wetlands would therefore result in a net loss of some functions no matter what kind of compensation is proposed.

4.5.5 Types of Compensatory Mitigation

Four general types of compensatory mitigation can be used to mitigate wetland impacts. These actions are creation, restoration (re-establishment and rehabilitation), enhancement, or preservation. A mitigation project can consist of a single type or a group of these four compensation types. Studies showed that a mitigation project with mixed compensation types is more likely successful than a project using only one of the creation or enhancement types.

Wetland restoration focuses on reestablishing functions and values of wetlands that had been partially or completely lost by proposed activities. Activities associated with wetland restoration could be removing fill materials, plugging ditches, or breaking drain tiles. It is the preferred form of mitigation because it typically has the greatest chance of successfully establishing natural wetland functions (Granger et al. 2005). Restoration is typically considered feasible and cost effective for a large area, but opportunities for on-site wetland restoration are usually limited (Sheldon et al. 2005). Restoration can be further broken down into two different approaches: re-establishment and rehabilitation. Re-establishment restores functions to a former wetland site (a site that was historically a wetland but due to human activities, no longer meets wetland criteria) whereas rehabilitation restores some functions to a degraded wetland (Granger et al. 2005).

Wetland creation generally establishes wetland conditions (area, functions, and values) in a location where a wetland previously did not exist. It offers the benefit of maintaining no-net-loss of wetland acreage, but there is less assurance of success in creating a new wetland than in restoring a degraded one (Erwin 1991). Success rates appear to be increasing as wetland construction technology improves.

Wetland enhancement usually involves altering a specific structural feature of an existing wetland to improve one or more selected functions or values based on management objectives. Enhancement typically consists of planting vegetation, controlling non-native or invasive species, and modifying site elevations of the proportion of open water to influence hydroperiods (Sheldon et al. 2005; Granger et al. 2005). A review of the scientific literature identified three main concerns regarding the use of enhancement in mitigation project:

- Enhancement fails to replace lost wetland area (Shaich and Franklin 1995).
- Enhancement may fail to replace wetland functions (Kruczynski 1990; Lewis 1990).
- Enhancement may result in a conversion of HGM and/or Cowardin classes, typically producing a compensation wetland without natural analogues (Shaich and Franklin 1995; Gwin et al. 1999; Johnson et al. 2002).

An evaluation study conducted by Johnson et al. (2002) showed that longer timeframes are necessary to replicate structurally complex habitats. This is equally true for all three compensation types described above.

Preservation provides the opportunity to protect wetland areas that might otherwise be in jeopardy. Preservation is highly controversial because of following reasons:

- Preservation results in a net loss of wetland area.
- Preserved wetlands are generally not large enough to protect ecosystems and biodiversity over the long term.
- Preserved areas may not be checked by regulatory agencies to verify that they contain the specified acreage of wetland.

For these reasons, Ecology recommends that preservation is only used to compensate for wetland losses in exceptional circumstances (Granger et al. 2005).

4.5.6 Monitoring

Monitoring requirements are another critical component of most wetland mitigation plans. Monitoring is used to determine whether a project is achieving its performance standards within a time frame. The types of monitoring data collected and the timing of the data collection depend upon the performance standards being evaluated. Most mitigation projects are monitored for at least five years on an annual basis (Ecology 2004). Monitoring reports that present the data collected and compliance with performance standards are typically provided by the project applicant and are reviewed by the regulator agency for project success and compliance.

4.5.7 Mitigation Banking

Mitigation banking provides an alternative for compensatory wetland mitigation that can be used to offset impacts to the environment. The practice of mitigation banking has commonly been applied to wetlands, but banks can be also used to generate a variety of habitat credits. Mitigation banking involves the generation of “credits” through restoring, creating, enhancing and, in exceptional circumstances, preserving wetlands and other

natural resources. These credits can then be sold to permit applicants who need to offset the adverse environmental impacts of projects.

Wetland banking can be used to achieve mitigation for projects permitted at the federal, state, and/or local levels. Recently, proposed joint USACE and U.S. EPA recognized the benefits of applying banking in a watershed approach to achieve "no net loss" of wetland functions and areas (Ecology et al. 2006a). Banks are generally established prior to the majority of wetland losses, and this practice may provide advantages over traditional compensatory mitigation by reducing the temporal loss of wetland functions (Driscoll and Granger 2001). A study conducted by the Environmental Law Institute (ELI) (2002) indicated that 78% of mitigation banks used multiple types of compensation, and a combination of enhancement and restoration was most commonly used.

Effectiveness of wetland mitigation banks have been studied by Brown and Lant (1999). They examined 68 banks that had been established by the beginning of 1996 and found that wetland mitigation banks were projected to result in a net loss of 21,328 acres of wetlands nationally, as already credited wetland acreages are converted to other uses.

The authors noted that most wetland mitigation banks were using appropriate compensation methods and ratios, but that several of the largest banks use preservation or enhancement at ratios of 1:1, instead of restoration or creation. They also cautioned that mitigation banking inevitably leads to geographic relocation of wetlands, and therefore changes the functions and ecosystem services that they provide, possibly resulting in a net loss of certain functions (Brown and Lant 1999).

Bank sites are not likely to be established in the city of Aberdeen because most remaining wetlands are in the urban area. Use of wetland banks established in Grays Harbor County that serve in the same basins may provide mitigation for wetland impacts in the city and have greater beneficial impacts on watersheds as a whole.

Aberdeen could use wetland banks to provide credit for mitigation by using the ratios incorporated in the local code or the ratios specified in the wetland banking agreement. Washington State's Draft Administrative Rules on Wetland Mitigation Banking list the following ranges of conversion ratios for determining credits available from each bank site:

- **Restoration** of wetlands shall generate credits at a ratio of 1:1 to 1:2 acre-credit to acres of restored wetland
- **Creation** of wetlands shall generate credits at a ratio of 1:1 to 1:5 acre-credit to acres of creation
- **Enhancement** of wetlands on bank sites shall generate credits at a ratio of 1:2 to 1:6 acre-credit to acres of enhanced wetland
- **Preservation** in combination with restoration and creation of wetlands on bank sites shall generate credits at a ratio of 1:2 to 1:10 acre-credit to acres of protected wetland
- **Preservation** alone shall generate credits at a ratio of 1:5 to 1:20 acre-credit to acres of preserved wetland.

4.5.8 Wetlands Mitigation Recommendations

Both the USACE and Ecology have established a coordinated framework for mitigating impacts to wetlands, and providing compensatory mitigation to off-set losses of wetlands (Ecology et al 2006a; Ecology et al 2006b). It is recommended that Aberdeen adopt regulations that are as consistent as possible with this state and federal framework. This will ensure that mitigation projects are reviewed and approved by local, state and federal agencies using on a consistent basis, and provide the least uncertainty for prospective permittees. These common requirements should include provisions for submittal and content of mitigation plans, monitoring the success of mitigation projects, and providing financial securities and titles on notice to ensure long term protection of the created resources. The city should allow for consideration of alternative mitigation practices and use of mitigation banks on a case by case basis.

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5 Geologically Hazardous Areas

This chapter describes geologically hazardous areas that can be found in Aberdeen, summarizes the scientific literature concerning various types of geologic hazards, and describes how these areas can affect or be affected by land use and other human activities. The chapter also presents the management and protection tools for these areas that can be implemented through a CAO and other city ordinances.

According to WAC 365-190-080 (4)(a), geologically hazardous areas include areas susceptible to erosion, landslides, earthquakes, volcanic eruptions, or other geological events. These areas can pose a threat to the health and safety of citizens when incompatible commercial, residential, or industrial development is sited in areas of significant hazard. Some geologic hazards can be reduced or mitigated by engineering, design, or modified construction practices so that risks to health and safety are acceptable. The following explanation of geologically hazardous areas is excerpted from the WAC (Chapter 365-190-080 (4)):

> *(a) Areas that are susceptible to one or more of the following types of hazards shall be classified as a geologically hazardous area:*
>
> > *(i) Erosion hazard;*
> >
> > *(ii) Landslide hazard;*
> >
> > *(iii) Seismic hazard; or*
> >
> > *(iv) Areas subject to other geological events such as coal mine hazards and volcanic hazards including: Mass wasting, debris flows, rockfalls, and differential settlement.*
>
> *(b) Counties and cities should classify geologically hazardous area as either:*
>
> > *(i) Known or suspected risk;*
> >
> > *(ii) No risk;*
> >
> > *(iii) Risk unknown - data are not available to determine the presence or absence of a geological hazard.*
>
> *(c) Erosion hazard areas are at least those areas identified by the United States Department of Agriculture Soil Conservation Service as having a "severe" rill and inter-rill erosion hazard.*
>
> *(d) Landslide hazard areas shall include areas potentially subject to landslides based on a combination of geologic, topographic, and hydrologic factors. They include any areas susceptible because of any combination of bedrock, soil, slope (gradient), slope aspect, structure, hydrology, or other factors. Example of these may include, but are not limited to the following:*
>
> > *(i) Areas of historic failures, such as:*

(A) Those areas delineated by the United States Department of Agriculture Soil Conservation Service as having a "severe" limitation for building site development;

(B) Those areas mapped as class u (unstable), uos (unstable old slides), and urs (unstable recent slides) in the department of ecology coastal zone atlas; or

(C) Areas designated as quaternary slumps, earthflows, mudflows, lahars, or landslides on maps published as the United States Geological Survey or department of natural resources division of geology and earth resources

(ii) Areas with all three of the following characteristics:

(A) Slopes steeper than fifteen percent; and (B) Hillsides intersecting geologic contacts with a relatively permeable sediment overlying a relatively impermeable sediment or bedrock; and

(C) Springs or ground water seepage;

(iii) Areas that have shown movement during the holocene epoch (from ten thousand years ago to the present) or which are underlain or covered by mass wastage debris of that epoch;

(iv) Slopes that are parallel or subparallel to planes of weakness (such as bedding planes, joint systems, and fault planes) in subsurface materials;

(v) Slopes having gradients steeper than eighty percent subject to rockfall during seismic shaking;

(vi) Areas potentially unstable as a result of rapid stream incision, stream bank erosion, and undercutting by wave action;

(vii) Areas that show evidence of, or are at risk from snow avalanches;

(viii) Areas located in a canyon or on an active alluvial fan, presently or potentially subject to inundation by debris flows or catastrophic flooding;

(ix) Any area with a slope of forty percent or steeper and with a vertical relief of ten or more feet except areas composed of consolidated rock. A slope is delineated by establishing its toe and top and measured by averaging the inclination over at least ten feet of vertical relief.

(e) Seismic hazard areas shall include areas subject to severe risk of damage as a result of earthquake induced ground shaking, slope failure, settlement, soil liquefaction, or surface faulting. One indicator of potential for future earthquake damage is a record of earthquake damage in the past. Ground shaking is the primary cause of earthquake damage in Washington. The strength of ground shaking is primarily affected by:

(i) The magnitude of an earthquake;

(ii) The distance from the source of an earthquake;

(iii) The type of thickness of geologic materials at the surface; and

(iv) The type of subsurface geologic structure.

Settlement and soil liquefaction conditions occur in areas underlain by cohesionless soils of low density, typically in association with a shallow ground water table.

(f) Other geological events:

(i) Volcanic hazard areas shall include areas subject to pyroclastic flows, lava flows, debris avalanche, inundation by debris flows, mudflows, or related flooding resulting from volcanic activity.

(ii) Mine hazard areas are those areas underlain by, adjacent to, or affected by mine workings such as adits, gangways, tunnels, drifts, or air shafts. Factors which should be considered include: Proximity to development, depth from ground surface to the mine working, and geologic material.

5.1 Overview of Aberdeen's Geological Setting

Geologic hazards exist when a geologic process can affect public health and safety or the safety of structures. Geological processes can take years to develop, the slow weathering of rocks and slopes for example, or can occur very rapidly, such as earthquakes, leaving little time for residents to prepare and react.

Aberdeen's underlying geology can be described in terms of two main geological areas: tertiary bedrock that forms the higher elevations in the northeast and northwest portions of the city, and the alluvial deposits that form the lower elevations along the north and south shore of the Grays Harbor Estuary, and the mouths of the Wishkah and Chehalis Rivers.

Soils in the higher elevations in the north of the city consist of sediments that were deposited from 5 to 20 million years ago in the Miocene and Pliocene ages. The resulting Astoria and Montesano formations were then uplifted and folded as a result of movement of tectonic plates located in the Pacific Ocean. The "Bluff" located north of Highway 12 entering the city to the east is a good example of these tertiary formations (Phipps 1996). Over time, the surface of these formations has weathered to very weak sandstone (Badger 1994). Slopes range from 8 to more than 60 percent.

Soils in the flood plain are primarily alluvial silts and fine sands, with some organic material. The dominant native soil types of the flood plain area are approximately 5 to 6 feet deep and are moderately well to excessively drained. The slope in the flood plain is 0 to 2 percent.

The other type of soil found primarily in the flood plain of South Aberdeen is a silty clay loam found on flood plains and deltas protected from tidal overflow. This soil type forms

in clayey alluvium deposited in quiet water of coastal bays, and also has a slope of 0 to 2 percent.

Close to the fairly abrupt boundary between the flood plain and the adjacent uplands are zones of coarse sand and gravel. It appears that these zones are probably interbedded with finer grained materials. (USDA., Soil Conservation Service 1984).

In modern history, and to create additional constructible area for the city, portions of the estuary were also filled with soils excavated from the upland slopes and dredged alluvial deposits within and around the Aberdeen area. As a result of the different placement methods and the different soil sources, the fill consists of variable soil types, which can have very different engineering properties from one location to the next and can react in unexpected ways in response to abrupt geological events (Shannon and Wilson 2002).

Geologic hazards in Aberdeen include landslides, erosion, seismic, and tsunami and seiche events related to earthquakes. The areas associated with these hazards have been mapped in the following documents: City of Aberdeen Critical Area Map 5: Geologic Hazard Areas: Landslide, Liquefaction and Seismic; and City of Aberdeen Critical Area Map 6: Geologic Hazard Areas: Erosion and Steep Slopes. The hazard areas outlined on these maps are based on data collected from publicly available sources including:

1. USGS 10-meter Digital Elevation Model (slope);
2. USDA Soil Survey of Grays Harbor County Area, Washington;
3. Washington State Department of Natural Resources Liquefaction Susceptibility Map of Grays Harbor County, Washington;
4. Washington State Department of Natural Resources Tsunami Hazard Map of the Southern Washington Coast;
5. Washington State Department of Natural Resources Site Class Map of Grays Harbor County, Washington; and
6. Grays Harbor County Landslide Hazards Map.

As described in detail below, volcanic eruptions can also impact Aberdeen at a distance through ash falls or tephra plumes. However, geologically hazardous areas can not be associated with such long distance impacts. These hazards will therefore only be described briefly below.

5.2 Landslide Hazards

5.2.1 Description of Landslide Hazards

Landslides are the release of rock, soil or other debris and its subsequent movement down a slope or hillside (USGS 2004). Landslides can be caused by the inherent structure of the geological formation and its weaknesses (weak or sensitive materials, weathering, shearing or fissuring, discontinuities, and differences in permeability or stiffness for example), and by natural impacts that change the geological formation (uplift due to tectonic or volcanic events, glacial rebound, erosion due to fluvial, wave or subterranean action, freeze and thaw weathering or vegetation removal through fire or drought). Landslides can also be caused by human activity such as excavation of

slopes, loading by structures, removal of vegetation or deforestation, irrigation, drawdown of natural water reservoirs, or mining.

Landslides vary greatly in size and composition: from a thin mass of soil a few yards wide to deep-seated bedrock slides miles across. The travel rate of a landslide can range from a few inches per month to many feet per second depending on the slope, type of material and moisture content. The materials may move by falling, toppling, sliding, spreading, or flowing. Figure 5-1 illustrates various types of landslides and how they can be typically classified. Other classification systems incorporate additional variables, such as the rate of movement and the water, air, or ice content of the landslide material.

Figure 5-1. Types of Landslides. Abbreviated Version of Varnes' Classification of Slope Movements (Varnes 1978)

<table>
<tr><td colspan="2" rowspan="3">TYPE OF MOVEMENT</td><td colspan="3">TYPE OF MATERIAL</td></tr>
<tr><td rowspan="2">BEDROCK</td><td colspan="2">ENGINEERING SOILS</td></tr>
<tr><td>Predominately course</td><td>Predominately fine</td></tr>
<tr><td colspan="2">FALLS</td><td>Rock fall</td><td>Debris fall</td><td>Earth fall</td></tr>
<tr><td colspan="2">TOPPLES</td><td>Rock topple</td><td>Debris topple</td><td>Earth topple</td></tr>
<tr><td rowspan="2">SLIDES</td><td>ROTATIONAL</td><td rowspan="2">Rock slide</td><td rowspan="2">Debris slide</td><td rowspan="2">Earth slide</td></tr>
<tr><td>TRANSLATIONAL</td></tr>
<tr><td colspan="2">LATERAL SPREADS</td><td>Rock spread</td><td>Debris spread</td><td>Earth spread</td></tr>
<tr><td colspan="2" rowspan="2">FLOWS</td><td rowspan="2">Rock flow
(deep creep)</td><td>Debris flow</td><td>Earth flow</td></tr>
<tr><td colspan="2">(soil creep)</td></tr>
<tr><td colspan="5">COMPLEX – combination of two or more principal types of movement</td></tr>
</table>

Landslide hazard areas are those portions of the landscape that have existing landslides or are at risk of future failure. The most common types of landslides are described below and are illustrated in Figure 5-2 (USGS 2004).

Even though the mechanics of landsliding processes are well understood, the site-specific elements of each event can be very variable. Evaluation of specific landslide areas is subject to some level of uncertainty because there may be limited information about the subsurface geological conditions, and subtle changes in soil properties, structures, and ground water elevations can have significant impact on slope stability.

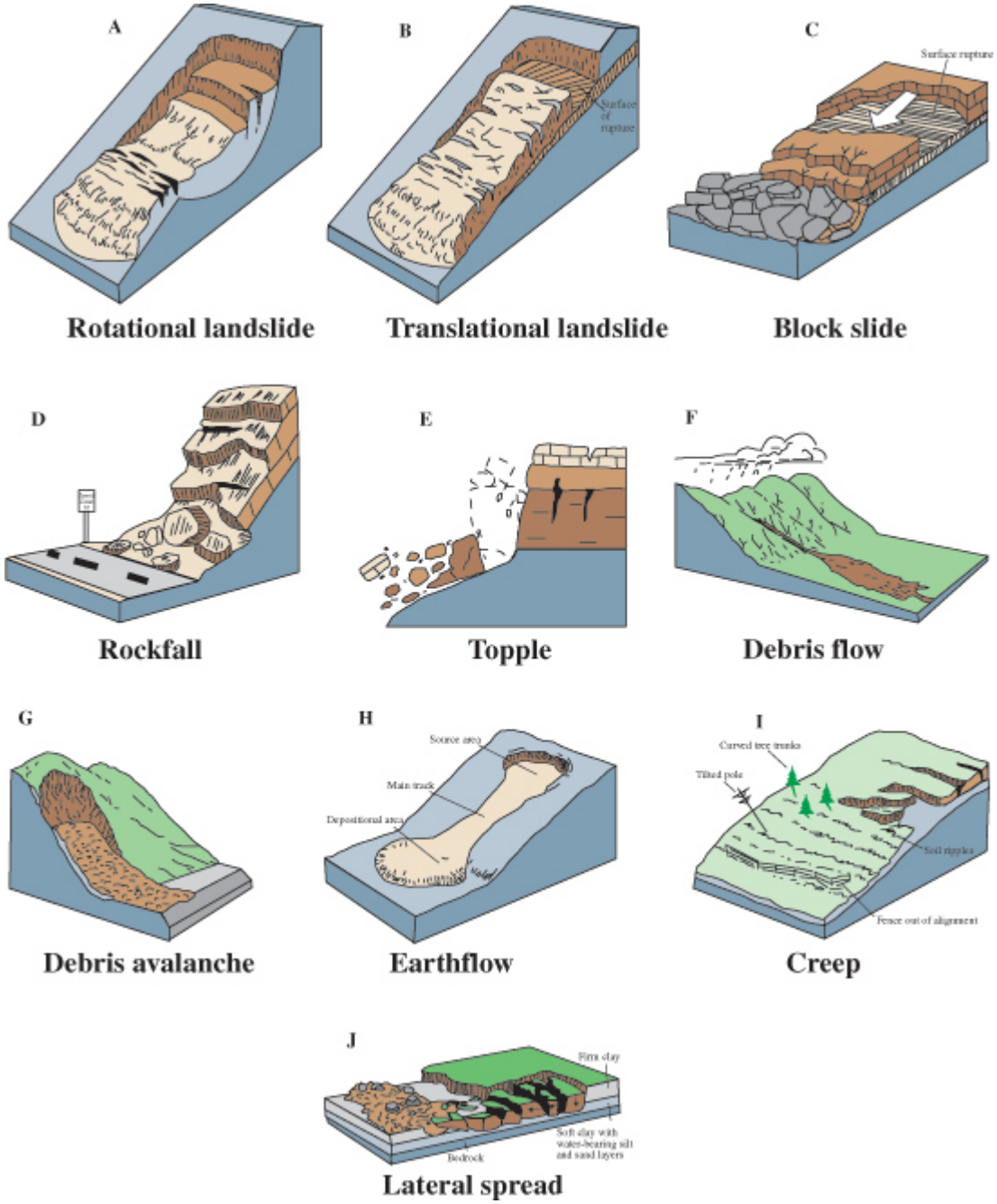
Translational Slides

Translational slides occur along relatively shallow, fairly planar failure surfaces. Because they occur rapidly they are also called shallow rapid translational slides. Shallow rapid translational slides are especially common in the Pacific Northwest because of steep topography, surface materials, and moisture conditions. They are easily caused by ground disturbance, concentrated runoff, logging, and roads.

Run-out of translational slides often extends far downslope until a low-gradient bench or valley bottom is encountered. Depending on site and moisture conditions, translational slides can form into debris flows (see below). Planning studies need to consider the

risks associated with both the slide sources and their potential run-out paths (USGS 2004).

Figure 5-2. Common types of Landslides (USGS 2004)



Deep-Seated Rotational Slides

Another type of landslide is the rotational slide or slump. Such slides are often deep-seated and have a bowl-shaped or broad curving failure surface with a steep headwall scarp and additional scarps in the slide mass. Rotational slumps can be small, covering only a few yards (as is common along road cuts), or they can be very large, covering many square miles. Slumps and deep-seated rotational slides are more common in glacial tills and glacial lake deposits. Source areas are associated with over-steepened valley walls with thick glacial deposits, geologic contacts, and ground water conditions. They often occur over many months or years. Thus, human actions that alter surface conditions have relatively minor effects compared to the forces involved with the rotational-slide formation or activity.

Larger deep-seated rotational slides are characterized by a constantly shifting surface layer that poses hazards to buildings, roads, and other facilities. Remedial actions to slow the slide can be costly, and often the slide is so big that little can be done to mitigate its motion. Even small slumps can be difficult and costly to deal with. In some cases, deep-seated rotational slides can be initiated or reactivated by earthquakes or changes to water conditions related to logging road construction or other activity. Large deep-seated slides can block creeks and rivers, changing channel directions and short-term sediment supply. Smaller slumps in steeply cut slopes above buildings can be a hazard to people if buildings are damaged, generally, however, motion is slow and damage to facilities is the primary hazard (USGS 2004)

Rockfalls

With rockfalls, the slide material travels mostly through the air and movement is very rapid. Movement includes freefall, tumbling, and rolling of fragments of rock or highly compact glacial soils (Norman et al. 1996; Chatwin et al. 1991). Rockfalls typically originate from steep cliffs or mine faces, and form a debris wedge or fan in the accumulation zone. Material strength, surface gradient, joint pattern and spacing, geologic contacts, ground water, and faulting are some of the primary factors related to rockfall occurrence. Run-out from the source area can extend quite far on steep slopes. Typically, however, debris forms a wedge or debris fan at the toe of the source area, and is identified by landform shape, slope position, and a mix of angular, often well-drained fragments of various size. Over time the accumulation zone can become overly steep and prone to secondary ravel, and translational slides can occur (USGS 2004).

Debris Flows

Debris flows are common in upland creeks, swales, and slopes. They can be triggered by valley wall translational slides, slumps, road fill failures, diversion of surface water, logging, and other ground disturbance on the valley walls or channels of steep hill areas. Debris flows occur rapidly and travel down the creek to low gradient reaches or the valley bottom where the debris comes to rest in debris deposits or alluvial fans. Active flows accumulate additional material by scouring the hillslope colluvium or valley bottom alluvium down to bedrock or dense glacial deposits, and by carrying along the trees in the debris path. Debris flows can be small, originating from a small drainage and moving a short distance down slope. More often, debris flows are 100 to 200 feet wide and travel one half to several miles down slopes or creek drainages. Very large debris flows may be caused by a glacial outburst flood or collapse of a volcanic cone, as occurred at

Mt. St. Helens in 1980. Debris flows can stall partway down a confined channel or at channel junctions, forming a temporary dam that breaks and results in an even larger debris flow downstream. Slides along confined valleys can block the channel, forming a dam that can also start a debris flow (USGS 2004)

Soil Creep and Raveling

Other types of mass movement that could occur are soil creep and raveling. These are ongoing gradual movements of slope materials. Over many years, soil creep and raveling result in the accumulation of thicker soils at the lower portions of slopes. Motion is too slow to present a safety hazard but development that requires cutting into steep slopes need to plan for maintenance related to raveling and soil creep (USGS 2004).

Landslides in Aberdeen

Aberdeen is located in the Southwest Washington Landslide Province, where earth flow or slump/earth flow and debris flow landslides are commonly seen. In Aberdeen, landslides are generally caused or controlled by a combination of geology, topography, weather and hydrology and can be influenced by development practices (Aberdeen 2003, Thorsen 1989). Landslides can occur when steeper slopes are destabilized or under cut, when heavy rains undercut stream banks, or when earthquakes occur.

Mopang and Zenker silt loam soil types make up approximately 20 percent of the steep slopes of Aberdeen. Soil data specific to these soil types indicates that slopes greater than about 30 percent are significantly less stable and exhibit a high water run-off hazard; these slopes can therefore be prone to slippage (USDA 1986).

The incidence of landslides has been limited in recent history. Over the last 20 years, landslides have occurred in the vicinity of Hospital Hill, Canyon Court, along Wishkah Road at the northern city boundary, behind the city's water reservoir, and along the bluff located north of U.S. Highway 12 (Bledsoe 2007, Voss 2007). Rockfalls have also been experienced on the bluff located north of U.S. 12 (Aberdeen 2003).

Given the large distance of active volcanoes to Aberdeen, landslides due to volcanic activity would not likely occur in the city.

5.2.2 Impact of Human Activity on Landslide Hazards

Both natural processes and human activities can cause landslides. Many factors influence the occurrence and severity of landslides, including slope gradient, slope shape, surface and subsurface materials, precipitation, surface and subsurface water conditions, drainage area, elevation, slope aspect, vegetation history and condition, roads and other ground disturbance, earthquakes, and volcanic eruptions (Selby 1993; Montgomery et al. 1998). Extensive research and literature exists related to landslides, based on local, regional, and worldwide investigations (Benda and Cundy 1990; Benda and Dunne 1997; Chatwin et al. 1991; Coho and Burges 1994; Coppin and Richards 1990; Dietrich and Dunne 1978; Eisbacher and Clague 1984; Fiksdal and Brunengo 1981; Gray and Sotir 1996; Greenway 1987; Montgomery and Dietrich 1994; Montgomery et al. 1998; Selby 1993; Thorsen 1989; Tubbs 1974a, b; Varnes 1978, 1984; Wieczorek 1984; and numerous others). Landslides and slope stability are analyzed using the infinite slope, circular arc, or other similar approaches (Selby 1993;

Montgomery et al. 1998; Gray and Sotir 1996; and others). The study of the reduction of landslide hazards has been ongoing, with numerous regional and local studies appearing since the 1970s (Artim 1973a, b; Booth 1989; Miller 1973; Thorsen 1989; Tubbs 1974a, b and many others).

A variety of human actions can create conditions that promote landslides and erosion: alteration of slopes by development or roads intercepts surface and shallow ground water; removing vegetation increases surface runoff and shallow ground water; and diversion and concentration of increased water runoff down steep slopes reduces stability of the surface soils (Montgomery et al. 2000; Bunn and Montgomery 2004; Church 2002; Gomi et al. 2002; Dunne and Leopold 1978; and others).

Hillslope development can contribute to debris flows by intercepting surface or shallow ground water and diverting it down swales or into the heads of small mountain creeks. The addition of water to these areas reduces soil strength by increasing saturation. In addition, hillslope development is often associated with removal of trees, which further reduces the soil strength through loss of root reinforcement.

Vegetation cover plays an important role in controlling landslide formation. Vegetation reduces shallow ground water infiltration by interception and evaporation; in addition, the complex web of roots reinforces the soil. Many surface soils on slopes over 22 degrees do not have enough strength between the individual soil grains to remain cohesive and it is the additional strength provided by deep roots that holds the slope together. Clearing and grading reduce or remove the protective layer of vegetation that protects the slope from precipitation (Konrad 2000, 2003; Konrad and Burgess 2001; Booth 1990; Burgess et al. 1998). Removing vegetation, especially deep-rooted mature plants, reduces or removes the strength that roots provide to the soils on river banks and steep slopes (Gray and Meghan 1981; Bennett and Simon 2004; Gray and Barker 2004; Schiechtl 1980; Schiechtl and Stern 1996).

Creation of new impervious surfaces can also reduce the natural infiltration of water into the ground, and increase runoff from a particular area. Increased storm flow runoff is then concentrated by surface and subsurface drains, ditches, and roads, and directed down swales and into creeks. The combined cumulative impact of all of these management actions causes surface erosion and landslides in high risk areas where adequate control measures are not provided and maintained.

Shoreline erosion is affected in a similar way by excavation and grading that removes some or all of the natural shoreline slope structure and strength. Clearing and grading along the shore and inland increases runoff that is directed across the shore zone; causing erosion and promoting landslides. Lake and coastal shorelines, river channels, and stream banks are naturally changing on at least an annual time scale, due to floods, storm waves, and tides; these natural processes of change combine with development modifications, causing even more rapid erosion and slides. Building structures, yards, roads and other development near these active areas creates the need to artificially stabilize the shore, which often can adversely impact nearby neighbors, wetlands, and aquatic habitat conditions.

In some cases natural erosion processes must be protected because they contribute an important function to the natural ecosystem. For example, large pieces of wood (also called large woody debris or LWD) can be transported by landslides into streams, rivers

or wetlands, where over time the LWD forms and participates in the formation of habitat for aquatic species. LWD also provides nutrients to the aquatic area, provides shelter from predators to fish and amphibians, provides some shade, and serves to stabilize stream channels and beach environments. LWD is naturally deposited when unstable forested slopes fail (King County 2004). Protection and regulation of landslide hazard areas promotes natural deposition of LWD by landsliding processes.

5.2.3 Protection and Regulation of Landslide Hazard Areas.

Protection from landslide hazards has generally focused on two main practices: establishing buffers around identified landslide areas, and requiring site specific analyses for the design and construction of structures in or near landslide areas.

Literature indicates that buffers should be established around the perimeter of mapped landslide hazard areas (Gerstel et al. 1997). More specifically, buffers should be established from the tops and toes of 30 percent slopes.

Landslide hazard areas can be identified using the example criteria outlined in the WAC (see the Introduction to this chapter). Inland landslide hazard areas can be estimated by identifying areas between 15 and 35 percent slope that have permeable sediments over impermeable sediments/bedrock. Other potential hazard areas include ground water seepage or springs; slopes greater than 35 percent; and unstable slopes caused by stream incision, bank erosion, or wave action. These areas tend to be concentrated in scattered drainage ravines throughout the city.

Because of the extreme variability that is exhibited by areas that are subject to landsliding, site-specific studies may be required in order to design, construct, and safely occupy a structure within such an area. The hazard area and proposed development should be evaluated by a geotechnical engineer or engineering geologist, including subsurface exploration in the area, soil sampling and testing, and development of a detailed construction sequencing and monitoring plan. Development in landslide and steep slope hazard areas should be supported by a critical area report that indicates that the development as proposed will not further destabilize the slope and that the slope will remain stable during and after construction. A qualified engineering geologist or geotechnical engineer who is licensed to practice in the State of Washington would prepare this type of study. Development that is proposed within those buffers or within the slide area itself should also meet scientifically based rigorous design and construction standards.

In addition to avoidance and specific analysis described above, landslide areas should also receive the same types of protections to reduce water borne soil erosion, as described in the following section.

Under SEPA, the city has the authority to require mitigation of impacts to geologically hazardous critical areas. The city has exercised this authority to require geotechnical analyses for developments in steep slope areas (Aberdeen 2007).

5.3 Erosion Hazards

5.3.1 Description of Erosion Hazards

Excessive erosion can be very damaging to water quality in adjacent and downstream water bodies—waters that often support salmonid fish and other species. Silt and sand-sized particles are particularly damaging to the stream environment if excessive deposition occurs. The silt and sand can bury and asphyxiate fish eggs that are deposited in gravel, can fill the spaces between gravel that support aquatic insects, and can even kill fish by damaging or clogging their gill structure. Larger-scale erosion also leads to deposition of materials downstream that can create numerous negative impacts, including channel in-fill and avulsion, channel blockage and blockage to fish passage, burying of habitat(s), and loss of local flood storage. In extreme cases erosion can also lead to landslides.

Many issues cause and influence the severity and impacts of erosion, including rainfall intensity, vegetation cover, landform shape, slope gradient and length, soil type and drainage conditions, land-use, and proximity to water bodies where erosion impacts are most felt (Houghton and Charman 1986).

In general, rainfall or accidental surface-water discharges begin the erosion cycle. Individual raindrops impacting a disturbed or denuded surface cause soil particles of sand and silt size to break away from the surface and move downslope. As water accumulates on the surface, it tends to concentrate in small channels that develop as the soil particles are moved or "mobilized." The water in these small channels gains volume and energy and is able to mobilize ever larger particles. In this way, erosion features develop on a surface—they start as very small channels, or rills, and tend to grow in size to large gullies and canyons over time. Climatic stresses such as very intense storm events that drop a large volume of water over a short period of time can contribute considerably to erosion hazards. Material that is caught up in the erosion process described above is carried downslope until the gradient flattens out and the energy of the water is reduced. When the energy drops below a certain threshold, the particles, or bedload, drop out of the water. This deposition of bedload generally occurs either on land in flood plains or within waterbodies like lakes. Very fine particles of certain clay minerals, once mobilized, can take days or even years to drop out of suspension in the water.

Undisturbed areas of the Pacific Northwest typically have dense vegetation, decomposed organic material, and loose surface soils. Vegetation, the organic duff layer, small depressions, and soil density all minimize runoff and erosion. Runoff and erosion can occur when vegetation or surface soil layers are removed, and may continue until vegetative cover is re-established.

Each specific land use has its own erosion hazard. Erosion hazard on land under cultivation and permanent pasture is long-term while erosion hazard in urban areas is often confined to the construction phase (from the time of initial disturbance until a good ground cover and appropriate stormwater drainage controls are established). Erosion can also be induced as a result of broad geologic processes such as volcanic activity or channel migration. Another important factor affecting erosion potential is the degree of development in a basin or subbasin area. Impermeable surfaces have two effects on stormwater runoff. First, the volume of runoff tends to increase significantly. Second, the

peak rate of runoff also increases. Both effects result in a significant increase in the erosion potential (NSW-CMM 1990).

The proximity of ground-disturbing activities to surface waters, in any soil type, is closely associated with the type or level of risk associated with erosion hazard areas. If erosion sources are located close to water bodies, there is less opportunity for natural soil and vegetative conditions to absorb flowing water and stop the movement of eroded soil particles (Terzaghi & Peck 1948).

Soils that are impermeable or minimally permeable generate surface water runoff and begin to erode sooner than very porous soils. Because they often overlap, erosion and landslide hazard areas are sometimes grouped together for regulatory purposes. Steep slopes and impermeable soils combined can increase erosion hazards.

Erosion-prone soils in Aberdeen are associated with steep slopes (such as the Zenker Silt loam) or loose silty soils fond in the low lying areas of the Grays Harbor Estuary and Wishkah and Chehalis rivers(such as the Elochoman silt loam).

5.3.2 Impact of Human Activity on Erosion Hazards

As noted above, many types of human activities can interrupt the natural processes that protect soils from erosion. Clearing of vegetation and disturbance of the natural duff layer can make soil particles available for erosion by wind and water. Urban developments such as parking lots, roads, single family residences, and other buildings result in the replacement of permeable natural surfaces like forest floors with impermeable surfaces. Industrial development can also modify the natural ground cover. Both of these types of development can increase impermeable surfaces as a whole, leading to more significant run-off and greater erosion potential. Construction in areas with steep slopes increases the risk of water run-off which can in turn cause erosion.

5.3.3 Protection and Regulation of Erosion Hazard Areas

It should be understood that some erosion is natural and is in fact very important to the overall function and health of a stream system. Natural erosion and landsliding processes provide the sand, gravel, cobbles, and boulders that streams need to remain productive with respect to fish and other aquatic organisms. The difficulty is in determining what is the natural background level of sediment input and what exceeds it.

Regulation of erosion hazard areas generally focuses on the following practices:

1) Avoiding disturbance in areas where erosion prone soils exist, and limiting their exposure;
2) Protecting natural soil stabilization process that prevent erosion
3) Requiring scientifically based design standards for man made slope modifications where natural slopes are impacted;
4) Requiring surface water controls during construction and for the life of the project.

Avoiding disturbance in areas with high erosivity focuses on identifying if development is proposed in such areas, and requiring that development in such areas be reduced to the extent possible to minimize impacts to erodible soils.

Protection of natural soil stabilization processes focuses on retention of natural vegetation and vegetative layers. Several approaches are possible – prohibiting the clearing of vegetation in erosion prone areas, or allowing clearing based on the slope of the site. For example, the city of Shelton allows a graduated scale of disturbance allowed on a site, based on the steepness of the site (Shelton 2007):

- 0 to 15 percent slope: 100 percent
- 15 to 25 percent slope: 60 percent
- 25 to 40 percent slope: 45 percent
- Greater than 40 percent slope: 0 percent.

Where disturbance cannot be avoided, regulations can limit changes in natural slopes, and can define the design standards for man-made slopes, in order to limit future slope instability. Soil erosion prevention and surface water drainage protection are commonly administered through drainage and grading plans that are a part of project design, construction, and maintenance. Clearing or land-disturbing activities greater than one acre are required to obtain coverage under Ecology's construction stormwater general NPDES permit (Ecology 2005).

Finally, the control of stormwater is of high importance. Protections range from requiring the use of standard stormwater manuals in the design of surface water abatement and control (Ecology's Stormwater Manual for Western Washington for example), requiring the preparation of a Temporary Erosion and Sediment Control (TESC) Plan, to including specific best management practices to be consider by the developer in regulation. BMPs that are commonly employed include covering bare ground with straw and/or plastic sheeting, using silt fences, and by planting denuded areas as soon as possible after development. Aberdeen already implements a number of these provisions through its SEPA Authority (Aberdeen 2007).

5.4 Seismic Hazards

5.4.1 Description of Seismic Hazards

Grays Harbor County is located near a tectonic plate boundary where the oceanic Juan de Fuca plate dives beneath the continental North American plate. This plate boundary is called the Cascadia Subduction Zone, and lies about 50 miles offshore, extending from near Vancouver Island to northern California. These plates are converging at a rate of 1 to 2 inches per year (EMD 2001; DNR 2003; USGS 2003).

As the Juan de Fuca plate slides beneath the North American plate, cracks or faults develop at their boundary and at the surface in response to bending. The friction caused by this sliding movement tends to stick the two plates or sides of the faults together. Over time tremendous pressure builds up and friction is overcome. When this happens, one plate or one side of the fault moves relative to the other plate resulting in the sudden release of energy that is felt as an earthquake. Because the amount of energy released can vary, earthquakes can be small to extremely large events that can seriously impact both distant and local structures. (Riddihough 1984; Heaton and Hartzell 1986). Three kinds of earthquakes are recognized in the Pacific Northwest:

Shallow earthquakes occur along faults close to the surface of the North American plate. They have a maximum depth of about 19 miles though most occur much nearer to the surface. The majority of earthquakes in the Pacific Northwest are of the shallow type. They could potentially produce magnitudes as high as 7.5, though most are less than 3.0.

Deep earthquakes occur along faults in the Juan de Fuca plate as it sinks beneath the North American plate. Their depths generally range from 16 to 62 miles. Magnitudes of 7.5 have been recorded.

Subduction zone earthquakes occur when there is motion between the two plates rather than at localized faults. The movement can occur over hundreds of miles and last for several minutes. Subduction zone earthquakes are considered to be the most destructive with potential magnitudes of 9.0 or greater. Critical facilities within the city can be vulnerable to earthquake due to their age.

Most earthquake damage is caused by ground shaking. The magnitude of an earthquake, distance to the earthquake center (or focus), type of faulting and type of subsurface material are important factors in determining the amount of ground movement that might be produced at a particular site. The magnitude of earthquakes influences both the size of the ground motions, as well as their duration. Large earthquakes also produce earth motion over larger areas.

The horizontal and vertical distance of a site from the earthquake determines the impact of the earthquake on that location. In general the amplitude of ground motion decreases with increasing distance from the focus of an earthquake. The influence of distance is felt both from the consideration of linear distance on the surface as the earth, and from the depth of the earthquake. Frequency of the shaking also changes with distance. Frequency of motion is an important factor in determining the severity of structural damage.

Finally, the thickness and type of surface and subsurface geologic materials experiencing the earthquake event also influence the impacts of an earthquake. (Rasmussen et al. 1974; Newmark and Hall 1982) (see King County BAS for references). Natural and artificial unconsolidated anteruils, such as sediments in river deltas and materials used as landfill commonly amplify ground motions relative to motion in consolidated sediments or bedrock.

In addition to earth shaking, there are other direct and secondary consequences that may occur. The earth surface may fracture, causing localized faults. Surface faults in Washington have been mapped (for example, McLucas 1980), and most of these faults have been found to be inactive. The best-documented active surface faults in the state are located near Lake Cushman. Earthquakes can also cause sudden elevation changes. Major subsidence or uplift of large regions often occurs as a result of great subduction-style thrust earthquakes. Submerged marshlands in several estuaries along Washington's coast suggest that episodes of sudden subsidence have occurred in the Pacific Northwest (Atwater 1987).

Secondary causes of earthquake damage include ground failures due to landslides, differential compaction of soil, and liquefaction of water-saturated deposits like landfills, sandy soils, and flood plain deposits. Earthquakes can also cause destructive water

waves such as tsunamis (see Section 5.5 below). Earthquakes can also cause liquefaction, a phenomenon in which the strength and stiffness of a soil is reduced by shaking or other rapid loading. During such shaking, water between the soil grains exerts a pressure on the soil particles and influences how tightly the particles are pressed together. During an earthquake, shaking can cause the water pressure to increase to the point where particles can move as a liquid or plastic flow, causing settling. This settlement can in turn cause the loss of bearing strength of soils under buildings, causing slumping and sinking of foundations. Differential compaction can also occur when foundation materials have different physical properties. Mixed materials in the subsurface will settle by different amounts when shaken.

Seismic hazard areas in Aberdeen are those areas that are subject to severe risk of damage as a result of ground shaking and motion, surface faulting, subsidence and uplift, seismically induced landsliding and settlement, soil liquefaction, and tsunami. Severe risk of damage is loosely defined as the potential for damage that is structural rather than cosmetic in nature. Earthquakes and the mechanism that cause them have been studied around the world. Nevertheless, these studies have still not been able to predict the location and strength of earthquake events.

No active earthquake faults are located in the city of Aberdeen, and the city is most at risk of earthquakes caused by geologic processes happening through out the Pacific Northwest region as a whole (USGS 2007).

The potential for strong shaking in a specific area can be evaluated based on the “site class” system established by the National Earthquake Reduction program (DNR 2004a). According to the most recent site class maps developed by the Washington State Department of Natural Resources, Aberdeen is located in two different site class areas. The higher elevations in the north of the city are located in Site Class B, a soft rock condition that neither amplifies or reduces ground shaking. The low lying areas along the shores of the grays harbor Estuary and in the Chehalis and Wishkah River valleys are classified as Site Class “D to E”. These areas represent increasingly softer soil conditions that can amplify ground shaking (DNR 2004a).

A number of these low lying areas also consist of artificial fill that was placed to increase ground surface levels for construction. The majority of these materials were hydraulically placed, and therefore have relatively high moisture contents, low strengths, high compressibilities, and high potential for liquefaction during an earthquake. Such materials are prevalent under the parts of downtown and waterfront areas of Aberdeen (Shannon and Wilson 2002). Washington state ahs classified these areas as having moderate to high liquefaction susceptibility (DNR 2004b).

5.4.2 Impact of Human Activity on Seismic Hazards

Humans have little influence over when and where seismic events occur, However, they can chose whether certain structures should be built in areas prone to seismic events, or how development and structures survive seismic events, as further described below.

5.4.3 Protection and Regulation of Seismic Hazard Areas.

Although the study of earthquakes and seismicity is a mature science, we can still not predict the exact location and magnitude of seismic events. The impact of seismic events is generally regulated through the following mechanisms:

1. Avoiding construction in areas that are known to be actively seismic;
2. Incorporating site specific seismic-studies to characterize building sites where seismic events might occur;
3. Requiring construction to adhere to building codes that require earthquake resistant design and construction;
4. Preparing emergency preparedness systems to respond to the impacts of seismic events when they do happen.

Seismic development standards are addressed both through Chapter 9 of the Comprehensive Plan (policies O-246 and O0247 in particular), and through the city's adoption of up-to-date building codes in Chapter 15.08.010 of the Municipal code.

Additional requirements that should be considered by Aberdeen focus en ensuring that potential hazards are identified through mapping existing active seismic areas, evaluating the potential impacts of seismic activity on the site and its activities, and preparing geotechnical reports to properly characterize subsurface soils and evaluate their liquefaction potential.

5.5 Tsunami and Seiche Hazards

5.5.1 Description of Tsunami and Seiche Hazards

Grays Harbor and the city of Aberdeen are potentially vulnerable to tsunamis, trains of waves that threaten people and property along shorelines. Sudden raising or lowering of the Earth's crust during earthquakes generally causes a tsunami. Tsunamis can also be a result of an earthquake or sub oceanic landslide near the shore, or from the eruption of an underwater volcano (Walsh et al. 2003; Aberdeen 2003).

Tsunamis become hazards only when they approach land; in shallow water such as near a shoreline, tsunamis gain height as their waves slow and compress. Tsunamis do not resemble towering waves with a breaking crest. Instead, they come onshore resembling a series of quickly rising tides, and they withdraw with currents much like those of a river. Swift currents commonly cause most of the damage from tsunamis. For example, four waves struck Crescent City, California, following the 1964 Alaska earthquake, with the third and fourth waves being the most damaging (EMD 2004). Washington's outer coast is subject to tsunamis generated by distant sources, such as earthquakes in Alaska, Japan, Chile, Hawaii and the Pacific Ocean. Tsunamis can cross the ocean at very high speeds, close to 600 miles per hour.

The Cascadia Subduction Zone fault has caused large earthquakes. This earthquake fault could generate a tsunami that could impact the Washington coast in minutes. Earthquakes of magnitude 8 or larger have occurred at least six times in the past 3,500 years, as shown by coastal and offshore geology. The most recent of these earthquakes, estimated at magnitude 9, occurred the evening of January 26, 1700. The

tsunami it generated in Japan was probably 6 to 16 feet high. Computer models indicate that a Cascadia tsunami can be up to 30 feet in height and affect the entire Washington coast. Its wave train would begin to reach coastal communities in tens of minutes after the earthquake.

As noted above, tsunamis can also be caused by smaller local events resulting from larger earthquakes. For example, a landslide set off a tsunami in the Tacoma Narrows a few days after the 1949 Olympia earthquake.

The impact of a tsunami on the Grays Harbor Estuary will depend on the magnitude of the earthquake event at the source of the tsunami, the distance of the source to the estuary, and how the tsunami wave interacts with the local conditions at the time of the event. These local conditions can be modified by weather and flood conditions that impact water elevations in the estuary, as well as the shape of the estuary itself and how the wave interacts with the immediate shoreline.

The potential impacts of a tsunami created by earthquakes along the Cascadia Subduction Zone have been modeled by different researchers. For example, Kowalik and Murty (1985) modeled the potential effect of a tsunami generated by a seismic event in the Shumagin Gap on the Grays Harbor Estuary. The Shumagin Seismic Gap area of Alaska is located in a segment at the plate boundary along the eastern Aleutian arc. The Shumagin Gap has a repeat time of approximately 50 to 90 years for seismic events, with the last rupture having occurred during the 1899-1903 period (Davies et al. 1981).

Kowalik and Murty based their hypothetical scenario on a rupture of the Shumagin Gap, alone or in combination with the Unalaska Gap and/or the 1938 zone, in a series of large (magnitude 7.2 to 7.8) earthquakes rather than a single great shock. This type of event would be expected to generate large tsunamis, with run-up wave heights of several tens of meters along Pacific shorelines near the rupture areas. According to their scenario, the leading wave of the tsunami would take about three hours to arrive at the southern British Columbia coast and the northern coast of the State of Washington. This leading wave would measure 8 to 9.75 feet in height as it enters the coastal area in the vicinity of Ocean Shores. For comparative purposes it should be noted that the tsunami generated in conjunction with the 1964 Alaskan earthquake measured 9.75 feet at Ocean Shores.

Grays Harbor essentially has a diamond shape. The narrow one-mile configuration at the mouth of Grays Harbor, widens to approximately 13 miles, and then narrows at the mouth of the Chehalis River. This configuration is expected to cause the wave to break at the mouth. Energy is dissipated as the wave breaks. The amplitude then declines as the wave travels inland up the harbor to the Chehalis River. An initial wave amplitude of approximately 7 to 10 feet above the tidal level at the mouth of the harbor would diminish to between 4.8 to 6.5 feet by the time the incident wave reaches Aberdeen. Because the waves break at the mouth of the harbor, energy will be considerably reduced.

Other researchers have modeled tsunamis potentially created by a Cascadia Subduction zone earthquake event similar to historic events (Walsh et al. 2000). Walsh et al. estimated that the wave generated by a magnitude 9.1 event along the subduction zone would result in wave heights ranging from 2.5 to 4.5 feet in height in Aberdeen. The first wave crest would arrive in Grays Harbor more than one hour from the earthquake event.

For comparison, the 1964 Alaska earthquake did not cause any changes in water level in Grays Harbor but did cause the breakup of three log rafts in the Saginaw Shingle Co. in Aberdeen (Grays Harbor County 2003, Walsh et al. 2000).

Seiches are water waves generated in enclosed or partly enclosed bodies of water such as reservoirs, lakes, bays and rivers by the passage of seismic waves caused by earthquakes (Walsh 2003; UW 2003; Barberopoulou et al.2003). Sedimentary basins beneath the body of water can amplify a seismic seiche. Seismic waves also can amplify water waves by exciting the natural sloshing action in a body of water or focusing water waves onto a section of shoreline. A seiche was reported in the Aberdeen city reservoir following the 1964 Alaska earthquake (Walsh et al. 2000). The Aberdeen Daily World reported that the wave overtopped the reservoir's walls, washing gravel into the nearby neighborhood.

5.5.2 Impact of Human Activity on Tsunami and Seiche Hazards

As for seismic hazards, humans do not have control over when and where tsunamis and seiches will occur. They can however influence whether certain structures should be built in areas prone to such events, or how development and structures survive tsunamis.

5.5.3 Protection and Regulation of Tsunami and Seiche Hazard Areas

Avoidance of high-risk hazard areas like tsunami inundation zones or landslide hazard areas are among the few protection options for most structures from tsunami events. Tsunami and seiche hazards can be minimized by building restrictions in known hazard areas, and by implementation of hazard monitoring systems and local warning systems to help residents flee an oncoming danger.

Measures such as establishing sufficiently high floor elevations and using properly engineered foundation designs can help avoid the type of damage from coastal flooding and potential wave velocity and heights associated with tsunamis within the Grays Harbor Estuary. Building on fills that are not engineered, or on delta and loose alluvial deposits along estuary and river shorelines, puts structures and residents at great risk from large waves that are generated from submarine or shoreline slumps. Spills and earthquake or tsunami-related damage to fuel storage tanks, pipelines, and hazardous materials storage areas are also of particular concern. Planning for safe failure of these facilities should be an important part of risk reduction.

Critical structures like hazardous materials or petroleum storage facilities can be moved away from tsunami hazard areas and built for safe failure for seismic loadings. The city could consider more stringent review for new critical facilities in areas that could be potentially flooded by tsunami waves. As discussed above, scenarios for tsunamis induced by Pacific Northwest earthquake events have been developed, and have been incorporated in both local and state levels of emergency planning (Aberdeen 2003; EMD 2004). Areas of high wave impact could be classified and the hazard listed on property titles.

Aberdeen and Grays Harbor County have implemented warning and evacuation systems in the event that a tsunami is generated by a distant earthquake. Aberdeen has also

adopted the most up-to-date building standards that include seismic design requirements.

5.6 Volcanic Hazards - Ash Falls or Tephra Plumes

Even though active volcanoes are not located in Grays Harbor County, a volcanic eruption form a volcano located elsewhere in the state or region can impact Aberdeen. Long distance impacts of a volcanic eruption would most likely occur as a result from ash and tephra falls (Aberdeen 2003).

Tephra falls are from explosive eruptions that blast fragments of rock and ash into the air. Large fragments fall to the ground close to the volcano, but small fragments and ash can travel thousands of miles downwind and rise thousands of feet into the air (Wolfe and Pierson 1995; Gardner et al. 1995). Ash fall hazards can vary from life-threatening to a nuisance. Tephra particulates, toxic gases and acid rain could affect public health, water supplies and aquatic life.

Ash plumes are a hazard to aviation, causing damage to engines that can result in loss of power; in addition, ash particles can block visibility, sandblast windshields, and generate a lot of lightning (Casadevall 1994). Wet ash four inches thick places a load of about 20 to 25 pounds per square foot (Wolfe and Pierson 1995), and can cause structural collapse. Ash carried by winds can be a hazard to machinery and transportation systems for months after an eruption. For example, the ash fallout from the 1980 eruption of Mt. St. Helens caused considerable disruptions in Aberdeen, primarily in the cleanup phase (Aberdeen 2003).

Best available science clearly suggests that construction in areas adjacent to volcanoes, particularly within the areas are located in vicinity to the predicted path of lava flows, landslides or lahars that result from volcanic activity, should be regulated to guard against the obvious hazards. Worldwide standards of practice include the establishment of roughly circular zones that represent decreasing risk with distance from a volcano based on the geologic record of past eruptive events as mapped by geologists (Wolfe and Pierson 1995). However, given Aberdeen's location far from active volcanoes in the Pacific Northwest, no areas within the city would experience the more serious effects of lava flows, landslides, or lahars. Regulation of volcanic hazard areas is therefore not necessary for Aberdeen.

Existing non-regulatory emergency preparedness programs acknowledge the risk of ash fall in the city, and the city has plans in place for reaction to such events (Aberdeen 2003).

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6 Frequently Flooded Areas

For regulatory purposes, frequently flooded areas are defined as "lands in the flood plain subject to a one percent or greater chance of flooding in any given year" (WAC 365-190-030 (7)). This is equivalent to the 100-year flood plain designation mapped by the Federal Emergency Management Agency (FEMA) on Flood Insurance Rate Maps (FIRMs).

Flood plain areas can be adjacent to rivers, lakes or tidewater. For rivers and flowing waters, the FIRMs delineate flood plains into two designations:

- Floodway - the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than one foot
- Floodway fringe - the 100-year flood plain outside the designated floodway.

The floodway is managed for substantial conveyance of floodwaters and for fast-flowing water, while the floodway fringe typically has less significant flow amounts and velocity. The FIRMs also depict areas of floodwater inundation (usually associated with low-lying areas), saltwater or lake fringes, or areas behind levees that are typically managed for flood plain storage. The 100-year flood is also termed the Base Flood, and the total area subject to flooding during the Base Flood is the Area of Special Flood Hazard. Existing FEMA designated flood plains for the city of Aberdeen are indicated in Critical Areas Map 3 – Frequently Flooded Areas.

Development within a flood plain creates a risk to human health and property. Flood plain development can also pose risks to aquatic habitats and species and disrupt natural riverine processes.

WAC 365-190-080 (3) states that counties and cities should consider the following when designating and classifying frequently flooded areas:

- *Effects of flooding on human health and safety, and to public facilities and services*
- *Available documentation including federal, state, and local laws, regulations, and programs, local studies and maps, and federal flood insurance programs*
- *The future flow flood plain defined as the channel of the stream and that portion of the adjoining flood plain that is necessary to contain and discharge the base flood flow at build out without any measurable increase in flood heights.*
- *The potential effects of tsunami, high tides with strong winds, sea level rise resulting from global climate change, and greater surface runoff caused by impervious surfaces*

This chapter discusses frequently flooded areas chiefly from the perspective of flood effects on human health, safety, and property protection, and the effects of human activities on flooding. Flood plain development also has the potential to affect other critical areas designated in the Growth Management Act under RCW 36.70A.030(5). For the most part, the ecological issues associated with flood plain management will be addressed in the chapters for wetlands, and fish and wildlife habitat conservation areas.

Flood plain management issues will also be addressed in the chapter for geologically hazardous areas and aquifer recharge areas. One important goal of these reviews will be to ensure that the connection between frequently flooded areas and the other critical areas is integrated, so that ecological impacts associated with development within frequently flooded areas are adequately reviewed.

6.1 Flood Plain Functions and Values

River flood plains convey and store flood waters when river flow exceeds the capacity of the main river channel. As river stages increase, the depth and velocity of the flood water increases, increasing the areal extent of inundated land and flowing water. Encroachment into the flood plain of a river can increase the flood level in some sections of the river and the subsequent flow velocity. Displaced floodwater (lost flood plain storage) can also increase flooding and flood duration.

Flood plains are also areas of reduced flow velocity. As water overflows from the main channel of a river or stream, it spreads over the land surface, resulting in a much wider flow path over rougher vegetated land. The increased roughness and relatively shallow flow depth result in lower flow velocity which allow for suspended sediment to settle in the flood plain. This provides a mutual benefit for the flood plain and stream, depositing fertile soil and nutrients in the flood plain, and reducing sedimentation in the stream channel.

Flood plains are an interface between ground water and surface water, providing areas of ground water discharge or recharge. These areas may vary spatially or seasonally. For example, some areas may always function as either discharge or recharge areas, based on relatively constant ground water levels and flow patterns. Other areas may act as recharge areas during dry months when the water table is low and as discharge areas during the wet season when the water table rises. Ground water discharge is critical to maintaining stream base flows, which are in turn critical to maintaining aquatic habitat and water quality during dry months by maintaining wetted channels and delivery of cool, oxygenated water.

Flood plains are also a setting for riparian ecosystems. Riparian ecosystems are found where high water tables, overbank flooding, or channel meandering occur. Riparian ecosystems are highly variable environments both spatially and temporally. They form a transition between terrestrial and aquatic ecosystems. They are saturated or flooded during most of the wet season followed by recession of the water table below the root surface during the summer. Riparian ecosystems have a high flux of energy, water, and other material. As such, they generally have high plant and animal species diversity, high species and biomass density, and high productivity (Mitsch and Gosselink 1993).

6.2 Overview of Inventory

6.2.1 Existing Inventory

The existing FIRMs which were prepared by FEMA and have an effective date of July 16, 1984, are the basis for the existing inventory of frequently flooded areas. These FIRMs are also used for regulating development in the city's flood plains,. There are four map panels for the existing FIRMs, and a composite of the four map panels is shown in Critical Areas Map 3.

6.2.2 Past Major Floods

The city of Aberdeen has experienced many floods over the years, which are typically the result of a combination of river and tidal flooding caused by heavy winter rainfall associated with high tides in the Grays Harbor estuary. The combination of high river flows along with high tides also can cause additional flooding by backup of the city's storm drainage system. The highest river and harbor water stages result from a combination of high tides, low barometric pressure, strong onshore winds, and heavy rains.

The highest water level elevation measured at the Port of Grays Harbor staff gage since 1912 occurred in December 1933 with a gage reading of 10.3 feet (NGVD). The second highest measured water level was 10.0 feet in December 1934. Several other events have been recorded at over 9.0 feet. The elevation of the 100-year frequency flood which is mapped on the FIRMs is 10 feet NGVD. Flooding has occurred in South Aberdeen along the Chehalis River, and in North Aberdeen along the Wishkah River. During a major flood, such as the December 1933 flood, which also resulted from high river flows on the Chehalis and Wishkah Rivers, much of the downtown Aberdeen area was flooded.

6.2.3 Updates to Inventory

FEMA is in the process of updating all the FIRMS and Flood Insurance Studies through their Map Modernization program, with the largest population centers and areas of highest flood damages receiving the highest priority for their maps to be updated. The updated maps associated with this program will be county-wide digital maps, using updated orthophotogrammetry and topography to produce more accurate base maps, from which improved flood plain boundaries will be delineated. In conducting the Map Modernization Program, FEMA will consult with, receive information from, and enter into agreements or other arrangements with state, regional, and local agencies to more accurately identify flood plain areas.

An update to the city of Aberdeen's FEMA Flood Insurance Study and FIRMs is not currently scheduled.

6.3 Human Activity and Frequently Flooded Areas

The most common types of human disturbance to flood plains are filling, channelization, and construction or alteration of barriers. Each of these is described below.

6.3.1 Filling

Filling is typically performed to raise an area above the flood elevation so that it may be developed. Without compensatory volume replacement, filling would reduce flood plain storage. FEMA model regulations require that the cumulative effect of a proposed development, when combined with all other existing and anticipated development, will not increase the water surface elevation of the base flood more than one foot at any point within the community. Encroachments into the floodway are typically prohibited unless it is demonstrated that the encroachment will not result in any increase of flood levels during the base flood. This is addressed in Section 15.52.110 Floodways in the

Aberdeen Municipal Code. Encroachments in the floodway fringe outside of the floodway are typically allowed in the current code.

6.3.2 Channelization

Stream or river channelization can be described as the deliberate or unintended alteration of channel slope, width, depth, sediment roughness or size, or sediment load (Bolton and Shellberg 2001). Widening, deepening, dredging, removal of live or dead vegetation, bank armoring, straightening, and construction of levees or similar structures may alter these variables. The physical effects of channelization include higher flow velocities, increased sediment transport, increased channel incision, bank instability, loss of channel and flood plain capacity, increased flood heights, and draining of wetlands and flood plains. These effects result in damage to or loss of stream and wetland habitat (Bolton and Shellberg 2001).

Channelization also results in loss of natural habitat-forming processes, and even intentional homogenization of the channel. As a result, channel complexity is reduced and specific habitat types (pool-riffle sequences, logjam-formed pools, meander pools, etc.) are reduced or eliminated. Loss of specific habitat types (pools, eddies, and off-channel areas), increased flow velocity, and longer durations of elevated flows affect fish and invertebrates.

Filling and channelization also reduce the water quality maintenance function of flood plains, through loss of wetlands and flood plain vegetation that filter sediment, nutrients, and chemicals, and by reducing the volume of flood flow that interacts with the flood plain outside of the channel.

6.3.3 Barriers

Barriers are features that restrict the movement of water, sediment, animals (fish), or other material such as large woody debris (LWD), either downstream or laterally within the flood plain. Barriers may also restrict channel migration. Barriers include levees, road, and highway embankments, bridges and culverts, flood plain fill, bioengineering structures (cribwalls, rootwad/rock mixtures, etc.), and walls.

Levees protect infrastructure from flooding. Levees also affect conveyance and storage of floodwaters in two ways: (1) levees isolate naturally occurring flood plain storage from the channel, and (2) levees constrict flows to a narrower channel, resulting in increased flow depth and velocity. This may cause increased scour, sedimentation, and transference of flooding problems to downstream areas (Hey 1994). Other types of barriers such as road embankments, bridges, culverts, fill, and embankments may impede flow, causing greater flood heights. Levees also physically disconnect riparian areas, wetlands, and off-channel habitats, from the main channel, which has adverse effects on natural ecological processes (Bolton and Shellberg 2001).

Levees have been constructed in several areas within the city to prevent or reduce tidal or riverine overflow from flooding events. None of these levees are considered to be sufficient to provide protection from the 100-year (base) flood, and as a result all of the low-lying areas located behind these levees are shown on the FIRMs to be in the 100-year flood plain (frequently flooded areas).

6.4 Flood Control Projects

The only existing projects that are specifically designed for controlling flooding within the city of Aberdeen are some levees that have been constructed along the lower reaches of the Chehalis and Wishkah Rivers. Levees have been in place for many years along the south bank of the Chehalis River to reduce flooding in the South Aberdeen area, but were frequently overtopped by floodwaters. A new levee system was installed in 1995 to an elevation of 12.2 feet, which is approximately two feet above the elevation of the 100-year frequency flood event. In addition, approximately nearly one mile of levees has been constructed near the mouth of the Wishkah River to an elevation of 10.2 feet.

6.5 Flood Hazard Management Planning

The Disaster Mitigation Act of 2000 (44 CFR 201) requires state, local, and tribal governments, taxing districts, and not-for-profit organizations to develop Hazard Mitigation Plans (HMPs) to remain eligible for FEMA pre-disaster mitigation and post-disaster relief funding. The HMP identifies hazards (such as flooding, volcanic, landslides, and earthquakes) that could potentially affect or be present in a community or area, and estimates the level of risk these hazards pose in the event of a natural disaster. These risk estimates are then used to prioritize mitigation planning efforts. The law requires that each HMP include the following elements:

- Public involvement
- Planning process documentation
- Risk/vulnerability assessment
- Mitigation strategy(ies)
- Plan maintenance and updates
- Formal plan adoption by each participant.

The city of Aberdeen has an approved Hazard Mitigation Plan that was approved by FEMA on August 24, 2004. The primary hazard addressed in this Plan is flooding. Other hazards addressed in the Plan are tsunamis, earthquakes, hazardous materials incidents, landslides, winter storms, and wildland/forest fires.

6.6 GMA Requirements and Regulatory Options

This section analyzes the existing code for potential deficiencies in meeting the requirements of chapter 36.70A.

6.6.1 GMA Standards

Chapter 365-190 WAC contains minimum guidelines for classification of critical areas including frequently flooded areas. WAC 365-190-080(3) states that classifications of frequently flooded areas should include, at a minimum, the 100-year flood plain designations of the Federal Emergency Management Agency and the National Flood Insurance Program.

GMA guidelines in chapter 365-190 WAC do not provide specific guidelines to address hazards to human health and safety from frequently flooded areas. CTED policy interpreting the GMA discourages allowing any new development within a flood plain.

However, if a local jurisdiction does allow development in flood plains, the CTED guideline for density in a flood plain is 1 dwelling unit per 10-20 acres.

6.6.2 FEMA/Ecology Requirements

Even though they are not requirements, the GMA guidelines and CTED policies are more restrictive than the FEMA/Ecology minimum requirements, which do not specifically regulate or prohibit development densities in the flood plain. Minimum Ecology requirements are contained in chapter 173-158 WAC and do prohibit residential development in the floodway portion of the flood plain, but there are no prohibitions or density restrictions in the fringe portion of the flood plain. Minimum building requirements must still be met, such as elevating floor levels of residential structures at or above the base flood level, flood-proofing non-residential structures and electrical equipment and ensuring that development does not raise downstream flood levels, etc. FEMA minimum requirements are less restrictive than Ecology requirements.

The interrelationship of frequently flooded areas with other critical areas means that all important functions and values need to be considered in establishing comprehensive plan policies and development regulations for these critical areas (CTED 2004). To address this policy, the CTED Example Code proposes requiring that all structures, utilities and other improvements be located outside of flood plains, unless a site has no buildable area outside of the flood plain (CTED 2003).

Growth Management Hearings Board decisions on frequently flooded areas are limited. The most relevant clarifies that location of development within a flood plain is an issue:

> *"Ordinances which merely regulated building requirements within a flood plain and did not address issues of whether and under what conditions building should occur in a flood plain did not comply with the GMA." WWGMHB Diehl* v. *Mason County 95-2-0073 (Final Decision and Order, 1-8-96)*

6.6.3 Existing City of Aberdeen Regulations

Existing city of Aberdeen requirements for frequently flooded areas are contained in the Aberdeen Municipal Code (AMC), Chapter 15.52 - Flood Damage Prevention. This chapter was adopted by the city as an element of the requirements for the city's participation in the National Flood Insurance Program (NFIP), which is administered by FEMA.

The following are some of the key standards from Chapter 15.52 that relate to frequently flooded areas:

- AMC 15.52.030 requires that the area regulated under this chapter (area of special flood hazard) is based on the city's Flood Insurance Study and is shown on the city's FIRMs, with an effective date of July 16, 1984.
- AMC 15.52.100A requires that new construction or substantial improvement of any residential structure shall have the lowest floor elevated to one-half foot or more above the base flood elevation, or above elevation 8.7 feet (NGVD), whether or not in the area of special flood hazard, whichever is the higher elevation.

- AMC 15.52.100B requires that new construction or substantial improvement of any non-residential structure shall be floodproofed or have the lowest floor elevated to one-half foot or more above the base flood elevation, or above elevation 8.7 feet (NGVD), whether or not in the area of special flood hazard, whichever is the higher elevation.
- AMC 15.52.100B.7 states that to the extent possible, construction of new critical facilities shall be located out of the area of special flood hazard.
- AMC 15.52.110 contains additional requirements for floodways, including the prohibition of any fill or development of any nature that would result in any increase in flood levels and the prohibition of new construction or substantial improvement of any residential structure.

6.6.4 Regulatory Options

There are four basic approaches to limiting flood exposure for new development:

- Limiting the types and density of uses allowed in flood plains by zoning these areas for resource use rather than for residential, commercial, and industrial use.
- Limiting or prohibiting subdivisions within these areas, or requiring new lots to have a buildable area outside the flood plain.
- Requiring new construction on existing parcels to locate outside of the flood plain if a buildable area is outside the flood plain.
- Allowing limited new development in flood plains, but requiring construction to be done in such a manner that potential flood damages are minimized and do not cause an increase in flood levels

Limitations on Development in Flood plains

The restriction of development in the flood plain has a threefold purpose:

(1) To reduce risk to human health, safety, and property

(2) To prevent development activities from adversely affecting the capacity of the flood plain or floodway to convey and store floodwaters

(3) To preserve important ecological functions of the flood plain.

In the city of Aberdeen, the majority of the area identified as flood plain on the FIRMs is in the tidal area where flooding occurs as a result of a combination of high tides and high river flows from the Chehalis and Wishkah rivers. In this area, near the mouths of the Chehalis and Wishkah rivers, the water surface elevation in Grays Harbor is the governing factor in determining the flood levels. There are low velocities from the river flows and there is no designated floodway along this tidal area.

There are areas within the northerly portion of the city along the Wishkah River where the flow in the Wishkah River with accompanying velocity governs the water surface elevations for the flood plain. These areas along the Wishkah River also have a designated floodway.

The majority of the flood plain area within the city is in already developed areas, including the downtown area on the north side of Grays Harbor, which is essentially entirely all within the flood plain. In addition, much of the area in South Aberdeen on the south side of Grays Harbor is also within the identified 100-year flood plain, and is regulated by Chapter 15.52 of the AMC.

There are areas within the identified flood plain in the northern portion of the city along the Wishkah River, as well as areas in the southwesterly portion of the city, that are not extensively developed. These are the areas that the city has the most potential for restriction of future development in the flood plain and the resulting reduction in future flood damages, if they choose to do so. Future development of these undeveloped portions of the flood plain that are not identified as floodway, is allowable under the existing Chapter 15.52 of the AMC, as well as Ecology and FEMA requirements. However, construction is subject to existing restrictions, including the elevation requirements in the city ordinance.

6.7 Floodproofing

Floodproofing is designed to limit the damage from flooding. In a flood situation, individuals are often evacuated, but with adequate floodproofing they can often return to their property after the flood and resume activities with little need for repair.

Section 15.52.100B of the AMC and State Department of Ecology and FEMA requirements require floodproofing of new non-residential development and substantial improvements to existing development within the flood plain, to reduce damage to structures during floods. Key floodproofing provisions include the following:

- Anchoring to prevent flotation, lateral movement, or collapse
- Construction of utilities to prevent entry of water during flooding
- Elevation of residential structures to one-half foot or more above the base flood elevation (BFE)
- Prohibition of enclosed areas below the lowest floor, or allowance for flow of floodwaters
- Elevation of non-residential structures above the BFE or floodproofing so that portions of the structure below the BFE are watertight and non-buoyant.

6.8 Findings and Code Recommendations

In its present form, the city of Aberdeen Chapter 15.52 Flood Damage Prevention addresses the minimum guidelines for frequently flooded areas, and with some minor updates, would meet the FEMA and Ecology minimum requirements for continuation of being in good standing for participation in the National Flood Insurance Program.

The following are recommendations for the city's consideration in updating Chapter 15.52

- Update the existing 1999 version of Flood Damage Prevention to incorporate the 2002 revisions to the Ecology requirements contained in Chapter 173-158 WAC-Flood Plain Management

- Consider increasing the elevation requirement from one-half foot above the base flood elevation to one foot or more above the base flood elevation for floor levels for residential structures and for floodproofing levels for nor-residential structures
- Consider establishing setback areas from river banks to provide additional safety from erosion as well as providing a riparian buffer for protecting fish and wildlife habitat, or establish setback areas through the Fish and Wildlife Habitat Conservation Areas
- Consider adding language relating to wetlands management as described in Chapter 173-158 WAC

6.9 References

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7 Critical Aquifer Recharge Areas

Critical Aquifer Recharge Areas (CARAs) are defined as areas with a critical recharging effect on aquifers used for potable water that is vulnerable to contamination that would water quality (WAC 365-190-030(2)). Examples include sole-source aquifers designated pursuant to the federal Safe Drinking Water Act; areas established for special protection pursuant to RCW 90.44, 90.48, and 90.54; and wellhead protection areas designated pursuant to WAC 246-290-135. Critical aquifer recharge areas function to protect human health from contaminated drinking water (anti-degradation of ground water), and to maintain stream flows and moderate temperatures for fish and wildlife.

7.1 Summary of Aquifers in Aberdeen and its Vicinity

Aquifers in Aberdeen and its vicinity occur in the alluvial deposits that were formed by the geological processes that shaped the Lower Chehalis River Valley and its adjacent areas (Eddy 1966). The oldest rocks in the area are basalt and basaltic sediments approximately 25 years old, of the Crescent Formation of Eocene age. Above this sequence lie several Tertiary rock units, ranging in age from 25 to 5 million years (the Oligocene to Pliocene ages). These “bedrock” tertiary rocks are unimportant as aquifers.

At the end of the Tertiary period, what is now the lowlands bordering Grays Harbor was the site of deposition of sedimentary materials. These sediments consist mainly of stream-laid gravel and coarse sand derived from the Olympic Mountains and, to a lesser extent, from the Willapa Hills. These deposits were deeply incised by streams during more recent geologic periods, leaving gravel terraces as remnants of the more extensive valley deposits. The reworked materials were carried to the Chehalis Valley to become incorporated with the larger stream’s sediments and to be deposited as alluvium. The Chehalis and Hoquiam River sediments partially filled the marine embayment at their mouths. Alluvial deposits are also found beneath and adjacent to the larger streams and rivers within the area. These deposits range in thickness from a few feet in the tributary valleys, to as much as 200 feet in the Chehalis River Valley.

All wells in the Aberdeen area historically derive their water from these Pliocene-Pleistocene sediments. Wells in the tertiary foothills in the northeast and northwest locations of Aberdeen are drilled mainly in consolidated rock, and are not very productive. Wells drilled in the alluvial deposits of the Chehalis River Valley (i.e., in the lower lying areas of Aberdeen) can obtain water from an upper or lower aquifers located respectively above and below a depth of approximately 100 feet below ground surface.

Aberdeen’s potable water supply is derived from surface water withdrawals from the Wishkah River Watershed (Eddy 1966). There is no use of ground water as a public drinking water supply source.

7.2 Overview of Aquifer Functions and Values

7.2.1 Drinking Water Supply

Advantages of ground water as a water supply source include natural filtration as precipitation percolates through unsaturated soils; protection from turbidity, algal blooms, and other surface water quality issues; generally constant cool temperature; and readily

accessible with wells and pumps. Ground water provides more than 65 percent of drinking water for Washington State through private wells and public water systems (Ground Water Protection Council 2004).

7.2.2 Base Flow to Streams

Ground water and surface water systems constantly interact with respect to recharge and discharge of ground water. One critical interaction is discharge of ground water into streams as base flow during parts of the year and the recharge of ground water from streams during other parts of the year. The magnitude and timing of ground water discharge and recharge depends upon the relative elevations of the stream bed and the water table, the flow gradient between the aquifer and the stream, the water-transmitting characteristics of the geologic strata that comprise the aquifer and the stream channel, the location and extent of pumping from ground water wells, drainage activity, climate, and other actions and conditions. Base flow from ground water also provides critical water volumes to support fish life cycles (including moderation of stream temperatures) and to maintain public water supplies that draw water from streams and rivers.

A number of past and current studies provide insights into base flow contributions from ground water, including Lindsay (1998), Gibbons and Culhane (1994), and Sinclair and Pitz (1999). These studies indicate that the shallow aquifers are responsible for approximately 70 percent of stream base flow (Ground Water Protection Council 2004).

7.2.3 Discharge to and Recharge from Wetlands

Shallow aquifers can be recharged by wetlands and can also discharge to wetlands that support vegetation and wildlife. Wetlands provide beneficial water quality functions including particulate filtration and buffering of pollutants. The interrelationships of wetlands, aquifer recharge, discharge from shallow aquifers, and water quality occur on both a landscape and site-specific scale. Assessment of the potential impacts of changes in ground water conditions (such as water-table elevation, ground water recharge and discharge rates, and water quality) on wetlands requires field data to define wetland hydrology and function.

7.2.4 Storage of Infiltrated Precipitation

Aquifers can provide temporary storage of the portion of precipitation that infiltrates into the ground and moves downward past the root zone (i.e., is not lost to the system through evapotranspiration). This storage can function as a detention mechanism that reduces stormwater runoff and allows delayed discharge into streams and lakes well after the precipitation event. Stored ground water becomes a resource for water supply, base flow, and discharge to wetlands and other surface water bodies.

7.3 Overview of Critical Aquifer Recharge Area Issues

7.3.1 Susceptibility of Aquifer Recharge Areas

Aquifer susceptibility is defined as the ease with which contaminants can move from source areas to the aquifer based solely on the characteristics of surface and subsurface geologic materials in the unsaturated zone above the aquifer (Cook 2000). For example, an aquifer with a ground water depth less than 20 feet and overlain by course sand and

gravel would have high susceptibility to contamination, but a confined aquifer overlain by 50 feet of clay would have a relatively low susceptibility.

Susceptibility can be estimated in a number of ways ranging from evaluation matrices supported by the scientific literature and field data, to ground water computer models calibrated with data from field aquifer tests. There are no susceptible aquifer recharge areas that supply potable water in Aberdeen.

7.3.2 Vulnerable Aquifer Recharge Areas

Aquifer vulnerability is defined as the combined effects of susceptibility and the presence of chemicals above the aquifer at specific locations (Cook 2000). The factors that contribute to vulnerability include the nature of the chemical threat (potential or confirmed release), the form of the chemicals (solid or liquid), the toxicity of the chemical, and the mobility of the chemicals in the subsurface.

Vulnerability can be approached from varying levels of detail. For example, non-point contamination sources such as agricultural chemicals may best be addressed on a regional scale, whereas point sources such as leaking underground storage tanks or registered hazardous waste disposal sites are best addressed on a site-specific basis. There are no vulnerable aquifer recharge areas that supply potable water in Aberdeen.

7.3.3 Wellhead Protection Areas

The 1986 amendments to the federal Safe Drinking Water Act mandated measures to protect ground water supplies through wellhead protection. The State of Washington adopted regulations (WAC 246-290-135, Source Water Protection) to address these requirements. Potable water-supply purveyors in Washington using ground water must develop and implement wellhead protection programs that include delineation of protection areas around each well, and inventory of contamination sources within wellhead protection areas, and development and implementation of water supply contingency and spill response plans to address contamination incidents that could cause loss of a well. The U.S. Environmental Protection Agency (1987, 1993) and Washington State Department of Health (1995) provide guidance for wellhead protection program development.

The State of Washington wellhead protection regulations exclude individual domestic wells and well systems that do not meet the definition of public water supplies. The well drilling regulations (Chapter 173-160 WAC) include requirements to locate water wells minimum distances from potential contamination sources such as feedlots and landfills. There are no wellhead protection areas in Aberdeen.

7.3.4 Sole Source Aquifer

The federal Safe Drinking Water Act also authorized the United States Environmental Protection Agency (USEPA) to designate aquifers that are the sole or principal source of drinking water for an area. To meet the criteria for designation, a sole source aquifer must supply at least 50 percent of the drinking water to persons living over the aquifer, and there can be no feasible alternate source of drinking water. Designated sole-source aquifers are subject to USEPA review for proposed projects that are to receive federal

funds and that have the potential to contaminate the aquifer. No sole source aquifers are designated in Aberdeen.

7.3.5 Susceptible Ground Water Management Areas and Special Protection Areas

WAC 173-100-010 provides guidelines, criteria, and procedures for the designation of ground water management areas, subareas, or zones and to set forth a process for the development of ground water management programs. The objectives of these designations are protection of ground water quality, assurance of ground water quantity, and efficient management of water resources for meeting future needs while recognizing existing water rights. WAC-173-200-090 addresses designation of special ground-water protection areas that require special consideration or increased protection. There are no susceptible ground water management areas or special protection areas in Aberdeen.

7.3.6 Ground Water Quality

The quantity of ground water present in aquifers under natural conditions represents an equilibrium of recharge, storage, and discharge, and responds to changes in climate. Land-use activities that can affect ground water quantity by reducing recharge include impervious surfaces with drainage diversion, drainage ditches, ground water cutoff trenches, overpumping from wells and springs. Increases in recharge also occur as a result of irrigation, leakage from irrigation canals, and septic system discharges in areas served by surface water supplies.

7.4 Human Activity and Aquifer Functions

7.4.1 Ground Water Quality

Use and disposal of chemicals is the principal cause of adverse impacts to ground water quality from human activities. Leaks and spills of chemical products and hazardous residues from manufacturing operations, storage tanks, shipping containers, and waste disposal areas are major point sources of contamination. On-site septic systems that are improperly installed or maintained are also potential point sources of ground water contamination. Non-point sources of ground water contamination include runoff from agricultural areas, field application of fertilizers and manure at greater than agronomic rates, concentrated agricultural feeding operations, paved and unpaved areas used by vehicles or used for chemical storage, runoff from residential and business uses, and areas where airborne dispersion of hazardous chemicals has contaminated soils.

Recent studies indicate that on-site septic systems can be a significant contributor to ground water contamination, depending upon system density and hydrogeologic conditions. Generally, a maximum density of one system per one acre is sufficient to avoid ground water contamination (Cook 2000). However, varying soil types and depths may cause modification to this one system per one acre suggested density.

Intrusion of saltwater from marine water bodies into coastal aquifers can result from overpumping of wells and reversal of ground water flow directions from seaward to landward.

7.4.2 Ground Water Quantity

Withdrawal of ground water at rates and/or volumes exceeding natural recharge causes depletion of ground-water storage in aquifers. If this situation persists for an extended period of time, significant declines in ground water levels and change of flow gradients and directions can occur, and damaging compaction of the aquifer matrix can result from extreme long-term water level declines. In principle, ground water withdrawals are regulated by the Department of Ecology through water rights, although ground water withdrawals that are less than 5,000 gallons per day (approximately 3.5 gallons per minute continuous pumpage) and for the certain purposes (stock watering, single or group domestic purposes, industrial purposes, or watering a lawn or non-commercial garden that is not larger than one-half acre) are exempt from the water-right permitting process.

Natural ground water recharge rates can be reduced by changes in land use. For example, agricultural drainage systems and drainage systems associated with roads and urban areas are specifically designed and constructed to intercept water that would, in an unaltered state, discharge from the site and recharge aquifers. Similarly, installation of impervious areas (such as pavement and buildings) and soil compaction from heavy equipments, and changes in vegetation type and quantities can affect recharge rates to ground water (Fair 2003). Techniques to mitigate some of these impacts are addressed by the Stormwater Manual for Western Washington (Ecology 2004).

Agricultural drainage systems, stormwater collection and conveyance systems in developed areas, and impervious surfaces have the effect of reducing the amount of ground water available to support baseflow in streams. Decreased recharge can lower ground water levels and cause reversal of ground water flow directions and gradients. The aquifer is then recharged by the stream (i.e., stream flow depletions are increased), rather than discharging to the stream to augment baseflow.

7.5 Applicability of CARAs in the City of Aberdeen

There is no applicability of CARAs within the city of Aberdeen since there are no public ground water supplies in this area. The only two public water supply purveyors in the Aberdeen-Hoquiam vicinity are the cities of Aberdeen and Hoquiam. Each of these cities get their potable drinking water from surface waters sources located several miles north of the two cities. Neither city has ground water sources within the city limits of Aberdeen or Hoquiam. The nearest public water supplier that uses ground water as a source is Grays Harbor Water District No. 2, which provides water to the Central Park area east of Aberdeen. The city of Cosmopolis located just south of South Aberdeen, receives its public water supply from the city of Aberdeen.

There are very few ground water wells for water supply located within the vicinity of the city of Aberdeen. The Department of Ecology's Water Resources Program maintains records of well logs for the State of Washington. In checking the well logs within the Aberdeen city limits, only one water well log was found, which was for the Port of Grays Harbor. In further checking with Ecology records, it was found that this well has a ground water right issued in 1976 and is for cooling water for a blower. It was also learned from the Port of Grays Harbor records that the Port obtains its potable water supply from the city of Aberdeen.

Even though well logs are not available, it is expected however, that there are other water wells within the city for individual domestic supply, especially near the outer city limits.

There are several well logs shown in Ecology's records in the vicinity, but essentially all of them are for Resource Protection wells, instead of Water wells. Resource Protection wells are drilled wells that are used for monitoring purposes, instead of for withdrawal of ground water. Resource Protection wells are constructed for various monitoring purposes including ground water levels and determining the existence or movement of pollutants within an underground formation (RCW 18.104.020(19)).

One example of the usage of Resource Protection wells in this area is documented in a Department of Ecology report, entitled *Saginaw Mill (Aberdeen) Ground Water Monitoring Results, April and August 2006,* (Publication No. 07-03-029, May 2007, by Pamela B. Marti). This report documented the sampling and the results of the samples collected for analysis of the presence of formaldehyde in seven monitoring wells at the former Saginaw Mill site, which was located on the south shore of the Chehalis River, just downstream of the mouth of the Wishkah River. Upon completion of monitoring in 2006, formaldehyde concentrations had decreased significantly from 1993, and were low enough that the recommendation was that no further monitoring was needed at this site.

Although the purpose of this report was to document the presence and changes in formaldehyde levels at this site from the beginning of monitoring in 1993 to August 2006, this report contains the best available recent data on ground water levels and flow direction in the Aberdeen area. Summary information relating to ground water levels and flow direction from this report which is expected to be typical for the Aberdeen vicinity, includes the following:

- Water table elevations ranged from 3 to 11 feet below the ground surface
- Water table elevations varied between readings in April and August 2006
- Water table elevations were lower nearer to Grays Harbor, meaning ground water flow directions was toward Grays Harbor
- Water table elevations likely are variable with tidal fluctuations.

7.6 Recommendations

Based on the information contained in the Ecology report described above, ground water levels in the Aberdeen vicinity are very shallow, and as such could be subject to pollutants from the ground surface. In addition, with the presence of Grays Harbor and the associated saltwater, there is the potential for saltwater intrusion in wells in this vicinity. Because of these factors, use of ground water as a water source in this vicinity would likely be problematic, which is also likely the reason there are so few ground water wells in this vicinity.

Since there are no public ground water supplies within the Aberdeen city limits and there are no CARAs in Aberdeen, no recommendations for protecting potable ground water sources are made at this time.

Because of the scientific evidence that ground water supplies play an important role in natural ecosystem processes, it is recommended that Aberdeen adopt CTED model code CARA regulations to protect natural and potable water sources both now and in the future.

7.7 References

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Critical Areas Maps

Note: the following maps are presented here in standard publication format (i.e. 8.5" by 11" size), but will be available to city staff to be viewed at a larger scale.

1. City of Aberdeen Critical Area Map 1: Wetlands
2. City of Aberdeen Critical Area Map 2: Frequently Flooded Areas
3. City of Aberdeen Critical Area Map 3: Critical Aquifer Recharge Areas
4. City of Aberdeen Critical Area Map 4: Fish and Wildlife Habitat Conservation Areas
5. City of Aberdeen Critical Area Map 5: Geologic Hazard Areas: Liquefaction and Landslide
6. City of Aberdeen Critical Area Map 6: Geologic Hazard Areas: Seismic/Shaking Potential
7. City of Aberdeen Critical Area Map 7: Geologic Hazard Areas: Erosion Potential
8. City of Aberdeen Critical Area Map 8: Geologic Hazard Areas: Steep Slopes