Chapter 7: AQUATIC AREAS

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1 INTRODUCTION

Fish and Wildlife Habitat Conservation Areas (FWHCAs) are one of the five Growth Management Act defined critical areas (RCW 36.70A.030(5)). Fish and Wildlife habitat conservation means land management for maintaining species in suitable habitats within their natural geographic distribution so that isolated subpopulations are not created; it does not mean maintaining all individuals at all times (WAC 365-190-080(5)). The State of Washington has established guidelines regarding FWHCAs (WAC 365-190-080(5)(a)) and after considering these guidelines, King County has promulgated Comprehensive Plan policies regarding FWHCAs. King County has designates certain areas as FWHCAs and protects these FWHCA through the use of regulations such as the proposed CAO, incentives, capital projects and purchase. Aquatic areas are the habitat for the aquatic species and habitats designated as FWHCAs in King County's Comprehensive plan and include the following aquatic habitats and species:

- Habitat for federal or state listed endangered, threatened or sensitive species;
- Habitat (including juvenile feeding and migration corridors in marine waters) for Salmonids of Local Importance including:

- *Chinook/king salmon*
- *kokanee/sockeye/red salmon,*
- *chum salmon,*
- *coho/silver salmon,*
- *pink salmon,*
- *coastal resident/searun cutthroat,*
- *rainbow trout/steelhead,*
- *bull trout,*
- *Dolly Varden, and*
- *pygmy whitefish;*

- Commercial and recreational shellfish areas;
- Kelp and eelgrass beds;
- Herring, sand lance and smelt spawning areas; and
- Riparian corridors.

2 REVIEW OF LITERATURE

The most basic functions of an aquatic area are the storage, purification, or transport of water. In so doing, they also function as habitat for water-dependent plants and animals. Specific types of aquatic habitats in King County include rivers, streams, lakes, ponds, wetlands[1], estuaries, marine nearshore areas, and shallow aquifers (See Chapter 1 – Introduction). These habitats and the species that use them are integrated parts of an aquatic ecosystem that has developed, and continues to develop, due to a myriad of climatic, geologic, and plant and animal interactions. Human development of land and water often affects this ecosystem in profound ways, ultimately affecting the type and abundance of species that exist.

This review focuses primarily on the formation and habitat functions of aquatic and riparian areas, factors that influence those functions and how King County is proposing to protect them. Much of this discussion focuses on salmonids and their habitats in part because of their social and commercial importance. But also because more is known about them than any group of animals and their near-ubiquitous distribution and sensitivity to environmental change makes them good indicators of habitat impacts and of the effectiveness of protection measures for aquatic systems and other aquatic species.

Despite this report's focus on habitats and species, it is important to note that aquatic areas and their ecosystems include people and provide many other socially valuable benefits including flood hazard reduction, conveyance of stormwater runoff, water supply, water quality purification, recreation, and navigation. Increasingly it is being recognized that the management of ecosystems for both their natural resources and social values results in systems that are more productive and less expensive to maintain over time.

2.1 Processes that Form and Sustain Aquatic Areas and Species

Understanding how aquatic habitats and species are formed and sustained is essential in devising a strategy for their protection. The following describes the physical and biological processes that are critical in this understanding.

The Role of Water

Water-generated energy and the chemical properties of water set the stage for the formation and function of aquatic areas. Movements of water whether as slow-moving glaciers, flowing streams, tides or waves generate the energy necessary to scour, transport and deposit sediments (Richards 1982; Downing 1983). In addition, the chemical properties of water allow for the dissolution, suspension, or absorption of many materials--including fine sediments, nutrients and chemical compounds--further adding to water's habitat forming capabilities (Hynes 1972).

[1] The proposed King County Critical Areas Ordinance discusses and defines wetlands separately from other aquatic areas, since wetlands are regulated under different statutes and legal mandates.

Acting together, these properties of water shape or set the template for many of the processes that form and determine the productivity of aquatic habitats.

The Role of Glaciers

Glaciers set the stage for today's habitats (Booth et al. 2003). They blanketed much of Puget Sound's landscape as recently (in geologic time) as ten to fifteen thousand years ago and, as they receded from the lowlands, created the initial shape of the landscape seen today. (King County 1987; Downing 1983; Booth 1987).

The unstable bluffs along much of Puget Sound and the region's river valley hillsides, steep ravines, shifting shorelines and meandering river channels are a direct result of the actions of glaciers. These features and the dynamic erosional processes they encompass, while dangerous to improperly sited human structures (Gerstel et al. 1997; Palmer et al. 1998), are the source of sediments which, when delivered at natural rates and magnitudes, replenish and rejuvenate aquatic habitats.

Glaciers also left an array of less dynamic but equally important features, including extensive till and outwash-based plains, containing springs, lakes, ponds, bogs, and fens. Some of these features, such as springs and especially bogs and fens, are uniquely adapted to the highly stable post-glacial conditions in which they formed. As a result they are highly susceptible to subtle changes in the rate and magnitude of water and sediment delivery caused by improperly controlled land development (Kulzer et al. 2000).

Glaciers also greatly influenced soils (Gerstel et al. 1997). In some cases, receding glaciers left highly compressed surface soils, called till, with relatively low water permeability (although usually far more permeable than paved surfaces). In other cases, glaciers left well-washed, highly permeable gravel and coarse sand deposits called outwash. The type of soils within its catchment heavily influences the hydrology of aquatic areas. Streams draining areas with high levels of till will have faster runoff and flashier flows than those dominated by glacial outwash.

The Role of Forests

Following glaciation, land was stabilized and hydrology moderated by coniferous-based forests that became established in coastal areas of the Pacific Northwest. These forests were comprised of some of the largest trees and highest vegetation biomass of any ecosystem on earth (Franklin 1988). Where those forests remain intact, their canopy, understory, accumulated organic matter and surface soils intercept and store the vast majority of storm precipitation and subsequently meter it out gradually to aquatic habitats and underlying aquifers. The type and amount of vegetation, both riparian and upland, tempers the erosive energy of water as well as the rate of sediment scour and transport (Gordon et al. 1992).

In addition to its hydrologic influence, forest vegetation serves as a source of nutrients upon which other plants and animals thrive, is important in water, sediment and nutrient storage and cycling, and helps create structurally and functionally diverse aquatic habitat.

Dead and down woody vegetation (woody debris) of all species, shapes and sizes accumulates, sometimes in huge quantities, on the forest floor as well as in streambeds and estuaries and along lake and marine shorelines. Prior to modern development, large amounts of large woody debris extensively littered marine shorelines, estuaries, and rivers (see Maser et al. 1988; Bilby and Bisson 1998; Collins and Montgomery 2002; Collins et al. 2002). In some cases, the size and volume of the woody debris was sufficient to create logjams that spanned rivers as large as the Skagit (Sedell et al. 1988).

Large and small woody debris interacts with water and sediment to create localized sediment scouring and deposition, and results in more complex, and in many cases, more stable habitat than would occur in the absence of such material (Sedell and Beschta 1991; White 1991; Montgomery and Buffington 1998; Heede 1985; Jackson and Sturm 2002; Ralph et al. 1994; Beechie and Sibley 1997; Ulrike and Peter 2002). In streams, woody debris generated pools and riffles provide habitats for migration, spawning, rearing, and refuge from periodic disturbances, such as major storms or landslides. In marine nearshore environments, woody debris diffuses the energy of tides and waves, thereby modifying on-shore sediment transport and helping to create habitats ranging from muddy bays to gravel or bedrock beaches. In all aquatic environments, including lakes, ponds and estuaries where water energy is very low, woody debris increases the amount, diversity, and quality of cover for resting, foraging, and predator avoidance.

The Role of Animals

In addition to water, glaciers, and forests, aquatic animals themselves can play a major role in the structure and functioning of their habitats and ecosystems. Beavers (*Castor canadensis*) and Pacific salmon (*Oncorhynchus spp)* are perhaps the best examples of aquatic animals that modify their own environments, often with profound, far-ranging effects. Beavers, which were once much more abundant than they are today, dam extensive segments of small stream channels and riverine valley floors altering flow and sediment deposition patterns and creating considerable habitat for plant and animal species such as willow and coho salmon (*Oncorhynchus kisutch*), respectively (Naiman et al. 1992; Beechie et al. 1994; Murphy et al. 19889; Snodgrass and Meffe 1998; Collen and Gibson 2000). Pollock et al. (2003) found documentation of use of beaver ponds as habitat by more than 80 species of fish, 48 of which commonly used them. Beaver ponds create highly productive slow water with high-vegetated edge-to-surface ratios and extensive cover. As a result they typically harbor more and larger fish than unponded areas (Gard 1961; Hanson and Campbell 1963; Murphy et al. 1989; Leidholt Bruner et al. 1992; Schlosser 1995). In addition to fish, beaver ponds have been shown to be productive habitats for many birds, mammals, plants, and insect (Naiman et al. 1988; Pollock et al. 1994).

Salmon, especially when returning in large numbers, can reshape substantial areas of stream and, in some cases, near-shore substrates by loosening gravels during excavation of their nests, and in the process improving spawning substrates by releasing fine sediments and organic matter which could interfere with continuous oxygenation of their embryos (National Research Council 1995; Quinn and Peterson 1994). They also deposit large amounts of marine-derived nutrients that boost aquatic food chain productivity and survival of their juveniles as well as nourishing many other plants and aquatic and terrestrial animals (National Research Council 1995; Cederholm et al. 1989; Cederholm et al. 1999; Gende et al. 2002). Given the role of these and many other species in the functioning of aquatic habitats, it is necessary to protect fish and wildlife species directly, in addition to protecting the physical and vegetative components of these critical areas in order to achieve full and comprehensive protection of aquatic areas.

2.2 Natural Cycles of Change and the Role of Disturbance

As described above, the type, amount, and condition of aquatic habitats reflect a complex, dynamic interplay of water, soil, plants, and animals. This interplay is not static (Independent Multidisciplinary Science Team 2002). Rather it occurs in cycles of intensity driven by global, regional and local climatic (temperature and rainfall) and geologic processes (National Research Council 1995). While the cycles may be gradual and subtle, the effect is sometimes dramatic, in the form of floods, fires, and droughts and, at much longer intervals, volcanoes, and ice ages. These periodic events are referred to as “disturbances.” Often viewed as disasters when people, homes, or property are affected, they are important for the functioning of an ecosystem and for the persistence of many species (Reice et al. 1990; Reice 2001). The frequency and magnitude of these events over time define a region’s disturbance regime. It is to those regimes that the native species are adapted.

Regardless of how or why they occur, such environmental perturbations have favored the evolutionary survival of plants and animals with life history strategies that enable them to cope with and to some extent thrive on disturbance (Reeves et al. 1995; Independent Multidisciplinary Science Team 2002). Natural disturbances periodically reshape and rejuvenate the landscape and its habitats. For example, regional climatic cycles of warming or drying may culminate in intense and widespread fires (Agee 1997), which in turn are important for the propagation of certain plants and animals. Conversely, periods of increased moisture may lead to greater frequency and intensity of storms resulting in greater flooding and erosion (Swanson et al.1982; Independent Multidisciplinary Science Team 2002) that in turn can lead to improved spawning and rearing habitat and riparian vegetation for fish.

Channel Migration and Shoreline Erosion

Stream channel migration and shoreline erosion are key erosional processes that are critical for creating and sustaining healthy, diverse habitats. In large part, they are ecological processes driven by disturbance regimes, such as floods and cycles of freezing and thawing which periodically deliver large volumes of water, sediment, and large woody debris. They contribute fine sediments, spawning gravel, woody debris and nutrients that sustain and invigorate existing habitats, create new habitats, such as side channels and oxbow ponds, where none previously existed, or fill in old, less productive habitats. In less dramatic ways, these processes also result in lateral scouring along banks and shorelines creating pools and riffles in stream channels and diverse habitats along marine, estuarine and lake shorelines (White 1991)

Recognition of the role these processes play and the hazards they represent to people have resulted in the designation of channel migration zones (CMZs) along rivers and protective setbacks along eroding bluffs and beaches of Puget Sound (see Section on Flood Control and Channel Migration Zones). But much historic development has occurred in these areas and to some degree is still occurring. As a result, habitat-forming processes have been greatly reduced or lost along many of King County’s rivers and shorelines. In turn, this has contributed to a significant loss of habitat quantity and quality. For example, in a study of the Cedar River, it was found that the combination of reduction peak flood flows caused by water supply operations and bank armoring for flood protection resulted in a 56 percent loss of river channel area and a dramatic reduction in off-channel habitats (Perkins 1994).

2.3 The Diversity of King County's Aquatic Life

King County's aquatic areas provide habitat for a wide array of aquatic plants and animals. For example, Wydoski and Whitney (1979) identify a total of 76 species of fish occupying inland waterways of Washington (some of these are found in both fresh and salt waters), of which 45 are found in King County. Of these, 18 are non-native species which thrive and sometimes out-compete valuable native species because of degraded habitat conditions. A large array of other aquatic and riparian species also exists in the County. For example, during a multi-year research program on King County wetlands, 242 plant species (Cooke and Azous 2000), 115 aquatic and semi-aquatic insect taxa (Richter 2000), 10 amphibian species (Richter and Azous 2000a), 90 species of birds (Richter and Azous 2000b) and 22 species of small mammals (Richter and Azous 2000c) were identified. The King County Wetlands Inventory (King County 1990) species list identifies 19 tree, 43 shrub, 96 herbaceous, 65 graminoid plant species; 113 bird, 27 mammalian, 19 fish, and 27 combined shellfish and amphibian species found while conducting field surveys during preparation of the inventory. While some of these are obligatory wetland species, many others are found in non-wetland aquatic areas.

Salmonids as Indicator and Keystone Species

Salmonids (salmon, trout, char, whitefish and grayling) are of particular interest in King County as well as throughout the Pacific Northwest because of their cultural, social, political, legal and economic importance (National Research Council 1995). They are also important ecologically, as they are the region's most diverse family of freshwater and anadromous fishes. Their distribution in streams is also very broad as some species (cutthroat and rainbow trout) can be found in small ephemeral streams with gradients as steep as 22 percent (Latterell et al. In Press). Ocean-going (anadromous) forms bring nutrients from highly productive marine areas to otherwise nutrient-poor freshwater streams and riparian areas when they return to spawn (Willson and Halupka 1995; Naiman et al. 2002). An unknown number of aquatic invertebrates and 137 species of birds, mammals, amphibians, and reptiles have been found to be predators or scavengers of salmon at one or more stages of the salmon life cycle (Cederholm et al. 2000). In some cases, they spawn in sufficient numbers that their digging action modifies the shape of streams and in the process clean sands and silts from stream substrates. (Cederholm et al. 1999; Gende et al. 2002). For these reasons, salmonids are considered keystone species and are a commonly used benchmark for setting protection standards (i.e., what's good for salmon is good for other species) and assessing the effectiveness of aquatic habitat protection and restoration measures.

Compared to other fishes in King County, salmonids exhibit exceptionally high life history diversity both within and among species. Although they overlap considerably in their distribution, each species and life history variation presumably has arisen in adaptation to specific aspects (flow, gradient, size, temperature, presence of other species) of the dynamic and complex aquatic habitat found in our region. Some species (e.g., Chinook salmon) are adapted to spawning in rivers and larger tributaries, while others (e.g., cutthroat trout and coho salmon) reproduce in smaller streams. The juveniles of some species (e.g., steelhead) prefer rearing in very fast water; others (e.g., coho) do best in slow areas such as beaver dams or backwater ponds or, as with sockeye, large lakes. Some species, such as bull trout, gravitate toward the coldest and often the highest elevation streams possible for spawning and early rearing, and others, pink and chum salmon, tend to be found primarily in the lowermost reaches of streams.

Where they have access to saltwater, most salmonid species are anadromous—they spawn in freshwater, then, after a variable amount of time migrate into, grow and mature in marine waters, ultimately returning a year or more later (depending on the species) to their natal streams as mature, much larger individuals. In contrast, resident forms spend their entire life history in freshwater. Some residents migrate very little, spending the majority of their life within a relatively small reach of stream usually limited by a natural barrier, such as an impassible falls or cascade. Other resident forms are referred to as either fluvial or adfluvial, meaning they migrate extensively within a river or river-lake system, respectively.

Anadromy is an especially important life history strategy for salmon. It allows access to highly productive ocean environments, improving the growth and reproductive potential for those individuals and populations using this strategy. It also allows for transport of significant amounts of nutrients from the ocean to natal streams and riparian areas. Freshwater streams of Puget Sound tend to be naturally low in nutrients, thus these nutrients benefit the fish's offspring and many other plants and animals (Welch et al. 1998; Cederholm et al. 1999). Because of their migratory behavior and near-ubiquitous presence in Puget Sound streams and shorelines, salmon are food or nutrients for a wide host of other plants and animals. From the perspective of habitat management, anadromy complicates our understanding of the role of local (King County and smaller watersheds) habitat and development impacts because ocean conditions are a major factor in controlling the abundance and productivity of ocean-going salmon populations. This factor adds to the difficulty in understanding relationships between local habitat conditions and development impacts.

Development can have profound effects on salmonids and they are potentially valuable indicators of change. Lucchetti and Fuerstenberg (1993) and Ludwa et al. (1997), found fish species diversity declined with increasing levels of urban development, and that cutthroat trout (*Oncorhynchus clarki*) became the dominant salmonid species (sometimes the only remaining fish species) in small streams draining heavily urbanized catchments in the Lake Washington watershed. Pess et al. (2002) found adult coho salmon (*O. kisutch*) densities in the Snohomish River basin of Washington to be correlated with wetland occurrence, local geology, stream gradient and land use. They also found median densities of coho spawners in forest-dominated areas were 1.5 to 3.5 times the densities in rural, urban, and agricultural areas. Furthermore, they found that forested areas maintained positive correlations with spawner abundance, whereas those converted to agriculture or urban uses had negative correlation with spawner abundance. Moscrip and Montgomery (1998) found systematic declines in salmon abundance in Puget lowland streams related to changes in flood frequency caused by urbanization.

Roni and Quinn (2000) found that adding large woody debris to small streams (four to 12 meters in bankfull width) in Oregon and Washington impacted by land uses (mostly forestry) can lead to higher densities of coho during summer and winter, and higher densities of cutthroat and steelhead during winter. May et al. (1997) found that the ratio of coho to cutthroat trout was a good correlate of habitat impact. Even when a salmonid species, such as cutthroat trout in urban streams or chinook salmon in the highly modified Green River, persists in the face of development-induced habitat changes and may appear healthy based on abundance, there is concern that the *diversity* of the species' life history, and thus the health of the species, is much reduced due to loss or modification of habitat complexity .

Finally, it should be recognized that in addition to marine and freshwater habitat conditions, many salmonids are heavily affected by commercial, sport, or subsistence fisheries and the hatcheries' fishery managers often use to restore or increase the fishing opportunities (NRC 1995). Fisheries can alter the abundance, size, age structure, and fecundity of populations. Hatcheries tend to cause domestication reduced genetic fitness, increases in predation, competition and disease risk to naturally spawning populations. When not properly managed, fisheries and hatcheries tend to reduce the productivity of managed populations, adding to the scope of factors affecting fish.

Other Species as Indicators

Many other plant and animal species beyond salmonids contribute to the overall aquatic habitat functions and biodiversity of King County. Their requirements are not necessarily the same as for salmonids and some may be better indicators because they are less mobile and have less tolerance for change. Good examples are amphibians such as the Pacific giant salamander (*Dicamptodon tenebrosus*), tailed frogs (*Ascaphus truei*) which use very small, steep streams and seeps that may have little or no potential for salmonid use. Bogs are also not used by salmonids or fish in general due to their low pH; see the wetlands section for information about wetland habitat and species.

In a study of small, mostly steep headwater streams of the Olympic Peninsula, Bisson et al. (2002) concluded that stream-dwelling amphibians were more influenced by riparian and watershed conditions and fish were more strongly influenced by in-stream habitat conditions. They conclude that the fish were probably responding to frequent disturbance events, such as landslides that modify in-stream habitat, whereas the amphibians were responding more to watershed level changes in forest cover that alter hydrology and water quality. Using the same study of streams, Raphael et al. (2002) concluded that in-stream and near-stream amphibians were better indicators than fish, birds or mammals of stream and stream-side habitat condition, probably because of their low mobility, tendency to reside in or return to specific locations, lengthy larval period ability to populate beyond obstacles to movement and narrow limits of environmental tolerance.

Mollusks are another class of animals that can be indicators of change. For freshwater habitats, they have been noted as being good measures of environmental change as they can be sensitive to changes in water quality and fine sediments (Fevold and Vanderhoof 2002). As with amphibians, they are also relatively immobile and therefore cannot avoid changes in environmental conditions.

Finally, Karr and Chu (1999) discuss the use of benthic invertebrates (insects, crustaceans, and mussels) and fish in the development of indices of biotic integrity. The IBI evaluates the presence and abundance of pollution tolerant and pollution intolerant species to gage the biological effect of pollution and other changes. Originally developed using fish species in the Midwest, an area that has a high diversity of fishes, the IBI was altered for the Puget Sound region to use benthic invertebrates to improve the discriminatory capabilities of the index because the Pacific Northwest has a relatively low diversity of fish species.

2.4 Integrated Ecological Models: The River Continuum Concept and Marine Intertidal Zonation

To integrate knowledge about ecosystems into a common framework and to guide research and management, scientists have constructed a variety of models that describe how freshwater and marine habitats work and the relative importance of various physical, chemical and biological processes. For riverine system, the dominant model is the River Continuum Concept proposed by Vannote et al. (1980). The complimentary model for marine nearshore habitats is that of Intertidal Zonation as initially described by Ricketts and Calvin in 1938 and later substantially revised by Hedgpeth (1968). These two models are described briefly below.

The River Continuum Concept (RCC)

The RCC holds that the distribution of stream characteristics reflects a headwater-mouth gradient of physical conditions that affect the biological components in a river including the location, types, and abundance of food resources with stream order. Some of the key features of the concept are shown in Figure 5A.1 and summarized in Table 5A.1.

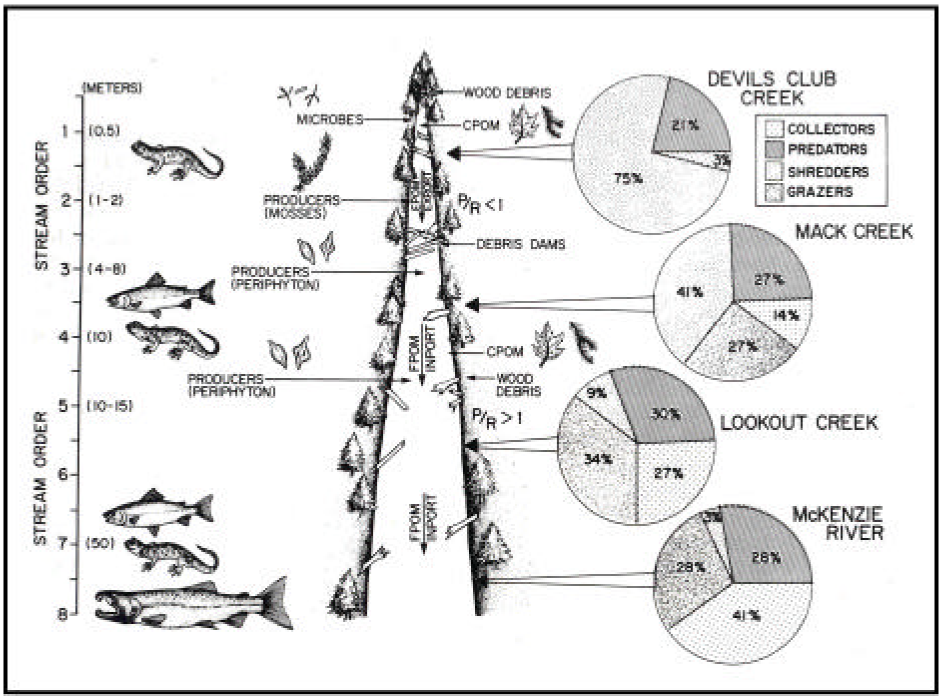

Figure 1. Changes in aquatic communities from small streams to large rivers in the McKenzie River drainage, illustrating the River Continuum Concept.

Coarse Particulate Organic Matter (CPOM) and Fine Particulate Organic Matter (FPOM) are coarse (>0.04 inches) and fine (>0.04 inches) particulate organic matter. Pie charts show how abundance of four different types of aquatic insects feeding guilds (collectors, predators, shredders and grazers) vary from headwater to large streams (from Gregory and Ashkenis 1990).

Table 1. Summary of the Features Important in the River Continuum Concept[1]

Feature	Headwater	Mid-Sized Streams	Large Rivers
Stream Order	1-2	3-5	6-9
Channel	Confined	Moderately Confined	Wide
Riparian Growth	Dense (stream channel covered at least part of year)	Moderate (majority of channel exposed)	Low (only stream margins covered; organic input is minimal)
Shading	High	Moderate to Low	Low
Substrate	Boulder, cobble, and gravel	Generally cobble and gravel	Gravel, sand, and silt
Water Temperature	Low and stable	Highly variable	High and stable
CPOM-Coarse Particulate Organic Matter	High (input from riparian growth)	Moderate (from upstream and little new input)	Low
FPOM-Fine Particulate Organic Matter	Low	High (flowing from upstream and produced here)	High (flowing from upstream and produced here)
Primary Production	Low (low algal growth due to little direct light)	High (high algal growth due to direct light and low turbidity)	Low (low algal growth due to insufficient light and substrate conditions)
Shredders	High	Low	Low
Collectors	High	High	High
Grazers	Low	High	Low
Predators	Low	Low	Low

[1]From Vannote et al. 1980.

The influence of riparian and landscape factors varies depending on stream size. For example, small to medium-sized, forested streams have relatively large inputs of terrestrially derived plant matter (e.g., leaf litter and wood) and woody debris from surrounding riparian and upland areas compared to high-order (larger) river systems. The productivity of smaller streams is more dependent on riparian vegetation for their nutrients than larger streams, which are dominated by primary production (e.g., algae growth). Similarly, the temperature regime of small headwater streams is much more strongly influenced by vegetative shading than that of large streams.

More recently, it is being recognized that considerable variation in processes and distribution of resources (sediment, woody debris, and animals) occurs in the context of the continuum. For example, Rice et al. (2001) showed that tributary junctions create discontinuities in substrate conditions and invertebrate abundance. Similarly, Osborne and Wiley (1992) showed that tributary junctions affected the distribution of fish species. And Benda and Dunne (1997) describe the discontinuous nature of sediment as it is routed through a stream system. Thus the role of discontinuities, (e.g., tributary junctions, braided areas, logjams, debris flows) in creating diverse habitat patches and uneven distributions of species has been getting attention as the RCC is updated to reflect increased awareness of the complexity of stream ecosystems (see Fausch et al. 2002).

Functions of headwater streams

(Note: additional information on the functions and values of headwater streams will be provided in later drafts.)

Headwater streams (1st and 2nd order) play an important role in stream ecosystems. Typically they make up most of the stream length within a watershed (Benda et al. 2002). They heavily influence downstream habitats and they also often contain some of the most sensitive (albeit not necessarily the most abundant or productive) stream species, including bull trout, Pacific giant salamanders and tailed frogs (Bisson et al. 2002; Raphael et al. 2002). They are often situated among the most steep and sensitive slopes making them susceptible to landslides, which when triggered in these areas can contribute to extensive destabilization of downstream areas (i.e., streams unravel from the top down). However, as discussed earlier, landslides and other disturbances are not necessarily bad. When they occur at their natural rates and magnitudes are necessary for streams to function properly.

Functions of fishless and isolated aquatic areas

(Note: additional information on the functions and values of these aquatic areas will be provided in later drafts.)

Some aquatic areas have no fish or fish-bearing potential. For example, Latterell et al. (In Press) found that absent impassable barriers, salmonids were rarely found in small streams at gradients greater than 22 percent. In some cases, small streams originating as spring seeps go underground before making a surface connection with a fish-bearing aquatic area. In other situations lakes and ponds having no surface connection to a fish-bearing stream or have waters that are unsuitable for fish (e.g., bogs are too acidic). Regardless, isolated or otherwise fishless isolated waters can be used extensively by other animals, especially amphibians and macroinvertebrates (e.g., stoneflies) for breeding, rearing, or refuge (Muchow and Richardson 2000). When they disappear due to infiltration, their waters can contribute to local aquifers that may ultimately supply fish-bearing waters with cool, clean groundwater. Thus fishless and isolated waters can function as habitat for non-fish species and in protecting the water quality and hydrologic functioning of waters with fish.

Marine Intertidal Zonation

Similar to rivers, habitat and species use along marine shorelines occur in gradients that are determined by fluctuations in currents, water level (tides), geologic conditions, water quality, and salinity. The Intertidal Zonation model accounts for most of these factors using zones occurring vertically between the upper extent of marine water influence and the photic zone, which extends down to the depth at which rooted photosynthetic plants, such as Giant Kelp, exist.

Zones are generally delineated into one of four categories: the spray, high intertidal, low intertidal and subtidal zones. Steep, unprotected shorelines composed of large boulders or bedrock will have a different set of habitats and species than shorelines at the base of actively eroding, sandy banks with a gradual slope. For example, barnacles generally do not occur in the low intertidal and subtidal zones or in areas without large substrate. This is due to predation by numerous other organisms and the need to adhere to something stable. They have adapted to life in the harsh transition area between the terrestrial and marine environments, where predation is much lower and exposure to the sun and air is much greater. Whereas, species like sand dollars and eelgrass occur in the low intertidal and subtidal zones. They are unable to live in the higher zones since they can not be out of water for extended periods of times like barnacles. They are also found only in areas with sandy substrates. Proximity, to large rivers and streams also changes the water quality (turbidity, salinity, temperature, etc) which can cause similar looking marine nearshore environments to have substantially different plants and animal communities.

Another factor shaping marine and estuarine shorelines that is not illustrated well within the intertidal zonation model is the horizontal, along-shore affects of currents, waves, and winds. Drift cells are systems in which sediment is suspended by waves or currents and transported along the shoreline in a repetitious cycle of suspension and deposition. Essentially, they are the mechanism that supplies marine nearshore environments with the majority of the sediments that form beaches, sand and mud flats, and maintains rarer features like sand spits and their associated marshes.

2.5 Effects of Land Development on Aquatic Habitats and Species

Land development (e.g., houses, landscaping, clearing, agricultural activity, roads, piers, gravel mining, bridge building, filling, bank armoring, bulk-heading) can significantly alter the natural habitat structures and processes to which native plants and animals are adapted. (See Chapter 2 – Scientific Framework and Context, and Appendix C). Depending on the type of habitat affected, biological consequences include changes in the quantity and quality of spawning, rearing, migration, and disturbance refuge habitats, availability and quality of food, greater exposure to predators and increased competitive interactions. The effects of development varies with where it occurs in relation to the aquatic area. Three locations are discussed below: (1) at the edge of, on top of, or within an aquatic area; (2) in floodplains and riparian corridors; and (3) occurs far away from water.

Development that occurs *at the edge of, on top of, or within,* an aquatic area can affect the quantity and quality of aquatic habitats by directly eliminating a habitat or altering natural processes that support it, such as bank erosion, channel migration, and the delivery and transport of sediment and woody debris. Bortleson et al. (1980), Canning and Shipman (1995), Crzastowoski (1983), Haas and Collins (2001) and King County (1993) document dramatic changes in marine and freshwater habitat as a result of human development occurring within, on top, or at the edge of aquatic areas. Williams and Thom (2001) provide an extensive discussion of the effects of shoreline modification on marine and estuarine habitats and species. Similarly, Nightingale and Simenstad (2001) provide an extensive review of effects of overwater structures (e.g., docks and piers). Kelty and Bliven (2003) summarize a NOAA workshop, which evaluated the status of the science on the environmental and aesthetic impacts of small docks and piers. Effects of such activities and structures include changes in currents, amount and transport rates of shoreline sediment and woody debris, changes in night-time ambient light levels (developed areas are often much brighter at night due to lighting), introductions of toxic chemicals, and reductions in the quantity and quality of habitat.

Development *in floodplains and riparian corridors* affects aquatic areas when it removes or modifies native forest vegetation, or when it alters rates and patterns of bank and channel erosion, migration, surface, and groundwater flow. Riparian areas provide a variety of functions including shade, temperature control, water purification, woody debris recruitment, channel, bank and beach erosion, sediment delivery, and terrestrial-based food supply (Gregory et al. 1991; Naiman 1998; Spence et al.1996). These are potentially affected when riparian development occurs (Waters 1995; Stewart et al. 2001; Lee et al. 2001). Bolton and Shellberg (2001) provide an extensive discussion of the effects of riparian and floodplain development on aquatic habitats and species. Effects include: (1) reduction in amount and complexity of habitat; (2) increased scouring of channels due to channel and floodplain confinement; (3) reduction or loss of channel migration, vegetation, sediment supply; and (4) woody debris recruitment.

Even development that *occurs far away from* water has the potential to affect aquatic habitat primarily by modifying water storage and runoff patterns and sediment erosion rates (Booth 1989; Harr et al. 1975; Hicks, et al. 1991; Booth and Reinelt 1993; Booth and Jackson 1997; Booth and Henshaw 2001; Booth et al. 2002). Booth and Reinelt (1993) found that when a watershed reaches approximately 10 percent effective impervious area, that demonstrable, and probably irreversible, loss of aquatic system function occurs in western Washington streams. They and May et al. (1997) also note that detrimental effects were evident well before the 10 percent threshold was reached.

Wherever it occurs, development has the potential to affect species migration and dispersal patterns by isolating habitats and fragmenting the landscape (McKinney 2002). It also tends to expose plants and animals to unnatural and potentially very harmful chemicals (Scholz 2000), and puts people and their pets in close proximity to native plants and animals that may not be tolerant of them (Baker and Haemmerle 1990).

There are many ways in which these changes affect plants and animals. In general, the physical and chemical effects are to create hydraulically simplified and/or polluted aquatic habitats with disturbance regimes much different from pre-development conditions (e.g., dramatically more or less intensity or frequency of flooding, erosion, or fire). In turn, native species diversity, distribution, abundance and productivity is lost or greatly reduced, especially among the most pollution intolerant species. Oftentimes these changes contribute to or their effects are exacerbated by invasions of undesirable, pollution-tolerant invasive or exotic species (May et al. 1997; Harding et al. 1998; Frissel 1993; McKinney 2002; Waters 1995; Stewart et al. 2001).

2.6 Processes Conclusion

Aquatic areas and the native species that use them have evolved in response to the ongoing interactions of water, soil, vegetation communities and animals at local, regional and global scales over long temporal scales (several millennia to millions of years). The sustainability and restoration of these habitats and species will require protection and, to the extent feasible, restoration of the ecological processes that sustain them as well as direct protection of the habitats themselves. Without providing substantial habitat protection, development will cause reductions (sometimes very dramatic) in productivity and species diversity, and contribute to damage caused by invasive, pollution tolerant and exotic species, which commonly benefit from habitat degradation.

Salmonids are the most studied and valued group of aquatic animals in the Pacific Northwest. They are widely distributed, a focus of legal and social concerns, and exhibit responses including loss of productivity and inter- and intra-specific diversity to development-related impacts. As a result they are considered a keystone species and are an often-used benchmark for environmental performance. Their use as such is complicated, however, by the influence of harvest, hatcheries, and ocean conditions. Other species, such as amphibians, molluscs, and insects may be better indicators, depending on the effect and habitat being assessed.

2.7 Strategies for Protection

Protective measures, such as proposed in the CAO and Stormwater ordinances should be part of a comprehensive and integrated habitat and species protection and restoration strategy. Such a strategy prioritizes areas based on their biological potential, sets realistic goals and objectives accordingly (Roni et al. 2002; IMST 2001), and recognizes natural and human-induced variations in physical, chemical and biological conditions. Critical to understanding this variation is information on the following four parameters (IMST 2001; National Research Council 1996): (1) spatial structure of the watershed; (2) temporal and natural disturbance history,(3);riparian vegetation community; and (4) nature and magnitude of human impacts.

Because protection measures (regulatory, capital investment, or programmatic), entail monetary and social costs, it is important to apply them where they will provide the most benefit to the aquatic area. An emerging generalized strategy for conservation is to first protect the best remaining habitats, and then, to the extent feasible, restore those that are impaired (Roni et al. 2002; IMST 2001; NRC 1996).

In order to pursue the above strategy, it is necessary to protect or restore the processes that sustain habitats, and not just the habitat themselves. Many aquatic areas in King County are already severely degraded. In some heavily urbanized areas it is unrealistic to expect full restoration of habitat (Booth et al. 2002). For example, aquatic areas in or downstream of high-intensity land-use areas (cities, unincorporated urban lands, high intensity agricultural lands) are generally degraded with severity of degradation increasing with proximity to high intensity land-use. Wider buffers acting along a downstream gradient can ameliorate but not completely reverse these effects (Morley and Karr 2002). Certain localized conditions such as the presence of large amounts of highly porous outwash and relatively flat landscapes and channels can also help to reduce the effects. Where large buildings and major infrastructure surround or encroach into aquatic areas, options for future restoration are likely to be limited because of the extremely high cost of removing such structures. Conversely, aquatic areas in or downstream of lower-intensity land uses are generally in better condition and offer more cost-effective opportunities for protection and restoration.

This gradation of development, habitat conditions and future restoration options has implications for protection strategies. For example, there may be a point beyond which requiring wider buffers or forest cover in areas of existing high-intensity land use (i.e., where parcels are small and few remain undeveloped) is ineffective at meeting habitat or biological goals. In this context, higher protections may be best applied in areas where comprehensive protection and/or substantial restoration are realistic goals (i.e., achievable given socioeconomic constraints), a subjective standard but nonetheless a threshold that does exist. Similarly, in areas that are highly constrained by intense development, it may be best to focus protective actions on functions such as improving water quality and overhead shade, which are achievable with smaller buffers, rather than large woody debris recruitment and microclimatic controls which require wider buffers to achieve substantial results.

While restoration might be possible in intensely developed areas, it would likely entail highly engineered and costly solutions. Buffers in low-intensity land-use areas can potentially better protect habitat and preserve future restoration options than buffers in highly urbanized areas. Placing a higher priority on protecting areas with high habitat restoration or species recovery potential is consistent with recommendations for protection of aquatic resources in developing areas (Booth et al. 2002; Roni et al. 2002) and for salmonid recovery (Spence 1996).

In addition, the location and condition of habitats, biological resources and watershed processes are factors to consider in aquatic area protection measures. Finally, Puget Sound headwater areas tend to have the least development (with some notable exceptions for small lowland streams fully encased in urban development, e.g., Thornton, Hamm, Kelsey and Longfellow Creeks). Therefore, relatively high protection of headwater areas and their streams may offer the greatest systemic benefits for the protection of certain functions, such as water quality protection, hydrology and sediment routing, critical to streams. This is not to imply other parts or features of a watershed are insensitive or have any lesser importance, rather that it is important to understand the role and issues relative to the watershed location.

Similarly, the condition and distribution of key biological resources also plays a role in a comprehensive protection strategy. Thus buffers of sufficient width and condition to provide direct protection of fish (i.e., on fish-bearing streams) may be unnecessary on streams with low numbers of fish or no critical fish species. Local knowledge of the distribution and relative condition of fish and other aquatic biota is increasing in Puget Sound (see for example King County fish and benthic invertebrate maps, WRIA Near-Term Action Agenda plans and State Limiting Factor Reports). However, while much improved over historic information, the reliability of some of this information is uncertain and the uses of many aquatic habitats by key biota remains unknown. In the face of uncertainty some level of conservatism in setting protections is warranted, as land-use decisions are often irreversible. To this end, the need to protect waters with salmonid-bearing potential, not just those known with high certainty to have salmonids, should be considered until their biological role is well known.

2.8 Approaches to Aquatic Area Protection

Effective protection measures should provide protections for both critical habitats as well as ecological processes (water flow, sediment routing, vegetation succession, woody debris processing, and plant and animal speciation) that sustain them. Aquatic areas, the species that use them, and the ecological processes that sustain them occur at multiple habitat (aquatic, riparian and landscape) and time (days to centuries and longer) scales. Therefore protections should address potential impacts protection needs at those multiple scales (Booth and Reinelt 1993). This means having regulations that protect aquatic habitats from direct harm from in-water and riparian activities as well as protecting key riparian and upland functions that sustain aquatic habits.

In lieu of effective protection standards, many attempts have been made to mimic natural processes, such as through artificial stormwater or streambed controls, or hatcheries . Unfortunately, such approaches generally have been found to be ineffective or counter-productive and costly substitutes for natural conditions (see Booth 1989, 1991; Booth et al. 2002; National Research Council 1995; Roper et al. 1998; Frissel and Nawa 1992). In some cases where larger landscape processes were not adequately considered, they have generated additional problems and costs rather than being the hoped-for solution (Kondolf 2000; Booth et al. 2002).

Some extensively urbanized parts of the landscape may be irreversibly impacted (Booth and Reinelt 1993; Booth et al. 2002). In such situations, artificial, highly engineered measures such as stormwater ponds, piping systems, and retrofitting of stream channels with artificial bed controls may be the only realistic choices left. Where such thresholds have not been reached, however, planning for and accommodating natural rates of change is considered one of the keys to sustaining aquatic habitats and the species that use them. In order for this to happen, it is necessary to maintain or restore where impaired, the processes that allow water, soil, vegetation and animals to interact (i.e., connectivity, see Chapter 2 – Science Framework).

Riparian Areas

Riparian Functions

Natural riparian corridors are essential for wild fish populations and "are the most diverse, dynamic, and complex biophysical habitats on the terrestrial portion of the Earth" (Naiman et al. 1993). The Puget Sound area's wild salmonids are adapted to thrive in forest-lined fresh waters during significant parts of their life cycles and depend on the riparian system's diversity, dynamism, and complexity. There is no known suitable, long-term substitute for healthy riparian forest as a generator of habitat for Puget Sound's salmonids.

Gregory et al. (1997) stated that before the widespread removal of riparian forests in the Northwest's lower valley floodplains, the forests were critical for survival of rearing salmon during winter floods and as cold-water refuges during warm seasons, particularly along secondary channels and off-channel ponds (referencing Ward et al. (1982), Peterson and Reid (1984), and Brown and Hartman (1988)). Pollack and Kennard (1998) point out that "riparian buffers are the key component of any salmonid habitat conservation strategy because they … provide the majority of the ecological goods and services required to keep salmonid habitat functional."

Protection of Puget Sound's native salmonids requires maintenance of healthy riparian forests. In the natural state, this area's mature riparian forest is generally dominated by coniferous trees, usually Douglas fir, western hemlock, and western red cedar (Brosofske et al. 1997; May 2000). However, many species compose the native riparian plant communities. Some riparian vegetation is characterized as *obligate*, for species growing only in riparian areas, and some as *facultative*, for species commonly occurring there but also in upland terrain. Obligate riparian plants tend to depend on a high water table, tolerate inundation and soil anoxia, tolerate physical damage from floods, colonize flood-scoured surfaces, and colonize and grow in substrates having few soil nutrients (Kondolf et al. 1996).

Healthy riparian zones are living, ever-changing systems, often undergoing natural disturbance (flood, drought, fire, landslide, insect infestation, etc.), then responding via *self*-regeneration. These dynamic riparian ecosystems perform various functions that form salmonid habitat. Below are descriptions of some of the commonly cited major functions.

1. ***Producing and delivering large and small woody debris (LWD and SWD) to shorelines and stream channels.*** The important role of fallen trees and tree parts as structure-forming elements in stream channels is well known (Zimmerman et al. 1967; Heede 1972; Swanson et al. 1976; Swanson and Lienkaemper 1978; Keller and Swanson 1979; Bilby and Likens 1980; Bilby 1981; Lisle and Kelsey 1982; Megahan 1982; Harmon et al. 1986; Lisle 1986; Bisson et al. 1987; Leinkaemper and Swanson 1987; Andrus et al. 1988; Bilby and Ward 1989; Hartman and Scrivener 1990; Robison and Beschta 1990; Bilby and Ward 1991; Maser and Sedell 1994; O'Connor and Harr 1994; Montgomery et al. 1995; Beechie and Sibley 1997; Montgomery and Buffington 1997; Bilby and Bisson 1998; Pollack and Kennard 1998). Major salmonid habitat benefits of woody debris are apparent (Bustard and Narver 1975; Bisson et al. 1982; Tschaplinski and Hartman 1983; Grette 1985; Sullivan et al. 1987)

(Hartman and Scrivener 1990). The complex, submerged structure formed by LWD and SWD (and roots of woody vegetation) provides flow refugia (McMahon and Hartman 1989) and essential cover in which salmonids conceal themselves from enemies and competitors and find profitable feeding positions, as inferred from observations in natural streams (Fausch and White 1981) and experiments in a stream aquarium (Fausch 1984; Fausch and White 1986).

Removal of riparian forest results in long-term reduction of LWD (McDade et al. 1990; Van Sickle and Gregory 1990) and SWD (Bilby and Ward 1991) in streams. LWD deprivation leads to adverse changes in channel forming processes (Bilby 1984; Bisson and Sedell 1984; Heifetz et al. 1986), and a marked decrease in salmonids result (Lestelle 1978; Bryant 1983; Dolloff 1986; Elliot 1986; Fausch and Northcote 1992). Reduced LWD is deemed a major reason for salmonid decline in Pacific Northwest streams ((Sedell and Luchessa 1981; Sedell and Froggart 1984; Bisson et al. 1987; Sedell et al. 1989; FEMAT 1993; Stouder et al. 1997; Naiman and Bilby 1998).

One of the pertinent functions of LWD in streams is that it traps and accumulates smaller WD and other organic matter (Bilby 1981), including salmon carcasses. Pollack and Kennard (1998) reviewed roles of SWD in streams and developed a procedure for estimating potential SWD delivery from riparian areas. WD in non-fish-bearing streams also benefits downstream salmonids by regulating sediment flow (Megahan 1982; Perkins 1989; Montgomery et al. 1996).

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

   The riparian vegetation that protects shorelines also provides structural habitat for aquatic organisms, such as many salmonid microhabitats in live vegetation and in woody debris (see item 1, above). This material, most important being tree roots and brush that drapes into the water, creates positions that are concealed from predators and give shelter from water velocity but are near fast currents that bring food (Bossu 1954; Fausch 1984; Fausch and White 1986). Vegetation resists shoreline erosion but generally not as drastically as do rock-riprap, concrete bulkheads, steel sheet-piling, and the like. Diverse native vegetation can be expected to moderately retard shoreline erosion while maintaining their dynamism, letting channels flex, thus forming and reforming salmonid habitat features. Reeves (et al. 1995) described the dynamism of salmonid-producing ecosystems in the Pacific Northwest and put forth ideas for managing them so as to accommodate disturbance regimes.

3. ***Removing sediments and dissolved chemicals from water***. Uptake of dissolved chemicals and filtration of sediments from overland-runoff and flood water is an important riparian function(Lowrance et al. 1984; Cummins et al. 1994). Spence (1966) reviewed evidence for these processes and for alteration of the flux of these material through stream systems. Literature analysis by (FEMAT 1993) indicated that healthy riparian zones greater than 200

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

4. ***Moderating water temperature.*** Thermal benefits of shading by riparian vegetation in summer are obvious (Hall and Lantz 1969; Brown and Krygier 1970; Newbold et al. 1980; Beschta et al. 1987; Holtby 1988). Aside from summer cooling, riparian forest cover also exerts winter-insulating effects (Murphy and Meehan 1991). Spence (1966) reviewed studies that elucidate riparian thermal benefits.

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

6. ***Providing habitat for terrestrial animals.*** Various animals that live in or frequent riparian zones are associated with salmonid populations. These include habitat modifiers, such as moose and beaver (Naiman and Rogers 1997), the former altering vegetation, the latter (Bustard and Narver 1975; Cederholm and Scarlett 1982; Murphy et al. 1989) making ponds, digging side channels, and altering vegetation. In addition, riparian-dwelling predators, such as otter and various birds, exert beneficial selective pressure on fish populations. Predators and scavengers recycle nutrients from salmonid carcasses. These relationships are reviewed for Washington and Oregon in Cederholm (et al. 2000), which contains 576 references.

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

Note that many of these seven major functions are interrelated, that all are performed primarily by vegetation, and that all are decreased or eliminated when riparian vegetation is degraded or destroyed.

Further riparian functions important to salmonids include exchange of water between the ground and the water body (hyporeal flow, Stanford and Ward, 1988); flux of gravel between stream beds and banks, and light patterning which salmonids (Gibson and Keenleyside 1966; MacCrimmon and Kwain 1966; Butler and Hawthorne 1968; Stewart 1970; Bassett 1978; DeVore and White 1978; Gruber 1978) and invertebrates (Myers and Resh 2000) use for concealment.

Approaches to Protecting Riparian Functions

The most common method for protecting vegetation and its riparian functions from adjacent land uses has been the use of buffers. Castelle and Johnson (1998) define buffers as vegetated zones located between natural resources, such as streams, wetlands, or critical wildlife habitat, and nearby areas subject to human alteration. Fixed riparian buffers are intended to protect an area of sufficient size to provide functions considered important for protecting aquatic and riparian species and to buffer against development impacts (Haberstock et al. 2000). Key functions considered in establishing the width of buffers include shade and temperature regulation, flood conveyance, water quality protection and pollutant removal, nutrient cycling, sediment transport, bank stabilization, woody debris recruitment, wildlife habitat and microclimate control (Spence et al. 1996; IMST 2001; May 2000).

A variety of technical reports summarize the scientific literature on buffer functions and make recommendations for buffer widths. Findings of three such reports are shown in Tables 1, 2 and 3; (from Parametrix 2002). Others include Castelle et al. (1992), Castelle and Johnson (2000), Desbonnet et al. (1994), Johnson and Ryba (1992), Portland Metro (1999) and Pollack and Kennard (1998).

Table 1. Riparian Buffer Functions and Appropriate Widths Identified by May (2000)

Function	Range of Effective Buffer Widths	Minimum Recommended	Notes On Function
Sediment Removal/Erosion Control	26 - 600 ft (8 – 183 m)	98 ft (30 m)	For 80% sediment removal
Pollutant Removal	13 - 860 ft (4 - 262 m)	98 ft (30 m)	For 80% nutrient removal
Large Woody Debris Recruitment	33-328 ft (10 –100 m)	262 ft (80 m)	1 SPTH [define in a footnote] based on long-term natural levels
Water Temperature Protection	36 - 141 ft (11 – 43 m)	98 ft (30 m)	Based on adequate shade
Wildlife Habitat	33 - 656 ft (10 – 200 m)	328 ft (100 m)	Coverage not inclusive
Microclimate Protection	148 - 656 ft (45 – 200 m)	328 ft (100 m)	Optimum long-term support

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

Function	Range of Effective Buffer Widths
Water Temperature Protection	35 - 151 ft (11 - 46 m)
Pollutant Removal	13 - 600 ft (4 - 183 m)
Large Woody Debris Recruitment	100 - 200 ft (30 - 61 m)
Erosion Control	100 - 125 ft (30 - 38 m)
Wildlife Habitat	25 - 984 ft (8 - 300 m)
Sediment filtration	26 - 300 ft (8 - 91 m)
Microclimate	200 - 525 ft (61 - 160 m)

Table 3. Riparian Functions and Appropriate Widths Identified from FEMAT (1993)

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

Fixed Versus Variable Width Buffers

Approaches to establishing buffers vary between fixed or variable width, with the former generally being the most common (Haberstock et al. 2000). Castelle and Johnson (1998) note that fixed buffer widths are more easily established, have a lower need for specialized personnel with a knowledge of ecological principles, and require less time and money to administer. Conversely, they note that variable width buffers can potentially allow for greater flexibility, account for variation in site conditions and land management practices, and potentially achieve desired ecological goals while minimizing undue losses to landowners. Variable width buffers are considered more ecologically sound because they have the potential to reflect the true complexity of the environment and management goals (Haberstock et al. 2000; IMST 2001). Todd (2000 as cited in May 2000) suggests that variable width buffers provide the best protection while respecting property rights. While variable-width buffers may be more ecologically sound and theoretically allow landowners more flexibility, there are no generally accepted criteria for the establishment of variable-width buffers. To be effective under a worst-case scenario and to ensure success in the face of uncertainty about specific site conditions, May (2000) and Haberstock (2000) suggest that fixed-width buffers should be designed conservatively (i.e., larger than the bare minimum needed for protection).

Variable width buffer approaches have been proposed by Forman (1995) and, as cited by Castelle and Johnson (1998) by Darling et al. 1982, Steinblums et al. (1984), Barton et al. (1985), Roman and Good (1985), Budd et al. (1987), and Groffman et al. (1990). Haberstock et al. (2000) provides recommendations for a variable width two-zone approach for the protection of endangered Atlantic salmon habitat. In their approach, Zone One is a fixed 35-ft (10.7-m) width closest to the water in which no disturbance should occur. Zone Two is a variable-width area wherein limited low-impact uses (recreation, low-impact forestry) that do not compromise the desired functions of the buffer could be allowed. Total buffer widths (Zone One plus Zone Two) range from a minimum of 70 feet (21 m) to 400 feet (122 m), with a maximum of 1,000 feet (305 m) in rare cases, such as along streams that are flanked by extensive steep (> 25 percent) slopes.

Adjustments in Zone Two width can be made for the presence of surface and groundwater seepage features, forest floor roughness, sand and gravel aquifers, wetlands, floodplains, very steep slopes, and stream order. All but one of the adjustment factors (the degree of forest floor surface roughness) causes Zone Two to increase. These authors note that buffer widths are expected to vary regionally as a function of buffer conditions, management objectives, and instream habitat characteristics. They also note that theirs is a conceptual model and potentially subject to change as studies and scientific literature provide new data that better indicate the relationships between buffer characteristics and buffer effectiveness.

There is no consensus in the scientific literature regarding single buffer widths for particular functions, or to accommodate all functions. However, neither does the literature indicate that buffers are not needed, nor that riparian buffers beyond the equivalent of several site potential tree heights (SPTHs) are needed. One SPTH, the maximum height a tree will attain given the existing geology, soils, and other site conditions, ranges from 50 to 250 feet (15-76 m), depending on species, for a tree at least 300 years old in western Washington forests. A buffer width equal to one SPTH would provide for a broad range of riparian functions important for sustaining salmonids. However, some wildlife, such as stream breeding amphibians, beavers and other mammals, may need considerably more than this for land migrations associated with foraging and breeding (see Chapter 8 – Wildlife Areas).

The type and intensity of human activities in and near buffers are factors not often assessed in reviews of buffer widths, but they can affect conditions in the buffer. In a survey of 62 Native Growth Protection Easements (NGPEs) along streams, wetlands, and steep slopes in developing areas of western King County, Baker and Haemmerle (1990) found that the vegetated condition of two-thirds of the NGPEs had been altered by people, and of those, 25 percent had been judged as being negatively affected. Moreover, the number and seriousness of impacts increased with increasingly intense residential development near the NGPEs. May (2000) suggests that more protective buffers are needed for more sensitive or valuable resources. Similarly, he suggests that more protective buffers should be applied for higher intensity land uses or when the land use poses higher risk of impact.

Site Potential Tree Height Concept

The concept of scaling riparian buffer widths to the potential height of a tree was first proposed by the Federal Ecosystem Management Team who was assessing riparian protections for national forest lands (FEMAT 1993). They reasoned that trees were a logical scaling factor because (1) they are a dominant factor in determining habitat conditions and (2) when left unmanaged, their size (height) reflected inherent productivity and constraints of a given site. As a result of this logic generalized curves using scientific data and professional judgement were developed to help rate buffer effectiveness for a variety of ecological functions, including shade, litter fall (e.g., leaves, branches), root strength and coarse woody debris inputs. Curves for a set of factors (soil moisture, radiation, soils temperature, air temperature, wind speed, and relative humidity) relating to microclimate were also developed. These curves are shown in Figure 2.

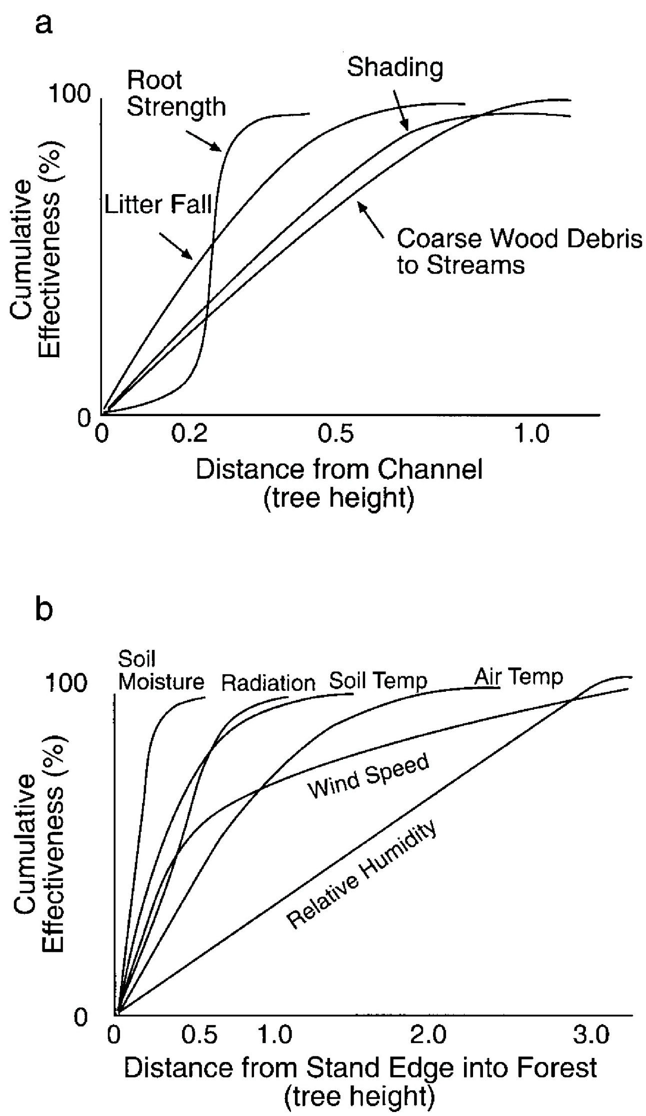

Figure 2. Riparian vegetation effectiveness as a function of the height of a site potential tree distance from the water's edge.

Graph (a) shows cumulative effectiveness of four riparian processes as a function of relative distance from the edge of a stream, in fractions of a dominant tree height. Graph (b) shows cumulative effectiveness for six microclimate factors as a function of relative distance from the stream edge. Modified from FEMAT (1993) and Naiman et al (2000).

Based on these curves, all but microclimate functions would likely be protected with a buffer width equivalent to one SPTH. Microclimate functions would need approximately three SPTH for full protection.

Sedell et al. (1993) defined a SPTH as the average maximum height to which a dominant tree will grow if left undisturbed. Depending on the species, soils, climate, disturbance history of a site a dominant tree could be between 200 to 500 years old. Pollock and Kennard (1998) provide detailed explanation of a SPTH. Using tree growth information for two riparian plant association groups (PAGs) on the Mount Baker-Snoqualmie National Forest, they estimate the SPTH for Douglas Firs would range from 218 to 198 feet for PAGs four and five, respectively. Similar data are not readily available for other trees, such as western red cedar, sitka spruce, which can be as tall or taller than Douglas Firs, depending on site conditions, or for black cottonwood, red alder and bigleaf maple, which are smaller in maximum height and therefore would likely have smaller SPTH values than for Douglas fir. Soil surveys by the U.S. Department of Agriculture, Soil Conservation Service, typically provide estimates of tree height for given soils (USDA 1992). However the information is based on growth achieved in fifty or 100-years and thus do not represent a site's SPTH for longer lived trees such as Doug firs, western red cedars or sitka spruce. For example, for Alderwood soils, which are the dominant soils for King County, the average height of a 100-year Doug fir would be 146 feet, roughly 75 to 80 percent of the SPTH assuming a 300 year old tree (Pollock and Kennard 1998).

Marine Near-Shore, Estuarine, Lake and Pond Habitats

Riparian buffer literature cited above is derived primarily from work pertaining to streams, rivers and wetlands. Few data exist on the marine-riparian interface in the Pacific Northwest (Levings and Jamieson 2001). However, in many ways the needs of marine nearshore habitats are similar to those of streams and rivers and thus the buffer widths recommended for riverine habitats are also applicable to marine nearshore habitats. For example, as with streams, riparian areas can contribute significant amounts of food for marine fish. Duffy et al. (2002) found that terrestrial invertebrates made up a large contribution of the diet of fishes in north Puget Sound. A study of marine fishes along King County shorelines also found terrestrial insects were a significant part of the diet of juvenile salmon (Jim Brennan pers. comm., August 2003). Also, marine shorelines can be viewed as similar to riverine shorelines because of energy from tides, waves and currents, i.e., their condition is influenced by energy that scours, transports and deposits sediment and woody debris. Woody debris in marine nearshore environments is derived both from onsite vegetation and transported from offsite locations subject to longshore currents. Marine nearshore woody debris also contributes nutrients to nearshore environment, and is a major component in forming and maintaining shoreline structural habitat (Everett and Ruiz 1993).

With respect to the value of buffers for temperature and shading in the marine nearshore environment, Levings and Jamieson (2001) note that the temperature of surficial and interstitial water emanating from marine riparian areas and flowing into marine nearshore habitats may be affected by shading. Pentilla (2001) found that reduced survival of surf smelt eggs was related to reduced shade from trees overhanging marine nearshore spawning habitats. Freshwater aquifers emanating from underneath a riparian forest can discharge into the intertidal zone, creating localized fresh and brackish water habitats. Levings and Jamieson (2001) suggest that populations of some species of prey for marine fish (e.g., the amphipod *Paramoera bousfieldi*, Staude 1984) may be adapted to cool freshwater seeps as well as brackish conditions. The integrity of such aquifers and seeps could be affected by the integrity of the riparian vegetation (Levings and Jamieson 2001).

Levings and Jamieson (2001) also conducted a review of the literature pertaining to buffer width recommendations for protection of marine riparian habitat in British Columbia, Washington State and Alaska. Depending on shore class, recommended marine buffers zones in British Columbia range from approximately 300 feet (100 m) for Class B marine shores to approximately 450 feet (150 m) for Class A (1) and A (2) shores (those with low banks adjacent to open waters)

(Ministry of Forests 1996; Saanich Inlet Study 1996, both as cited in Levings and Jamieson 2001). In Washington State, the Shoreline Management Act sets a buffer zone of one-half SPTH or 100 feet (30 m), whichever is greater (Anon. 2001). In Chesapeake Bay, forest buffers of 35 to 125 feet (11 - 38 m) are recommended, depending on pollutant loading and site conditions (Palone and Todd 1977, as cited in Levings and Jamieson 2001). In addition, in the Tongass National Forest, protection is recommended for a 1,000-foot-wide (305 m) beach fringe of mostly unmodified forest, primarily for wildlife habitat protection (U.S. Forest Service 1997, as cited in Levings and Jamieson 2001).

Buffers for lakes and ponds are commonly prescribed, especially for protection of water quality. The basis for these prescriptions, however, seems to be derived from the literature for streams, rivers and wetlands, given the absence of scientific literature assessing functions or effectiveness of buffer widths for lakes and ponds. In a review of habitats and lakes, Schindler and Scheuerell (2002) note that studies of linkages between lakes and their riparian habitats are rare. Gasith and Hasler (1976, as cited in Schindler and Scheuerell) found that depending on riparian characteristics, shoreline complexity, and overall productivity of the aquatic system, litterfall from riparian vegetation can be a major source of organic matter to benthic and pelagic lake habitats. In some instances, terrestrial insects can provide substantial inputs of prey for lake dwelling predators and contribute to lake nutrient cycles (Carlton and Goldman 1984; Cole et al. 1990, both as cited in Schindler and Scheuerell). Schindler and Scheuerell (2002) also note that there has been almost no research on the roles of coarse woody debris (CWD) as habitat in lake ecosystems. However, they note that based on decomposition rates and habitat complexity associated with macrophytes, CWD would be expected to play a major role in providing habitat structure that could regulate predator-prey interactions along shorelines and in deeper benthic areas.

While woody debris is an important component of lake and pond habitat structure and serves as a nutrient source, it may be that it has less of a hydraulic function since erosive energy gradients along lake and pond shorelines are lower than those along riverine and marine shorelines. Wave action due to winds and fetch can be quite erosive on large lakes. In those places woody debris would be expected to play a role in dampening wave energy similar to its role in diffusing energy in stream channels. Temperature regulation by riparian vegetation is probably less critical since the overall thermal condition of lakes and ponds is regulated more by air temperature and temperature of tributary inputs than by microclimatic controls provided by surrounding riparian forests. However, spring seeps and surface runoff into lakes and ponds can create localized temperature gradients, and their temperature regimes could be influenced by riparian conditions. Also, the temperature of small spring-fed ponds and littoral lake habitats with northerly aspects may be influenced by the condition (height, width, species composition) of adjacent riparian forests. Other functions, such as terrestrial food sources, overhead shade (for hiding cover rather than temperature), bank stability, pollutant removal, etc., are likely similar for lakes and ponds as those affecting riverine and marine aquatic areas.

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

Protecting Landscape Scale Functions

Landscape scale measures (such as protection of forest cover) are needed to protect functions such as hydrology, sediment routing and nutrient cycling that largely originate in large part outside of the immediate riparian corridor (May 2000; Haberstock et al. 2000). Physical (severe erosion and flooding) and biological (loss of species productivity and diversity) effects tend to be more pronounced in heavily urbanized areas with considerable impervious surfaces (Booth and Reinelt 1993; Booth and Jackson 1997; May et al. 1997; Booth and Henshaw 2001) But they can also occur in relatively rural areas where impervious area is low but forest cover has been reduced (see Pess et al. 2002).

To help minimize impacts of development, a 65 percent forest retention standard has been implemented in selected watersheds of King County. For the Issaquah and Bear Creek Basins this is a requirement while for the Lower Cedar River its is a voluntary measure. (King County 1996; 1995 and 1998.) This 65 percent standard is being implemented through a 35 percent clearing restriction on rural residential zoned parcels within the selected watersheds. The Tri-County Model (2001) proposed a “65/10” standard for all rural residential zoned parcels. This standard called for retaining native vegetation on at least 65 percent of the parcel and restricting the amount of “effective impervious surface” to no more than 10 percent through application of runoff dispersion and infiltration techniques. The 65/10 standard was based on the estimated point when land use and land cover changes are observed to cause downstream channels to start to become seriously degraded (Booth 2000). While this 65/10 threshold is helpful in *minimizing* impacts, it is not sufficient for avoiding them, as measurable impact occurs at virtually any level of development (Booth et al. 2002). Booth et al. summarizes evidence of various aquatic resource damages associated with conversion of forest cover to impervious area, and the limitations and problems associated with reliance on traditional stormwater mitigation efforts such as detention ponds. They note that preservation of aquatic resources in developing areas must include impervious area limits, forest retention policies, stormwater detention, riparian buffer maintenance and protection of wetlands and unstable slopes. Specific elements (landscape level and riparian) for effective protection recommended by Booth et al. include:

- “clustered developments that protect half or more of the forest cover, preferably in headwater areas and around streams and wetlands to maintain intact riparian buffers;
- a maximum of 20 percent total impervious area, and substantially less effective impervious area through widespread reinfiltration of stormwater (Konrad and Burges 2001);
- on-site detention, realistically designed to control flow durations (not just peaks);
- riparian buffer and wetland protection zones that minimize road and utility crossings as well as overall clearing; and
- no construction on steep or unstable slopes.”

Finally, these authors stress that these recommendations rely on extrapolation, model results, and judgement and thus the specific values (not the concepts) are still tentative.

In summary, the key to attaining effective aquatic area protection against landscape level changes is maximizing native forest cover (including continuity of riparian areas along streams and wetlands) and minimizing impervious surfaces. Where this is not possible, conventional (albeit improved over historic practices) stormwater runoff controls that detain and clean stormwater to match predevelopment conditions in terms of timing and magnitudes of flows should be employed. In order to achieve this, it is critical to implement the most advanced and accurate methodologies to model stormwater runoff and treatment benefits such as the KCRTS model recommended by Jackson et al. (2001).

2.9 Strategies for Protection Conclusion

Historically, protection of aquatic habitats and species has been inadequate resulting in the ongoing decline of habitat and species diversity and productivity. In part this is because there was a high reliance on buffers which were too small to protect all the riparian-based ecological processes (forest succession and large woody debris recruitment, stream channel migration and beach and bank erosion) needed to sustain the aquatic areas they encompassed. But landscape level actions were also inadequate because they relied heavily on stormwater detention ponds, which were insufficient to protect or simulate the ecological processes (mainly forest hydrology) or high water quality. Furthermore, efforts at trying to mitigate impacts or restore habitats and species with artificial or unnatural approaches have not worked well, and in some cases have lead to unanticipated and costly damage repairs and ongoing maintenance because the nature of the problems were not well understood. Current approaches recommend concurrent application of both riparian-based such as buffers or vegetated filter strips for agriculture and landscape level actions ,such as protection of forest, minimizing impervious surface, and much enhanced stormwater controls. Furthermore, development and application of these approaches should be part of a larger conservation strategy that has clear biological goals and objectives, prioritizes actions to protect the best remaining places to achieve those goals, and preserves feasible opportunities for realistic restoration given type and intensity of land-use impacts.

3 ASSESSMENT OF PROPOSED KING COUNTY STANDARDS

3.1 Fixed Regulations – Proposed Critical Areas, Clearing and Grading, and Stormwater Ordinances

Buffers

Standards:

Overview of the Fixed Buffers: For waters classified as either Type S (Shorelines of the State; RCW 90.58) or Type F (waters not a Type S but that contain fish or fish habitat), the CAO proposes a minimum riparian buffer of 165 feet (50 m) for the Rural Area (i.e., outside Urban Growth Areas (UGA), APD, and FPD) and 115 feet (35 m) for unincorporated UGA areas. For urban waters classified as *Special Urban Waters*, defined as having high biological and habitat functioning, the rural buffer standard would apply. Buffer widths are variable and would be expanded to include steep slopes, mapped channel migration zones and wetlands. Furthermore, fish-bearing (Type F) waters are conservatively defined as streams 2ft or greater in width and with a sustained gradient of less than 22 percent or lakes and ponds connected to a known fish-bearing water by a stream channel of similar dimensions.

For Type N waters (no fish but drains via surface to fish-bearing water) a fixed 65-ft (20 m) buffers would be required, except on Bear Creek, tributary to the Sammamish River, where a 100-ft buffer would be required.

For Type O waters (i.e., no fish and no surface connection to a fish-bearing water) a 25 feet (8 m) buffer would be required.

Assessment:

Much of the logic for the proposed buffers stems from the Tri-County model proposal. Early in the development of the Tri-County model, the proposed total width of the management zone along fish-bearing waters was 300 feet (91 m), roughly equivalent to two SPTHs (using the FEMAT 1993 estimate of 150 feet, or 46 m, per SPTH). This distance was broken into a variable width inner "no-touch" zone that was a minimum of 150 feet and that expanded to include channel migration zones, steep slopes, and wetlands. A fixed outer 150-foot-wide zone in which a variety of low impact development activities could occur within certain clearing and impervious area limits bound this inner zone. As a result of linking buffer requirements with forest retention requirements, the Tri-County recommended width for the management zone was reduced to 200 feet composed to two zones: (1) a variable width, "no touch" inner zone (with a minimum 150 feet, or 46 m, distance equal to one SPTH but expanding to include wetlands, steep slopes and CMZs) and (2) a fixed width (50 ft., or 15 m) outer zone in which up to 65 percent forest cover would be retained or enough of the site would remain undeveloped to attain such cover. For salmonid-bearing streams in unincorporated UGAs, the Tri-County model called for a smaller 115 feet (35 m) variable width, "no touch" inner zone and a fixed width 85 feet (26 m) outer zone with enhanced stormwater measures including some required retention of vegetation (but not 65 percent). In both land-use settings, structures and other developments would be placed as far from the inner buffer as possible.

By comparison, for salmonid-bearing habitats, the proposed King County CAO eliminates the outer zone and, for Rural Area habitats, increases the no-touch buffer zone by 15 feet (5 m). The two-zone approach was eliminated to reduce complexity of implementation and to improve the likelihood the standard would be implemented properly. Also, the proposed CAO buffers continue to be coupled with clearing and impervious area restrictions to provide the forest cover/undisturbed vegetation functions that would have otherwise been provided by the outer zone.

Departure(s) from BAS

For Type S and F waters, the proposed buffers **are consistent with BAS** because they are:

1) variable in width to account for a) variability in ecological processes (steep slope erosion and channel migration zones) and b) connectivity with wetlands,

2) larger in rural and higher quality urban habitats and where salmonid resource values are higher, and

3) within the range of recommended buffers for shade, water temperature and erosion control, removal of sediment and pollution, and large woody debris recruitment, albeit on the low end for the latter function.

Departures from BAS are:

1) somewhat less than full riparian functionality and much less (roughly 55 percent) than what the literature would recommend for microclimate and wildlife (see Chapther 8 – Wildlife Areas for specific wildlife impacts); and

2) roughly 15 to 25 percent less than one SPTH assuming a good growing site and the dominant trees are 200- to 300-year-old conifers.

For Type N waters the proposed buffers **are mostly consistent with BAS**. They depart from BAS because they do not protect the microclimate function. They provide much more protection than is called for under Washington's Forest and Fish Agreement and the Washington DNR Habitat Conservation Plan, both of which have been subject to scientific review. However, additional protection may be warranted for streams in developing landscapes because land development impacts are more intense and permanent than forestry activities. Furthermore, headwater streams do not need woody debris as large as for larger fish-bearing streams because there is not the need for pool formation and hiding cover. Their small size and lower ability to transport material means smaller pieces of wood can play a relatively greater role in providing woody debris benefits such as channel stability and nutrient processing. Amphibians and other classes of animals using these waters may suffer, however, depending on the extent to which they benefit from channel complexity and large wood.

For *Type O water*, the proposed 25-foot wide buffers **are *not* consistent with BAS**. Buffers of this width provide relatively little protection for most riparian functions. The extent of these type waters is not known, but where they do exist they likely provide habitat for certain classes of animals other than fish, such as certain amphibians and insects, that are aquatic and do best in fishless environments. Furthermore, the buffer is not consistent with recommendations for pollutant and sediment removal, which in turn may effect water quality of fish-bearing waters that derive some of their flow from Type O waters.

For *Special Urban Waters*, the standards **are consistent with BAS**. They provide a scientifically based approach to recognizing higher valued and more intact habitat in otherwise highly impacted and constrained landscapes and apply the higher buffer standards in those areas.

Risk to Functions and Values

For all but microclimate functions, the risk to a function is considered low to moderate. The risk that microclimate protection will not be provided is high. For large woody debris recruitment, the risk is considered moderate. For a low-risk approach to buffers, Pollack and Kennard (1998) recommend 250-foot forested buffer widths along perennial streams, and widths equal to one site-potential tree height (at age 300 years—$SPTH_{300}$) along seasonal (intermittent) streams. Riparian forest along non-salmon-bearing channels that flow into salmon habitat is needed to provide appropriate supply regimes of water, sediment, LWD, and other materials. Pollack and Kennard (1998) point to studies and reviews that indicate debris flows and inputs from upstream sources as significant contributors of LWD to channels. Also, to prevent deleteriously high rates of LWD and sediment flow from intermittent and non-fish-bearing channels into salmonid waters, destabilization of steep tributary channels must be avoided (Hartman and Scrivener 1990). However, the Riparian Management Zone widths for such streams can be less than the 1-SPTH (site-potential tree height) distance that Pollack and Kennard (1998) recommend because most of the small, non-salmonid-bearing streams that the King County regulations cover are *lowland* headwater creeks. These creeks have a low gradient and are much less subject to destabilization and debris flows compared with those covered by Pollack and Kennard (1998), which arise mostly in mountain terrain that falls under Forest Practices regulations. Furthermore, where steep unstable slopes are of concern, larger set-backs will likely be applied primarily for human safety concerns. This should provide more protection that would occur through recommended buffers for resource protection alone.

The proposed systems of buffers are based on the protection of salmonids and their habitat. As such they are considered low risk to salmonids and most classes of plants and animals that are directly associated with their habitats. However, the standards are not "no-impact" and therefore some organisms may suffer. The standards are clearly lower where salmonids are not present. Thus, classes of plants and animals that could experience moderate to high risk of impact are those that are either extremely intolerant of even slight amounts of change and/or those that are highly dependent on microclimate for their persistence, especially those that may be found in Type N and O waters. For example, amphibians, especially giant salamanders and tailed frogs, would be a class of animals that would be expected to suffer if riparian areas become drier. Freshwater mussels and some long-lived species of insects (e.g., certain species of stoneflies) may be good examples of animals relatively intolerant of change.

Level of Uncertainty

There are at least five issues that create uncertainty about the level risk and cumulative effects associated with the proposed CAO buffer standards. Of the five concerns, numbers 1-4 would tend to increase risk and cumulative impacts while number 5 (*clearing restriction benefits*) would tend to decrease risk and impact.

1) *Natural variability in resource condition and distribution*. By their nature, application of prescribed standards, even those tailored according to a variety of land use and biological factors, run the risk of not fully or adequately addressing local variations in resource conditions or land management needs. There is however, no mechanism for regulations to be increased based on new or better knowledge about local conditions. Thus, the concern from a resource protection standpoint is ensuring *a priori* that the buffers will be adequate in all cases, or at least in those cases considered most important for resource protection. The degree of risk caused by the latter situation is uncertain, but appears to be relatively small for salmonids and not likely to create serious problems for the protection of aquatic areas and species associated with salmonids. This is because many of the risk factors (e.g., presence of steep slopes, wetlands, channel migration zones) have been anticipated and the variable nature of the buffers should accommodate those variations. Further, Lucchetti (2002) found that for endangered chinook salmon and bull trout, arguably the two most critical salmonid species for which to ensure adequate protection, almost all of their habitat under King County jurisdiction will get the highest rural protections.

2) *Exceptions and allowed alterations*. Exceptions (i.e., activities that would not require a permit) and allowed alterations (i.e., activities that would be allowed in an aquatic area or a buffer) are a concern because the frequency and geographic extent of occurrence of these activities is unknown creating an unknown – but not zero – level of risk. For a discussion of allowed alterations see separate section below). Exceptions include activities such as house painting and other basic house and landscape maintenance, which are clearly very low impact.

3) *Application of standards to situations where they may not apply*. The riparian buffer standards are largely derived from studies and logic that assumes the buffer is already forested. However, in many situations riparian areas have little or no existing forest and what forest is present is often heavily degraded. There is no scientific literature that provides direction for sizing non-forested buffers or buffers in a degraded condition. In addition, there is no legal mechanism to require landowners to mitigate for an existing condition (i.e., after the fact) although some programs (e.g., tax incentives, forest stewardship program) do provide financial incentives and technical assistance for those landowners willing to reforest buffers and other sensitive areas. Thus, until a healthy, mature riparian forest is established, the protected buffers would provide fewer functions and protective benefits than a forested buffer. It may be reasonable to assume that while near term goals may not be attained, long term goals should be served as the natural forest condition recovers, provided land owners follow the regulations and allow riparian forests to regenerate.

4) *Agriculture and the limitations agriculture places aquatic habitats. (See separate section on agriculture below.)*

5) *Clearing restriction benefits*. *(See separate section on clearing restrictions below.)* In rural areas, concerns over the size of the buffers may be alleviated by rural restrictions on clearing in rural areas. These restrictions should serve to protect forest or areas that could be forested. Forest at the landscape level can help reduce wind and erosion problems thus reducing reliance on buffers. Depending on the extent of the forest and its contiguity with the buffers, some of the concerns for loss of microclimate could be alleviated.

Buffers are perhaps the most studied scientific concept relative to protection of aquatic resources. Thus, while there remains a degree of uncertainty over the BAS for buffers, it is probably less than for any other element of aquatic resource protection. There is high certainty that buffers are a valuable part of a larger habitat protection and species conservation strategy and no credible source advocates "no or exceedingly small buffers" as part of a strategy for protecting habitats and species from the effects of land use. Depending on goals and objectives and risk tolerance, most recommend from one to two SPTH. Typically, the debate, and therefore the uncertainty, is over how wide for a given type of water, applicability for various types and intensities of land use, and what is the desired vegetative condition of the buffer. This stems from the concern to be efficient and not burden landowners and managers with needlessly wide buffers.

Allowed Alterations

Overview: A wide range of activities that could potentially damage aquatic habitats and habitat processes are classified as "allowed alterations" and given special dispensation to occur in aquatic areas or their buffers. These activities include new road crossings and utility lines or maintenance of such infrastructure have the potential to create impact, such as fragmentation of riparian corridors, that is not readily mitigated, if at all. Still, these actions do generally require avoidance and minimization of impact and full mitigation where impact is unavoidable, thus their classification as an "allowed alterations" does not mean they can be implemented without concern for impacts. These activities are allowed because they are considered to be either very low impact, necessary to meet legal requirements (e.g., constitutionally guaranteed property rights), or necessary to efficiently meet other goals of the County. Some of these activities are limited to maintenance and repair, such as for existing residential land uses, flood control facilities and roads, providing there is no expansion of the use. In some of the potentially more damaging activities, BMPs that guide the timing and type of construction and that provide guidance for site restoration after construction must be followed. Other activities, such as new roads or utility crossings across small streams (< 20 cfs mean annual flow) would be new or significant changes in existing structures and would be subject to proof that there is no feasible alternative. In all but the most innocuous cases, use of BMPs, impact avoidance, and full mitigation of unavoidable impacts would be required.

Assessment:

There is no direct BAS for allowed alterations, *per se*. However, many of the allowed alterations are ongoing or new incursions into buffers and aquatic areas. These incursions would tend to fragment habitats and there is considerable science that shows fragmentation creates barriers to species migration and transport of sediment, nutrient and woody debris. Thus, the standard for allowed alterations is a departure from what the BAS would indicate is protective of aquatic areas and species.

Risk to Functions and Values

Risk to functions and biological values caused by allowed alterations would be considered potentially moderate to high depending on the frequency and geographic extent of the alterations. The intensity of impact of any individual alteration is generally low, however if they occur at moderate to high frequency and over a large geographic extent the cumulative effect could be high. In some cases, existing impacts and associated risks may be reduced by use of site restoration BMPs (for example, maintenance and repair of flood control facility requires use of native vegetation and LWD). In other situations, such as expansion of an existing road or residential land use, the impact is limited by requirements that limit the size of expansion and that require such expansions occur away from a critical area or its buffer. Mots problematic would be new alterations, such as new utility crossing and roads. Proponents of new alterations would be required to show there is no feasible alternative and follow stringent avoidance, minimization, and mitigation requirements. This does not guarantee, however, that they would occur at a low frequency or in a very limited geographic extent.

Level of Uncertainty

This standard allows many relatively small, but cumulatively significant activities to occur or be created. While it is likely that risk will increase due to this standard, these is a large degree of uncertainty regarding the degree to which it will increase because the number and type of activities is unknown. There is no science of allowed alterations, thus no assessment of uncertainty of BAS on this subject is provided.

Mitigation

See Chapter 9 – Wetlands for an assessment of mitigation that is applicable to other aquatic areas.

Clearing Restrictions

Standard: 35 Percent Clearing Restriction

> *Clearing shall be limited to a maximum of 35 percent of the development proposal site. The restrictions would apply when an expansion or change in land use is propose on RA-zoned parcels in the Rural Area (excludes unincorporated UGA, APD, and FPD). When a change in land use is not proposed, a maximum clearing limit still applies, but the open space requirement only applies to area that has not been legally cleared beyond the 35 percent maximum.*

Overview: This standard would restrict clearing to a maximum of 35 percent of the development proposal site. The restrictions would apply when an expansion or change in land use is proposed on RA-zoned parcels in the Rural Area (excludes unincorporated UGA, APD, and FPD). Small lots (generally < 0.5 acre) and industrial and commercially zoned lots would not be subject to this restriction. However, these land constitute a small percentage of the area (< 5 percent) while rural residential parcels > 0.5 acre constitute around 85 percent of the land base, thus most rural residential land would be subject to this restriction. When a change in land use is not proposed, a maximum clearing limit still applies, but the open space requirement only applies to area that has not been legally cleared beyond the 35 percent maximum.

Assessment:

This standard **is *mostly* consistent with BAS** because it strives to protect natural hydrology at the landscape scale and at the level recommended by the literature to protect hydrology. The standard **departs from BAS**, however, because it: (1) doesn't emphasize protection of hydrologically mature forest (which is the intent of the 65 percent forest retention element of the 65/10 goal); and (2) doesn't require contiguity of preserved vegetation with riparian buffers or upland wildlife habitat.

Risk to Functions and Values

Risk to hydrology and sediment functions is considered low for most situations. Risk may rise to a moderate level when the standard is applied in steep sub-basins with high amounts of glacial till, which would tend to increase potential for erosion caused by relatively small changes in peak flows and durations. This clearing restriction standard was derived from the 65/10 stormwater standard, originally developed for the Issaquah Basin using empirical information on stream conditions and level of development from that basin. Thus, it is most applicable for watersheds with rainfall, vegetation, soil, and topography similar to the Issaquah Basin. Where watersheds are similar or less sensitive to change (e.g., less steep channels, less rainfall, less glacial till) than Issaquah Basin, downside risk of applying the 35 percent clearing restriction standard is considered low. Where watershed characteristics are more sensitive to change (steeper, more rainfall, more till) than Issaquah, the standard is not likely to achieve its goal and habitat will be at higher risk. It is expected that these areas would generally be small steep drainages with limited direct use by salmonids other than cutthroat trout (due to the propensity for them to occupy small steep streams). The larger concern is that these smaller steep streams may be important to their receiving areas and if destabilized by the effects of rural development may deliver excessive sediment or polluted water to the receiving water body or shoreline.

The proposed clearing restriction is based on the protection of salmonids and their stream habitat. As such they are considered relatively low risk to salmonids and most classes of plants and animals that are directly associated with their habitats. However, the standard is not a "no-impact" standard and therefore some habitat will degrade and organisms may suffer. Classes of plants and animals that could experience moderate to high risk of impact, depending on steepness and sensitivity of habitat to erosion, are those that are either extremely intolerant of even slight amounts of change and/or those that are highly dependent on stable channels, low levels of silt and fine sediment and high water quality for their persistence. As noted earlier, amphibians, especially giant salamanders and tailed frogs, freshwater mussels and some long-lived species of insects (e.g., certain species of stoneflies) may be good examples of animals relatively intolerant of change.

Level of Uncertainty

Because the science is clear that protection of native vegetation (especially hydrologically mature forests) is a valuable part of an aquatic habitat protection strategy, there is low uncertainty about the risk to functions and generally about biological benefits as well. However, because this is not a no-impact standard and it has not been adequately evaluated in Bear and Issaquah creeks, where it has been implemented, there is a high degree of uncertainty about whether the standard is sufficient to provide substantial protection for highly sensitive, pollution-intolerant species. Similarly, there is little doubt that cumulative effects of land use will be much less with this standard, the cumulative effect or value of allowing landscapes with considerably more than 65 percent forest cover to degrade to 65 percent is not well known, creating significant uncertainty that the standard will be effective over the long term.

Stormwater Control

Standard –10 Percent Impervious Surface:

An impacting impervious surface limit of 10 percent is proposed for projects on Rural Area zoned residential parcels. Impacting impervious surface is that portion of actual impervious surface that has an effect on downstream flows.

See general description in Chapter 1 – Introduction or, for more detail see http://www.metrokc.gov/ddes/cao/ or http://dnr.metrokc.gov/wlr/dss/Manual-Draft.htm

Assessment:

The proposed stormwater ordinance and SWDM update **is consistent with BAS**. King County's proposed manual update, together with other stormwater-related changes in the Clearing & Grading Ordinance, is considered equivalent to and in some ways more protective of habitat than the latest Washington State Dept. of Ecology (WDOE) *Stormwater Management Manual for Western Washington*, published in August 2001 (WDOE 2001). Examples of more protective features include a proposed 65 percent forest protection standard applied in rural areas (a.k.a. the 35 percent clearing restriction standard, see above), required use of full dispersion/infiltration measures to minimize effective impervious surface on rural development sites, required pipe conveyance of discharges through mapped landslide hazard areas and certain steep slope hazard areas, and increased flow control required where severe flooding problems are known downstream.

The WDOE manual recently underwent a BAS evaluation by Washington State's Independent Science Panel (WISP 2003). The panel concluded that the WDOE did "a credible job of developing guidelines and standards" and that the manual was one of the most comprehensive in the United States and impressive in its scope, coverage and quality." Three concerns were expressed by the WISP: (1) that a larger watershed scale perspective is needed to assure that desired goals are met, including salmon; (2) monitoring is needed to assess implementation, effectiveness and validation both onsite and downstream and to help extrapolate procedures to other locations; and (3) an adaptive management plan should be instituted to assure timely correction of problems and to guide future management. The panel also noted that of the manual should help prevent further degradation of stream channels but that a reversal of declining trends in habitat conditions for salmon was not a specific goal of the manual and that "information needed to design adequate guidelines to prevent "fish kills" is generally lacking, especially for effects of interacting pollutants." Although they raised a variety of technical concerns regarding specific standards or requirements, the panel felt the scientific issues were insufficient to preclude use of the manual.

At least some of the concerns raised by the WISP, are dealt with in the King County manual, especially those dealing with using a watershed perspective. The County's use of three different levels of stormwater control reflects experience gained from extensive basin planning by King County from the late 1980s through the 1990s. For example, among other things, the county informed its stormwater management by identifying key stream and wetland habitats (Locally and Regionally Significant Resource Areas) which in turn lead to higher levels of stormwater treatment to protect those areas.

Risk to Functions and Values

There are two principal risk concerns with the stormwater control proposal. The first is that it is not "no impact," thus some degradation of stream channels and water quality above current levels is likely to occur even in rural areas where a 65 percent forest protection standard is proposed. Secondly, by not applying a 65 percent forest cover protection standard (beyond required critical area buffers) in those urban areas where significant forest cover remains, some additional loss of forest-based hydrology and water quality will occur. This will place greater reliance on artificial methods of control (e.g., detention facilities) which are not as effective as natural forests at protecting hydrology and water quality. The likely result will be some incremental degradation of habit (erosion, siltation, poorer water quality) with effects likely to be greater in urban than rural areas which will have forest retention requirements, but nonetheless occurring to some extent in both areas.

The proposed stormwater manual changes will increase the mitigation measures applied to new development and redevelopment to further minimize flooding and erosion risks and increase protection of water quality and salmonids and their stream habitat. As such, the changes to stormwater standards will generally increase protection above existing standards and are therefore considered relatively low risk to salmonids and most plants and animals that are directly associated with their habitats. However, as noted earlier, the proposed changes are not a "no-impact" standard of mitigation and therefore some habitat will degrade and, as a result, some organisms may suffer. Classes of plants and animals that could experience moderate to high risk of impact are those that are extremely intolerant of even slight amounts of change from natural water flow fluctuations or high water quality and that are highly dependent on clean, stable, gravel-bedded channels for their persistence. The likelihood and degree of impact would be expected to be higher for steep, erosion prone stream channels. As noted earlier, amphibians, especially giant salamanders and tailed frogs, freshwater mussels and some long-lived species of insects (e.g., certain long-lived species of stoneflies) may be good examples of animals relatively intolerant of change.

Level of Risk

Because the science is clear that proper stormwater controls are a valuable part of an aquatic habitat protection strategy in developing landscapes, there is generally low uncertainty about the risk and biological benefits of hydrologic aspects of the stormwater standard. There is also little doubt that treatment of stormwater for certain, well-studied conventional pollutants can be effective. There is an emerging high uncertainty, however, about the efficacy of the proposed treatment for removing chemicals such as endocrine disrupters, which affect reproductive physiology of fishes.

Furthermore, because the stormwater element is not a "no-impact" standard and it's biological efficacy has not yet been fully evaluated, there is a high degree of uncertainty about whether the standard is sufficient to meet the salmonid protection objectives and even greater uncertainty about its effect on more highly sensitive, pollution-intolerant species. Similarly, while there is little doubt that cumulative effects of land use will be much less with this standard, the cumulative effect or value of allowing development to rely wholly (in urban areas) or in part (in rural areas) on engineered solutions such as R/D ponds and bioswales is not well known, creating significant uncertainty that the standard will be effective over the long term.

3.2 Farm Planning

Standard – Best Management Practices:

> *Site specific performance standards and best management practices to protect and enhance critical areas and their buffers, and maintain and enhance native vegetation on the site. This includes BMPs for the installation and maintenance of agricultural drainage.*

See Appendix C, The Effects of Agricultural Operations on Critical Areas.

Assessment:

Based on analysis in Appendix C, the farm planning element departs from Best Available Science because it does not provide for the greatest probability of protection of a critical area, equal to a "no net loss" standard for functions and values.

Risk to Functions and Values

Appendix C (Table 1) notes that the present condition of the agricultural landscape in King County imposes considerable risk on most of the functions and values associated with the critical areas found in those landscapes. Table 1 of Appendix C provides detailed assessment of functions under current, five-year and twenty-five year timeframes for existing, new and expanded agriculture (forested or non-forested settings) and agricultural ditch maintenance.

3.3 Rural Stewardship Planning

Standard – Buffers – Variable:

> *Buffers may be reduced based on a combination of factors that include the amount of native vegetation and site location. For wetlands, the existing wetland function is also included.*

Standard – Best Management Practices:

The Rural Stewardship Plan will include site specific performance standards and best management practices to protect and enhance critical areas and their buffers, and maintain and enhance native vegetation on the site. An implementation plan for performance standards and best management practices will be developed.

KEY

Subbasin condition and location in the subbasin are on maps adopted in accordance with section 142 of this ordinance.

The criteria to determine buffer condition and maximum clearing requirements are set forth in section 142 of this ordinance.

AQUATIC AREA TYPE	SUBBASIN CONDITION	LOCATION IN SUBBASIN	BUFFER CONDITION	MAXIMUM CLEARING	BUFFER SIZE
Type S or F	High	Upper	Low	25%	125 feet
	High	Lower	Low	25 %	125 feet
	Medium	Upper	Low	25%	125 feet
	High	Upper	Low	15%	80 feet
	High	Lower	Low	15%	80 feet
	Medium	Upper	Low	15%	80 feet
	Medium	Lower	High	50%	125 feet
	Low	Upper	High	50%	125 feet
	Low	Upper	Low	50%	125 feet
	Low	Lower	High	50%	125 feet
	Medium	Lower	Low	0% 1	80 feet
	Low	Lower	Low	0% 1	80 feet
Type N	High	Upper	Low	25%	50 feet
	High	Lower	Low	25 %	50 feet
	Medium	Upper	Low	25%	50 feet
	High	Upper	Low	15%	30 feet
	High	Lower	Low	15%	30 feet
	Medium	Upper	Low	15%	30 feet
	Medium	Lower	High	50%	50 feet
	Low	Upper	High	50%	50 feet
	Low	Upper	Low	50%	50 feet
	Low	Lower	High	50%	50 feet
	Medium	Lower	Low	0% 1	30 feet
	Low	Lower	Low	0% 1	30 feet
Type O	High	Upper	Low	25%	20 feet
	High	Lower	Low	25 %	20 feet
	Medium	Upper	Low	25%	20 feet
	High	Upper	Low	15%	15 feet
	High	Lower	Low	15%	15 feet
	Medium	Upper	Low	15%	15 feet
	Medium	Lower	High	50%	20 feet
	Low	Upper	High	50%	20 feet
	Low	Upper	Low	50%	20 feet
	Low	Lower	High	50%	20 feet
	Medium	Lower	Low	0% 1	15 feet
	Low	Lower	Low	0% 1	15 feet

Assessment:

The Rural Stewardship Plan is **mostly consistent with BAS** because it sets standards based on sub-basin, site, and biological context. It **departs from BAS** for the same concerns about adequacy of the size of the fixed buffer widths and clearing restrictions and for protecting microclimate and wildlife functions.

Risk to Functions and Values

This standard provides greater flexibility to landowners but no greater protection of aquatic areas. In many instances, it may actually provide for substantially less protection than would the fixed standards. Thus risk to functions and biological values would be similar to or higher than for the fixed standards. Because the flexibility and reductions would be tailored to landscape and site location and condition and biological value, the increase in risk will be minimized. As with the fixed standards, this proposal is probably low risk to salmonids and moderate to high risk for highly sensitive, pollution-intolerant species.

Level of Risk

Because there is high uncertainty about how many landowners will choose this option and thus there is uncertainty about the degree and geographic scope of its application. Thus there is high uncertainty about the standards overall risk and cumulative effects. There is low uncertainty about the BAS that a tailored approach to protection measures is appropriate but high uncertainty about the variables and thresholds for making decisions.

3.4 Institutional Context and Consistency with BAS

Just as aquatic areas and their species exist in an ecological context which must be understood to evaluate effectiveness of standards, so should the standards be understood in the context of the institution that implements them. For example, high standards may be ineffective if a jurisdiction applies them blindly or doesn't enforce them. Similarly low standards may be more effective than they appear if implemented in the context of other management actions, such as capital and programmatic actions, that protect or restore habitat and if the agency has a history of proper planning, informed management, and adequate enforcement.

King County is a large municipal government with major responsibility for managing highly diverse and often fractious land use and natural resource issues. By the mid-1980s, serious erosion and flooding problems caused by improperly controlled land use were becoming apparent (see Booth 1989). In response, the County conducted a Basin Reconnaissance program followed by more in-depth and more-sophisticated Basin Planning program. These programs focused on identifying and understanding the cause of problems and then identifying and prioritizing solutions in King County's Surface Water Utility Fee Service Area (mainly urbanizing areas). Solutions focused on prevention or reducing impacts of development on people, property and infrastructure as well as protection and restoration of water quality and key aquatic resources.

For aquatic habitats and species, the Basin Planning program's key strategy was protection and restoration of biologically productive, unique or rare resources. Key to this was the identification and protection of "the best" habitats using the Regionally and Locally Significant Resource Areas (RSRA and LSRA) concept. While a primary emphasis of this planning was salmonid based, other aquatic resources were also a priority, resulting in designation of bogs and other non-salmonid habitats as significant resource areas. Today, much of King County's habitat-based programs, regulations, capital projects and even the UGA boundaries reflect information that was developed under the Reconnaissance and Basin Planning programs. Monitoring programs were developed and implemented to assess the effectiveness of the Basin Planning programs and make course changes as needed.

In 1998 listing of two salmonids, Puget Sound chinook and Coastal bull trout, on the federal Endangered Species Act shifted attention even more toward salmon-based conservation, although significant work continues to be done for other species and habitats (see for example studies by Fevold and Vanderhoof (2002) on mussels and William's et al. 2001 on the near-shore environment). In response to the ESA listings, King County conducted an unprecedented, comprehensive biological review of the consistency of its regulatory, maintenance and capital programs with salmon conservation (see "Return of the Kings", King County 1999). Following this, King County joined with Snohomish and Pierce counties and major cities including Seattle, Bellevue, Everett and Tacoma, to develop a model proposal for saving salmon in the Tri-County area (Tri-County 2001). The regulatory elements of the Tri-County model proposal, as well as the early action and watershed salmon conservation planning programs it instigated, are the basis for most of the aquatic area protections in the proposed CAO and Stormwater ordinances. A biological review of the scientific basis for and efficacy of Tri-County program was recently conducted (Parametrix 2002). The review concluded that model proposal is primarily based on BAS and is likely to conserve habitat and habitat functions supporting salmonid species consistent with federal guidelines. The Tri-County proposal was focused on salmonid conservation, however, and as a result did not explicitly address the needs of all fish and wildlife or of GMA designated critical areas and functions.

As a result of this attention on salmonids, major multi-jurisdiction and interdisciplinary planning efforts have been implemented and early actions to protect and restore the aquatic habitats and change programs have occurred at almost all levels of County government. King County has developed a strategic and comprehensive approach to aquatic resource conservation, still heavily focused on salmonids but also with considerable attention toward protecting or restoring ecological processes which benefits a variety of plants and animals. Just since 2000, the County has spent approximately $17.3 million to acquire 2,300 acres (931 ha) in riparian areas, forested watershed areas, and floodplains. Furthermore, the County's Comprehensive Plan and environmental regulations have been modified several times in response to increased knowledge about the problems and needs related to aquatic resources. Major changes to minimize the impacts of roads and wastewater maintenance on aquatic areas have also been implemented. Additionally, the County funds substantial public education and involvement programs for aquatic resource protection.

Management and regulation of agriculture (horticulture and livestock production) has been a unique situation in King County. The County has spent considerable effort and money to protect and promote agricultural lands and industries. This has been done to support agriculture based economies, provide for availability of locally grown products and protect the rural, agrarian lifestyle. To help with this, agricultural lands and activities tend to receive less-restrictive regulations to ensure the economic viability of agriculture. Unfortunately, many agricultural areas surround, straddle or are adjacent to aquatic areas or are situated in drained and radically modified floodplains that historically had extensive and productive aquatic habitats, such as side-channels, oxbow ponds, springs, and wetlands in particular (Bissonette 2003). As a result, there is often conflict between agricultural and aquatic resource goals.

To help resolve this conflict, King County has expended considerable effort in studying the effects of agriculture and has implemented projects to promoted a series of projects to update and monitor Best Management Practices (BMPs) and develop new ones as needed. These programs have increased our knowledge about agricultural practices and habitat impacts considerably and has been translated into new or improved BMPs (e.g., requirement of VFS and winter cover crops and fencing requirement in the Snoqualmie Valley, where it wasn't previously required) in the proposed CAO. See the Appendix C on Agriculture for more description of agriculture and proposed BMPS.

Institutional Risks and Uncertainties

Despite the major King County's investments and advancements described above, some uncertainty and associated risk remains in at least four elements: roads planning and capital programs, agricultural lands, enforcement and monitoring. Unlike the County's road maintenance program, the roads capital program has not yet engaged in comprehensive planning to help guide its activities in a manner consistent with conservation of aquatic resources; and yet roads can have significant impacts to aquatic resources (Alberti et al. 2003). Road construction (new and redevelopment) will be required to abide by the proposed CAO, but the planning phase of road network design often dictates the placement and nature of the road. If the original road planning did not properly consider impacts to aquatic resources, then regulations can only help to minimize the impact. Further, relying on mitigation is generally unsatisfactory, as mitigation projects often fail to provide full mitigation of impact (King County 1998; Ecology 2000; Ecology 2002).

Effective protection of aquatic areas will also rely on effective enforcement. Chasan (2000) discusses widespread failure associated with lack of enforcement of environmental laws. Mockler et al. (1998) found that failure to enforce mitigation agreements was a primary factor in poor performance of mitigation. The level of enforcement necessary to ensure compliance with the proposed CAO and Stormwater Manual is unknown.

Finally, monitoring is extensively performed in King County, but a comprehensive summary of this information has not been accomplished. However, data management systems are being developed and a more comprehensive picture based on data collected to date is expected in the next few years. Also, while highly desirable, the presence or lack of monitoring information does not result in aquatic area impacts, *per se*.

In sum, these major actions and improvements made over the years by King County indicate that the proposed CAO is part of a larger, systematic and comprehensive approach to protect and restore habitats. This should help to lower the risk associated with departures from BAS.

4 CONCLUSION

OVERALL CONSISTENCY OF PROTECTION APPROACH WITH BAS

The proposed CAO and Stormwater Ordinances updates are a major improvement in protections for aquatic resources, with provisions for comprehensive protection of not only specific aquatic areas but also the ecological processes that form and sustain them. For the most part, the proposed standards and the institutional context in which they developed and would be implemented are highly consistent with aquatic area protection BAS. For the standards, primary departures from BAS are lack of effective buffers for microclimate control, small buffers on Type O waters, and, in farm planning, inadequately sized buffers and BMPs to provide more than improved water quality benefits.

Biologically, the proposal is a relatively low incremental risk strategy for protection of salmonids and salmonid habitat forming processes. The overall proposal is not "no impact," however, and as result pollution and change intolerant species could be placed at moderate to high risk. In freshwater, examples of such species may include pacific giant salamanders, tailed frogs, freshwater mussels and certain long-lived species of stoneflies. In marine waters, particularly sensitive species include eel grass, beach spawning forages fish, such as surf smelt and sandlance, and certain halophytic plants (dune grasses and sedges) that rely on soft, sandy shorelines.

Major uncertainties that could increase risk include a lack of knowledge about local conditions and sensitive species, and the efficacy of the proposed standards. Also, a wide variety of alterations would be given special dispensation to occur in aquatic areas or their buffers. Individually the impacts of these may be small, but they will create additional burden on habitats and species and if they occur at high frequency, may have a significant cumulative impact.

One uncertainty that may actually reduce risk is the proposal's combination of both riparian *and* upland protection measures, which may help to offset their individual weaknesses. For example, having clearing restrictions to protect vegetation across the broader landscape could help to offset the effects of buffers that may be too small.

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