GIG HARBOR
THE MARITIME CITY

Agenda for Gig Harbor Planning Commission
Gig Harbor Civic Center
Thursday, February 19, 2026 at 5:30 P.M.

This meeting may also be accessed through Zoom at https://zoom.us/j/95353411299 or by calling (253) 215- 8782 and entering Meeting ID 953 5341 1299. Please see the Public Comment & Decorum section at the end of this agenda for information on options to make public comment.

This meeting may also be viewed live in the Council Chambers at the Civic Center.

Call to Order/Roll Call:

Approval of Minutes: February 5, 2026

Public Comment:

Agenda Items:

Welcome Commissioner Wozniak

Election of Chair and Vice Chair

Critical Area Code Update – Presentation Community Development Director, Eric Baker and Commission discussion

Other Business: Next meeting Thursday, March 5, 2026

Adjournment:

PUBLIC COMMENT & DECORUM

The city desires to allow a maximum opportunity for public comment. However, the business of the Planning Commission must proceed in an orderly, timely manner. The purpose of a Planning Commission meeting is to advise on subjects prescribed by the City Council; it is not a public forum.

Public comment may be made in-person from the microphone, remotely via Zoom or by phone during designated portions of the meeting. To speak during the meeting via Zoom, press the Raise Hand button near the bottom of your Zoom window or press *9 on your phone. Please refrain from raising your hand until the Chair has announced that the Commission has opened the public comment portion of the meeting. Your name or the last three digits of your phone number will be called out when it is your turn to speak. When using your phone to call in, you may need to press *6 to unmute yourself. Speakers will be allotted 3 minutes per individual, unless revised by the chair. Comments shall be made, first giving the speaker's name and address. Anyone making "out of order" comments may be subject to removal from the meeting.

Instead of making oral comments, written comments may be submitted to the Planning Commission at PlanningComments@gigharborwa.gov.

All remarks shall be addressed to the commission as a body and not to any specific commissioner. All speakers shall be courteous in their language and deportment and shall not engage in or discuss or comment on personalities or indulge in derogatory remarks or insinuations with regard to any commissioner, or any member of the staff or the public.

There will be no demonstrations during or at the conclusion of any public comment. These guidelines are intended to promote an orderly system of holding public meetings, to give every person an opportunity to be heard and to ensure that no individuals are embarrassed by voicing their opinions.

AMERICANS WITH DISABILITIES (ADA) ACCOMMODATIONS

ADA accommodations can be provided upon request. Those requiring special accommodations should contact the city clerk at cityclerk@gigharborwa.gov or (253) 853-7613 at least 24 hours prior to the meeting.

GIG HARBOR
THE MARITIME CITY

Minutes for Gig Harbor Planning Commission
Thursday, February 5, 2026 at 5:30 P.M.
Council Chambers

Call to Order/Roll Call

Vice Chair Jordan called the meeting to order at 5:33p.m. Commissioners Anderson, Cornell, Henderson and Zhou were present. Commissioner Burcar was excused

Staff: Community Development Director, Eric Baker and Planning Technician, Michelle Thomas

Approval of Minutes

Motion: Move to approve minutes from January 22, 2026 (Anderson/Cornell)
Vote: Unanimously approved

Public Comment on Non-Agenda Items

None.

Agenda Items

Critical Areas Code Update, Presentation by Eric Baker and Commission discussion.

Other Business

Next meeting Thursday, February 19, 2026 topics are welcoming new Commissioner, election of Chair and Vice Chair and continued discussion of the Critical Areas Code Update.

Adjournment 6:53 p.m.

Michelle Thomas
Michelle Thomas
Planning Technician

Best Available Science Summary Report

CRITICAL AREAS ORDINANCE UPDATE

KITSAP COUNTY

MAY 31, 2023

Prepared for:

Kitsap County
Department of Community Development

DCG WATERSHED

Title-page image: Chico Creek.

TABLE OF CONTENTS

LIST OF EXHIBITS

AUTHORS

Mark Daniel, Senior Planner. B.A. Kinesiology, B.A. Economics/Environmental Studies, Master of Urban Planning. American Institute of Certified Planners.

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Clover McIngalls, Environmental Planner/Ecologist. B.S. Environmental Science, M.Sc. Marine Affairs. Wetland Science and Management Certificate, Society of Wetland Scientists – Professional Wetland Scientist #2630.

Dan Nickel, Environmental Engineer. B.S. Biology. M.Sc. Environmental Science.

Alexandra Plumb, Environmental Planner. B.S. Oceanography, Marine Biology.

Al Wald, Hydrogeologist. B.S. Renewable Natural Resource Management, M.S. Forest Hydrology. Licensed Hydrogeologist.

1 INTRODUCTION

1.1 BACKGROUND

Kitsap County is currently performing the periodic update of its Comprehensive Plan and development regulations as required by the Washington State Growth Management Act (GMA). The GMA requires all local jurisdictions to review and evaluate their critical areas ordinance (CAO) as part of the periodic update.

Kitsap County's CAO is codified in Title 19 of the Kitsap County Code (KCC). The County's last periodic update of its CAO was completed in 2017.

Critical areas subject to regulation under GMA include wetlands, areas with a critical recharging effect on aquifers used for potable water, fish and wildlife habitat conservation areas, frequently flooded areas, and geologically hazardous areas (Revised Code of Washington [RCW] 36.70A.030(6)).

In developing regulations to protect the functions and values of these critical areas, the GMA requires that best available science (BAS) be included, and "special consideration" be given to conservation or protection measures necessary to preserve or enhance anadromous fisheries.

This BAS Summary Report has been prepared specifically to support the update of Kitsap County's CAO. Building upon and supplementing the County's existing record of BAS, this report highlights recent additional BAS, including BAS related to climate change.

A companion document to this BAS Summary Report is the Consistency and Gap Analysis Report (DCG/Watershed 2023). The Consistency and Gap Analysis Report identifies where the BAS presented in this BAS Summary Report is already applied in the current CAO, or how it might be incorporated in the County's CAO during this periodic update.

1.2 BEST AVAILABLE SCIENCE

Chapter 365-195 of the Washington Administrative Code (WAC) addresses the subject of BAS.

BAS documents are those prepared by qualified scientific experts and follow a valid scientific process. The scientific process, which produces reliable information, is generally characterized by 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).

While the body of scientific knowledge pertaining to critical areas continues to evolve as new studies are conducted and new technologies are employed, BAS may not always provide decisive information for developing policies and development regulations to protect the functions and values of critical areas. Where the scientific literature shows variable methods or results, a range of values may be provided.

In some cases, incomplete scientific information or an absence of valid scientific information may lead to uncertainty about what development and land uses could lead to harm of critical areas or uncertainty about the risk to critical area functions of permitting development. In such cases, in accordance with WAC 365-195-920, a precautionary or no risk approach should be taken in which development and land use activities are strictly limited until the uncertainty is sufficiently resolved. In the interim, local jurisdictions can implement an adaptive management program that relies on scientific methods.

The BAS documents in this report were selected based on their significance to conditions in Kitsap County, common use in scientific discipline, and relevance to current scientific practices or principles.

1.2.1 Climate Change

Climate change is projected to strain critical areas and the functions they provide; this poses a challenge for natural resource management (Mote et al. 2014). This report includes a review of known climate change issues affecting each type of critical area.

Anthropogenic global climate change is projected to impact climatic variation and natural resources in the Pacific Northwest. Climate models project annual temperature increases totaling 3.2 degrees Fahrenheit by the 2040s (Mote & Salathe 2010). At current rates of warming, global warming may exceed 2.7 degrees Fahrenheit (1.5 degrees Celsius) by 2030 (Snover et al. 2019). Modeled changes include reduced regional snowpack, reduced summer water supply, and a greater frequency and duration of extreme weather events including flooding and high temperatures (Mauger et al. 2015). As described in the *Kitsap County Climate Change Resiliency Assessment* (Kitsap County et al. 2020), Kitsap County's relative sea level is largely projected to rise by 2100, with a range from -0.1 feet to 2.7 feet.

Climate change studies and modelling continue to provide information about what changes to expect globally and in the Pacific Northwest. However, climate change is a complex issue and guidance on how best to manage critical areas in a changing environment is continually evolving.

1.3 REPORT STRUCTURE

This report features a section for each of the critical area types subject to regulation under the GMA. For each type of critical area, the report includes:

- A definition/description of the critical area;
- A summary of the functions and values provided by the critical area, including a discussion of recent additional BAS; and
- A summary of BAS related to climate change.

2 WETLANDS

2.1 DEFINITION/DESCRIPTION

Wetlands are dynamic environments characterized by seasonally or permanently wet areas. Wetlands also have anaerobic hydric soil indicators and water-dependent or water-tolerant plant species.

RCW 36.70A.030(31) defines "wetlands" as follows:

> *"Wetland" or "wetlands" means those areas that are inundated or saturated by surface 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, including, but not limited to, irrigation and drainage ditches, grass-lined swales, canals, storm water 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 nonwetland areas created to mitigate conversion of wetlands.*

2.2 FUNCTIONS & VALUES

2.2.1 Summary of Functions & Values

The capacity of an individual wetland to perform functions is dependent upon multiple factors, including the wetland landform or hydrogeomorphic class. For example, wetlands on slopes have less potential to store water relative to depressional wetlands. Wetland functions are also dependent on the geomorphic and hydrologic characteristics of each wetland (Brinson 1993, Hruby 2014). Other factors that impact wetland functions are landscape setting, vegetation structure, hydroperiods, proximity to potential sources of pollution, and priority habitat corridors and connectivity. Wetlands naturally perform several functions at low cost relative to engineered solutions, such as water storage, flood protection, water reserve, pollutant and nutrient retention, and provisional fisheries habitat; these are valued as human services (Hattermann et al. 2008).

For regulatory purposes, wetland functions and values are commonly ranked in a rating system. The current BAS-based rapid assessment tool for wetland functions is the *Washington State Wetland Rating System for Western Washington* (Hruby 2014) developed by the Washington State Department of Ecology (Ecology). The Ecology wetland rating system broadly groups wetland functional values into three categories: 1) water quality functions, 2) flood storage or hydrologic functions, and 3) habitat functions (Sheldon et al. 2005, Hruby 2014). The functional score for each category is ranked as high, medium, or low. Each category assesses site potential to perform each function, relative to landscape setting, and value to society.

2.2.1.1 Water Quality

Wetlands improve water quality by intercepting runoff, retaining inorganic nutrients, converting organic wastes, settling sediment, and removing contaminants (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 2014). Wetlands uptake nutrients, particularly nitrogen and phosphorus, and protect downstream areas from nutrient spikes. Wetland plants and microorganisms are known to uptake or remove nitrogen through the biochemical processes of nitrification and denitrification, which occur in aerobic and anaerobic conditions, respectively (Sheldon et al. 2005). According to Kerr et al. (2008), low oxygen concentrations that are common to wetland environments also make them particularly good sinks for copper. Studies of constructed wetlands have shown wetland plants remediate pharmaceuticals and personal care products to various extents and provide some phytoremediation (Wang et al. 2019, Zhang et al. 2014). Some wetlands may also help improve water quality by regulating stream temperature. A recent study by Dittbrenner et al. (2022) looked at changes in temperature and water storage following relocation of beaver into headwater stream reaches. Beaver activity is known to create wetland complexes that can alter aquatic ecosystems. The study found that the creation of beaver wetland complexes has the potential to decrease stream temperatures.

2.2.1.2 Hydrologic

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 within a watershed where stored water is slowly released down-gradient after being retained in surface or groundwater (Hruby et al. 2009, Adamus et al. 1991). This has a cumulative impact on magnitude and intensity of peak flow events (Sheldon et al. 2005).

Increased impervious surface area within a drainage basin commonly alters wetland hydrology by increasing or decreasing flows from the surrounding landscape (Sheldon et al. 2005). Such wetland hydrology changes are linked to other negative urbanization effects, such as stream channel erosion downcutting and disconnection, sediment deposition, and altered seasonal water regimes (Sheldon et al. 2005). Changes in wetland ponding depths, seasonal hydroperiods, or water level flux can also impact wetland plant communities (Schueler 2000).

2.2.1.3 Wildlife Habitat

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 et al. 2005). Several factors including buffer width and condition, vegetative structure, habitat interspersion, wetland hydroperiods, and landscape setting all impact wetland habitat functions (Hruby 2014). A study of wetland and non-wetland landscape matrix quality on wetland vertebrates found that while species abundance generally increases in landscapes with more wetland areas, some species are more sensitive to the larger landscape condition, such as amphibians (Quesnelle et al. 2015). For example, native amphibian species richness has been negatively correlated with urban landscape attributes (Guderyahn et al. 2016).

Cumulative impacts of direct and indirect wetland alterations, including hydrologic changes, compromised water quality, and habitat fragmentation tend to reduce the habitat functions and values a wetland provides (Sheldon et al. 2005). Urban and rural development commonly reduces wetland buffering and increases encroachment by people and pets.

2.2.2 Additional BAS

Ecology's latest wetland guidance for CAO updates was issued in October 2022 (Ecology 2022). The guidance provides three BAS-based options for wetland buffer tables.

Ecology's preferred option, Option 1, provides the most flexibility and site-specific buffers. This option considers habitat score and includes the potential to reduce the buffer through provision of a habitat corridor and implementation of minimization measures to reduce the level of impact from the adjacent land use. Use of the lowest buffer widths under this option, shown in Exhibit 2-1 below, requires the implementation of minimization measures. If an applicant chooses not to apply the applicable minimization measures, then an approximately 33% increase in the width of all buffers is required. Note that to use the reduced widths in Exhibit 2-1, the protection of a wildlife corridor is also required between higher functioning wetlands that score six or more habitat points and certain other protected areas. If this cannot be provided, then the non-reduced (33% increase) buffer would be required for those higher functioning wetlands.

Exhibit 2-1 Ecology wetland buffer Option 1

Wetland Category	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 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	40	40	40	NA

Ecology buffer Option 2, shown in Exhibit 2-2 below, is based on wetland category and the level of impact from the adjacent proposed or existing land use. This option necessitates inclusion of a table with levels of impacts from proposed land use types.

Exhibit 2-2 Ecology wetland buffer Option 2

Wetland Category	Land Use Impact		
	Low	Moderate	High
I	150	225	300
II	150	225	300
III	75	110	150
IV	25	40	50

Ecology buffer Option 3, shown in Exhibit 2-3 below, is based solely on the category of wetland. It is the simplest to administer; however, it is the least flexible.

Exhibit 2-3 Ecology wetland buffer Option 3

Wetland Category	Buffer
I	300
II	300
III	150
IV	50

As discussed above, Ecology buffer Option 1 includes the option of reducing the buffer through provision of a habitat corridor and implementation of minimization measures to reduce the level of impact from the adjacent land use. Ecology's 2022 guidance has updated the language for habitat corridor requirements. While the overall concept remains the same, more detail and clarification is provided on what a "legally protected, relatively undisturbed and vegetated area" is and what buffer would be required if the applicant is unable to provide a corridor.

Current BAS does not support additional buffer reductions beyond the habitat corridor/minimization measures reduction to reduce the level of impact from adjacent land use described above. In the past it was common to allow a buffer reduction with enhancement of existing, degraded buffer. However, Ecology's current buffer recommendations are based on a buffer that is already well vegetated. If the existing buffer area is not currently vegetated in a manner to provide the necessary buffer function, then the buffer area should be planted, or the buffer width should be increased. Reducing buffer area in these circumstances is a high-risk approach to protecting wetland functions and values.

2.3 CLIMATE CHANGE BAS

Wetlands play an important role in creating and maintaining community and ecosystem resilience to climate change. Coastal wetlands help protect communities by buffering shorelines from erosion and reducing flooding by holding back floodwaters and reducing the rate that water enters downstream waterbodies. As sea levels rise, coastal wetlands may adapt by migrating landward. However, when the presence of coastal development blocks the path for such migration, wetlands can be lost. This is commonly known as "coastal squeeze" and is identified as a particular risk to low-lying coastal communities in Kitsap County in the *Kitsap County Climate Impact Resiliency Assessment* (Kitsap County et al. 2020).

Wetlands are dynamic and highly productive ecosystems that provide water quality, hydrologic, and habitat functions. Wetlands, like riparian corridors, also provide microclimate functions. Microclimate functions can provide some refuge from higher temperatures and habitat for species affected by climate-related impacts. Wetlands can provide corridors for the movement of species whose range may be shifting in response to climate impacts, as well as refuge for species needing wetter conditions in drought-prone areas (ASWM 2015, Ecology n.d.). Additionally, wetlands help offset climate change through carbon storage. Wetlands store carbon both in organic soil and tree biomass. Carbon storage in undisturbed wetlands is approximately twice as high as carbon storage in wetlands disturbed by human-driven land use changes (Nahlik 2016, Ecology n.d.). Bogs are important carbon sinks that are highly sensitive to disturbance, particularly stormwater discharges and changes in pH.

Wetlands provide several beneficial ecological and economic benefits to Kitsap County. Benefits may include flood control, filtration of contaminants, groundwater recharge, fish and wildlife habitat and recreation activities (KCDCD 2017). Changes to wetland compositions and biodiversity can have direct impacts on available area for habitat and can negatively impact Kitsap County's water resources because of reduced groundwater recharge.

Climate-driven changes in hydrologic patterns and temperatures may cause hydroperiods of saturation or inundation in wetlands to change. This may cause some wetlands to lose seasonal ponding characteristics or to dry up entirely, whereas other wetlands may experience increased ponding (Halabisky 2017, Ecology n.d.).

As described in the *Kitsap County Climate Change Resiliency Assessment* (Kitsap County et al. 2020), increased evaporation rates and decreased water quality associated with climate change impacts can reduce the overall area of wetlands and threaten associated amphibian species. Wetland amphibians are cold-blooded and are subsequently highly sensitive to changes in water temperatures (Mauger et al. 2015). The anticipated impacts to water quality and quantity will likely increase the mortality of these species and cause impacts to downstream ecosystems, including food systems.

Although wetlands are dynamic by nature, their 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 (U.S. EPA 2015, Ecology n.d.). Native plant species distribution is being impacted by climate change; adaptive potential and climate tolerance for native plant species are being studied in the scientific community (Vose et al. 2012).

3 FISH & WILDLIFE HABITAT CONSERVATION AREAS

3.1 DEFINITION/DESCRIPTION

The WAC defines "fish and wildlife habitat conservation areas" and makes associated definitional clarifications as follows (WAC 365-190-030(6)):

> *(a) "Fish and wildlife habitat conservation areas" are areas that serve a critical role in sustaining needed habitats and species for the functional integrity of the ecosystem, and which, if altered, may reduce the likelihood that the species will persist over the long term. These areas may include, but are not limited to, rare or vulnerable ecological systems, communities, and habitat or habitat elements including seasonal ranges, breeding habitat, winter range, and movement corridors; and areas with high relative population density or species richness. Counties and cities may also designate locally important habitats and species.*
>
> *(b) "Habitats of local importance" designated as fish and wildlife habitat conservation areas include those areas found to be locally important by counties and cities.*
>
> *(c) "Fish and wildlife habitat conservation areas" does not include artificial features or constructs as irrigation delivery systems, irrigation infrastructure, irrigation canals, or drainage ditches that lie within the boundaries of, and are maintained by, a port district or an irrigation district or company.*

3.2 FUNCTIONS & VALUES

3.2.1 Summary of Functions & Values

Critical areas regulated as fish and wildlife habitat conservation areas are interdependent. Natural disturbances, including floods, landslides, and channel migration, are part of temporal and spatial dynamics that support formation of habitat niches and associated ecological diversity (Naiman et al. 1993). Land use can significantly alter the frequency and intensity of disturbance events (Felipe-Lucia et al. 2020); such events may become common.

3.2.1.1 Streams & Riparian Areas

Washington Department of Fish and Wildlife defines riparian ecosystems as:

> *…transitional between terrestrial and aquatic ecosystems and are distinguished by gradients in biophysical conditions, ecological processes, and biota. They are areas through which surface and subsurface hydrology connect waterbodies with their adjacent uplands. They include those portions of terrestrial ecosystem that significantly influence exchanges of energy and matter with aquatic ecosystems (Quinn et al. 2020).*

High impervious surface area cover is correlated with increased high flows, increased variability in daily stream flow, reduced groundwater recharge, and reduced summer low flow conditions (Konrad & Booth 2005, Cuo et al. 2009). Untreated and uncontrolled stormwater from impervious surface areas can increase stream flows and decrease the capacity and function of riparian buffers to reduce pollutants (Quinn et al. 2020). Changes in hydrology related to development are generally associated with soil compaction, draining, ditching, increased impervious surface cover and decreased forest cover (Booth et al. 2002, Moore & Wondzell 2005). Direct water withdrawals from groundwater or surface water, or overall reductions of floodplains are considered barriers to fish and wildlife movement and can result in fragmentation of habitat (Quinn et al. 2020). Together, these changes reduce infiltration, evapotranspiration, and groundwater storage. Further, these changes reduce flow desynchronization and flows tend to be more variable and volatile.

Specific stream and riparian area functions are discussed below.

Recruitment of Large Woody Debris

Large woody debris plays a significant role in geomorphic functions such as directing stream flows to shape channel form and influencing sediment storage, transport and deposition rates. The many effects of large wood create a variety of channel morphologies—dam pools, plunge pools, riffles, glides, undercut banks, and side channels, which provide a diversity of aquatic habitats (Quinn et al. 2020). As large woody debris is seldom transported by small and headwater streams, accumulated obstructions cause alterations in hydrology and geomorphology (Knutson & Naef 1997). Instream large wood provides for a wider range of flow velocities, in turn resulting in a diversity of aquatic habitats resulting from pool formation, streambed scour, sediment deposition, and channel migration (Quinn et al. 2020). These instream structures play an important role in forming complex in-water habitat structures, increasing water residence time, and subsequently retaining small debris and related organic material.

This process provides flow refugia and essential cover and improved foraging conditions for fish. The accumulated organic materials provide a substrate for microbes and algae as a food source for macroinvertebrates and other aquatic life (Bolton & Shellberg 2001). Through food webs, food is supplied by this process to fish and, ultimately, their predators including birds and mammals. Large wood provides the downward scour necessary for streams to create pools and protective cover for fish in those pools. Pools provide rearing habitat for juvenile fish and resting space for adults. Large wood that partially blocks flow can also help to encourage hyporheic flow through the streambed substrate (Poole & Berman 2001, Wondzell et al. 2009). Such flow within the streambed substrate is important to bring oxygen to incubating salmonid fish eggs and aquatic insects.

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 (Pollock et al. 2004). Removal of these structures throughout history has been linked to a significant reduction in coho salmon summer and winter rearing habitat (Pollock et al. 2004). This is further supported by a study (Pollock et. al 2013) that concluded that encouraging long-lived beaver dams could be a low-cost method to produce measurable improvement in riparian and stream habitats, and consequently increase abundance of native steelhead.

The Washington State Legislature has found 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." (RCW 77.32.585). Further:

> *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*.

Shade & Microclimate

Riparian vegetation contributes to reduced stream temperatures and improved microclimate conditions, which are closely tied to each other. Factors influencing water temperature and microclimate include shade, orientation, relative humidity, ambient air temperature, wind, channel dimensions, groundwater, and overhead cover. Significant increases in maximum stream temperatures have been documented in association with the removal of riparian vegetation (Murray et al. 2000, Moore et al. 2005, Gomi et al. 2006).

Salmon and other native freshwater fish require cool waters (55-68 degrees Fahrenheit) for migrating, rearing, spawning, incubation, and emergence (U.S. EPA 2003). Specifically, salmonids require less than or equal to 60 degrees Fahrenheit (15.6 degrees Celsius) for survival and productivity (Quinn et al. 2020). However, thermal tolerances differ by species. For example, amphibians have narrow thermal tolerances and are particularly influenced by changes in microclimate conditions (Bury 2008). 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 management zones help maintain forest microclimates, which are controlled by edge effects, which tend to extend well into forested areas adjacent to clearings. Accordingly, riparian management zones that range from approximately 30-145 feet in width may minimize microclimate effects related to light, soil, and air temperatures.

Bank Integrity

Vegetated riparian zones help to stabilize stream banks and have mechanical and hydrologic effects on bank stability (Quinn et al. 2020). Riparian vegetation helps provide bank stabilization through a complex of tree roots, brush, and soil/rock. Woody vegetation tends to provide greater bank stability than herbaceous vegetation because woody vegetation has larger roots that extend deeper into the streambank (Wynn & Mostaghimi 2006). Bank stabilization functions are at a higher risk of degradation in urbanized watersheds. As with sediment reduction, the streambank stabilization functions of vegetation increase with buffer width[1] out to approximately 80-100 feet; after this point, disproportionately large increases are needed to improve riparian function (Castelle & Johnson 1998). While natural bank stabilization is important to prevent mass wasting events, some bank erosion is critical to maintaining a natural streambed composition and preventing subsurface low flows from an over-coarsened stream bed. Maintaining a

[1] One of the important functions that Riparian Management Zones serve is to buffer streams from the impacts of development; thus, the term “stream buffer” has traditionally been used interchangeably with RMZ when referring to RMZ buffer functions and is used commonly throughout the literature.

vegetated riparian zone helps prevent the need for structural stabilization measures that may interrupt natural bank erosion and reduce the recruitment of natural streambed sediment.

Runoff Filtration & Nutrient Inputs (Water Quality)

Water quality is characterized by several physical, chemical, and biological factors, including suspended sediment, nutrients, metals, pathogens, herbicides and pesticides, and other pollutants. Water quality characteristics are controlled by upslope, as well as riparian conditions. Riparian areas have consistently shown an ability to remove pollutants through filtration, but their effectiveness is variable based on complex and interconnected factors. The function of pollutant removal differs from the other ecological functions because here the primary focus is on mitigating activities that occur outside the riparian area and the function is necessary only in the presence of human activities that generate polluted water and when runoff from upland activities threaten to degrade water quality (Quinn et al. 2020).

When development results in reduced infiltration and increased surface flows, sediment and contaminants are transported more directly to receiving bodies without interfacing with natural soil filtration and flow attenuation processes. Because of this, urban areas tend to contribute a disproportionate amount of sediment and contaminants to receiving waters relative to the percentage of urbanized area within the watershed (Sorrano et al. 1996). Heavy metals, bacterial pathogens, as well as polychlorinated biphenyls, 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 not fully understood (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 has found that mature coho salmon returning to urban creeks are experiencing mortality prior to spawning from a stormwater-linked condition called urban runoff mortality syndrome (Tian et. al 2022). The specific cause of the condition has been recently attributed to 6PPD-quinone, a breakdown product of tire wear (Tian et al. 2022). Coho pre-spawn mortality is most positively correlated with traffic and road density (Tian et al. 2022). To address impacts from 6PPD-quinone, Ecology has published *6PPD in Road Runoff, Assessment and Mitigation Strategies* (2022).

The following water quality subsections closely follow those provided in *Riparian Ecosystems, Volume 1: Science Synthesis and Management Implications* from Washington Department of Fish and Wildlife (Quinn et al. 2020).

Sediment

While natural sediment recruitment is important for maintaining stream health, excess inputs of fine sediments into stream channels reduce habitat quality for fish, amphibians, and macroinvertebrates. Highly turbid water can impair fertilization success in spawning salmonids (Galbraith et al. 2006) and interfere with respiration and reproduction in amphibians (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 benthic macroinvertebrates.

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

Sediment input to streams is supplied by bed and bank erosion, landslides, and upland erosion processes. These processes occur naturally at background levels but are also associated with and accelerated by forest practices and development activities. Other contaminants, including heavy metals and phosphorus, readily bind to suspended clay particles, and these contaminants are often transported with fine sediment in stormwater runoff. Excess inputs of fine sediments into a stream channel reduce habitat quality for fish, amphibians, and macroinvertebrates. Fine sediment adversely affects stream habitat by filling pools, embedding gravels, reducing gravel permeability, and increasing turbidity.

Vegetated riparian zones help stabilize stream banks, slow and filter overland flow, and temporarily store 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 & Anderson 1998).

In addition to width, the slope, vegetation density, and sediment composition of a riparian area have significant bearing on sediment filtration potential (Jin & Romkens 2001). Multiple studies have found that larger particles tend to settle out within the first 10-20 feet 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 approximately 150-400 feet, 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. 2006, Yuan et al. 2009).

Excess 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 dissolved oxygen in the water and result in poor water quality and fish kills (Mayer et al. 2005, Simenstad et al. 2006, Heisler et al. 2008).

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 vegetation 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 position in the landscape (Baker et al. 2006). There is significant evidence to support that riparian buffers effectively reduce non-point source water pollution, and the width of riparian buffer is the most important variable in the efficiency of pollutant removal (Quinn et al. 2020).

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 & McDonnell 2007). Removal of phosphorus 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). Subsequently, if a riparian buffer becomes saturated with phosphorus, its capacity for soluble phosphorus removal will be more limited (Polyakov et al. 2005).

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

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 improve riparian function.

Metals

Riparian Ecosystems, Volume 1: Science Synthesis and Management Implications indicates that riparian buffers effectively reduce nonpoint source water pollution for a variety of metals and pollutants (Quinn et al. 2020). Riparian buffer width is considered the most important variable in the efficacy of pollutant removal followed by vegetation structure and composition. 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 aquatic organisms (Kakade et. al 2023). A review of contaminant effects on aquatic organisms summarized the factors affecting the toxicity of metals as follows: duration and concentration of exposure; form of the metal at the time of exposure; 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.

In general, heavy metals enter the aquatic ecosystem through one of four main sources: agriculture, industries, mining, or livestock (Kakade et. al 2023). Heavy metals and contaminants can also reach aquatic ecosystems and streams through existing stormwater systems. Stormwater systems that circumvent buffers limit the opportunity to filter runoff through adjoining soils and vegetation. Accordingly, current stream buffers are typically underutilized for the treatment of metals, hydrocarbons and other pollutants found in typical stormwater runoff.

Copper brake pad dust has been linked to chronically depressed Chinook salmon populations, particularly young salmon (U.S. 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 (U.S. EPA 2015). The Washington State Legislature passed a law in 2010 that requires manufacturers to reduce the use of toxic materials in brakes and shoes. The law required asbestos and several metals to be phased out in 2015 with a schedule for copper. Under the Better Brakes Washington Law, vehicle brake pads manufactured after 2021 must contain less than 5% copper by weight and must contain less than 0.5% copper by 2025. Ecology estimates that 66 tons of copper per year enter Puget Sound from vehicle brake pads.

Pathogens

The capacity of vegetated buffers to remove or reduce can be variable based on site-specific factors including, but not limited to, soil infiltration, vegetation composition, topography and rainfall intensity and duration (Quinn et al. 2020). While not necessarily a problem for fish and other wildlife, waterborne pathogens associated with human and animal wastes are a concern for direct and indirect human exposure. Although pathogens include a suite of bacteria and viruses, fecal coliform bacteria, specifically E. coli, are typically used as an indicator of the possible or presumed presence of these pathogens. Fecal pollution tends to be positively correlated with human population densities and impervious surface coverage (Glasoe & 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 & Christy 2004). As municipal wastewater systems have improved treatment quality and capacity in recent years, non-point source (septic systems, stormwater, wildlife, and pets) pollution is increasingly responsible for fecal contaminants in surface water (Glasoe & Christy 2004).

Herbicides & 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 these 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). Despite our limited understanding, the effects of these chemicals may be long-lasting, as has been observed for legacy pollutants such as polychlorinated biphenyls and polycyclic aromatic hydrocarbons in salmon, seabirds, and marine mammals in Puget Sound (O'Neill et al. 1998, Ross et al. 2000, Wahl et al. 2005, Grant & Ross 2002, Oneal & Rotenberry 2009).

While the effect of these herbicides and pesticides may be uncertain, science is clear that they may reach aquatic systems through several pathways, including surface runoff, erosion, subsurface drains, groundwater leaching and spray drift. Additionally, a meta-analysis found that filtration effectiveness increased logarithmically from approximately 1.5 feet to an asymptote at approximately 60 feet (Zhang et al. 2010). Relatively narrow vegetated buffers may be effective in limiting herbicides and pesticides from reaching aquatic habitats in surface runoff, erosion, and spray drift; however, transport via subsurface drainage and leaching are not affected by riparian buffers, and these processes are best addressed using best management practices for herbicide and pesticide applications to avoid contaminating groundwater (Reichenberger et al. 2007).

Pharmaceuticals

Riparian Ecosystems, Volume 1: Science Synthesis and Management Implications from Washington Department of Fish and Wildlife (Quinn et al. 2020) discusses that it is recognized that pharmaceuticals and personal care products can have negative impacts on fish and other aquatic organisms at individual and population levels even at extremely low concentrations. Phytoremediation by riparian vegetation may be a technique to reduce water quality impacts from organic contaminants, but additional research is recommended to determine overall effectiveness and design guidelines (Quinn et al. 2020). Many commonly used pharmaceuticals are found in wastewater, particularly around urbanized areas (Long et al. 2013). Many common pharmaceuticals have endocrine-disrupting properties, which can affect fertility and development in non-target aquatic species (Caliman & Gavrilescu 2009).

3.2.1.2 Wildlife Habitat

Intact riparian management zones in urban areas provide habitat that act as wildlife corridors to connect fragments of habitat, and to provide space for wildlife movement away from human interaction, thus reducing conflict between humans and wildlife. As adjacent uplands are typically more degraded than riparian management zones, riparian management zones subsequently become the only remaining areas where these habitat functions are provided (Rentz et al. 2020). Riparian ecosystems, including the streams, provide this wildlife habitat through the presence of unique structures and processes. The aquatic ecosystems provide habitat for a broad range of fauna including invertebrates, reptiles and amphibians, anadromous and resident fish, birds, and mammals.

The performance of riparian habitat functions are affected to varying degrees by the width and/or character of the surrounding management zones. Disturbance vectors include noise; nighttime light; physical intrusion by equipment, people, or pets; and garbage. Each of these vectors 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.

Habitat fragmentation is a consequence of urbanization. As land is developed, continuous tracts of native habitat are reduced to patches, which become progressively smaller and more isolated. Dale et al. (2000) found that ecological impacts of development are often overlooked and landscape-scale changes, particularly habitat fragmentation, alter the structure and function of those ecosystems. 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 the riparian zone (Sheldon et al. 2005, Azous & Horner 2000).

3.2.2 Additional BAS

3.2.2.1 Riparian Management

In 2020, the Washington Department of Fish and Wildlife came out with new guidance (Rentz et al. 2020) for the protection of riparian areas. The guidance emphasizes a shift in terminology from the concept of “stream buffers” to “riparian management zones” (RMZs). An RMZ is defined as “… the area that has the potential to provide full riparian functions” (Rentz et al. 2020) Further, an RMZ is now 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 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 of an area is defined as “The average maximum height of the tallest dominant trees (200 years or more) for a given age and site class.” (Rentz et al. 2020). Exceptions may occur where 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 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 in forested ecoregions of the state, including Kitsap County. Where site potential tree height is 100 feet or more, the agency recommends RMZ establishment within one site potential tree height, driven by the largest dominant tree species at any location. 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, improving 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.

3.3 CLIMATE CHANGE BAS

Changes in temperatures and seasonal precipitation patterns are projected to place additional stressors on fish and wildlife habitat conservation areas. 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, which would increase peak winter flows, mobilize greater volumes of sediments and pollutants into streams, reduce groundwater recharge that supports base stream flows in summer, and result in decreased streamflow overall. Instream habitats are particularly negatively impacted by excess sediment discharge and deposition.

Stressors associated with climate change are projected to significantly impact fish and wildlife species, including Chinook, coho, and sockeye salmon, steelhead and bull trout, and amphibians. The surface and subsurface water temperatures in Hood Canal and Puget Sound have already warmed from 0.8-1.6 degrees Fahrenheit since 1950 (Mauger et al. 2015, Hansen et al. 2016). The projected impacts from climate change will result in increased mortality of these species and will directly impact downstream ecosystems and the marine food system (Mauger et al. 2015, Port Gamble S’Klallam Tribe Natural Resources Department 2017).

4 GEOLOGICALLY HAZARDOUS AREAS

4.1 DEFINITION/DESCRIPTION

Geologically hazardous areas pose a threat to human health and safety when incompatible development is sited in areas of significant hazard (WAC 365-190-120(1)). However, such areas also provide ecological functions and values.

The WAC defines “geologically hazardous areas” as follows (WAC 365-190-030(9)):

> *"Geologically hazardous areas" are areas that because of their susceptibility to erosion, sliding, earthquake, or other geological events, are not suited to siting commercial, residential, or industrial development consistent with public health or safety concerns.*

The four main types of geologically hazardous areas recognized in the GMA are (RCW 36.70A.030(9) and WAC 365-190-120):

1. Erosion hazard areas;
2. Landslide hazard areas;
3. Seismic hazard areas; and
4. Areas subject to other geologic events.

The WAC defines "erosion hazard areas" as follows (WAC 365-190-030(5)):

> *"Erosion hazard areas" are those areas containing soils which, according to the United States Department of Agriculture Natural Resources Conservation Service Soil Survey Program, may experience significant erosion. Erosion hazard areas also include coastal erosion-prone areas and channel migration zones.*

The WAC defines "landslide hazard areas" as follows (WAC 365-190-030(10)):

> *"Landslide hazard areas" are areas at risk of mass movement due to a combination of geologic, topographic, and hydrologic factors.*

The WAC defines "seismic hazard areas" as follows (WAC 365-190-030(18)):

> *"Seismic hazard areas" are areas subject to severe risk of damage as a result of earthquake induced ground shaking, slope failure, settlement, soil liquefaction, debris flows, lahars, or tsunamis.*

4.2 FUNCTIONS & VALUES

4.2.1 Summary of Functions & Values

4.2.1.1 Erosion Hazard Areas

Erosion is a natural process that can contribute sediment, rocks, and large woody debris to aquatic environments. Natural levels of erosion are important for maintaining sediment processes in aquatic environments, such as appropriate spawning substrate for surf smelt or sand lance in the nearshore, fine sediment that builds stream deltas and estuary complexity, and spawning substrate for salmon in streams.

However, excessive erosion and deposition can harm streams, shorelines, and the plants and animals that inhabit them. Erosion events can occur in a number of ways, one of which is due to anthropogenic effects, such as clearing vegetation and increasing surface runoff through the creation of new impervious surface. In cleared areas, rainfall tends to concentrate in small channels, and as the water gains depth and volume, sediment can be mobilized by the flow. In this way, small channels or rills can eventually develop into gullies. Vegetation increases the stability of geologic hazard areas. Vegetation reduces erosion by preventing a significant amount of rainfall from reaching the soil and physically binds the soil together with root materials (Booth et al. 2002, Naiman & Decamps 1997).

In areas with impervious surfaces, the reduction in stormwater infiltration generates more rapid runoff from land into streams and rivers. This results in an increase in peak flow volume, which in turn produces higher energy and increases the potential for streambank erosion (Booth 1990, Booth 1991, Nelson & Booth 2002).

When development encroaches on geologically hazardous areas, it also increases the probability that protective measures to prevent geologic movement, such as armoring or retaining walls, will be needed to protect property. This impacts the ecosystem by interrupting natural geologic processes. Further, when structures are placed in areas susceptible to erosion, or land use actions cause formerly stable areas to begin eroding, the risk of erosion increases for surrounding land uses as well.

4.2.1.2 Landslide Hazard Areas

Landslides can be fast or slow, and deep or shallow, initiating from the bottom of a slope, the top of a slope, or somewhere in between.

Areas prone to landslides in coastal areas of Kitsap County are commonly slopes comprised of relatively permeable materials, such as sand and gravel, over a less permeable material, such as bedrock or clay. The most common type of landslide in the Puget Sound region occurs in response to either heavy precipitation (Tubbs 1974) or elevated groundwater conditions (Thorsen 1987) in colluvium derived from glacial deposits. Glacial deposits often result in surface layers that are more permeable than the deeper layers, causing water to perch at the contact between the two layers. The weight and increase in pore pressure from the water causes the upper layer to fail, and slide over the deeper, more resistant layer.

Most coastal bluff retreat (top of the bluff recedes landward) within the Puget Sound occurs through landsliding, most of which are shallow landslides and debris avalanches. Large slumps and landslides are less common and seem to be associated with taller bluffs (Shipman 2004) and are triggered by elevated groundwater (Savage et al. 2000) and seismic activity (Chleborad 1994). According to Shipman (2004), steeper slopes are more prone to failure due to increased gravitational stresses. However, due to the heterogeneous nature of bluff geology in the Puget Sound lowlands, variability in hydrologic conditions and rock strengths make landslides difficult to predict.

Landslides are also common in interior Kitsap County above rivers and streams and in steep terrain.

Activities associated with urban development, including vegetation removal and increased impervious surfaces, can increase the landslide hazard of susceptible areas. Vegetation plays a significant role in landslide potential by intercepting a substantial amount of rainfall, preventing it from infiltrating into the soil. Roots from vegetation also take up and transpire some of the water that does reach the soil (Watson & Burnett 1995). This reduces the amount of water that rests at the contact between the permeable and impermeable layer. A dense matrix of roots can also lend considerable strength to the soil on a slope (Schmidt et al. 2001), decreasing the likelihood of slope failure and shallow-rapid landslides.

4.2.1.3 Seismic Hazard Areas

Washington is located on the Cascadia Subduction Zone at the plate boundary between the Juan de Fuca and the North American tectonic plates. Earthquakes initiating from the Cascadia Subduction Zone are generally less frequent than other earthquake locations but tend to be larger in magnitude.

Seismic Risk Zones are classified on a scale from zero to four, with four being the highest risk. The Puget Lowland, which includes Kitsap County, is classed as a Seismic Risk Zone 3. The largest of the recorded earthquakes in the region were the magnitude 7.1 Olympia earthquake in 1949, followed by the magnitude 6.8 Nisqually earthquake in 2001. The Nisqually earthquake was the most recent earthquake to cause substantial damage in Kitsap County, causing minor to moderate damage to approximately 750 residents (FEMA 2015).

Secondary hazards associated with seismic events include liquefaction of the soil, rockfall, landsliding, dam failure, levee failure, and tsunamis or seiches. Areas of moderate to high susceptibility to liquefaction within Kitsap County tend to be collocated with the floodplains of rivers.

As described in the Kitsap County Multi-Hazard Mitigation Plan (KCDEM 2019), in the event of a Seattle Fault 7.2 magnitude earthquake, unincorporated Kitsap County's building losses are estimated to be $3.6 billion, representing a 18% loss ratio (dollar losses/total building value). Essential facilities and infrastructure are also anticipated to lose function immediately after an event.

4.3 ADDITIONAL BAS

A variety of recommendations were made by the SR 530 Landslide Commission following the Oso mudslide that occurred in Snohomish County in March 2014. For example, the commission included that "the Legislature significantly expand data collection and landslide mapping efforts, which will provide the foundation for sound public and private land-use planning and decision-making" (SR 530 Landslide Commission 2014). The commission's recommendations may result in additional guidance and tools for regulating geologically hazardous areas in the coming years as they are implemented.

4.4 CLIMATE CHANGE BAS

Geologically hazardous areas, particularly erosion hazard areas and landslide hazard areas, are prone to impacts from changing patterns in precipitation and associated stress on native trees and shrubs and groundcover plants. 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). This indicates that heavy rains will be more common outside of summer months. When the magnitude and frequency of rain events increase, it can over-saturate soils and contribute to instability. Rainfall intensity and duration is a predictor for landslide events (Chleborad et al. 2006, DNR 2020). Extreme precipitation events modeled by the UW Climate Impacts Group are expected to increase in intensity and frequency (Morgan et. al. 2021). If significant plant mortality occurs in dry summer periods, in conjunction with heavy rains, there will potentially be less vegetation rooted in hazard areas to stabilize them.

Coastal areas will also become more prone to erosion and landslides as, coupled with increased precipitation intensity, sea level rises and increases flood inundation of estuarine and riverine systems. As described in the *Kitsap County Climate Change Resilience Study* (Kitsap County et al. 2020), sea levels in Bremerton have risen at a rate of approximately one inch every 12.3 years, and heavy rainfall event intensity increased by 50% since 1990 (Kitsap County et al. 2020). The cities of Bainbridge Island and Port Orchard have experienced similar precipitation and sea level rise impacts. Concurrently, sea level rise and increased riverine inundation could also increase tsunami inundation in the event of seismic activity.

5 FREQUENTLY FLOODED AREAS

5.1 DEFINITION/DESCRIPTION

Frequently flooded areas are topographic features or landforms flooded by streams and rivers, shoreline waves and storm surges, high groundwater levels, or increased runoff from urban development. They usually overflow during high runoff, high tides, prolonged or intense rainfall and snowmelt, or a combination of these conditions. Frequently flooded areas are typically depressional areas defined by their elevation, geological controls, and watershed or drainage area characteristics.

Frequently flooded areas serve important habitat functions for fish and wildlife, but also pose a risk to public safety.

The WAC defines "frequently flooded areas" as follows (WAC 365-190-030(8)):

> *"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.*

5.2 FUNCTIONS & VALUES

5.2.1 Summary of Functions & Values

While often thought of in the context of safeguarding the public from hazards to health and safety, frequently flooded areas are dynamic and ecologically productive environments. Flooding is a natural process and provides important hydrologic and biological functions.

Dynamic hydrologic processes, including mobilization of large woody debris and other allochthonous inputs, can be critical to the maintenance of fish and wildlife habitat (Naiman & Decamps 1997, Gurnell et al. 2005). High-flow channels carved into floodplains provide important habitat for a variety of fish species, creating areas of refuge from high flows. Over time, during periods of high flow, streams will overtop their banks and deposit sediment load, cumulatively forming a floodplain (Dunne & Leopold 1978, Knighton 1998). Floodplain storage reduces peak stream flows and contributes to infiltration and aquifer recharge.

Flooding is more than a water surface elevation from a fixed-bed hydraulic model. It is a three-dimensional process with overbank flow that mobilizes bed sediments, recruits large woody debris, and initiates channel migration. It stores the fluvial sediment behind large woody debris that drives downwelling and hyporheic flows downstream. The frequency of flooding varies with local drainage characteristics and variable high flows, but most frequently flooded areas experience high flows every year or two. Frequent flooding is an essential element of a healthy, dynamic natural environment.

When streams are altered through urbanization, including channel straightening and armoring, they can become disconnected from their natural floodplain and associated wetlands (Booth 1990). Additionally, increased impervious surfaces and loss of forest within a basin increases peak flow magnitude and frequency (Booth et al. 2002). Associated downcutting of stream channels further separates them from floodplains, increases in-stream erosion, and deposits sediment in downstream environments, blocking culverts in some cases (Booth 1990). As noted by Booth et al. (2004), integrated management of complex stream environments requires more detail than total impervious basin area figures. Patterns of urban development are relevant to watershed functions and both increased impervious surface area and its aggregation or patch size directly impact stream ecosystems (Alberti et al. 2006). As described above, stream dynamics are closely linked to floodplain functions.

5.2.2 Additional BAS

New developments in GIS mapping of frequently flooded areas offer a comprehensive, geomorphic approach to the delineation of floodplains in alluvial basins (USGS et al. 2013). This basin-specific approach recognizes the geological and hydrological elements of sediment transport, large woody debris dynamics, and more frequent (2-year to 10-year recurrence interval) high-flow processes (Wald 2009). The use of spatial data, particularly LiDAR (Light Detection and Ranging) coverages, for mapping floodplains is a useful and applicable augmentation of hydraulic modeling used in Federal Emergency Management Agency flood insurance studies. Most frequently flooded areas can be delineated and mapped using LiDAR coverages available from the Washington Geologic Information Portal (DNR n.d.) and other sources. Integrating geospatial data to identify floodplain functions is a recommended strategy for protecting floodplains (NFFA & WMC 2023).

5.3 CLIMATE CHANGE BAS

Seasonal changes in the Pacific Northwest are projected to entail wetter autumns and winters and drier summers (Mote & Salathe 2010). Increased precipitation in autumn and winter with climate change will increase the frequency of flood events in any given year

(Ecology 2021). The projected increases in extreme precipitation and flooding will increase the risk of interruptions to transit, food systems, ecosystems, and municipal operations while damaging structures and critical infrastructure located in or adjacent to the currently designated floodplains.

Flooding is the most repetitive and damaging natural hazard in Kitsap County (KCDEM 2019). Coastal cities and adjacent areas of the county are anticipated to experience risk to their infrastructure and structures, worth approximately $13.4 million (Kitsap County et al. 2020). Future risk of flooding is anticipated to increase in urban areas because of increasing heavy rains, sea level rise, and storm surges. This flooding activity may overwhelm existing stormwater and wastewater infrastructure capacity (Kitsap County et al. 2020).

As described in the *Kitsap County Climate Change Resiliency Assessment* (Kitsap County et al. 2020), sea level rise projections indicate a 51% and a 98% risk of at least one flood over four feet occurring in Kitsap County between 2020 and 2050 under low and high emissions scenarios, respectively (Climate Central 2016). Two square miles of land are projected to be at risk of being impacted by a flood exceeding four feet in Kitsap County. Within those two square miles, there are 1,521 individuals, 940 homes, ten miles of public roads, and an estimated property value of over $300 million (Climate Central 2016). These impacts are projected to increase in severity under higher emissions scenarios.

Increased flooding may increase sediment transport in winter and spring (Mauger et al. 2015). Extreme flood events may negatively impact instream habitats by mobilizing sediment and pollutants (Talbot et al. 2018).

Federal Emergency Management Agency maps have historically played a central role in the identifying frequently flooded areas. However, these maps cover less than half the frequently flooded areas in Kitsap County, are currently based only on past flood events, and do not consider future flood risk. These maps also do not consider sea level rise, other climate change impacts, or channel migration zones (Commerce 2023).

To integrate climate change into flood risk management in Washington State, an interagency group called the Washington Silver Jackets was formed. 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).

Evaluations specific to Kitsap County to anticipate precipitation and flooding increases will inform strategic land use planning to mitigate climate change impacts and risks (Bell et al. 2016). As described in the *Comprehensive Emergency Management Plan* (KCDEM 2020), the installation of rain gauges throughout Kitsap County has provided improved information on water tables, droughts, and rainfall data to inform future mitigation strategies.

6 CRITICAL AQUIFER RECHARGE AREAS

6.1 DEFINITION/DESCRIPTION

An aquifer is a geologic formation that readily transmits water to wells or springs. Aquifer recharge occurs when water infiltrates the ground and flows to an aquifer.

An aquifer can be confined or unconfined. An unconfined aquifer is one in which the upper boundary is the water table. A confined aquifer is a deeper aquifer that is separated from the surface by an aquitard (a geologic formation that limits but does not prevent the transmission of water) or aquiclude (a geologic formation that does not allow for the transmission of water) 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) (Driscoll 1986, Winter et al. 1998).

Local aquifers are often relatively shallow (less than 100 feet below land surface) and unconfined. Regional aquifers are often deeper, semi-confined or confined, with recharge areas extending beyond jurisdictional boundaries.

The WAC defines “critical aquifer recharge areas” as follows (WAC 365-190-030(3)):

> *"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.*

Critical aquifer recharge areas are usually delineated for Group B water systems (fewer than 15 connections and fewer than 25 people per day) regulated by local health departments in conjunction with the Washington State Department of Health. Critical aquifer recharge areas for the larger Group A systems are regulated by the Washington State Department of Health. Individual domestic wells are regulated by well construction standards administered by Ecology.

6.2 FUNCTIONS & VALUES

6.2.1 Summary of Functions & Values

The functions and values of critical aquifer recharge areas, as stated in the Ecology *Draft Critical Aquifer Recharge Areas Guidance* (2021), "are to provide the public with clean, safe, and available drinking water."

In addition to providing drinking water, groundwater also plays a major role in other critical area functions and values. Groundwater contributes to stream surface water flows, wetland hydrology, and flood flows. Surface water and groundwater are interconnected. Groundwater is the source for stream base flow, and during drier periods, this base flow may be the sole source of stream surface flow. Thus, a stream or wetland can serve as a discharge point for groundwater during drier periods; during wetter periods, the same streams can recharge groundwater, and therefore an aquifer. Under natural conditions, this surface and groundwater cycle attenuates surface water flows following storm events. Groundwater conditions can also influence geologic hazards, including landslide hazards and erosion hazards.

6.2.1.1 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. The risk of groundwater contamination—impacts to water quality—is related to two main parameters: the susceptibility of the aquifer and the contamination loading potential or source loading (U.S. EPA 1995, DOH 2017).

Aquifer susceptibility refers to how easily water and pollutants can move from the surface through the ground to reach the underlying aquifer. A shallow, unconfined aquifer in a gravel-rich basin would be more susceptible to contamination than a deep, confined aquifer overlain by dense glacial till.

The susceptibility of an aquifer can be assessed by looking at three critical factors (Morgan 2005):

1. The overall permeability of the vadose zone (the unsaturated material between the aquifer and the ground surface, through which any contaminants would need to pass to reach the aquifer);
2. The thickness of the vadose zone or depth to the aquifer; and
3. The amount of recharge available.

Permeability of the vadose zone can be estimated from soil and geologic mapping. Depth to an aquifer can be determined by examining well logs in the vicinity.

Contamination loading refers to the quantity and types of pollutants present in the area, and how they are handled. Unmanaged open space would have a low contamination loading potential, while a light industrial area would likely have a higher loading potential, and an older industrial site with multiple leaking storage containers would have a high loading potential.

Together, susceptibility and loading potential determine the vulnerability of an aquifer. A highly susceptible aquifer may have a low vulnerability if the land use within the area is primarily open space. 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.

6.2.1.2 Water Quantity

Surface water and groundwater are cyclic and frequently interact through recharge and discharge areas. Maintaining water quantity within an aquifer supports both potable water uses and landscape-scale habitat functions, which are groundwater-dependent.

Aquifer recharge areas are areas where water from rainfall, snowmelt, lakes, rivers, streams, or wetlands infiltrates into the ground to an aquifer. Aquifer discharge areas are areas where water flows away from an aquifer to the ground's surface. Aquifer discharge areas can include seeps, springs, wetlands, streams, lakes, estuaries, and shorelines. Wells are also considered an aquifer discharge. Groundwater movement is driven by gravity, so an aquifer's recharge area is typically at a higher elevation than its discharge area. However, in some cases, subsurface conditions may result in groundwater flow that does not reflect surficial topography (Driscoll 1986).

The quantity of water available in an aquifer is a balance between recharge, storage, and discharge. Land use and development typically alter water conveyance within a basin, and thus this balance. For example, replacing forests with buildings, roads, driveways, lawns, and even pastures typically reduces the recharge to underlying aquifers while simultaneously increasing peak runoff rates to streams. As water usage increases with population growth, the potential water level of an aquifer decreases and the risk of seawater intrusion increases (Jones et al. 2016). In rare instances, 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 et al. 1998).

Recharge to an aquifer is dependent on precipitation and infiltration into the soil below the root zone, in the form of deep percolation (Welch et al. 2014). Infiltration below the root zone is controlled by several factors, including temperature, wind, soil type, geology, vegetation type, and land surface slope. The root zone is an important factor to consider as evaporation and transpiration of water by plants reduces the water available for groundwater recharge and can use up much or most of the rainfall during some months (Wang et al. 2022). As referenced in the *Kitsap County Initial Basin Assessment* (Kitsap Public Utility District 1997), it is estimated that only 44% of annual rainfall is recharged as groundwater. The remaining precipitation is typically evaporated, absorbed, and transpired by vegetation, or diverted as runoff.

As mentioned above, an unconfined aquifer occurs when there is no semi-permeable or impermeable barrier between the ground surface and the aquifer. The recharge area for an unconfined aquifer is typically the land area contributing infiltration to the aquifer. Surface water, in lakes, streams, and wetlands, may play a large role in both recharge to and discharge from unconfined aquifers, and the function may vary from season to season (Dunne & Leopold 1978, Winter et al. 1998).

For a confined aquifer, more involved site-specific studies must be undertaken to understand the movement of subsurface water. Well logs from a given area can be used to map aquifers, and water elevations in the wells can be mapped to define a hydraulic gradient, which can then be used to determine flow direction in the aquifer (Senior et al. 2005).

Changes in groundwater recharge and withdrawal of water by wells are the primary drivers of reductions in groundwater quantity.

6.2.2 Additional BAS

Recent Ecology guidance (2021) recommends the following eight steps to characterize and protect critical aquifer recharge areas in a local community:

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 are implemented and followed.
8. Manage groundwater withdrawals and recharge impacts to:
    - Maintain availability for drinking water sources.
    - Maintain stream base flow from groundwater to support in-stream flows, especially for salmon-bearing streams.

6.3 CLIMATE CHANGE BAS

Climate change impacts to surface and groundwater quality and quantity based on regional trends are summarized below.

- Hotter, dryer summers will reduce ground surface saturation during the growing season. This is likely to reduce wetland areas and the groundwater recharge they provide.
- Changes to seasonal precipitation patterns are likely to reduce groundwater recharge. This would reduce streams flows that are supported, in part, by groundwater.
- Wildfires will bring more particulates into the environment and settle into surface and groundwater.
- Increased winter flooding increases the likelihood of overwhelming stormwater treatment facilities and flooding roads, which may transport contaminants into surface water, including local streams and wetlands.

Changes to surface water inputs will alter timing, frequency, and duration of surface water presence are projected to alter hydrologic patterns. Altered hydrology is projected to include earlier peak stream flows, increased frequency and extent of flooding, and reduced summer flows (Mauger et al. 2015).

However, groundwater is likely to be more resilient under climate change stressors relative to surface water resources (U.S. EPA n.d.). Ecology notes in their *Draft Critical Aquifer Recharge Areas Guidance* that groundwater impacts may occur with climate change. The primary stressors noted are changes in the timing and amount of groundwater recharge, and increased pressure to use groundwater as surface water conditions change. Ecology recommends focusing on water conservation (2021).

Population growth also presents challenges for protecting critical aquifer recharge areas as land use intensity increases (Ecology 2021). 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). According to the *Kitsap County Climate Change Resiliency Assessment* (Kitsap County et al. 2020), there are many public water systems in Kitsap County that serve at least 25 people or have 15 or more connections with only a single water source with no back-up supply. Communities that are reliant on single-source systems may have increased vulnerability to future water shortages or water quality degradation (May et al. 2018).

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Best Available Science Review FINAL

PIERCE COUNTY CRITICAL AREAS ORDINANCE UPDATE

December 2022

Prepared for:

Pierce County
Planning & Public Works |
Long Range Planning
2401 S. 35th Street
Tacoma, WA 98409

THE WATERSHED COMPANY

The information contained in this report is based on the application of technical guidelines currently accepted as the best available science. All discussions, conclusions and recommendations reflect the best professional judgment of the author(s) and are based upon information available at the time the study was conducted. All work was completed within the constraints of budget, scope, and timing. The findings of this report are subject to verification and agreement by the appropriate local, state and federal regulatory authorities. No other warranty, expressed or implied, is made.

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1 Introduction

1.1 Best Available Science

This review of best available science (BAS) was compiled to support Pierce County's Critical Areas Ordinance (CAO) update. The intent of this report is to meet Washington State Growth Management Act (GMA) requirements and inform county staff of current BAS relevant to management of critical areas. The GMA require cities and counties to "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" (WAC 365-195-900). Regulated critical areas include wetlands, areas of critical recharging effect on aquifers used for potable water, fish and wildlife habitat conservation areas, frequently flooded areas, and geologically hazardous areas, critical aquifer recharge areas, wetlands [RCW 36.70A.030 and Pierce County Code (PCC)].

BAS documents are prepared by qualified scientific experts and follow a valid scientific process. The scientific process, which produces reliable information, is generally characterized by 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).

The report authors compiled BAS references for each section or discipline. BAS documents were selected based on their significance to conditions in Pierce County, common use in each discipline, and relevance to current scientific practices or principals.

The scientific body of knowledge evolves as new studies are conducted and new technologies are employed. While the BAS information provided here is intended to provide a framework for critical area protections, it may not provide definitive criteria for all regulatory decisions. Ecologic systems, including urban environments, are complex and based on both landscape-scale and local processes, comprised of many variables. Where definite guidance is lacking or studies in the scientific literature show variable methods and results, a range of values is commonly provided here. In accord with WAC 365-195-920, where scientific information is incomplete with regard to a land use, a precautionary or no risk approach should be taken.

This BAS review will be referenced as the County moves forward with ther development regulations updates, including a CAO update. The next step in that process will be a gap analysis report, which identifies where current BAS can and should be incorporated into critical area regulations.

1.2 Climate Change

This BAS review also addresses known climate change issues affecting each type of critical area and BAS-based recommendations for management. Anthropogenic global climate change is projected to impact climatic variation and natural resources in the Pacific Northwest. Climate models project annual temperature increases totaling 3.2 degrees Fahrenheit by the 2040s (Mote and Salathe 2010). At current rates of warming, global warming may exceed 1.5 degrees Celsius by 2030 (Snover et al. 2019). Modeled changes include reduced regional snowpack, reduced summer water supply, a greater frequency and duration of extreme weather events including flooding and high temperatures (Mauger 2015). Sea level rise and saltwater intrusion are also byproducts of climate change that impacts coastal habitats, increases coastal flooding and bluff erosion. Sea level rise along the Tacoma shoreline is modelled to increase by 0.6 to 1.2 feet by 2050 (Roop et al. 2020). Climate change is projected to strain critical areas and the functions they provide; this poses a challenge for natural resource management (Mote et al. 2003).

Climate change studies and modelling tools continue to provide information about what changes to expect globally and in the Pacific Northwest. However, climate change is a complex issue and guidance on how best to manage critical areas in a changing environment is currently under study.

2 Critical Aquifer Recharge Areas (CARAs)

2.1 Definition

As described in WAC 365-190-030 for critical aquifer recharge areas (CARA),

> *"'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."*

and Pierce County Code 18.25.030 Definitions for aquifer recharge areas (ARA),

> *"'Aquifer recharge area' means areas that have a critical recharging effect on groundwaters used for potable water supplies and/or that demonstrate a high level of susceptibility or vulnerability to groundwater contamination from land use activities. Examples of aquifer recharge areas include: (1) Wellhead protection areas delineated pursuant to the Federal Safe Drinking Water Act; and (2) Other areas with a high level of susceptibility or vulnerability to contamination as demonstrated through the use of the DRASTIC Model."*

When this report references CARA, it includes the County's definition of an ARA. An aquifer is a geologic formation that readily transmits water to wells or springs. Aquifer recharge occurs when water infiltrates the ground and flows to an aquifer. An aquifer can be confined or unconfined. An unconfined aquifer is one in which the upper boundary is the water table, with 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 et al. 1998). The delineation of CARA provides recharge area protection for Group B Water Supply Systems regulated by the Local Health Jurisdiction, Tacoma Pierce County Health Department.

An aquifer is considered to be used for potable water if it has existing wells, or is in the identified protection area for an existing well; if it is a sole-source aquifer; is planned to be used for potable water in the future; or is otherwise identified as an important supply. The Central Pierce County Aquifer is a sole source aquifer, and numerous wells rely on this source of water (Jones *et al* 1999; TPCHD 2022). To maintain potable water uses and potential uses of existing aquifers, both water quality and quantity must be managed.

2.2 Functions and Values

The functions and values of Aquifer Recharge Areas (ARAs), as stated in the 2021 Washington State Department of Ecology (Ecology) Draft Critical Aquifer Recharge Areas Guidance (Ecology Publication #05-10-028), "are to provide the public with clean, safe, and available drinking water."

In addition to drinking water, groundwater also plays a major role in other critical areas. Groundwater contributes to stream surface water flows, wetland hydrology, and flood flows. Surface water and groundwater are interconnected. Groundwater is the source for stream baseflow and during drier periods, base flow may be the sole source of stream surface flow. A stream or wetland can serve as a discharge during drier periods and recharge groundwater, and therefore an aquifer, during wetter periods. Under natural conditions, this surface and groundwater cycle attenuates surface water flows following storm events. 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. The risk of groundwater contamination (impacts to water quality) is related to two main parameters: The susceptibility of the aquifer and the contamination loading potential or source loading (WDOH 2017, EPA 1995).

Aquifer Susceptibility

Aquifer susceptibility refers to how easily water and pollutants can move from the surface through the ground to reach the underlying aquifer. A shallow, unconfined aquifer in a gravel rich basin would be more susceptible to contamination than a deep, confined aquifer overlain by dense glacial till. Contamination loading refers to the quantity and types of pollutants present in the area, and how they are handled. Unmanaged open space would have a low contamination loading potential, while a light industrial area would likely have a higher loading potential, and an older industrial site with multiple leaking storage containers would have a high loading potential. Together, susceptibility and loading potential determine the vulnerability of an aquifer. A highly susceptible aquifer may have a low vulnerability if the land use within the area is primarily open space. 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.

The susceptibility of an aquifer can be assessed by looking at three critical factors (Morgan 2005):

1. The overall permeability of the vadose zone (the unsaturated material between the aquifer and the ground surface, through which any contaminants would need to pass to reach the aquifer)
2. The thickness of the vadose zone or depth to the aquifer,
3. The amount of recharge available.

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 (Washington State DNR/Geology; https://fortress.wa.gov/dnr/geology/?Site=wigm). Chambers-Clover Creek watershed has high permeability and transmissivity due to coarse gravel/cobble outwash deposits with high groundwater levels (Savoca 2010).

Depth to an aquifer can be determined by examining well logs in the vicinity. As mentioned above, well logs are available at the Department of Ecology (WDOE) website (see Washington

State Department of Ecology Well Log in Section 7 for web address; http://apps.ecy.wa.gov/welllog/mapsearch.asp). In many cases, there may be several moderate to deep aquifers underlying a given location, and different wells in a given vicinity may be at widely varying depths if they are drawing from different aquifers.

The northwestern part of Pierce County, the location of the Central Pierce County sole source aquifer, is largely underlain by unconsolidated glacial sediment. The glacial deposits tend to be heterogenous and discontinuous in places. The USGS has identified 10 hydrogeologic units in their 1999 assessment of hydrology in the Tacoma-Puyallup area including 5 aquifers and 5 semi-confining units (Jones *et al* 1999). Hydrogeologic units include aquifers Qvr and Qc l through Qc4 and semi-confining units Qvt and Qfl through Qf4. Additionally, an undifferentiated unit, Qdu, is identified where insufficient data was available (Jones *et al* 1999). In 1999, the USGS estimated that of the 38 inches of average annual precipitation in the Tacoma-Puyallup area, 14 inches infiltrates and recharges groundwater supply. The amount of water recharge available to an aquifer can also be estimated from soil permeability and rainfall data. This dynamic is discussed in greater detail in the water quantity section below. Groundwater that has infiltrated then discharges to local streams, springs, and wetlands and generally moves north and east toward Puget Sound and the Puyallup River.

2.2.2 Surface Water-Ground Monitoring Continuity

Surface water and groundwater are cyclic and frequently interacting. Maintaining water quantity within an aquifer supports both potable water uses and landscape-scale habitat functions, which are groundwater-dependent.

Aquifers have recharge and discharge areas. Groundwater movement is driven by gravity, an aquifers' recharge is typically at a higher elevation than its discharge area. Higher elevations tend to be recharge areas and lower elevations tend to be discharge areas. However, in some cases subsurface conditions may result in groundwater flow that does not reflect surficial topography (Discroll 1986). An aquifer recharge area is an area where water from rainfall, snowmelt, lakes, rivers, streams or wetlands, flows into the ground to an aquifer. Aquifer discharge areas are where water flows away from an aquifer to the ground surface. Those areas can include seeps, springs, wetlands, streams, lakes, estuaries, and shorelines. Wells are also considered an aquifer discharge.

The quantity of water available in an aquifer is a balance between recharge, storage, and discharge. Land use and development typically alters water conveyance within a basin. For example, replacing forests with buildings, roads, driveways, lawns, and even pastures typically reduces the recharge to underlying aquifers to varying extents, 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 and Leopold 1978, Winter et al. 1998).

Recharge to an aquifer is dependent on precipitation and infiltration into the soil below the root zone. Infiltration below the root zone is controlled by a number of factors, including temperature, wind, soil type, geology, vegetation type, and land surface slope. The root zone is an important factor to consider, since evaporation and transpiration of water by plants reduces the water available for groundwater recharge and can account for much or most of the rainfall during some months (SJC 2004).

Unconfined aquifers occur when there is no barrier between the ground surface and the aquifer. The recharge area for unconfined aquifers is typically the land area contributing infiltration to the aquifer. Surface water, in lakes, streams, and wetlands, may play a large role in both recharge to and discharge from unconfined aquifers, and the function may vary from season to season (Dunne and Leopold 1978, Winter et al. 1998).

For a confined aquifer, more involved studies must be undertaken to understand the movement of subsurface water. Well logs from a given area can be used to map aquifers, and water elevations in the wells can be mapped to define a hydraulic gradient, which can then be used to determine flow direction in the aquifer (Golder Associates 2007).

Changes in groundwater recharge and withdrawal of water by wells are the primary drivers of reductions in groundwater quantity.

2.3 Key Protection Strategies

Key protection strategies for CARAs are still based on identifying and protecting ARAs 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:

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 implemented and followed, including application of BMPs in the Pierce County Stormwater Management and*

Site Development Manual for new developments in aquifer recharge areas. Review BMPs for infiltration designs with water quality treatment in the Chambers/Clover Creek watershed because of high infiltration rates and high water table conditions. 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.*
    - *Maintain stream base flow from groundwater to support in-stream flows, especially for salmon-bearing streams.*

Detailed guidance on completing the eight steps above is provided in Ecology Publication 05-10-028, Revised March 2021 (WDOE 2021a).

Pierce County last updated their GIS layer for aquifer recharge protection area maps in December 2015 and updated the mapping in 2018. The Central Pierce County Aquifer is designated as a sole source aquifer by the Environmental Protection Agency and occupies a significant portion of northwest Pierce County. ARAs are regulated under county code, PCC 18E.50.020. Review by the Tacoma/Pierce Department of Health is required for proposed regulated activities within mapped ARAs.

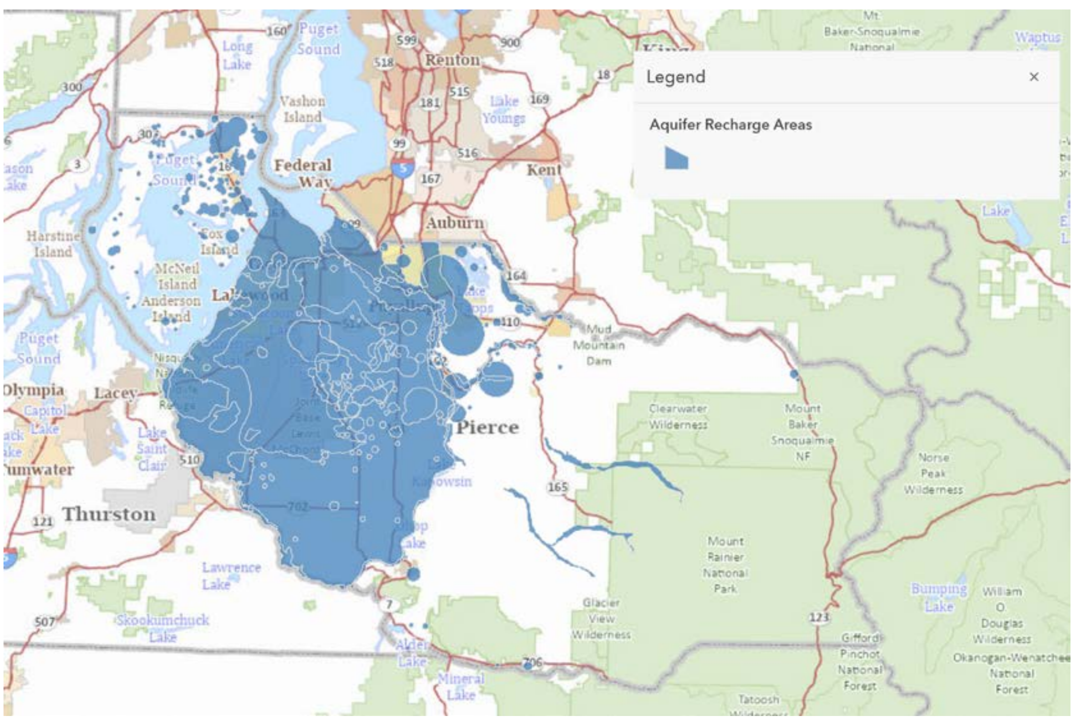


Figure 1. Pierce County Aquifer Recharge Areas. Source: https://gisdata-piercecowa.opendata.arcgis.com/

2.4 Climate Change Impacts & Mitigation

Climate change impacts to surface and groundwater quality and quantity based on regional trends are summarized below. Changes to surface water inputs will alter timing, frequency, and duration of surface water presence are projected to alter hydrologic patterns.

- The US Geological Survey stream gage on the Puyallup River near Orting has been in operation since 1932. Eight of the top ten peak floods have been recorded since 2006. (USGS). Stewart *et al* (2005) found that the timing of peak spring streamflow has been occurring 0-20 days earlier in many snowmelt-influenced rivers in the Pacific Northwest between 1948 and 2002.
- Hotter dryer summers will reduce ground surface saturation during the growing season. This is likely to reduce wetland areas and the groundwater recharge they provide.
- Changes to seasonal precipitation patterns are likely to reduce groundwater recharge. This would reduce streams flows that are supported, in part, by groundwater.
- Wildfires will bring more particulates into the environment and settle into surface and groundwater.
- 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.

Altered hydrology is projected to include earlier peak stream flows, increased frequency and extent of flooding, and reduced summer flows (Mauger 2015). However, groundwater is likely to be more resilient under climate change stressors relative to surface water resources (HDR, Inc. 2016). Ecology notes in the Critical Aquifer Recharge Areas Guidance draft comment and response summary that groundwater impacts may occur with climate change. The primary stressors noted are changes in the timing and amount of groundwater recharge, and increased pressure to use groundwater as surface water conditions change. Ecology recommends focusing on water conservation (WDOE 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 (WDOE 2021a). Population growth also presents challenges for protecting CARAs as land use intensity increases (WDOE 2021a). For example, multi-year droughts can increase reliance on groundwater source, 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 20-year planning horizon to manage supply and demand given climate trends and projections (Asinas et al 2022).
- Adaptive management of stormwater has the potential to better mimic natural systems and mitigate for 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 for increased flooding can reduce the likelihood of contaminated runoff events.
- Preserve open space and concentrate urban development away from CARAs.
- If necessary, strengthen regulatory protection of ARAs. For example, the County may review the 2015 and 2018 ARA 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.
- Continue to protect CARAs by maintaining 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 preservation and restoration of open spaces and native vegetation tracts.

3 Frequently Flooded Areas (FFA)

3.1 Definition

Frequently Flooded Areas (FFA) 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."*

FFAs in Pierce County include potential flood hazard areas, natural waters/watercourse areas, groundwater flooding areas, potholes, channel migration zones, Critical Areas Atlas - Flood Hazard Areas Maps, flood fringe, coastal flood hazard areas, FEMA floodways, and deep or fast-flowing water areas (PCC 18E.70.020). Rivers in Pierce County with mapped floodplains (frequently flooded areas) include White River, Nisqually River, Carbon River, and the Puyallup River. Seven rivers with Channel Migration Zones (CMZs) are regulated as floodways in Pierce County. Those CMZ rivers are South Prairie Creek, Carbon River, Puyallup River, White River (including West fork of the White River), Greenwater River, Nisqually River, and Mashel River (PCC 18E.10.140.H.4).

3.2 Functions and Values

FFAs are dynamic and ecologically productive environments. Dynamic hydrologic processes, including mobilization of large woody debris and other allochthonous inputs, can be critical to the maintenance of fish and wildlife habitat (Naiman and Decamps 1997, Gurnell 2005). High flow channels carved into floodplains provide important habitat for a variety of fish species, creating areas of refuge from the high flows. Over time, during periods of high flow, streams will overtop their banks and deposit sediment load, cumulatively forming a flood plain (Dunn and Leopold 1978, Knighton 1998). Floodplain storage reduces peak stream flows. It also contributes to infiltration and aquifer recharge. Flooding is identified as the most costly natural hazard (WDOE 2021b, Ecology Publication # 21-06-019).

Flooding generates high costs annually across the nation as homes are damaged, business fail and lives are lost. This is unique among most of the other critical areas, save for landslides, where the critical area can be directly harmful to the person who encroaches it. Floodplains have been used for agriculture, residential development, and urbanization for centuries. Much infrastructure was developed to take advantage of proximity to rivers and large water bodies with advantages for travel, transport, and discharge of waste generated from human uses. Floodplains have historically been diked, leveed, and filled to provide for development although these “improvements” have not prevented downstream impacts or, in many cases, flooding of areas they were meant to protect over the long term. Changing river dynamics, including sediment and large woody debris accumulation as well as increased flows due to upstream land use changes, may overwhelm aging flood control works that have not been maintained or improved. The human and societal cost of flooding has increased over the years with increasing populations and the failure to recognize long term potential flooding.

When streams are altered through urbanization, including channel straightening and armoring, they can become disconnected from their natural floodplain and associated wetlands (Booth 1990). Additionally, increased impervious surfaces and loss of forest within a basin increases peak flow magnitude and frequency (Booth 2002). Associated downcutting of stream channels further separates them from floodplains, increases in-stream erosion, and deposits sediment in downstream environments, blocking culverts in some cases (Booth 1990). As noted by Booth et al. (2004), integrated management of complex stream environments requires more detail than total impervious basin area figures. Patterns of urban development are relevant to watershed functions and both increased impervious surface area and its aggregation or patch size directly impact stream ecosystems (Alberti et al. 2007). As described above, stream dynamics are closely linked to floodplain functions.

3.3 Key Protection Strategies

The County is working on Comprehensive Flood Hazard Management Plan (CFHMP) with the aim to adopt the new plan by October 2023. As detailed in the WAC 173-145-040, a CFHMP contains specific elements including a determination of the need for flood control work based on known and potential flood damages, alternative flood control measures, consideration of instream and critical area impacts, coverage area, conclusion with recommendations, and lastly certification from the Emergency Management Division of the Washington State Military Department / local emergency management organization (Ecology 2021b).

Pierce County continues to work to reduce flood risks to communities although it does not guarantee a level of protection. After 100 years of building levees the one consistent theme is they all eventually fail to protect what is behind them. The investment does lower risk during lesser, more frequent floods. In the 1991 Puyallup River Basin Comprehensive Flood Control Management Plan this is clearly stated on page 1-2 , and has led to a change in philosophy by the County from trying to "control" floods to attempting to reduce damages caused by flooding.

County from trying to “control” floods to attempting to reduce damages caused by flooding.

Integrated floodplain management (IFM) is recommended by the Washington State Department of Ecology. IFM is a collaborative approach that brings together multiple parties to develop strategies and actions that benefit people, fish and wildlife, community interests, and tribal rights. IFM also focuses on sustainability and costs (Ecology 2021b). The Floodplain for the Future program that SWM manages is IFM at the watershed-scale for the Puyallup watershed. Pierce County has also developed a Clear Creek Strategy Plan to improve conditions related to flooding and drainage in addition to agriculture, fish habitat, and community support (Anchor QEA 2020).

In general, the County can reduce hazards associated with frequently flooded areas by restricting development in mapped floodplains. Pierce County has adopted requirements for Zero-rise, placing the floodplain in protected tracts, and compensatory storage measured in foot-for-foot increments. These regulations were recognized by the authors of the NMFS BiOp as best practices. They were some of the reasons Pierce County is one of only four Counties in the nation to be a Community Rating System Class 2 or better.

Floodplain management is generally based on a no adverse impact strategy (ASFPM 2003). This approach requires one floodplain property owner to ensure that their land use does not adversely affect onsite flood storage or neighboring flood risk, including flow velocities and erosion risks. 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.

The County requires habitat assessments for floodplain as required by FEMA and the federal agency Biological Opinion (BiOp). The 2008 National Marine Fisheries Service (NMFS) Biological Opinion (BiOp), which found that implementation of the National Flood Insurance Program (NFIP) in the Puget Sound region jeopardizes 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, water quantity, flood volumes, flood velocities, spawning substrate, or floodplain refugia for listed salmonids. Because the NFIP is implemented by 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. Habitat assessments evaluate developments in the floodplain with potential impacts to fish habitat.

3.4 Climate Change Impacts & Mitigation

Seasonal changes in the Pacific Northwest are projected to entail wetter autumns and winters and drier summers (Mote and Salathe 2010). Changes in rainfall patterns, particularly increased intensity and duration of rainfall events, due to climate change will increase the frequency of floods with resulting flood hazards (WDOE 2021b). Increased flooding may increase sediment transport in winter and spring (Mauger et al. 2015). Heavy precipitation in the Pacific Northwest is commonly associated with atmospheric rivers and climate change models project increased frequency of these extreme events (Salathe et al. 2014; Mauger and Kennard 2017). Climate change can drive flooding in coastal areas due to sea level rise, high tides, storm surges and waves. Stream channel migration can also drastically alter food risks (Mauger and Kennard 2017). Extreme flood events may impact instream habitats by mobilizing sediment and pollutants (Talbot et al 2018). Increased flood flows or increased sediment deposition are projected to expand the floodplain boundary and put structures and lives at risk that the current mapping does not show. A combined increase of discharge and loss of river conveyance could be devastating to properties close to the river. Most homes are built to at least a 100-year design life. Projected sea level rise around Puget Sound in future decades could mean that a home built in shoreline areas today might not be viable in the future.

To integrate climate change into flood risk management in Washington State, an interagency group called the WA Silver Jackets was formed. 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 and Kennard 2017).

3.4.1 Strategies to manage climate change impacts to FFAs

- Complete and maintain a comprehensive flood hazard management plan (CFHMP) to support stormwater management, salmonid habitat, and streamflow planning (WDOE 2021b). As noted above, the County is currently revising the CFHMP.
- 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.
- Utilize WA Silver Jackets Work Plan to support resiliency planning for flood management (Mauger and Kennard 2017).

4 Geologic Hazard Areas

Consistent with WAC 365-190-030, "Geologically Hazardous Areas" are "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." The four main types of geologically hazardous areas recognized in the GMA are 1) erosion hazard areas; 2) landslide hazard areas; 3) seismic hazard areas, and 4) areas subject to other geologic events such as coal mine hazards and volcanic hazards (RCW 36.70A.030(9) and WAC 365-190-120). Pierce County regulates volcanic, landslide, seismic, mine, and erosion hazard areas (PCC 18E Development Regulations).

The purpose of regulating activities in geologically hazardous areas is to protect the public from the hazard. Geologic hazard areas are subject to periodic events that can result in property damage, injury and the loss of life. Land use in these areas can pose a safety concern, and, in some cases, may increase the potential for a hazardous event. Failure of a geologic hazard on one property can impact large surrounding areas. It is important to identify where such hazard areas are, and to ensure that activities and development in those areas is managed for safety and stability.

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

4.1 Definitions

4.1.1 Volcanic Hazard Area

Volcanic hazard areas include areas in the recent geologic past that have been affected by pyroclastic flows, pyroclastic surges, lava flows, ballistic projectiles, and inundation by Case I, II, or III lahars, debris flows, or flooding resulting from geologic and volcanic events on Mount Rainier. 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*).

4.1.2 Landslide Hazard Area

Landslide hazard areas are areas identified as having the potential for mass wasting due to a combination of geologic, seismic, topographic, hydrologic, or human-created factors. Regulated landslide hazard areas are identified for regulation within Pierce County by the presence of any of the following indicators:

- Areas of historic and recent failures

- Areas with active bluff retreat that result in a vertical or steep bluff face with little or no vegetation
- Areas with both slopes steeper than 20 percent with a vertical relief of 20 feet or more; and hillsides that intersect geologic contacts with a relatively permeable sediment overlying a relatively impermeable sediment or bedrock where water may become perched.
- Slopes that are parallel or sub-parallel to planes of weakness, such as bedding planes, joint systems, and fault planes.
- Areas exhibiting geomorphological features indicative of past slope failure, such as hummocky ground, back-rotated benches on slopes, etc.
- Areas with tension cracks or ground fractures along and/or near the edge of the top of a bluff or ravine.
- Areas with structures that exhibit structural damage including but not limited to settling and cracking of building foundations or separation of accessory structures from a main structure located near the edge of a bluff or ravine.
- The occurrence of toppling, leaning, curved tree trucks, or jackstrawed trees that are caused by disruption of ground surface by active mass wasting.
- Areas with slopes containing liquifiable soils.
- Areas where gullying and surface erosion have dissected the bluff edge or slope face as a result of natural or artificial surface or groundwater drainage.
- Areas where indicators of a shallow groundwater table are observed on or adjacent to the face of the slope.
- Any area with a slope of 40 percent or steeper and with a vertical relief of 15 or more feet, except those manmade slopes created under the design and inspection of a geotechnical professional or slopes composed of competent bedrock. For the purposes of determining whether a slope is considered to be a landslide hazard area, the horizontal and vertical distance between the top and toe of slope are utilized.
- Areas that are at risk of mass movement due to seismic events.
- Areas that include alluvial or colluvial fans located at the base of steep slopes and drainages.

4.1.3 Seismic Hazard Area

Seismic hazard areas are areas subject to damage resulting from earthquake-induced landsliding, seismic ground shaking, dynamic settlement, fault rupture, soil liquefaction, or flooding caused by tsunamis and seiches.

4.1.4 Mine Hazard Area

Mine hazard areas are directly underlain by, adjacent to or abutting, or affected by old mine workings such as adits, tunnels, drifts, or airshafts that have the potential for subsidence.

4.1.5 Erosion Hazard Area

Erosion Hazard Areas regulated by Pierce County include shoreline, riverine, and soil erosion hazard areas. Shoreline erosion hazard areas include areas within 200 feet landward of the ordinary high water mark (OHWM) of a freshwater (lake or pond) or marine (Puget Sound, tidal marshes, and estuaries) shoreline. Riverine erosion hazard areas include the channel migration zones (CMZ) of the following rivers: South Prairie Creek; Carbon River; Puyallup River; White River (including W. fork White River); Greenwater River; Nisqually River; and Mashel River. Channel Migration Zone studies have been completed and which identify areas at severe risk for erosion are regulated under 18E.70.040.B as a floodway. Soil erosion hazard areas contain slopes of 20 percent or greater and are classified as having severe, or very severe erosion potential by the Soil Conservation Service, US Department of Agriculture (USDA).

4.2 Functions and Values

4.2.1 Volcanic Hazard Area

Mount Rainier is a stratovolcano located in eastern Pierce County. At 14,410 feet, Mount Rainier is the tallest peak in the state of Washington and the tallest volcano in the US Cascade Range. The most recent magmatic eruption was approximately 1000 years ago. The USGS categorizes Mount Rainier as having a very high potential threat based on several factors including elevation, relief, hydrothermal alteration, the presence of glaciers, and the volcano’s proximity to major metropolitan areas. Of the potential volcanic hazards, lahars are the greatest potential risk to the greatest number of people. The map reproduced below is taken from the USGS informational website on Mount Rainier and shows areas likely to be affected by pyroclastic flows and lahars (Figure 1). The Washington State Department of Natural Resources completed an assessment of the potential economic loss resulting from Mount Rainier lahar hazards. For the Puyallup Valley, the loss estimate was approximately $6 billion excluding the value of building contents in 2012 when the assessment was completed (Cakir and Walsh 2012).

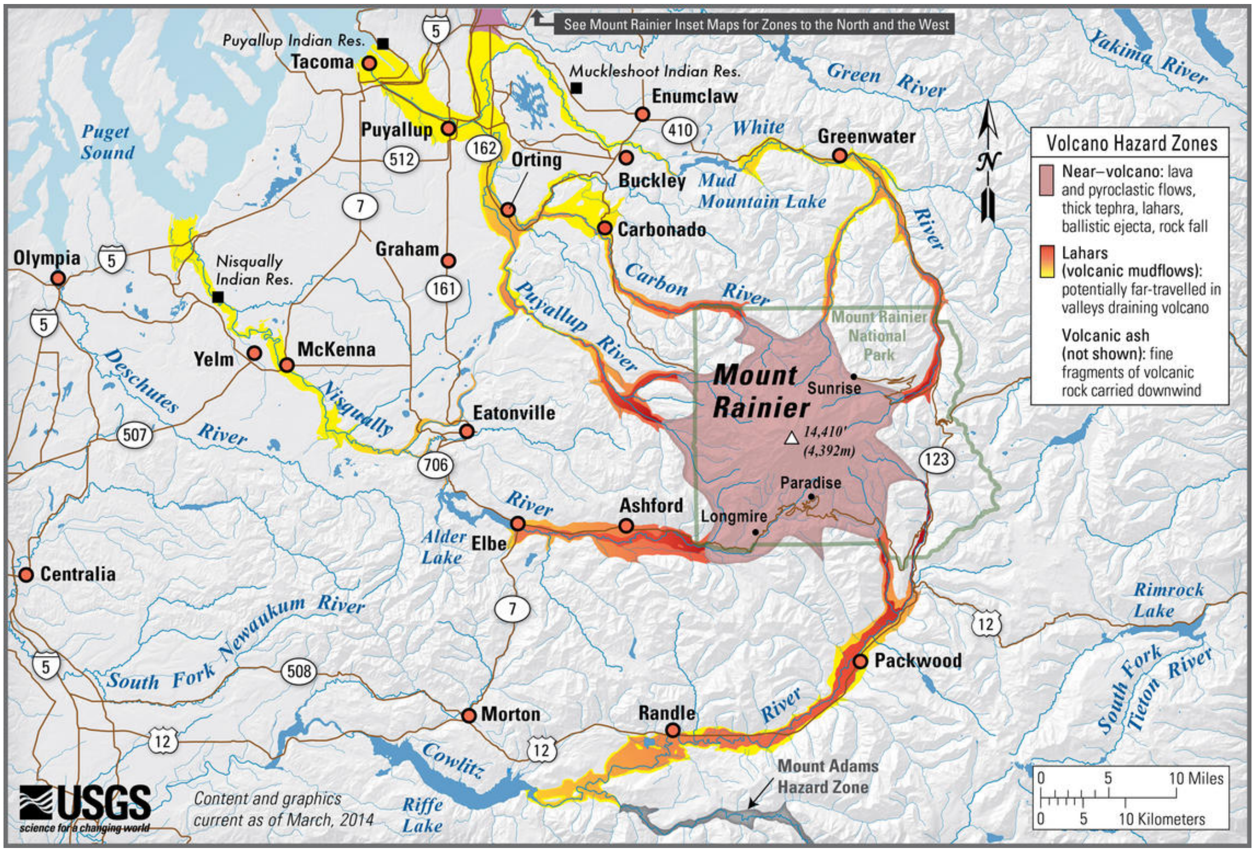


Figure 2. Source: USGS Volcanic Hazards at Mount Rainier (https://www.usgs.gov/volcanoes/mount-rainier/volcanic-hazards-mount-rainier)

4.2.2 Landslide Hazard Area

Landslides can be fast or slow, and deep or shallow, initiating from the bottom of a slope, the top of a slope, or somewhere in between.

The Washington Department of Natural Resources (WDNR) Geologic Information Portal provides mapping for known landslide areas within Pierce County.

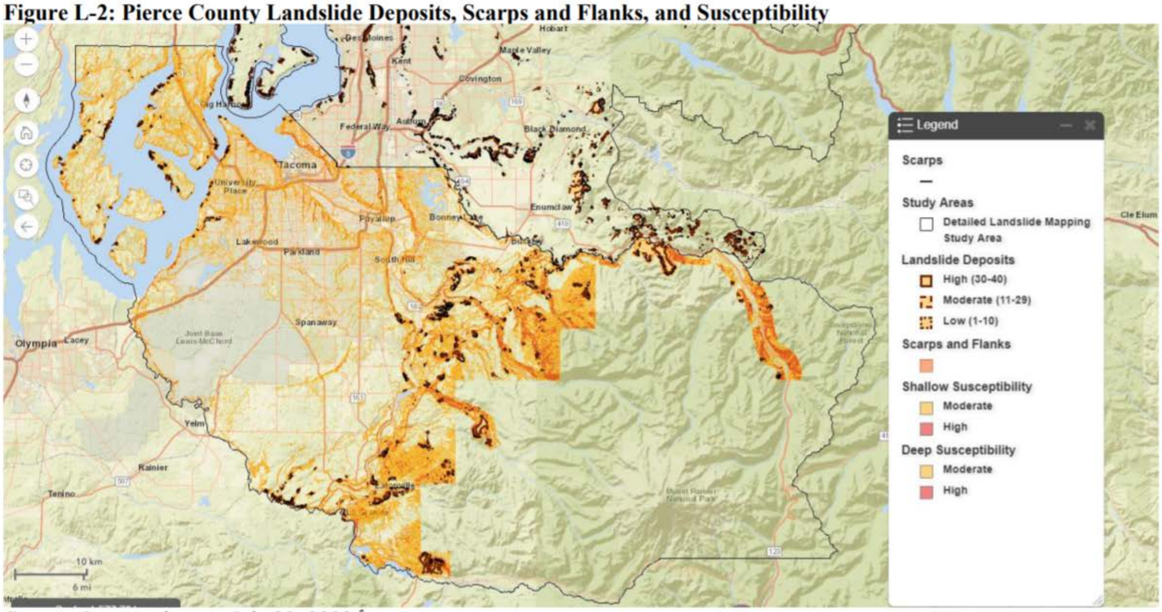
Areas prone to landslides in the coastal areas of Pierce County are commonly slopes comprised of relatively permeable materials, such as sand and gravel, over a less permeable material, such as bedrock or clay. The most common type of landslide in the Puget Sound region occurs in response to either heavy precipitation (Tubbs 1974) or elevated groundwater conditions (Thorsen 1987) in colluvium derived from glacial deposits. Glacial deposits often result in surface layers that are more permeable than the deeper layers, causing water to perch at the contact between the two layers. The weight and increase in pore pressure from the water and causes the upper layer to fail, and slide over the deeper, more resistant layer.

Most coastal bluff retreat (top of the bluff recedes landward) within the Puget Sound occurs through landsliding, most of which are shallow landslides and debris avalanches. Large slumps and landslides are less common and seem to be associated with taller bluffs (Shipman 2004) and are triggered by elevated groundwater (Savage *et al* 1999) and seismic activity (Chleborad 1994).

According to Shipman (2004), steeper slopes are more prone to failure due to increased gravitational stresses. However, due to the heterogeneous nature of bluff geology in the Puget Sound lowlands, variability in hydrologic conditions and rock strengths make landslides difficult to predict.

Landslides are also common in interior Pierce County above rivers and streams and in steep terrain. Activities associated with urban development, including vegetation removal and increased impervious surfaces, can increase the landslide hazard of susceptible areas. Vegetation plays a significant role in landslide potential by intercepting a substantial amount of rainfall, preventing it from infiltrating into the soil. Roots from vegetation also take up and transpire some of the water that does reach the soil (Watson and Burnett 1995). This reduces the amount of water that rests at the contact between the permeable and impermeable layer. A dense matrix of roots can also lend considerable strength to the soil on a slope (Schmidt, et al. 2001), decreasing the likelihood of slope failure and shallow-rapid landslides.

Figure L-2: Pierce County Landslide Deposits, Scarps and Flanks, and Susceptibility



Source: Image taken on July 30, 2019.[5]

Figure 3. Pierce County Landslide Deposits, Scarps and Flanks, and Susceptibility. Image taken from Pierce County Hazard and Risk Assessment (2015).

4.2.3 Seismic Hazard Area

The State of Washington is located on the Cascadia Subduction Zone at the plate boundary between the Juan de Fuca and the North American tectonic plates. Earthquakes initiating from the Subduction Zone are generally less frequent than other earthquake locations but tend to be larger in magnitude. Intraplate earthquakes tend to be deep earthquakes and are the most frequent earthquakes to affect Pierce County. Shallow crustal earthquakes have occurred historically on the Tacoma Fault. The last known earthquake on the Tacoma fault occurred approximately 1,100 years ago and is estimated to have been a magnitude 7 earthquake (USGS 2010).

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 Pierce County are mapped by the Washington Department of Natural Resources. The area located between Sumner and where the Puyallup River enters Commencement Bay is mapped as high liquefaction susceptibility (WDNR GeologyPortal). Other areas of moderate to high susceptibility to liquefaction within Pierce County tend to be collocated with the floodplains of rivers. Mud Mountain Dam is located within Pierce County and both contains over 10 acre-feet at peak storage and could be affected by seismic activity (Pierce County 2015). Areas most susceptible tsunami inundation include all coastlines and the Puyallup River Delta area (Dolcimascolo *et al* 2022).

4.2.4 Mine Hazard Area

Pierce County has a rich history of coal mining in the eastern part of the County. The Pierce County Hazard and Risk Assessment (PCHRA) completed in 2015 gives a summary of mining between the 1870s, when mines began to file maps, and the time when the cost of mining was no longer economically viable. As described in the PCHRA, there are several hazards associated with abandoned mines. Individuals may gain access to potentially unstable mines through entrances that do not have engineered barriers or through airshafts that have not been sealed or have not remained sealed. The ground surface above the mines may subside or fail as a result of aging structural supports that stabilize the mine shaft walls. The degree of failure depends on the strength of the overlying earth material. Gases that would have been vented to the surface during mining operations, but are no longer vented, may become trapped and result in asphyxiation for individuals entering these areas. The risk for deterioration of structural supports for the mine shafts, pooling of hazardous gases, and the potential accumulation of groundwater within the interior of mines increases with time. Thus, abandoned mines become more dangerous with time.

There are approximately 40 mines within Pierce County. Mine mapping remains incomplete in some cases, as some mines went out of business before the mining companies submitted the required mine documentation for new excavations. Known areas containing mine hazards have been mapped (See Figure AM-3 in the PCHRA).

4.2.5 Erosion Hazard Area

Erosion and landslides are natural processes that contribute sediment, rocks, and large woody debris to streams. However, these events can be damaging when erosion exceeds natural conditions due to anthropogenic effects such as clearing vegetation and increasing surface runoff through the creation of new impervious surface. Excessive erosion and deposition can harm streams, shorelines, and the plants and animals that inhabit them.

When structures are placed in areas susceptible to erosion, or land use actions cause formerly stable areas to begin eroding, the risk of erosion increases for surrounding land uses as well. A reduction in stormwater infiltration due to the creation of impervious surfaces, as part of urban development, generates more rapid runoff from the land into streams and rivers. This results in an increase in peak flow volume, which in turn produces higher energy and increases the potential for streambank erosion (Booth 1990, Booth 1991, Nelson and Booth 2002).

Vegetation increases the stability of geologic hazard areas. Vegetation removal can contribute to increased erosion in susceptible areas. Vegetation reduces erosion by preventing a significant amount of rainfall from reaching the soil and physically binds the soil together with root materials (Booth et al. 2002, Niaman and Decamps 1997). In cleared areas, rainfall tends to concentrate in small channels, and as the water gains depth and volume, sediment can be mobilized by the flow. In this way, small channels or rills can eventually develop into gullies.

4.3 Key Protection Strategies

The primary goal of protection measures for geologic hazards is to protect people and property. The prior 2002 BAS review noted common protective measures applied to geologic hazards, including promoting sound development, use of Best Management Practices (BMPs), and establishing buffers adjacent to geologic hazard areas. The 2002 BAS Review further noted, at the time, that for volcanic hazards there was little BAS available for mitigation and/or land use policy. However, the USGS has since mapped volcanic hazards for Mount Rainier within Pierce County (2014) as part of a volcanic hazard assessment, which is the first step in planning for volcanic eruptions. An early detection system for volcanic activity in excess of background levels on Mount Rainier is monitored by the Cascade Volcano Observatory 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 advance warning of months to days before an eruption. The primary mechanism for protecting people is limiting the risk to people by limiting the occupancy and limiting the development of essential or hazardous facilities in volcanic hazard zones.

In addition to volcanic hazard areas, erosion hazards, landslide hazards, and seismic hazards can be mapped and classified. The classification systems can be used to determine site limitations and development requirements. If development is proposed within the buffer or erosion hazard or landslide hazard area, rigorous design and construction standards should be adhered to in order to prevent the development from causing instability, either at the site or elsewhere on the slope. 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. Data used in such analyses should be site-specific and include subsurface exploration and testing of soils at an appropriate frequency across the site.

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. The commission recommends the governor establish a geologic hazards institute focused on education, outreach, research needed, and best professional practice guidelines (SR530 Landslide Commission 2014).

Per the SR-530 Landslide Commission's 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 (SR530 Landslide Commission 2014). 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. Adherence this guidance can mitigate seismic hazards.

4.4 Climate Change Impacts and Mitigation

Geologically hazardous areas, particularly erosion hazard areas and landslide hazard areas, are prone to impacts from changing patterns in precipitation and associated stress on native trees and shrubs and groundcover plants. 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). This indicates that heavy rains will be more common outside of summer months. When the magnitude and frequency of rain events increase, it can over-saturate soils and contribute to instability. Rainfall intensity and duration is a predictor for landslide events (Cheleborad *et al* 2006l WDNR 2020). Extreme precipitation events modeled by the UW Climate Impacts Group are expected to increase in intensity and frequency (Morgan, H., Mauger, G., Won, J., Gould, D. 2021). If significant plant mortality occurs in dry summer periods, in conjunction with heavy rains, there will be potentially fewer vegetation rooted in hazard areas to stabilize them.

Coastal areas will also become more prone to erosion and landslides as, coupled with increased precipitation intensity, sea level rises and increases flood inundation for estuarine and riverine systems. Under the RCP 8.5 scenario, sea level rise is projected to be between approximately 0.2 to 1.6 feet by 2050, depending on the location on Pierce County's coastal shorelines (Miller *et al* 2018). Concurrently, sea level rise and increased riverine inundation could also increase tsunami inundation in the event of seismic activity.

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) including sea level rise
- 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 County is included in statewide collaborative efforts to manage geologic hazard areas

5 Wetlands

5.1 Definition

Since interest in managing and protecting wetland resources began in the mid-fifties, ecologists have worked to develop a wetland definition based on scientifically defensible criteria. Implementation of the 1977 Clean Water Act requires a scientifically based legally defensible wetland definition (Mitsch and Gosselink 2000). Wetlands are 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 U.S. Army Corps of Engineers (Corps) wetland definition is similar to the definition from the WAC. The Corps definition does not list the features not included in the wetland definition for regulatory purposes (Corps 1987).

Wetlands are dynamic environments characterized by seasonally or permanently wet areas. Wetlands also have anaerobic hydric soil indicators and water dependent or water tolerant plant species.

5.2 Functions and Values

Wetland functions are the biological, chemical, and physical processes that occur within a wetland. Wetland values refers to the resources a wetland provides that are valued by society, either ecologically, economically, recreationally, or aesthetically.

The capacity of an individual wetland to perform functions is dependent upon multiple factors, the including the wetland landform or hydrogeomorphic (HGM) class. For example, wetlands on slopes have less potential to store water relative to depressional wetlands. Wetland functions are dependent on the geomorphic and hydrologic characteristics of each wetland (Brinson 1993; Hruby 2014). Other factors that impact wetland functions are landscape setting, vegetation structure, hydroperiods, proximity to potential sources of pollution, and priority habitat corridors and connectivity. Wetlands naturally perform several functions at low-cost relative to engineered solutions, such as water storage, flood protection, water reserve, pollutant and nutrient retention, and provisional fisheries habitat; these are valued as human services (Hattermann et al. 2008).

For regulatory purposes, wetland functions and values are commonly ranked in a rating system. The current BAS-based rapid assessment tool for wetland functions is the *Washington State Wetland Rating System for Western Washington: 2014 Update* (Ecology Publication #14-06-029, Hruby 2014). The Ecology wetland rating system, broadly groups wetland functional values into three categories: 1) water quality functions, 2) flood storage or hydrologic functions, and 3) habitat functions (Sheldon et al. 2005; Hruby 2014). The functional score for each category is ranked as high, medium or low. Each category assesses site potential to perform each function, relative to landscape setting, and value to society.

5.2.1 Water Quality Functions

Wetlands improve water quality by intercepting runoff, retaining inorganic nutrients, converting organic wastes, settling sediment and removing contaminants (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 2014). Wetlands uptake nutrients, particularly nitrogen and phosphorus, and protect downstream areas from nutrient spikes. Wetland plants and microorganisms are known to uptake or remove nitrogen through the biochemical processes of nitrification and denitrification, which occur in aerobic and anaerobic conditions, respectively (Sheldon et al. 2005). According to Kerr et al. 2008, low oxygen concentrations that are common to wetland environments also make them particularly good sinks for copper. Studies of constructed wetlands has shown wetland plants remediate pharmaceuticals and personal care products (PPCPs) to various extents and provide some phytoremediation (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 within a watershed where stored water is slowly released down-gradient after being retained in surface of groundwater (Hruby et al. 1991; Adamus et al. 1991). This has a cumulative impact on magnitude and intensity of peak flow events (Sheldon et al. 2005).

Urbanization, or increased impervious surface area within a drainage basin, commonly alters wetland hydrology by increasing or decreasing flows from the surrounding landscape (Sheldon et al. 2005). Those wetland hydrology changes are linked to other negative urbanization effects, such as stream channel erosion and downcutting, sediment deposition, and altered seasonal water regimes (Sheldon et al. 2005). Changes in wetland ponding depths, seasonal hydroperiods or water level flux can also impact wetland plant communities (Schueler 2000).

5.2.3 Habitat Functions

A diverse group of fauna depend 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, in Sheldon 2005). Several factors including buffer width and condition, vegetative structure, habitat interspersion, wetland hydroperiods, and landscape setting all impact wetland habitat functions (Hruby 2014). A study of wetland and non-wetland landscape matrix quality have on wetland vertebrates found that while species abundance generally increases in landscapes with more wetland areas, some species are more sensitive to the larger landscape condition, such as amphibians (2015 Quesnelle et al.). For example, native amphibian species richness has been negatively correlated with urban landscape attributes (Guderyahn et al. 2016).

Cumulative impacts of direct and indirect wetland alterations, including hydrologic changes, compromised water quality, and habitat fragmentation tend to reduce the habitat functions and values a wetland provides (Sheldon et al. 2005, Azous and Horner 2010). Urban and rural development commonly reduces wetland buffering and increases encroachment by people and pets.

5.3 Key Protection Strategies

Wetlands are primarily protected through regulatory requirements at the local, state and federal levels to avoid, minimize, and mitigate for any impacts. Common BAS-based 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, landscape-scale corridors can be protected by establishing corridor retention requirements for development proximate to a wetland complex.

5.3.1 Wetland Identification and Classification

To protect wetlands, they must first be identified by a qualified professional. Currently per PCC 18E.30.020 and consistent with BAS, wetland delineations are conducted using the 1987 Corps of Engineers (Corps) *Wetlands Delineation Manual* (Manual) with the *Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Western Mountains, Valleys, and Coast Region Version 2.0* (Regional Supplement)(Corps 2010). The Regional Supplement provides greater detail on determining presence or absence of wetlands based on an examination of vegetation, soils and hydrology in our ecoregion.

The *Ecology Wetland Rating System for Western Washington* was first issued in 2004, annotated in 2006, and updated in 2014. Pierce County has adopted 2014 Ecology rating system in their current critical area regulations, but PCC 18E.30.020.D and associated Appendix A still refer to the older version of the Ecology wetland rating system. However, in practice, the County is requiring use of the 2014 version for current permit applications. The focus of the 2014 update was to change the scoring to a high, medium or low ranking that better reflects the accuracy of this rapid assessment tool. Additional clarifications were added to the rating system guidance to incorporate annotations from the prior version (Hruby 2014).

Jurisdictional status of an area meeting wetland criteria according to the Manual and Regional Supplement can vary depending on the agency involved and the wetland definition applied. Wetlands are regulated at the local, state and federal levels. For example, local and state agencies exclude stormwater features. Whereas the Corps may still regulate certain features and conveyances to project water quality under the Clean Water Act.

5.3.2 Wetland Buffers

Wetlands are commonly protected from surrounding land uses through fixed buffer width requirements. Documented wetland buffer functions include moderation of stormwater inputs, sediment removal, pollutant settlement, microclimate, habitat for wetland-dependent fauna, habitat connectivity, and disturbance screening (Sheldon et al. 2005). Buffer functions vary depending on several factors, including the vegetation community present, gradient, soil conditions, and adjacent land use intensity (Sheldon et al. 2005). Ecology provides buffer width alternatives in *Appendix 8-C: Guidance on Buffers and Ratios for Western Washington Wetlands in Washington State Volume 2 – Protecting and Managing Wetlands* (Ecology Publication No. 05-06-008, modified October 2014). The recommended buffer widths assume the buffer is vegetated with a native plant community appropriate to the ecoregion (Granger et al. 2005, modified 2018). Wetland buffer widths under current Pierce County Code (PCC 18E.30.060 and Appendix F are based on wetland category, habitat functions score, land use intensity, and implementation of minimizations measures. This is one of the BAS-based options in Appendix 8-C (Ecology Publication #05-06-008, Modified 2018).

A synthesis of scientific studies summarizing, among other wetland topics, effectiveness of various buffer widths relevant to Western Washington was published by the Washington State Department of Ecology (Sheldon et al. 2005). These studies focus on buffer widths relative to water quality functions, hydrologic maintenance, wildlife habitat, and disturbance barrier effectiveness. General studies on stream buffer widths were also deemed relevant to discussions of wetland buffer widths because a vegetated buffer often operates independently of the sensitive area it is intended to protect, particularly for "sink" functions such as sediment and pollutant removal. The effective buffer width ranges given below (Table 1) are broad and variations are largely dependent on buffer condition, landscape setting, and specific metrics. For example, buffer widths that can effectively maintain water quality functions differ for sediment removal, nutrient removal, and pathogen removal. Effective buffer widths for sediment removal vary by particle size (Sheldon et al. 2005). Generally, buffer widths recommended in the literature to protect a wetland varies depending on multiple factors, including land use intensity, habitat functions being protected, and pollutant removal necessary to protect water quality (Granger et al. 2005).

Current Ecology wetland guidance documents consistent primary factors to considers 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)

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).

Three BAS-based wetland buffer alternatives are presented in Ecology's Appendix 8-C (Ecology Publication No. 05-06-008, modified 2018) and referenced in the current Ecology guidance for CAO updates (ECY 2022). Those buffer options are:

1. Width Based Only on Wetland Category
2. Width Based on Wetland Category and Modified by the Intensity of the Impacts from Proposed Land Use
3. Width Based on Wetland Category, Intensity of Impacts, Wetland Functions, or Special Characteristics

Buffer option 1 is the least flexible and most conservative option (Table 1). It is a simple model to apply, but it does allow for more detailed project impact considerations.

Table 1. Buffer option 1.

Category of Wetland	Widths of Buffers
IV	50 ft
III	150 ft
II	300 ft
I	300 ft

Buffers options 2 and 3 allows for a more detailed review of the proposed project relative to land use intensity and specific wetland functions, particularly habitat functions in the case of option 3 (Tables 2 and 3). Buffer option 3 is the most complex and the most flexible. In buffer options 2 and 3, land uses are designated high, moderate or low intensity. Dense residential development (>1 unit/acre), institutional, commercial, and high use recreation (e.g. ball fields) are considered high-intensity impacts. Moderate-intensity residential developments (1 unit/acre or less) and moderate-intensity open space (parks with paved trails) are examples of moderate-intensity land uses. Low-intensity land use would be open spaces or natural areas with unpaved trails for low impact activities like hiking (Granger et al. 2005; ECY 2018).

Table 2. Buffer option 2.

Category of Wetland	Land Use with Low Impact	Land Use with Moderate Impact	Land Use with High Impact
IV	25 ft	40 ft	50 ft
III	75 ft	110 ft	150 ft
II	150 ft	225 ft	300 ft
I	150 ft	225 ft	300 ft

Table 3. Buffer option 3 (comprised of 4 Tables from Appendix 8-C (ECY 2018).

Table 8C-4. Width of buffers needed to protect Category IV wetlands in western Washington (Buffer Alternative 3 for wetlands scoring less than 16 points for all functions).

Wetland Characteristics	Buffer Widths by Impact of Proposed Land Use	Other Measures Recommended for Protection
Score for all 3 basic functions is less than 16 points	Low - 25 ft Moderate – 40 ft High – 50 ft	No recommendations at this time[1]

Table 8C-5. Width of buffers needed to protect Category III wetlands in western Washington (Buffer Alternative 3 for wetlands scoring 16 - 19 points for all functions).

Wetland Characteristics	Buffer Widths by Impact of Proposed Land Use	Other Measures Recommended for Protection
Moderate level of function for habitat (score for habitat 6 - 7 points)* *If wetland scores 8-9 habitat points, use Table 8C-6 for Category II buffers	Low - 75 ft Moderate – 110 ft High – 150 ft	No recommendations at this time
Score for habitat 3-5 points	Low - 40 ft Moderate – 60 ft High – 80 ft	No recommendations at this time

Table 8C-6. Width of buffers needed to protect Category II wetlands in western Washington (Buffer Alternative 3 for wetlands scoring 20 - 22 points for all functions or having the "Special Characteristics" identified in the rating system).

Wetland Characteristics	**Buffer Widths by Impact of Proposed Land Use** (Apply most protective if more than one criterion is met.)	**Other Measures Recommended for Protection**
High level of function for habitat (score for habitat 8 - 9 points)	Low - 150 ft Moderate – 225 ft High – 300 ft	Maintain connections to other habitat areas
Moderate level of function for habitat (score for habitat 6 - 7 points)	Low - 75 ft Moderate – 110 ft High – 150 ft	No recommendations at this time[2]
High level of function for water quality improvement and low for habitat (score for water quality 8 - 9 points; habitat less than 6 points)	Low - 50 ft Moderate – 75 ft High – 100 ft	No additional surface discharges of untreated runoff
Estuarine	Low - 75 ft Moderate – 110 ft High – 150 ft	No recommendations at this time[2]
Interdunal	Low - 75 ft Moderate – 110 ft High – 150 ft	No recommendations at this time[2]
Not meeting above characteristics	Low - 50 ft Moderate – 75 ft High – 100 ft	No recommendations at this time[2]

Table 8C-7. Width of buffers needed to protect Category I wetlands in western Washington (Buffer Alternative 3 for wetlands scoring 23 points or more for all functions or having the "Special Characteristics" identified in the rating system).

Wetland Characteristics	**Buffer Widths by Impact of Proposed Land Use** (Apply most protective if more than one criterion is met)	**Other Measures Recommended for Protection**
Wetlands Of High Conservation Value	Low - 125 ft Moderate – 190 ft High – 250 ft	No additional surface discharges to wetland or its tributaries No septic systems within 300 ft of wetland Restore degraded parts of buffer
Bogs	Low - 125 ft Moderate – 190 ft High – 250 ft	No additional surface discharges to wetland or its tributaries Restore degraded parts of buffer
Forested	Buffer width to be based on score for habitat functions or water quality functions	If forested wetland scores high for habitat, need to maintain connections to other habitat areas Restore degraded parts of buffer
Estuarine	Low - 100 ft Moderate – 150 ft High – 200 ft	No recommendations at this time[3]
Wetlands in Coastal Lagoons	Low - 100 ft Moderate – 150 ft High – 200 ft	No recommendations at this time[3]
High level of function for habitat (score for habitat 8 - 9 points)	Low – 150 ft Moderate – 225 ft High – 300 ft	Maintain connections to other habitat areas Restore degraded parts of buffer
Interdunal wetland with high level of function for habitat (score for habitat 8 - 9 points).	Low – 150 ft Moderate – 225 ft High – 300 ft	Maintain connections to other habitat areas Restore degraded parts of buffer
Moderate level of function for habitat (score for habitat 6 - 7 points)	Low – 75 ft Moderate – 110 ft High – 150 ft	No recommendations at this time[3]
High level of function for water quality improvement (8 – 9 points) and low for habitat (less than 6 points)	Low – 50 ft Moderate – 75 ft High – 100 ft	No additional surface discharges of untreated runoff
Not meeting any of the above characteristics	Low – 50 ft Moderate – 75 ft High – 100 ft	No recommendations at this time[3]

Recommended buffer widths vary widely depending on individual characteristics such as adjacent stressors, targeted functions, buffer condition, and species-specific habitat niche requirements.

Hydrology Maintenance

Vegetated wetland buffers can affect water quantity and hydrology in the wetland by moderating the input of runoff in several ways. Vegetation slows the movement of water from above and outside of the buffer, allowing the water to infiltrate into the soil. This slows or desynchronizes hydrologic inputs into the wetland. Leaf and other vegetative litter on and in the soil also capture water and improve the soil's infiltration capacity (Castelle et al. 1992b). Depending on the size of the basin, the type of wetland, and the degree to which stormwater falling on impervious surfaces is routed away from the buffer (either directly to the sensitive area protected by the buffer, to a detention or infiltration pond, or to some other facility), the contribution of a specific buffer to water quantity maintenance in a wetland may be high or low (McMillan 2000). Buffer characteristics that influence performance of hydrologic maintenance are: "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 allowing greater time for 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. 1992b). The plant species growing in buffers are an important factor in the buffers' ability to perform this function. Plants with fine roots are most effective at preventing erosion by binding the soil (Kleinfelter et al. 1992, in McMillan 2000).

Water Quality Improvement

As detailed in Ecology's Wetlands in Washington State, Volume 1: A Synthesis of the Science publications, buffers protect water quality in wetlands through removal of sediment and suspended solids, nutrients, and pathogens and toxic substances (Desbonnet et al. 1994; McMillan 2000; Castelle et al. 1992b; in Sheldon et al. 2005). Performance of the water quality improvement function depends on a number of variables, including slope, vegetation composition, leaf and wood litter, soil type, and the type of pollutant (Desbonnet et al. 1994). In general, optimum performance could be achieved with a diverse mix of trees, shrubs and groundcovers; poorly drained clay-loam soils with organic content; abundant downed wood and leaf litter; and no slope. Sediment and pollutants can either be prevented from reaching the wetland through physical mechanisms, such as wood or leaf litter holding or binding these materials, or through chemical and biological means, such as breakdown or uptake of certain pollutants by root systems or microorganisms in the soil (Desbonnet et al. 1994; McMillan 2000; Castelle et al. 1992b). Buffer vegetation can reduce sediment input to the wetland through stabilization of soils by roots, and reduction in rain energy by the vegetation canopy and organic material on the soil (Castelle et al. 1992b). Shading and wind reduction by buffer vegetation also influences water quality by maintaining cooler temperatures. Water temperature in wetlands can be critical to 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 (McMillan 2000), and limits excessive algal growth (Castelle et al. 1992b; Sheldon et al. 2005).

Desbonnet et al.'s (1994) literature summary concluded that approximately 70 percent or greater sediment and pollutant removal was obtained at buffer widths between approximately 65 and 100 feet. Between 60 and 70 percent of sediment and pollutant removal, except for phosphorus, occurs in buffers between 25 and 50 feet (Desbonnet et al. 1994). Phosphorus removal efficiencies of 60 percent or more are found in buffers greater than 40 feet wide (Desbonnet et al. 1994). McMillan's (2000) summary analyzed 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 (Sheldon et al. 2005).

Wildlife Habitat

Vegetated wetland buffers provide essential habitat for a wide variety of wildlife species, particularly those that are wetland-dependent, but require adjacent upland habitat for some part of their life cycle (e.g., some amphibians, waterfowl, some mammals). They also provide habitat for non-wetland-dependent species that prefer habitat edges, use the wetland as a source of drinking water, or use the protected buffer corridors to travel between different habitats. Studies have been done to determine necessary wetland buffer widths for wildlife in general, for particular species, and for particular life stages of particular species.

The recommended buffer widths range widely in the literature and are clearly species dependent. For example, a study conducted in urban King County (Milligan 1985) found that bird diversity was positively correlated with vegetated buffers of 50 feet or greater. One literature summary reports an effective buffer range of 50 feet (15 m) for many bird species up to 3,280 feet (1,000 m) for native amphibians (Milligan 1985 and Richter 2001, in Sheldon et al. 2005). A large number of studies recommend buffers between 150 and 300 feet (WDW 1992, in Castelle et al. 1992b). Triquet et al. (1990, in Desbonnet et al. 1994) recommend minimum buffer widths of 50 to 75 feet to provide general avian habitat. A minimum recommended wildlife corridor is 98 feet (Shisler et al. 1987, in McMillan 2000), although 490 feet was also recommended as a minimum travel corridor by Richter (1997). The generally recommended buffer widths for habitat protection range between 50 and 300 feet depending on factors including wetland habitat conditions, target species, buffer condition, and surrounding land uses (Sheldon et al. 2005).

Disturbance Barrier

Dense, vegetated buffers also 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 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. 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 (Shisler et al. 1987 in Sheldon et al. 2005). The buffer itself, and the functions that it provides, is subject to human-related disturbance. Cooke (1992, in Castelle et al. 1992a) found that buffers less than 50 feet wide experienced the most loss of buffer function related to human disturbance, and this loss is related to gradual reduction in buffer width as adjacent land uses encroach.

5.3.3 Mitigation

Mitigation Sequencing

Mitigation sequencing requires project applicants to first avoid all feasible wetland and buffer impacts, then to minimize unavoidable impacts, and lastly to mitigate for unavoidable impacts. This standard approach to wetland regulation is stated in PCC 18E.30.010 and .050. This is consistent with federal directives to achieve no-net-loss of wetland functions and values. Mitigation sequencing is also stated in the U.S. Environmental Protection Agency (EPA) issued 2008 Wetlands Compensatory Mitigation Rule and the WAC 197.11.768. Per current Ecology guidance for CAO updates, mitigation must be applied in the following order:

1. "Avoiding the impact altogether by not taking a certain action or parts of an action;
2. 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;
3. Rectifying the impact by repairing, rehabilitating, or restoring the affected environment;
4. Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action;

5. Compensating for the impact by replacing, enhancing, or providing substitute resources or environments; and/or
6. Monitoring the impact and taking appropriate corrective measures." (ECY 2022)

Compensatory Mitigation

Compensatory mitigation may be achieved through a programmatic approach or an approved permitee-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 commonly concurrent with wetland impacts, but it may be done in advance. Mitigation banks are state-certified to ensure ecologic replacement is achieved. ILF programs collect fees and apply the funds to restoration projects within the service area. ILF programs are reviewed and approved by the Corps and Ecology. Whereas, the applicant must complete installation, site maintenance and monitoring, and adaptive management as needed to achieve approved mitigation plan goals and performance standards for PRM projects (ECY 2021).

Ecology recommendations for mitigation ratios for projects in Western Washington varies by wetland category and the mitigation action proposed (Appendix 8-C: Guidance on Buffers and Ratios for Western Washington, Table 8C-11). Buffer impacts are commonly mitigated at a one-to-one ratio. Mitigation ratios for direct wetland impacts are increased to account for temporal losses (ECY 2022). When applying advanced mitigation, the Ecology recommended ratios vary by wetland category and proposed mitigation actions (ECY 2021).

To better address ecologic 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 (Hruby et al. 2009) and the Credit-Debit Method (Hruby 2012). The credit-debit method can be used to calculate mitigation credits needed for a given project. The credit calculations can be used to determine compensation when utilizing a mitigation bank or in-lieu fee program. Depending on specific site conditions, this may result in less or more mitigation than would be required under a set the standard mitigation ratio guidance (Hruby 2011).

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

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 (ECY 2008; Johnson et al. 2002). The goal of no net loss of wetland function cannot be achieved through mitigation alone, but may be met through a number of factors, including adequate monitoring and maintenance and appropriate performance standards. 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

Wetlands are dynamic and highly productive ecosystems that provide water quality, hydrologic, and habitat functions. Wetlands, like riparian corridors, also provide microclimate functions. These microclimate functions can provide some refuge from higher temperatures and provide landscape-scale corridors for wildlife passage (ASWM 2015; Ecology). Additionally, wetlands help off-set climate change through carbon storage. Wetlands store carbon both in organic soil and tree biomass. Carbon storage in undisturbed wetlands is approximately twice as high as carbon storage in wetlands disturbed by human-driven land use changes (Nahlik 2016; Ecology webpage). Bogs are important carbon sinks that are highly sensitive to disturbance, particularly stormwater discharges and changes in pH.

Climate driven changes in hydrologic patterns and temperatures may cause hydroperiods of saturation or inundation in wetlands to change. This may cause some wetlands to lose seasonal ponding characteristics or to dry up entirely, whereas other wetlands may experience increased ponding (Halabisky 2017; Ecology webpage).

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 (U.S. EPA 2015b; WDOE). Native plant species distribution is being impacted by climate change; adaptative potential and climate tolerance for native plant species are being studied in the scientific community (Vose 2012).

5.4.1 Strategies to manage climate change impacts to 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.
- Encourage use of native plant stock grown under local conditions to increase resilience under climate stressors.

6 Fish and Wildlife Habitat Conservation Areas (FWHCAs)

6.1 Definition

Fish and Wildlife Habitat Conservation Areas (FWHCAs) are defined under WAC 365-190.130 and also in the Pierce County Code (PCC). According to PCC 18.25.030 Definitions:

> "*Fish and wildlife habitat conservation areas" means a geographic area or areas necessary for maintaining species and may include areas of unique vegetation, successional stage, or habitat elements important to fish and wildlife, and may also include the connecting corridors between these areas*."

FWHCAs are further described under PCC 18E.40.020 to include areas which have a primary association with federally-listed endangered, threatened, and candidate species of fish or wildlife or State-listed endangered, threatened, sensitive, candidate, and monitor species that if altered may reduce the likelihood that the species will survive and reproduce over the long term.

Species of Local Importance and their Associated Habitats are also regulated under FWHCA provisions in Pierce County. Species whose habitat shall be so-regulated are named under PCC 18E.40.020.C and include 1) Fish: Coho salmon, Chinook salmon, bull trout, pink salmon, chum salmon, sockeye salmon, cutthroat trout, native/wild rainbow trout/steelhead, greenlings (lingcod), Pacific whiting, smelt (longfin, surfsmelt), herring, and sandlance (Pacific), 2) Birds: Osprey, and 3) Vulnerable Aggregations of fish and wildlife species as defined in the Washington Department of Fish and Wildlife (WDFW) Priority Habitats and Species/Heritage Program that reside in Pierce County.

In addition, PCC 18E.40.020.D includes a list of 20 types of Habitats of Local Importance to be regulated as FWHCAs. These include: (1) Oregon white oak woodlands, (2) prairies, (3) old growth/mature forests, (4) caves, (5) cliffs, (6) snag-rich areas and downed logs, (7) elk herd winter range, (8) talus, (9) shellfish areas, (10) kelp and native eelgrass beds, (11) herring, smelt and sandlance spawning areas, (12) natural waters and adjacent riparian shoreline, (13) estuaries and tidal marshes, (14) connectable relic channels and oxbows, (15) wetlands, (16) heron rookeries, (17) cavity nesting duck habitat, (18) western bluebird non-artificial nesting sites, (19) marine shoreline critical salmon habitat, and (20) critical saltwater habitats.

Please note, some ESA-listed species associated with the habitats of local importance above, such as prairies and Mazama pocket gophers, are described in more detail below.

6.2 Functions and Values

The critical areas and associated habitats of flora and fauna regulated as FWHCAs are interdependent. Natural disturbances, including floods, landslides, and channel migration, are part of temporal and spatial dynamics that supports formation of habitat niches and associated ecological diversity (Naiman et al. 1993). Land use can significantly alter the frequency and intensity of disturbance events (Nakamura et al. 2000); such events may be more or less common.

6.2.1 Streams, Lakes and Ponds, and Riparian Areas

High impervious surface area cover in developed areas is correlated with increased high flows, increased variability in daily streamflow, reduced groundwater recharge, and reduced summer low flow conditions (Burges et al. 1998, Jones 2000, Konrad and Booth 2005, Cuo et al. 2009). Changes in hydrology related to development are generally associated with soil compaction, draining, and ditching across the landscape, increased impervious surface cover, and decreased forest cover (Booth and Jackson 2002, Moore and Wondzell 2005). Together, these changes reduce infiltration, evapotranspiration, and groundwater storage, which reduces flow desynchronization – flows tend to be more variable and volatile.

A study assessing changes in forest canopy, stream flows, and stream bank erosion, found that if forest retention is less than 40 percent within a watershed, unstable channels are expected to occur (Booth et al 2002). Increased erosion and bank instability coupled with a reduction of forest cover has been found to simplify stream morphology, leading to incised, wider, 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).

WDFW defines riparian ecosystems as, "…transitional between terrestrial and aquatic ecosystems and are distinguished by gradients in biophysical conditions, ecological processes, and biota. They are areas through which surface and subsurface hydrology connect waterbodies with their adjacent uplands. They include those portions of terrestrial ecosystem that significantly influence exchanges of energy and matter with aquatic ecosystems" (Quinn et al. 2020). Specific stream and riparian area functions are discussed below.

Recruitment of large woody debris to the stream

Large woody debris (LWD) plays a significant role in geomorphic functions such as directing stream flows to shape the channel form and influencing sediment storage, transport, and deposition rates. The many effects of large wood create a variety of channel morphologies—dam pools, plunge pools, riffles, glides, undercut banks, and side channels - which provide a diversity of aquatic habitats (Quinn et al. 2020). Instream large wood provides fish with cover from predators, and by increasing a water body's effective space, wood structures may increase fish densities (Bisson et al. 1987). Large wood provides the downward scour necessary for streams to create pools, and it provides protective cover for fish in those pools. Pools provide rearing habitat for juvenile fish and resting space for adults.

The collection of large woody debris and the subsequent entrapment of smaller branches, limbs, leaves and other material 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). Just as riparian areas have a more significant effect on smaller channels compared to larger channels (Vannote et al. 1980), the effects of LWD in small channels are particularly significant (Harmon et al. 1986). In small channels, LWD provides important structures in the stream, controlling rather than responding to hydrologic and sediment transport processes (Gurnell et al. 2002). For this reason, large wood is responsible for significant sediment storage in small channels (Nakamura and Swanson 1993, May and Gresswell 2003), thereby increasing channel stability (Quinn et al. 2020). The significant role of large wood for storing sediment is further revealed where wood has been experimentally removed from streams and sediment is mobilized and storage reduced (Bilby 1981). Large wood that partially blocks flow can also help to encourage hyporheic flow through the streambed substrate (Poole and Berman 2001, Wondzell et al. 2009).

Instream large wood provides for a wider range of flow velocities, in turn resulting in a diversity of aquatic habitats - pool formation, streambed scour, sediment deposition, and channel migration (Quinn et al. 2020). As such, large woody debris plays an important role in forming complex in-water habitat structures that provide flow refugia and essential cover and improved foraging conditions for fish. 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. Roni and Quinn (2001) found that winter densities of coho salmon, steelhead, and cutthroat trout were higher in streams where LWD had been added.

Large wood recruitment is often the 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). A comparison of 51 streams with varying channel form in mature forests of British Columbia found that of the approximately one-third of LWD pieces for which the source could be identified, tree mortality was the most common entry mechanism (Johnston 2011). Streambank erosion and associated channel migration is a common method of wood recruitment in large alluvial channels (Murphy and Koski 1989), whereas in smaller, steeper channels, wood recruitment predominantly occurs 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 90 percent of the 51 streams surveyed in British Columbia, 90 percent of the LWD at a site 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 percent 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 finding 2012 c 167 § 1, the Washington legislature indicated 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 went on to state: “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.” As such, beaver relocation can be a beneficial wildlife management practice and conditions for wild beaver release are given in RCW 77.32.585. Related to this legislation, WDFW has instigated a Beaver Relocation Program, which is described on their website.

Shade and microclimate

Riparian vegetation contributes to reduced stream temperatures and improved microclimate conditions, which are closely tied to each other. Factors influencing water temperature and microclimate include shade, orientation, relative humidity, ambient air temperature, wind, channel dimensions, groundwater, and overhead cover. Significant increases in maximum stream temperatures has been documented in association with the removal of riparian vegetation (Murray et al. 2000, Moore et al. 2005, Gomi et al. 2006).

Salmon and other native freshwater fish require cool waters (55-68°F) for migrating, rearing, spawning, incubation, and emergence (USEPA 2003). Thermal tolerances differ by species; coho salmon prefer the coolest temperatures, whereas steelhead can tolerate higher temperatures. 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). Amphibians have narrow thermal tolerances, and they are particularly influenced by 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).

A number of studies have considered the extent to which different riparian zone widths modulate stream temperature. In headwater streams in British Columbia, 10 m (33 ft) riparian zones generally minimized effects to 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 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).

Bank integrity

Vegetated riparian zones help to stabilize stream banks. Riparian vegetation helps provide bank stabilization through a complex of tree roots, brush, and soil/rock. Woody vegetation tends to provide greater bank stability than herbaceous vegetation because woody vegetation has larger roots that extend deeper into the streambank (Wynn and Mostaghimi 2006).

Bank stabilization functions are at a higher risk of degradation in urbanized watersheds. As with sediment reduction, the streambank stabilization functions of vegetation increase with buffer width out to approximately 80 to 100 feet; after this point, disproportionately large increases are needed to improve riparian function (Castelle and Johnson 1998).

Runoff filtration and nutrient inputs (water quality)

Water quality is characterized by several physical, chemical, and biological factors, including suspended sediment, nutrients, metals, pathogens, and other pollutants. Water quality characteristics are controlled by upslope, as well as riparian conditions. This section discusses how water quality is maintained under natural conditions. Water temperature is also a component of water quality, which is addressed separately.

When development results in reduced infiltration and increased surface flows, sediment and contaminants are transported more directly to receiving bodies without interfacing with natural soil filtration and flow attenuation processes. Because of this, urban areas tend to contribute a disproportionate amount of sediment and contaminants to receiving waters relative to the percentage of urbanized area within the watershed (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 not fully understood (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 prior to spawning, a condition called pre-spawn mortality (Feist et al. 2011, Sholz et al. 2011). After a prolonged and diligent investigation, the specific cause of the condition has been recently attributed to 6PPD-quinone, not specifically a component of tire formulation but a breakdown product of tire wear (Tian *et al*., 2020). Coho pre-spawn mortality is positively correlated with the relative proportion of roads, impervious surfaces, and commercial land cover within a basin (Feist et al. 2011). A model of the effects of pre-spawn mortality on coho salmon populations indicates that, depending on future rates of urbanization, localized extinction of coho salmon populations could occur within a matter of years to decades (Spromberg and Scholz 2001). Hopefully, tires can be re-formulated in time to prevent this. This finding emphasizes the significance of efforts to address both point-source and non-point-sources of contaminants in the landscape.

The following water quality subsections closely follow those provided in *Riparian Ecosystems, Volume 1: Science Synthesis and Management Implications* from WDFW (Quinn et al. 2020).

Sediment

Excess inputs of fine sediments into stream channels reduce habitat quality for fish, amphibians, and macroinvertebrates. Highly turbid water can impair fertilization success in spawning salmonids (Galbraith et al. 2006) and interfere with the respiration and reproduction amphibians (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 and, furthermore, sediments tend to serve as a transport mechanism for other pollutants, carrying attached contaminants from upland sources to the stream channel. Suspended sediment can cause gill abrasion in fish and interfere with foraging and predator avoidance (Quinn et al. 2020).

Sediment input to streams is supplied by bed and bank erosion, landslides, and upland erosion processes. These processes occur naturally at background levels, but are also associated with and accelerated by forest practices and development activities. Other contaminants, including heavy metals and phosphorus, readily bind to suspended clay particles, and these contaminants are often transported with fine sediment in stormwater. Excess inputs of fine sediments into a stream channel reduce habitat quality for 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). Similarly, embedded, low-permeability gravel substrates reduce aquatic insect production, such insects being a primary food source for juvenile salmonid fish. Higher levels of fine sediment are also correlated with lower salmonid growth rates (Suttle et al. 2004). Highly turbid water can impair fertilization success in spawning salmonids (Galbraith et al. 2006) and interfere with the respiration and reproduction of amphibians (Knutson et al. 2004).

Vegetated riparian zones help stabilize stream banks and slow and filter overland flow, and temporarily store 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 (Sheridan et al. 1999, reviewed in Wenger 1999, reviewed in Parkyn 2004, reviewed in Yuan et al. 2009) without a significant improvement in sediment retention beyond 15 meters (Abu-Zreigh et al. 2004).

It is significant to note, however, that field plot experiments tend to have much shorter field lengths (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 (Helmers et al. 2005) or for stormwater components that bypass filter strips through ditches, stormwater infrastructure, and roads (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, many studies on sediment retention in riparian zones consider sediment retention from one storm event, rather than accounting for sediment accumulation over time. Two studies used Cesium-137 to track the location of sediment deposition over many years (Lowrance et al. 1988 and Cooper et al. 1988 in Wenger 1999). Together 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.

In addition to width, the slope, vegetation density, and sediment composition of a riparian area have 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 (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 1). This study exemplifies the effects that soil type and hillslope have on sediment retention.

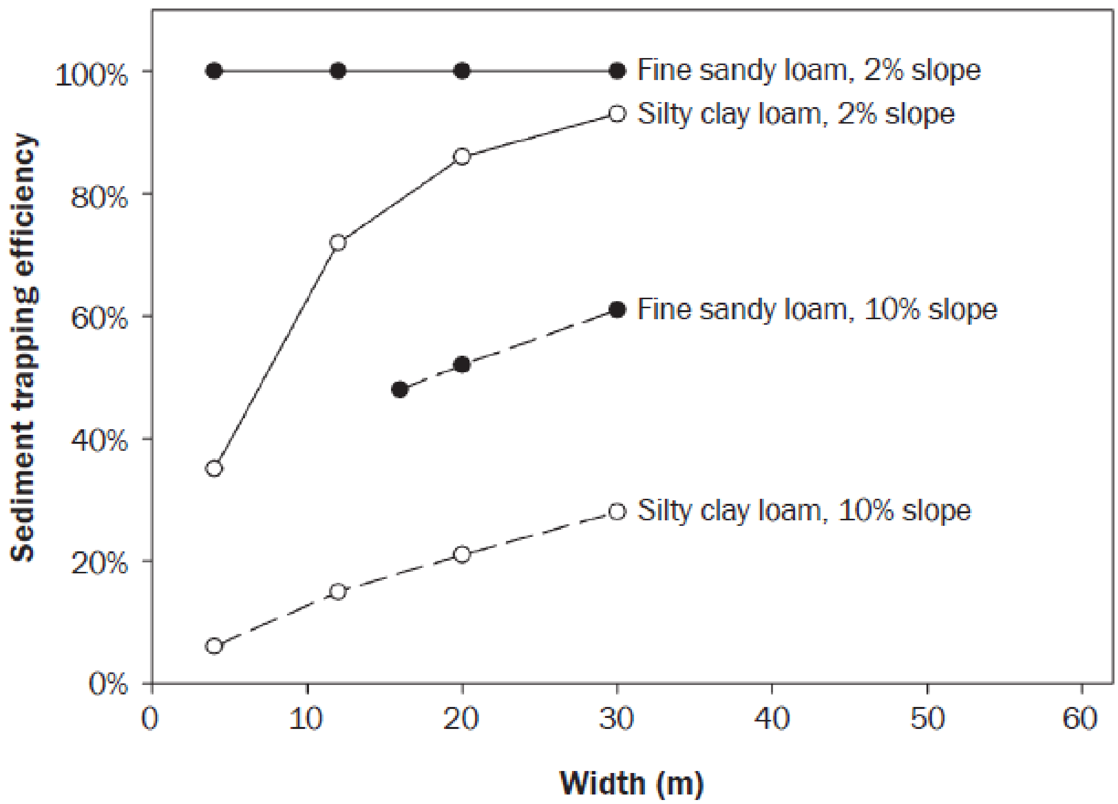


Figure 4. - Sediment trapping efficiency related to soil type, slope, and buffer width. (Figure from Dosskey et al. 2008).

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 (reviewed in 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 (Mayer et al. 2005, Dethier 2006, Heisler et al. 2008).

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 flowpath of surface runoff, and 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. However, nitrate removal from *surface* runoff *was* related to riparian zone width, where 50%, 75%, and 90% surface nitrate removal was achieved 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 affects the efficiency of nutrient removal, but studies are conflicting as to whether grass, wetland, herbaceous, or forested buffers are most effective at removing nutrients (reviewed in 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 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 improve riparian function.

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). A review of contaminant effects on aquatic organisms summarized the factors affecting the toxicity of metals as follows:

- Duration and concentration of exposure
- The form of the metal at the time of exposure
- 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 (ESV Environment Consultants 2003).

Metals are typically transported to the aquatic environment through fossil fuel combustion, industrial emissions, municipal wastewater discharge, and surface runoff (ESV Environment Consultants 2003). 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 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 (U.S. 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* (U.S. EPA 2015a).

Pathogens

While not necessarily a problem for fish and other wildlife, waterborne pathogens associated with human and animal wastes are a concern for direct and indirect human exposure. Although pathogens include a suite of bacteria and viruses, fecal coliform bacteria, specifically E. coli, is typically used as an indicator of the possible or presumed presence of these 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 (septic systems, stormwater, wildlife, and pets) pollution 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). Despite our limited understanding, 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 reduce herbicide concentration exiting the buffer to zero (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, transport via subsurface drainage and leaching are not affected by riparian buffers, and these processes are best managed through the use of best management practices in herbicide and pesticide applications to avoid contaminating groundwater (Reichenberger et al. 2007).

Pharmaceuticals

Pharmaceuticals are another class of contaminants, the effects of which remain poorly understood. Many commonly used pharmaceuticals are found in wastewater, particularly around 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 population-scale effects of these chemicals in the environment are not yet well-understood (Mills and Chichester 2005, Caliman and Gavrilescu 2009).

Wildlife Habitat

As urban density continues to increase under the Growth Management Act, urban natural areas become increasingly valuable to both wildlife and humans. A growing knowledge base confirms what is best captured in the summary: "All urban areas have the potential to contribute to conservation of wildlife diversity" (Marzluff and Rodewald 2008).

Riparian ecosystems, including streams and associated riparian areas, including wetlands, provide important wildlife habitat within the landscape due to the presence of unique structures and processes. Ecological features that are linked to species richness and abundance in a landscape include structural complexity, connectivity to other ecosystems, plentiful sources of food and water, and a moist moderate microclimate (Knutson and Naef 1997). Riparian ecosystems, depending on site-specific conditions, landscape position, and surrounding land use, will have some or all of these habitat features.

These aquatic ecosystems provide habitat for a broad range of fauna including invertebrates, reptiles and amphibians, anadromous and resident fish, birds, and mammals. Aquatic invertebrates that depend on stream and wetland ecosystems are important to aquatic trophic systems or food webs (Rosenberg and Danks 1987, Wissinger 1999, both in Sheldon et al. 2005). Native frogs and salamanders require wetlands for breeding. Buffer condition, habitat interspersion, wetland hydro-period, and diameter of emerged plant stems are all important factors that impact amphibian richness and abundance (Sheldon et al. 2005). Wetlands with surface connections to salmon-bearing streams can provide backwater refuge for anadromous fish if they also have ponded water at least 18 inches deep, low flow conditions, and cover such as overhanging or submerged plants (Sheldon et al. 2005). Waterfowl rely upon riparian ecosystems for all or part of their life cycle (Kauffman et al. 2001, in Sheldon 2005). Suitability of habitat for birds is dependent on buffer condition and width, presence of snags or other perches, corridor connections, open water, and forest canopy cover (Sheldon et al. 2005). Mammals typically associated with water, such as beaver and muskrat, also seek out well buffered vegetated corridors, interspersed habitat with open water, and a seasonally stable water level (Sheldon et al. 2005). According to a Washington Department of Fish and Wildlife (WDFW) study conducted by Knutson and Naef (1997) a predominance of terrestrial vertebrate species in Washington are dependent on streams and riparian areas, including wetlands.

Riparian ecosystems also provide habitat for many native plants species. Wetland characteristics that are correlated with plant richness are the hydro-period, duration of flooding, and variety of water depths (Schueler 2000 and Sheldon et al. 2005). Vegetated areas surrounding streams and wetlands perform several important functions that in turn protect their habitat functions.

Habitat fragmentation is a consequence of urbanization. As land is developed, continuous tracts of native habitat are reduced to patches, which become progressively smaller and more isolated. Dale et al. (2000) found that ecologic impacts of development are often overlooked and landscape-scale changes, particularly habitat fragmentation, alter the structure and function of those ecosystems.

The performance of stream and wetland habitat functions is affected to varying degrees by the width and/or character of the surrounding buffers. Urbanization reduces wetland buffering and increases human encroachment. Disturbance vectors include noise; nighttime light; physical intrusion by equipment, people, or pets; and garbage. Each of these vectors 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. Semlitsch and Bodie (2003) found that upland areas surrounding wetlands are core habitats for many semi-aquatic species, such as amphibians and reptiles.

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 an urban wetland provides (Sheldon et al. 2005, Azous and Horner 2010).

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

WDFW lists priority habitats and species (PHS) by county. Below is a summary of the Pierce County PHS list. As WDFW notes, habitats and species can change over time as distributions expand or contract.

Table 4. Pierce County priority species list (source: WDFW).

	Common Name	State Status	Federal Status
Fish	River lamprey	C	
	Bull trout/Dolly Varden	C	T
	Rainbow trout/Steelhead	C	T
	Chinook salmon		T / E
	Chum salmon		T
	Coho salmon		T - Lower Columbia
	Sockeye salmon		T - Ozette Lake, E - Snake River
	Bocaccio rockfish		E
	Canary rockfish		T
	Yellowtail rockfish		T
Birds	Common loon	S	
	Marbled murrelet	T	T
	Western grebe	C	
	Great blue heron	M	
	Golden eagle	C	
	Northern goshawk	C	
	Northern spotted owl	T	E
	Black-backed woodpecker	C	
	Oregon vesper sparrow	E	
	Streak-horned lark	E	T
Mammals	Gray whale	S	
	Orca (Killer whale)	E	E
	Harbor porpoise	C	
	Keen's Myotis	C	
	Townsend's big-eared bat	C	

	Western gray squirrel	T	
	Mazama (Western) pocket gopher	T	T
	Cascade red fox	C	
	Fisher	E	
	Woverine	C	
Amphibians	Cascade torrent salamander	C	
	Larch mountain salamander	S	
	Van Dyke's salamander	C	
	Oregon spotted frog	E	T
	Western toad	C	
Reptile	Western pond turtle	E	
Invertebrates	Pacific clubtail	C	
	Western bumble bee	C	
	Johnson's hairstreak	C	
	Mardon skipper	E	
	Puget blue	C	
	Valley silverspot	C	
	Taylor's checkerspot	E	E

C=Candidate species
Co=Species of Concern
E = Endangered
M=Monitor species
S=Sensitive species
T = Threatened

Pierce 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. These habitats include forested upland, wetlands, riparian areas, scrub-shrub, and open habitat such as prairies. A current list of priority habitats in Pierce County is in the table below.

Table 5. Pierce County priority habitats (source: WDFW).

Terrestrial Habitats
Aspen stands
Biodiversity areas & corridors
Herbaceous balds
Old-growth/mature forest
Oregon white oak woodlands
Westside prairie
Riparian

Aquatic Habitats
Freshwater wetlands & fresh deepwater
Instream
Puget Sound nearshore
Habitat Features
Caves
Cliffs
Snags and Logs
Talus

6.2.3 Habitats and Species of Local Importance

Significant Oaks and Stands

Oregon white oak (Quercus garryana) is the only native oak tree in Washington state. These trees and their associated woodland ecosystems are rare and in decline. Oaks provide habitat for species that are state listed as Sensitive, Threatened, Endangered, or candidates for these listings. Oregon white oak woodland provide habitat for an abundance of animals, including invertebrates and neotropical migrant birds (Larsen et al 1998). This habitat is defined as follows.

> "Priority Oregon white oak woodlands are stands of pure oak or oak/conifer associations where canopy coverage of the oak component of the stand is ≥ 25%; or where total canopy coverage of the stand is < 25%, but oak accounts for at least 50% of the canopy coverage present. The latter is often referred to as an oak savanna. In non-urbanized areas west of the Cascades, priority oak habitat is stands > 0.4 ha (1 ac.) in size." (Larsen et al. 1998)

Prairies

Once common in the South Puget Sound region, prairies are now rare, with just 3% of original prairies remaining. Most remaining prairies are in south Puget Sound. Approximately 15,000 years ago glaciers left behind the gravelly soils on which the prairies grow. Prairie vegetation is dominated by a variety of grasses and wildflowers with few trees. Prairies were commonly lost to farming and development from non-indigenous settlement. Prior to settlement, prairies were maintained by indigenous peoples using systematic burns. Prairies are fire-adapted ecosystems (WDFW PHS). In prairie ecosystems, invasive plants can modify soils to facilitate conditions favorable to themselves and other invasives (Jordan and Larsen 2008). This is of particular concern in Pierce County, where areas of prairie are in decline.

Prairies provide habitat for some species listed as threatened or endangered under the federal Endangered Species Act, including Oregon spotted frog, Mazama pocket gopher, and Taylor's checkerspot butterfly (WDFW PHS).

Mazama Pocket Gopher

Mazama pocket gophers (*Thomomys mazama*) are fossorial animals, meaning they are uniquely adapted to a life of extensive underground burrowing (Chase 1982). They exploit a wide of array of above and below ground vegetation for food (Chase 1982) and are associated with glacial outwash prairies in western Washington, which are ecosystems of concern (Hartway 2005). Studies have shown that they play important ecological roles in soil aeration, mixing, and drainage, and in the distribution and succession of plant species and communities in prairies (Chase 1982).

Physiology

Pocket gophers are highly adapted to a fossorial mode of life; body tapers from heavily muscled head and shoulders to relatively narrow hips. Legs are short. Five toes on the four feet are equipped with long tapering claws and fimbriae (bordering fringe); five toes on rear feet have shorter and less curved claws. Eyes are small and ears are short (Verts 2000).

The subspecies *Thomomys mazama* has a physiology including long claws and short teeth which favors its preferred burrowing style (digging). This is in comparison to other species of pocket gopher which prefer harder soils and utilize their teeth for burrowing.

Habitat

Pocket gopher herbivory and burrowing are associated with specific landscape features and sensory experiences (El-Hani 1998). For thousands of years, the balance of soil and climate appears to delicately delineate boundaries between competitive species of pocket gophers (Marcy 2013).

Soil characteristics are key to pocket gopher distribution and are more important than vegetation. Glacial outwash soils characterized as light-textured, porous, well-drained soils are necessary habitat for pocket gophers (Stinson 2020). Pocket gopher distributions depend primarily on soil characteristics of depth to bedrock, percent clay soil, bulk density, linear extensibility, as well as the timing and amount of effective moisture (Marcy 2013). Soil types know to be preferred by gophers are listed in Table 6 below (USFWS 2018 in Stinson 2020).

Table 6. NRCS Soil types know to provide suitable habitat for pocket gophers.

	NRCS Soil Map Unit Name
Prefer	Cagey loamy sand
	Indianola loamy sand, 0-3% slopes

	Nisqually loamy fine sand, 0-3% slopes
	Nisqually loamy fine sand, 3-15% slopes
	Spanaway gravelly sandy loam, 0-3% slopes
	Spanaway gravelly sandy loam, 3-15% slopes
	Spanaway-Nisqually complex, 2-10% slopes
Suitable soil type	Alderwood gravelly sandy loam, 0-3% slopes
	Alderwood gravelly sandy loam, 3-15% slopes
	Everett very gravelly sandy loam, 0-3% slopes
	Everett very gravelly sandy loam, 3-15% slopes
	Indianola loamy sand, 3-15% slopes
	Kapowsin silt loam, 3-15% slopes
	McKenna gravelly silt loam, 0-5% slopes
	Norma fine sandy loam
	Norma silt loam
	Spana gravelly loam
	Spanaway stony sandy loam, 0-3% slopes
	Spanaway stony sandy loam, 3-15% slopes
	Yelm fine sandy loam, 0-3% slopes
	Yelm fine sandy loam, 3-15% slopes

Soil attributes exert greater influence on the predominantly claw-digging subgenus Thomomys, who associate with softer soils, for both foraging depth (surface to 20cm) and at the entire burrow depth (surface to 1m) (Marcy 2013). This is because the *Thomomys* subspecies are more energetically efficient in softer soils by requiring smaller tunnels or by requiring less energy to support a smaller body size (Busch 2000). The pocket gophers require certain soils in order to achieve ideal depth for burrowing. Deep burrows may provide important refugia during inclement weather and may help drain the burrow system during periods of heavy or prolonged rainfall (Teipner 1983)

Pocket gophers rely on certain soil conditions as well as certain temperatures to survive in grassland habitats. Soil facilitates the majority of heat loss for pocket gophers. They depend primarily on conduction through contact with the soil to dissipate excess heat (Sedlacek 2007). Studies in have shown that stable temperatures exist at a depth of greater than 50cm in most soils (Burda 2007). The depth of soil available for burrow construction likely plays a role in pocket gopher distribution (Thaler 1968).

Food

Gophers typically clip and cache fleshy and succulent roots and stems (Marsh 1992), which allies with their association with prairie/grassland habitat. Pocket gopher diets are biased towards forbs over grasses but have been observed to closely track resources available seasonally (Busch 2000). Pocket gophers prefer plants with higher nutritional quality and moisture content (Jenkins 1989). Forested areas likely support few gophers because gophers require the forbs and grasses of an early successional stage for food (Witmer 1996).

Ecosystem Support

Pocket gophers play important roles in their ecosystems. Small scale, predictable disturbances such as those created by gopher mounds often promote species diversity in communities by providing refuge to species that are inferior competitors but good colonizers (Paine 1969). Burrows (both active and abandoned) are used by other animal species (Chase 1982). Gopher burrows provide escape tunnels, breeding grounds, and homes for insects, herpetological fauna (amphibians and reptiles), and other mammals and therefore a source of prey for most types of carnivores (Davidson 2012). Additionally, because of the large investment of energy in making a burrow system, burrows are believed to be a valuable resource sought out by dispersing gophers (Reichman 1990). More indirectly, burrow and mound construction along with underground foraging increases soil nutrients and water infiltration into the soil (Reichman 1990).

Because subterranean rodents create distinctive habitat patches that maintain grassland biodiversity, it is important for increased management efforts to support their populations (Reichman 1990)(Stinson 2020).

U.S. Fish and Wildlife Service issued a Mazama pocket gopher 4(d) special rule summary in April 2014. The rule details allowed activities for various land use, including agricultural and residential.

Old Growth and Mature Forests

WDFW defines old growth and mature forest areas based on tree diameters, presence of snags and woody debris, and patch size. Old-growth forest west of the Cascades is comprised of stands totaling at least 7.5 acres with at least 8 trees per acre that have a dbh of 32 inches or more, at least 4 snags per acre, and 4 downed logs per acre. Mature stands are younger and contain trees that are at least 21 inches dbh; these forests generally contain fewer snags and downed logs (WDFW 2008). Common native forest conifers are Douglas-fir, Western red cedar, and Western hemlock. Old growth and mature forests ecosystems in our region provide habitat for numerous species, including Northern spotted owl and marbled murrelet. Both species utilize old growth trees for nesting.

Snag-rich area and downed logs

Dead or dying trees that exhibit decay and cavities provide habitat for numerous animals and invertebrates. Snags and downed logs are features of old growth and mature forests, but they occur in younger forest stands as well. To be considered a priority snag or log the dbh must be at least 12 inches; snag height must be greater than 6.5 feet, and log length greater than 20-feet. Snags and logs add complexity to habitat structure and support numerous species, including woodpeckers.

Caves and Cliffs

Caves are naturally occurring cavities or voids in rock or other geologic formations under earth. Old mine shafts serve similar functions to natural caves. WDFW defines cliffs as greater the 25 feet high and occurring below 5000 feet. These features provide unique habitats for birds and mammals, such as cliff swallows and bats, including listed bat species.

Elk herd

Priority habitat areas for elk herds include calving areas, migration corridors, and foraging areas where regular concentrations gather. Pierce County is part of the range for the North Rainier Elk Herd. The elk herd commonly resides west of the Cascades in summer and small satellite groups utilize the foothills and habitat patches near developed areas. The elk herd provides cultural, recreational, aesthetic and economic benefits to the region (WDFW 2020).

Talus

Talus is the accumulation of debris in sheets or cones at the bases of rockwalls. Scree is a collection of broken rock fragments at the base of a cliff or other steep rocky mass that has accumulated through periodic rockfall. Landforms associated with these materials are often called talus deposits. WDFW defines talus as, "Homogenous areas of rock rubble ranging in average size 0.5-6.5 ft composed of basalt, andesite, and/or sedimentary rock, including riprap slides and mine tailings. May be associated with cliffs." (WDFW 2008).

Marine / Saltwater habitats and species

Marine shorelines, together with estuaries, encompass what is known as the nearshore. The nearshore ranges from the deepest saltwater areas along shorelines where the sun can still reach underwater vegetation, all the way up to the top of coastal bluffs and rocky cliffs that line beaches. The nearshore also extends upstream to the highest part of the river that is influenced by the tide. Nearshore areas and habitats include, but are not limited to: kelp beds, native eelgrass beds, spawning and holding areas for forage fish, such as herring, smelt and sandlance; subsistence, commercial, and recreational shellfish beds; mudflats, intertidal habitats with vascular plants, and areas with which priority species have a primary association.

As described by WDFW, the nearshore can be divided into four zones:

- **Riparian zone:** Marine-influenced uplands that may have vegetation (trees, shrubs, grasses) as well as rocky cliffs and banks that may include "feeder" bluffs whose sediment feeds and sustains beaches.

- **Intertidal zone:** Area directly influenced by tidal changes in water levels throughout the day, ranging from the high tide level to the low tide level. This zone is biologically among the richest of coastal habitats, and includes beaches, estuaries, and large river deltas.
- **Subtidal zone:** Area that is permanently underwater. Rocky bottoms in the subtidal zone are particularly important for eelgrass, native oyster reefs, and forage fish.
- **Photic zone:** Uppermost layer of marine shore waters where phytoplankton gets sufficient sunlight to perform photosynthesis, which in turn, enriches this area with nutrients.

Oxbows

When a stream or river segment becomes separated from the active channel through natural meandering processes, oxbow form. Oxbow wetlands typically form in these environments. Oxbow wetlands provide flood water storage, water quality, and juvenile fish refuge. Oxbows can also provide fish protection from predators.

Waterfowl Concentrations

Waterfowl includes cavity-nesting ducks, Harlequin duck, snow geese, trumpeter swan, and Tundra swan. It excludes Canada geese in urban areas. Priority areas include significant breeding areas and regular winter concentrations. These vulnerable aggregations have recreational, commercial, and Tribal importance (WDFW 2008).

6.3 Key Protection Strategies

6.3.1 Streams, Lakes and Ponds, and Riparian Areas

Lakes are generally larger waterbodies than ponds. For the purposes of this summary, only small lakes, less than 20-acres, are included. Lakes that exceed 20-acres are regulated separately under the Shoreline Master Program.

Stream Classification

Flow conditions, fish habitat, seasonality, and accessibility for salmonids are commonly assessed to determine stream classifications. The Department of Natural Resources (DNR) 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 (water 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.

FEMA Floodplain Habitat Assessments

In 2008, the National Marine Fisheries Service (NMFS) issued a Biological Opinion, 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 assertain their potential effects on federally-listed endangered species. In particular, floodplain storage volumes may not be decreased nor base flood level elevations increased.

Buffers

For the purpose of this narrative, clarification needs to be made between the terms "stream buffers" and "riparian management zones" (RMZs). WDFW current guidance (Windrope et al 2020) for protection of riparian areas heavily emphasizes a shift in terminology from the concept of "stream buffers" to "riparian management zones" (RMZs). An 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." This differs from the use of "buffer(s)," as an RMZ is by definition wide enough to potentially provide full riparian function. Stream buffers are established through policy decisions and are clearly intended to protect streams, but may or may not be intended to provide full riparian function or a close approximation of it.

Habitat types in Pierce County vary across the landscape. The County falls mainly within the Puget Trough Ecoregion, with the eastern portions in the West Cascades Ecoregion. Both of these ecoregions tend to be forested except in areas cleared for agriculture or development or, for the West Cascades Ecoregion, in alpine areas above tree line in elevation and climate. No portions of the more arid ecoregions, such as are found east of the Cascades, are present in the County. The Puget Trough Ecoregion is forested primarily with Douglas fir (Pseudotsuga menziesii), western red cedar (Thuja plicata), and western hemlock (Tsuga heterophylla), and also includes black cottonwood (Populus trichocarpa) and red alder (Alnus rubra) along river channels more subject to disturbance. In the West Cascades Ecoregion, the same tree species occur at lower elevations with added Pacific silver fir and noble fir at mid elevations and stands of mountain hemlock and subalpine fir in the highest areas (Landscope Washington, 2022, http://www.landscope.org/washington/natural_geography/ecoregions/). The plant community and ecology of this region have important implications for how riparian buffers are established or RMZs defined.

WDFW's current recommendations for establishing RMZ widths are based primarily on a Site Potential Tree Height (SPTH) framework. The SPTH of an area is defined as "…the average maximum height of the tallest dominant trees (200 years or more) for a given site class." Exceptions may occur where SPTH is less than 100 feet, in which case WDFW recommends assigning an RMZ width of 100 feet at a minimum based primarily on what is needed to provide adequate biofiltration and infiltration of runoff for water quality protection, but also in consideration of other habitat-related factors including shade and wood recruitment (Windrope et al. 2020). A 100-foot width buffer is estimated to achieve 95 percent pollution removal (Rentz et al. 2020). WDFW recommends measuring RMZ widths from the outer edge of the Channel Migration Zone (CMZ), where present, or from the Ordinary High Water Mark (OHWM) where a CMZ is not present.

To apply their methodology, WDFW has developed a web-based mapping tool for use in determining SPTH in forested ecoregions of the state, such as occur in Pierce County. Where SPTH is 100 feet or more, WDFW recommends RMZ establishment within one SPTH, driven by the largest dominant tree species at any location. Acknowledging that establishing functional RMZs of these dimensions using these recommended methods may not practical in many developed areas, WDFW recommends effective watershed management, preservation, and protection, resulting in as nearly full restoration of riparian ecosystem habitat functions as is feasible within existing constraints. WDFW RMZ establishment and management recommendations are detailed in their Riparian Ecosystems, Volume 2: Management Recommendations document (Windrope et al. 2020).

Below is a graphical representation of the Forest Ecosystem Management Assessment Team (FEMAT) curves, the same as or similar to that included in WDFW's recommendations for establishing the bounds of RMZs (Windrope et al 2020). The curves show percentage of full function for various riparian habitat attributes with increasing distance from a stream. The WDFW recommendations show this graphic and these curves to support recommending one full SPTH for RMZ width to attain "full" riparian function. The SPTH is one point along a continuum of functional returns, with the highest rates of return on all habitat functions except root strength generally occurring within the inner buffer(Figure 2).

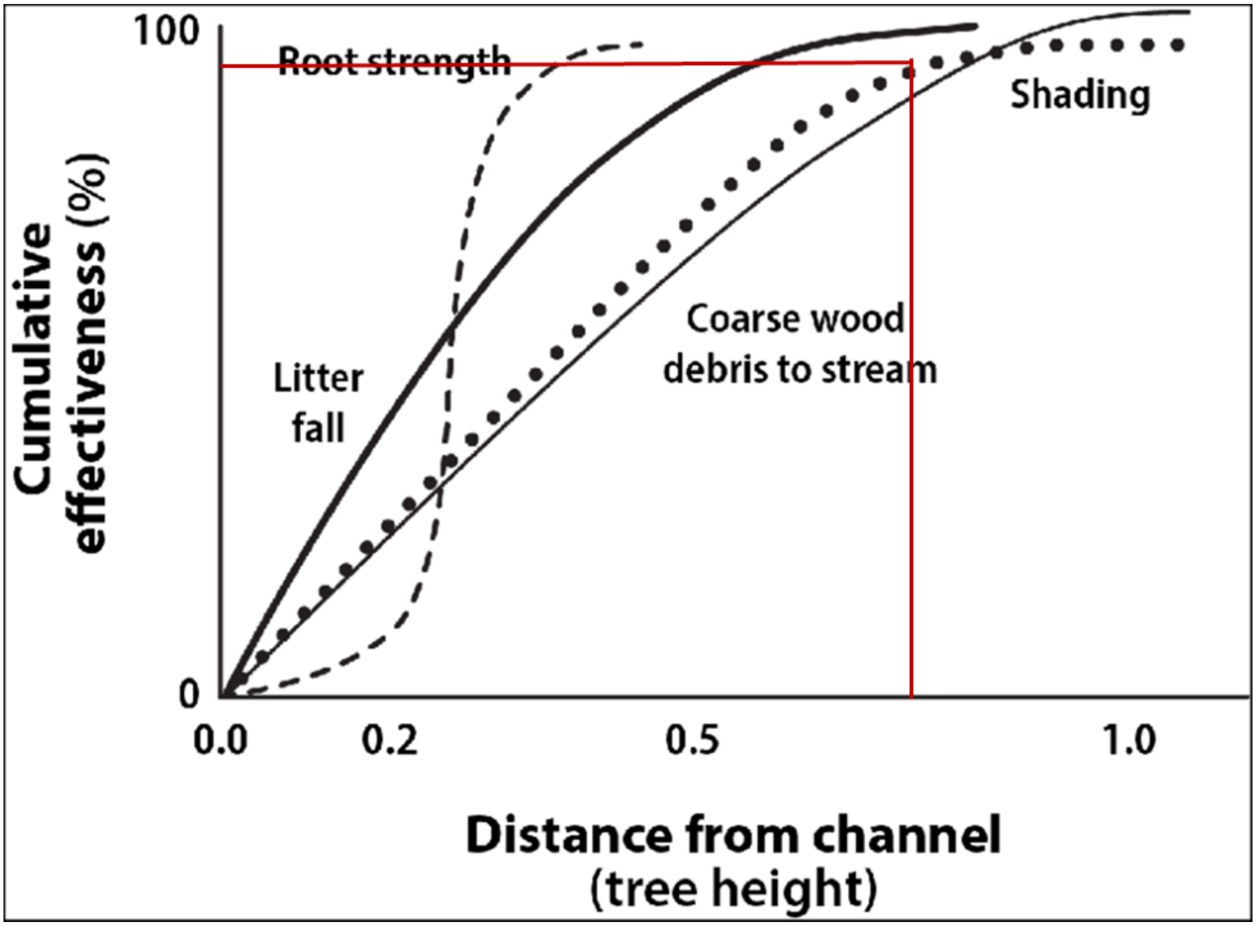


Figure 2. The "FEMAT Curves" (FEMAT 1993): a generalized conceptual model describing contributions of key riparian ecosystem functions to aquatic ecosystems as the distance from a stream channel increases. "Tree height" refers to average height of the tallest dominant tree (200 years old or greater); referred to as site-potential tree height (SPTH).

The list below is not an exhaustive evaluation of the relevant data, but using WDFW's on-line mapping tool yielded the following ranges of values for SPTH in feet for various dominant forest types throughout Pierce County. Douglas-fir was the predominant species, and red alder or western hemlock are present to some extent.

Douglas-fir	193-225 feet
Red Alder	105 feet
Western Hemlock	206 feet

This informal sampling indicates that the riparian buffer width in the current CAO for Type F streams (150 feet), tends to be moderately under the high end of the range for Douglas fir or western hemlock. 150 feet falls above the SPTH range for Red Alder, but below the upper end of the ranges for Douglas fir and western hemlock. As such, the current 150-foot fixed width is within the range of values expected from a custom delineation for an RMZ based buffer widths. In our best professional judgement, these values support a conclusion that a 150-foot Type F riparian buffer is a good approximation for the widths that would be determined by the recommended SPTH mapping process for determining RMZ widths. As noted (PCC 18E.40.060.B.1b), Pierce County currently follows the WDFW recommendation of measuring stream buffer (or RMZ) widths from the outer edge of the Channel Migration Zone (CMZ) where present. In those cases effective or functional RMZ widths are often or typically wider than 150 feet as would be measured from the OHWM unless the current channel location abuts the outer CMZ boundary. Some widths determined using the SPTH mapping process are above and some below a 150-foot buffer width. Both methods result in a high level of riparian habitat protection.

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 more urban settings. Thus, although stream and riparian conservation measures should be based in Best Available Science (BAS), some level of policy interpretation must be made by each local jurisdiction.

Pierce County currently assigns riparian buffers based on water type ranging from 35-feet to 150-feet (PCC 18E.40.060, Table 18E.40.060-1 Fish and Wildlife Habitat Conservation Area Buffer Requirements, see below). In addition, per PCC 18E.40.060.B.2.c, “The required buffer shall be extended to include any adjacent regulated wetland(s), landslide hazard areas and/or erosion hazard areas and required buffers.”

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. Table 7 notes the ranges of effective buffer widths (as outlined in each subsection) based on each function and some notes on the functions that were studied.

Table 7. Range of Effective Buffer Widths for Each Applicable Riparian Function

Function	Range of Effective Buffer Widths	Notes on Function
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.
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.
Metals	NA- Appropriate buffer width not established	Stormwater system improvements to slow and infiltrate runoff could help reduce metals entering aquatic systems.
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

Function	Range of Effective Buffer Widths	Notes on Function
		transport of pathogens to aquatic systems.
Herbicides	6-18 m (20-59 feet)	Best management practices during application of herbicides and pesticides can help limit leeching to groundwater.
Pharmaceuticals	NA- Appropriate buffer width not established	Best management practices for disposal of pharmaceuticals may limit potential impacts.
Bank Stabilization	10-30 m (33-98 feet)	Beyond 98 feet from the stream, buffers have little effect on bank stability.
Stream Temperature	10-30 m (33-98 feet)	Leaf cover is more closely related to stream temperature than buffer width.
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.

6.3.2 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. For other critical habitat areas, buffer widths will be determined according to PCC 18E.40.060.C on a case by case basis based on species' needs and in coordination with WDFW.

Where species-specific management recommendations are available from WDFW guidance documents, those should be followed. Examples are the recovery plans for the Mazama pocket gopher (Stinson 2016; USFWS 2022) and Management Recommendations for Washington's Priority Species; Invertebrates (Larsen 2018); amphibians and reptiles (Larsen 1997); Birds (Larsen 2018); mammals (WDFW 2010). General recommendations for BAS-based strategies to protect terrestrial habitat are listed below.

General Terrestrial Habitat Management Recommendations

- 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.

6.4 Climate Change Impacts & Mitigation

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).

6.4.1 Strategies to manage climate change impacts to FWHCAs

The following actions or policies have the potential to reduce negative climate change impacts on FWHCAs (Redmond 2022).

- Promote retention of significant trees and maintain tree replacement requirements.
- Encourage and incentivize enhancement and restoration of native forest patches throughout the County, particularly where connectivity to one or more FWHCAs is demonstrated. Both voluntary and required restoration planting should be paired with monitoring and maintenance that allows for dry season irrigation and adaptive management.
- Encourage the use of local nursery plant stock grown under current conditions to increase resilience of plant communities considering climate stressors.
- 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 andromous fish, such as chinook salmon.

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Climate Change

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APPENDIX B

Pierce County Planning and Public Works Department BAS Policy Memos

Planning and Public Works Department
Resource Management Policy

Policy Number:	**RM2018-02**
Title:	**Use of Ecology's Revised Buffer Tables**
Date:	**August 20, 2018**
Effective Date:	**September 4, 2018**
Management Sponsor:	**Dennis Hanberg**
Related Documents:	**Wetlands in Washington State - Volume 2: Guidance for Protecting and Managing Wetlands**

Purpose

To implement the use of the Department of Ecology's modified habitat score ranges.

Discussion

- The Department of Ecology conducted a detailed analysis of habitat scores for 211 wetlands and found that wetlands scoring 3, 4, or 5 points for habitat were more similarly distributed to those scoring ≤19 points in the 2004 version of the buffer table.
- In the 2014 buffer table, low habitat function was represented by a score of 3 or 4 points and moderate habitat function by a score of 5 to 7 points.
- Ecology has modified its buffer table to adjust the habitat score break points.
- The modified table now groups habitat scores of 3 to 5 into low habitat function and scores of 6 and 7 into moderate habitat function.
- Pierce County Planning and Public Works will use the modified scores for rating wetlands.
- Wetland Specialists submitting work to Pierce County shall use the modified scores, effective September 4, 2018.

Planning and Land Services Department
Resource Management Section Policy

K Larrabee

Policy Number:	**RM2015-2**
Title:	**Using the updated Washington State Wetland Rating System for western Washington, effective January 2015.**
Date:	**May 15, 2015**
Effective Date:	**July 1, 2015**
Management Sponsor	**Kathleen Larrabee**
Related Documents:	**PCC, Title 18E**

Purpose: To implement the use of the updated Washington State Wetland Rating System for western Washington.

Discussion

- The Department of Ecology updated the Washington State Wetland Rating Systems for eastern and western Washington in 2014; the effective date was January 1, 2015.
- The 2014 update provides a more accurate characterization of wetland functions based on the most recent science.
- As a county planning under the Growth Management Act, we are required to use Best Available Science to protect the functions and values of critical areas.
- Wetlands are critical areas, and the 2014 update is considered to be Best Available Science.

Policy

Effective July 1, 2015 Pierce County Planning and Land Services will implement the 2014 Washington State Wetland Rating System for use when categorizing wetlands in Pierce County. When referring to the tables contained in Appendix F of Title 18E to establish the appropriate buffer width of a wetland, please use the conversion table written by Department of Ecology – "Converting scores for categories and function scores between the 2004 and 2014 rating systems" at:

http://www.ecy.wa.gov/programs/sea/wetlands/ratingsystems/2014updates.html

CRITICAL AREA CODE COMPARISON - OTHER SOUTH SOUND JURISDICTIONS

City of Gig Harbor - February 11, 2026

Critical Area Buffers	GH Existing	GH Proposed	Pierce County	Kitsap County*	Port Orchard*
Wetlands					
Category I Wetlands Buffers	50 - 300	100 - 300	75 -300	50 - 300	75 - 300
Category II Wetlands Buffers	50 - 300	100 - 225	75 - 300	50 - 300	75 - 300
Category III Wetlands Buffers	40 - 150	75 - 150	60 - 300	40 - 150	60 -300
Category IV Wetlands Buffers	25 - 50	25 - 50	40 -50	25 - 50	40 - 50
Stream/Riparian Managament Zone Buffers					
Type 1/S	200	200	0 - 150	200	N/A
Type 2/F	100	150	175	200	150
Type 3/F	50	150	175	200	150
Type 4/Np	25	100	115	75	50
Type Ns	N/A	100	100	75	50

*All stream types in Kitsap County and Port Orchard have additional building setback of 15 feet beyond buffer

RECEIVED
By MThomas City of Gig Harbor at 3:53 pm, Feb 05, 2026

FRIENDS OF PIERCE COUNTY

February 5, 2026

Gig Harbor Planning Commission Members
3510 Grandview Street
Gig Harbor, WA 98335

RE: Comments on Gig Harbor's draft Critical Areas Ordinance

Dear Planning Commission Members:

Friends of Pierce County is a non-profit environmental organization that was founded in 2003. We have been an advocate of responsible and environmentally friendly development practices and smarter growth for over two decades.

We appreciate improvements that the city is considering to increase stream buffers from 25 feet to 100 feet on Type Ns waters, but we would like to point out that for stream riparian areas, the Washington Dept of Fish and Wildlife (WDFW) recommends their best available science (BAS) for stream buffers which uses Site Potential Tree Height at 200 years, not Department of Natural Resources (DNR) water typing system (currently proposed by the city), which is based on a system for forest streams, not urban areas.

State law (WAC 365-196-485 b) requires that cities and counties include best available science in their policies and regulations to protect the functions and values of critical areas.

The current BAS for Fish and Wildlife Habitat Conservation Areas (FWHCAs) is from the WDFW that updated its protections for riparian ecosystems in 2020. In *Riparian Ecosystems, Science Synthesis and Management Implications (2020)* Volume 1, WDFW reported that riparian ecosystem functions of **all streams** (not just **fish-bearing)** streams was vital to protect. In Riparian Ecosystems, Management Recommendations Volume 2 jurisdictions can find management recommendations on how to protect these areas. Vol 1 and Vol 2 represent the BAS from a state agency that is an expert technical advisor for FWHCA.

Adopting WDFW policies will help your jurisdiction meet the requirements for BAS in your CAO to protect full riparian ecosystem functions and values[i] as required by state law and help to achieve no net loss of these areas, as required by state law (WAC 365-190-080).

Habitat Connectivity and Open Spaces

State law (WAC 365-196-485 c) requires that cities and counties identify open space corridors within and between urban growth areas for multiple purposes, including critical wildlife habitat.

State law (WAC 365-196-660 (2)(b): recommends **critical areas regulations** be reviewed to ensure they are achieving no net loss of ecosystem functions and values. This review should include an analysis of monitoring plans, regulations and permits to ensure they are efficient and effective at achieving protection goals and implementation benchmarks.

We urge you to implement the following:

1) Update your CAO to include BAS and follow WDFW recommendations for riparian areas (found here).
2) Include habitat connectivity of open spaces and riparian areas to facilitate wildlife movement on a regional level, not just within jurisdiction boundaries.
3) Plan for climate change and climate mitigation by protecting all ecosystem values and functions.
    a. Assess and protect tree canopy, supporting carbon sequestration and biodiversity.
    b. Protect maximum size and full function of wetland and riparian areas to help with flooding and thermal regulation, carbon sequestration, and maintaining biodiversity.
4) Adopt a Monitoring and Adaptative Management to gauge the city's Critical Areas Regulation's effectiveness in achieving no net loss of ecosystem functions and values as required by state law.

Thank you for the opportunity to comment. Please contact us if you have any questions.

Sincerely,

Carmela Micheli

Carmela Micheli
Board Member
253-988-1204
carmela@harbornet.com

Critical Areas Ordinance Code Update

Planning Commission Briefing

February 19, 2026

Eric Baker
Community Development

IMPORTANCE

Wetlands and Streams

- Floodwater storage
- Supports stream flows
- Water quality improvement through filtration
- Feeds aquifers
- Shoreline stabilization
- Essential habitat for fish and wildlife

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WETLAND CHARACTRISTICS

Basic Rules

- **Soils** – Dark Brown
- **Vegetation** – Skunk cabbage, rush grass other plants/grass with rounded leaves
- **Water** – Saturated at some point in the year. Standing water

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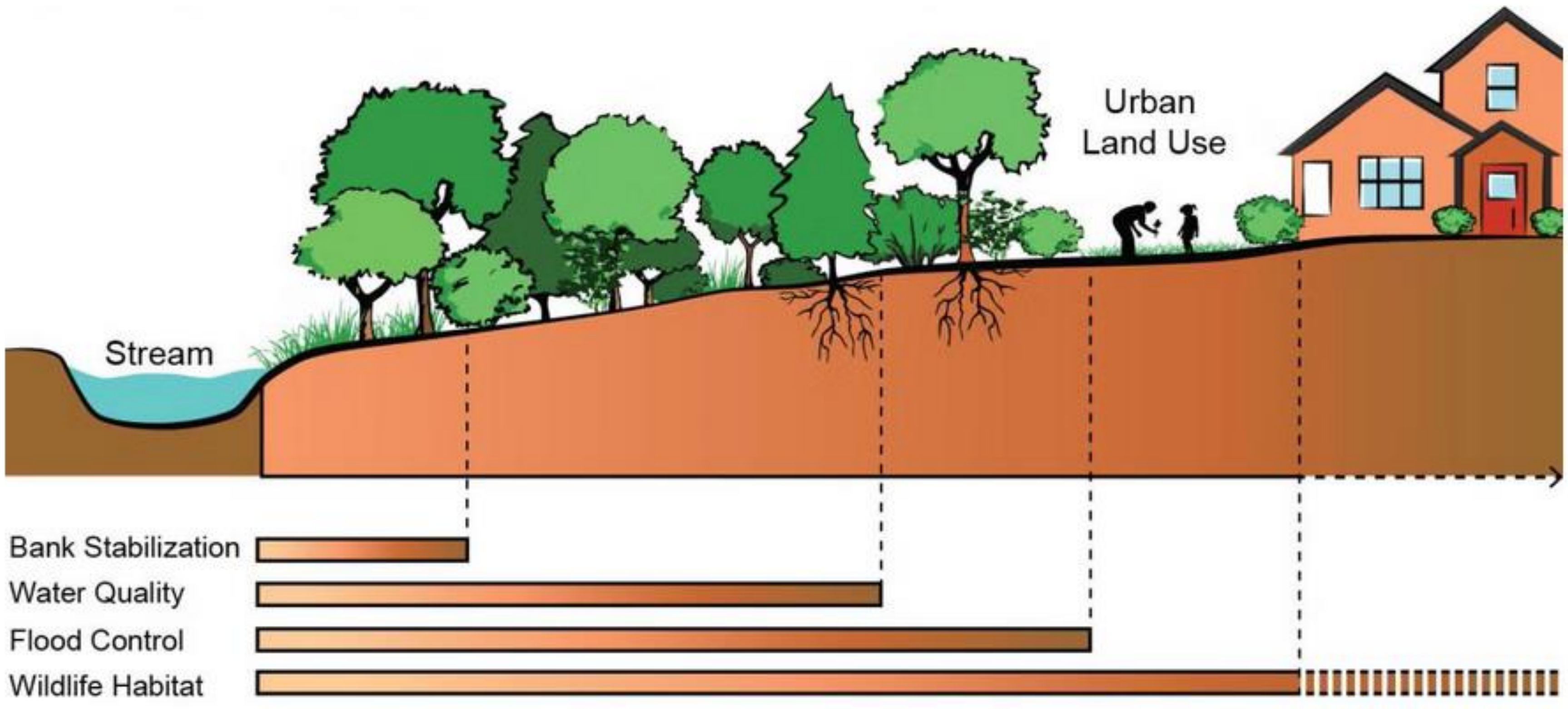
WHY BUFFERS?

- Fish habitat
- Provide shading
- Moderate water temperatures
- Filter sediment and pollutants
- Wildlife habitat and connectivity



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WETLAND BUFFERS

Proposed Use in Calculation

- **High** – Residential > 1 dwelling an acres, commercial, retail and service, industrial, active recreation.
- **Moderate** – Residential < 1 dwelling per acre, paved trails, logging roads.
- **Low** – Forestry, passive recreation, utility corridors.

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BUFFER COMPARISONS

Critical Area Buffers	GH Existing	GH Proposed	Pierce County	Kitsap County	Port Orchard
Category 1 Wetlands	50 - 300	**100 - 300**	75 -300	50 - 300	75 - 300
Category II Wetlands	50 - 300	**100 - 225**	75 - 300	50 - 300	75 - 300
Category III Wetlands	40 - 150	**75 - 150**	60 - 300	40 -150	60 - 300
Category IV Wetlands	25 - 50	**25 - 50**	40 - 50	25 - 50	40 - 50
Stream/Riparian Management Zone Buffers					
Type 1/S	200	**200**	0 - 150	200	N/A
Type 2/F	100	**150**	175	200	150
Type 3/F	50	**150**	175	200	150
Type 4/Np	25	**100**	115	75	50
Type Ns	N/A	**100**	100	75	50

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STREAM BUFFERS
SITE POTENTIAL TREE HEIGHT

- Expected height of a tree species at 200 years
- Varies by tree species
- Douglas Fir can be up to 300 feet.
- Other species lesser.
- No bulk regulation as starting point. A study is required to determine the buffer width for most development.

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WILDLIFE CORRIDORS

- Connectivity between habitats
- Stream buffers and wetland system are our considerations.
- Acquisition of lands in addition to regulation.
- Other species lesser.
- No bulk regulation as starting point. A study is required to determine the buffer width for most development.

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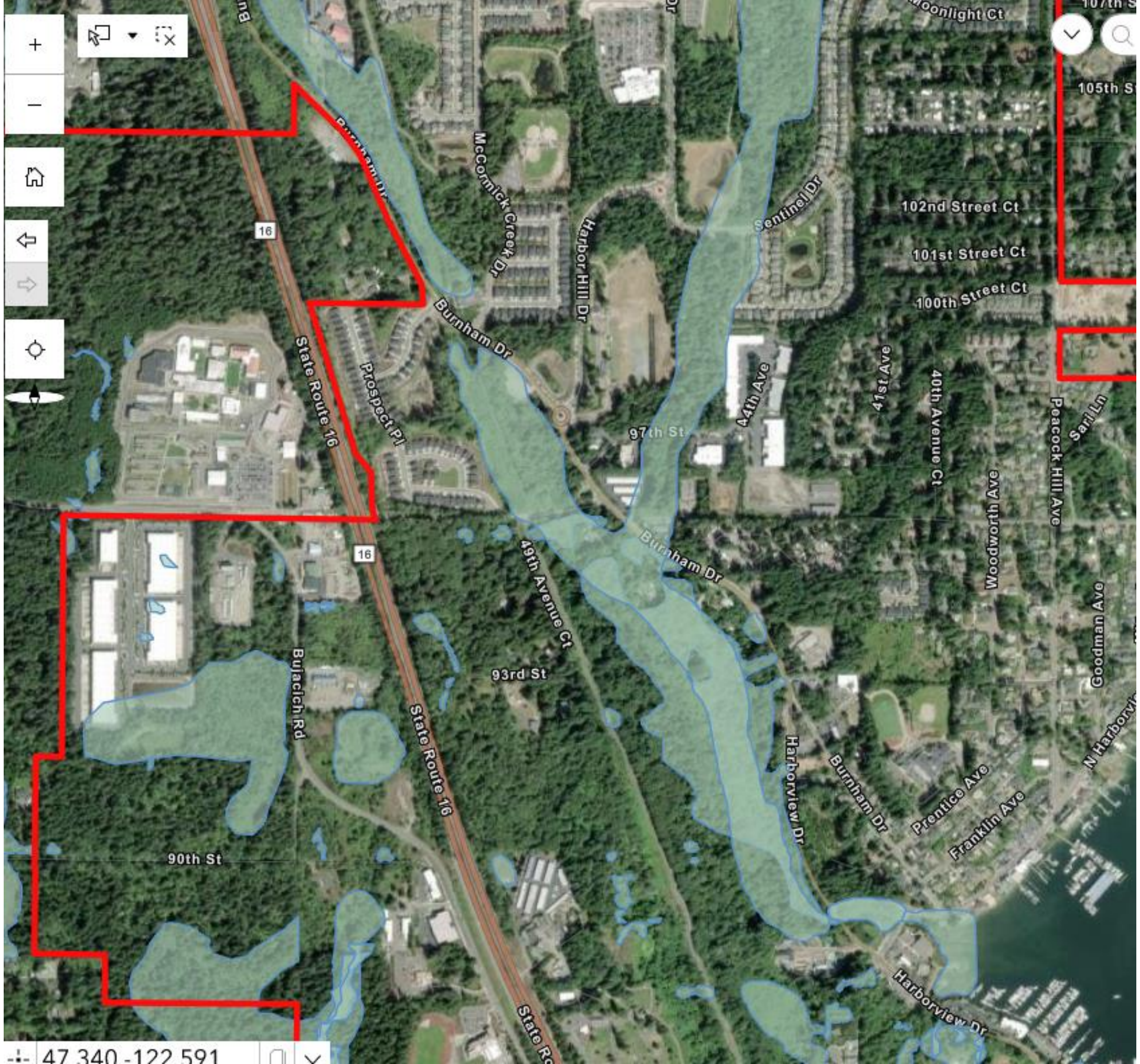
WILDLIFE CORRIDORS



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WETLANDS

Proposed revisions based on BAS.

Wetland Type	Existing	Draft
Category 1 Wetlands Buffers		
Wetlands of High Conservation Value	125 - 250	250
Bogs	125 - 250	250
Forested	50 - 300	100 - 300
Estuarine and wetlands in coastal lagoons	100 - 200	200
Not meeting any of the above characteristics	50 - 100	150 - 300
Category II Wetlands Buffers		
Estuarine and wetlands in coastal lagoons	75 - 150	150
Not meeting above characteristics	50 - 100	100 - 225
Category III Wetlands Buffers		
Score for all three basic functions is 16 - 19 points**	75 - 150	75 - 150
Category IV Wetlands Buffers		
Score for all three basic functions is 9 - 15 points	25 - 50	25 - 50

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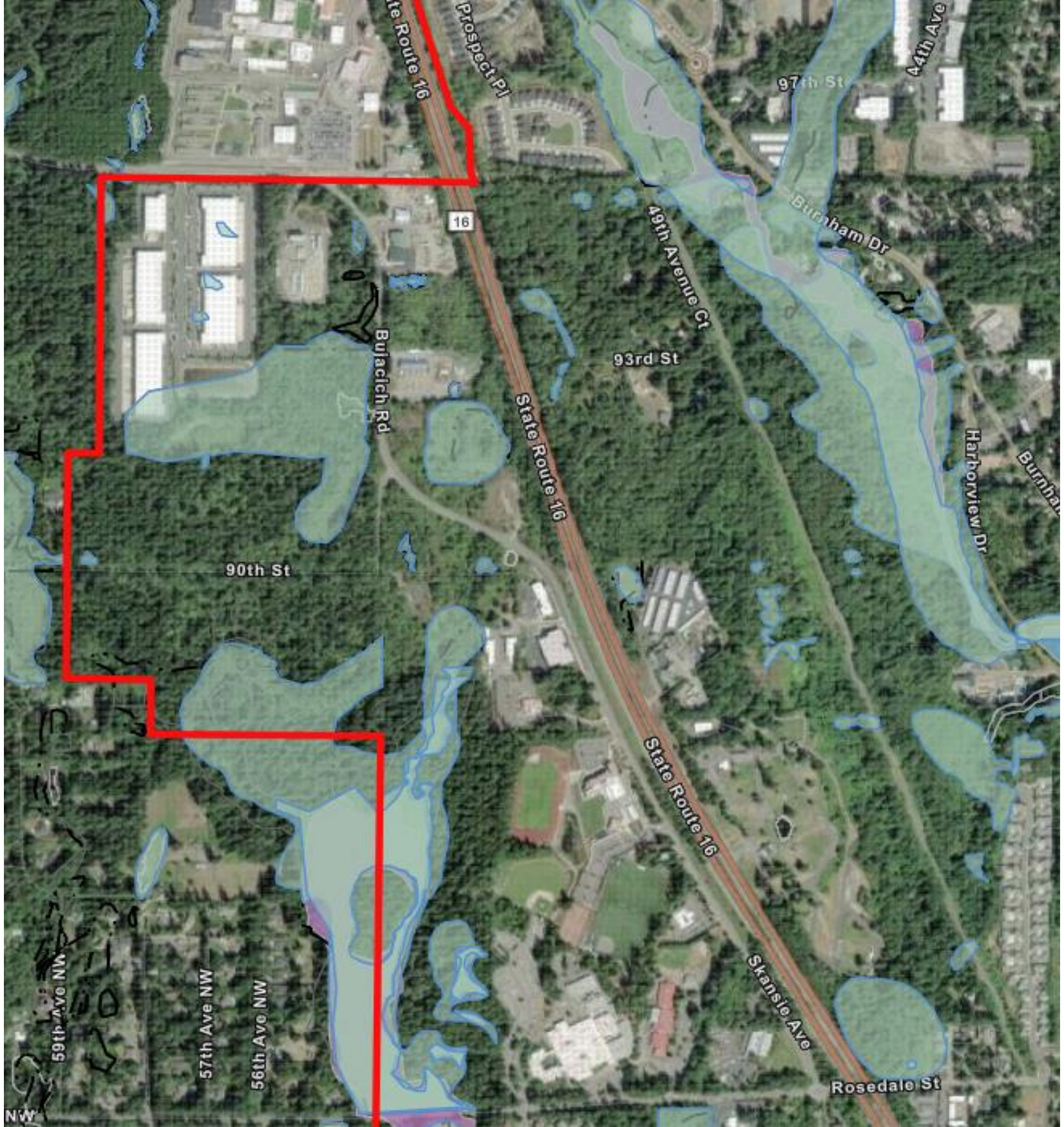
WETLANDS



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STREAMS

Protections again based on stream type broken into segments (DNR Mapping).

- **Type 1 (Type S)** – Shorelines of the state. Lakes and year-round, fish-bearing often directly connected to the shoreline.
- **Type 2 and 3 (Type F)** – Large streams, year-round and fish-bearing.
- **Type 4 (Type Np)**- Smaller, year-round without fish habitat.
- **Type 5 (Type Ns)** – Intermittent streams without fish habitat.

Any work within the stream banks is regulated by WA Fish and Wildlife.

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STREAMS

Proposed buffer widths based on BAS.

Critical Area Buffers	Existing	Draft
Stream/Riparian Management Zone Buffers		
Type 1/S	200	200
Type 2/F	100	150
Type 3/F	50	150
Type 4/Np	25	100
Type Ns	N/A	100

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FPARS Stream Typing (DNR)

- Type S
- Type F
- Type N, Np, Ns
- U, unknown
- X, non-typed per WAC 222-16

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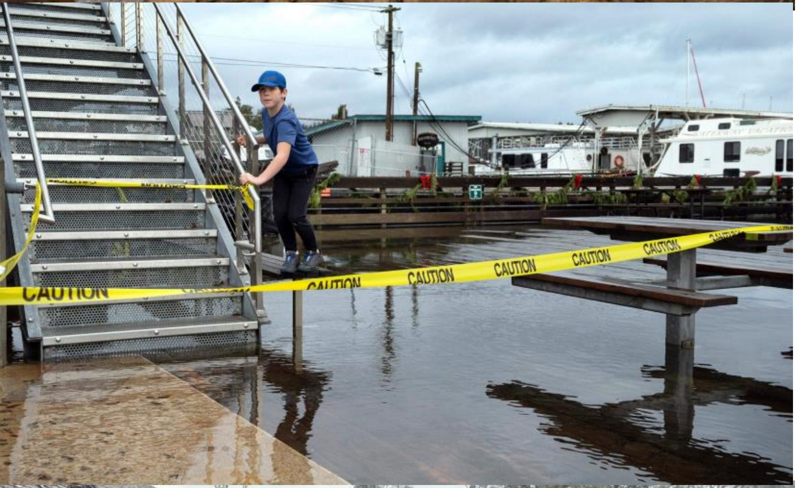

UPDATE PROCESS

- Based on BAS review, draft code update published for public review – **January**
- Postcards to properties within 300 feet of wetlands and streams – **February**
- Advertised public meetings (virtual and in-person) – **March 3 and 10 5:30PM**
- Public outreach to stakeholder groups, developers and the community – **Q1 2026**
- Planning Commission recommendation – **February-March**
- Council consideration – **April-May**

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DO WANT TO KNOW MORE?

Online Information

Planning

- https://www.gigharborwa.gov/676/Community-Development

Harbor Atlas

- https://experience.arcgis.com/experience/f156ffee424443528faa849f35846bad

Contact

Eric Baker

Community Development Director

ebaker@gigharborwa.gov

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