WETLAND BUFFERS: Use and Effectiveness

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for

Washington State Department of Ecology
Shorelands and Coastal Zone Management Program
Olympia, Washington

February 1992
EXECUTIVE SUMMARY

This report was developed to assist efforts by Washington State agencies and local governments developing policies and standards for wetlands protection. The report summarizes and evaluates scientific literature, an agency survey, and a recent field study on wetland buffer use and effectiveness. Published literature was obtained from several sources and contains information from throughout the country on the concept of wetland buffers, their important functions, effective buffer widths, and buffer determination models. The agency survey reviewed buffer requirements of several states throughout the U.S. and for counties and cities in Washington. The field study reviewed the current state of buffers at several sites in King and Snohomish counties.

Scientific Literature Review

Wetland buffers are areas that surround a wetland and reduce adverse impacts to wetland functions and values from adjacent development. The literature indicates that buffers reduce wetland impacts by moderating the effects of stormwater runoff including stabilizing soil to prevent erosion; filtering suspended solids, nutrients, and harmful or toxic substances; and moderating water level fluctuations. Buffers also provide essential habitat for wetland-associated species for use in feeding, roosting, breeding and rearing of young, and cover for safety, mobility, and thermal protection. Finally, buffers reduce the adverse impacts of human disturbance on wetland habitats including blocking noise and glare; reducing sedimentation and nutrient input; reducing direct human disturbance from dumped debris, cut vegetation, and trampling; and providing visual separation. Wetland buffers are essential for wetlands protection.

Scientists generally agree that appropriate buffer widths are based on several variables, including:

- existing wetland functions, values, and sensitivity to disturbance;
- buffer characteristics;
- land use impacts; and
- desired buffer functions.

Wetland functions, values, and sensitivity are attributes that will influence the necessary level of protection for a wetland. Those systems which are extremely sensitive or have important functions will require larger buffers to protect them from disturbances that may be of lesser threat to a different site. Where wetland systems are rare, or irreplaceable (e.g., high quality estuarine wetlands, mature swamps, bogs), greater buffer widths will ensure a lower risk of disturbance.

Buffer characteristics influence their ability to reduce adverse effects of development, most importantly in relationship to slope and vegetative cover. Buffers with dense vegetative cover on slopes less than 15% are most effective for water quality functions. Dense shrub or forested vegetation with steep slopes provide the greatest protection from direct human disturbance. Appropriate vegetation for wildlife habitat depends on wildlife species present in the wetland and buffer. Effectiveness is also influenced by ownership of the buffer.
Land uses with significant construction and post-construction impacts need larger buffers. Construction impacts include erosion and sedimentation, debris disposal, vegetation removal, and noise. Post-construction impacts are variable depending on the land use, but residential land use, in particular, can have significant impacts. Residential land use is associated with yard maintenance debris, domestic animal predation, removal of vegetation, and trampling. Wetland areas and their buffers should not be included in residential lots.

Appropriate buffer widths vary according to the desired buffer function(s). Temperature moderation, for example, will require smaller buffer widths than some wildlife habitat or water quality functions. Buffer widths for wildlife may be generalized, but specific habitat needs of wildlife species depend on individual habitat requirements.

Buffer effectiveness increases with buffer width. As buffer width increases, the effectiveness of removing sediments, nutrients, bacteria, and other pollutants from surface water runoff increases. One study found that for incrementally greater sediment removal efficiency (e.g., from 90 to 95%), disproportionately larger buffer width increases are required (e.g., from 100 to 200 feet). As buffer width increases, direct human impacts, such as dumped debris, cut or burned vegetation, fill areas, and trampled vegetation will decrease. As buffer width increases, the numbers and types of wetland-dependent and wetland-related wildlife, that can depend on the wetland and buffer for essential life needs, increases.

In western Washington, wetlands with important wildlife functions should have 200 to 300-foot buffers depending on adjacent land use. In eastern Washington, wetlands with important wildlife functions should have 100 to 200-foot buffers depending on adjacent land use. To retain wetland-dependent wildlife in important wildlife areas, buffers need to retain plant structure for a minimum of 200 to 300 feet beyond the wetland. This is especially important where open water is a component of the wetland or where the wetland has heavy use by migratory birds or provides feeding for heron. The size needed would depend upon disturbance from adjacent land use and wetland resources involved. Priority species may need even larger buffers to prevent their loss due to disturbance or isolation of subpopulations.

Buffer widths effective in preventing significant water quality impacts to wetlands are generally 100 feet or greater. Sensitive wetland systems will require greater distances and degraded systems with low habitat value will require less. The literature indicates effective buffers for water quality range from 12 to 860 feet depending on the type of disturbance (e.g., feedlot, silviculture) and the measure of effectiveness utilized by the author. For those studies that measured effectiveness according to removal efficiency, findings ranged from 50 to 92% removal in ranges of 62 to 288 feet. Studies that measured effectiveness according to environmental indicators such as levels of benthic invertebrates and salmonid egg development in the receiving water generally found that 98-foot buffers adjacent to streams were effective. These latter buffer distances may be conservative for wetlands, where lower water velocities and presence of vegetation result in increased sediment deposition and accumulation.

Studies indicate that buffers from 50 to 150 feet are necessary to protect a wetland from direct human disturbance in the form of human encroachment (e.g., trampling, debris). The appropriate width to prevent direct human disturbance depends on the type of vegetation, the
slope, and the adjacent land use. Some wetlands are more sensitive to direct disturbance than others.

Various methods are used for determining buffer widths in a regulatory context. Regulatory agencies often establish a rating system, commonly of three or four categories, assessing a given wetland's functional value, sensitivity, rarity, or other attributes. Accordingly, the amount of protection afforded to each type differs.

**Agency Survey**

A survey conducted of regulatory requirements for wetland buffers indicated that of 16 states surveyed, ten require wetland buffers and eight incorporate wetlands rating, either adopted or proposed. Of five Washington counties with adopted wetlands protection ordinances, all five require buffers and four utilize wetlands rating systems (the fifth is currently proposing an amendment that incorporates rating). Of 28 identified cities with wetlands protection ordinances, 27 contain specific buffer standards and 20 utilize wetlands rating systems. The one city without specific standards has adopted an interim policy statement for wetlands protection.

Specific buffer requirements vary widely at the state and local level. State buffer requirements range from 0 to 300 feet; Washington county buffer requirements range from 0 to 200 feet; and Washington city buffer requirements range from 0 to 300 feet.

**Field Study**

A field analysis of the current state of buffers in King and Snohomish counties found that effectiveness of the buffer was determined by the type of buffer in place, the type of alteration to the buffer and surrounding area, the width of the buffer, the time elapsed from development, and the ownership of the buffer and adjacent wetland.

Buffer function was found to be directly related to the width of the buffer. Ninety-five percent of buffers smaller than 50 feet suffered a direct human impact within the buffer, while only 35% of buffers wider than 50 feet suffered direct human impact. Human impacts to the buffer zone resulted in increased impact on the wetland by noise, physical disturbance of foraging and nesting areas, and dumping refuse and yard waste. Overall, large buffers reduced the degree of changes in water quality, sediment load, and the quantity of water entering the adjacent wetland. As a rule, buffers were subjected to a reduction in size over time. Of 21 sites examined, 18 were found to have reduced buffer zones within one to eight years following establishment.
I. INTRODUCTION

This report was developed to assist efforts by the Washington State Department of Ecology (Ecology), other Washington State agencies, and local governments to develop policies and standards for wetlands protection within existing authorities. Specifically, the report summarizes and assesses information related to wetland buffer use and effectiveness.

The report is organized into four sections accompanied by an executive summary, references, and appendices. The sections include:

- introductory information;
- a review of the existing literature;
- an agency survey of existing regulatory requirements for buffers; and
- conclusions drawn from the literature review and agency survey.

Appendix A presents the results of a field study that provides a post-construction evaluation of the effectiveness of required wetland buffers in protecting wetlands from adverse impacts. Several local projects in King and Snohomish counties were assessed to determine the effectiveness of buffers that were required for development projects adjacent to wetlands.

A companion document entitled Wetland Buffers: An Annotated Bibliography is also available.
II. SCIENTIFIC LITERATURE REVIEW

The scientific literature review is a compilation of the findings of a literature search for information on wetland buffers. A general discussion of the concept of buffers is followed by background information on wetlands buffers and their important functions. Research on recommended buffer widths and buffer determination models is presented.

Information was obtained from a review of published literature as well as from oral and written personal communications. Sources of information included computer search programs, on-line library collections, existing bibliographies, research centers, federal and state agencies, county and city planning departments, professional organizations, environmental organizations, and individuals. A specific list of information sources for this section is listed in Appendix B.

Buffers and Setbacks in Land Use Planning

Our present landscape is a mosaic of developed lands and natural areas, forests and fields, wetlands, and uplands. Expanding human use within the landscape presents a difficult problem to the community and to decision makers: how best to fit the pieces of this mosaic together. Such long-range planning is further complicated by the knowledge that some land uses are incompatible in close proximity to one another.

Designating buffer areas between zones of incompatible land uses has been a common regulatory mechanism for minimizing environmental as well as other physical impacts. In diverse situations ranging from buffer zones around power plants, to tree-lined streets, buffers are employed to lessen the impact of one activity on another. In general, as the level of activity or potential for conflict increases, the width of the buffer needed to minimize conflict between the two land uses will increase proportionally (Brown and Schaefer, 1987). For example, the level of noise, light, temperature, and activity are dramatically higher in developed areas than in natural areas, and the border between developed and natural areas is frequently characterized by "overflows" of these disturbances from the developed land to the undeveloped. These "overflows" may take many forms: subsurface and surface water flow; increased sedimentation; atmospheric pollution; increases in noise and temperature; the introduction of toxins, bacteria, and viruses; more frequent, extensive, and intensive physical disturbances; and the introduction of non-native plant and animal species. Buffer zones are used to protect natural areas such as streams, shorelines, steep slopes, and wetlands from these impacts.

Wetland Buffers

Wetlands are among the most valuable and complex ecosystems on earth. They provide many functions and values to society, including flood control, ground water recharge and discharge, water quality improvement, shoreline stabilization, fish and wildlife habitat, recreational and educational opportunities, and aesthetic values (Smardon, 1978; Williams and Dodd, 1978; Adamus and Stockwell, 1983; Roman and Good, 1983; Brown, 1985).

Until recently, the complexity and importance of wetlands were not widely known, and accordingly, wetlands protection was non-existent or ineffective. Land use strategies in the past
frequently encouraged the filling of wetlands, calling it "reclamation," and granted title to anyone who would fill the land. More recently, however, wetlands have been recognized as ecologically and economically valuable. Federal, state, and local governments have responded by enacting laws and developing programs to protect the important values of wetlands recognized by society.

Many wetlands managers believe that the most effective means of stemming the loss of wetlands is avoiding and minimizing adverse impacts of development from the outset (Shisler, 1987). This includes both impacts originating within the wetland perimeter as well as impacts originating adjacent to the wetlands. Uses and development adjacent to wetlands can negatively affect wetland systems through increased runoff (Harris and Marshall, 1963); sedimentation (Darnell, 1976); introduction of chemical and thermal pollutants (Ehrenfeld, 1983); diversion of water supply; introduction of invasive and exotic species; and reduced populations of wetland-dependent species (Zeigler, 1990). The area immediately upland of the wetland boundary is important as a seed reservoir, as habitat for aquatic and wetland-dependent wildlife species, and as a refuge to wildlife during periods of high water (Brown and Schaefer, 1987).

One method of reducing the impacts of development upon adjacent wetlands is to provide a buffer around the wetland. Wetland buffers are those areas that surround a wetland and reduce adverse impacts to the wetland functions and values from adjacent development. Wetland buffers can include both upland and aquatic areas contiguous with a wetland edge, however, the focus of this study is on vegetated upland buffers.

**Wetland Buffer Functions**

Wetland health can be measured in terms of water quality, hydrology, and fish, wildlife and plant species diversity and abundance. The protective functions provided by wetland buffers can be described under these same parameters.

**Water Quality**

Wetlands are generally located in low areas of the landscape, causing them to be particularly susceptible to sediment loading from upland sources and to erosional scouring that results from increased water velocities from mismanaged upland surface waters (Brown and Schaefer, 1987). Vegetated wetland buffers function to reduce adverse impacts to water quality by controlling the severity of soil erosion and removing a variety of pollutants from stormwater runoff (Shisler et al., 1987).

Soil erosion is reduced within buffers as vegetation and organic debris shields the soil from the impact of rain and binds soil particles with root materials. Vegetation acts as an obstruction to water flow thereby decreasing water velocities, allowing infiltration, and reducing the erosion potential of stormwater runoff. As a physical barrier to flowing water, vegetation also traps sediments and other insoluble pollutants. The proper functioning of a buffer zone depends in great part on its ability to resist channelization (Broderson, 1973). If the majority of stormwater moving through the buffer does so as sheet flow, the rate of flow is significantly slower, and the residence time of the water in the buffer is increased, allowing more time for settling of waterborne sediments and infiltration. In addition, the root systems of the buffer vegetation aid in the maintenance of soil structure and bank stability (Broderson, 1973).
Soluble nutrients and pollutants are also removed or transformed by the soils, bacteria, and plants in wetland buffers (EPA, 1988). The uptake of dissolved heavy metals and large amounts of nutrients by plants has been well-documented (Murdoch and Capobianco, 1979; Shisler et al., 1987; Gallagher and Kibby, 1980). For example, Murdoch and Capobianco (1979) found that *Glyceria grandis*, a wetland grass, took up 80% of the available phosphorus, and also took up significant quantities of lead, zinc, and chromium. Gallagher and Kibby (1980) found that salt marsh species such as *Carex tyngbyei* (Lyngbi’s sedge), *Salicornia virginiana* (pickleweed), *Juncus balticus* (Baltic rush), and *Potentilla pacifica* (Pacific silverweed) accumulated copper, chromium, iron, manganese, strontium, lead, and zinc.

Vegetation scatters sunlight and provides shade, reducing water temperature in the summer, limiting nuisance algae growth, and reducing the release of nutrients from the sediment (Karr, 1978).

**Hydrology**

Large, sudden fluctuations in wetland water levels often destroy wetland vegetation, particularly along the wetland edge (Clark, 1977). Where wetland vegetation is weakened or destroyed by periods of drought or flooding, native plants give way to weedy, invasive species, invertebrate communities are altered, and wildlife species dependent on these food sources disappear. Increased water level fluctuations caused by increased urbanization have been found to be a major threat to remaining wetlands in the Puget Sound Region, with potential effects on plant succession, habitat, and breeding conditions (Stockdale, 1991).

Wetland buffers play a role in moderating water level fluctuations. Vegetation impedes the flow of runoff and allows it to percolate into the ground. The soil then yields this water to the wetland over an extended period of time, resulting in stable, natural ecosystems. Vegetation also produces litter which increases the humus content of the soil and increases adsorption and infiltration. It also protects other soil properties that are important to infiltration capacity. By intercepting intense rainfall, vegetation preserves soil composition so that infiltration is not impaired (Dunne, 1978).

Bertulli (1981) concluded from his study of a southern Ontario, Canada watershed that adjacent forest vegetation and litter lowered stream flow from 388 to 207 inches in a 100-year flood event. It should be noted, however, that when a catchment area for a wetland has been urbanized and the natural infiltration system has been disrupted, the role of buffers in reducing abnormal water level fluctuations is less significant.

**Fish and Wildlife Habitat**

The vegetated uplands adjacent to wetlands are considered to be one of the richest zones for aquatic organisms, mammals, and birds (Clark, 1977; Williams and Dodd, 1978). Wetland buffers provide essential habitat for wetland-associated species. In Washington State, 85% of the terrestrial vertebrate species use wetlands and/or their buffers; 359 of 414 species in western Washington (Brown, 1985), and 320 of 378 species in eastern Washington (Thomas, 1979). In Washington, stream buffers and riparian areas provide essential habitat for 68 species of mammals, birds, amphibians, and reptiles. One hundred and three species are more numerous in riparian ecosystems or use them more heavily than upland habitat (Riparian Habitat Technical
Committee, 1985). In western Washington and Oregon, 236 animal species are reported to use coastal, riparian, or wetland communities as their primary breeding or feeding habitats. One hundred and twenty-one species of animals use both aquatic systems and associated uplands for primary breeding or feeding habitat. One hundred and six species use upland edges associated with aquatic systems as primary breeding and feeding habitats (Brown, 1985). This increased use of riparian and other transitional areas demonstrates the concept of "edge effect," a term first coined by Leopold (1933), who proposed that species numbers of both plants and animals increase at edges, due to overlap from adjacent habitats and to creation of unique edge-habitat niches. Such edges are the location of increased wildlife use including feeding, roosting, breeding and rearing of young, and cover for safety, mobility, and thermal protection (Ranney et al., 1981). Naturally vegetated wetland buffers frequently provide vertical as well as horizontal edges that provide ground, shrub, and tree canopy cover (Zeigler, pers. comm., February, 1992).

Often birds and animals that are considered to be wetland-dependent species have essential life needs that can only be met in the adjacent upland buffer (Naiman, 1988, WDW [Appendix C, this report]). These life needs include food, water, shelter from climatic extremes and predators, and structure and cover for reproduction and rearing of young. Waterfowl feed primarily in wetlands but most species nest on dry ground to avoid flooding their nest (WDW, [Appendix C, this report]). Species such as wood ducks, great blue herons, pileated woodpeckers, and ospreys require large trees for nesting. While amphibians, such as the Pacific chorus frog, spend only a short portion of their life span actually in a wetland, they cannot complete their life cycle without one. Many wetland-associated mammals, such as mink and river otters, feed in wetlands, but breed and raise their young in the buffer (Zeigler, 1990). These animals must burrow above the high water mark to avoid inundation of their burrows, which means that they spend significant portions of their lives in the buffer.

Wetland buffers are also important for wetland-related wildlife: animals that concentrate near wetlands but are not necessarily wetland-dependent. The Department of Wildlife (Appendix C, this report) notes that "lush and divergent vegetation in wetland buffers provide food and cover for many species ranging from large mammals, such as deer and elk, to small ones, such as voles and shrews. These areas are used for rearing of young."

Wildlife species have varying spatial requirements to maintain viable populations for survival. Buffers provide an area where animals have needed separation and interspersion to reduce competition and maintain populations (WDW [Appendix C, this report]). Habitat alterations and land use changes adjacent to wetlands can affect wetland-dependent wildlife populations by fragmenting habitat to non-functional sizes and shapes and by introducing disturbance factors above the tolerance levels of some species (Brown and Schaefer, 1987). In 1916, Dice reported that along the Touchet River in southeastern Washington, the natural vegetated buffer was about a quarter mile from the stream. He noted that where the tall cottonwood and shrubby understory had not been disturbed by man, it provided excellent refuges for birds and mammals. Today, the average width of the riparian vegetation is about 50 feet and species that have been totally eliminated or greatly reduced in number since Dice's time include sandhill crane, bobwhite quail (bobwhite), sparrow hawk (American kestrel), Lewis' woodpecker, chipping sparrow, black-headed grosbeak, warbling vireo, Macgillivray warbler, redbird, and long-tailed chickadee.
Particularly in urban environments where isolated wetlands and riparian wetlands often afford much of the greenspace and wildlife habitat, the use of buffer zones as travel corridors is critical. The vegetated buffer allows animals and birds to move through the urban landscape with some protection from humans and domestic animals. These wildlife corridors have become increasingly important to wildlife with the continuing development of the natural landscape into smaller and smaller isolated units. Corridors effectively increase the size of the habitat area and its ability to maintain viable wildlife populations.

Riparian buffers maintain fish habitat by providing shade, keeping water temperature low enough in the summer to retain dissolved oxygen to support fish and to prevent lethal low temperatures in winter. Streamside vegetation provides a food source through leaf litter and insect drop and provides cover through deposition of large organic debris. By decreasing sediment loads, buffers reduce siltation of essential spawning ground and the destruction of aquatic invertebrates that are important fish food sources. Buffers provide bank cover for fish and provide bank stability through the soil binding capacity of root systems and energy dissipation during flood periods (Riparian Habitat Technical Committee, 1985; Young, 1989).

Direct Human Disturbance

Vegetated buffers provide visual separation between wetlands and developed environments, blocking glare and human movement from sensitive wildlife (Young, 1989). Buffers also discourage direct human disturbance within a wetland in the form of dumping debris, cutting vegetation, or trampling. Direct human disturbance affects both the habitat provided by wetlands vegetation and the wildlife species that are dependent on the wetland. Plant loss can result from either direct crushing or the compaction of soil. Plants in wet soils are especially vulnerable to trampling. Compaction of the soil damages roots, decreases soil water retention, lessens seed germination and seedling survival, and promotes the survival of more aggressive weedy species. As cover is reduced by trampling, for example, wildlife species that depend on the cover or food provided by the vegetation decrease. All wildlife respond to human activities but the intensity and duration of the response varies with life-cycle stage and the affected species. Disturbance at breeding and nesting time can lead to reduced populations caused by loss of eggs and/or young to predation or injury following abandonment by the parents. Repeated disturbance during feeding or nesting can result in depletion of vital energy stores during flight or other avoidance responses to humans (Josselyn et al., 1989).

Size of Wetland Buffers

The literature review found a number of approaches used to assess the adverse impacts on wetlands from adjacent land uses and to determine what buffer width will be effective in reducing adverse impacts. Some researchers focused on the use of buffers to reduce impacts of specific land uses such as silviculture, agriculture and recreation. These studies and others have examined buffer requirements and effectiveness either holistically or have isolated one or two specific functions in their studies. Researchers have measured buffer effectiveness by using
various biological, chemical, and physical components to assess wetland impacts. These studies include monitoring water quality and quantity; examining plant and animal species distribution; monitoring habitat quality and composition; and measuring levels of human use. Each of these approaches gives a portion of the information necessary to make informed decisions about buffer widths.

The width of buffer considered appropriate to protect a wetland from degradation is related to the wetland functions being protected and the buffer functions being provided (Rogers, et al., 1988). Because buffer function is an important factor in determining buffer widths, information from the literature is summarized according to the following functions:

- sediment removal;
- nutrient removal;
- fecal coliform removal;
- temperature moderation;
- human impact deterrence; and
- wetland species distribution and diversity.

**Sediment Removal**

Sediment removal is recognized as an important function of wetland buffers, not only to protect the wetland from the adverse impacts of increased sediments loads, but because most nutrients are attached (adsorbed) to sediment. Several investigators have researched the width of buffer necessary to reduce sediments. These studies measure effectiveness based on percentage of sediments removed rather than other measures of ecosystem health.

Wong and McCuen (1982) analyzed the ability of vegetated buffers to trap sediment. They found that average particle size, slope, roughness of vegetated cover, and runoff characteristics must be taken into account in determining buffer widths effective to trap a given percentage of sediment in stormwater flow. Using these parameters, they derived an equation to determine effective buffer widths. While small buffers were found to remove small amounts of sediments, these investigators found that the direct relationship between buffer width and percent sediment removal was non-linear and that disproportionately large buffer width increases were required for incrementally greater sediment removal. For example, effective buffer widths approximately doubled (from 100 to 200 feet at 2% slope) when the design criteria increased from 90 to 95% sediment removal. The authors did not address the removal of the soluble components in stormwater. Young et al. (1980) looked at sediment trapping from livestock feedlots and found that an 80-foot vegetated buffer reduced the suspended sediment in the runoff by 92%. Gilliam and Skaggs (1988) found that 50% of the sediment from agricultural fields was deposited in the first 288 feet adjacent to the exit location of the fields. Horner and Mar (1982) found that a 200-foot grassy swale removed 80% of the suspended solids and total recoverable lead.

The effectiveness of buffers at improving water quality adjacent to logging operations was examined by Broderson (1973), Darling et al. (1982), Lynch et al. (1985), and Corbett and Lynch (1985). Broderson studied three watersheds in western Washington (Green River, North Fork Snoqualmie River, and South Fork Tolt River). He noted that buffers will have little or no effect on sediment removal if the sediment-laden waterflows cross the buffers as channelized flow; buffers can only be effective if they resist channelization and maintain overland flow as
Broderson found that 50-foot buffers were sufficient for controlling most sedimentation on less than 50% slopes, while steeper slopes required wider buffers. A maximum buffer width of 200 feet was found to be effective even on extremely steep slopes. Furthermore, Broderson recommended that buffer widths be measured not from the top of the streambank, but rather from "visual signs of high water."

Corbett and Lynch (1985), citing research for an earlier paper by Corbett et al. (1978), concluded that a 40-foot buffer may be adequate to protect streams from excessive temperature elevation following logging, but that a zone of 66 to 100 feet may be necessary to buffer the entire ecosystem, especially when steep slopes are encountered and increased runoff with heavy sediment loads are generated.

Darling et al. (1982) assessed an Oregon State University (OSU) formula for protecting streams and wetlands from tree blow-downs and subsequent large debris and sediment incursions into streams and wetlands. This formula included factors, such as slope and horizontal and elevational distances, from the midpoint of the buffer to the top of the nearest major ridge in the direction of the prevailing winds. Additionally, soil stability and antecedent soil moisture were considered. These investigators were primarily interested in buffer stability over time, and concluded that the OSU formula could be successfully applied in Olympic National Forest, Washington. Further, they found that the best-functioning buffers were the most stable, and that buffer stability was in turn enhanced by high percent vegetative cover and dense stands of trees, rather than by sparse vegetation or individual trees protruding above an understory. They did not, however, directly address buffer widths.

Lynch et al. (1985) assessed the success of 98-foot buffer strips between logging activity and wetlands and streams in Pennsylvania. They found that these buffers removed an annual average of approximately 75 to 80% of the suspended sediment in stormwater. Greater sedimentation resulted from forested areas which had been commercially clear-cut and then denuded with an herbicide. Surface flow in these areas tended to be channelized rather than sheetflow, although Lynch et al. (1985) made no recommendations for larger buffers in such areas.

Moring (1982) assessed the effect of sedimentation following logging with and without buffer strips of 30 meters (98 feet). The author found that increased sedimentation from logged, unbuffered, stream banks clogged gravel streambeds and interfered with salmonid egg development. With buffer strips of 98 feet or greater, the salmonid eggs and alevins developed normally.

Both Erman et al. (1977) and Newbold (1980) found that a 98-foot buffer zone was successful in maintaining background levels of benthic invertebrates in streams adjacent to logging activity in a study of California streams.

**Nutrient Removal**

A number of studies have assessed the use of buffers to control nutrient inputs into wetland and stream surface waters. Vanderholm and Dickey (1978) monitored feedlots exposed to natural levels of rainfall and found buffer widths ranging from 300 (at 0.5% slope) to 860 feet (at 4.0% slope) to be effective in removing 80% of the nutrients, solids, and oxygen-demanding substances from surface runoff through sediment removal and nutrient uptake. Doyle et al. (1977) assessed
the effect of forest and grass buffer strips at improving the quality of runoff from manure application. These investigators found that both forested and grass buffers were effective at reducing nitrogen, phosphorus, potassium, and fecal bacteria in 12.5 and 13.1 feet respectively. In addition, grass buffer strips were effective in reducing nitrate and sodium levels. The percentage reduction of these nutrients was not discussed. Lynch et al. (1985) evaluated the utility of vegetated buffers in reducing soluble nutrient levels in runoff from logging operations. They found that a 98-foot buffer reduced nutrient levels in the water to “far below drinking water standards.” Wooded riparian buffers in the Maryland coastal region were found to remove as much as 80% of phosphorus and 89% of nitrogen from agricultural runoff, most of it in the first 62.3 feet (Shisler et al., 1987).

Phillips (1989) studied non-point source pollution in North Carolina, and found that the current 75-foot regulatory requirement for estuarine shorelines was inadequate for filtering polluted runoff from typical residential development. Phillips used a hydrologic model that measures the ability of a buffer to detain polluted stormwater. Pollutant removal efficiencies were estimated for biochemical oxygen demand, total nitrogen, and total phosphorus.

A slightly different approach was used by Bingham et al. (1980), who studied pollutant runoff from caged poultry manure. Rather than recommending specific buffer widths, the authors reported that a 1:1 buffer area to waste area ratio was successful in reducing nutrient runoff to background levels for animal waste applications. Overcash et al. (1981) analyzed grass buffer strips as vegetative filters for non-point source pollution from animal waste with a one dimensional model, and also concluded that a 1:1 ratio of buffer area to waste area was sufficient to reduce animal waste concentrations by 90% to 100%.

Lowrance et al. (1984) evaluated the ability of riparian forest vegetation to remove sediment and nutrient discharges from surrounding agroecosystems. They found that nutrient uptake and removal by the soil and vegetation in the upland forested buffer was high and prevented outputs from adjacent disturbances from reaching the stream channels. However, they did not recommend any specific buffer widths.

**Fecal Coliform Removal**

A fecal coliform reduction model for dairy waste management was developed by Grismer in 1981 and applied to the Tillamook basin in northwestern Oregon. The model considered the effects of precipitation, season, method of waste storage and application, die-off of the bacteria in storage, die-off of the bacteria on the land surface, infiltration of bacteria in the soil profile, soil characteristics, overland transport of bacteria through runoff, and buffer zones. Grismer’s model suggested that a 98-foot “clean grass” strip would reduce the concentration of fecal coliform by 60%. Buffer strips of 118 feet were found to be sufficient in reducing the concentration of nutrients and microorganisms to acceptable levels in feed lot runoff from summer storms (Young et al., 1980).

**Temperature Moderation**

Forested buffers adjacent to wetlands function to provide cover, thereby helping to maintain lower water temperatures in summer and lessen temperature decreases in winter. The ability of forested buffer strips to maintain lower water temperatures in the summer months has been investigated by several researchers.
Broderson (1973) found that 50-foot buffers provided 85% of the maximum shade for small streams (defined as streams with mean annual discharges of less than five cubic feet per second). Broderson also found that buffer widths along slopes could decrease with increasing tree height. For instance, a stand 200 feet tall on level ground provides shade approximately 90 feet from the trunk during mid-July when temperature problems often occur. If this stand of trees were on a 60% slope, the effective shade width would increase to 150 feet. Shadow length also increases in the summer months with increasing latitude.

Lynch et al. (1985) found that a 98-foot buffer from logging operations maintained water temperatures within 1°C of their former average temperature. Barton et al. (1985) found a strong correlation between maximum water temperatures and buffer length and width for trout streams in southern Ontario, Canada. They derived a regression equation in which buffer dimensions accounted for 90% of the observed temperature variation.

In their study, Brazier and Brown (1973) sought to define the characteristics of buffer strips that were important in shading small streams adjacent to logging. They found that 73 feet was often ample buffer to shade these streams, maintaining pre-logging temperature ranges. They advocated establishing a buffer range that would apply to different situations of slope, exposure, and canopy cover on a case-by-case basis.

**Human Impact Deterrence**

Buffer zones function to protect wetlands from direct human impact through limiting easy access to the wetland and by blocking the transmittal of human and mechanical noise to the wetland. Direct human impact to wetlands most often consists of refuse dumping, the trampling of vegetation, and noise. Shisler et al. (1987) analyzed 100 sites in coastal New Jersey to evaluate the relationship between buffer width and direct human disturbance to wetlands. The investigators completed a post construction analysis to demonstrate the effectiveness, or lack thereof, of different buffer widths for different land uses. Disturbance came in the form of abandoned or dumped constructions materials, dumped debris, cut or burned vegetation, fill areas, excavation, trampled paths, bulldozed areas, and adjacent residents expanding their property illegally into the wetlands. Shisler found that the adjacent land use type accounted for much of the variation found in the level of human disturbance. In all cases, human disturbance was higher in wetlands adjacent to dense residential or commercial/industrial uses. As a result of their investigation, Shisler et al. recommended that low intensity land uses (agriculture, low density residential, and recreation) maintain buffers of 50, 50, and 100 feet, respectively, for salt marshes, hardwood swamps, and tidal freshwater marshes. For high intensity land uses (high density residential and industrial/commercial), buffers of 100, 100 and 150 feet were recommended. As buffer width increased, direct human disturbance decreased. Disturbance levels were double at sites with narrow buffers (less than 50 feet). Buffers of 100 feet and greater provided significantly more protection and reflected in lower disturbance to the wetlands than did buffers less than 50 feet. Steeply sloping buffers with dense shrub understories provided the greatest protection.

Cooke (Appendix A, this report) studied 21 wetlands in King and Snohomish counties in a post-project evaluation to assess the effectiveness of buffers in protecting wetlands from human disturbances. Efficiency was measured qualitatively, using observations of human caused
disturbance to the wetland and buffer to indicate loss of buffer effectiveness. Cooke felt that the effectiveness of a buffer in protecting adjacent wetlands was dependent on:

- intensity of adjacent land use;
- buffer width;
- buffer vegetative cover type; and
- buffer area ownership.

Buffers functioned most effectively when adjacent development was of low intensity; when buffer areas were 50 feet wide or greater and were planted with shrub and/or forested plant communities; and when the buffers were located on land owned by individuals who understood the rationale for establishing buffers, or were on land outside of residential lots. Projects that incorporated the buffer within residential lots resulted in the loss of the natural vegetation community to lawn over time. Buffer functions were found to be reduced most often as a result of decreasing the effective size of the buffer. Nearly all of the buffers that were less than 50 feet wide at the time they were established demonstrated a significant decrease in effective size within a few years; in some instances, degradation was so great that the buffers were effectively eliminated. Fewer than half of the buffers that were originally at least 50 feet wide showed demonstrable degradation.

The ability of vegetated buffers to abate noise has been analyzed by Harris (1985). Harris studied vegetated borders along busy streets, and concluded that the insertion loss per foot through an evergreen vegetated buffer was between 0.2 to 0.3 decibels(A), and a 20-foot wide mature evergreen buffer would provide an insertion loss of approximately 4 to 6 decibels(A). (A loss of 3 to 4.5 decibels(A) corresponds to approximately tripling the distance between the source of noise and the receptor.)

Josselyn et al. (1989) studied the effects of public activities on waterbirds in wetland habitats in the San Francisco Bay region. In measuring bird disturbance responses (usually movement to another location within the site), they found the distance from the human activity causing a disturbance ranged between 50 and 175 feet. The distance varied between species and habitats, with dabbling ducks exhibiting the most sensitivity. The Washington Department of Wildlife (WDW) (Appendix C, this report) concluded that "a person approaching heron or a flock of waterfowl can agitate and flush them even at distances of 200 to 300 feet. This is especially true for grazing waterfowl on shallow wetlands and wet pastures or black brant on open water."

**Wetland Species Distribution and Diversity**

Often, the health of a particular type of habitat is measured by the presence or abundance of a particular species of plant or animal or by the presence of particular community types called indicators. These indicator species and communities are used to determine the amount or extent of protection that a habitat needs in order to remain viable. Protection afforded to wetlands and streams by buffers has been assessed using various species of birds and animals as indicators.

Milligan (1985) studied bird species distribution in 23 urban wetlands in King County, Washington. She found that bird species diversity, richness, relative abundance, and the breeding numbers were moderately positively correlated with wetland buffer size. Specifically,
increases in species diversity were associated with wetland buffer size increases from 50 to 100 to 200 feet. Milligan concluded, however, that wetland size and the amount of wetland edge were more important than buffer size. Her work suggested a minimum 50 feet of buffer for bird habitat preservation. Finally, Milligan noted that larger buffers may be required for wetlands adjacent to high intensity land uses.

The following information is summarized from Buffer Needs of Wetland Wildlife, prepared by the Department of Wildlife and attached as Appendix C to this report.

In herbaceous vegetation next to wetlands, blue-winged teal use select grassy vegetation for establishment of nest sites. They need three acres of upland for each acre of wetland for breeding. The annual loss of untilled upland nesting cover is a major factor contributing to suppressed duck production, regardless of water conditions. Because of conversion of adjacent uplands, teal and gadwall production in Washington state has been significantly reduced (Zeigler, pers. comm., February 1992). Blue-winged teal nests in North Dakota averaged 256 meters from water. Optimum nest cover values are assumed to occur at less than 250 meters from any wetland other than ephemeral wetlands. Great blue herons tolerate human habitation and activities about 100 meters from a foraging area and occasional, slow moving, vehicular traffic about 50 meters from a foraging area.

In shrub vegetation next to wetlands, the beaver use zone includes an area 600 feet from the wetland edge. Trees and shrubs closest to water are used first. A majority of beaver feed within 328 feet of water. In dry environments, 90% of the beaver feed within 100 feet of water. Belted kingfisher broods use shrub cover along water for concealment. Roosts were 30.5 to 61 meters from water.

In either shrub or herbaceous vegetation in buffers, foraging sites within 200 meters of wetlands that contain nest sites are assumed useful for blackbirds. The average distance from gadwall nest sites to water was less than 45.8 meters in several studies of gadwalls, but nests in North Dakota averaged 351 meters from water. Gadwalls typically select the tallest, densest, herbaceous or shrubby vegetation available in which to nest. The majority of lesser scaup nests have been recorded within 10 meters of the water’s edge. They have been found up to 0.4 kilometers from water. The most preferred nesting habitat for lesser scaup is assumed to occur when a 50-meter zone surrounding permanently flooded, intermittently exposed, and semipermanent flooded wetlands with 30 to 75% canopy cover of herbaceous vegetation. Lesser scaup most frequently are observed on wetlands with at least half of the shoreline bordered by trees and shrubs.

In forested buffers, the limiting features for wood duck use are open water, marsh or shrubs and snags. They distance from 0 to 1149 feet from water but average 262 feet. Most nests are within 600 feet of water. Beaver feed up to 600 feet from the wetland edge, using trees and shrubs closest to water first. Lesser scaup use forest buffers, nesting up to 165 feet from water in herbaceous layers. Mink use forested buffers within 600 feet from open water. Most use is within 328 feet of the wetland edge. Mink need 75 to 100% forested cover. Den sites in Idaho were placed up to 328 feet from the wetland edge. Pileated woodpeckers nest within 492 feet of water; most nest within 164 feet. Because of impacts caused by timber harvest to the marten
populations. WDW management guidelines recommend no harvest within 200 feet of riparian corridors.

McMahon (1983) found that vegetated buffers were important for survival of juvenile coho salmon, both for temperature moderation, cover and increased food supply. Brook trout are also extremely susceptible to elevated temperatures, and Raleigh (1982) recommended a 30-meter (98-foot) buffer width with 50 to 75% midday shade as optimal. Eighty percent of this buffer should be vegetated, for erosion control, for maintaining the undercut bank areas, and for providing essential cover for the trout along the bank. Raleigh et al. (1984) described similar habitat requirements for rainbow trout, and recommended the same size and make-up for buffer areas.

Some researchers have assessed the value of buffers for several species concurrently, and offer general buffer recommendations. Mudd (1975) studied the Touchet River, analyzing current conditions along the river, and the amount of riparian and wetland wildlife habitat that existed. Bird, mammal, and plant species were surveyed, although game species were studied most. Mudd found that a minimum of 75 feet of natural riparian, primarily mature, vegetated buffer promoted optimum wildlife populations for pheasant, quail, mourning dove, and deer.

The WDW (Appendix C, this report) summarizes that:

"To retain wetland-dependent wildlife in important wildlife areas, buffers need to retain plant structure for a minimum of 200 to 300 feet beyond the wetland. This is especially the case where open water is a component of the wetland or where the wetland has heavy use by migratory birds or provided feeding for heron. The size needed would depend upon disturbance from adjacent land use and resources involved.

Influence of the water table on the landscape and vegetation is often reduced on the eastside of the state with more abrupt wetland-upland edges. Wildlife use tends to be concentrated closer to water in drier climates. Hall (1970) showed more narrow beaver use on streams in eastern California than had been reported in the literature (100 feet vs. 328 feet). Mudd (1975) showed minimum riparian area for maximum pheasant and deer use to be 75 feet in one eastern Washington study.

In western Washington, wetlands with important wildlife functions should have 300-foot upland buffers for intense land uses and 200-foot upland buffers for low intensity land uses. In Eastern Washington, wetlands with important wildlife functions should have 200-foot upland buffers for intense land use and 100-foot buffers for low intensity land uses.

Priority species or especially sensitive animals or wetland systems such as bogs/fens or heritage sites may need even larger buffers around wetlands to prevent their loss to disturbance or isolation of subpopulations or other loss of wetland function or value."

**Wetland Buffer Determination Models and Recommendations**

Washington State agencies and local governments are not the first to consider the question of wetland buffer protection and buffer sizes. Others, most notably in the eastern United States,
<table>
<thead>
<tr>
<th>STATE</th>
<th>Buffer Requirement</th>
<th>Rating System</th>
<th>Buffer Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>yes</td>
<td>yes</td>
<td>100 feet</td>
</tr>
<tr>
<td>Connecticut</td>
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</tr>
<tr>
<td>Delaware</td>
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<td>0 to 300 feet</td>
</tr>
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<td>Illinois</td>
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</tr>
<tr>
<td>Louisiana</td>
<td>no</td>
<td>yes</td>
<td>none</td>
</tr>
<tr>
<td>Maine</td>
<td>yes</td>
<td>yes</td>
<td>25 to 100 feet</td>
</tr>
<tr>
<td>Maryland</td>
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<tr>
<td>Michigan</td>
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<td>no</td>
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</tr>
<tr>
<td>Minnesota</td>
<td>no</td>
<td>no</td>
<td>none</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>yes</td>
<td>no</td>
<td>0 to 100 feet</td>
</tr>
<tr>
<td>New Jersey</td>
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<td>0 to 100 feet</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>yes</td>
<td>yes</td>
<td>300 feet</td>
</tr>
<tr>
<td>Oregon</td>
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<td>none</td>
</tr>
<tr>
<td>Rhode Island</td>
<td>yes</td>
<td>no</td>
<td>50 to 100 feet</td>
</tr>
<tr>
<td>Vermont</td>
<td>yes</td>
<td>yes</td>
<td>0 to 100 feet</td>
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<thead>
<tr>
<th>COUNTY</th>
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<th>Buffer Range</th>
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</thead>
<tbody>
<tr>
<td>Clark</td>
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<td>yes (I-V)</td>
<td>25 to 300 feet</td>
</tr>
<tr>
<td>Island</td>
<td>yes</td>
<td>yes (A-C)</td>
<td>25 to 100 feet</td>
</tr>
<tr>
<td>King</td>
<td>yes</td>
<td>yes (1-3)</td>
<td>25 to 100 feet</td>
</tr>
<tr>
<td>Pierce</td>
<td>yes</td>
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<td>100 feet</td>
</tr>
<tr>
<td>Thurston</td>
<td>yes</td>
<td>no</td>
<td>0 to 200 feet</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>CITY</th>
<th>Buffer Requirement</th>
<th>Rating System</th>
<th>Buffer Range</th>
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</thead>
<tbody>
<tr>
<td>Anacortes</td>
<td>yes</td>
<td>no</td>
<td>25 feet min.</td>
</tr>
<tr>
<td>Bainbridge</td>
<td>yes</td>
<td>yes (I-IV)</td>
<td>25 to 150 feet</td>
</tr>
<tr>
<td>Bellevue</td>
<td>yes</td>
<td>yes (Class A-C)</td>
<td>0 to 50 feet</td>
</tr>
<tr>
<td>Bellingham</td>
<td>yes</td>
<td>yes (1-3)</td>
<td>25 to 100 feet</td>
</tr>
<tr>
<td>Bothell</td>
<td>yes</td>
<td>yes (1-3)</td>
<td>25 to 150 feet</td>
</tr>
<tr>
<td>Bonney Lake</td>
<td>yes</td>
<td>yes (I-IV)</td>
<td>25 to 200 feet</td>
</tr>
<tr>
<td>Burlington</td>
<td>yes</td>
<td>no</td>
<td>25 feet</td>
</tr>
<tr>
<td>Camas</td>
<td>yes</td>
<td>no</td>
<td>25 to 100 feet</td>
</tr>
<tr>
<td>Des Moines</td>
<td>yes</td>
<td>yes (Sig &amp; Imp)</td>
<td>35 to 100 feet</td>
</tr>
<tr>
<td>Eatonville</td>
<td>yes</td>
<td>yes (I-IV)</td>
<td>10 to 100 feet</td>
</tr>
</tbody>
</table>

1. State information includes proposed as well as adopted standards.
2. Applied on a case-by-case basis.
<table>
<thead>
<tr>
<th>CITY Cont.</th>
<th>Buffer Requirement</th>
<th>Rating System</th>
<th>Buffer Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enumclaw</td>
<td>yes</td>
<td>yes (I-IV)</td>
<td>25 to 100 feet</td>
</tr>
<tr>
<td>Everett</td>
<td>yes</td>
<td>yes (1-3)</td>
<td>35 to 100 feet</td>
</tr>
<tr>
<td>Federal Way</td>
<td>yes</td>
<td>no</td>
<td>100 feet</td>
</tr>
<tr>
<td>Kirkland</td>
<td>yes</td>
<td>no</td>
<td>50 feet</td>
</tr>
<tr>
<td>Lacey</td>
<td>yes</td>
<td>yes (1-V)</td>
<td>25 to 300 feet</td>
</tr>
<tr>
<td>Lynden</td>
<td>yes</td>
<td>no</td>
<td>25 to 100 feet</td>
</tr>
<tr>
<td>Milton</td>
<td>yes</td>
<td>yes (I-IV)</td>
<td>25 to 300 feet</td>
</tr>
<tr>
<td>Olympia</td>
<td>yes</td>
<td>yes (I-IV)</td>
<td>25 to 300 feet</td>
</tr>
<tr>
<td>Port Angeles</td>
<td>yes</td>
<td>yes (I-IV)</td>
<td>25 to 300 feet</td>
</tr>
<tr>
<td>Puyallup</td>
<td>yes</td>
<td>yes (I-IV)</td>
<td>25 to 150 feet</td>
</tr>
<tr>
<td>Redmond</td>
<td>no</td>
<td>no</td>
<td>none</td>
</tr>
<tr>
<td>Seattle</td>
<td>yes</td>
<td>no</td>
<td>25 feet</td>
</tr>
<tr>
<td>Shelton</td>
<td>yes</td>
<td>yes (I-3)</td>
<td>25 to 150 feet</td>
</tr>
<tr>
<td>Snoqualmie</td>
<td>yes</td>
<td>yes (1-3)</td>
<td>25 to 100 feet</td>
</tr>
<tr>
<td>Tacoma</td>
<td>yes</td>
<td>yes (I-IV)</td>
<td>25 to 200</td>
</tr>
<tr>
<td>Tukwila</td>
<td>yes</td>
<td>yes (1-3)</td>
<td>25 to 100 feet</td>
</tr>
<tr>
<td>Tumwater</td>
<td>yes</td>
<td>yes (I-IV)</td>
<td>25 to 300 feet</td>
</tr>
<tr>
<td>Wenatchee</td>
<td>yes</td>
<td>yes (I-IV)</td>
<td>50 to 250 feet</td>
</tr>
</tbody>
</table>
IV. SUMMARY AND CONCLUSIONS

- **Wetland buffers are essential for wetlands protection.** No scientific study, no government agency, and no recommendations made during any communications with wetlands specialists nationwide suggested otherwise.

- **Wetland buffers reduce the adverse impacts of adjacent land uses to wetlands.** Wetland buffers also provide important habitat for wildlife which utilize wetlands and buffer areas for essential life needs. Buffers reduce wetland impacts by moderating impacts of stormwater runoff including stabilizing soil to prevent erosion; filtering suspended solids, nutrients, and harmful or toxic substances; and moderating water level fluctuations. They reduce the adverse impacts of human disturbance on wetland habitat including blocking noise and glare; reducing sedimentation and nutrient input; reducing direct human disturbance from dumped debris, cut vegetation, and trampling; and providing visual separation. They also provide essential habitat for wetland-associated species for use in feeding; roosting; breeding and rearing of young; and cover for safety, mobility and thermal protection.

- **Buffer effectiveness increases with buffer width.** As buffer width increases, the effectiveness of removing sediments, nutrients, bacteria, and other pollutants from surface water runoff increases. However, for incrementally greater sediment removal efficiency (e.g., from 90 to 95%), disproportionately larger buffer width increases are required (e.g., from 100 to 200 feet).

As buffer width increases, direct human impacts, such as dumped debris, cut or burned vegetation, fill areas, and trampled vegetation, will decrease.

As buffer width increases, the numbers and types of wetland-dependent and wetland-related wildlife that can depend on the wetland and buffer for essential life needs increases.

- **Appropriate buffer widths are based on four variables:** (1) existing wetland functions, values and sensitivity to disturbance; (2) buffer characteristics; (3) land use impacts; and (4) desired buffer functions.

- **Wetlands with important functions and values or wetlands which are sensitive to disturbance will require greater buffers to reduce the risk of disturbance.** Wetland functions, values, and sensitivity are attributes that will influence the necessary level of protection for a wetland. Those systems which are extremely sensitive or have important functions will require larger buffers to protect them from disturbances, which may be of lesser threat to a different site. Where wetland systems are rare or irreplaceable (e.g., high quality estuarine wetlands, mature swamps, and bogs) larger buffer widths will ensure a lower risk of disturbance.

- **The uplands immediately adjacent to the wetland vary in their ability to reduce adverse effects of development, most importantly in relationship to slope and vegetative cover.** Buffers with dense vegetative cover on slopes less than 15% are most effective for water...
quality functions. Dense shrub or forested vegetation with steep slopes provide the
greatest protection from direct human disturbance. Appropriate vegetation for wildlife
habitat depends on wildlife species present in the wetland and buffer. Effectiveness is
also influenced by ownership of the buffer.

- Land uses associated with significant construction and post-construction impacts need
greater buffers. Construction impacts include erosion and sedimentation, debris disposal,
vegetation removal and noise. Post-construction impacts are variable depending on the
land use, but residential land use, in particular, can have significant impacts. Residential
land use is associated with yard maintenance debris, domestic animal predation, removal
of vegetation and trampling. Wetland areas and their buffers should not be included in
residential lots.

- Appropriate buffer widths vary according to the desired buffer function(s). Temperature
moderation, for example, will require smaller buffer widths than some wildlife habitat or
water quality functions. Buffer widths for wildlife may be generalized, but specific
habitat needs of wildlife species depend on individual habitat requirements.

- Buffers of less than 50 feet in width are generally ineffective in protecting wetlands.
Buffers larger than 50 feet are necessary to protect wetlands from an influx of sediment
and nutrients, to protect wetlands from direct human disturbance, to protect sensitive
wildlife species from adverse impacts, and to protect wetlands from the adverse effects of
changes in quantity of water entering the wetland.

- In western Washington, wetlands with important wildlife functions should have 200 to
300-foot buffers based on land use. In eastern Washington, wetlands with important
wildlife functions should have 100 to 200-foot buffers based on land use. To retain
wetland-dependent wildlife in important wildlife areas, buffers need to retain plant
structure for a minimum of 200 to 300 feet beyond the wetland. This is especially the
case where open water is a component of the wetland or where the wetland has heavy use
by migratory birds or provides feeding for heron. The size needed would depend upon
disturbance from adjacent land use and resources involved. Priority species may need
even larger buffers to prevent their loss due to disturbance or isolation of subpopulations.

- Buffer widths effective in preventing significant water quality impacts to wetlands are
generally 100 feet or greater. Sensitive wetland systems will require greater distances and
degraded systems with low habitat value will require less.
The literature indicates effective buffer widths for water quality range from 12 to 860 feet
dpending on the type of disturbance (e.g., feedlot, silviculture) and the measure of
effectiveness utilized by the author. For those studies which measured effectiveness
according to removal efficiency, findings ranged from 50 to 92% removal of specific
pollutants in ranges of 62 to 288 feet. Studies which measured effectiveness according to
environmental indicators, such as levels of benthic invertebrates and salmonid egg
development in the receiving water, generally found that 98-foot buffers adjacent to
streams were effective. These latter buffer distances may be conservative for wetlands
where lower water velocities and presence of vegetation result in increased sediment
deposition and accumulation.
Buffers from 50 to 150 feet are necessary to protect a wetland from direct human disturbance in the form of human encroachment (e.g., trampling, debris). The appropriate width to prevent direct human disturbance depends on the type of vegetation, the slope, and the adjacent land use. Some wetlands are more sensitive to direct disturbance than others.

Some state agencies and many local governments rely upon wetlands rating systems to establish buffer widths. These rating systems are typically based upon perceived wetland value and upon acceptable levels of risk to the wetland from adjacent land uses. Of 16 states surveyed, ten require wetland buffers and eight incorporate wetlands rating, either adopted or proposed. Of five Washington counties, with adopted wetlands protection ordinances, all five require buffers and four utilize wetlands rating systems (the fifth is currently proposing an amendment which incorporates rating). Of 28 identified cities with wetlands protection ordinances (or interim ordinances), 27 contain specific buffer standards and 20 utilize wetlands rating systems. The city without specific standards has adopted an interim policy statement.

Specific buffer requirements vary widely at the state and local level. This has resulted in differing buffer requirements and levels of wetland protection that are not necessarily effective. For example, the buffer requirements of many agencies are less than those that are reported in the literature to be effective.

State buffer requirements range from 0 to 300 feet; Washington county buffer requirements range from 0 to 200 feet; and Washington city buffer requirements range from 0 to 300 feet.