Best Available Science Summary Report

CRITICAL AREAS ORDINANCE UPDATE
KITSAP COUNTY

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Prepared for:
Kitsap County
Department of Community Development

DCG WATERSHED

Title-page image: Chico Creek.

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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 & II: Forested	75	110	150	NA
Category I: Bogs, calcareous fens, and Wetlands of High Conservation Value	NA	NA	NA	190
Category I: Alkali	NA	NA	NA	150
Category II: Vernal pool	NA	NA	NA	150
Category III	60	110	150	NA
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	125	190	250
II	100	150	200
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

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[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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