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Best Available Science Review

Skagit County Critical Areas Ordinance Update

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Prepared for:

Skagit County
Skagit County Planning and Development
1800 Continental Pl
Mount Vernon, WA 98273

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Prepared by:

Sam Payne
Ecologist
B.S. in Environmental Science at Western Washington University, P.S.M. in Fish and Wildlife Administration at Oregon State University, and P.C. Wetland Science & Management at University of Washington
SWS certified professional wetland scientist and ISA certified arborist

Tami Camper
Environmental Planner
B.S. in Environmental Science at Western Washington University, M.S. Biology-Botany at CalPoly Humboldt

Kim Frappier
Senior Environmental Planner and Urban Forester
B.A. in English at Boston College, M.S. in Restoration Ecology and P.C. in Wetland Science & Management at the University of Washington
ISA certified arborist

Nell Lund
Senior Ecologist & Principal of Natural Resources
B.S. in Biology at Arizona State University, P.C. in Wetland Science & Management at the University of Washington
SWS certified professional wetland scientist

Dan Nickel
Principal of Planning
B.S. in Biology at Pacific Lutheran University, M.S. in Environmental Science at the University of Washington

FACET
Kirkland Office
750 6th Street S
Kirkland, WA 98033
425.822.5242

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1. Introduction

This review of the best available science (BAS) was compiled to support Skagit County's Critical Areas Ordinance (CAO) update. As a requirement of the Washington State Growth Management Act (GMA) cities and counties must "include the 'best available science' [BAS] when developing policies and development regulations to protect the functions and values of critical areas and must give 'special consideration' to conservation or protection measures necessary to preserve or enhance anadromous fisheries"[1] (WAC 365-195-900). Regulated critical areas include wetlands, aquifer recharge areas, fish and wildlife habitat conservation areas, frequently flooded areas, and geologically hazardous areas (RCW 36.70A.030 and SCC 14.24).

BAS means the current and best available information that follows a valid scientific process as specified in WAC 365-195-900 through WAC 365-195-900. According to WAC 365-195-905, characteristics of a valid scientific process include peer review, standardized methods, logical conclusions and reasonable inferences, quantitative analysis, proper context, and references. Common sources of scientific information include research, monitoring, inventory, modeling, assessment, and synthesis (WAC 365-195-905). BAS literature reviews are a synthesis of the current scientific body of knowledge, and only resources that meet these requirements are included as reference materials for this BAS.

The BAS review is a resource for critical area management but is not intended to provide definitive answers for all policy and regulatory decisions. Policy and regulations should incorporate BAS but also necessitate decision-making processes based on societal values. Additionally, ecological systems are highly complex and the scientific body of knowledge is constantly evolving with the advancement of new research and technology. Despite these advancements, there are limits to the current state of science and certain topics may not be fully understood. Where there is scientific disagreement in the literature about a particular subject, this review presents a range of potential ideas, theories, or findings. In accordance with WAC 365-195-920, decision-makers may opt for a precautionary, or no-risk approach, when scientific information is incomplete.

As of July 2023, with passage of Washington HB 1181: Climate Change in Local Comprehensive Planning, the GMA requires jurisdictions to incorporate and evaluate the effects of climate change in long-range planning. Climate change is anticipated to have a profound influence on natural systems and inclusion of these topics allows for decision-makers to respond by incorporating climate resilience into policy and regulations.

This BAS review serves as a reference for Skagit County for planned CAO updates, a component of comprehensive updates to the unified development code. Following the establishment of this BAS review, a gap analysis will be developed to identify current shortcomings and provide recommendations on critical area regulation updates.

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[1] Anadromous refers to fish or fish species that spend portions of their life cycle in both fresh and salt waters, entering fresh water from the ocean to spawn.

2. Critical Aquifer Recharge Areas (CARAs)

2.1 Definitions

Critical aquifer recharge areas (CARAs) are defined in the Washington Administrative Code (WAC) 365-190-030 as follows:

> *Critical aquifer recharge areas are areas with a critical recharging effect on aquifers used for potable water, including areas where an aquifer that is a source of drinking water is vulnerable to contamination that would affect the potability of the water, or is susceptible to reduced recharge.*

Skagit County describes these CARAs as simply aquifer recharge areas (ARAs), and are defined in the following quote. For the purpose of consistency with GMA and CAO terminology, these critical areas are referred to as CARAs, below.

> *areas that, due to the presence of certain soils, geology, and surface water, act to recharge groundwater by percolation.*

CARAs have been categorized by Skagit County according to the following classification system.

(a) Category I areas are those so designated because of the need for protection due to a pre-existing land use, or because they are identified by the County, State or Federal government as areas in need of aquifer protection where a proposed land use may pose a potential risk which increases aquifer vulnerability. Category I areas are shown on the aquifer recharge area map. Category I areas include:

(i) Areas served by groundwater which have been designated as a "sole source aquifer area" under the Federal Safe Drinking Water Act; and

(ii) Areas identified by the County as potential or existing sea water intrusion areas; and

(iii) Areas designated as "wellhead protection areas" pursuant to WAC Chapter 246-290 and the groundwater contribution area, or otherwise recognized by the Health Officer or Administrative Official as needing wellhead protection. Wellhead protection areas shall, for the purpose of this regulation, include the identified recharge areas associated with:

(A) The 10-year groundwater time of travel for all Group A public water systems; or

(B) The 1-year groundwater time of travel for all Group B public water supply wells.

(iv) Areas within 1/2 mile of a surface water source limited (SWSL) stream as designated in SCC 14.24.340(3)(c).

(b) Areas throughout the County not identified as Category I areas are designated as Category II areas.

(c) When any portion of the proposed project area is located partly within a Category I area, the proposed project shall be subject to the level of scrutiny provided for a Category I area.

Groundwater is water that exists underground in the saturated pore spaces of soil and rock. The upper surface of the saturated zone is referred to as the *water table*. An aquifer is a geologic formation that readily transmits groundwater to wells or springs above ground. According to WAC 173-150-030, an aquifer is defined as "any geologic formation that will yield water to a well or other withdrawal works in sufficient quantity for beneficial use." Aquifer recharge occurs when water infiltrates the ground and percolates to an aquifer. An unconfined aquifer is an aquifer that has no aquitard (a geologic formation that does not readily transmit water) or aquiclude (a geologic formation that does not allow for the transmission of water) between the water and the ground surface. A confined aquifer is a deeper aquifer that is separated from the surface by an aquitard or aquiclude and is often under pressure. Groundwater recharge areas are characterized by decreasing hydraulic head with depth (direction of groundwater movement is downward). Groundwater discharge areas are characterized by increasing hydraulic head with depth (direction of groundwater movement is upward, towards the surface) (Driscoll 1986; Winter 1998).

The Department of Ecology considers *aquifers used for potable water* as those with existing wells and their protection area, a sole-source aquifer, those planned to be used for potable water in the future, and aquifers otherwise identified as an important supply (ECY 2021a). Maintenance of potable water uses and potential uses of aquifers require the management of water quality and quantity, which is covered in the following section.

2.2 Functions and Values

The goal of establishing CARAs is to protect the functions and values of a community's drinking water by preventing pollution and maintaining supply. RCW 36.70A.172 requires counties and cities to incorporate the best available science in developing policies and development regulations to protect the functions and values of critical areas. Counties and cities are also required to give special consideration to conservation or protection measures necessary to preserve or enhance anadromous fisheries (ECY 2021a). Since groundwater is an important component of stream flow, it is necessary to maintain the groundwater supply for streams to protect salmon and other anadromous species. Groundwater conditions can also influence geologic hazards, including landslide hazards and erosion hazards.

2.2.1 Water Quality

While aquifer recharge areas serve to replenish groundwater supplies, they can also serve as a conduit for the introduction of contaminants to groundwater. Vulnerability to public water supply is primarily influenced by two main factors, the history of contamination loading and hydrogeologic susceptibility of the aquifer (WDOH 2017).

Contamination loading refers to the quantity and types of pollutants present in an area, including exposure concentration, frequency, and chemical composition. Together, susceptibility and loading potential determine the vulnerability of an aquifer. To be considered vulnerable, an aquifer would need to be both susceptible and have significant contamination loading. For example, a highly susceptible aquifer may have a low vulnerability if the land use within the area is primarily open space, since there is minimal contamination loading. Likewise, an industrial site with multiple leaking storage containers may not create significant vulnerability if it is separated from the nearest aquifer by several hundred feet of dense glacially compressed clay.

Aquifer susceptibility refers to how easily water and pollutants can move from the surface through the ground to reach the underlying aquifer. There are many factors which influence susceptibility including the following (Eberts et al. 2013; ECY 2021a):

1. Characteristics of the vadose zone including depth to watertable and travel time. Travel time is influenced by hydrogeologogical factors including material composition and preferential flow paths
2. Permeability
3. Infiltration rate
4. Chemical retardation
5. Adsorption
6. Hydraulic conductivity
7. Hydrologic and pressure gradients
8. Groundwater flow direction
9. Groundwater flow rate

Permeability of the vadose zone can be estimated from soil and geologic mapping. The Washington Department of Natural Resources has an interactive web-based geologic map of the state which provides some insight into the permeability of the vadose zone[2]. Depth to an aquifer of a site can also be estimated by examining existing public data such as well logs in the vicinity. As mentioned above, well logs are available at the Ecology website[3]. Using nearby well data alone may be insufficient. Aquifers are managed and monitored by local water purveyors, in this case, Skagit Public Utility District (PUD).

2.2.2 Water Quantity

Potable water and groundwater-dependent, landscape-scale ecological processes are both supported by groundwater quantity and can be influenced by land use and human activities. This section provides a description of hydrologic processes in aquifers related to water quantity and the effects of human activities on these resources.

The quantity of water available in an aquifer is a balance between recharge, storage, and discharge. Aquifers have discrete recharge and discharge areas. Since groundwater movement is the result of downward gravitational forces, the location of recharge areas in aquifers is typically at a higher elevation than its discharge areas. This is not universal because subsurface conditions may result in groundwater flow and hydrologic gradients do not always reflect surficial topography (Driscoll 1986). Aquifer recharge can originate from rainfall, snowmelt, lakes, rivers, streams, or wetlands. Aquifer

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[2] https://fortress.wa.gov/dnr/geology/?Site=wigm
[3] http://apps.ecy.wa.gov/welllog/mapsearch.asp

discharge occurs when water leaves the aquifer and is discharged to surface water. These areas can include seeps, springs, wetlands, streams, lakes, estuaries, and shorelines. Extraction from wells or by other means is also considered an aquifer discharge.

Land use and development typically alter the dynamics of aquifer recharge within a basin. For example, replacing forests with buildings, roads, driveways, lawns, and even pastures typically reduces the recharge to underlying aquifers, while simultaneously increasing the peak runoff rates to streams. In rare instances, however, some land uses can increase recharge rates. For example, if homes in an area receive water from a river or lake and discharge that water into septic systems, the result can be an increase in recharge to the underlying aquifer, and one that has potential for introducing contaminants (Dunne & Leopold 1978; Winter 1998).

Agricultural, residential, commercial and/or industrial development may result in alterations to the natural hydrologic cycle by stripping vegetative cover, removing and destroying native soil structure, modifying surface drainage patterns, and adding impervious and nearly impervious surfaces, such as roads and other compacted soils. Loss of water in stream channels and riparian areas due to water withdrawal and consumptive use of water from streams, rivers and aquifers further reduces groundwater recharge (ECY 2021a). One of the ways in which these processes influence groundwater is through land use interactions with vegetation and the soil root zone. Vegetation has a strong effect on groundwater recharge due to evapotranspiration, with grasslands generally having greater levels of recharge and forests (Kim and Jackson 2012). Despite the influence of evapotranspiration, vegetation also improves groundwater recharge by reducing runoff and increasing soil porosity (Xiao et al. 2024). Observed groundwater declines are primarily a result of changes in groundwater recharge and well water withdrawals. The Hirst Decision (*Whatcom County vs. Hirst*) is a 2016 landmark case where the Washington State Supreme Court ruled that water is not legally available if a new well would impact a protected river or stream, or an existing senior water right. In response, Ecology collaborated with local partners to develop watershed plans and implement Streamflow Restoration Act (RCW 90.94) in the affected Water Resource Inventory Area (WRIA). As shown in Figure 1, There are four WRIAs in Skagit County including WRIA 1 (Nooksack), WRIA 3 (Lower Skagit – Samish), WRIA 4 (Upper Skagit), and WRIA 5 (Stillaguamish). Of these, only WRIA 1 is subject to the Streamflow Restoration Act. Most of the Skagit River Watershed (WRIA 3 and 4) are also subject to the Instream Flow Rule (WAC 173-503), which would interrupt any water right established after 2001 if the Skagit River falls below a minimum of 10,000 cubic feet per second (cfs). In general, these regulations seek to balance consumptive water rights with the maintenance of base stream flows necessary to support fish, particularly anadromous fish.

The Watershed Planning Act (ESHB 2514) is also applicable to CARAs in Washington State. This legislation, created in 1998, encourages voluntary planning by local governments, citizens, and tribes for water supply and use, water quality, and habitat at the WRIA or multi-WRIA level. Grants are available to conduct assessments of water resources and develop goals and objectives for future water resource management.

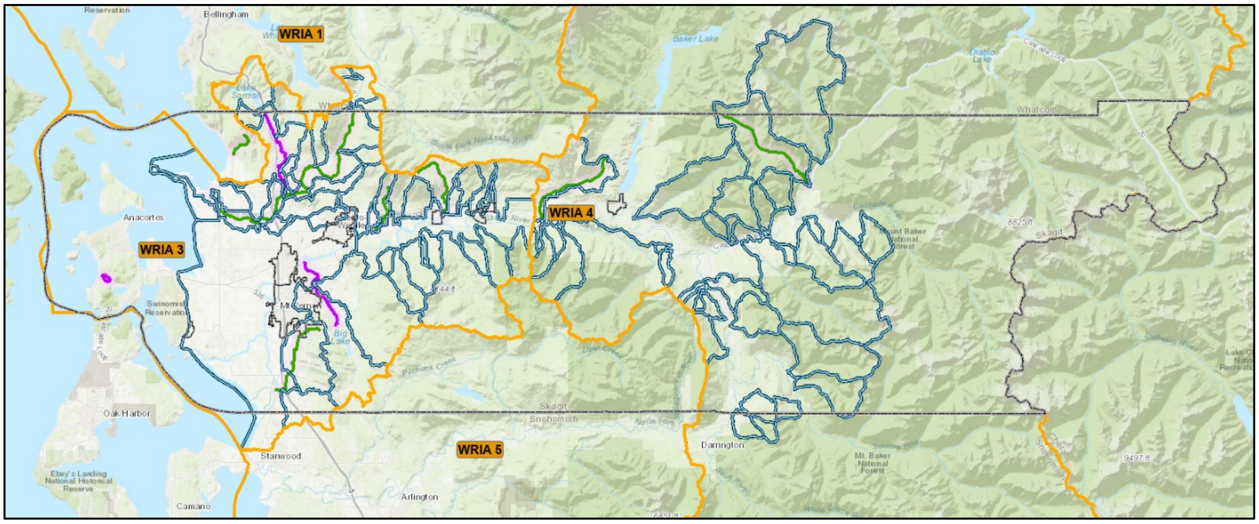

Figure 1. Skagit County WRIA Map and Low Flow Streams (printed from Skagit County iMap).

2.3 Key Protection Strategies

Key protection strategies for CARAs are based on identifying and protecting CARAs through regulations and educational community outreach. Current 2021 Ecology CARA Guidance recommends the following eight steps to characterize and protect CARAs in a local community (ECY 2021a).

1. *Identify where groundwater resources are located.*
2. *Analyze the susceptibility of the natural setting where groundwater occurs.*
3. *Inventory existing potential sources of groundwater contamination.*
4. *Classify the relative vulnerability of groundwater to contamination events.*
5. *Designate areas that are most at risk to contamination events.*
6. *Protect by minimizing activities and conditions that pose contamination risks.*
7. *Ensure that contamination prevention plans and best management practices (BMPs) implemented and followed. Review BMPs for infiltration designs with water quality treatment. Stormwater control usually affects the vadose zone and seasonal water tables with low risk to deeper water supply aquifers. Some exceptions are those glacial outwash plains with extensive deposits of coarse gravels near the surface.*
8. *Manage groundwater withdrawals and recharge impacts to maintain availability for drinking water sources and maintain stream base flow from groundwater to support in-stream flows, especially for salmon-bearing streams.*

Watershed planning is recommended to maintain in-stream flow as required by the 2018 Streamflow Restoration Act and for water supply planning under the 1998 Watershed Planning Act (Ecology 2021a).

Skagit County regulations including classification, prohibited activities, site assessment requirements, and mitigation for impacts are specified in SCC 14.24.300-340. Skagit County also maintains static maps of Category I CARA locations which are available to the public. Skagit County has one sole source aquifer on Guemes Island.[4]

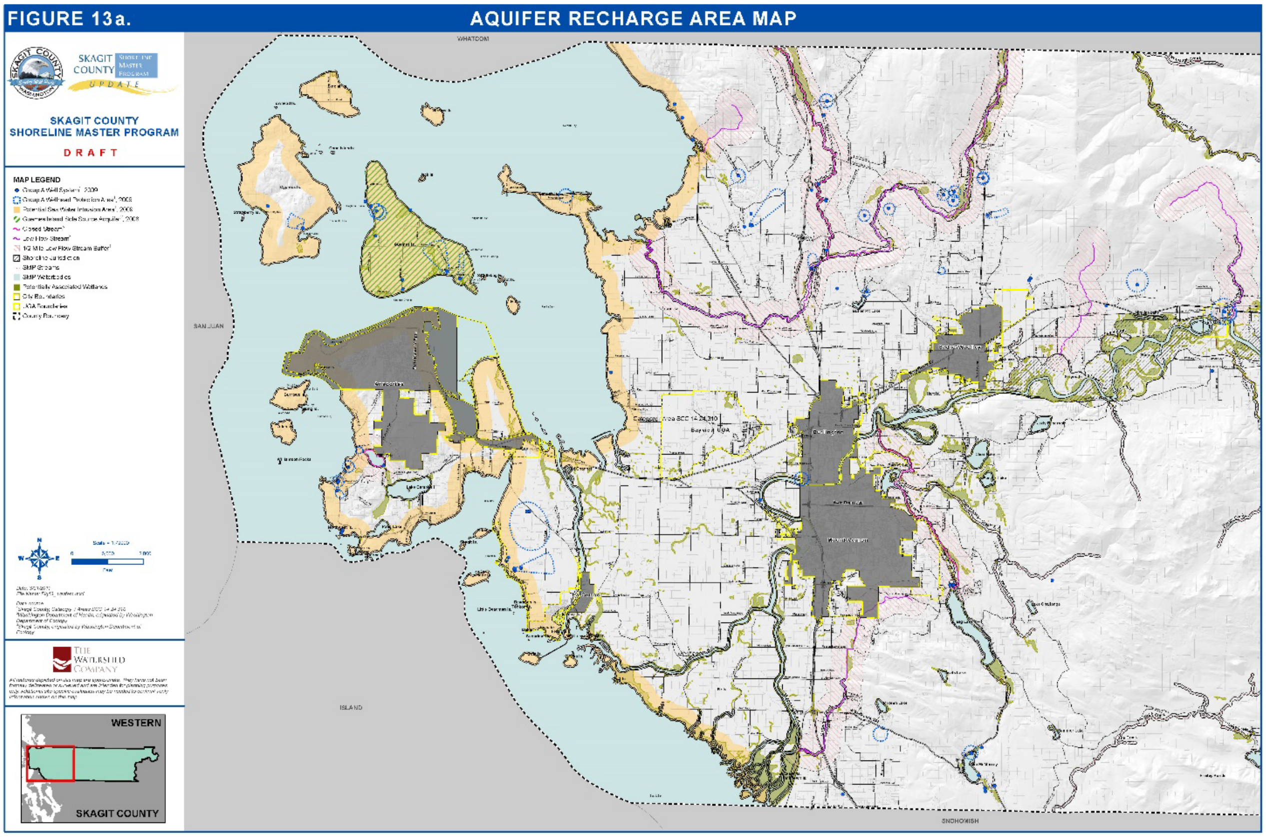

Figure 2. Skagit County Aquifer Recharge Areas (reproduced from The Watershed Company 2011).

[4] https://epa.maps.arcgis.com/apps/webappviewer/index.html?id=9ebb047ba3ec41ada1877155fe31356b

2.4 Climate Change Impacts & Mitigation

Climate change impacts groundwater quality and quantity are influenced by regional trends as summarized below. Changes to surface water inputs can alter the timing, frequency, and duration of surface water presence and are projected to alter hydrologic patterns that can affect interactions with groundwater.

- Changes in precipitation levels in summers may reduce ground surface saturation during the growing season (Mauger et al. 2919). Higher temperatures will also increase the rate of evaporation in surface waters. This will likely reduce wetland areas and the groundwater recharge they provide during the dry season. This can influence streams, wetlands, and other surface waters impacted by groundwater in addition to anthropogenic consumption.
- Wildfires will introduce more particulates and contaminants into the environment, which settle on surface water and infiltrate into groundwater (Burton et al. 2016; Mansilha et al. 2020).
- Increased winter flooding increases the likelihood of overwhelming stormwater treatment facilities and flooding roads. Thereby transporting contaminants into surface water, including local streams and wetlands that can infiltrate and contaminate aquifers (Mauger et al. 2019).
- Rising sea levels increase the potential for saltwater intrusion into coastal aquifers (Mauger et al. 2015).
- Demand for aquifers may increase as crops require greater levels of groundwater consumption to compensate for changes in precipitation levels.

Altered patterns of precipitation resulting from climate change are projected to include earlier peak stream flows, increased frequency and extent of flooding, and reduced summer flows (Mauger, et al., 2015). Groundwater is believed to be more resilient to the effects of climate change relative to surface water resources (HDR 2019). The primary stressors to aquifers are changes in the timing and amount of groundwater recharge, and increased pressure to use groundwater as surface water conditions change. Ecology recommends understanding water resources, tracking water levels and recharge sources, and focusing on water conservation as a strategy to plan for climate change impacts (ECY 2021a).

Other stressors on CARAs that may require further study include reclaimed water use and temporary construction dewatering. Ecology recommends that jurisdictions conduct a multi-year infiltration study (ECY 2021a). Population growth also presents challenges for protecting CARAs as land use intensity increases (ECY 2021a). For example, multi-year droughts can increase reliance on groundwater sources, lead to reductions in groundwater tables, aquifer depletion, and potentially result in saltwater intrusion (Asinas et al. 2022).

2.4.1 Strategies to Manage Climate Change Impacts to CARAs

- Manage stormwater to maintain groundwater recharge in CARAs. Utilize a 20-year planning horizon to manage supply and demand given climate trends and projections (Asinas et al. 2022).
- Design stormwater systems to better mimic natural systems and mitigate some of the functions lost elsewhere in the landscape due to changes in surface and groundwater

inputs. For example, the use of roadside bioswales may be expanded. Stormwater treatment capacity may be increased as needed to protect water quality and manage water quantity.

- Planning and implementing flood mitigation strategies can reduce the likelihood of contaminated runoff events.
- Preserve open space and concentrate urban development away from CARAs.
- If necessary, strengthen regulatory protection of CARAs. For example, the County may review the CARA mapping, determine the areas of highest risk to drinking water, and prioritize protection of those areas. The County can reduce the risk of groundwater contamination by prohibiting land uses that are high-risk within high-priority areas. Public outreach education on best management practices (BMPs) for spills and leaks can also be improved.
- Maintain updated CARA maps and classifications.
- Review regulatory requirements for reclaimed water use and temporary dewatering during construction to ensure adequate protections are in place. This may involve additional County-specific studies.
- Continue to modify public outreach efforts to educate residents about best practices in CARAs and promote water conservation and water use efficiency programs.
- Promote and incentivize low-impact development, specifically infiltration of clean runoff to support aquifer recharge.
- Balance growth and development with the preservation and restoration of open spaces and native vegetation tracts.

3. Frequently Flooded Areas

3.1 Definitions

Frequently flooded areas (FFAs) are floodplains and flood prone areas that pose a risk to public safety. FFAs also serve important habitat functions for fish and wildlife. FFAs are defined in WAC 365-190-030(8) as follows:

> *Frequently flooded areas" are lands in the flood plain subject to at least a one percent or greater chance of flooding in any given year, or within areas subject to flooding due to high groundwater. These areas include, but are not limited to, streams, rivers, lakes, coastal areas, wetlands, and areas where high groundwater forms ponds on the ground surface.*

The Skagit County's definition of a frequently flooded area is (SCC 14.04.020):

lands in the floodplain subject to a 1% or greater chance of flooding in any given year, and those lands that provide important flood storage, conveyance, and attenuation functions, as determined by the Administrative Official in accordance with WAC 365-190-080(3). At a minimum, the 100-year floodplain designations of the Federal Emergency Management Agency and the National Flood Insurance Program.

3.2 Functions and Values

Floods are regularly occurring weather events that can result in destruction of property and loss of life, but are also responsible ecological processes that sustain river systems. Floods typically occur following large storm events, but may also result from a collapse of impounded water, such as from a dam or levee failure, or beaver activity. FFAs are dynamic and ecologically productive environments that provide important habitats for fish and wildlife and floodplain storage that alleviates downstream flood zone impacts. These processes overlap with many of the functions of Fish and Wildlife Conservation Areas (FWHCAs) as discussed in Section 6.2.1, so this section briefly summarizes processes and functions as they relate to floodplain dynamics.

Dynamic hydrologic processes, including the mobilization of large woody debris and other allochthonous inputs, can be critical to the maintenance of fish and wildlife habitat (Naiman & Decamps 1997; Petts et al. 2005). High-flow channels carved into floodplains provide important habitat for a variety of fish species and create areas of refuge from the high-velocity flows. Streams overtop their banks during periods of high flow and deposit sediment load, cumulatively forming a flood plain (Dunne and Leopold 1978; Knighton 1998). Floodplains also provide storage of floodwaters that can reduce the severity of other areas in the watershed, and contribute to infiltration and aquifer recharge.

Streams are often modified to protect development from destructive floods, typically in the form of channel straightening and armoring. These modifications can cause rivers to become disconnected from their natural floodplains and associated wetlands (Booth 1990). Other land use changes associated with urbanization such as impervious surfaces and deforestation also influence floodplains by increasing the magnitude and frequency of floods (Booth et al. 2002). In landscape-level assessments, patterns of urban development, particularly impervious surface area and distribution, have been demonstrated to influence watershed functions (Alberti et al. 2006). Among these are stream channel downcutting, a process associated with watersheds that have frequent and short duration high peak flows, that further disconnects floodplains, increases in-stream erosion, and deposits sediment in downstream environments leading to blocked culverts (Booth 1990). Stream incision also affects surface and ground water interactions and may result in lower water table levels (Petralia 2022).

Flooding can result in significant economic costs from damaged homes and infrastructure, business disruption, and loss of life. Floodplains have been used for agriculture, residential development, and urbanization for centuries because the geographic locations tend to be well-suited for development during periods between floods. The proximity of development to rivers and large water bodies, and advantages in travel, transport, and discharge of waste, otherwise provide ideal settlement locations. Dikes, levees, and associated floodplain fill have been a historically common approach to protecting development, which has consequentially worsened flood impacts to some downstream areas and sometimes failed to protect the areas that were intended. Altered river dynamics, including sediment and large woody debris accumulation as well as increased flows associated with upstream land use changes, has overwhelmed some aging flood control works that have not been maintained or improved. The human and societal costs of flooding have increased over time as the population and amount of infrastructure in floodplains has increased and from climate change.

3.3 Key Protection Strategies

Floodplain protection strategies serve the dual purpose of protecting property and infrastructure, and the ecological integrity of streams and watersheds. In 1989, Skagit County developed a Comprehensive Flood Hazard Management Plan (CFHMP) (Brown and Caldwell 1989). A Comprehensive Flood Hazard Management Plan (CFHMP) is a planning document that presents information about existing streams, rivers, land uses, and regulations related to flood hazards, identifies goals for flood hazard reduction consistent with the needs of residents, businesses, and neighboring jurisdictions, and identifies flood hazards, evaluates alternative solutions, and recommends future projects or program modifications to address these hazards, and lastly certification from the Emergency Management Division of the Washington State Military Department / local emergency management organization (ECY 2021a). Skagit County has also developed a natural hazard mitigation plan to review and manage natural hazards, most recently updated in 2023 (Skagit County 2023).

One of the primary strategies to reduce hazards associated with frequently flooded areas is to restrict development in mapped floodplains (Figure 3). Skagit County has adopted and codified regulations in SCC Chapter 14.34 to enforce flood damage prevention as a part of the Unified Development Code. Flooding strategies are also addressed in the shoreline master program (SMP) as codified in SCC 14.26 and the critical areas ordinance in SCC 14.24.

Floodplain management is generally based on a no-adverse-impact strategy (ASFPM 2003). This approach requires floodplain property owners to ensure that their land use does not adversely affect flood storage or flood risk for others, including risks of flow velocities and erosion. This is commonly achieved by requiring no net increase in flood elevations. This approach protects natural floodplain processes and encourages restoration, such as reconnecting side channels and reducing armoring.

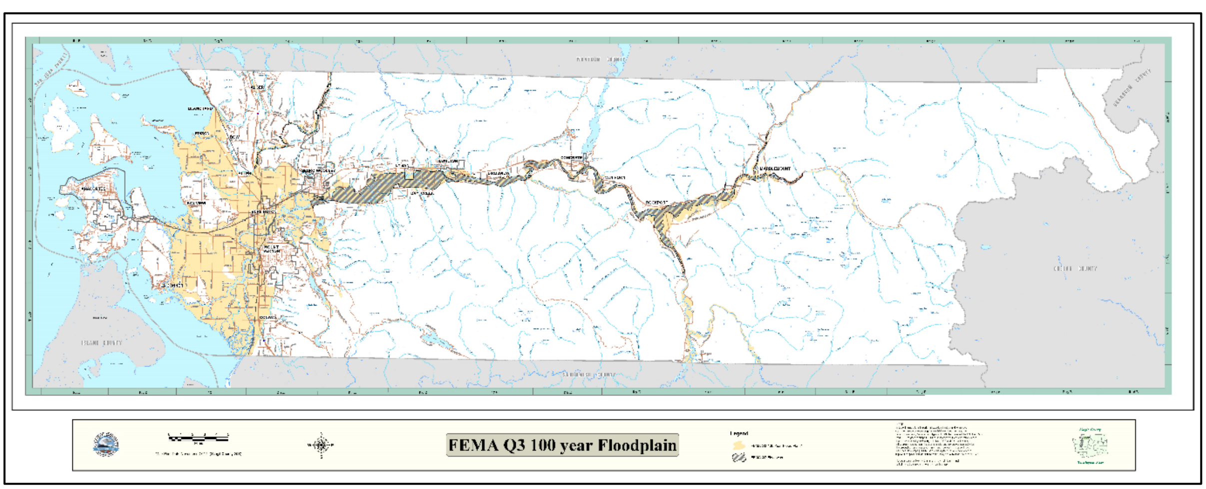

Figure 3. Skagit County floodplains (reproduced from Skagit County 2017).

3.4 Climate Change Impacts & Mitigation

Climate change in the Pacific Northwest is anticipated to result in wetter autumns and winters and drier summers (Mote and Salathe 2010). Climate change models predict that the frequency of atmospheric rivers, which contribute to severe deluges in rainwater and other extreme weather events, will become more frequent and severe (Mauger & Kennard 2017; Salathe et al. 2014). Greater flood risks are predicted as a result of the increased precipitation paired with the increased frequency and intensity of extreme weather events (ECY 2021a). The resulting increase in floodwater elevation and expansion of floods to new areas is a risk to property and public safety. Stream channel migration can also drastically alter flood risks and migration dynamics are expected to shift as a result of climate change (Mauger and Kennard 2017). Climate change can also influence flooding in coastal areas due to sea level rise, high tides, storm surges and waves (Mauger and Kennard 2017).

Extreme floods impose both positive and negative effects on stream health. Impacts include physical trauma and stress to aquatic organisms, displacement or stranding, erosion and sedimentation, loss of vegetation, pollution, disruptions to food webs and spawning, and disrupted migration. As a result, extreme floods have been documented to reduce fish densities (Milner et al. 2013). However, some studies show that fish assemblages are resilient to the effects of floods at a basin scale and recover quickly (George et al. 2015). Potential positive effects include the creation of new habitats and nutrient redistribution (Peters et al. 2015).

3.4.1 Strategies to Manage Climate Change Impacts to FFAs

The Washington Silver Jackets is an interagency group that was formed in 2010 to plan and manage flood risks. This group works to develop improved estimates of future flooding, develop resources for local planners, build capacity and coordinate on resiliency, improve public engagement, and coordinate floodplain management goals (Mauger & Kennard, 2017). The University of Washington Climate Impacts Group has collaborated with the Washington Silver Jackets to integrate climate change predictions and impacts into flood management planning efforts. This resulted in the development of the report: *Integrating Climate Resilience in Flood Risk Management: a Work Plan for the Washington Silver Jackets Team* which provides a framework for strategic management (Mauger & Kennard 2017).

- Develop improved estimates of future flood impacts (Mauger & Kennard 2017).
- Develop resources for local planners (Mauger & Kennard 2017).
- Build capacity and coordination on resiliant floodplain management (Mauger & Kennard 2017).
- Improve public engagement (Mauger & Kennard 2017).
- Coordinate floodplain goals and mangement (Mauger & Kennard 2017).
- Maintain and update CFHMP and SMP to support stormwater management, salmonid habitat, and streamflow planning (ECY 2021a).
- Implement and enforece Skagit County and Washington State laws and policies regarding flood prevention during permitting and development.

- Encourage and incentivize floodplain restoration actions to restore floodplain connectivity to streams and wetlands and protect or restore riparian corridors to maintain microclimate.
- Utilize the FEMA Climate Resiliency approach to support flood hazard management planning and follow grant funding opportunities.
- Refine topographic floodplain analysis to identify potential changes in floodplain extents.

4. Geologically Hazardous Areas

Geologically hazardous areas are defined similarly by Washington State and Skagit County as follows:

> Washington State Definition*: areas that because of their susceptibility to erosion, sliding, earthquake, or other geological events, are not suited to the siting of commercial, residential, or industrial development consistent with public health or safety concerns" (WAC 365-190-030)*
>
> *Skagit County Definition: areas that may not be suited to development consistent with public health, safety, or environmental standards, because of their susceptibility to erosion, sliding, earthquake, or other geological events as designated by WAC 365-190-080(4). Types of geologically hazardous areas include: erosion, landslide, seismic, mine, and volcanic hazards." (SCC 14.04.020)*

The four main types of geologically hazardous areas recognized in the GMA are erosion hazard areas, landslide hazard areas, seismic hazard areas, and areas subject to other geologic events such as coal mine hazards and volcanic hazards (RCW 36.70A.030; WAC 365-190-120). Skagit County regulates these four categories of geologic hazard areas, consistent with GMA requirements (SCC 14.24.400).

The purpose of regulating activities in geologically hazardous areas is to protect the public from potential risks. Geologic events may occur in hazardous areas that can result in property damage, injury, and the loss of life. The type of land use and development in these areas influences the level of risk and may, in some cases, increase the potential for a hazardous event. There is public interest in regulating these areas because a geologic event occurring on one property can impact large surrounding areas. It is important to identify where such hazard areas are located to ensure that activities and development in those areas are managed for safety and stability.

Although the general protective approach is to avoid disturbing geologic hazard areas, WAC § 365-190-080(4) states "Some geological hazards can be mitigated by engineering, design, or modified construction or mining practices so that risks to health and safety are acceptable".

4.1 Definitions

4.1.1 Erosion Hazard Areas

Erosion hazard areas are defined by Skagit County as "those areas containing soils which, according to the United States Department of Agriculture Soil Conservation Service Soil Classification System, may experience severe to very severe erosion" (SCC 14.04.020). According to SCC 14.24.410(1) the following are considered known or suspected erosion hazards:

- *Areas with gradients greater than or equal to 30%.*
- *Areas located within the following map units: No. 1 Andic Cryochrepts, Nos. 3 and 4 Andic Xerocrepts, No. 13 Birdsview, Nos. 47 and 48 Dystric Xerochrepts, Nos. 50 and 51 Dystic Xerorthents, Nos. 63 and 65 Guemes, No. 69 Hoogdal, No. 90 Lithic Haploxerolls, No. 91 Marblemount, No. 99 Mundt and Nos. 150 and 151 Typic Croyorthods or mapped severe erosion hazard, as identified in the U.S. Department of Agriculture Natural Resources Conservation Service Soil Survey of Skagit County Area, WA (1989).*
- *Coastal beaches or bluffs.*
- *Areas designated in the Department of Ecology, Coastal Zone Atlas, Washington, Volume Two Skagit County (1978) as U (Unstable), UB (Unstable Bluff), URS (Unstable Recent Slide), or UOS (Unstable Old Slide).*
- *Areas susceptible to rapid stream incision and stream bank erosion.*

4.1.2 Landslide Hazard Areas

Landslide hazard areas are defined by Skagit County as "areas potentially subject to risk of mass movement due to a combination of geologic, topographic, and hydrologic factors." (SCC 14.04.020). According to SCC 14.24.410(2), regulated landslide hazard areas are classified by the presence of any of the following indicators:

- *Areas designated in the Department of Ecology, Coastal Zone Atlas, Washington, Volume Two, Skagit County (1978) as U (Unstable), UB (Unstable Bluff), URS (Unstable Recent Slide), or UOS (Unstable Old Slide).*
- *Slopes having gradients of 15% or greater: that intersect geologic contacts with permeable sediments overlying low-permeability sediment or bedrock and springs or groundwater seepage are present; or that are parallel or subparallel to planes of weakness (such as bedding planes, joint systems, and fault planes) in subsurface materials.*
- *Slopes of 40% or steeper and with a vertical relief of 10 feet or more.*
- *Areas of previous failure such as earth slumps, earthflows, mudflows, lahars, debris flows, rock slides, landslides or other failures as observed in the field or as indicated on maps or in technical reports published by the U.S. Geological Survey, the Geology and Earth Resources Division of the Washington Department of Natural Resources, or other documents authorized by government agencies.*
- *Potentially unstable areas resulting from rapid stream incision, stream bank erosion, and undercutting by wave action.*
- *Coastal bluffs.*
- *Slopes with a gradient greater than 80% and subject to rock fall.*
- *Areas that are at risk from snow avalanches.*
- *Areas designated on the Skagit County Alluvial Fan Study Orthophoto Maps as alluvial fans or as identified by the Administrative Official during site inspection.*

- *Areas located in a narrow canyon potentially subject to inundation by debris flows or catastrophic flooding.*
- *Those areas delineated by the U.S. Department of Agriculture's Natural Resources Conservation Service Soil Survey of Skagit County as "severe" (Table 9) limitation for building development.*

4.1.3 Seismic Hazard Areas

Seismic hazard areas are defined by Skagit County as "those areas that are subject to severe risk of damage as a result of earthquake-induced ground shaking, slope failure, settlement, soil liquefaction or surface faulting" (SCC 14.04.020). Seismic hazard areas are areas subject to damage resulting from earthquake-induced landslides, seismic ground shaking, dynamic settlement, fault rupture, soil liquefaction, or flooding caused by tsunamis and seiches. Seismic hazards are identified in the Washington State Department of Natural Resources (WDNR) Geologic Information Portal[5]. The WDNR Geologic Information Portal contains information projecting the Cascadia, Seattle, and Tacoma Seismic Scenarios which include Skagit County.

Regulated landslide hazard areas are identified for regulation within Skagit County by the presence of any of the following indicators (SCC 14.24.410(3)):

- *Areas located within a high liquefaction susceptibility as indicated on the Liquefaction Susceptibility Map of Skagit County issued by Washington Department of Natural Resources dated September 3, 2004, or as amended thereafter. A site assessment is not required for high liquefaction hazard areas for single-family residence proposals unless other criteria provided in this Section apply.*
- *Areas located within 1/4 mile of an active fault as indicated on investigative maps or described in studies by the United States Geologic Survey, Geology and Earth Resources Division of the Washington Department of Natural Resources, or other documents authorized by government agencies, or as identified during site inspection.*
- *Those known or suspected erosion and landslide hazards referenced in Subsections (1) and (2) of this Section.*
- *Tsunami and seiche hazard areas include coastal areas and lake shoreline areas susceptible to flooding, inundation, debris impact, and/or mass wasting as the result of coastal or inland wave action generated by seismic events or other geologic events. Suspect tsunami hazard areas are indicated on the Tsunami Hazard Map of the Anacortes-Whidbey Island Area, Washington: Modeled Tsunami Inundation from a Cascadia Subduction Zone Earthquake. A site assessment is not required for tsunami and seiche hazard areas but they are addressed through the frequently flooded section of this Chapter.*

4.1.4 Mine Hazard Areas

Mine hazard areas are defined by Skagit County as "areas underlain by or affected by underground mine workings such as adits, tunnels, air shafts and those areas adjacent to steep slopes produced by open pit mining or quarrying but excluding any areas where the mine workings have been properly

[5] https://geologyportal.dnr.wa.gov/

stabilized and closed and made safe consistent with all applicable Federal, State and local laws" (SCC 14.04.020). Mine hazard critical areas are further designated under SCC 14.24.410(5) as "designated on the Department of Natural Resources Map: Coal Measures of Skagit County (1924) or within 200 feet of any other current or historic mine operations determined to be a suspect or known geologically hazardous area by the Administrative Official."

4.1.5 Volcanic Hazard Areas

Skagit County defines volcanic hazard areas as "those areas subject to pyroclastic flows, lava flows, debris avalanches, and inundation by debris flows, mudflows, lahars or related flooding resulting from volcanic activity" (SCC 14.04.020). Volcanic hazard areas also include areas that have not been recently affected but could be affected by future such events. The classes of lahar hazards (Class I, II, and III) were classified in a 1998 USGS open-file report on Mount Rainier's volcanic hazards (Hoblitt et al. 1998).

4.2 Hazard Characterization

4.2.1 Erosion Hazard Areas

Erosion hazard areas present risks to infrastructure, the environment, and public safety. For example, erosion may undermine the foundation of buildings or other structures, and increase the risk of landslides which threaten property and human life. There is also a direct link between erosion and impacts to other aquatic critical areas including streams, ponds, and wetlands (Dubois et al. 2018).

Erosion and landslides are natural processes that contribute sediment, rocks, and large woody debris to streams and other waterbodies. The introduction of periodic pulses or chronic turbidity and suspended solids associated with erosion has been demonstrated to harm certain types of aquatic life, particularly salmonids (Bash et al. 2001). This can occur from activities such as clearing vegetation and the creation of new impervious surfaces, which can introduce sediments and pollutants to natural waterways (Booth 1991). Further discussion of the effects of erosion and sediment on streams is provided in Section 6.2.1.

The stability of erosion hazard areas is influenced by the vegetation composition, structure, and cover. Vegetation reduces erosion through rainwater interception and by anchoring soils within root networks (Booth et al. 2002; Naiman and Decamps 1997). In cleared areas, rainfall tends to concentrate in small channels, and sediment can be mobilized as the water gains depth, volume, and increased flow. Small channels or rills can eventually develop into gullies in these types of exposed soils.

4.2.2 Landslide Hazard Areas

Landslides are difficult to predict because bluff geology, sediment composition, topography, and hydrology all influence risk of failure. Steeper slopes are more prone to failure due to increased gravitational stresses (Shipman 2004). Certain land use modifications and development activities have the potential to increase the likelihood of landslides to occur, such as vegetation removal and the creation of new impervious surfaces. In addition to anchoring sediments, the process of evapotranspiration by plants transforms groundwater into atmospheric vapor and intercepts rainwater (Schmidt et al. 2001; Watson and Burnett 1995). The anchoring and hydrologic functions of vegetation lower the risk of slope failure and shallow-rapid landslides (Schmidt, et al., 2001). The WDNR Geologic Information Portal provides mapping for known landslide areas within Skagit County (Figure 4).

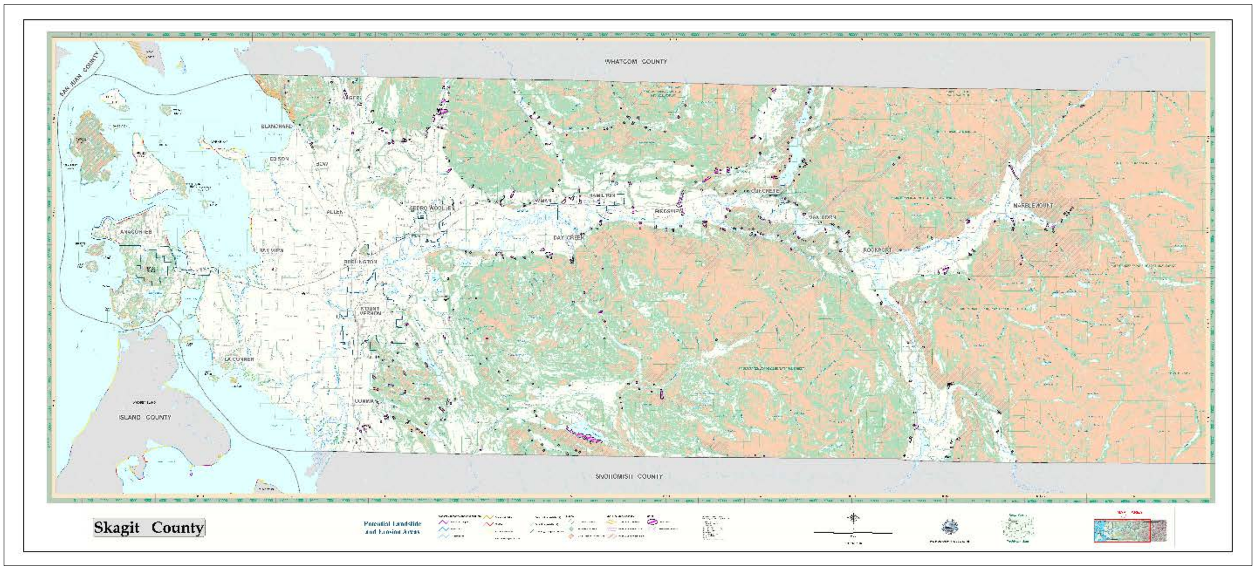

Figure 4. Skagit County potential landslide and erosion hazard map.

Alluvial fans are triangle shaped deposits of sediment which occur when mountainous areas approach topographically flatter areas. They are included in the concept of landslide hazard areas although they also share characteristics of flood hazard areas due the associated risks include debris flows, flash floods, mudflows, and outburst floods. These types of flows are extremely dangerous even in small levels because of the destructive nature of swiftly moving large debris and floodwaters. The risk of flash floods and debris flows increases following wildfires due to changing hydrologic characteristics in landscapes with bare soils and lacking vegetation (WALERT 2023). Skagit County has inventoried alluvial fans subject to critical area regulations as shown in Figure 5.

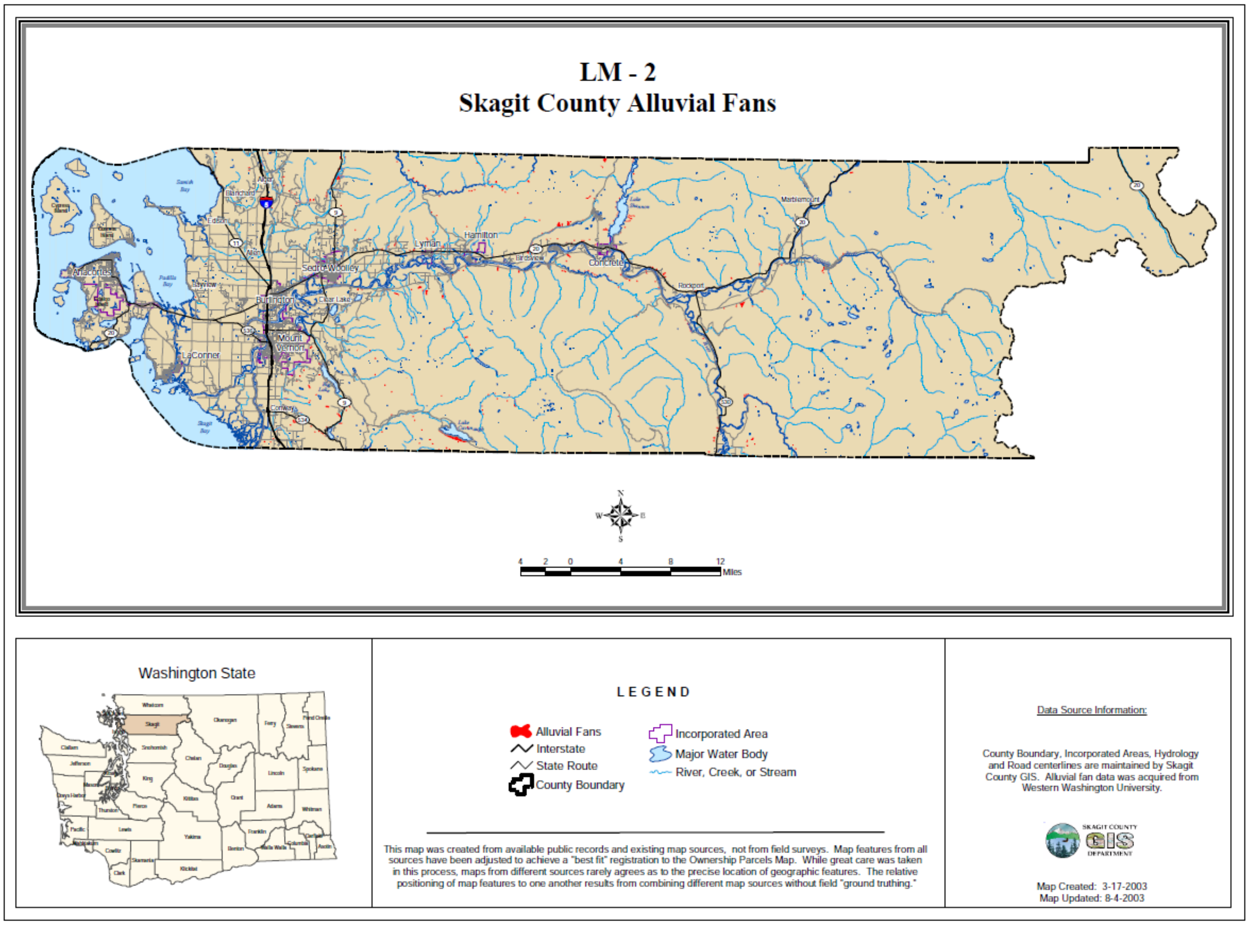

Figure 5. Skagit County alluvial fan map.

4.2.3 Seismic Hazard Areas

Skagit County is located in an area of high seismic activity, as are all areas of Western Washington (Cooper 2006). There are between 1,000-2,000 earthquakes which occur annual between Washington and Oregon, although most are small and fewer than 25% are perceptible (Cooper 2006; McCrumb et al. 1989). The probability of occurrence and risk of earthquakes depends on location, and seismic hazard areas have been mapped to identify areas with the greatest risk.

Secondary hazards associated with seismic events include liquefaction of the soil, rockfall, landsliding, dam failure, levee failure, and tsunamis or seiches. Liquefaction hazard areas within Skagit County are mapped by the Washington Department of Natural Resources (Figure 6), in addition to seismic site class and seismic design categories. Nearly all areas of Skagit County have some level of seismic risk, even outside of designated critical areas.

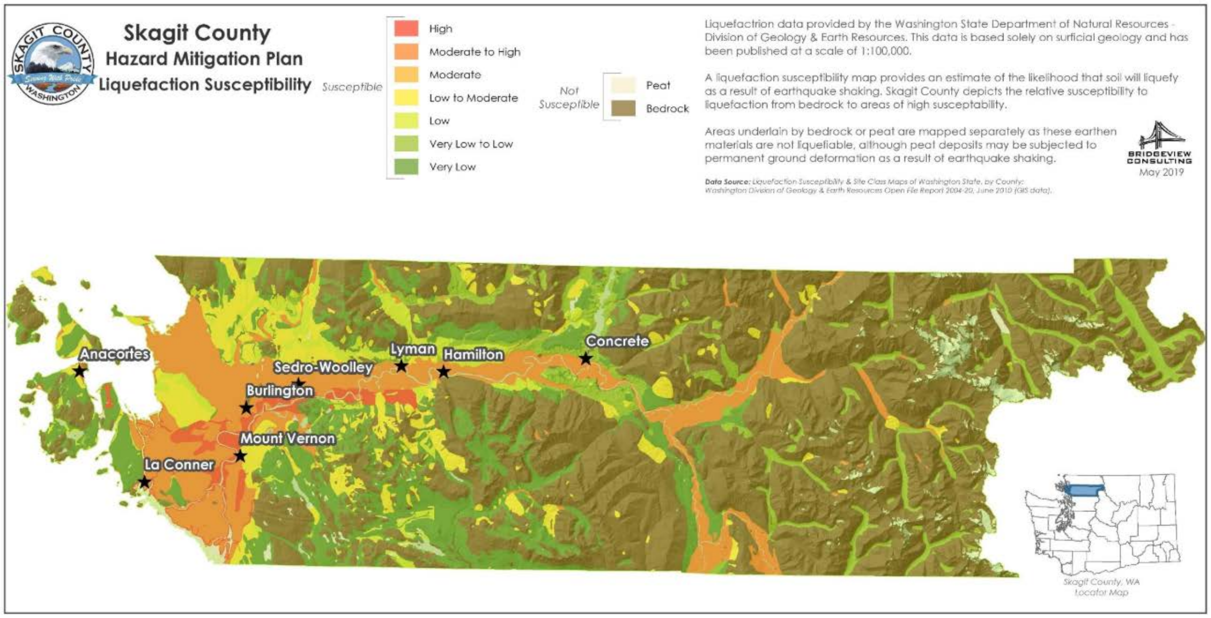

Figure 6. Skagit County Liquefaction Susceptibility (reproduced from Bridgeview Consulting 2019).

4.2.4 Mine Hazard Areas

Active and closed mines pose potential hazards because they can lead to increased risks of erosion, mass wasting, and landslides near surface mines, and subsidence over collapsed tunnels and shafts in subsurface mines. Since the potential risks of subsurface mines are not obvious, evaluation and disclosure to landowners are essential to protecting infrastructure and public safety.

Skagit County has 1,363 records of mining claims on public land managed by the Bureau of Land Management (BLM) and 122 records of mining mines listed by the United States Geological Survey (USGS). Mined commodities are primarily metals such as gold, copper, silver, nickel, chromium, lead, zinc, manganese, and iron[6].

4.2.5 Volcanic Hazard Areas

There are five major active volcanoes in Washington which include Mount Rainier, Mount Saint Helens, Mount Adams, Mount Baker, and Glacier Peak. These mountains are part of a volcanic arc that extends from northern California to British Columbia (Hildreth 2007). All of these volcanoes have erupted in the last 250 years and together have erupted over 200 times in the prior 12,000 years (Cooper 2006; Pringle 1994).

Mount Baker and Glacier Peak are both located near Skagit County's jurisdictional boundary, though no volcanoes are present within Skagit County. Mount Baker is reported to erupt approximately every 100-200 years but has low relative incidence of explosive eruption (Waldron 1989). Glacier Peak erupts approximately every 900-1,100 years and has a low-to-high relative incidence of explosive eruptions

[6] Mine claims and commodities data obtained from https://thediggings.com/usa/washington/skagit-wa057

(Waldron 1989). Lahars from previous eruptions at both Glacier Peak and Mount Baker have extended to the Skagit River delta (Cooper 2006; Pringle 1994).

Areas mapped in Skagit County to have potential risk for lahar flows from Mount Baker include the Skagit River valley by way of Shannon Lake, to the Puget Sound (Waldron 1989; WDNR 2014). Lahar flows from Glacier Peak in can potentially extend through Sauk River, Suiattle River, and Skagit River to the Puget Sound (Waldron 1989; WDNR 2014). Previous eruptions from Glacier Peak have generated lahar flows that extended all the way to the Puget Sound at the Skagit River delta (Pringle 1994). Ashfall hazard zones, areas with the potential to accumulate 2 in (5 cm) or more of volcanic ash also extend through much of eastern Skagit County (Waldron 1989).

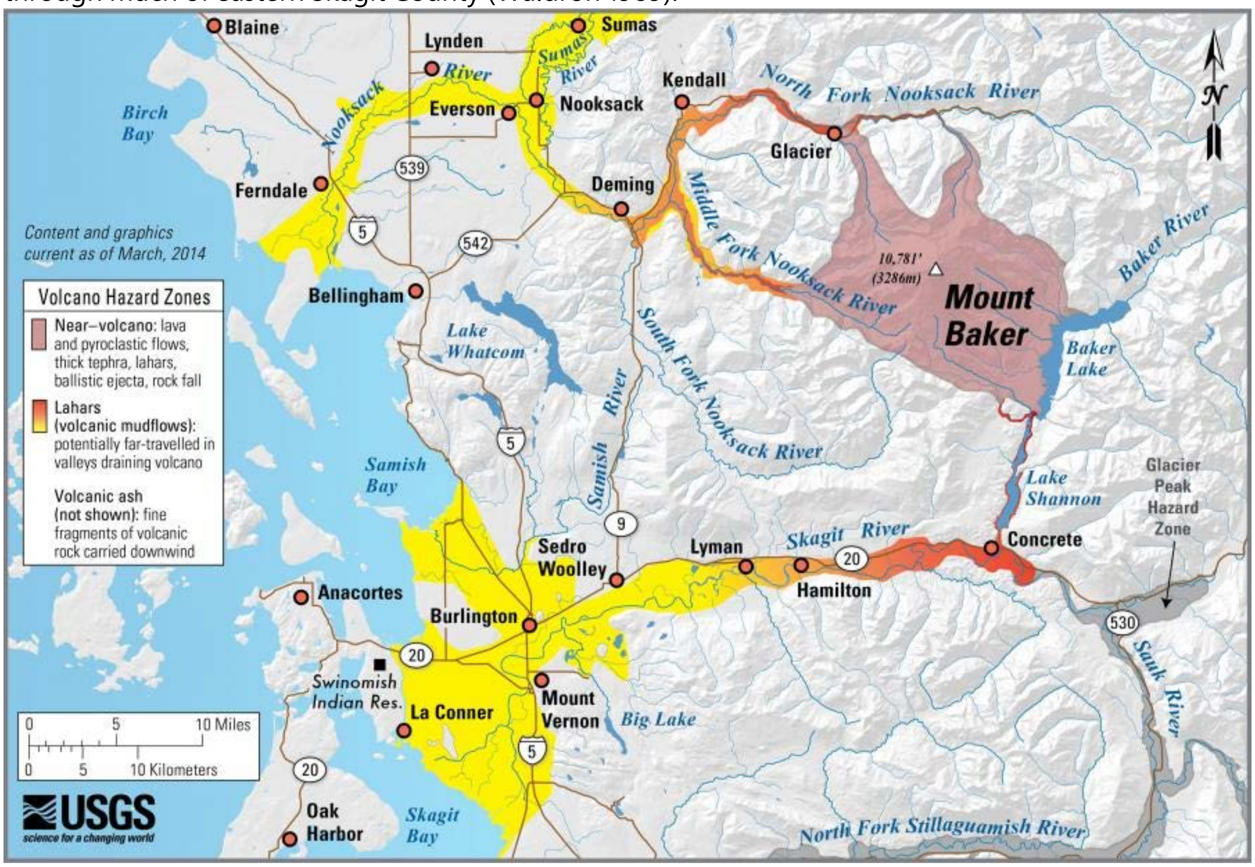

Figure 7. Volcanic hazard zones from Mount Baker (reproduced from USGS 2014a).

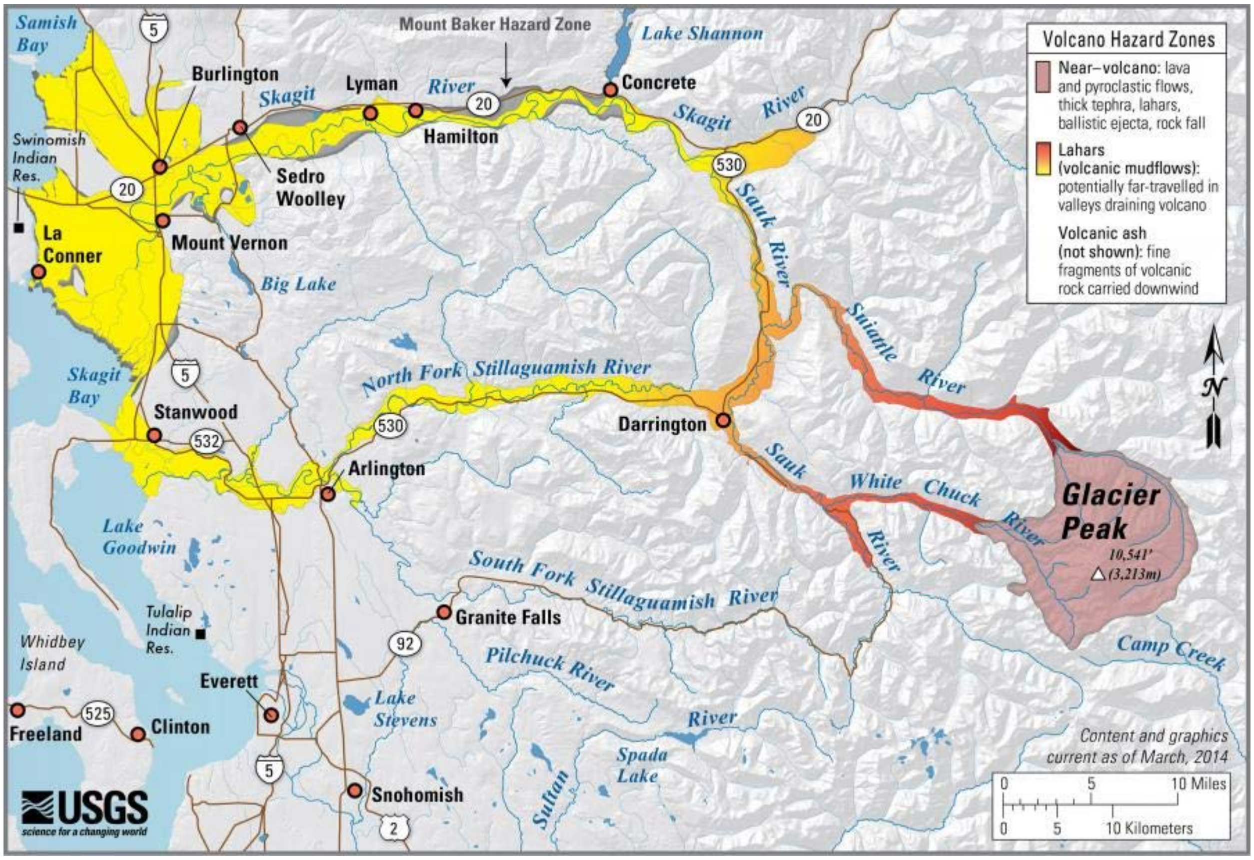

Figure 8. Volcanic hazard zones from Glacier Peak (reproduced from USGS 2014b).

4.3 Key Protection Strategies

The primary goal of protection measures for geologic hazards is to protect people and property. USGS has mapped volcanic hazards for Mount Baker and Glacier Peak as part of a volcanic hazard assessment, which lays the groundwork for risk management. An early detection system for volcanic activity exceeding background levels on Mount Baker and Glacier Peak is monitored by the Cascade Volcano Observatory, of the USGS, in cooperation with the Pacific Northwest Seismic Network. Volcanic eruptions typically have a longer warning phase before the onset of eruption than the initiation of other natural disasters such as flooding and earthquakes with potential warning of months to days. This warning system is a primary mechanism for protecting people who live in hazard zones.

Risk management also occurs at the stage of planning and development. Risks can be minimized by limiting the occupancy and development in geologic hazard areas. This risk of development in geologic hazard areas is evaluated with classification systems to inform site development restrictions and requirements. One method to manage risk is the protection of buffers around geologic hazard areas to restrict development in hazard areas. For development in erosion hazard or landslide hazard area, design and construction standards are necessary to prevent the development from reducing slope stability and ensuring that development is resilient to potential hazards. Any such development in the hazard area or its buffer should be evaluated on a site-specific basis by a licensed geotechnical engineer or engineering geologist. Methods used in site studies should adhere to best professional standards and include subsurface exploration and testing of soils at an appropriate frequency across the site as necessary.

Additional protection strategies were identified by the SR-530 Landslide Commission following the Oso mudslide that occurred in March 2014. Recommendations from the commission include integrating and funding Washington's emergency management system, supporting a statewide landslide hazard and risk mapping program, establishing a geologic hazards resilience institute, conducting landslide investigations, and advancing public awareness of geologic hazards. Integrating Washington's emergency management system would bring together, "the Governor's office, the [state] Legislature, tribes, county and municipal government, first responders, transportation agencies, non-government support agencies, the private sector, and members of the public" (SR530 Landslide Commission 2014). To improve landslide hazard and risk mapping, collaboration among agencies and landowners is recommended along with risk prioritization, utilization of lidar mapping and GIS database tools.

Per the SR-530 Landslide Commission's 2014 findings, updates to critical area regulations are recommended to better identify and regulate land uses in geologic hazard areas. This may include requiring geologic risk assessments as part of subdivision permit application reviews, slope-density regulations, conservation easements, and grading ordinances. Slope-density calculation is a method for determining the number of allowable development units of subdivisions with geological hazards. Usually the steeper the slope, the fewer the number of units permitted.

Seismic hazards can be managed by applying earthquake-resistant building standards to at-risk areas. The Washington State Building Code (WAC 51-50) offers guidance from the 2018 International Existing Building Code with amendments specific to the State, including several directly related to seismic standards.

4.4 Climate Change Impacts and Mitigation

Geologically hazardous areas, particularly erosion hazard areas, and landslide hazard areas, are anticipated to be influenced by climate change. Climate change models project warmer, drier summers, and increased precipitation in other seasons while maintaining roughly the same amount of annual precipitation (Dalton et al. 2013). Extreme precipitation events modeled by the UW Climate Impacts Group are expected to increase in intensity and frequency (Mauger et al. 2021). Increased magnitude and frequency of rain events can lead to over-saturated soils and contribute to slope instability in hazard areas. Consequentially, geologic hazard risks are anticipated to increase because rainfall intensity and duration are known indicators of landslide events (Chleborad 2006; WDNR 2020). Additionally, the severity and frequency of wildfire is expected to increase, heightening susceptibility to erosion and landslide hazards (Mauger et al. 2015).

Changing climate is also anticipated to affect vegetation community composition and native plant mortality due to shifts in plant hardiness zones and species ranges (Lenoir & Svenning 2015). Existing species assemblages, canopy types, and root systems may be disrupted and displaced by invasive species. Although plant provenance is not the only indicator of a plants capability to stabilize slopes, opportunistic invasive plants often have shallow root systems and short lifespans that are less effective at anchoring soils than native counterparts. Himalayan blackberry, for example, is a wide spread invasive plant likely to displace lost plants and has shallow root system and can cause soil erosion by preventing the establishment of native counterparts (Gaire 2015). High levels of plant diversity also generally improve soil stability by combining multiple forms of root architecture (Ghestem et al. 2014).

4.4.1 Management Recommendations for Climate Change Impacts

- Encourage or require climate-informed design for development and infrastructure in or near geologic hazard areas (WDNR 2020).
- Require appropriate surface and ground water management practices for development near coastal bluffs.
- Encourage utilization of soft shore protection strategies.
- Identify and prioritize geologic hazards within the County, then update mapping as needed using current practices such as LiDAR and GIS database tools.
- Keep in communication with the governor's office to ensure the Skagit County is included in statewide collaborative efforts to manage geologic hazard areas.
- Manage vegetation for climate resilience and slope stability.

5. Wetlands

5.1 Definitions

Scientists have worked to develop a wetland definition based on scientifically defensible criteria since interest in managing and protecting wetland resources scaled up in the 1950s. When the Clean Water Act of 1977 (CWA) was signed into law, a definition was agreed upon and applied consistently at a national scale. It is defined as follows (33 CFR § 328.3):

> *Wetlands are 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.*

Washington State also has a wetlands definition that is similar to the CWA but includes certain exceptions for artificial wetlands. It is defined in WAC 365-190-030(22) as follows:

> *'Wetland' or 'wetlands' means areas that are inundated or saturated by surface water or groundwater 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 do not include those artificial wetlands intentionally created from nonwetland sites, 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 a road, street, or highway. However, wetlands may include those artificial wetlands intentionally created from nonwetland areas to mitigate conversion of wetlands, if permitted by the county or city.

The Skagit County definition of a wetland is a combination of the CWA and Ecology definitions, as follows (SCC 14.04.020):

…areas that are inundated or saturated by surface water or groundwater 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. For the purposes of this Title, those portions of a lake that meet the definitional criteria for "wetland" shall be regulated under the wetland section of this Title. Wetlands do not include those artificial wetlands intentionally created from non-wetland sites, including, but not limited to, 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 a road, street, or highway. Wetlands may include those artificial wetlands intentionally created from non-wetland areas created to mitigate conversion of wetlands.

5.2 Functions and Values

Wetland processes provide many functions that are recognized for their social, ecological, and economic benefits. Three functional categories which include water quality, hydrology (water quantity), and habitat, are typically considered to be most crucial in terms of their influence on that natural and built environment and are the focus of this analysis. Wetland values refer to the resources a wetland provides that are valued by society, for their ecological, economic, recreational, or aesthetic benefits.

Wetland functions are influenced by hydrogeomorphic characteristics of a site which affect how water moves through a wetland system (Brinson 1993; Hruby 2014). For example, wetlands situated in depressions (depressional wetlands), have greater floodwater retention capacity than slope or flat wetlands. Wetland functions are also influenced by landscape scale and site scale characteristics including vegetation structure, hydroperiods, proximity to potential sources of pollution, and priority habitat corridors and connectivity. Many of the functions and services wetlands provide are valuable to society, such as water storage, flood protection, pollutant and nutrient attenuation, and habitat supporting fisheries (Hattermann et al. 2008). Since these functions are provided naturally, or through restoration projects they are often less costly than engineered solutions (Hattermann et al. 2008).

For regulatory purposes in Washington, wetland functions and values are typically categorized in a rating system. The most widely accepted rating system, the *Washington State Wetland Rating System for Western Washington: 2014 Update, version 2*, was developed by the Department of Ecology and is considered to be the regional standard by all regulating agencies (Hruby and Yahnke 2023). This rating system is a rapid assessment tool that evaluates wetland functions in the categories of water quality, hydrology, and habitat, among a framework of three dimensions of site potential, landscape potential, and societal value (Hruby and Yahnke 2023).

5.2.1 Water Quality Functions

Wetlands can improve water quality in waterways through several physical, chemical, and biological processes including settling, filtration, diffusion, volatilization, oxidation, precipitation, adsorption, ion exchange, UV radiation, biodegradation, evapotranspiration, and biotransformation. (Sheldon et al. 2005). Wetlands perform these functions to varying degrees depending on several factors including residence time of polluted waters, vegetation structure and density, and soil composition (Hruby and Yahnke 2023). Wetlands uptake nutrients, particularly nitrogen and phosphorus, and mediate the effect of nutrient spikes to downstream areas (Sheldon et al. 2005). Wetland plants and associated microorganisms can uptake and remove nitrogen through the biochemical processes of nitrification and denitrification, which occur in respective aerobic and anaerobic conditions (Sheldon et al. 2005). According to Kerr et al. (2008), low oxygen concentrations that are common to wetland environments allow them to be sinks for copper, a heavy metal. Studies of constructed wetlands have shown wetland plants remediate pharmaceuticals and personal care products (PPCPs) to various extents (Wang et al. 2019; Zhang et al. 2013).

5.2.2 Hydrologic Functions

Hydrologic wetland functions include groundwater recharge, reduction in peak surface water flows, reduced stream erosion, and flood-flow desynchronization (Sheldon et al. 2005). Flood-flow desynchronization is a landscape-scale process where peak flows of sub-basins vary temporally in a watershed, and lower the magnitude of downstream flooding (Adamus et al. 1991; Hruby et al. 1991). This has a cumulative effect on the magnitude and intensity of individual peak flow events (Sheldon et al. 2005).

Impervious surface area within a drainage basin has been demonstrated to alter wetland hydrology by increasing or decreasing flows from the surrounding landscape, affecting hydroperiods and flood severity (Sheldon et al. 2005). These modified hydroperiod regimes are often accompanied by other impacts, such as stream channel erosion and downcutting, and sediment deposition (Sheldon et al. 2005). Changes in wetland ponding depths, hydroperiods, or water level fluctuation dynamics can also impact wetland plant communities (Schueler 2000).

5.2.3 Habitat Functions

A diverse group of fauna depends on wetlands for at least a portion of their life cycle, including wetland-associated mammals, waterfowl, fish, invertebrates, reptiles, and amphibians (Kauffman et al. 2001; Sheldon 2005). There is a diverse range of ecological variables and factors that influence habitat functions and quality, such as buffer width and condition, vegetative structure, habitat interspersion, wetland hydroperiods, and landscape setting (Hruby and Yahnke 2023). A meta-analysis of the relative effects of landscape-scale wetland area and landscape matrix quality on wetland vertebrates found that while species abundance generally increases in landscapes with more wetland areas, the abundance of some taxa such as amphibians are more sensitive to the larger landscape conditions (Quesnelle et al.

2015). Native species diversity for most taxa is also negatively correlated with the degree of urbanization, though overall species richness is often greatest in areas of intermediate disturbance (Guderyahn et al. 2016; Müller et al. 2016).

Wildlife are also sensitive to water quality impairments which affect wetlands. Additionally, habitat fragmentation tends to reduce the habitat functions and values a wetland provides (Azous and Horner 2010; Sheldon et al. 2005). Land disturbance associated with urban and rural development results in habitat loss and reduces the area of buffers between wetlands and human land use impacts.

5.3 Key Protection Strategies

Wetlands are protected through government regulations at the local, state, and federal levels, with each indecently requiring impact avoidance, minimization, and mitigation. Effective wetland protection strategies include regulatory protocols to identify and classify wetlands, assign buffer widths, and require impact avoidance and compensatory mitigation for any wetland or buffer impacts. Additionally, the preservation of local and landscape-scale corridors can be protected by establishing corridor protection regulations for developments near wetlands.

5.3.1 Wetland Identification and Classification

To protect wetlands, they must first be identified by a qualified professional. The nationwide standard for wetland delineations is the 1987 Corps of Engineers (Corps) *Wetlands Delineation Manual* with the *Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Western Mountains, Valleys, and Coast Region Version 2.0* (Regional Supplement). The Regional Supplement provides greater detail on determining the presence or absence of wetlands specific to the land resource regions.

The *Ecology Wetland Rating System for Western Washington* was first issued in 2004, annotated in 2006, revised in 2014, and annotated in 2023. One major change during the 2014 update provided intermediate categories for each assessed function, scoring to a high, medium, or low ranking. These were thought to better reflect the coarseness of the tool. Additional clarifications were added to the rating system guidance in Version 2 to incorporate annotations from the prior version (Hruby and Yahnke 2023).

The jurisdictional status of a wetland can vary depending on the government agency and the statute regulations under consideration. For example, the CWA only applies to wetlands that meet specific criteria regarding connectivity to Waters of the U.S. and does not apply to isolated wetlands. Local and state wetland regulations are more broadly encompassing, but generally exclude artificially created stormwater features, for example.

5.3.2 Wetland Buffers

Wetlands in Washington are protected from surrounding land uses through buffer requirements based on recommendations from the Department of Ecology. Similar to wetlands, buffers also provide functions that have ecological, sociological, and economic benefits. Wetland buffer functions include moderation of stormwater inputs, sediment removal, pollutant abatement, microclimate, habitat for wetland-dependent fauna, habitat connectivity, and disturbance screening (Sheldon et al. 2005). Buffer functions vary depending on a wide variety of factors such as the vegetation community, gradient, soil conditions, and adjacent land use intensity (Sheldon et al. 2005).

In 2005, Sheldon et al. developed a synthesis of the science for wetlands in Washington which included the topic of buffer width efficacy. The synthesis includes a discussion of the topics of buffer widths relative to water quality functions, hydrologic maintenance, wildlife habitat, and disturbance barrier effectiveness. Due to the similarity of processes and functions, studies on stream buffer widths were compiled into the synthesis (Sheldon et al. 2005). A detailed account of specific buffer functions as they relate to buffer widths can be found in Section 6.2.1.

BUFFER APPROACHES

Ecology provides guidance for wetland buffers framed around several alternatives in *Wetlands in Washington State - Volume 2: Guidance for Protecting and Managing Wetlands– Protecting and Managing Wetlands, Appendix 8-C* (Granger 2005, modified 2018) and 2022 Ecology *Guidance for Critical Area Ordinance Updates*. Both guidance documents provide similar but slightly differing approaches and both are considered to be consistent with BAS at this time.

Current Ecology wetland guidance documents outline the following primary factors to consider when determining buffer widths (ECY 2022):

- The wetland type and the functions needing protection (buffers filter sediment, excess nutrients, and toxics; screen noise and light; provide forage, nesting, or resting habitat for wetland-dependent species; etc.),
- The types of adjacent land use and their expected impacts, and
- The characteristics of the buffer area (slope, soils, vegetation)

Three wetland buffer alternatives are presented in the current Ecology guidance for CAO updates. See Appendix A of this report, for a detailed summary.

As buffer determination options are reviewed, it is important to note that, "Ecology's buffer width recommendations are based on the assumption that the buffer area is well vegetated with native species appropriate to the ecoregion" (ECY 2022). Those buffer options are:

- **Option 1.** Width based on wetland category and habitat score, if minimization measures are applied, and a habitat corridor is provided. If a habitat corridor is not provided or minimization measures are not implemented, then buffer width requirements increase. Modified buffers should be not less than 75 percent of the otherwise required buffer. Option 1 provides the most flexiblity.
- **Option 2.** Width based on wetland category and modified by the intensity of the impacts from proposed land use. Option 2 decreases regulatory flexibility and eliminates buffer averaging and reduction provisions through the application of corridors and minimization measures.
- **Option 3.** Width based on wetland category only. Option 3 is the least flexible and simplest to administer.

FUNCTIONALLY DISCONNECTED BUFFER AREAS

In urban areas, standard buffer widths are sometimes interrupted by development. When a buffer area is functionally disconnected from a wetland, Ecology recommends providing clear direction on how buffer regulations address this condition by providing specific criteria. A distinction between minor and major developments is central to determining if a functional barrier is present (ECY 2022). Minor developments, such as trails, accessory structures, and driveways for a single residence would not completely block wetland buffer functions (ECY 2022). Significant developments associated with the complete loss of buffer functions include public infrastructure (paved roads, railroads), housing developments, or commercial structures. An interruption may impact all or just a portion of a buffer area (ECY 2022).

INFLUENCE OF BUFFERS ON HYDROLOGY

Wetland buffers can mediate the effects of surrounding land use impacts, with variable interactions depending on site conditions and landscape position. Development and impervious surfaces often result in runoff to surface waterbodies which negatively alters hydrologic regimes and introduces pollutants to waterways, these impacts are reduced by the presence of wetland buffers (Hruby 2013; Sheldon et al. 2005). Infiltration of rainwater to soils in wetland buffers reduces surface flows and improves groundwater recharge. Vegetation slows the movement of surface runoff, allowing for greater time for infiltration to occur, which slows or desynchronizes hydrologic inputs into the wetland and potentially diverts them to other groundwater systems. Leaf and other vegetative litter on and in the soil also capture water and improve the soil's infiltration capacity (Castelle et al. 1992a). Vegetation also intercepts rainwater and converts liquid water back to atmospheric vapor through evapotranspiration. Buffer characteristics that influence the performance of hydrologic maintenance vegetation cover, soil infiltration capacity, rainfall intensity, and antecedent soil moisture conditions (Wong and McCuen 1982).

Buffers also function to control erosion by slowing water flow and improving infiltration. Buffer vegetation can reduce erosion by capturing sediment before it enters the wetland, through soil stabilization by roots, and reduction in rain energy by both the vegetation canopy and organic material on the soil (Castelle, et al. 1992a). The vegetation composition and structure in buffers are important factors in the capability of a buffer to perform this function.

INFLUENCE OF BUFFERS ON WATER QUALITY

Buffers protect water quality in wetlands through the removal of sediment and suspended solids, nutrients, pathogens and toxic substances, and other pollutants (Castelle et al. 1992a; McMillan 2000; Sheldon et al. 2005). The ability of a buffer to improve water quality depends on several variables such as slope, vegetation composition, leaf and wood litter, soil type, the type of pollutant, size of the basin, and the fate of stormwater conveyance from adjacent land use (Desbonnet et al. 1994; McMillan 2000). Buffers are typically higher functioning when they have a structurally complex mix of trees, shrubs, and groundcovers, abundant downed wood and leaf litter, and low slopes (Hruby 2013). This is in-part facilitated by physical and biological processes, such as the retention, binding, and filtering of sediments and pollutants through wood or leaf litter, and the breakdown and uptake of pollutants by plants and microorganisms in the soil (Castelle et al. 1992a; Desbonnet et al. 1994; McMillan 2000). Buffer vegetation can reduce sediment input to the wetland through the stabilization of soils by roots, and reduction in runoff via rainwater interception and buildup of organic material on the soil (Castelle, et al. 1992a). Shading and wind reduction by buffer vegetation also influence water quality by maintaining cooler temperatures. Water temperature in wetlands can be critical to the survival of aquatic wildlife species, but more importantly from a water quality perspective, it helps maintain sediment-pollutant bonds, increases the water's dissolved oxygen capacity, and limits excessive algal growth (Castelle et al. 1992a; McMillan 2000; Sheldon et al. 2005).

Approximately 50% of overall pollution removal except nitrogen occurs in the first 16 ft (5 m) of buffer and 70% occurs at 115 ft (35 m) (Desbonnet, et al. 1994). For sediments and suspended solids, 60% removal is achieved with a 7 ft buffer (2 m), and 80% removal is achieved at 82 ft (25 m) (Desbonnet, et al. 1994). Phosphorus removal of 60% is achieved with a buffer of 39 ft (12 m), and 80% is achieved at 279 ft (85 m) (Desbonnet, et al. 1994). Analysis of a range of buffer widths by specific water quality function and identified the following effective buffers: 5 to 100 meters (16 to 330 feet) for sediment removal; 10 to 100 meters (33 to 330 feet) for nitrogen removal; 10 to 200 meters (33 to 656 feet) for phosphorus removal; and 5 to 35 meters (16 to 100 feet) for bacteria and pesticide removal (McMillan 2000; Sheldon, et al. 2005).

INFLUENCE OF BUFFERS ON WILDLIFE HABITAT

Wetland buffers provide habitat for a wide variety of wildlife species and are particularly essential for wetland-dependent and wetland-associated species that require adjacent terrestrial habitat during their life cycle. They also provide habitat well suited for non-wetland-dependent species that prefer habitat edges, use the wetland as a source of drinking water, or use the protected buffer corridors for migrations and movements.

The current body of research includes a range of studies that assess how certain focal species utilize buffers at varying widths, following disturbance events or land use changes. One study in urban King County found that bird diversity was positively correlated with the percentage of wetland perimeter that has vegetated buffers, though only a minor increase in diversity was found with the tested buffer widths of 50, 100, and 200 feet (Milligan 1985). One literature summary reports an effective buffer range of 50 feet (15 m) for many bird species and up to 3,280 feet (1,000 m) for native amphibians (Azous and Horner 2010; Milligan 1985). Many studies recommend buffers between 150 and 300 feet with minimum buffer widths of 50 to 75 feet to provide general avian habitat (Desbonnet et al. 1994; ECY 1992). Wildlife corridors of at least 98 feet are recommended to connect wetlands by McMillan (2000), and Reichter (1997) recommends 490 feet as a minimum travel corridor. A synthesis by Sheldon et al. (2005) found that buffer widths for habitat protection range between 50 and 300 feet depending on factors including wetland habitat conditions, target species, buffer conditions, and surrounding land uses.

In addition to providing habitat for wetland-dependent and wetland-associated species, buffers provide a barrier between a wetland and the various vectors for human encroachment, including noise, light, trampling of vegetation, and the introduction of garbage and other pollutants. Buffer widths necessary to effectively reduce impacts vary by the intensity of the adjacent land use. Buffer widths of

49 to 98 feet can effectively screen low-intensity land uses, such as agriculture and low-density residential (Sheldon et al. 2005). High-intensity land use, such as high-density residential (more than 1 unit/acre), commercial, and industrial, require buffer widths of 98 to 164 feet (Sheldon et al. 2005). The buffer itself, and the functions that it provides, is influenced by the degree of human-related disturbance. Buffers less than 50 feet wide experienced the most loss of buffer function related to human disturbance, and this loss is related to a gradual reduction in buffer width as adjacent land uses encroach (Castille et al. 1992b).

5.3.3 Mitigation

MITIGATION SEQUENCING

Mitigation sequencing is the structured process of avoiding, minimizing, and mitigating all impacts to a particular resource. Skagit County has incorporated mitigation sequencing into existing wetland regulations, according to SCC 14.24.080(5). This is consistent with federal directives to achieve no net loss of wetland functions and values. Mitigation sequencing is also required by the 2008 Wetlands Compensatory Mitigation Rule issued by the U.S. Environmental Protection Agency (2008) and WAC 197.11.768. Per current Ecology guidance for CAO updates, mitigation sequencing must be applied in the following order (ECY 2022):

> *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, by using appropriate technology, or by taking affirmative steps to avoid or reduce impacts;*
>
> *Rectifying the impact by repairing, rehabilitating, or restoring the affected environment;*
>
> *Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action;*
>
> *Compensating for the impact by replacing, enhancing, or providing substitute resources or environments; and/or*
>
> *Monitoring the impact and taking appropriate corrective measures*.

COMPENSATORY MITIGATION

Compensatory mitigation may be achieved through a programmatic approach or an approved permittee-responsible mitigation (PRM) plan. Programmatic approaches utilize third-party sponsors to obtain mitigation credits, such as a mitigation bank or in-lieu fee (ILF) program. PRM is an applicant-managed mitigation project. PRM is typically developed and implemented concurrently with wetland impacts, but it may be done in advance. Mitigation banks are state-certified to ensure ecological function replacement is achieved. ILF programs collect fees and apply the funds to restoration projects within the service area. The Corps and Ecology review and approve ILF programs. Whereas, PRM applicants must complete installation, site maintenance, monitoring, and adaptive management as needed to achieve approved mitigation plan goals and performance standards (ECY 2021b).

Ecology's recommendations for mitigation ratios for projects in Western Washington depend on the wetland category and type of mitigation action (Granger 2005, Modified 2008). Mitigation ratios for direct wetland impacts are increased to account for temporal losses (ECY 2022). Current mitigation ratio recommended by Ecology are provided in Appendix B of this report. When applying advanced mitigation, the Ecology-recommended ratios account for the wetland category and proposed mitigation actions (ECY 2021b).

To address ecological priorities in Washington State's watersheds, Ecology has developed additional guidance and tools for applicants, including details on using a watershed approach for mitigation site selection and the credit-debit method (Hruby 2012; Hruby et al. 2009). The credit-debit method is a system to calculate mitigation credits needed for a given project. The credit calculations can be used to determine compensation when utilizing in-situ mitigation, a mitigation bank, or an in-lieu fee program. Depending on specific site conditions, this may result in less or more mitigation than would be required under a set traditional mitigation ratio guidance (Hruby 2012).

Compensatory wetland mitigation methods in order of preference are (ECY 2021b):

1) Restoration: Re-establishment,
2) Restoration: Rehabilitation-hydrologic processes restored,
3) Creation (establishment),
4) Preservation, and
5) Enhancement

Preservation and enhancement-only mitigation are least preferred since they result in a net loss of wetland area. Ecology prefers to see preservation or enhancement in combination with a no net loss mitigation method, such as wetland creation (ECY 2021b).

Ecology recommends applying at least a one-to-one ratio to buffer impacts (ECY 2022). A ratio greater than 1:1 may be required to replace all lost critical area functions. Ecology also recommends evaluating indirect wetland impacts to determine appropriate compensatory mitigation (ECY 2021b).

MONITORING

Evaluations of wetland mitigation outcomes found that most wetland mitigation does not fully replace impacted functions and falls short of the goal of no net loss (Johnson et al. 2002; ECY 2008). The goal of no net loss of wetland function cannot be achieved through mitigation alone but may be met through several factors, including adequate monitoring and maintenance and appropriate performance standards. Compensatory mitigation sites typically require performance standard monitoring for a 3- to 10-year period, to ensure that implemented sites provide the functions which were planned. There are few studies of long-term compliance with performance standards, and one assessment found a reduction in site compliance 8 to 20 years following installation (Van den Bosch and Matthews 2017). NRC (2001) identifies factors that reduce the risk of mitigation failure, such as detailed functional assessment, high success standards, detailed mitigation plans, larger bonds with up-to-date market values, high replacement ratios, and greater expertise.

5.4 Climate Change Impacts & Mitigation

Climate change is predicted to significantly impact wetland ecosystems by altering hydrology, reducing biodiversity, disrupting of carbon storage, modifying community composition, and increasing rates of disease (Aukema et al. 2017; Burkett and Kusler 2000; Lee et al. 2015). Altered hydrology and precipitation patterns from climate change can result in earlier drawdowns of wetlands during droughts, a process that will likely result in wetland loss where hydrologic conditions are significant and modify community composition (Lee et al. 2015). Wetlands may also experience greater polarity in seasonal water levels with increased ponding during wet seasons and decreased water levels during dry seasons (Halabisky 2017). Sea level rise is also expected to change the landscape of coastal wetlands, resulting in wetland loss, spatiotemporal changes to coastal wetland distribution, and shifts in community composition resulting from disturbance, climate change effects, and elevated salinity (Burkett and Kusler 2000). Climate change impacts on biodiversity are discussed in Section 6.4. and are caused by a wide range of effects that modify habitats from historic baselines and reduce biodiversity (Aukema et al. 2017). Furthermore, warming effects may result in a disruption of carbon storage, by reducing storage rates or even reverting some wetlands from carbon sinks to carbon sources, particularly in boreal peatlands (Burkett and Kusler 2000).

Wetlands also provide functions that assist in the mediation of climate change impacts. Wetlands and wetland buffers, like riparian corridors, support a shaded and cool microclimate that provides refuge for wildlife from higher temperatures as well as wildlife corridors at a local or landscape scale (ASWM 2015). Additionally, wetlands help offset climate change through carbon storage by protecting the remineralization of organic stocks and sequestering greenhouse gas emissions (Gallagher et al. 2022). Carbon stocks in undisturbed wetlands are approximately twice as high as carbon storage in wetlands disturbed by human-driven land use changes. However, it is uncertain whether this is a causal relationship or influenced by patterns of human settlement in avoiding the wettest sites which are challenging to develop (Nahlik & Fennessy 2016). Bogs and peatlands are important carbon sinks that could release hundreds of years of stored carbon if disturbed (Nahlik and Fennessy 2016).

Although wetlands are dynamic by nature, the ability to adapt to change is limited. Alterations in stormwater runoff conditions and changes to seasonal wetland hydrologic cycles can reduce the ability of wetland soil bacteria and plants to retain, process, and sequester pollutants (EPA 2015). Climate change is impacting native plant species distribution; adaptative potential and climate tolerance for native plant species are being studied in the scientific community (Vose et al. 2012).

5.4.1 Strategies to Manage Climate Change Impacts on Wetlands

- Continue to encourage and incentivize direct wetland impact avoidance to maintain existing carbon storage.
- Continue to regulate wetland buffers to encourage and require width retention/limitations and enhancement with native vegetation. Both voluntary and required restoration planting should be paired with monitoring and maintenance that allows for dry-season irrigation and adaptive management.

- Continue to manage and regulate stormwater infrastructure to avoid and minimize discharges of untreated runoff to wetlands.
- Apply increased protections to bog wetlands and associated buffers to prevent stormwater impacts that could change pH and alter sensitive plant communities.
- Consider assisted migration for seed selection of native plants from locations that are better adapted to future climate conditions.

6. Fish and Wildlife Habitat Conservation Areas (FWHCAs)

6.1 Definitions

Washington State defines fish and wildlife conservation as "*land management for maintaining populations of species in suitable habitats within their natural geographic distribution so that the habitat available is sufficient to support viable populations over the long term and isolated subpopulations are not created*" (WAC 365-190-130). Fish and Wildlife Habitat Conservation Areas (FWHCAs) are lands designated for this conservation action and are defined under WAC 365-190.130 and in the Skagit County Code (SCC). According to *SCC 14.04 - Definitions*:

(1) Areas with which endangered, threatened, and sensitive species have a primary association;
(2) Habitats and species of local importance that have been designated by the County at the time of application;
(3) All public and private tidelands suitable for shellfish harvest;
(4) Kelp and eelgrass beds, herring and smelt spawning areas;
(5) Naturally occurring ponds under 20 acres with submerged aquatic beds that provide fish or wildlife habitat;
(6) Waters of the State as defined by WAC 222-16-030;
(7) Lakes, ponds, streams, and rivers planted with game fish by a governmental or tribal entity;
(8) Areas with which anadromous fish species have a primary association;
(9) State Natural Area Preserves and Natural Resource Conservation Areas;
(10) Other aquatic resource areas;
(11) State priority habitats and areas associated with State priority species as defined in WAC 365-190-080; and
(12) Areas of rare plant species and high quality ecosystems as identified by the Washington State Department of Natural Resources through the Natural Heritage Program in Chapter 79.70 RCW.

FWHCAs are further described under SCC 14.24.500(2) to include "*additional habitats and species of local importance may be designated by the Administrative Official based on declining populations, sensitivity to habitat manipulation or special value including but not limited to commercial, game or public appeal.*" A nomination and review process is established in SCC 14.24.500(3) that requires a demonstration of declining populations, sensitivity to habitat manipulation, or commercial or game value or other special value, such as public appeal, along with management strategies and species location maps that would be reviewed in a public hearing.

Designated species of local importance are named under SCC 14.24.500(4) and include (a) great blue heron nest sites, (b) Vaux's swift communal roosts, (c) pileated woodpecker nest sites, (d) osprey nest sites, (e) Townsend's big-eared bat communal roosts, (f) cavity nesting duck breeding areas, (g) trumpeter swan concentrations, (h) harlequin duck breeding areas, and (i) waterfowl concentrations.

6.2 Functions and Values

FWHCA functions include the biological, chemical, and physical processes that affect wildlife. Since wildlife may include all species, from the largest megafauna to microorganisms, these functions encompass a complex web of interacting ecological processes. At the highest level, FWHCAs provide wildlife with suitable habitat. This section discusses functions of FWHCAs most relevant to wildlife and habitat management, with a focus on streams and riparian areas. Functions of certain habitat areas is also considered if relevant to a particular societal value other than wildlife.

FWHCA values are the range of societal, economic, and ecological benefits provided by these lands and the wildlife that may inhabit them. These include *indirect values* that include non-consumptive uses such as recreation, tourism, scientific research, option values (valuing future opportunities), and intrinsic existence values (Chardonnet et al., 2002). They also include *direct values*, the consumptive and productive uses, such as commercial harvest, hunting, timber, and firewood (Chardonnet et al., 2002). These values represent diverse public interests and attitudes toward wildlife issues which change over time (Teel & Manfredo, 2010).

6.2.1 Streams, Lakes and Ponds, and Riparian Areas

Streams, lakes, ponds, and their associated riparian areas provide critical habitat for a diversity of wildlife species and directly contribute to surface and subsurface hydrology as well as nutrient and energy exchange across the landscape. The following section describes the functions and values most prominent to stream, lakes, ponds, and riparian area ecosystems as well as land use activities including (1) land cover and impervious surfaces; (2) recruitment of large woody debris to aquatic areas; (3) shade, temperature, and microclimates; (4) stream migration and bank stability.

LAND COVER AND IMPERVIOUS SURFACE

Human development is well documented to negatively impact aquatic ecosystems and is often evaluated using landscape scale metrics such as impervious surface, and other land cover measures. Impervious surface is positively correlated with high flow volumes, daily streamflow variability and negatively correlated with groundwater recharge rates and summer low flow volumes (Burges et al. 1998; Cuo et al. 2009; Jones 2000, Konrad & Booth 2005). Other types of development also result in hydrological changes include soil compaction, draining, and ditching across the landscape, and logging (Booth & Jackson 2002; Moore & Wondzell 2005). Together, these landscape modifications have been documented to reduce rates of infiltration, evapotranspiration, and groundwater storage

(Sheldon et al. 2005). As a result, flows become more synchronized and become more variable and volatile (Sheldon et al. 2005).

A study assessing changes in forest canopy, stream flows, and stream bank erosion found that unstable channels are expected to occur if forest retention is less than 40 percent within a watershed (Booth et al 2002). Increased erosion and bank instability coupled with a reduction of forest cover have been found to simplify stream morphology, leading to incised, wider, and straighter stream channels (Konrad et al 2005). This less dynamic stream morphology is linked to accelerated water transport and reduced temporary instream flood storage capacity (Kaufmann and Faustini 2012). Positive correlations have been found between spawner abundance and forested areas; negative correlations were found between spawner abundance and areas converted to agriculture or urban development (Pess et al. 2002).

RECRUITMENT OF LARGE WOODY DEBRIS TO AQUATIC AREAS

Large woody debris (LWD) plays a significant role in the geomorphic formation of stream channels by deflecting and redirecting stream flows, and influencing sediment storage, transport, and deposition rates (Quinn et al. 2020). These processes result in complex and diverse channel morphologies that include dam pools, plunge pools, riffles, glides, undercut banks, and side channels (Quinn et al. 2020). The creation of these features is also facilitated by variability in stream flow velocity which factors into scour, sediment deposition, and pool formation (Quinn et al. 2020). Large wood actuates the downward scour necessary for streams to create pools, which provides protective cover for fish in those pools (Quinn et al. 2020).

These processes result in complex and spatially heterogeneous stream habitats that support diverse communities of aquatic species. LWD and associated habitat complexities provide conditions suitable for rearing, and refugia from predators. In one study, the density of juvenile salmonids was found to be substantially higher in streams in which LWD was experimentally introduced (Roni & Quinn, 2001). Similarly, Fausch and Northcote (1992) found that streams containing large amounts of LWD supported populations of juvenile cutthroat trout and coho salmon five times greater than streams within the same river system that had been cleared of LWD.

The aggregation of LWD and associated entrapment of smaller branches, limbs, leaves, and other materials reduce flow conveyance in small streams and increase temporary flood storage (Dudley et al. 1998). By retaining smaller organic debris, LWD provides substrate for microbes and algae, and prey resources for macroinvertebrates (Bolton and Shellberg 2001). The overall influence of LWD on biological processes is greater in smaller streams than in larger ones (Harmon et al. 1986). This is similar to the relationship with riparian areas, in which allochthonous inputs compose a greater proportion of small stream volume than large streams and are more influential on biological processes (Vannote et al. 1980). In small channels, LWD provides a structural component in the stream that controls rather than responds to hydrologic and sediment transport processes (Gurnell et al. 2002). It follows that large wood is responsible for significant sediment storage in small channels, thereby increasing channel stability (May and Gresswell 2003; Nakamura and Swanson 1993; Quinn et al. 2020). In a study where wood was experimentally removed from streams, Bilby (1981) found increased sediment mobilization and reduced storage. LWD that partially blocks flow may also encourage hyporheic flow through the streambed substrate (Poole and Berman 2001, Wondzell et al. 2009).

Large wood recruitment is typically introduced to streams as a result of bank erosion, windthrow, landslides, debris flows, snow avalanches, and tree mortality due to fire, ice storms, insects, and disease (Swanson et al. 1976; Maser et al. 1988). Large woody debris can enter channels through individual trees falling into the stream, as well as through larger disturbances (Bragg 2000). In a comparison of 51 streams with varying channel characteristics in mature forests of British Columbia, a study found that tree mortality was the most common entry mechanism of LWD where the source could be identified (Johnston 2011). Streambank erosion and associated channel migration is also a common method of wood recruitment in large alluvial channels (Murphy and Koski 1989), whereas, in smaller, steeper channels, LWD recruitment occurs primarily through slope instability and windthrow (May and Gresswell 2003).

The probability of a tree entering the channel decreases with distance from the streambank (McDade et al. 1990, Grizzel et al. 2000). Past research has found that most LWD originates within approximately 30 m (98 ft) of a watercourse (Murphy and Koski 1989, McDade et al. 1990, Van Sickle and Gregory 1990, Robison and Beschta 1990). In one study involving 51 streams surveyed in British Columbia, 90% of the LWD at most sites originated within 18 m (59 ft) of the channel (Johnston 2011). May and Gresswell (2003) found that wood was recruited from distances farther from the stream channel in small, steep channels (80% from 50 m (164 ft) from the channel), compared to broad alluvial channels (80 percent from 30 m (98 ft) from the channel) because of the significance of hillslope recruitment in narrow valleys.

The likelihood of downstream transport of LWD is dependent on the length of wood relative to bankfull width of the stream (Lienkaemper and Swanson 1987). Wood that is shorter than the average bankfull width is transported more readily downstream compared to wood that is longer than the bankfull width (Lienkaemper and Swanson 1987). Therefore, large wood is rarely transported downstream from small channels less than 5 m (16 ft) in width (May and Gresswell).

Beaver dams incorporate both small and large wood, and serve to slow water, retain sediment, and create pools and off-channel ponds used by rearing coho salmon and cutthroat trout (Naiman et al. 1988, Pollock et al. 2004). The removal of these structures throughout history has been linked to a significant reduction in coho salmon summer and winter rearing habitat in the nearby Stillaguamish River (Pollock et al. 2004). In Washington House Bill 2349, the Washington legislature states that "*beavers have historically played a significant role in maintaining the health of watersheds in the Pacific Northwest and act as key agents in riparian ecology*." They continue with "*The benefits of active beaver populations include reduced stream sedimentation, stream temperature moderation, higher dissolved oxygen levels, overall improved water quality, increased natural water storage capabilities within watersheds, and reduced stream velocities. These benefits improve and create habitat for many other species, including endangered salmon, river otters, sandhill cranes, trumpeter swans, and other riparian and aquatic species.*" These statements indicate the policy support of beaver conservation and consistent with scientific evidence and recognize that beavers play an important role in stream ecosystems. Relocations and introductions to stream ecosystems can be beneficial wildlife management practices. Conditions for wild beaver release are provided in RCW 77.32.585. Related to this legislation, WDFW has instigated a beaver relocation program.

SHADE, TEMPERATURE, AND MICROCLIMATE

Riparian vegetation influences stream temperatures and microclimate conditions such as air temperature, wind, light, and moisture. Factors affecting water temperature and microclimate include shade, orientation, relative humidity, ambient air temperature, wind, channel dimensions, groundwater, hyporheic exchange, and overhead cover (Quinn et al. 2020).

Salmon and other native freshwater fish require cool waters for migrating, rearing, spawning, incubation, and emergence, with summer maximum temperature recommendations ranging from 55-68°F (EPA 2003). Thermal tolerances differ by species; salmonids here been studied frequently due to their cultural and economic importances, relative sensitivity to high temperatures, and narrow thermal tolerance (Quinn et al. 2020). Amphibians also have narrow thermal tolerances, and they are particularly sensitive to changes in microclimate conditions (Bury 2008). Several studies have documented significant increases in maximum stream temperatures associated with the removal of riparian vegetation (Beschta et al. 1987; Murray et al. 2000, Moore et al. 2005, Gomi et al. 2006). Considering the correlation between riparian vegetation and stream temperature, loss of vegetation presents a risk to the affected fish species. The importance of riparian vegetation in maintaining viable stream temperatures is clear in the literature (Quinn et al. 2020).

Several studies have considered the extent to which various riparian zone widths modulate stream temperature. In headwater streams in British Columbia, 10 m (33 ft) riparian zones generally minimized effects on stream temperature from timber harvest, although maximum daily temperatures reached 3.6°F higher than control streams (Gomi et al. 2006). A comparative study of 40 small streams in the Olympic Peninsula found that mean daily maximum temperatures were 2.4°C higher in logged compared to unlogged watersheds, and that logged watersheds had greater diurnal fluctuations in water temperatures (Pollock et al. 2009). Another study of streams in Washington found that stream temperatures were most closely correlated with vegetation parameters associated with the riparian area, such as total leaf area and tree height, and that the effect of buffer width was less significant, particularly for buffers larger than 30 m (98 ft) (Sridhar et al. 2004). These findings are consistent with an earlier study relating angular canopy density, a proxy for shading, to riparian buffer width; which found that the correlation between shade and riparian buffer width increases up to around 30 m (98 ft) (Bestcha et al. 1987). Therefore, for buffers less than 30 m (98 ft), buffer width is expected to be more closely related to shading and stream temperatures than buffers over 30 m (98 ft).

Riparian microclimate affects many ecological processes and functions, including plant growth, decomposition, nutrient cycling, succession, productivity, migration and dispersal of flying insects, soil microbe activity, and fish and amphibian habitat (Brosofske et al. 1997). Riparian buffers necessary to maintain forest microclimate are controlled by edge effects, which tend to extend well into forested areas adjacent to clearings. However, riparian buffers ranging from 10-45 meters in width may minimize microclimate effects related to light, soil, and air temperatures. A study of small streams in Western Washington indicated that buffers greater than 45 m (147 ft) wide are generally sufficient to protect riparian microclimate in streams (Brosofske et al. 1997).

STREAM MIGRATION AND BANK STABILITY

Streams migrate naturally which often results in complex natural geomorphology, floodplains, and heterogeneous ecosystems. One consequence of the erosive power of streams is damage to human-built infrastructure. Bank stability is influenced by factors such as bank material, hydraulic forces, and vegetation (Ott 2000). Riparian vegetation improves bank stabilization through root networks which encapsulate and anchor soil particles and rocks, thereby reducing soil movement. Vegetation also reduces the quantity of surface water runoff through rainwater capture and evapotranspiration (Wynn and Mostaghimi 2006). The effectiveness of bank stabilization is also dependent on the type of vegetation present. For example, woody vegetation tends to provide greater bank stability than herbaceous vegetation because woody vegetation has larger and firmer roots that extend deeper into the streambank (Wynn and Mostaghimi 2006). Bank stability is lower in urban watersheds because factors such as vegetation composition and hydraulic forces are degraded. The width of vegetated riparian buffers improves bank stability up to a distance of approximately 80 to 100 feet, after which diminishing returns limit marginal benefits (Castelle & Johnson 2000; Sheldon et al. 2005).

RIPARIAN INFLUENCE ON WATER QUALITY

Water quality is characterized by several physical, chemical, and biological factors, including temperature, suspended sediment, nutrients, metals, pathogens, and other pollutants. These water quality parameters are influenced by riparian areas and other terrestrial environments which control shade and runoff.

Conversion of natural environments to developed sites often results in a reduction of infiltration and an increase in surface flows, resulting in sediment and contaminants being transported more directly to receiving bodies, bypassing natural soil filtration and flow attenuation processes. Consequentially, urban areas tend to contribute a disproportionate amount of sediment and contaminants to receiving waters (Sorrano et al. 1996). Heavy metals, bacterial pathogens, as well as PCBs, hydrocarbons, and endocrine-disrupting chemicals are aquatic contaminants that are commonly associated with urban and agricultural land uses.

The full suite of sublethal and indirect effects of these contaminants and combinations of contaminants on aquatic organisms is a subject of ongoing research (Fleeger et al. 2003). Likely some contaminants with potentially severe repercussions for fish and wildlife have yet to be identified. For example, research in the Puget Sound region had identified mature coho salmon that return to urban creeks and die before spawning, a condition called pre-spawn mortality (Feist et al. 2011, Sholz et al. 2011). After a prolonged investigation, the specific cause of the condition has been recently attributed to 6PPD-quinone, a breakdown product of tire wear (Tian et al., 2020). Coho pre-spawn mortality is also positively correlated with the relative proportion of roads, impervious surfaces, and commercial land cover within a basin (Feist et al. 2011).

Sediment

Sediment input to streams is supplied by bed and bank erosion, landslides, and upland erosion processes. These processes occur naturally but are acutely associated with and accelerated by forest practices and development activities. Other contaminants, including heavy metals and phosphorus, readily bond to suspended clay particles, and these contaminants are often transported with fine sediment in stormwater.

Excess inputs of fine sediments (e.g., silt and clay particles) into stream channels reduce habitat quality for certain species of fish, amphibians, and macroinvertebrates. Fine sediment adversely affects stream habitat by filling pools, embedding gravels, reducing gravel permeability, and increasing turbidity. In salmon-bearing streams, fine sediment fills interstitial spaces in redds, reducing the flow of oxygenated water to developing embryos and reducing egg-to-fry survival (Jensen et al. 2009). For example, highly turbid water can impair fertilization success in spawning salmonids and interfere with the respiration and reproduction amphibians (Galbraith et al. 2006; Knutson et al. 2004). Fine sediments that settle out of the water column can smother gravel and cobble streambeds that are essential habitat for salmonid spawning and for benthic macroinvertebrates. These fine sediments fill interstitial spaces of gravel in redds, reducing the flow of oxygenated water to developing salmonid embryos and reducing egg-to-fry survival (Jensen et al. 2009).

Excessive sediment loads can significantly degrade water quality. Additionally, sediments tend to serve as a transport mechanism for other pollutants, carrying attached contaminants from upland sources to the stream channel. Suspended sediment can also cause gill abrasion in fish and interfere with foraging and predator avoidance (Quinn et al. 2020).

Vegetated riparian zones help stabilize stream banks by slowing and filtering overland flow, and temporarily storing sediment that is gradually released to both seasonal and perennial streams. Sediment filtration is also high within intermittent and ephemeral streams, presumably because of the high interface with vegetative structures and the flux in water surface elevation, which allows for sediment storage along the streambanks (Dietrich and Anderson 1998).

Upland clearing and grading can result in long-term increases in fine sediment inputs to streams (Gomi et al. 2005, Jackson et al. 2007). Numerous studies have investigated the effectiveness of varying widths of buffers at filtering sediment. These studies have typically found high sediment filtration rates in relatively narrow buffer areas without a significant improvement in sediment retention beyond 15 meters (Abu-Zreigh et al. 2004; Parkyn 2004; Sheridan et al. 1999; Wenger 1999; Yuan et al. 2009).

However, field plot experiments tend to have much shorter field lengths (e.g., hillslope length contributing to drainage) than would be encountered in real-world scenarios (i.e., ~5:1 ratio of field length to riparian width for a field plot compared to 70:1 ratio in NRCS guidelines). Since water velocities tend to increase with field length, field plot experiments may suggest better filtration than would be encountered under real-world conditions. Additionally, field-scale experiments generally do not account for flow convergence, which reduces sediment retention or for stormwater components that bypass filter strips through ditches, stormwater infrastructure, and roads (Helmers et al. 2005; Verstraeten et al. 2006). Therefore, the effectiveness of filter strips at filtering sediment under real world conditions and at the catchment scale is likely to be lower than what is reported in field plot experiments.

Additionally, studies on sediment retention in riparian zones are often based on a single storm event, rather than accounting for sediment accumulation over time. Two of the reviewed studies used

Cesium-137 to track the location of sediment deposition over many years (Cooper et al. 1988; Lowrance et al. 1988; Wenger 1999). The findings of these studies suggest that riparian zones from 30-100 m (98-328 ft) or more may be necessary to provide long-term sediment retention and that studies of short-term sediment retention underestimate the riparian zone width needed for ongoing sediment filtration (Cooper et al. 1988; Lowrance et al. 1988; Wenger 1999).

In addition to riparian zone width, the slope, vegetation density, and sediment composition of a riparian area have a significant bearing on sediment filtration potential (Jin and Romkens 2001). A recent model of sediment retention in riparian zones found that a grass riparian zone as small as 4 m (13 ft) could trap up to 100% of sediment under specific conditions (i.e., 2% hillslope over fine sandy loam soil), whereas a 30 m (98 ft) grass riparian zone would retain less than 30% of sediment over silty clay loam soil on a 10% hillslope (Dosskey et al. 2008) (Figure 8). This study demonstrates the effects that soil type and hillslope have on sediment retention.

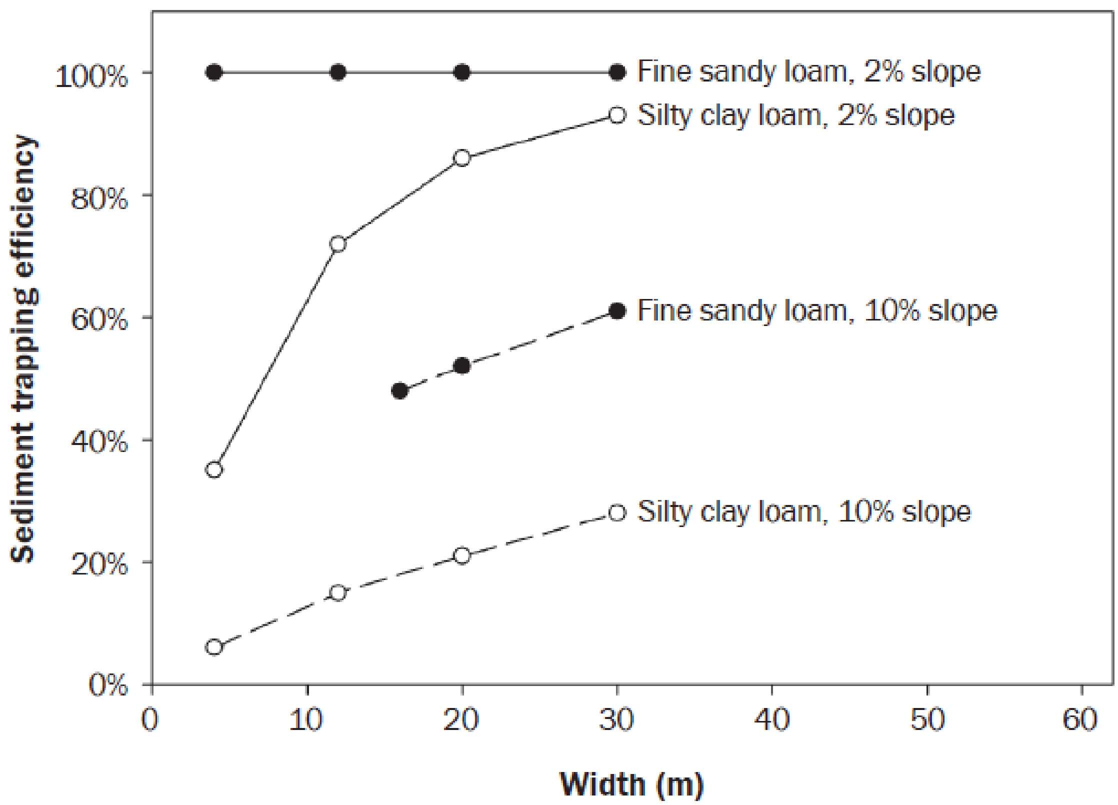

Figure 9. Sediment trapping efficiency related to soil type, slope, and buffer width. Reproduced from Dosskey et al. (2008).

Multiple studies have found that larger particles tend to settle out within the first 3-6 m (10-20 ft) of the riparian zone, but finer particles that tend to degrade instream habitat, such as silt and clay, need a larger riparian zone, ranging from 15-120 m (49-394 ft), for significant retention (Parkyn 2004).

Vegetative composition within the buffer also affects sediment retention. Vegetation tends to become more effective at sediment and nutrient filtration several years after establishment for both grass and forested buffers (Dosskey et al. 2007). Thin-stemmed grasses may become overwhelmed by overland flow while dense, rigid-stemmed vegetation provides improved sediment filtration that is expected to continue to function better over successive storm events (Blanco-Canqui et al. 2004, Yuan et al. 2009).

Nutrients

Established vegetation in a dense composition can provide effective sediment and nutrient filtration (Dosskey et al. 2007). Riparian zones can also reduce nitrogen pollution through nutrient uptake, assimilation by vegetation, and denitrification (Sobota et al. 2012). In excess concentrations, nitrogen and phosphorus can lead to poor water quality conditions, including reduced dissolved oxygen rates, increased pH, and eutrophication (Mayer et al. 2005; Mayer et al. 2007). Excessive amounts of nitrogen and phosphorus speed up eutrophication and algal blooms in receiving waters, which can deplete the dissolved oxygen in the water and result in poor water quality and fish kills (Dethier 2006; Heisler et al. 2008; Mayer et al. 2005).

Riparian zones can reduce nitrogen pollution through nutrient uptake, assimilation by vegetation, and through denitrification (Sobota et al. 2012). The rate of nitrogen removal from runoff varies considerably depending on local conditions, including soil composition, surface versus subsurface flow, riparian zone width, riparian composition, and climate factors (Mayer et al. 2005, Bernal et al. 2007, Mayer et al. 2007). Nutrient assimilation is also dependent on the location of vegetation relative to the nitrogen source, the flow path of surface runoff, and its position in the landscape (Baker et al. 2006).

Nutrients enter waterways through channelized runoff, groundwater flow, and overland flow. Nitrogen loading is often associated with agricultural activities, whereas low-density residential development has been found to result in nitrate levels comparable to a forested basin (Poor and McDonnell 2007).

Mayer et al. (2005, 2007) found that there was little relationship between riparian zone width and removal of *subsurface* nitrates. Subsurface nitrates were removed effectively regardless of riparian zone width. Conversely, nitrate removal from *surface* runoff *is* related to riparian zone width, and 50%, 75%, and 90% of surface nitrate removal was measured at widths of 27 m (88 ft), 81 m (266 ft), and 131 m (430 ft) respectively (Mayer et al. 2007). This suggests that surface water infiltration in the riparian zone should be a priority to promote effective nutrient filtration. Where soils are poorly drained and infiltration capacity is limited, the effectiveness of nutrient removal in riparian buffers may also be limited (Wigington et al 2003).

The size and species composition of the riparian zone buffer also affect the efficiency of nutrient removal, but studies are conflicting as to whether grass, wetland, herbaceous, or forested buffers are most effective at removing nutrients (Polykov 2005). Where nitrogen-fixing species predominate, such as red alder, these buffers tend to have higher soil nitrate concentrations (Monohan 2004).

Removal of phosphorus in surface runoff by riparian buffers is dependent on the form of phosphorus entering the buffer. Whereas phosphorus that is adsorbed by soil particles is effectively removed through sediment retention within a buffer, the retention of soluble phosphorus relies on infiltration and uptake by plants (Polyakov et al. 2005). One long-term study found that phosphorus uptake was directly proportional to the plant biomass production and root area over the four-year study period (Kelly et al. 2007). If a riparian buffer becomes saturated with phosphorus, its capacity for soluble phosphorus removal will be more limited (Polyakov et al. 2005). Another long-term study found that following a 15-year establishment period, a 40-meter (131 ft) wide, three-zoned buffer reduced particulate phosphorus by 22 percent, but dissolved phosphorus exiting the buffer was 26 percent higher than the water entering the buffer, so the buffer resulted in no net effect on phosphorus (Newbold et al. 2010).

In summary, most riparian zones reduce subsurface nutrient loading, but extensive distances are needed to reduce nutrients in surface runoff. Filtration capacity decreases with increasing loads (Mayer et al. 2005), so best management practices across the landscape that reduce nutrient loading will reduce the amount of nutrients that enter streams and other surface waters.

Metals

Although most metals can be toxic at high concentrations, cadmium, mercury, copper, zinc, and lead are particularly toxic even at low concentrations. Chronic and acute exposure to heavy metals have been found to impair, injure, and kill to aquatic plants, invertebrates, fish, and particularly salmonids (Grant and Ross 2002, Dethier 2006, Hecht et al. 2007, McIntyre et al. 2008, McIntyre et al. 2012). The toxicity of metals is influenced by a variety of factors including (Duffus et al 2002; Nagajyoti et al. 2010; Tchounwou et al. 2012; Wang & Rainbow 2008):

- Properties of the metal
- Duration, frequency, and concentration of exposure
- The form and bioavilability of the metal at the time of exposure
- Environmental conditions including water chemistry and physical properties such as pH, temparature, and salinity
- Synergistic, additive, or antagonistic interactions of co-occurring contaminants
- Species sensitivity
- Life stage
- Physiological ability to detoxify and/or excrete the metal and,
- The condition of the exposed organism.

Metals are typically transported to the aquatic environment through fossil fuel combustion, industrial emissions, municipal wastewater discharge, and surface runoff. In general, heavy metals and hydrocarbons (e.g. leaked motor oil, polycyclic aromatic hydrocarbons) are found in road runoff, and these contaminants can reach the County's streams directly through existing stormwater systems. Stormwater systems that circumvent buffers limit the opportunity to filter runoff through adjoining soils and vegetation. Accordingly, stream buffers are typically underutilized for the treatment of metals, hydrocarbons, and other pollutants found in typical stormwater runoff.

Copper brake pad dust has also been linked to chronically depressed Chinook salmon populations (EPA 2007). The U.S. EPA is working to reduce the use of copper and other heavy metals in motor vehicle brake pads through the *Copper-Free Brake Initiative*.

Pathogens

Waterborne pathogens associated with human and animal wastes are a concern for direct and indirect human exposure. Fecal coliform bacteria, specifically E. coli, is typically used as an indicator of the possible or presumed presence of a suite of bacterial and viral pathogens. Fecal pollution tends to be positively correlated with human population densities and impervious surface coverage (Glasoe and Christy 2004). The main sources of fecal pollutants include municipal sewage systems, on-site sewage systems, stormwater runoff, marinas and boaters, farm animals, pets, and wildlife (Glasoe and Christy 2004). As municipal wastewater systems have improved treatment quality and capacity in recent years, increasingly, non-point source pollution, including septic systems, stormwater, livestock, marinas and boaters, recreationalists, wildlife, and pets, is responsible for fecal contaminants in surface water (Glasoe and Christy 2004).

Herbicides and Pesticides

Commonly used herbicides, pesticides, and other pollutants may also affect aquatic communities, and the acute and chronic effects of these chemicals or combinations of chemicals are not always well understood. Additionally, effects documented in the laboratory may differ significantly from effects identified in a field setting (Relyea 2005, Thompson et al. 2004). The effects of these chemicals may be long-lasting, as has been observed for legacy pollutants such as polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) in salmon, seabirds, and marine mammals in Puget Sound (Calambokidis et al. 1984, O'Neill et al. 1998, Ross et al. 2000, Wahl and Tweit 2000, Grant and Ross 2002, O'Neill et al. 2009).

Herbicides and pesticides may reach aquatic systems through a number of pathways, including surface runoff, erosion, subsurface drains, groundwater leaching, and spray drift. Narrow hedgerows have been found to limit 82-97 percent of the aerial drift of pesticides adjacent to a stream (Lazzaro et al. 2008). In runoff, herbicide retention in a buffer is dependent on the percentage of runoff that infiltrates the soil (Misra et al. 1996). A study of herbicides in simulated runoff found that 6-meter-wide vegetated buffers were sufficient to remove 100% the tested herbicides (Otto et al. 2008). A meta-analysis found that filtration effectiveness increased logarithmically from 0.5 m to an asymptote at approximately 18 m (Zhang et al. 2010). In summary, relatively narrow vegetated buffers may be effective in limiting herbicides and pesticides from reaching aquatic habitats in surface runoff, erosion, and spray drift; however, these processes are best managed using best management practices in herbicide and pesticide applications to avoid contaminating groundwater (Reichenberger et al. 2007).

Pharmaceuticals

Pharmaceuticals are another class of contaminants which have been demonstrated to have negative impacts on the health of humans and aquatic organisms. There are a wide range of pharmaceutical compounds and toxicological research is variable, with many that are poorly understood. Many commonly used pharmaceuticals are found in wastewater, particularly in more urban areas (Long et al. 2013). Many common pharmaceuticals have endocrine-disrupting properties, which can affect fertility and development in non-target aquatic species (Caliman and Gavrilescu 2009). The existing and potential effects of these chemicals on the environment are not yet well understood and the extent of research has been limited by the range of potentially thousands of pharmaceutical substances (Caliman & Gavrilescu 2009; Mills & Chichester 2005).

FISH AND WILDLIFE HABITAT

The primary function of FWHCAs is the role they provide as habitat for fish and wildlife. All of the functions and processes listed above relate to habitat, and this section provides additional information on ecosystems, communities, and wildlife species. Habitat is the physical place an organism occupies at any stage of its life history for a particular species. Since species have evolved and adapted to the environmental conditions within their historic range, such baseline conditions can be used to determine types of suitable habitat. Associated habitat selection research is also conducted to refine the types of habitat preferred by a species at multiple spatial scales. The historic range of variability (HRV) is a useful metric of baseline conditions because environments change over time, particularly in response to disturbances processes and temporal shifts (Morgan et al. 1994).

The emergence of urbanization and other human development has had a profound effect on wildlife and their ecosystems, altering behavior, population dynamics and demographics, community composition, and may result in extirpations or extinctions of entire species (Gaston 2010). These impacts are largely driven by habitat loss, degradation, and fragmentation; processes that constrict habitats to smaller and smaller patches until a species can no longer persist (Wiegand et al. 2005; Young et al. 2016). The effects of urbanization on wildlife are also exacerbated by direct harvest, invasive species, pollution, and climate change which contribute to defaunation at a global scale (Young et al. 2016).

Habitat loss and fragmentation are significant drivers in biodiversity loss. As described by MacArthur and Wilson (1967), the *species-area relationship* posits that biodiversity is lower in smaller habitat patches. As land is developed, continuous tracts of native habitat are reduced to patches, which become progressively smaller and more isolated. This is compounded by fragmentation by roads, fences, buildings, and other infrastructures which restricts interpatch movements and migrations (Wiegand et al. 2005). Ecological impacts of development are often overlooked and landscape-scale changes, particularly habitat fragmentation, alter the structure and function of those ecosystems (Dale et al. 2000).

Skagit County contains ecosystems which range from alpine mountain peaks to marine waters of the Salish Sea. Most of the land in Skagit County was historically forestlands at low to middle elevations, and alpine shrublands, grasslands, and parklands in the higher peaks of the Cascade Range (Johnson & O'Neil 2001). Marine environments, aquatic areas, and wetlands are also abundant within Skagit County (Johnson & O'Neil 2001). Each ecosystem is host to a variety of wildlife species, while the range and ecological niche of individual species may overlap several ecosystem types.

Habitat features at a local scale or micro scale are also important to patterns of habitat use by wildlife. For example, woodpeckers rely on decadent wood for foraging and nesting, and marbled murrelets require specific types of nesting platforms. Since there innumerable wildlife species, each with specific habitat requirements, further decision relates to habitat elements common to a wide range of taxa.

Habitat composition at the local level is influential at predicting species richness and abundance. The diversity of physical and biological habitat elements in a particular area, also known as heterogeneity, is associated with species richness due to offering greater overlap in niche requirements (Callaghan et al. 2019; Parker et al. 2014). Heterogeneity can be evaluated through multiple spatial scales, and through a range of potential environmental metrics such as plant species richness, plant community composition, community interspersion, physical and vegetation structure, amount of edge, etc. Other local scale factors associated with species richness include patch area, habitat richness, level of management, herb, shrub, and tree density, cover, and structure, vegetation species richness, microclimate, bare soils, and edge effects (Beninde et al. 2015).

Certain habitat types, or microhabitats have been identified by WDFW as priority habitats which are present in Skagit County. In addition to aquatic and riparian habitats discussed previously, these include biodiversity areas and corridors, herbaceous balds, old-growth/mature forests, Oregon white oak woodlands, caves, cliffs, talus, and snags and logs. These specific habitats are recognized for either their role as biodiversity hotspots, or because they are habitat elements critical for individual species, or groups of species.

Aquatic ecosystems, including streams, lakes, and wetlands provide habitat for a broad range of fauna including invertebrates, reptiles and amphibians, anadromous and resident fish, birds, and mammals. For example, wetlands with surface connections to salmon-bearing streams provide backwater refuge for anadromous fish when ponded water at least 18 inches deep, low flow conditions are present, and overhanging or submerged plants provide adequate cover (Sheldon et al. 2005). Aquatic invertebrates that depend on stream and wetland ecosystems are important to aquatic trophic systems or food webs (Rosenberg & Danks 1987; Sheldon et al. 2005; Wissinger 1999). Native frogs and salamanders require wetlands for breeding. Buffer conditions, habitat interspersion, wetland hydroperiod, and emergent plants are all important factors that impact amphibian richness and abundance (Sheldon et al. 2005). Waterfowl rely upon riparian ecosystems for all or part of their life cycle (Kauffman et al. 2001; Sheldon 2005). The suitability of habitat for birds is dependent on buffer condition and width, the presence of snags or other perches, corridor connections, open water, and forest canopy cover (Sheldon et al. 2005). Water-associated mammals such as beaver and muskrat also seek out well-buffered vegetated corridors, interspersed habitats with open water, and a seasonally stable water level (Sheldon et al. 2005). According to a Washington Department of Fish and Wildlife (WDFW) management recommendation plan conducted by Knutson and Naef (1997) a predominance of terrestrial vertebrate species in Washington are dependent on streams and riparian areas, including wetlands. Semlitsch and Bodie (2003) found that upland areas surrounding wetlands are core habitats for many semi-aquatic species, such as amphibians and reptiles.

Ecological resources of these aquatic areas support high levels of species diversity and abundance since they are generally structurally complex, maintain connectivity to other ecosystems, have plentiful sources of food and water, and a moist moderate microclimate (Knutson and Naef 1997). Riparian and wetland ecosystems also support a diverse range of native plant species. Wetland characteristics that are correlated with plant richness include hydroperiod, duration of flooding, and variation in water depths (Schueler 2000; Sheldon et al. 2005).

The performance of stream and wetland habitat functions is affected to varying degrees by the width and composition of the surrounding buffers. Disturbance vectors include but are not limited to habitat loss, habitat modification, noise, light, physical intrusion by equipment, people, pets, air and water pollution, and garbage. Each of these can result in one or more of the following: disruption of essential wildlife activities, damage to native vegetation and invasion of non-native species, erosion or fill, among others.

Cumulative impacts of direct and indirect riparian ecosystem alterations, including hydrologic changes, compromised water quality, and habitat fragmentation tend to reduce the habitat functions and values of wetlands and riparian areas (Azous & Horner 2010; Sheldon et al. 2005).

6.3 Species and Habitats of Conservation Concern

6.3.1 State & Federal designated Endangered, Threatened, or Sensitive Species

WDFW lists priority habitats and species (PHS) by county. Table 1 includes a summary of the Skagit County PHS list. As WDFW notes, habitats and species can change over time as distributions expand or contract. Skagit County includes habitat types that are known to be used or could potentially be used by bird and mammal species of interest, including those species with State or federal status and WDFW priority species.

Table 1. List of WDFW-designated priority species which occur in Skagit County.

	Species/ Habitats	State Status	Federal Status
Habitats	Biodiversity Areas & Corridors		
	Herbaceous Balds		
	Old-Growth/Mature Forest		
	Oregon White Oak Woodlands		
	Riparian		
	Freshwater Wetlands & Fresh Deepwater		
	Instream		
	Puget Sound Nearshore		
	Caves		
	Cliffs		
	Snags and Logs		
	Talus		
Fishes	Pacific Lamprey		
	River Lamprey	Candidate	
	White Sturgeon		
	Pacific Herring		
	Longfin Smelt		
	Surf smelt		
	Bull Trout/ Dolly Varden	Candidate	Threatened

	Species/ Habitats	State Status	Federal Status
	Chinook Salmon		Threatened (Upper Columbia Spring run is Endangered)
	Chum Salmon		Threatened
	Coastal Res./ Searun Cutthroat		
	Coho Salmon		Threatened – Lower Columbia
	Kokanee		
	Pink Salmon		
	Rainbow Trout/ Steelhead/ Inland Redband Trout	Candidate	Threatened
	Sockeye Salmon		Threatened – Ozette Lake Endangered – Snake River
	Pacific Cod		
	Pacific Hake		
	Walleye Pollock		
	Black Rockfish		
	Brown Rockfish		
	Canary Rockfish		Threatened
	China Rockfish		
	Copper Rockfish		
	Greenstriped Rockfish		
	Quillback Rockfish		
	Redstripe Rockfish		
	Tiger Rockfish		
	Yellowtail Rockfish		
	Lingcod		
	Pacific Sand Lance		
	English Sole		
	Rock Sole		
Amphibians	Columbia Spotted Frog	Candidate	
	Oregon Spotted Frog	Endangered	Threatened
	Western Toad	Candidate	
Birds	American White Pelican	Sensitive	
	Common Loon	Sensitive	
	Marbled Murrelet	Endangered	Threatened
	Short-tailed Albatross	Candidate	Endangered
	Western grebe	Candidate	
	W WA nonbreeding concentrations of: Loons, Grebes, Cormorants, Fulmar, Shearwaters, Storm-petrels, Alcids		
	W WA breeding concentrations of: Cormorants, Storm-petrels, Terns, Alcids		
	Great Blue Heron		
	Western High Arctic Brandt (formerly called Brandt)		

	Species/ Habitats	State Status	Federal Status
	Cavity-nesting ducks: Wood Duck, Barrow's Goldeneye, Common Goldeneye, Bufflehead, Hooded Merganser		
	Western Washington nonbreeding concentrations of: Barrow's Goldeneye, Common Goldeneye, Bufflehead		
	Harlequin Duck		
	Snow Goose		
	Trumpeter Swan		
	Tundra Swan		
	Waterfowl Concentrations		
	Golden Eagle	Candidate	
	Northern Goshawk	Candidate	
	Sooty Grouse		
	W WA nonbreeding concentrations of: Charadriidae, Scolopacidae, Phalaropodidae		
	Band-tailed Pigeon		
	Northern Spotted Owl (formerly called Spotted Owl)	Endangered	Threatened
	Vaux's Swift		
	Black-backed Woodpecker	Candidate	
	Oregon Vesper Sparrow	Endangered	
Mammals	Dall's Porpoise		
	Gray Whale	Sensitive	Endangered
	Harbor Seal		
	Orca (Killer Whale)	Endangered	Endangered
	Harbor Porpoise (formerly called Pacific Harbor Porpoise)	Candidate	
	Roosting Concentrations of: Big-brown Bat, Myotis bats, Pallid Bat		
	Townsend's Big-eared Bat	Candidate	
	Keen's Myotis (formerly Keen's Long-eared Bat)	Candidate	
	Cascade Red Fox	Endangered	
	Fisher	Endangered	
	Grizzly Bear	Endangered	Threatened
	Lynx	Threatened	Threatened
	Marten		
	Wolverine	Candidate	Threatened
	Columbian Black-tailed Deer		
	Mountain Goat		
	Elk		
Invertebrates	Pinto (Northern) Abalone	Endangered	
	Pacific Geoduck (formerly Geoduck)		

	Species/ Habitats	State Status	Federal Status
	Butter Clam		
	Native Littleneck Clam		
	Manila (Japanese) Littleneck Clam (formerly called Manila Clam)		
	Olympia Oyster		
	Pacific Oyster		
	Dungeness Crab		
	Pandalid shrimp (Pandalidae)		
	Beller's Ground Beetle	Candidate	
	Western Bumble Bee	Candidate	Candidate
	Johnson's Hairstreak	Candidate	
	Valley Silverspot	Candidate	
	Red Sea Urchin (formerly Red Urchin)		

6.3.2 Habitats and Species of Local Importance

Skagit County currently recognizes 11 habitats and species of local importance. These include the following:

a. Great blue heron nest sites;

b. Vaux's swifts communal roosts;

c. Pileated woodpecker nest sites;

d. Osprey nest sites;

e. Townsend big-eared bat communal roosts;

f. Cavity nesting duck breeding areas;

g. Trumpeter swan concentrations;

h. Harlequin duck breeding areas;

i. Waterfowl concentrations.

6.4 Key Protection Strategies

6.4.1 Streams, Lakes[7] and Ponds, and Riparian Areas

WATER TYPE CLASSIFICATION

Aquatic areas are classified so that they can be managed and regulated based on their characteristics, fish use, and functions. Characteristics common to water typing systema are flow volume, fish use and accessibility, seasonality, and presence of salmonids. The WDNR is encouraging all jurisdictions within the State to adopt the permanent water typing system upon completion of fish habitat water type mapping. The permanent system provides for four stream classes, Type S (Waters of the State), Type F (fish habitat present), Type Np (non-fish habitat stream with perennial flow), and Ns (non-fish habitat stream with seasonal flow). The water typing system is detailed in WAC 222-16-030.

RIPARIAN MANAGEMENT ZONES

In 2020, the Washington Department of Fish and Wildlife developed BAS guidance for the protection of riparian areas (Rentz et al. 2020). The guidance emphasizes a shift in terminology and framework from the concept of "*stream buffers*" to "*riparian management zones*" (RMZs). A RMZ is defined as "*…a scientifically based description of the area adjacent to rivers and streams that has the potential to provide full function based on the SPTH [site potential tree height] conceptual framework*." Further, a RMZ is recommended to be regulated as a fish and wildlife habitat conservation area itself to protect its fundamental value, rather than as a buffer for rivers and streams (Rentz et al. 2020). Stream buffers are established in local critical areas ordinances based on the best available science and are intended to protect streams but may or may not provide full riparian function or a close approximation of it. To achieve full riparian function, the guidance recommends that RMZs be considered a delineable, regulatory critical area and that the guidance be applied to all streams and rivers, regardless of size and type.

Washington Department of Fish and Wildlife's current recommendations for establishing RMZ widths are based primarily on a site potential tree height framework. The site potential tree height is defined as "*…the average maximum height of the tallest dominant [8] trees (200 years or more) for a given site class.*" Exceptions may occur where the site potential tree height is less than 100 feet, in which case the agency recommends assigning an RMZ width of 100 feet at a minimum to provide adequate biofiltration and infiltration of runoff for water quality protection from most pollutants, but also in consideration of other habitat-related factors including shade and wood recruitment. A 100-foot-wide buffer is estimated to achieve 95% pollution removal and approximately 85% surface nitrogen (Rentz et al. 2020). Washington Department of Fish and Wildlife recommends measuring RMZ widths from the

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[7] Lakes 20-acres or larger are regulated separately under the Shoreline Master Program, therefore discussed BAS is focused on lakes smaller than this threshold.

[8] Dominant trees are those which extend above the normal level of the forest canopy.

outer edge of the channel migration zone, where present, or from the ordinary high-water mark where a channel migration zone is not present.

To apply their methodology, Washington Department of Fish and Wildlife has developed a web-based mapping tool for use in determining site potential tree height based on the 200-year site index. Modeled site potential tree heights range from 75-231 feet. Where site potential tree height is 100 feet or more, the agency recommends RMZ establishment within one site potential tree height (Rentz et al. 2020). Acknowledging that establishing functional RMZs using the recommended methods may not be practical in many developed areas, Washington Department of Fish and Wildlife recommends effective watershed management, preservation, and protection, resulting in nearly full restoration of riparian ecosystem habitat functions as is feasible within existing constraints. Washington Department of Fish and Wildlife RMZ establishment and management recommendations are detailed in their *Riparian Ecosystems, Volume 2: Management Recommendations* document (Rentz et al. 2020). Examples of watershed-scale approaches include considering stormwater management adjacent to pollution generating impervious surface areas and prioritizing impassable culverts on fish-bearing streams.

A graphical representation of the Forest Ecosystem Management Assessment Team (FEMAT) Curves are shown in Figure 10, which are considered in WDFW's recommendations for establishing the dimensions of RMZs (Rentz et al. 2020). The figure depicts the effectiveness of several functions based on buffer width from the edge of a stream. SPTH is a practical buffer dimension because it is large enough to protect nearly all riparian functions, and further increases yield diminishing returns.

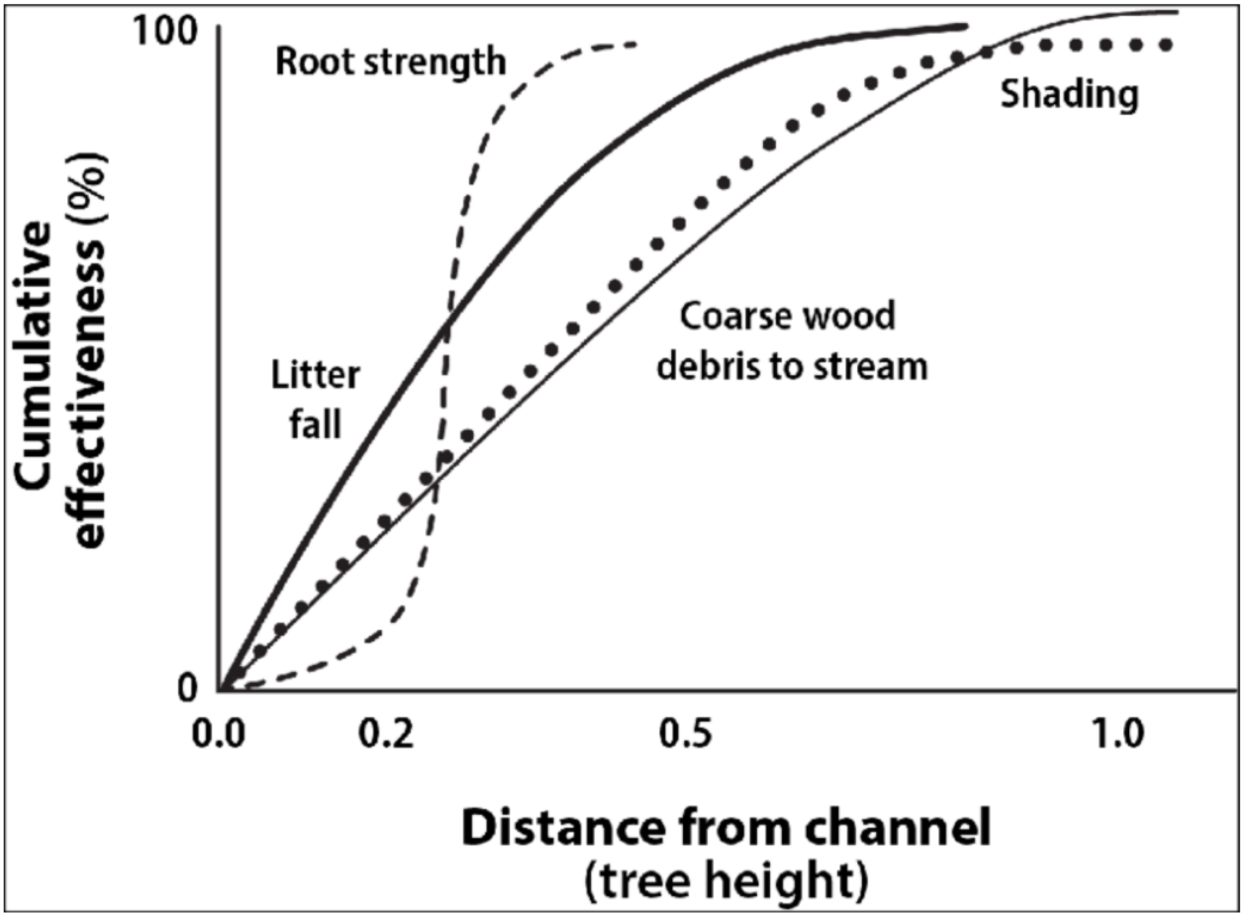

Figure 10. The “FEMAT Curves”: a conceptual model of the contributions of key riparian ecosystem functions which influence aquatic ecosystems by distance and cumulative effectiveness. Tree height refers to the average relative height of the site potential tree height (reproduced from FEMAT 1993).

Many of the scientific studies that examine the functions and values associated with riparian areas have been conducted in forested environments. However, there are fundamental differences between forested, agricultural, and urban areas, including land use and hydrology. Riparian studies often do not account for the contribution of engineering and public works projects, such as surface-water detention facilities, that can supplement natural riparian function in urban settings.

BAS-based literature points to a range of recommended management measures and buffer considerations to help maintain habitat functions for fish and wildlife. Effective methods to reduce impacts from urbanization and manage associated runoff can include the following:

- Limiting development densities and impervious surface coverage;
- Limiting vegetation clearing and retaining forest cover;
- Concentrating impact activities, particularly roads and pollutant sources, away from watercourses;

- Limiting the total area of roads and requiring joint use of new access roads;
- Protecting vegetation and limiting development on or near hydrologic source areas;
- Maintaining densely vegetated riparian buffers with native trees, shrubs, and groundcover species;
- Low impact development (LID);
- Municipal stormwater treatment;
- Public education.

In an analysis of riparian zone ordinances, Wenger and Fowler (2000) support using approaches that allow some flexibility in how policies are implemented on a parcel scale. Whereas variable-width policies provide greater flexibility and adaptability to address site-specific conditions, it is noted that fixed buffer widths are more easily established, require a lesser degree of scientific knowledge to implement, and generally require less time and money to administer (Castelle and Johnson 1998). Thus, although stream and riparian conservation measures should be based in best available science, some level of policy interpretation must be made by a local jurisdiction.

If fixed-width buffers are implemented, buffers should be sufficiently wide to ensure that riparian buffers are effective under a range of variable conditions. The ranges of effective buffer widths (as outlined in each subsection) based on each function that were previously discussed are summarized below in Table 2.

Table 2. Range of Effective Buffer Widths for Each Applicable Riparian Function.

Function	Range of Effective Buffer Widths	Notes
Water quality: sediment	4-30 m (13-98 feet), up to 120 m (394 feet) for fine sediment	Filtration is widely variable depending on slope and soils.
Water quality: nutrients	Subsurface flow: not dependent on buffer width Surface flow: 15-131 m (49-430 feet)	In addition to buffer width, the rate of nutrient removal is dependent on infiltration, soil composition, and climate. Filtration capacity decreases with increasing loads, so best management practices that reduce nutrient loading will improve riparian function.
Water quality: metals	NA- Appropriate buffer width not established	Stormwater system improvements to slow and infiltrate runoff could help reduce metals entering aquatic systems.
Water quality: pathogens	NA- Appropriate buffer width not established	Minimizing the density of septic systems, maximizing the distance of septic systems from aquatic resource areas, and promoting pet waste management will help limit the transport of pathogens to aquatic systems. Ongoing

Function	Range of Effective Buffer Widths	Notes
		agricultural activities can be addressed through Voluntary Stewardship Programs (VSP).
Water quality: herbicides	6-18 m (20-59 feet)	Best management practices during application of herbicides and pesticides can help limit leeching to groundwater.
Water quality: pharmaceuticals	NA- Appropriate buffer width not established	Best management practices for disposal of pharmaceuticals may limit potential impacts.
Water quality: stream temperature	10-30 m (33-98 feet)	Leaf cover is more closely related to stream temperature than buffer width.
Bank Stabilization	10-30 m (33-98 feet)	Beyond 98 feet from the stream, buffers have little effect on bank stability.
Microclimate	(10-45 m) 33-150 feet	Most microclimate changes occur within 10-45 m (33 to 150 feet) from the edge, but microclimate effects extend over 240 m (790 feet) from the forest edge.
Invertebrates and Detritus	30 m (98 feet)	Areas with 10 m (33 ft) buffers exhibit changes in invertebrate community composition.
Wildlife Habitat	100 to 600 feet	Minimum width for supporting habitat varies among taxa, guides, and species. Functions include both corridor (travel and migration) and support of lifecycle stages, including breeding.
In-stream Habitat (large woody debris – LWD)	18-50 m (59 to 164 feet)	Although most LWD is recruited from the area adjacent to the stream, tree-fall from beyond 1 SPTH may affect LWD loading.

To achieve improved water quality in the County's streams, small lakes, and ponds, riparian buffer areas should be utilized effectively to provide both biofiltration of stormwater runoff and protection from adjacent land uses. Both goals can be achieved by providing dense, well-rooted vegetated buffer areas.

Biofiltration swales, created wetlands, and infiltration opportunities for specific stormwater runoff discharges can be utilized to intercept runoff before it reaches stream channels. Stormwater runoff that is conveyed through stream buffers in pipes or ditch-like channels and discharged directly to stream channels "short circuits" or bypasses buffer areas and receives little water quality treatment via biofiltration. In areas where stormwater flows untreated through riparian buffer areas, the buffer is underutilized and is prevented from providing the intended or potential biofiltration function.

FEMA FLOODPLAIN HABITAT ASSESSMENTS

In 2008, the National Marine Fisheries Service (NMFS) issued a Biological Opinion under Section 7 of the Endangered Species Act, which found that the implementation of the National Flood Insurance Program (NFIP) in the Puget Sound region jeopardized the continued existence of federally threatened salmonids and resident killer whales. As a result, NMFS established Reasonable and Prudent Alternatives to ensure that development within the Special Flood Hazard Area (100-year floodplain), floodway, Channel Migration Zone (CMZ), and riparian buffer zone do not adversely affect water quality, flood volumes, flood velocities, spawning substrate, or floodplain refugia for listed salmonids. Because the NFIP is implemented by the Federal Emergency Management Agency (FEMA) through participation by local jurisdictions that adopt and enforce floodplain management ordinances, FEMA has delegated responsibility to the local jurisdictions to ensure that development does not adversely affect listed species. Projects within FEMA-designated floodplains are required to prepare habitat assessments to ascertain their potential effects on federally-listed endangered species. In particular, floodplain storage volumes may not be decreased nor base flood level elevations increased.

6.4.2 Endangered, Threatened, or Sensitive Species and Species of Local Importance

Effective BAS-based strategies can be applied to protect all Federal and State endangered or threatened species and WDFW-identified Priority Species and Habitats (PHS). Not all FWHCAs are water bodies or riparian areas associated with those water bodies. WDFW, USFWS, and NMFS provide information on species-specific management recommendations for certain species that can be used to guide management at the county level or site level. There is widely available information for high profile species, though many regulated species are poorly researched and lack specific management recommendations from state agencies. Where species-specific management recommendations are available from WDFW guidance documents, those should be followed or adapted to local regulations. Examples are Management Recommendations for Washington’s Priority Species; Invertebrates (Larsen 2018); amphibians and reptiles (Larsen 1997); Birds (Larsen 2018); and mammals (WDFW 2010). General recommendations for management strategies to protect terrestrial habitat are listed below.

GENERAL TERRESTRIAL HABITAT MANAGEMENT RECOMMENDATIONS

- Existing high quality habitats should be retained because habitat loss is one of the most important factors influening biodiversity and loss of species (Beninde et al. 2015).
- Generally, plan development to minimize fragmentation of native habitat, particularly large, intact habitat areas. Where large forest stands exist, manage for forest-interior species and avoid fragmentation (Donnelly and Marzluff 2004, Diffendorfer et al. 1995, Mason et al. 2007, Orrock and Danielson 2005, Pardini et al. 2005 and others).
- Manage agricultural development to limit fragmentation and edge; preserve vegetative structural diversity whenever possible in agricultural areas by retaining hedge rows and areas of native vegetation (Southerland 1993).
- Protect priority habitats that have a primary association with an ESA-list species or species of local importance by continuing to regulate for adherence to WDFW management recommendations and other applicable regulatory requirements.
- Control invasive species where needed on a site- and species-specific basis. Address invasive species specifically addressed in areas where environmental conditions tend to promote infestation, including created edges, roadways, and riparian zones where they are contiguous

with developed areas that may act as a seed source (Olden et al. 2004, Pimentel et al. 2005, McKinney 2002 and others).

- Maintain or provide habitat connectivity with vegetated corridors between habitat patches (Schaefer 2003, Clair 2008, Gilbert-Norton et al. 2010 and others).
- Protect, maintain, and promote habitat features such as snags and downed wood (Blewett and Marzluff 2005).
- Manage for increase native vegetative cover in landscaping and discourage lawns (Nelson and Nelson 2001).
- Plan habitat areas away from roads (Fahrig et al. 1995, Lehtinen et al. 1999).
- Promote buffers of adequate width to support wildlife guilds in adjacent habitat (Ficetola et al. 2008, Semlitsch and Bodie 2003, Crawford and Semlitsch 2007).
- Identify existing habitat patches and corridors and maintain connectivity with vegetated corridors to limit fragmentation and edge habitat (Gillies et al. 2008, Gilbert-Norton et al. 2010). Preserve habitat patches of at least moderate size 35 ha (86 ac) within developed areas (Kissling and Garton 2008).
- Promote restoration of FWHCAs, buffers, and other management zones through critical area regulations and public outreach. Encourage stewardship on a parcel by parcel and county-wide scale.

6.5 Climate Change Impacts & Mitigation

Climate change is predicted to result in significant and irreversible impacts to fish and wildlife, and their habitats. Global change is anticipated to result in habitat loss and modification through temperature changes, sea level rise, ocean acidification, extreme weather events, changes in precipitation, biological invasions, food web disruptions, and disease (Lyons et al. 2022; Nagelkerken 2023). The range of effects on fish and wildlife depend on species specific interactions and may include range shifts, phenological shifts, changes to morphology and behavior, biodiversity loss, and extinction (Sattar 2021). The cumulative impacts of these factors to wildlife is anticipated to result in loss of biodiversity and increases to extinction rates (Sattar 2021).

Changes in temperatures and seasonal precipitation patterns are projected to place additional stressors on FWHCAs. Some loss of riparian vegetation is anticipated due to the stresses of climate change, primarily warmer and drier summers. A reduction in riparian vegetation potentially triggers a cascading effect. A decrease in riparian vegetation would decrease shading, increase stream temperature, decrease detrital inputs, reduce available habitat structure, and reduce stream bank stability. Changes in seasonal hydrologic cycles may increase frequency and magnitude of flashy runoff events, mobilize greater volumes of sediments and pollutants into streams, and reduce groundwater recharge that supports base stream flows in summer. FWHCA Functions and Values, instream habitats are particularly negatively impacted by excess sediment discharge and deposition.

Hot dry summers are projected to reduce stream flow volumes and increase instream temperatures. This stressor is compounded by extreme precipitation events, flooding and erosion. All these stressors reduce instream habitat quality and stress salmonid populations, including Chinook salmon, the preferred food source for Orca whales. Global warming poses a threat freshwater fish habitat (Crozier et al. 2008).

6.5.1 Strategies to manage climate change impacts to FWHCAs

The following actions or policies have been developed for other local jurisdictions in coordination with the University of Washington Climate Impacts Group, and are potential strategies that Skagit County could use to reduce negative climate change impacts on FWHCAs (Redmond 2022).

- Promote retention of trees and forests and maintain tree replacement and reforestation requirements.
- Encourage and incentivize enhancement and restoration of native forest patches throughout the County, particularly where connectivity to one or more FWHCAs is identified. Both voluntary and required restoration planting should be paired with monitoring and maintenance that allows for dry season irrigation and adaptive management.
- Consider assisted migration for seed selection of native plants from locations that are better adapted to future climate conditions.
- Manage stormwater infrastructure to avoid and minimize discharges of increased and/or untreated runoff to streams and thereby offset the anticipated increase in intensive rainfall events. Promote the use of LIDs as a tool to effectively manage stormwater for minimal downstream impacts.
- Update and maintain regulations for habitats and species of local importance. This may include adding mapping resources to help identify the locations of potential habitats and species requiring protection and management.
- Prioritize protection of streams and riparian corridors to reduce the stresses of climate change on native fish species and anadromous fish, such as chinook salmon.
- Identify and protect cold water refugia in waterbodies.
- Conduct vulnerability assessments and climate action plans.

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APPENDIX A: Ecology's Wetland Buffer Width Recommendations

- **Wetland Guidance for Critical Areas Ordinance (CAO) Updates, Appendix C. Buffer Approaches for Western Washington (Ecology Publication 22-06-014)**

Appendix C. Buffer Approaches for Western Washington

Option 1

Table 1. Wetland buffer width requirements, in feet, if Table 2 is implemented <u>and</u> a habitat corridor is provided

Category of wetland	Habitat score 3-5 points (corridor not required)	Habitat score 6-7 points	Habitat score 8-9 points	Buffer width based on special characteristics
Category I or II: Based on rating of wetland functions (and not listed below)	75	110	225	NA
Category I: Bogs and Wetlands of High Conservation Value	NA	NA	225	190
Category I: Interdunal	NA	NA	225	NA
Category I: Forested	75	110	225	NA
Category I: Estuarine and wetlands in coastal lagoons	NA	NA	NA	150
Category II: Interdunal	NA	NA	NA	110
Category II: Estuarine and wetlands in coastal lagoons	NA	NA	NA	110
Category III: All types except interdunal	60	110	225	NA
Category III: Interdunal	NA	NA	NA	60
Category IV: All types	40	40	40	NA

Impact minimization measures

Developments that produce the listed disturbances and are requesting a buffer reduction are required to address the disturbance through the use of applicable minimization measures.

This is not a complete list of measures, nor is every example measure required. Though not every measure is required, all effort should be made to implement as many measures as possible. Regulatory staff should determine, in coordination with the applicant, which measures are applicable and practicable.

Table 2. Impact minimization measures

Examples of disturbance	Activities and uses that cause disturbances	Examples of measures to minimize impacts
Lights	• Parking lots • Commercial/Industrial • Residential • Recreation (e.g., athletic fields) • Agricultural buildings	• Direct lights away from wetland • Only use lighting where necessary for public safety and keep lights off when not needed • Use motion-activated lights • Use full cut-off filters to cover light bulbs and direct light only where needed • Limit use of blue-white colored lights in favor of red-amber hues • Use lower-intensity LED lighting • Dim light to the lowest acceptable intensity
Noise	• Commercial • Industrial • Recreation (e.g., athletic fields, bleachers, etc.) • Residential • Agriculture	• Locate activity that generates noise away from wetland • Construct a fence to reduce noise impacts on adjacent wetland and buffer • Plant a strip of dense shrub vegetation adjacent to wetland buffer
Toxic runoff	• Parking lots • Roads • Commercial/industrial • Residential areas • Application of pesticides • Landscaping • Agriculture	• Route all new, untreated runoff away from wetland while ensuring wetland is not dewatered • Establish covenants limiting use of pesticides within 150 ft. of wetland • Apply integrated pest management (These examples are not necessarily adequate for minimizing toxic runoff if threatened or endangered species are present at the site.)

Examples of disturbance	Activities and uses that cause disturbances	Examples of measures to minimize impacts
Stormwater runoff	• Parking lots • Roads • Residential areas • Commercial/industrial • Recreation • Landscaping/lawns • Other impermeable surfaces, compacted soil, etc.	• Retrofit stormwater detention and treatment for roads and existing adjacent development • Prevent channelized or sheet flow from lawns that directly enters the buffer • Infiltrate or treat, detain, and disperse new runoff from impervious surfaces and lawns
Pets and human disturbance	• Residential areas • Recreation	• Use privacy fencing • Plant dense native vegetation to delineate buffer edge and to discourage disturbance • Place wetland and its buffer in a separate tract • Place signs around the wetland buffer every 50-200 ft., and for subdivisions place signs at the back of each residential lot • When platting new subdivisions, locate greenbelts, stormwater facilities, and other lower-intensity uses adjacent to wetland buffers
Dust	• Tilled fields • Roads	• Use best management practices to control dust

Table 3. Wetland buffer width requirements, in feet, for applicants not providing a habitat corridor or implementing measures in Table 2

Category of wetland	Habitat score 3-5 points	Habitat score 6-7 points	Habitat score 8-9 points	Buffer width based on special characteristics
Category I & II: Based on rating of wetland functions (and not listed below)	100	150	300	NA
Category I: Bogs and Wetlands of High Conservation Value	NA	NA	300	250
Category I: Interdunal	NA	NA	300	NA
Category I: Forested	100	150	300	NA
Category I: Estuarine and wetlands in coastal lagoons	NA	NA	NA	200
Category II: Interdunal	NA	NA	NA	150
Category II: Estuarine and wetlands in coastal lagoons	NA	NA	NA	150
Category III: All types except interdunal	80	150	300	NA
Category III: Interdunal	NA	NA	NA	80
Category IV	NA	NA	NA	50

Conditions for implementing Tables 1, 2, and 3

1. Wetlands that score 6 points or more for habitat function: the buffers in Table 1 can be used only if all of the following criteria are met:

a. A relatively undisturbed, vegetated corridor at least 100 feet wide is protected between the wetland and:

i. A legally protected, relatively undisturbed and vegetated area (e.g., Priority Habitats, compensatory mitigation sites, wildlife areas/refuges, national, county, and state parks where they have management plans with identified areas designated as Natural, Natural Forest, or Natural Area Preserve, or

ii. An area that is the site of a Watershed Project identified within, and fully consistent with, a Watershed Plan as defined by RCW 89-08-460, or

iii. An area where development is prohibited according to the provisions of the local shoreline master program, or

iv. An area with equivalent habitat quality that has conservation status in perpetuity, in consultation with WDFW.

b. The corridor is permanently protected for the entire distance between the wetland and the shoreline or legally protected area by a conservation easement, deed restriction, or other legal site protection mechanisms.

c. Presence or absence of the shoreline or Priority Habitat must be confirmed by a qualified biologist or shoreline Administrator.

d. The measures in Table 2 are implemented, as applicable, to minimize the impacts of the adjacent land uses.

2. For wetlands that score 5 or fewer habitat points, only the measures in Table 2 are required for the use of the buffers in Table 1.

3. If an applicant does not apply the mitigation measures in Table 2 or is unable to provide a protected corridor, then the buffers in Table 3 shall be used.

4. The buffer widths in Tables 1 and 3 assume that the buffer is vegetated with a native plant community appropriate for the ecoregion. If the existing buffer is unvegetated, sparsely vegetated, or vegetated with invasive species that do not perform needed functions, the buffer must either be planted to create the appropriate native plant community or be widened to ensure that the buffer provides adequate functions to protect the wetland.

Note: An expanded table with graduated buffer widths based on habitat score is also outlined in the July 2018 Appendix 8-C[76] of *Wetlands in Washington State, Volume 2*. This is an approach that assigns unique buffer widths to each habitat score in seven increments. It is a gradual increase in buffer width with each point. Compared to Option 1, this avoids a marked increase in buffer width resulting from an increase of one point in the habitat score.

Option 2

Table 1. Width of buffers, in feet, needed to protect wetlands from impacts of proposed land uses (used with Table 2)

Category of wetland	Land use with low impact*	Land use with moderate impact*	Land use with high impact*
I	150	225	300
II	150	225	300
III	75	110	150
IV	25	40	50

*See Table 2 below for types of land uses that can result in low, moderate, and high levels of impacts to wetlands

Table 2. Levels of impacts from proposed land use types

[Local governments are encouraged to ensure the uses in this table match the uses specified in their development and land use regulations and are consistent with the principles in this example.]

Level of impact from proposed land use	Types of land use
High	• Commercial • Urban • Industrial • Institutional • Mixed-use developments • Residential (more than 1 unit/acre) • Roads: federal and state highways, including on-ramps and exits, state routes, and other roads associated with high-impact land uses • Railroads • Agriculture with high-intensity activities (dairies, nurseries, greenhouses, growing and harvesting crops requiring annual tilling, raising and maintaining animals, etc.)

[76] https://apps.ecology.wa.gov/publications/parts/0506008part3.pdf

Level of impact from proposed land use	Types of land use
	• Open/recreational space with high-intensity uses (golf courses, ball fields, etc.) • Solar farms (utility scale)
Moderate	• Residential (1 unit/acre or less) • Roads: Forest Service roads and roads associated with moderate-impact land uses • Open/recreational space with moderate-intensity uses (parks with paved trails or playgrounds, biking, jogging, etc.) • Agriculture with moderate-intensity uses (orchards, hay fields, light or rotational grazing, etc.) • Utility corridor or right-of-way used by one or more utilities and including access/maintenance road • Wind farm
Low	• Natural resource lands (forestry/silviculture–cutting of trees only, not land clearing and removing stumps) • Open/recreational space with low-intensity uses (unpaved trails, hiking, birdwatching, etc.) • Utility corridor without a maintenance road and little or no vegetation management • Cell tower

Option 3

Table 1. Wetland buffer width requirements, in feet, based solely on wetland category

Category of wetland	Buffer width
I	300
II	300
III	150
IV	50

APPENDIX B: Ecology's Recommended Wetland Mitigation Ratios for Western Washington

- **Wetland Guidance for Critical Areas Ordinance (CAO) Updates, Appendix E. Mitigation Ratio Tables (Ecology Publication 22-06-014)**

Appendix E. Mitigation Ratio Tables

Compensation ratios for permanent impacts (western and eastern Washington)

Table 1

Category of impacted wetland (based on score for function)	Re-establishment or creation	Rehabilitation	Preservation	Enhancement
Category I	4:1	8:1	16:1	16:1
Category II	3:1	6:1	12:1	12:1
Category III	2:1	4:1	8:1	8:1
Category IV	1.5:1	3:1	6:1	6:1

Notes:

- Ratios for rehabilitation, preservation, and enhancement may be reduced when combined with 1:1 replacement through re-establishment or creation. See Table 6B-2 in *Wetland Mitigation in Washington State – Part 1: Agency Policies and Guidance –Version 2* (Ecology et al., 2021 or as revised).
- All proposed preservation sites need to meet the preservation criteria listed in Chapter 070.3.E of Appendix A, Sample Wetland Regulations.
- The ratios provide in Table 1 are for permanent, direct impacts to wetlands. For recommended ratios for other types of impacts (e.g., long-term temporary, conversions), see Chapters 6B4.4 through 6B4.8 of *Wetland Mitigation in Washington State – Part 1: Agency Policies and Guidance –Version 2* (Ecology et al., 2021 or as revised).
- The category of impacted wetland is based on scores for functions. Compensation ratios in this table generally do not apply when impacts involve a wetland whose category is based on special characteristics. Compensation ratios for impacts to wetlands with special characteristics are provided in Table 2 below. Specific tables are provided for western and eastern Washington.

Compensation ratios for unavoidable permanent impacts to wetlands with special characteristics (western Washington)

Table 2. Western

Category of impacted wetland (based on special characteristics)	Re-establishment or creation	Rehabilitation	Preservation	Enhancement
Category I forested	6:1	12:1	24:1	24:1
Bogs	NA	NA	24:1	NA
Wetlands of High Conservation Value	Consult with WA DNR	Consult with WA DNR	24:1	Consult with WA DNR
Category I Estuarine wetlands	3:1 (re-establishment only)	6:1	12:1	Limited circumstances (case by case)
Category II Estuarine wetlands	4:1 (re-establishment only)	8:1	16:1	Limited circumstances (case by case)
Category I Interdunal wetlands	4:1	8:1 (limited circumstances)	16:1	Not considered an option
Category II Interdunal wetlands	2:1	4:1 (limited circumstances)	8:1	Not considered an option
Category III and IV Interdunal wetlands	1.5:1	3:1 (limited circumstances)	6:1	Not considered an option
Category I Wetlands in coastal lagoons	4:1 (re-establishment only)	8:1	16:1	Not considered an option
Category II Wetlands in coastal lagoons	3:1 (re-establishment only)	6:1	12:1	Not considered an option

Note: Methods of compensation are limited for certain wetlands with special characteristics. Some of these wetland types only occur naturally and have never been successfully created or rehabilitated. Some may take more than a lifetime to re-establish. Thus, avoidance is the best regulatory approach when addressing these wetlands. Refer to Chapter 6B.5 of Wetland Mitigation in Washington State – Part 1: Agency Policies and Guidance –Version 2 (Ecology et al., 2021 or as revised) for more information on methods of compensation and ratios for wetlands with special characteristics.