BELLEVUE CRITICAL AREAS UPDATE
BEST AVAILABLE SCIENCE PAPER: WETLANDS

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I. INTRODUCTION

This paper provides an overview of the "best available science" pertaining to management of wetlands and its application to urban environments such as those found in the city of Bellevue. In 1990, a new rule under Washington State's Growth Management Act (GMA) (RCW 36.70A.060) required counties and cities to adopt development regulations that protect the functions and values of critical areas, including wetlands. In 1995, the Washington State legislature added a new section to the GMA to ensure that counties and cities consider reliable scientific information when adopting policies and development regulations to designate and protect critical areas. As a result of this legislation, in 2000 the Growth Management Division of Washington's Office of Community Development (OCD) adopted as a rule procedural criteria to guide cities and counties in identifying and including the best available science in their critical area policies and regulations. In accordance with RCW 36.70A.172(1), communities "shall include the best available science in developing policies and development regulations to protect the functions and values of critical areas, including wetlands.

In thinking about the requirements of best available science, it is important to understand that the old rule makers began with the assumption that one of the objectives of GMA was to protect the functions and values of critical areas. They reasoned that this could only be achieved if those developing regulations: (1) accurately described these functions and values; (2) understood the likely adverse impacts associated with proposed land use planning alternatives; and, (3) made land use decisions that minimized or eliminated those adverse impacts to the extent possible. The rule makers concluded that identifying and describing functions and values and estimating the types and likely magnitudes of adverse impacts were scientific activities. Thus the team concluded that RCW 36.70A.172(1) required the **substantive inclusion** of best available science in developing critical area policies and regulations. This conclusion was eventually enshrined in the Best Available Science rule, which took effect on August 27, 2000.

Wetlands provide important functions and values for both the human and biological environment—these functions include flood control, water quality improvement, and nutrient production. This paper builds on the wetland inventory report by discussing in greater detail relevant research pertaining to wetland functions and values, as well as the challenges of managing wetland areas in urban settings such as those found in Bellevue. The following sections also discuss considerations such as wetland protection, mitigation, enhancement, and restoration strategies. Finally, gaps in information are noted where applicable.

II. WETLAND FUNCTIONS AND EFFECTS OF URBANIZATION

Wetlands are integral parts of Bellevue's natural landscape. Their "functions and values" to both the environment and to the citizens of Bellevue depend on several elements including their size and location within a basin, as well as their diversity and quality. While each of Bellevue's wetlands provides various beneficial functions, not all wetlands perform all functions, nor do they perform all functions equally well (Novitski et al., 1995).

Several studies have found that wetland functions and values are compromised by urbanization (Azous and Horner, 2001; Mitsch and Gosselink, 2000; Castelle et al., 1992a; May et al., 1997; Booth, 2000; City of Portland, 2001). In urban settings individual functions of wetlands may not be optimally functioning. However, the combined effect of functional processes of wetlands within basins provides benefits to both natural and human environments. For example, wetlands provide significant stormwater control, even if they are degraded and comprise only a small percentage of area within a basin. Also, wetlands are important elements of stream systems and fish habitat. Within the urban environment, even degraded wetlands can provide rearing and refuge habitat for fish and other wildlife, along with other benefits to keeping streams healthy.

As discussed in the Best Available Science Paper for streams, the synergistic effect of the available stream functions including wetlands, are sufficient to support salmonids within Bellevue's streams. The geographic location, topography, geology, and level of existing urbanization in the City of Bellevue limit the extent to which its streams can provide the functions described below. However, even in urban settings where individual functions of wetlands are not optimal, the combined effect of the functional conditions within the wetland systems may provide many of the functional benefits to be expressed. Protection and restoration of wetlands will maintain and improve their functional benefits to both natural and human environments.

Wetland Functional Assessment

The functions provided by wetlands and their assigned human-based values have been identified and evaluated through several studies (Cowardin et al., 1979; Adamus et al., 1987; Mitsch and Gosselink, 2000; Hruby, 1995; Reppert et al., 1979; Cooke, 1995). These functions include:

- Flood water attenuation and flood peak desynchronization;
- Stream base flow maintenance and groundwater support;
- Water quality improvement;
- Erosion / shoreline protection;
- Biological support and wildlife habitat; and
- Recreation, education, cultural resources, and open space.

Each of these functions is discussed in greater detail in following sections.

Several functional assessment methods have been developed to identify functions performed in a wetland and evaluate the effectiveness of the wetland in performing that function. Some methods are quantitative, while others are qualitative. For example, the Reppert method is a qualitative functional assessment based on vegetative and wetland habitat features, and uses the wetland classification system adopted by the U.S. Fish and Wildlife Service. Several modified methods have since been developed from Reppert to create semi-quantitative assessment methods, such as the Wetland and Buffer Functions Semi-quantitative Assessment Methodology by Sarah Cooke (1996).

Other assessment methods, including those developed by the U.S. Army Corps of Engineers, are more quantitative. For example, the Hydrogeomorphic Method (HGM) is based on the concept that wetland functions are driven primarily by the wetland's geomorphology (i.e., position in the landscape) and hydrologic characteristics (Brinson, 1993; Brinson, 1995). Other semi-quantitative functional assessment methods include the Wetland Evaluation Technique (WET) developed by Adamus et al. (1987) and the Indicator Value Assessment (IVA) by Hruby et al. (1995).

In 1996, Washington Department of Ecology (Ecology) began the Washington State Wetland Function Assessment Method (WFAM) project. The new functional assessment method, which was published in 1999, is a modified version of the HGM approach and is designed to provide a more scientific approach to assessing wetland functions (Hruby et al., 1999). This method is based on research using reference wetlands; to date, Ecology has developed methods based only on reference wetlands for riverine and depressional wetlands in the lowlands of western Washington. While based on science, this method requires additional field investigations and extensive training and cannot be conducted rapidly.

In 2000, Washington State Department of Transportation (WSDOT) developed another method for rapid wetland assessments for linear projects (Null et al., 2000); this is referred to as the "Wetland Functions Characterization Tool for Linear Projects." The WSDOT method is adapted, in part, from the Highway Methodology Workbook Supplement for Wetland Functions and Values (U.S. Army Corps of Engineers, 1995). The WSDOT method is considered a qualitative method and is based on the best professional judgment of a wetland specialist in the field. Along with the WFAM, the WSDOT method is also cited in the OCD citations for best available science.

Flood Water Attenuation and Flood Peak Desynchronization

Overview

Wetlands control stormwater flow by attenuating surface water runoff during and after storms and slowly releasing it to groundwater and/or to adjacent water bodies. Research has shown that this function can reduce and desynchronize peak flood crests and flow rates of floods (Novitzki, 1979 and Verry and Boelter, 1979 *in* Mitsch and Gosselink, 2000). The efficiency of a particular wetland system in controlling runoff is based on factors such as the storage capacity and outlet discharge capacity of the wetland relative to the magnitude of stormwater inflow (Marble, 1992; Reinelt and Horner, 1991). The effectiveness of a wetland in reducing downstream flooding increases with:

- An increase in wetland area;
- The size of the flood;
- The proximity to an upstream wetland;
- The proximity of the wetland to the flooded area; and
- The lack of other storage areas (Mitsch and Gosselink, 2000; Erwin, 1990).

Urbanization and Flood/Stormwater Control

In urban areas, the loss of wetlands or wetland area will affect their function in attenuating stormwater runoff, resulting in increased flood frequency and higher peak flood flows in drainage basins (Azous and Horner, 2001; Mitsch and Gosselink, 2000; Booth, 2000). As discussed in the wetland inventory, total impervious area in Bellevue's storm drainage basins ranges from approximately 25 percent to over 60 percent in the Meydenbauer basin, resulting in increased overland runoff and peak flood flows. Large and frequent floods can damage both human structures and aquatic habitats, particularly salmonid habitat in streams (City of Portland, 2001; Booth, 2000; May et al., 1997; Mitsch and Gosselink, 2000; Cooke, 1995). A previous study found that flood flow was 50 percent higher in an urbanized basin in Chesapeake Bay without wetland flood storage than in a basin that contained only four percent wetland area (Novitzki, 1985 *in* Mitsch and Gosselink, 2000).

In developed basins where wetlands have been lost, reduced flood storage capacity can be partially replaced through wetland restoration, stormwater control facilities, or potentially the use of isolated, degraded, and low-value wetlands as stormwater facilities. However, even in basins where flood storage has been maintained, discharge volumes from detention facilities in areas with moderate to high levels of impervious surface are still substantially higher than in less-urbanized or natural environments because of reduced rainfall infiltration into pervious soils (Booth, 2000). As a result, while wetlands can substantially contribute to flood control in basins, reduction of total impervious surface is also necessary to reduce flood flows and peaks (Booth, 2000).

Wetlands can also be negatively affected by direct discharge of stormwater and alteration of the hydrologic cycle due to increases in impervious surface. Increased discharge to wetlands can alter the hydrodynamics and hydroperiod (the pattern of fluctuating water levels) in a wetland, resulting in substantial modifications to plant and animal communities adapted to pre-existing hydrologic conditions (Azous and Horner, 2001). Use of only degraded, low-quality wetlands that are not associated with stream systems for stormwater control can limit these impacts (Horner et al., 1996).

In Bellevue, flooding has been minimal in areas where wetlands have been protected along streams, such as along the lower reaches of Mercer Slough. In these areas, development has been limited within the natural floodway or floodplain of the streams and forested/scrub-shrub wetlands provide a high level of stormwater control. Other wetlands along Bellevue's streams have been partially or entirely converted to stormwater detention facilities to reduce downstream channel erosion, flooding, and sedimentation, and to improve water quality. The use of wetlands for stormwater control has substantially altered the structure and hydrodynamics of these wetlands. For example, a scrub-shrub/forested wetland that originally existed along the upper reaches of Valley Creek is now an open water stormwater detention pond with a smaller scrub-shrub class (see Wetland Inventory).

Generally, the literature documents that wetlands in the upper watershed provide the greatest level of stormwater control within the watershed. As discussed in the Wetland Inventory, large wetland complexes in the Kelsey Creek and Small Lake Sammamish Tributaries Basins, particularly those wetlands located in the upper watershed, provide the highest level of stormwater control.

Stream Base-flow Maintenance and Groundwater Support

Overview

Wetlands contribute to stream baseflow and groundwater recharge by retaining large quantities of water and slowly releasing it to streams or groundwater (Mitsch and Gosselink, 2000; Erwin, 1990). While the contribution of wetlands to near-surface (surficial) aquifers has been documented, relevant studies on wetland deep aquifer recharge are lacking. Generally, available studies indicate that some wetland types provide greater recharge to groundwater systems than others (Carter et al., 1979; Novitzki, 1979; Carter and Novitzki, 1988). One study indicates that small depressional wetland systems can contribute substantially to regional deep aquifer systems because of their edge-to-volume ratio (Weller, 1981 *in* Mitsch and Gosselink, 2000). In riparian and coastal areas, wetlands were found to have significant radial infiltration into a surficial aquifer depending on wetland size and depth to the underlying surficial aquifer (Heimburg, 1984).

Wetlands can provide a continuous flow of water to streams because of their ability to store and slowly release water. This function is particularly important to stream flow-sensitive salmonids in the Pacific Northwest, because wetlands provide baseflow during the region's typically dry season (City of Portland, 2001; Booth, 2000; May et al., 1997; Mitsch and Gosselink, 2000). Generally, large, permanently-flooded, depressional wetlands (10 acres or greater) that are the headwaters of or connected to salmonid streams and are located in the upper one-third of the watershed have the best ability to provide stream baseflow and groundwater support (Brinson, 1993; Gwin et al, 1999; Cooke, 2000). Wetlands in the upper part of the watershed affect flows downstream, whereas those wetlands lower in the watershed affect less of the overall stream system.

Urbanization and Stream Baseflow and Groundwater Support

Providing groundwater recharge and base flow for streams are important functions of wetlands in urban settings such as Bellevue due to the high levels of impervious surface, which limit infiltration in upland areas. Wetlands may be one of the remaining sources of stream baseflow support and surficial and deep aquifer recharge in highly urbanized areas.

As for baseflows, several studies have noted the importance of wetlands, particularly riparian wetlands (Booth, 2000; Schueler, 2001; City of Portland, 2001; Mitsch and Gosselink, 2000; Brinson, 1993). Riparian wetland loss, reduction, and vegetation alteration reduce their capacity to provide baseflow support of streams. These disturbances to wetlands may contribute to low flows in streams during summer, which can be detrimental to fish and other aquatic biota (see Best Available Science White Paper for Streams).

In Bellevue, riparian wetlands, particularly those in the upper portions of drainage basins, provide the highest level of stream base flow benefits. Base flow is particularly important for smaller salmonid-bearing streams that have low flows during the dry season. The Stream Inventory reports low flows in the Lewis Creek basin; low flows in other streams may limit salmonid access. As discussed in the inventory report, the size and vegetative structure of many riparian wetlands in the upper portions of all basins, but particularly in the Kelsey Creek/Mercer Slough, Small Lake Washington Tributaries, and Small Lake Sammamish Tributaries basins, have been reduced or altered, compromising their ability to provide stream base flow and possibly groundwater support.

Water quality improvement

Overview

Another function provided by wetlands is the removal of sediment and pollutants from storm water through "biofiltration" (Mitsch and Gosselink, 2000; Cooke, 1995). The vegetative structure of wetlands slows the flow of water, causing sediments, nutrients (primarily nitrogen and phosphorous), petroleum products, heavy metals, pesticides, and herbicides to settle out of the water column. Anaerobic and aerobic processes in wetlands promote denitrification, chemical precipitation, and other chemical and biological reactions that help to remove pollutants from water. Nutrients, such as nitrogen and phosphorous, are taken up by vegetation; as vegetation dies, some of these nutrients are stored in wetland sediments, where decomposers further convert nutrients to biological use and contribute to breakdown of some petroleum products. Some nutrients are exported from wetlands to adjacent water bodies after seasonal die-off of emergent plants. Wetlands can remove chemicals, such as some petroleum products, heavy metals, and some pesticides that are not converted to biological uses and permanently store them in wetland sediments. Disruption of wetland soils and increased water fluctuations in the wetland may resuspend sediments and export buried pollutants.

The ability of a wetland to perform biofiltration can depend on a wetland's physical configuration, size, location within the basin, vegetation community structure, and productivity (Washington Department of Ecology, 1996; Marble, 1992). Wetlands remove particulates through settling, which is controlled by water velocity, particle size, residence time of water in the wetland, and physical filtration through vegetation and substrate (Washington Department of Ecology, 1996; Sather and Smith, 1984). Wetlands can have the most pronounced effects on water quality if the wetland:

- Is located in a highly developed watershed;
- Contains 80 percent or more vegetative cover;
- Experiences low velocity stormwater flows;
- Has a restricted outlet; and
- Attenuates 50 percent or more of overland flow (Mitsch and Gosselink, 2000; Cooke, 2000; Washington Department of Ecology, 1996).

In addition, wetlands that are most effective at biofiltration, particularly nutrient removal, are those that:

- Contain diverse and dense vegetative classes;
- Contain organic soils;
- Are permanently-flooded; and
- Have shallow water levels.

These characteristics are found in the large wetland complexes in the Kelsey Creek/Mercer Slough Basin. Organic soils are more likely than mineral soils to bind with metals and synthetic organic toxicants. A diversity of vegetation in a wetland is most effective at nutrient cycling; dense emergent vegetation is particularly effective because it creates frictional resistance to water flows, takes up nutrients rapidly, and releases it seasonally. Forested areas store greater amounts of nutrients for longer periods but generally offer less frictional resistance to water flow (Washington Department of Ecology, 1996).

However, once a wetland has been filled with sediment and is no longer able to provide additional storage, sediments and chemicals, such as heavy metals and phosphorous, will be transported out of the wetland (Mitsch and Gosselink, 2000; Washington Department of Ecology, 1996).

Urbanization and Water Quality Improvement

The ability of a wetland to improve water quality in urban environments is affected by physical alteration, loss of wetland area, and changes in hydroperiod (including bypass of overland runoff into wetlands due to piping and detention ponds). Physical changes to wetlands eliminate or reduce their ability to biofiltrate sediment, nutrients, and chemicals. Severe water fluctuations can increase or decrease sedimentation rates and limit denitrification and phosphorous retention (Washington Department of Ecology, 1996).

There are few studies that directly address the impacts of urban runoff on water quality in wetlands; most studies have focused on a wetland's ability to treat runoff. However, Azous and Horner (2001) address direct impacts to wetland water quality by studying the effects of urbanization on 28 wetlands in the Puget Sound lowlands. Generally, pollutant concentrations in wetlands located in urbanized watersheds were somewhat higher than those in undeveloped watersheds, but no concentrations exceeded state water quality standards in any of the wetlands (Horner et al., 1996). Dissolved oxygen (DO) levels in urban wetlands, however, were significantly lower than in undeveloped watersheds.

Wetlands have limits to the amount of sediments, nutrients and toxicants they can assimilate. The largest impact of pollutant accretion and sedimentation in wetlands in urbanized watersheds is on vegetation, wildlife, and invertebrates, particularly amphibians and salmonids, which are negatively affected by low DO and high turbidity and pollutant levels. Many studies document the negative effects of sedimentation, low DO, and pollutants on invertebrates, amphibians, and fish, particularly salmonids, in riparian wetlands, urban streams, and lakes (City of Portland, 2001; Booth, 2000; May et. al., 1997; Mitsch and Gosselink, 2000; Schueler, 1994). Biofiltration in wetlands, along with infiltration of runoff in upland areas, can reduce negative impacts to flora and fauna in adjacent streams and lakes.

Wetland complexes in the Kelsey Creek/Mercer Slough and Small Lake Sammamish Tributaries basins are large and contain diverse vegetation; therefore, these wetlands are most effective for improving water quality. Smaller disturbed wetlands in the upper portions of Bellevue's drainage basins have a more limited ability to improve water quality due to their small size and less diverse vegetation cover. While small wetlands in Lewis, Coal, and Small Lake Washington Tributaries basins have a more limited water quality improvement function than larger wetland complexes, they are the only wetlands existing in these basins and therefore are important for providing this function.

Erosion/Shoreline Protection

Overview

Erosion control is linked to other wetland functions and is the greatest factor in systems where water flow rates and levels are high enough to suspend and transport sediments. Decreased water velocity, vegetative structure, soil root-binding properties, and substrate type in wetlands influence the effects of water-related erosion in adjacent water bodies (Carter, 1986; Greeson et. al., 1979; Sather and Smith; 1984; Brinson, 1993). The erosion control function is particularly effective in shallow, floodplain wetlands where velocities are slow and vegetation is dense and woody. Wetlands in basins that have relatively undeveloped shorelines and stream banks that contain dense woody vegetation along the Ordinary High Water Mark (OHWM) of a lake or stream and extend more than 200 to 600 feet from the OHWM provide the highest level of erosion control (Hruby et al., 1999; Cooke, 2000).

Urbanization and Erosion/Shoreline Protection

As mentioned in the flood control section of this report, urban watersheds experience higher peak flood levels and flow velocities, as well as more frequent flooding. As little as 10 percent impervious surface in a watershed can result in stream channel instability (Booth, 1991 and Booth and Reinelt, 1993 *in* Schueler, 1994). Increasingly higher storm flows can result in sediment loading of the stream and destruction of habitat for fish and other aquatic organisms. (see Best Available Science Paper for Streams). Wetlands assist in moderating storm flows and preventing erosion; therefore protection of forested or scrub-shrub wetlands along streams and lakes can provide important erosion control functions even in low to moderately-urbanized areas.

As discussed in the inventory, the large wetland complexes in Bellevue provide the most effective erosion control along streams and lakeshores. The small riparian wetlands in Lewis and Coal Creek are forested/scrub-shrub wetlands and provide a moderate level of erosion control.

Biological Support and Wildlife Habitat

Overview

Wetlands are more highly productive for food that fuels the food chain than uplands or deep water habitats (e.g., lakes) (Hruby et al., 1999). Two major energy flow sources in wetlands are the grazing of living green plants by wildlife, and the detrital food chain composed of organisms that depend on detritus and/or organic debris for a food source (Erwin, 1990; Zedler et al., 1990). Pulses of nutrient export from wetlands to adjacent streams or lakes benefit aquatic systems that are commonly nutrient limited (Washington Department of Ecology, 1996). Riparian vegetation, including both wetland vegetation and upland forest, can contribute up to 99 percent of the energy in aquatic food webs (Budd et al., 1987). This function is especially important for salmonids that feed on both terrestrial and aquatic insects, which in turn feed on organic matter exported from adjacent riparian areas (including wetlands) (Cummins, 1974 and Gregory et al., 1991 *in* City of Portland, 2001; Higgs et al., 1995)

Wildlife species abundance and diversity is higher in wetland habitats than in isolated upland areas because they generally provide greater structural and plant diversity, more edge habitat where two or more habitat types adjoin, more varied forage, and a predictable water source (Kauffman, et al., 2001; O'Connell et al., 2000). Approximately 150 species of birds and 200 species of wildlife in North America depend on wetlands for at least some portions of their life cycle (Niering, 1985; Mitsch and Gosselink, 2000). Species that depend on wetlands (including deepwater lakes) for breeding and reproduction include waterfowl, amphibians, insects, and some species of fish and mammals (such as beaver). These wildlife species also use wetlands and wetland-upland edge habitat for foraging, roosting, and refuge. Wildlife species richness increases when wetlands are surrounded by natural undisturbed upland habitat (WDFW, 1992; Richter and Azous, 2001; Azous and Horner, 2001; Hruby et al, 1999).

While larger, vegetatively diverse wetlands are generally used by a greater diversity of wildlife, small wetlands and their surrounding upland habitat are important to wildlife species as well (WDFW, 1992). For example, in the Columbia basin, waterfowl reproduction was observed to be higher in wetlands of five acres or less in comparison to larger wetlands (WDFW, 1992). Also, many amphibians are most abundant in small shallow water wetlands that have adjacent forest land ranging from 50 to 1,000 feet from the wetland (WDFW, 1992; Richter and Azous, 2001). Urbanization that isolates small wetlands reduces amphibian species richness and increases populations of bullfrogs, which are introduced (non-indigenous) species (Richter and Azous, 2001).

Because of the specialized habitat provided by wetlands and surrounding uplands, a higher proportion of special status species (endangered, threatened, proposed, candidate, sensitive, monitor, and species of local importance) use these unique habitats (Mitsch and Gosselink, 2000; Hruby et al., 1999) (see Wildlife Inventory). Of the 209 animal species federally-listed as endangered in 1986, approximately 50 percent depend on wetlands for survival and viability (Mitsch and Gosselink, 2000). Many special status species in Bellevue forage on riparian- and wetland-dependent species such as insects, stream dwelling invertebrates, and fish. The presence of wetlands within and along wildlife linkages also provides critical habitat for fish and wildlife, such as rearing areas for juvenile salmon and water sources for all wildlife. All 19 of the special status species that were documented in Bellevue through the critical areas are closely or generally associated with riparian-wetlands or open water habitats (Johnson and O'Neil, 2001). Much of the remaining habitat structure in Bellevue for nest and roost sites and productive areas for forage for special status species is present in riparian and wetland areas.

Urbanization and wildlife habitat

Effects of urbanization on wildlife in Bellevue are discussed in detail in the Best Available Science Paper and Inventory for Wildlife. As discussed above, as little as 10 percent impervious surface in a watershed can increase stormwater runoff rates and flood peaks, substantially affecting vegetation and wildlife communities in wetlands (Richter, 2001, Ludwa and Richter, 2001, Richter and Azous, 2001, Azous and Horner, 2001). For example, sediment loading along streams can block off side-channel wetlands, which provide rearing and refuge habitat for fish (Swales and Levings, 1989) (see Best Available Science Paper for Streams, Section C) Additionally, hydrologic changes can cause excess flooding or drying of wetlands, impacting species, such as amphibians, that depend on the water column. Alterations in hydroperiod can be harmful or lethal to amphibian egg and larval development if egg masses attached to wetland vegetation are exposed and desiccated (Richter et al., 1991).

Recreation, Education, Cultural Resources, and Open Space

Because wetlands and their associated uplands are unique habitats, they provide natural areas for recreational and educational opportunities. Property values in neighborhoods surrounding wetlands tend to be higher than those in areas with no natural open spaces (Todd, 2000). These areas are highly valued, particularly within urban communities such as Bellevue. In urbanizing areas, aquatic resources and adjacent uplands may provide the foundation for greenways and open space. In Bellevue, wetlands and adjacent uplands provide important resources for wildlife viewing, passive recreation, and education about natural wetland-upland ecosystems. The Lake Hills Greenbelt connector bicycle and pedestrian trail provides a unique opportunity for residents to view a variety of wetland-upland habitats along the trail. These areas can also be important for commercial purposes because they attract tourists and local visitors.

III. WETLAND BUFFERS

Buffers, in the context of wetland protection, are vegetated upland areas immediately adjacent to wetlands. Buffers provide beneficial functions that enhance and protect the many functions and values of wetlands described above. Wetland buffers are particularly important for wildlife because many of the wildlife species that use wetlands in Bellevue also require terrestrial habitats for their survival; these areas are also used by special status species (see Wildlife Inventory, Section B).

Many of the functions associated with stream riparian areas also apply to wetland buffers. A brief discussion of buffer functions as they relate to wetlands is provided in this paper; a more detailed discussion of buffer functions is provided in the Best Available Science Paper for Streams (Section C).

Terrestrial habitats surrounding wetlands provide a buffer to help mitigate the impacts of urbanization. Terrestrial habitats support healthy wetland conditions through two groups of functions. These include:

- "Sink" functions; and
- "Source" functions.

First, as described in the Best Available Science paper for Streams, terrestrial habitats can act as "sinks," removing unwanted elements from the wetland environment (Castelle and Johnson, 2000). Sink functions include:

- Storm and Flood water control including erosion control;
- Sediment and pollutant retention; and
- Water temperature moderation through shade.

Terrestrial buffer areas retain sediments, nutrients, pesticides, pathogens, and other pollutants that may be present in runoff (Washington Department of Ecology, 1996). Reduction of sediment and pollutant discharge to wetlands prevents "sediment filling," degradation of water quality in wetlands, and alterations to plant and animal communities. As a result, buffers increase the ability of wetlands to further provide sediment and pollutant removal. Terrestrial habitats infiltrate flood water, reducing the effect of water level fluctuations within wetlands. Terrestrial wetland buffers, particularly forested and shrub habitats, provide shade for moderating temperatures of water in wetlands; maintaining water and wildlife habitat quality.

Terrestrial habitat areas also provide "source" inputs that are important for wildlife in wetland habitats (McMillan, 2002; Castelle and Johnson, 2000). Source inputs include:

- Habitat for wetland-dependent wildlife species that also require terrestrial habitats (wildlife habitat);
- Large woody debris for habitat structure;
- Biotic input (e.g., insects and nutrient export for food supply); and
- Protection from human disturbance.

Most species that use wetlands for a portion of their life cycle also depend on terrestrial habitats for food, cover, nesting, and/or travel corridors. The edge habitat between wetlands and terrestrial habitat is used by a variety of wildlife species. Terrestrial habitat areas provide a source of large woody debris used by wildlife for foraging, nesting, and cover (O'Connel, 2000).

Many insect species use wetlands for their entire life cycle, but wildlife in wetlands, including fish, also feed on insects from terrestrial habitats. Organic matter can also be exported from terrestrial habitats into wetlands and is an important source of food for a variety of wildlife and organisms. Terrestrial buffer provides separation between wetland habitat and human disturbance. This distance improves the quality of wildlife habitat by lessening the effects of noise, light, and human motion/activity upon animal species sensitive to these disturbances. It also provides area over which sediment or pollutant removal can occur, and for flood flow attenuation.

Wetland Buffer Function as a Factor of Buffer Width

Many literature reviews have been published summarizing the effectiveness of various buffer widths, mainly for riparian areas, but also for wetlands (Castelle et al., 1992a; Castelle and Johnson, 2000; Desbonnet et al., 1994; FEMAT, 1993). McMillan (2000) provides the most recent literature review specific to wetlands in western Washington. Generally, the riparian buffer literature also applies to wetlands because very similar functions are provided by riparian buffers as those for wetlands. However, the effects of buffers on streams and fish habitat differ from the effects on wetlands. For example, large woody debris from riparian areas along streams primarily contributes to instream structure and fish habitat, while large woody debris in wetlands provides structure or foraging habitat for a variety of wildlife species.

An overall conclusion of review of the scientific literature is that buffer width required to protect a given habitat function or group of functions depends on numerous site-specific factors - such as plant community (species, density, age), aspect, slope, channel width, and soil type, - and on adjacent land use. Generally, the science indicates that the appropriate buffer width is site- and function-specific.

Nevertheless, a general relationship between buffer width and buffer effectiveness is apparent in the research findings. The studies indicate that buffers 100 to 150 feet wide provide most (on the order of 80 percent) of the potential "sink" functions in most situations. Buffer requirements for wildlife habitat or "source" functions are typically larger, on the order of 100 to 600 feet. The literature also indicates that particularly for "sink" functions, the relationship between buffer width and effectiveness is logarithmic, so that after a certain width an incremental increase in buffer width provides diminishing functional effectiveness. For example, Wong and McCuen (1982) indicate that 90 percent of sediment removal can be accomplished within the first 100 feet of a riparian buffer, but an additional 80 feet of buffer is needed to remove just five percent more sediment (see Best Available Science Paper for Streams). A discussion of effective buffer widths for individual buffer functions is provided below.

"Sink" Functions

Storm and Flood Water Control. Wetland buffers, of widths between 50 to 300 feet, play a role in moderating water level fluctuations within wetlands by slowing and detaining surface runoff and slowly releasing it to the wetland, as well as providing floodwater storage and control for the basin overall (Wong and McCuen, 1982). However, the effects of buffers in moderating hydroperiods in wetland can be negated by high levels (> 15 %) of impervious surface within watersheds (Azous and Horner; 2001; McMillan, 2002). In high-density urban watersheds, buffers have a minimal or even insignificant effect on moderating water level fluctuations within wetlands; minimizing or reducing the amount of impervious surface would be more effective at controlling storm flows (Booth, 2000; McMillan, 2002).

Erosion Control. As stated earlier, *wetlands* that extend 200 to 600 feet from lake shorelines and stream banks would provide the most effective erosion control – buffering- for these aquatic resources (Cooke, 2000). Upland buffers can augment the erosion control function for aquatic resources by allowing infiltration and slowing sheet flow. Buffers that contain plant species with fine and very fine roots are most effective at binding the soil and preventing erosion (Karr and Schlosser, 1977 *in* McMillan, 2002).

Sediment and Pollutant Retention. As discussed in the Best Available Science Paper for Streams, the most effective buffer widths for water quality factors, including sediment or pollutant removal and temperature regulation, range from 15 to 125 feet in width (URS, 2002; Knutson and Naef, 1997). Specific studies have concluded that buffers of 100 feet can achieve sediment removal efficiencies of 75 to 100 percent, while depending on site-specific conditions and buffer type, buffers of 100 feet or less may provide substantial pollutant removal benefits. Several authors (Schultz et al., 1995; Lowrance, 1992; Welsch, 1991) advocate the use of a 3-zone buffer system (60 to 150 feet wide in total): 1) Zone 1: a grassy filter strip at the outer edge of the buffer designed to maximize sheet flow; 2) Zone 2: a managed forested area designed to provide maximal surface roughness and serve as a transition zone to the next zone; and 3) Zone 3: a natural forested area adjacent to the aquatic resource.

Temperature Moderation. As discussed in the Best Available Science Paper for Streams, effective buffer widths for temperature regulation range from 15 to 125 feet in width (URS, 2002; Knutson and Naef, 1997). This literature mainly applies to streams that are linear features, in contrast to the irregular outlines of most wetlands. There is a paucity of literature that specifies effective buffer widths for temperature moderation in wetlands, because this function depends on variable factors including topography, slope, and wetland configuration, size, and type.

"Source" Functions

Wildlife Habitat and Large Woody Debris. Appropriate buffers to maintain wildlife habitat functions of all but the most degraded wetlands range from 100 to 300 feet, if they contain a diversity of native trees and shrubs. This is also an appropriate width to provide large woody debris for wildlife habitat. However, certain animal groups may require larger buffers. For example, amphibians (that are highly affected by urbanization and fragmented forests) require upland forested buffer widths ranging from 50 to 1,000 feet (Richter and Azous, 2001). For most bird species that use wetlands, a forested and/or shrub buffer width of 50 to 300 feet provides adequate foraging, roosting, nesting, and cover for birds (McMillan, 2002). Mammals that use wetlands require buffers ranging from 100 feet (beavers [WDFW, 1992]) to 600 feet (mink [Allen, 1982 *in* McMillan, 2002]).

Biotic Input. Most studies regarding biotic inputs of buffers focus on inputs to streams for fish; however, the studies also apply to wetlands, particularly open water wetlands. Since wetlands contain vegetation, import of nutrients and organic matter from adjacent buffers may not play as important a role in wetlands as in streams. As discussed in the Best Available Science Paper for Streams, most studies found that buffers of 100 feet were necessary maintain healthy benthic communities (Roby et al., 1977; Newbold et al., 1980; Castelle & Johnson, 2000). This would also apply to benthic communities within wetlands, which in turn feed wildlife species that use wetlands, and contribute to nutrient uptake.

Protection of Wetlands and Associated Wildlife from Human Disturbance. Buffers of less than 50 feet are generally ineffective at screening out human disturbance to wetlands (Cooke, 1992). Shisler et al. (1987) found that buffers 45 to 100 feet are most effective at protecting wetlands and wildlife (Desbonnet et al., 1994) from disturbance in areas of low-intensity land uses (agriculture, recreation, and low-density residential housing). Buffers of 100 to 150 feet were recommended for protection of wetlands and wildlife from adjacent high-intensity land use - high-density residential, commercial/industrial development (Shisler et al., 1987; Desbonnet et al., 1994). However, other studies indicate that larger buffers, on the order of 150 feet to 200 feet, may be needed to prevent disturbance of wildlife, particularly waterfowl (WDFW, 1992; Josselyn et al., 1989 *in* McMillan, 2002).

Buffer Functions in the Urban Context

As with stream buffers, the type or quality of buffer is also important for wetlands, as reflected in the discussion above. A densely-vegetated buffer is most effective at protecting the water quality of wetlands. Buffers that have multi-layered, dense vegetation, with a predominance and diversity of native species, provide the best quality wildlife habitat.

As discussed in the Best Available Science Paper for streams, studies of buffer widths related to forest practices and agriculture indicate that buffers ranging from 25 to 100 feet may be adequate to preserve many of the beneficial functions to wetlands; however, the simple application of prescriptive buffers in these size ranges may not be adequate to protect urban wetlands because most of the source functions of buffers have been compromised by past land use actions. Due to the type and degree of cumulative impacts to urban wetlands (and streams) that have already occurred as a result of high levels of TIA and past disturbance to wetlands, it may be necessary to develop new strategies to successfully address the issue of adequate buffers in the context of basin-wide change (Booth, 2000; Azous and Horner, 2001; Booth and Reinelt, 1993).

The current draft of OCD's Model Critical Areas Ordinance (2002) recommends a range of standard buffers based on quality and sensitivity of wetlands, and intensity of adjacent land use. OCD's recommended buffers widths are provided in Appendix A.

IV. WETLAND MITIGATION/ENHANCEMENT STRATEGIES

The Clean Water Act Section 404(b)(1) Guidelines for wetland mitigation require "no net loss" of wetlands by first avoiding, minimizing, rectifying, and reducing impacts to wetlands and their functions. Where loss of wetland acreage and/or functions is necessary, replacement or compensatory mitigation should be required. Local jurisdictions in Washington implement these guidelines through local critical area regulations. Most local jurisdictions require compensatory mitigation for impacts to wetlands and/or their buffers resulting from development or associated activities.

Jurisdictions generally allow four types of mitigation: creation, restoration, enhancement, and exchange (Gwin et al, 1999):

- Creation entails creating new wetland area out of an area that is and was historically upland.
- Restoration entails restoring a filled or damaged wetland to its original state or better.
- Enhancement entails improvement of the functions of an existing wetland to replace lost functions (not acreage) of filled or impacted wetlands.
- Exchange is more involved enhancement, with most or all of a mitigation wetland being converted from one type of wetland to another (e.g., scrub-shrub to open water).

These mitigation types are generally considered to be in-kind (replacement of same functions and acreage as the impacted wetland) and are typically constructed on the development site where the wetland impact occurred.

Off-site and out-of-kind wetland mitigation has also been allowed by agencies in certain cases. The U.S. Army Corps of Engineers and other agencies have allowed off-site preservation of wetlands, and there has been growing interest in mitigation banks in Washington. Mitigation banking may give developers additional options for mitigation; banking also allows creation or preservation of larger and higher quality wetlands than might have been established on any one development site. Use of a single site for multiple mitigation efforts also facilitates adequate maintenance and monitoring, which in turn, increase the success of the project. Ecology has written a draft Mitigation Banking Rule to facilitate the use of this type of mitigation. The OCD Draft Model Critical Areas Ordinance also includes mitigation banking as an allowed type of mitigation.

Wetland and Buffer Mitigation Success

Wetland Mitigation Success

Most wetland mitigation projects have not been successful for various reasons and have resulted in lost acreage, wetland types, and wetland functions (Castelle et al., 1992b; Washington Department of Ecology, 2002; Mockler et al., 1998). Castelle et al. (1992b) reported that 50 percent or more of the mitigation projects studied did not meet permit requirements. Common problems included:

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

A predominant problem throughout wetland mitigation sites is the invasion of the site by non-native plant species. Studies have found that at least 50 percent of species in mitigation sites were non-native (Magee et al., 1999; Ecology, 2002). Mitigation areas that were not protected by upland buffer had a larger percentage of non-natives, and long-term maintenance of sites resulted in lower percentages of non-natives. Gwin et al (1999) also found mitigation areas to be functionally different from replaced wetlands, resulting in net loss of function and, in some cases, net loss of wetland area. The use of wetland exchange and enhancement of existing wetlands to replace lost wetlands does not actually create new wetlands but improves or modifies the functions of existing wetlands to compensate for those lost, therefore resulting in a "net loss" of wetland acreage and possibly wetland functions (depending on how the enhancement was implemented). (Shaffer et al., 1999; Gwin et al., 1999; Ecology, 2002).

Ecology (2002) conducted a study of 24 mitigation sites in Washington and found that although mitigation success has improved in the last 10 years, there is still much room for improvement. The Ecology (2002) study had the following findings:

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

Mitigation has been more successful for some wetland types, including emergent and open water wetlands (Castelle et al., 1992b). Other wetland types have been very difficult or impossible to replicate, such as mature forested or bog systems, or wetlands that contain habitat for sensitive wildlife species. Restoration of prior wetlands was often found to be easiest to achieve. The likelihood of success of restoration is greater than other types of mitigation because the site will benefit from restored hydrology, and seed sources from the original wetland may be present and viable. However, some authors suggest that mitigation projects in urban settings may not be able to recreate a historic wetland ecosystem due to changes in water regime and nutrient input (Ehrenfeld, 2000; Horner, 1997; Booth, 2000).

The Ecology (2002) study found two primary reasons for success (or failure) among enhancement projects: 1) achievement of vegetative structure and/or diversity and 2) replacement or improvement of functions lost. The study found that in some cases the mitigation enhancement had completely failed and the site was in its original (not enhanced) condition. Mitigation also was not found to provide enough gain to compensate for the functions lost. However, 10 of the 24 projects in the evaluation were less than five years old. Since enhancement generally entails creating new shrub or forest habitat, this may not have been a long enough period to adequately judge the success of the projects.

Ecology (2002) concluded that although better site selection, design and performance standards will help to improve wetland mitigation, consistent follow-up [adaptive management], both to correct problems with current projects and to provide feedback for decision-making on future projects, will result in the greatest overall improvement. Most successful projects had long-term monitoring of at least five years and applied adaptive management strategies. Many other studies support long-term (at least five years) monitoring for mitigation projects (Kentula, 2002; Kusler and Kentula, 1990).

On-site Versus Off-site Mitigation

Generally, the literature indicates that on-site, in-kind mitigation is desirable and can be most successful at replacing lost wetland functions, but is dependent on site constraints, particularly hydrologic conditions. The literature is conflicting on whether on-site mitigation or off-site mitigation can adequately compensate for loss of wetlands and their functions (Erwin, 1990; Castelle et al., 1992; Kusler, 1992). However, Kusler (1992) suggests that in cases where there are many small isolated wetlands and compensatory mitigation has been determined to be necessary (after evaluating mitigation sequencing), off-site mitigation may be more successful at replacing lost wetland acreage and functions, because replacement of these small wetlands is difficult to achieve. More functional benefit may be reached through a larger mitigation that is established within the context of landscape level assessment to determine optimum location to meet the "needs" of the hydrologic and ecological system (Kusler, 1992; Washington Department of Ecology, 2002; Bedford, 1996).

Buffer Mitigation Success

The success of buffer mitigation projects is generally affected by the same factors as wetland mitigation. Success of plant growth in the buffer depends on water, nutrient and soil requirements for plants, and controlling the invasion of non-native species (Gwin et al, 1999; Magee et al, 1999).

Success of buffer mitigation projects also depends on human disturbance in the buffer. Since buffer mitigation areas often include restoration or establishment of forest habitat, this can be difficult to achieve based on experience from wetland systems. Buffers in some urban environments, due to close proximity to development, have been altered through dumping of debris, clearing, and other human disturbances (Desbonnet et al., 1994; Cooke, 1992; Castelle et al., 1992a). Some buffers that were included in some residential lots in King County were eventually converted to lawn. However, impacts to buffer areas were less likely in areas where residents had been educated about the value of buffers (Gwin et al., 1999; Kentula, 2002).

Mitigation Ratios

Typically, wetland mitigation is implemented over a larger area than the wetland area adversely affected by a proposed project. Mitigation ratios are typically greater than 1:1 for several reasons. Higher ratios:

- Act as disincentives to fill wetlands;
- Provide an opportunity to achieve certain functions over a larger area, thus compensating for a temporal loss of function from the smaller but presumably more mature impact site; and
- Compensate for the inability to achieve full replacement acreage of lost wetlands (Washington Department of Ecology, 2000; Kusler and Kentula, 1990).

Several authors and agencies have recommended various replacement ratios (Castelle et al., 1992). Most ratios are based on known failures of compensatory mitigation and designed to compensate for historic loss of wetlands. Studies of the success of mitigation projects suggest that replacement ratios based on mitigation success could be between 3:1 and 1.25:1. However, more information is needed to understand whether lost wetlands functions and acreage can be entirely compensated for. The Draft OCD Model Critical Areas Ordinance (2002)[1] recommends the following wetland mitigation ratios by classification of wetland:

Category I wetlands - 6:1

Category II wetlands - 3:1

Category III wetlands - 2:1

Category IV wetlands - 1.5:1

Mitigation ratios for wetlands in most local jurisdictions in western Washington, however, currently range between 1:1 and 4:1.

V. WETLAND MANAGEMENT APPROACHES

The following is a brief discussion and comparison of two approaches that use regulatory (Kirkland, Washington) and non-regulatory, incentive-based (Portland, Oregon) strategies to manage wetlands. Both cities approach management of their wetlands and other aquatic resources from a drainage basin level. Similar to Bellevue, they have both studied and mapped their aquatic resources by drainage basin.

[1] As of March 2003, the Draft Model Critical Areas Ordinance was undergoing revisions.

Kirkland's Wetland Management

Kirkland generally manages its natural resources, including wetlands, using a drainage basin framework. Kirkland identified six major drainage basins and completed a detailed inventory of streams, wetlands, and wildlife in these basins (The Watershed Company, 1998). Three of the basins are less developed and contain higher quality aquatic resources than the remaining basins. These basins are designated as "primary basins." The remaining three basins, which contain higher percentages of impervious surface and have fewer and more degraded aquatic resources, are designated as "secondary basins."

Kirkland's critical areas ordinance provides higher protection for wetlands in primary basins than those in secondary basins. For example, 75-foot buffers are required for Type 2 wetlands in primary basins, while 50-foot buffers are required in secondary basins. Mitigation ratios are also slightly lower for Type 2 and 3 wetlands (not Type 1) in secondary basins compared to primary basins. The benefit of this program is that it focuses protection in areas that are less developed; in areas that are more intensively developed, protection levels are lower in recognition of the more degraded functions and values, as well as the limitation on restoration potential. This allows Kirkland to protect more valuable aquatic resources in target basins, while offering fewer restrictions to developers in more urbanized basins.

Portland's Wetland Management

Portland manages its aquatic and other natural resources through limited regulation and incentive-based programs. Portland approaches management of these resources from a watershed framework. Portland has established an “E-zone” in most of its basins, except in those areas that are highly urbanized. Within the E-zone, preservation of natural resources including upland forest habitat, wetlands, and streams is required. A 25-foot to 300-foot protected area is established, based on quality of habitat in the vicinity of project, value within the basin, and proposed land use intensity.

Portland also promotes and implements proactive restoration projects for wetlands and riparian areas. Portland has had an effective program of purchasing or creating conservation easements (owned by other organizations) along riparian corridors, starting with the highest priority watersheds. Community groups participate in restoration implementation. Portland provides grants and technical assistance to groups that are interested in implementing restoration through its Community Watershed Stewardship Program. Portland's approach to restoring its natural resources is to "preserve the best" habitats (through purchasing or regulation) and to "restore the rest" of the habitats that can be restored. Where complete recovery is not feasible, the City plans to restore or improve those elements within the watershed that can be improved. The program offers flexibility to Portland developers and residents in creating protective areas around wetlands and streams. Forest resources are protected under the E-Zone program, even in areas not directly adjacent to a stream or wetland, to maintain forested habitat. The program, however, does not protect streams in high-density urban areas, which may still provide important habitat for salmonids.

VI. ADVANCED BUFFER DETERMINATION METHODOLOGY

McMillan (2002) suggests an "advanced buffer determination method," that is more scientifically-based and incorporates 1) wetland type; 2) type of adjacent land use; and 3) buffer characteristics.

The "advanced buffer determination method" would result in establishment of buffers that are more site-specific, scientifically-supportable, and more flexible for the land developer than the standard buffer method recommended by OCD in its draft 2002 guidelines (McMillan, 2002). Because more buffer width choices would be available to developers, it may result in fewer buffer variance requests, saving local agency staff time. The disadvantages of this method are:

1) it requires an evaluation of the buffer characteristics prior to identifying an appropriate buffer width (this would be supplied by the applicant);

2) wetland types are determined differently from most existing wetland rating systems in Washington;

3) it is an untested method that requires scientific professional judgment; and

4) there are potential difficulties in administering the program consistently.

Buffer widths using the McMillan (2002) method are established by: 1) determining a score of buffer quality based on slope, soils, and vegetation; and 2) choosing the recommended buffer width from a matrix that relates buffer width to wetland type (based on subcategories of the Washington wetland rating system), land use intensity (high, moderate, low density) and buffer score (see Appendix B for detailed discussion of this method).

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APPENDIX BAS-WT-1.

2002 DRAFT OCD MODEL CODE RECOMENDATION WETLAND BUFFER RECOMMENDATIONS

Table 1. Draft OCD Model Critical Areas Ordinance Buffer Recommendations[1]

Wetland Classification (Highest to lowest)	**Type of Land Use**	**Buffer Recommendation (Feet)**
Class I	High Intensity[a]	300 feet
	Moderate Intensity[b]	250 feet
	Low Intensity[c]	200 feet
Class II	High Intensity[a]	200 feet
	Moderate Intensity[b]	150 feet
	Low Intensity[c]	100 feet
Class III	High Intensity[a]	100 feet
	Moderate Intensity[b]	75 feet
	Low Intensity[c]	50 feet
Class IV	High Intensity[a]	50 feet
	Moderate Intensity[b]	35 feet
	Low Intensity[c]	25 feet

[a] High intensity includes medium and high density residential (>1 home per 5 acres), multifamily residential, and commercial and industrial land uses.

[b] Moderate intensity includes, but not limited to, low density residential (≤ 1 home per 5 acres), active recreation, and agricultural land uses.

[c] Low intensity includes, but not limited to, passive recreation, open space, or forest management land uses.

[1] Note: As of March 2003, Model Code recommendations were undergoing revision, and revised buffer recommendations were not available.

APPENDIX BAS-WT-2. MCMILLAN (2002) ADVANCED BUFFER DETERMINATION METHOD

Advanced Buffer Determination Method

The Advanced Buffer Determination Method provides a practical alternative to the Basic Method. It incorporates three primary factors that the scientific literature says are important in deciding on appropriate buffers to protect wetland functions: 1) wetland type; 2) type of adjacent land use; and 3) buffer characteristics. The primary advantage of this method is that it prescribes a buffer width that is more tailored to the specific characteristics of the site being evaluated without the need for a special study by a wetlands specialist.

Use of the Advanced Method will result in a more site-specific and scientifically supportable buffer width than the Basic Method, while still providing a high level of predictability for landowners. It also removes much of the subjectivity and debate that may accompany attempts to design site-specific buffers using the Basic Method.

The disadvantages of the Advanced Method are that: 1) it requires an evaluation of buffer characteristics prior to identifying an appropriate width; and 2) wetland types are divided differently than most existing wetland rating systems in use in Washington.

The Advanced Method of determining buffer widths derives from the practice of developing environmental decision-making models, also known as "multiple criteria assessment" models (Hruby, 1999). These types of models are based on the selection and scaling of key variables that are known to be related to the system or process being modeled. The variables and their scaling are founded on hypotheses about how the variables combine to determine an appropriate buffer width, since specific, quantitative data about the relationships between the variables are lacking. The variables in the Advanced Method (wetland type, land-use intensity, and buffer slope, soils and vegetation) were selected and scaled by the author following analysis of the scientific literature. The buffer widths were selected based on the literature and the author's judgment that these widths would ensure a low level of risk that a wetland's functions would be impaired. This same method could be applied using greater or lesser buffer widths if one were willing to assume a greater or lesser level of risk.

Applying the Advanced Method requires that one determine the wetland type and land use intensity adjacent to the wetland using the descriptions below, evaluate the buffer area using the buffer scoring model (Table 6), and determine the buffer width using Table 5.

Table 5 illustrates the primary factors and recommended buffer widths of this approach. The land uses, wetland types and buffer scoring method are defined below.

Table 5 - Advanced Buffer Width Determination Method

Land Use		Wetland Type A			Wetland Type B			Wetland Type C		
	Buffer Score	*3-4*	*5-7*	*8-9*	*3-4*	*5-7*	*8-9*	*3-4*	*5-7*	*8-9*
High intensity	(buffer	350	300	250	250	200	150	125	100	75
Moderate intensity	widths	250	200	150	200	150	100	100	75	50
Low intensity	in feet)	200	150	100	150	100	75	75	50	25

Land Use definitions

High intensity: High intensity land use includes those that are associated with moderate to high levels of human disturbance, including but not limited to residential development at greater densities than 1 unit per 5 acres, including all multi-family residential development, commercial and industrial development and active recreational development such as ball fields.

Moderate intensity: Moderate intensity land use includes those that are associated with moderate levels of human disturbance, including but not limited to residential development at densities of 1 unit per 5 acres or less, and agricultural activities.

Low intensity: Low intensity land use includes those that are associated with low levels of human disturbance, including but not limited to silvicultural activities, passive recreational development, and open space.

Wetland Types

Wetland types are divided into three categories based on three primary factors: 1) sensitivity to inputs of nutrients or toxic substances; 2) sensitivity to human disturbances (noise, light, intrusion); and 3) likely presence of wetland-dependent wildlife species needing adjacent upland habitat to meet critical life needs. The criteria for placing a wetland in one of the three categories are based on the Washington State Wetland Rating System (Ecology, 1993) and are found in Appendix A. (These three categories differ from the four categories found in the Ecology rating system because this approach is based solely on buffer needs whereas the Ecology rating system addresses buffers, mitigation ratios and impact avoidance.) For purposes of establishing buffer widths, this type of wetland categorization scheme is more consistent with the best available science than the Ecology rating systems because it groups wetlands based solely on their need for buffering from adjacent land uses.

Wetland Type A

This category contains:

1. All Category 1 wetlands
2. Category 2 wetlands with open water*
3. Category 2 estuarine wetlands

Wetland Type B

This category contains:

1. Category 2 wetlands without open water*
2. Category 3 wetlands with open water*
3. Category 3 estuarine wetlands

Wetland Type C

This category contains:

1. Category 3 wetlands without open water*
2. Category 4 wetlands

** Open water means any area of standing water present for more than one month at any time of the year without emergent, scrub-shrub or forested vegetation. [This definition is consistent with the Washington State Wetland Rating System (Ecology, 1993).]*

Buffer Score

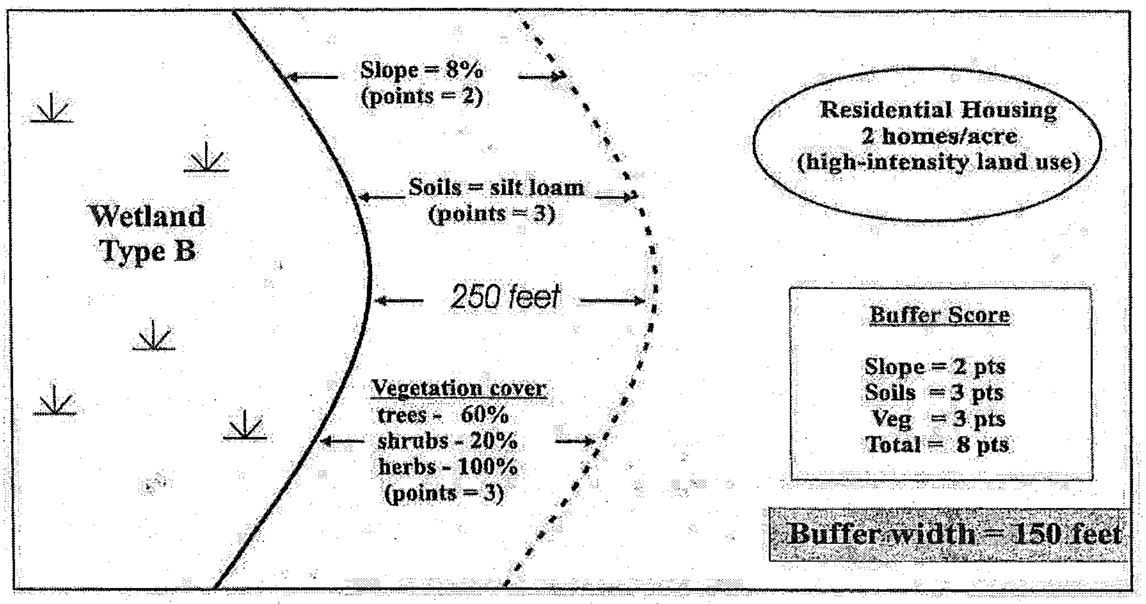
The buffer score takes into consideration three primary factors (slope, soils, and vegetation) that determine how well a buffer removes sediment, nutrients, and toxic substances, screens out adjacent human disturbances, and provides shading, microclimate protection, and general wildlife habitat. The buffer score is determined by adding scores from the three categories outlined in Table 6 below. These criteria should be applied to the existing buffer area within the maximum buffer width based on the type of wetland at issue (350 feet for Type A, 250 feet for Type B, 125 feet for Type C; Table 5). One does not need to apply these criteria to the buffer area around the entire perimeter of the wetland unless the proposed project surrounds the entire wetland. However, one must determine whether the slope, soils and plant community are uniform across the buffer. (See Appendix B for definitions of terms and guidance on how to address buffers that vary in slope, soils or plant community.)

Table 6 - Buffer Score Method			Total Score
Slope* pts.	**Soils*** pts.	**Vegetation*** pts.	
> 10% average = 1	Sand, loamy sand, clay or silty clay = 1	Bare ground > 30% or Impervious surface > 20% or Herbaceous vegetation with < 30% shrub/tree cover = 1	
5 - 10 % average = 2	Sandy clay, sandy clay loam, silty clay loam, or clay loam = 2	Conditions other than described above or below = 2	
< 5% average = 3	Loam, silt loam or sandy loam = 3	Tree cover > 50% with shrub cover > 50% or Tree cover 50% with herb cover > 80% or Shrub cover > 80% = 3	

* See Appendix B for definitions of terms and guidance and examples of how to determine buffer scores.

Figure 1, below illustrates how the Advanced Buffer Determination Method can be applied to a hypothetical site.

Figure 1. An example of Applying the Advanced Buffer Determination Method



Application of this method will result in a buffer width that is adequate to protect a wetland's functions, based on site-specific characteristics. However, local governments that choose to use this type of method may want to include the language outlined under the Basic Method above for increasing or reducing buffer widths to address those few instances in which an even more detailed, site-specific approach is necessary. Additionally, buffer averaging and reasonable use exception language above should be included with the Advanced Method.

While the Advanced Method requires more data collection than the Basic Method to determine a buffer width, it should save local government staff time because the extra data collection costs are typically born by the applicant, and requests for variances will be less frequent, since the prescribed buffer widths are based on more site-specific information. However, occasions will arise that necessitate a more detailed, site-specific analysis and the method described below is designed for such occasions.

Making site-specific determinations of buffer widths

Most local governments likely will utilize an approach similar to one of the two options described above because these approaches provide predictability for applicants and take less staff time and expertise to implement. However, given the lack of precision involved in categorizing wetlands, land uses, and buffer characteristics, it may be appropriate to make a site-specific determination to arrive at an optimum buffer. From the landowner or project applicant standpoint, an optimum buffer generally will be the smallest that is absolutely necessary to protect the wetland's functions. From the resource protection standpoint, an optimum buffer will be the one that ensures little or no risk to the wetland and the functions it provides.

The buffer widths included in the two methods above are designed to provide a buffer that ensures a low level of risk to the wetland based on a general understanding of the wetland's functions. However, all wetlands, even those in the same category, function differently. Likewise, similar land uses can have distinctly different levels of impact on wetlands depending on site-specific practices. Additionally, local government staff frequently need to evaluate land owner requests to increase or decrease standard buffers based on site-specific information.

A site-specific approach to determining buffers allows for consideration of more detailed information. However, making a site-specific determination requires collection and evaluation of considerably more data than applying a standardized approach. The site-specific method described below provides a standard format for collecting and evaluating site-specific information to help in determining an appropriate buffer. With this format, the results can be quickly reviewed for accuracy and adequacy. This method could be used as the primary basis for determining buffers or to make decisions about increasing or decreasing a standard buffer width as determined by one of the two methods described above. However, use of this method requires that one exercise substantial judgment in evaluating the data collected and arriving at a final decision regarding buffer width.

Site Specific Buffer Determination Method

The method outlined below for making site-specific buffer determinations follows a five-step data gathering and evaluation process. Each step requires that site-specific data be collected and/or evaluated by a person or team with expertise in wetland ecology. This will most typically be conducted by a consultant hired by a project applicant. This information should be provided to the appropriate decision-maker in the form of a report and the decision-maker should ensure that someone with appropriate expertise reviews the report for accuracy and adequacy.

STEP 1: Describe the wetland's characteristics by filling out the table below.

The information in Table 7 will provide a general description of the wetland including basic physical characteristics that contribute to a wetlands functions as well as more specific information on wildlife species expected to use the wetland. This information will help in determining the wetland's needs for buffering from adjacent land uses.

Table 7 - Wetland Characteristics		
Record the following information about the wetland under consideration.		
1	Wetland area (in acres)	
2	Wetland rating (class/category) and name of rating system	
3	Hydrogeomorphic Class (riverine, depressional, slope, lacustrine fringe, estuarine fringe)	
4	Cowardin classes present (forested, scrub/shrub, emergent, open water, aquatic bed)	
5	Area of permanent open water	
6	Area of seasonal open water	
7	Area of vegetated standing water	
8	Source(es) of water input to the wetland	
9	Threatened/Endangered/Sensitive or rare plant species present	
10	Threatened/Endangered/Sensitive or rare animal species present	
11	Known or expected bird species utilizing the wetland as habitat	

12	**Known or expected mammal species utilizing the wetland as habitat**	
13	**Known or expected fish species utilizing the wetland as habitat**	
14	**Known or expected herptile species utilizing the wetland as habitat**	

STEP 2: Describe the level of impact from adjacent development and measures to be taken to minimize impacts

Table 8 - Description of Potential Development Impacts		
15	**Describe the type of development**	
16	**Describe how surface water runoff will be addressed including plans for treatment and release to wetlands or streams.**	
17	**Describe how surface runoff will affect the hydroperiod of the wetland and what pollutants might be introduced into the wetland.**	
18	**Describe the potential for noise and light to affect the wetland and steps taken to reduce noise and light impacts on the wetland.**	
19	**Describe the potential for human and pet intrusion into the wetland and steps taken to minimize intrusion.**	

STEP 3: Describe the characteristics of the buffer

Table 9 - Buffer Characteristics			
Evaluate the area within 300 feet of the wetland edge in the vicinity of the proposed development and answer the questions below. Make a drawing to answer questions 21-22			
	SOILS		
20a	**Described the mapped soil type including horizons, texture and drainage class.**		Draw a typical soil horizon (0-20") for <u>the buffer soils</u>
20b	**Do field observations confirm the mapped soil type?**		
20c	**If not, describe soil type observed in the field including horizons, texture and drainage class.**		
	SLOPE		
21	On a drawing of the buffer area, show areas where the slope is:	**<5%** **5% - 10%** **>10%**	
	VEGETATION		
22	On a drawing of the buffer area, indicate approximate percent of areal cover of each vegetative strata as well as bare areas and areas with buildings or impervious surfaces	<u>Strata</u> Tree Shrub Herbaceous Bare Buildings/impervious	
23	Describe measures that could be taken to improve the functioning of the buffer area.		

STEP 4: Determine the buffer functions and width needed to protect the wetland

Table 10 - Buffer Functions

Based on the information recorded in Tables 7, 8 and 9 above, determine which buffer functions are needed to protect the wetland. For each function determined to be needed, describe the width necessary to protect the wetland and provide a rationale for the width selected. Include a description of enhancement activities proposed to improve the buffer or otherwise protect the wetland.

Buffer Function	Needed? Y/N	Needed Width & Rationale	Buffer or Site Enhancement
Sediment removal			
Nutrient removal			
Toxics removal (specify type of toxic substance)			
Shading & microclimate protection			
Screening noise, light, intrusion			
General wildlife habitat			
Habitat for particular species			

STEP 5: Determine the appropriate width of buffer and enhancement actions necessary to protect the wetland.

Summary (Describe the overall width needed to protect the wetland & a summary of the enhancement actions needed)	

Currently, most site-specific buffer determinations are conducted by consultants for project applicants. The consultants provide a short narrative statement advocating a particular buffer width based on certain wetland or buffer characteristics. Rarely do these reports contain the detailed information necessary to adequately determine an appropriate buffer, and thus, it is difficult to refute or concur with the recommendation provided by the report. The five-step process outlined above provides a "transparent" method for determining site-specific buffers. This process provides all of the relevant documentation and rationale needed to make a site-specific buffer determination and displays it in a manner that is easy to review.

A local government will need to allocate considerable staff time and expertise if the Site-specific Method is used as the primary means of determining buffer widths. Even if applicants provide all of the data required for this method, local government staff will need to have the time and technical expertise to review each buffer determination and corroborate the conclusions. Thus, this method will be most helpful when used in conjunction with one of the other two methods described above. Then, it would only be applied in those few cases when the applicant or local government believes that the buffer prescribed by the Basic or Advanced Methods is wider or narrower than is scientifically justified.

Conclusion

The best available scientific information unequivocally states that buffers are necessary to protect and maintain the water quality, habitat, and hydrologic functions of wetlands. The best available science also outlines four primary factors to be considered in determining appropriate buffer widths: 1) the quality, sensitivity and functions of the aquatic resource; 2) the nature of adjacent land use activity and its potential for impacts on the aquatic resource; 3) the character of the existing buffer area (including soils, slope, vegetation, etc.); and 4) the intended buffer functions. Given the tremendous variability of wetland types, land uses and buffer conditions across the landscape, developing a single buffer width that is appropriate for all situations is not possible. Thus, methods are needed that will take into account these primary factors and prescribe appropriate buffer widths.

However, regulatory buffer methods must provide some level of predictability for land owners and must be easy to apply. The three methods of determining wetland buffers outlined above provide methods that incorporate the best available science and are practical for regulatory programs. A local government or any other entity can select the method that best fits its needs and feel confident that the method will provide a scientifically sound approach to determining wetland buffers.