CITY OF RENTON

BEST AVAILABLE SCIENCE
LITERATURE REVIEW
AND STREAM BUFFER RECOMMENDATIONS

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1.0 SUMMARY

This report summarizes the results of a literature review of the best available science, undertaken to develop and support recommendations to the City of Renton for stream and lakeshore protection by buffers sized to various stream or lake shore classes. The Washington State Office of Community Development adopted administrative rule guidance in August 2000 (Chapters 365-195-900 through 925 WAC) to assist cities on identifying and including best available science in land use management regulations. This review followed those guidelines and used a valid scientific process by qualified individuals "…*that produces reliable information useful in understanding the consequences of* [the City's] *regulatory decisions*" (Washington State Office of Community Development 2002). A parallel effort, summarized in this report, was undertaken to review and recommend a stream classification system for the City.

2.0 APPROACH

The beneficial influences of riparian areas along streams of varying types and lakeshore within the City of Renton were evaluated by the following process:

- Review of existing fish distribution and habitat inventory information for Renton (Golder Associates 2001);
- Field reconnaissance of representative stream and lakeshore segments by the two principal scientists that prepared this report;
- Review of best available science in the literature;
- Organization of the scientific literature into a matrix of riparian functions that play a role in stream and lake health and fish habitat support;
- Assessment of reasonably expected riparian function potentials within the City of Renton, and their distribution by stream type; and
- Recommendation of standard buffer widths for each stream classification, using a combination of the literature data review and riparian function potential assessments.

To allow for and recognize a variety of existing land use and property constraints, allow for changing environmental conditions, and for variations in riparian function potential in various areas of the City, two regulatory approaches are encouraged as a result of this review. The Path A process would occur where standard water body classifications, standard buffer widths and other regulations are met by an applicant's proposal. These Path A buffer widths are recommended in this report. The Path B process would occur where standard conditions are uncertain, or standard buffers are not proposed by an applicant, requiring more information to determine whether the proposal protects the riparian functions identified in this report, to the reasonable limits of their potential on a site-specific basis. To allow flexibility within the Path B process, an inner and outer riparian management zone concept is being developed by the City (Schueler 1995, Portland 2002).

3.0 URBAN CONSIDERATIONS

The full suite of riparian functions that support stream and lake shore habitat quality in natural forest or grasslands is reduced in the highly modified riparian zones found in the City of Renton. The most realistic strategy for streams and lake shore in the City is to recognize and protect natural riparian features that have a direct functional role on water and habitat quality within the constraints of the urban environment. Vegetation in the riparian area is key to providing those functions under urban constraints. Examples of these constraints include:

- Existing riparian widths and conditions constrained by structure and infrastructure;
- Channelized streams within dense population areas and among large numbers of small private properties;
- Public safety, or example hazard trees or flooding;
- Culvert interference with large woody debris transport downstream and other stream processes;
- And permanent or semi-permanent artificial barriers isolating stream reaches.

Nearly all of the scientific literature and literature reviews are written from a perspective of riparian functions and widths necessary to provide fully functioning natural pathways in forested areas (May 2002, Pollack and Kennard 1998; Knutson and Naef 1997; Spence *et al.* 1996; FEMAT 1993; Thomas et al. 1993; Budd *et al.* 1987; Harmon *et al.* 1986). Much of the literature on riparian function has investigated the results of tree harvesting in forests, or the effects of various agricultural practices. While these types of literature and summary reviews must be approached with caution when evaluating riparian functions and reasonable function potential under urban constraints, they are useful in describing riparian functional processes that allow extrapolation to the urban condition.

It has been argued (May 2002) that riparian buffers need to be designed both on the basis of the resource and on the "threat" represented by the surrounding land use. Under this approach, higher urban density or more intense land use would justify wider buffers, as would higher resource sensitivity or value. We rejected the land use "threat" approach as inconsistent with the realistic recognition of existing urban condition of most of the City, and inconsistent with the direction of the Washington State Department of Ecology in developing guidelines for its Shoreline Master Program. Those guidelines recommend restoration of ecological functions of shorelines (which includes all Class 1 streams and lake shores regulated by the City), where degraded, occur "…*as a planning requirement for local government to address through non-regulatory means*" and recognize limitations to regulatory authority with respect to private property (Washington Department of Ecology 2003).

The approach in this report was to recognize resource sensitivity or value through the stream and lake shore classifications, and then develop riparian buffer width recommendations for each. Those recommendations are based on data providing reasonable confidence the buffers will preserve or enhance riparian influences actually functioning to improve habitat and water quality in Renton's urban setting.

Finally, wildlife habitat and the interaction of water-dependent species with streams and lakeshores are often cited as one riparian function. For example, larger animals such as beavers also interact with riparian areas to affect hydrology and water quality, and are listed as one reason for larger riparian buffers (Naiman and Rogers 1997). However, where they exist, such animals can be inconsistent with public safety and infrastructure maintenance requirements in urban environments by clogging culverts or causing local flooding, and often must be removed. Riparian function has been evaluated in this report from the perspective of fish habitat requirements (including water quality). Other non-fish habitat, including uplands habitat, is provided by the City's Habitat Conservation Regulations. Those regulations may overlay the stream and lakeshore buffer recommendations included in this assessment, but are not included within the buffer functional requirements evaluated herein.

4.0 STREAM BUFFER FUNCTIONS

4.1 Water Quality

Vegetation adjacent to streams can improve water quality by filtering pollutants, removing nutrients, or preventing sediment introduction, and lowering temperature through shading (FEMAT 1993). In urban areas, development eliminates natural infiltration pathways to streams, changing the hydrologic flow paths to favor piped drainage systems that either bypass the riparian area, or channel flow through the riparian area (Schueler 1995). Much of the natural buffer functions for hydrologic and water quality functions (peak flow attenuation, base flow releases, and water quality treatment) are removed from riparian buffer control by storm drain systems. Storm water detention and water quality treatment requirements are regulated for new development and redevelopment within the City without reliance on riparian buffer function.

Nonetheless, there are areas where storm runoff sheet flows through riparian areas. Particularly in headwater areas, where developed stormwater system discharges may not control water quality, or reaches where residential yards, parks, or other areas slope towards streams with no intervening catch basin, riparian areas benefit water quality. Riparian areas also play a role in regulating seasonal nutrient releases to streams and lakeshores, supporting a food chain that includes prey for salmonids.

4.1.1 Contaminants (metals, organics, bacteria, oil and grease) and Nutrients

Where storm runoff disperses into vegetated riparian areas, the water slows, pools, and may infiltrate. This allows contaminants such as heavy metals, which adhere to fine particles, to settle out before reaching the stream. Other contaminants, such as bacteria, are removed through filtration in the soil. Organic compounds, and oil and grease are removed through filtration (hydrophobic attraction to surfaces), microbial or physical degradation.

Vegetation cover is key to this function, playing both a direct structural role in slowing water and trapping contaminants, and an active direct role in absorbing and storing nutrients as they move through the riparian zone (Castelle *et al.* 1994, Spence 1996). Diverse stands of vegetation are better at improving water quality than stands consisting of one or a few species (Todd 2000).

Nutrients are also chemically transformed by interaction with riparian soils and in stream gravels in the stream (Ferald *et al.* 2000). The hyporheic zone is a saturated area beneath a stream and under the riparian zone where groundwater and surface water coexist in hydraulic continuity with the stream. This area changes the chemical composition of water through denitrification (volatilization of excess nitrogen by bacteria under low oxygen conditions), and storage of particulate organic matter, where it is processed over time by benthic invertebrates and bacteria (Naimen *et al.* 2000).

Physical-chemical interactions in the hyporheic zone that influence water quality are very important in relatively undisturbed watersheds (Naiman and Bilby 1998), but have much less influence in developed urban areas.

Riparian function for nutrients is not limited to improving water quality from water dispersed through it. Vegetation within the riparian area plays an important role in regulating nutrient inputs to stream food chains. Riparian vegetation is the primary carbon source for stream organisms, becoming available as plants die, drop leaves, or leach nutrients into water (Gregory *et al.* 1991, Huebner et al 1993). Nitrogen and phosphorus, like carbon, are vital plant nutrients; though in excess they can lead to excessive algae and plant growth, which in turn can cause low dissolved oxygen when it decomposes. Nitrogen is very water soluble, whereas phosphorus is mainly in mineral form attached to sediments. Some plants, like red alder, fix atmospheric nitrogen through symbiotic association with microbes, and release it into the stream with leaf litter.

Riparian buffers can trap particulate phosphorus where water is dispersed, and riparian vegetation can take up mineralized phosphorus from the soil and store it. Plant storage returns some phosphorus to the stream as leaf litter. Riparian vegetation likely does not remove phosphorus to storage in the long term, given constant inputs (Peterjohn and Correll 84; Lowrance *et al.* 97; Lowrance 98), but does affect the timing of its passage through the riparian zone to the stream, and returns phosphorus to the stream as leaf litter that is better suited to stream ecosystem function.

Some of the greatest riparian functional widths in the literature are attributed to nutrient removal, where water is dispersed through them, or to protect streams from agricultural influences, both crop and animal manure (i.e., up to 600 feet or an average of 250 feet by Knutson and Naef 1997; equal to area of manure origin by Overcash *et al.* 1981 and Bingham *et al.* 1980), or to protect streams from logging and burning (Snyder *et al.* 1975, Lynch *et al.* 1985). Very little literature pertains directly to the role of riparian zones for nutrient control in urban areas.

Vegetated stream or lake buffers can function to reduce nonpoint introduction of sediments and associated phosphorus during construction in urban areas, or from residential lots. Including sites up to 12 percent in slope, vegetated buffers of 50 feet were found to reduce phosphorus introduced by construction erosion to background (unaffected) levels (Woodard and Rock 1995). Vegetation cover had a more significant impact on suspended solids and phosphorus than slope, even up to the steepest studied slopes of 12 percent. Unvegetated, exposed soil areas in the riparian areas were sources of suspended solids to the streams.

Because of the altered means by which water enters streams in urban environments, it is recognized that source control and stormwater treatment best management practices will be the primary means to control stream nutrients (Binford and Buchenau 1993; Barling and Moore 1994; Spence *et al.* 1996; Leavitt 1998).

From an undisturbed watershed perspective, May (2002) concluded from his review of the literature that 100 feet of buffer would provide full nutrient riparian function. This conclusion is consistent with Knutson and Naef's (1997) literature review conclusion that, for most water quality parameters, 100 feet of buffer would protect this riparian function where water is dispersed through buffer and controls stream water quality in the forested watershed.

The one literature source that directly studied phosphorus removal from residential construction as a function of buffer width concluded that a 50-foot buffer would protect water quality, irrespective of slope so long as the buffer was well vegetated (Woodard and Rock 1995).

Table 1
Summary of Riparian Widths Reported to
Trap Nutrients and Stormwater Contaminants in a Vegetated Riparian Zone

Buffer Width	Citation	Notes
50 feet	Woodard and Rock 1995	100% removal of added phosphorus load from non-point residential construction runoff, where vegetative cover was good, irrespective of slopes.
100 feet	Castelle *et al.* 1994	Based on author's review of literature
100 feet	Todd 2000	Based on author's review of literature in multi-use watersheds.
100 feet	Knutson and Naef 1997	Based on author's review of literature; to preserve buffer function where natural routing of water through buffers is preserved (i.e., rural areas or forest practices).

4.1.2 Non-Point Fine Sediments

As with nutrients, sediment removal function by riparian zones has less relative importance where developed stormwater systems discharge directly to streams, bypassing riparian areas and dominating flow. In forested systems affected by logging, one site potential tree height (approximately 100 to 115 feet in the Renton area) has been suggested as protective (Broderson 1973), but extrapolation of these results to an urban context is difficult. It is clear that, where flow is overland through a riparian area, vegetation can slow or trap water, settling sediments before reaching the stream (Spence *et al.* 1996). Other literature reviews from a forest cover perspective concluded distances between 100 feet and 200 feet are needed to prevent most sediment from reaching streams (Karr and Schlosser 1977; Johnson and Ryba 1992; Broderson 1973). These distances pertain mainly to logging practices. They are in sharp contrast to the 50-foot recommendation resulting from studies by Woodward and Rock (1995), designed for the explicit purpose of examining suspended solids removal as a function of transit distance vegetated buffers adjacent to residential construction.

Table 2
Summary of Riparian Widths Reported to
Trap Most Suspended Solids and Sediments in a Vegetated Riparian Zone

Buffer Width	Citation	Notes
50 feet	Woodard and Rock 1995	Removal of most suspended solids from non-point residential construction runoff, where vegetative cover was good, irrespective of slopes.
100-125 feet	Karr and Schlosser 1977	75% sediment removal; in forested area
150 feet	Johnson and Ryba 1992	90% sediment removal at 2% grade; in forested area.
200 feet	Broderson 1973	To prevent sediment introduction from logging to streams.

4.2 Food - Particulate Organic Nutrient Input

Vegetation and plant material falling into the creek form an important component of the aquatic ecosystem food chain, especially in smaller stream channels (Gregory *et al.* 1991, Naiman et al. 1992). Particulate matter delivered by the adjacent riparian area directly or indirectly provides nutrients and energy for organisms eventually consumed by fish. Terrestrial insects living in the adjacent vegetation also contribute to the productivity of a stream. The majority of material comes from directly over, or within a very short distance of the stream. FEMAT (1993) suggests most leaf material is contributed within approximately 50 feet of the stream. Other studies have shown that benthic invertebrate communities in streams with riparian buffers greater than 100 feet are indistinguishable from those in streams in forested watersheds (Erman *et al.* 1977).

Table 3
Summary of Riparian Widths Reported to Provide
90 Percent or Greater of Particulate Nutrients

Buffer Width	Citation	Notes
50 feet	FEMAT 1993	Greater than 90 percent of function
100 feet	Erman *et al.* 1977	Approximately 100 percent protective of macroinvertebrate community which depend to a large extent on particulate nutrients

4.3 Microclimate

Riparian vegetation protects streams from climate changes caused by widespread development away from the stream, including soil and air temperature, humidity, and wind. The collection of these small-scale climatic variables is called microclimate. There is no direct link between microclimate and the condition of salmonid habitat that appears in the literature. However, it has been suggested that microclimate needs protection (in addition to shade or temperature control, discussed below) to maintain desirable assemblages of plants and animal species, including insects, beneficial to fish (Pollack and Kennard 1998).

If protection to natural forested microclimate conditions is the goal, the literature report buffers of 100 to over 500 feet of riparian forest could be necessary. For forested streams, one study found 100 percent function to control relative humidity occurs 250 feet from the stream; 50 percent function occurs within approximately 35 feet (Pollack and Kennard 1998). FEMAT (1993) concluded between 0.5 to 3 site potential tree heights would preserve natural mature forest riparian microclimates (approximately 58 to 345 feet in the Renton area). While there are several literature reports examining microclimate and forest practices (Table 4), there are no literature data for urban areas, where relative humidity and temperature are greatly influenced by surrounding development rather than vegetation.

Table 4
Summary of Riparian Widths Reported to Provide
Natural Forested Riparian Microclimate

Buffer Width	Citation	Notes
100 feet	Spence *et al.* 1996	Literature Review; Western Oregon forests
148 feet	Brosofske *et al.* 1997	Forest harvest effect study; Western Washington
250 feet	Pollack and Kennard 1998	Forest harvest study, 100% function; 50% function within 35 feet.
58 - 345 feet	FEMAT 1993	Mature forest; to maintain natural forested riparian microclimate; 0.5 to 3.0 site potential tree heights.
525 feet	Franklin and Forman 1987	Riparian forest ecosystem

4.4 Temperature and Shade

Overhanging vegetation shades streams, until the channels become so broad that, like lakes, most of the water surface is exposed to the sun. By intercepting solar radiation, vegetation prevents heat energy from reaching streams, maintaining cooler water. Vegetation also shades soil, cooling water introduced to streams through the hyporheic zone. Cool water is an essential habitat feature for salmonids, and increases the amount of atmospheric oxygen that will dissolve into the water, which also improves salmon habitat conditions and is essential for salmon spawning.

Sullivan *et al.* (1990) concluded that leaving 50 to 75 percent of larger (fish bearing) stream reaches shaded after logging would leave most streams in a temperature range suitable for fish. Once streams traveled 25 miles from their watershed divides, they were generally too wide for trees to shade their surfaces or exercise control over water temperature (for example, the Cedar River within the City of Renton, the Black River, and Lake Washington). It has been reported that overhanging vegetation on large rivers or lake shores can create cooler micro habitats for fish and aquatic organisms (Palone and Todd 1997).

One comparison of pre- and post-forest harvest conditions found that riparian buffer width did not affect stream water temperature, except in the complete absence of streamside trees (Brosofske *et al.* 1997). Soil temperature and not forested buffer width was the determining factor for stream water temperature.

Considered from a shading perspective with old growth forest conditions as the goal, Brazier and Brown (1973) found that angular canopy densities comparable to old growth stands could be attained within 70 to 100 feet of the stream in the southern Cascades and Oregon Coast range. Steinblums *et al.* (1984) recommends greater than 124-foot buffers in the western Cascades to retain 100% natural shading, based on studies performed at a range of 25 to 145 foot widths.

Stream temperatures in deforested watersheds, while warmer than they were in a forested state, do not approach the tolerance limits of resident fish species (Beschta *et al.* 1987). However, one effect of urbanization is to increase ambient temperatures above forested watersheds because of impervious surfaces. In these areas, local- or small-scale shade (that directly over the stream and riparian area) will influence water temperature. Larger-scale, or thermal corridor influences on temperature do not occur in urban areas, with the exception of streams in steeper canyons or valleys where development has not occurred or is restricted by steep slopes. In these situations, temperature in a stream reach is affected by the condition of the adjacent riparian forest and by riparian and hill slope conditions far upstream and upslope (Pollock and Kennard 1998).

In forested watersheds, where large-scale thermal corridor effects do occur, one study determined that 100 percent shade function required a 300-foot distance from the stream; 83 percent function required 120-foot distance; 75 percent function required a 100-foot distance; and 50% function required 50 feet of forest shade (Pollack and Kennard 1998). Most other studies found up to 100 percent temperature function within 100 feet of the stream under forested conditions (Table 5). There were no data in the literature reporting functional temperature data for various buffer widths in urban settings.

Table 5.
Summary of Riparian Width Reported to Provide
Shade and Control Temperature with a Forested Riparian Zone

Buffer Width	Citation	Notes
50 - 250 feet	Pollack and Kennard (1998)	50%-100% natural shade (full forest)
70 - 100 feet	Brazier and Brown (1973)	80-90% natural shade (full forest)
75 feet	FEMAT 1993	100% natural shade (0.75 SPTH for 100-foot lowland trees)
100 feet	Barton *et al*. (1985)	2°F reduction in stream temperature with 100 foot forested buffer
100 feet	Beschta *et al.* 1987	100% natural shade (full forest)
100 feet	Johnson and Ryba 1992	50-100% natural shade (full forest)

4.5 Human Access Control

One function of buffers in populated watersheds can be reducing the direct encroachment of humans (Leavitt 1998). Direct human impact to streams most often consists of refuse dumping, trampling of vegetation, bank erosion, and noise (King County 2002 and Castelle 1992). Plant loss due to the trampling of vegetation near a stream increases siltation of spawning gravels and reduces aquatic invertebrates that are important fish food sources. Riparian buffers protect sensitive areas from direct human impact by limiting easy access to the stream and by blocking the transmittal of human and mechanical noise. Riparian buffers provide visual separation between streams and the developed environment, blocking glare and human movement from fish species (Young 1989).

Twenty-one wetlands in King and Snohomish Counties were studied before residential development, and 8 years after development, to assess the effectiveness of buffers in controlling human disturbances (Cooke 1992). Although this study assessed wetland habitat and not streams, it nonetheless provides a basis to estimate the width of a buffer that discourages or reduces human disturbance to streams. Cooke (1992) concluded that buffers functioned most effectively when the adjacent land use consisted of low intensity development; when buffer areas were greater than 50 feet wide, and planted with high quality mixed species of native vegetation; and where there was a high degree of resident education on the value of buffers. Human disturbance most often took the form of lawn or landscaping encroachment. Twenty of the 21 buffers in the study that were less than 50 feet wide had some form of human alteration (95 percent). Three of 8 buffers in the study greater than 50 feet in width had some form of human alteration (35 percent).

Other authors recommend controlled human activity within riparian buffers, such as restricting human disturbance to footpaths, or roadway crossings within 25 feet of the stream, and allowing active recreation and bike paths within 25 to 50 feet of the stream (Schueler 1995).

Narrower buffers may suffice in areas to prevent human disturbance through education, such as signage and/or homeowner education; or through physical measures, such as fencing or vegetation that discourages passage (Schueler 1995).

Table 6
Summary of Riparian Width Reported to Provide
Human Disturbance Control

Buffer Width	Citation	Notes
25 feet	Schueler 1995	Passive footpaths and utilities; controlled access
25 - 50 feet	Schueler 1995	Active bike trails and recreation; controlled access
50 feet or greater	Cooke 1992	50-foot buffers protected from human disturbance nearly 3 times better than 25-foot buffers.

4.6 Large Woody Debris

Large woody debris (LWD) consists of downed tree stems and branches and is a functionally important structural component of stream channels in the Pacific Northwest (Fetherston *et al.* 1995, Naiman *et al.* 1992). Once LWD reaches a stream it may remain in place or migrate downstream depending on the size of the wood and stream energy. LWD can have a major effect on the quality of fish habitat within a stream as it influences the routing of water and sediment, helps trap and stabilize coarse gravel deposits, plays a role in the development of channel morphology, is an important source of overhead and velocity cover for fish, and acts as a surface for biological activity which contributes to the productivity of a stream system (Bisson *et al.* 1987; Beschta *et al.* 1987; Sullivan *et al.* 1987, Bilby and Ward 1991).

The probability that a falling tree will reach a creek is a function of its distance from the creek, tree size, ground slope near the stream, and predominant wind direction. In a mature coniferous forest, the majority (70 to 90 percent) of LWD in a stream comes from within 50 feet of the stream; 90 to 99 percent comes from within 100 feet, and virtually all LWD contributed to streams in a typical Puget Sound lowland forested region comes from within a distance equal to approximately 150 feet (Murphy and Koski 1989, McDade, 1990, Robison and Beschta 1990, FEMAT 1993, Fetherston *et al.* 1995). As a forested riparian stand ages, and trees get taller, proportionally more of the LWD contribution comes from further away (Fetherston *et al.* 1995). However, within the City of Renton urban areas, there are few if any mature to old growth trees and the potential of trees being allowed to grow for 100 to 300 years and then naturally fall is remote. Many if not most old and potentially unstable trees near homes, schools, parks and other public places are removed as hazard trees. Thus, most LWD recruitment in the future will come from young to moderate aged trees relatively close to the creek. Only within remote areas such as lower Honey Creek and portions of the Cedar River, and areas where a natural shorelines designation is provided such as portions of the Black River and Springbrook Creek, is it likely that older trees will develop to maturity.

Table 7
Riparian Width Reported to Provide
90 Percent or Greater of Natural LWD Recruitment in a Mature Forest

Buffer Width	Citation	Notes
65 feet	Murphy & Koski 1989	95% within 65 feet; 99% within 100 feet
95 feet	McDade *et al.* 1990	90% of mature conifer within 95 feet
65-120 feet	Van Sickle & Gregory 1990	Modeled data from mixed height and uniform mature stands
100-135 feet	FEMAT 1993	Mature to old-growth forest

4.7 Channel Migration

The channel migration zone (CMZ) is that area of the landscape that encompasses the lateral extent of likely stream channel movement over time due to stream bank erosion and new channel incision. Where not confined by nearby stable land forms or manmade flood control structures, stream channels naturally migrate as fluxes in sediment load aggrade the stream bed and cause flows to select more stable passageways (Montgomery and Buffington 1993). As channels move, new LWD and stream gravels are recruited resulting in the creation of new mainstem fish habitat. The abandoned mainstem channels often remain as side channels and backwaters offering off-channel rearing habitat opportunities for juvenile salmonids and their prey.

Identification of CMZs requires site-specific analysis by qualified fluvial geomorphologists. However, the CMZ can be roughly approximated by the 100-year flood zone as mapped by FEMA. The 100-year flood plains within the City of Renton have been mapped and are shown in the City of Renton Flood Hazard Sensitive Areas Map. The CMZ does not include areas that lie behind lawfully established flood control facilities for which a commitment exists to maintain the structure. These structures can include dikes, levees, or roads. The city code provides protection for floodplain areas, which would serve as an overlay to the standard stream buffers. Therefore CMZ function was not a determinant in consideration of riparian functions for buffers.

4.8 Bank Stability

Roots from vegetation growing along the streambank help stabilize soils and reduce erosion. Overhanging roots also provide habitat for fish where streams undercut the root balls. The soil stabilizing benefits of root structures is greatest within one-half of the crown diameter of the vegetation growing along the bank (Burroughs and Thomas 1977). Assuming that the largest plants growing along stream banks are trees, and the maximum crown diameter of a mature fir tree is approximately 80 feet, root strength benefits would be low beyond 40 feet from the channel. Smaller vegetation growing near the creek also strongly influences bank stability at distances nearer than 40 feet.

Table 8
Riparian Width Reported to Provide
90 Percent or Greater of Natural Bank Stability

Buffer Width	Citation	Notes
40-70 feet	FEMAT 1993	Based on tree size; affected by hydrology

5.0 STREAM CLASSIFICATIONS

For the purposes of this evaluation, streams were classified according to the following summary criteria:

- **Class 1** waters are perennial fish-bearing waters classified as shorelines of the state, and/or are identified as such on the City's adopted Chinook Distribution Map (Golder Associates 2001);
- **Class 2** waters are perennial or intermittent waters that historically or currently are salmonid-bearing, or a pond or lake between 0.5 and 20 acres in size;
- **Class 3** waters are non-fish bearing perennial waters during years of normal rainfall,;
- **Class 4** waters are non-fish bearing intermittent waters during years of normal rainfall; and
- **Class 5** waters are non-fish bearing waters which flow within an artificially constructed channel where no naturally defined channel had previously existed, or a surficially isolated water body less than 0.5 acres not meeting the definition of a wetland. These waters are deemed artificial and are not regulated.

6.0 BUFFER FUNCTION POTENTIAL

The potential for each riparian buffer function discussed in Section 4 to contribute to stream water quality and fish habitat health was evaluated as summarized in Table 9 and discussed below. No function was attributed to Class 5 (unregulated) waters.

- **Water quality function** by riparian buffers within the City is bypassed wherever storm drainage systems exist, either through direct discharge of stormwater to the stream or lake, or by introducing channelized flow that fails to disperse before reaching the stream or lake. Because of this, the role of riparian buffers in removing contaminants is determined to be low to moderate for all regulated water classes. Nutrient regulation was determined to be moderate for mid-sized to small streams, through seasonal release of leaf litter to the streams, despite the overriding influence of storm drains. However, nutrient regulation by riparian areas has lesser importance for Class 1 waters, because of the overriding dominance of upsteam contributions to nutrients. Fine sediment removal is determined to have no or low function influencing larger Class 1 waters, but increases in potential as the streams diminish in size down to Class 4 waters. Ranges of potential are listed where a range of site-specific conditions are known to exist that affect the importance of this function in maintaining water quality.

- **Food function**, or generation of leaves, vegetative litter, and terrestrial insects as food sources for aquatic food chains in riparian areas, increases in importance with smaller stream size. High in the watershed, leaf litter and insects form the primary source of nutrients and food, which are cycled and delivered to waters lower in the watershed. In large Class 1 waters, leaf litter function potential contribution is low, but increases to high function potential in Class 3 and 4 waters due to the greater proportional length of these water types in a basin.

- **Microclimate function** is determined to have no realized potential for some Class 1 waters (for example, the Cedar River through downtown Renton), to moderate potential (for example, May Creek). Moderate function potential is attributed to all other regulated water classes, because as streams decrease in size, streamside vegetation is more likely to control microclimate factors such as local humidity.

Table 9
Stream Riparian Buffer Function and Classification Matrix; Reasonably Expected Function Potentials for Stream Classes within the City of Renton

Function	Mechanism	Class 1	Class 2	Class 3	Class 4	Class 5
Water Quality	**Contaminants** are removed by dispersed flow through the buffer; settling particulates and promoting infiltration / filtration of water.	? _	? _	? _	? _	0
	Nutrients are controlled by dispersed flow through the buffer and vegetation, through microbial action and by cycling through plants and leaf litter.	?	_	_	_	0
	Fine Sediment is removed by dispersed flow through the buffer; settling particulates and promoting infiltration / filtration of water. **Hyporheic zone** (surface water / groundwater interface) adjacent to streams influences water chemistry.	0 ?	? _	? _	? _ ¦	0
Food	**Leaves, vegetative litter, and terrestrial insects** fall into stream as food source for a food chain stretching from bacteria to algae to aquatic invertebrates to fish and other aquatic animals.	?	_	¦	¦	0
Microclimate	**Riparian vegetation protects stream from climate changes** caused by widespread development away from the stream, including soil and air temperature, humidity, and wind.	0 ? _	_	_	_	0
Temperature & Shade	**Small-scale shade** keeps sun from water and soil, cooling stream and groundwater associated with the stream.	? _	¦	¦	?	0
	Large-scale, thermal corridor maintains cool air with mature trees to greater extent than small-scale shade, as in undeveloped valleys.	0	0	0	0	0
Human Access	**Limits human disturbance**, lowering vegetation trampling leading to bare dirt banks or encroachment by residential gardening.	0 ? _ ¦	_ ¦	_ ¦	_ ¦	0
Large Woody Debris (LWD)	**Conifer large branches or trunks** die and fall into stream, creating habitat complexity in stream, sorting of spawning gravel, trapping fine sediments, creating substrate for algae / diatom growth (see Food Function).	0 ? _ ¦	_	?	?	0
Channel Migration	**Natural meanders cut new channels** and deliver spawning gravels and LWD to streams.	0 ?	0 ? _	0 ?	0 ?	0
Bank Stability	**Roots and vegetation prevent bankside erosion.**	? _	_ ¦	¦	¦	0
Wildlife	**Non-Fish Habitat**	***See Habitat Conservation Regulations***				

0 No Function; ? Low Function; _ Moderate Function; ¦ High Function

- **Small-Scale Temperature and Shade function** potential is determined to be low to moderate for Class 1 waters (for example, the Cedar River and May Creek, respectively), but high for smaller perennial Class 2 and Class 3 waters. Intermittent Class 4 waters are ranked low in temperature or shade function potential, because they dry during the warmest part of the year. Large-scale, or thermal corridor-scale temperature control, was given no realized potential outside of areas already regulated as steep slopes.

- **Human Access control function** potential is determined to range from no to low for large Class 1 waters such as the Cedar River, where human access is provided to large reaches of the water, up to moderate to high for Class 1 waters such as May Creek. All other stream classes are determined to have moderate to high potential to control human access. Other means such as plantings, fencing and education could lessen the importance of realizing this riparian function.

- **Large Woody Debris (LWD) recruitment function** potential ranges from no to low for large Class 1 waters such as the Cedar River, where existing development precludes the growth of trees to hazard size along large reaches of the water, up to moderate to high for Class 1 waters such as the undeveloped May Creek corridor. The importance of LWD diminishes with smaller stream sizes in the urban environment, because of restrictions to public safety from the growth of trees to hazard size, and because of the numbers of culverts which clog with LWD. Culverts require maintenance (LWD and debris removal) to prevent flooding, and prevent transport of LWD to fish habitat downstream. Consequently, Class 2 stream buffers are determined to have moderate function potential for LWD recruitment, but Class 3 and 4 waters have low function potential.

- **Channel Migration function** potential is absent or low for Class 1, 3 and 4 waters. The large Class 1 waters within the City could not be allowed to meander into adjacent properties without measures being taken to prevent property damage. For the smaller Class 3 and 4 waters, the number of culverts and hydrologic control points largely constrain flow paths. Low or moderate channel migration potential could exist for Class 2 fish bearing waters in some areas of the City.

- **Bank Stability function** potential is determined low to moderate for larger Class 1 waters, because hydraulic flow energy in larger waters reduces the ability of bankside vegetation to resist it, and because many of the larger Class 1 waters are channelized. Bank stability function potential increases to high in the smaller stream Classes 3 and 4, where vegetation roots have much greater potential to prevent hydraulic erosion.

7.0 Recommended Buffer Widths

The recommended Path A buffer widths are shown in Table 10, synthesizing function potentials and the literature on buffer function. These buffer widths assume no enhancement of a degraded buffer to restore or improve riparian functions, which under Path B may allow for smaller buffers.

Table 10
Recommended Path A Riparian Buffer Widths

Class 1	Class 2	Class 3	Class 4	Class 5
100 feet	100 feet	75 feet	35 feet	0 feet

8.0 References

Please refer to Appendix A for a subject summary of the references listed below, which were evaluated during the preparation of this report.

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APPENDIX A: LITERATURE REFERENCE SUBJECT SUMMARY

Large Woody Debris (LWD) Recruitment Literature Review

Citation	Notes
May 2000 (cited in King County 2002) and 2002	Literature review; 1 SPTH (33-328 ft.) based on long term natural levels
Pollock and Kennard 1998	Forested watersheds (forest practices); LWD Recruitment 1 SPTH (105-250 ft.)
Knutson and Naef 1997	Literature review; LWD Recruitment 100-200 ft.
Spence *et al.* 1996	Literature review; LWD Recruitment in western Oregon forests (1 SPTH=170 ft.)
FEMAT 1993 (cited in King County 2002)	Forest ecosystem management; mature forest Multiple SPTH (1 SPTH =170ft.) may be required depending on site conditions for natural LWD recruitment
Thomas *et al.* 1993 (cited in Knutson and Naef 1997; May 2002)	Old growth forest in Pacific Northwest; 180 ft.
Robison & Beschta 1990 (cited in Knutson and Naef 1997; May 2002)	LWD Recruitment optimal 150 ft.
Van Sickle & Gregory 1990 (cited in City of Portland 2001; May 2002)	LWD Recruitment in old growth conifer forests in the Oregon Cascades 100 percent function (164 ft.)
McDade *et al.* 1990	Natural conifer forests western Oregon and Washington; 85% of naturally occurring LWD Recruitment (100%) 100-150 ft.
Murphy & Koski 1989 (cited in Knutson and Naef 1997; May 2002)	Forestry / harvesting effects, Alaska streams in undisturbed old growth hemlock and Stitka spruce forests; Minimum of 100 ft. for natural LWD recruitment.
Budd *et al* 1987 (cited in City of Portland 2001)	Literature review; LID Recruitment; Pacific Northwest (100-170 ft.)
Harmon *et al.* 1986 (cited in Knutson and Naef 1997; May 2002)	Comprehensive study of the ecology of LWD (148 ft.)
Bottom *et al.* 1983 (cited in Knutson and Naef 1997; City of Portland 2001; May 2002)	Instream habitat / LWD restoration study only (100 ft.)

Channel Migration Zone Literature Review

Citation	Notes
Pollock and Kennard 1998	Forested watersheds (forest practices); 100-year flood plain

Bank Stability/Erosion Control Literature Review

Citation	Notes
Knutson and Naef 1997	Erosion control, review of literature buffer width of 100-125 ft.
Spence *et al.* 1996	Literature review; forests of Western Oregon forests Buffer for bank stabilization 170 ft.
Cederholm 1994 (cited in Knutson and Naef 1997)	Western Washington riparian systems; High mass wasting area buffer of 125 ft.
FEMAT 1993 (cited in King County 2002)	Forest ecosystem management; mature forest; Bank stabilization riparian forest ecosystem 0.5 SPTH (100 ft.)
Johnson and Ryba 1992 (cited in City of Portland 2001; Levitt 1998)	Literature review; buffer recommended for channel morphology 65-100 ft.
Raleigh *et al* 1986 (cited in Knutson and Naef 1997)	Bank erosion control buffer 100 ft.

Organic Litter (leaf litter, pine combs and wood)

Citation	Notes
Spence et al. 1996	Literature review (170 ft.)
FEMAT 1993 (cited in King County 2002; City of Portland)	Forest ecosystem management; mature forest (0.5 SPTH=100 ft.)
Erman *et al.* 1977	Literature review (100 ft.)

Pollutant Removal/Water Quality Literature Review

Citation	Notes
GENERAL WATER QUALITY	
Fischer *et al.* 2000	Review of the literature; Improving or protecting water quality (33-100 ft.)
METRO 1997 (cited in City of Portland 2001	Literature review (50-100 ft.)
Knutson and Naef 1997	Literature review; pollutant removal (13-600 ft.)
FEMAT 1993 (cited in City of Portland 2001)	Forest ecosystem management; mature forest; Maintain water quality (12-860 ft.)
Johnson and Ryba 1992 (cited in Knutson and Naef 1997; Levitt 1998)	Literature review; maintain water quality (25-170 ft.)
Budd *et al.* 1987 (cited in City of Portland 2001)	Literature Review (100 ft.); Pacific Northwest
NUTRIENT REMOVAL/REGULATION	
May 2000 (cited in King County 2002) and 2002	Literature review; 80% nutrient removal (13-860 ft., minimum 98 ft.)
Todd 2000 (cited in City of Portland 2001)	Multi-land use watersheds; nutrient removal (33-100 ft.)
Wenger 1999	Literature review; N-Removal (50-100 ft.)
Spence *et al.* 1996	Literature review; nutrient regulation (170 ft.)
Schultz *et al.* 1995 (cited in Knutson and Naef 1997; May 2002)	Nutrient removal in a multi-species riparian buffer strip (66 ft.)
Woodard and Rock 1995	100 % removal of TP from non-point residential construction runoff (50 ft.)
Castelle *et al.* 1994 (cited in City of Portland 2001)	Literature review; Filter metals and nutrients (100 ft.)
Osborne and Kovacic 1993 (cited in May 2002)	96% N removal (52 ft.)
Madison et al. 1992 (cited in May 2002; Spence et al 1996)	Vegetated filter strips (tillage and grass) 90-96% removal of N & P using VFS; 7-12% slopes (15-30 ft.)
Petersen et al. 1992 (cited in Knutson and Naef 1997; cited in May 2002)	Minimum buffer width for effective P removal (33 ft.)
Xu *et al.* 1992 (cited in May 2002; Spence *et al* 1996)	95% removal of N in mixed herbaceous and forested riparian buffer in North Carolina (33 ft.)
Terrell & Perfetti 1989 (cited in Knutson and Naef 1997; May 2002)	Minimum width for effective nutrient removal in forested riparian areas (100 ft.)
Jones *et al.* 1988 (cited in Knutson and Naef 1997)	Natural riparian ecosystems; Nutrient and fecal coliform removal (100-141 ft.)
Peterjohn and Correll 1984 (cited in May 2002)	73-84% P removal; 5% slope (VFS). Riparian forest treating an agricultural watershed (164 ft.)

SEDIMENT FILTRATION	
May 2000 (cited in King County 2002) and 2002	Literature review; 80% sediment removal (26-600 ft.)
Knutson and Naef 1997	Review of literature (26-300 ft.)
Cederholm 1994 (cited in May 2002)	Minimum to protect stream banks in high erosion or mass wasting areas (125 ft.)
Desbonnet *et al*. 1994 (cited in May 2002)	Coastal zone vegetative buffers. Optimum "sediment" removal (82 ft.)
FEMAT 1993 (cited in King County 2002; City of Portland)	Forest ecosystem management; mature forest (200 ft.)
Belt *et al*. 1992 (cited in Knutson and Naef 1997; May 2002)	50% removal by riparian vegetation; control of non-channelized sediment flow (200-300 ft.)
Johnson and Ryba 1992 (cited in Knutson and Naef 1997; Levitt 1998)	Literature review; 90 % sediment removal at 2% grade (10-400 ft.)
Terrell and Perfetti 1989 (cited in Knutson and Naef 1997; May 2002)	80% sediment removal by vegetation (200 ft.)
Gilliam & Skaggs 1988 (cited in Knutson and Naef 1997; May 2002)	50% removal by riparian vegetation (290 ft.)
Budd *et al*. 1987 (cited in City of Portland 2001) Vanderholm & Dickey 1978 (cited in May 2002)	(100 ft.) 80% TSS removal on a 0.5% slope (300 ft.)
Vanderholm & Dickey 1978 (cited in May 2002)	80% TSS removal on a 4% slope (860 ft.)
Broderson 1973 (cited in May 2002)	90% removal by riparian vegetation (200 ft.)

Microclimate Literature Review

Citation	Notes
May 2000 (cited in King County 2002) and 2002	Literature review; optimum long-term function (148-656 ft. or 328 ft. minimum)
Pollock and Kennard, 1998	Forested watersheds (forest practices) (250 ft.)
Brosofske *et al.* 1997	Forest / harvesting effects; Western Washington with 70-80% over story coverage (Douglas fir and western hemlock) (148 ft.)
Knutson and Naef 1997	Review of literature (200-525 ft.)
Spence *et al.* 1996	Literature review; forests of Western Oregon forests (100 ft.)
Chen *et al.* 1995 (cited in May 2002)	Riparian forest ecosystem (200-400 ft.)
FEMAT 1993 (City of Portland 2001; King County 2002; May 2002)	Forest ecosystem management; mature forest; Maintain natural riparian microclimate (0.5 to 3 SPTH=100-600 ft.)
Franklin and Forman 1987 (cited in Knutson and Naef 1997; May 2002)	Riparian forest ecosystem (535 ft.)
Harris 1984 (cited in Knutson and Naef 1997; May 2002)	Riparian forest ecosystem (525 ft.)

Temperature Literature Review

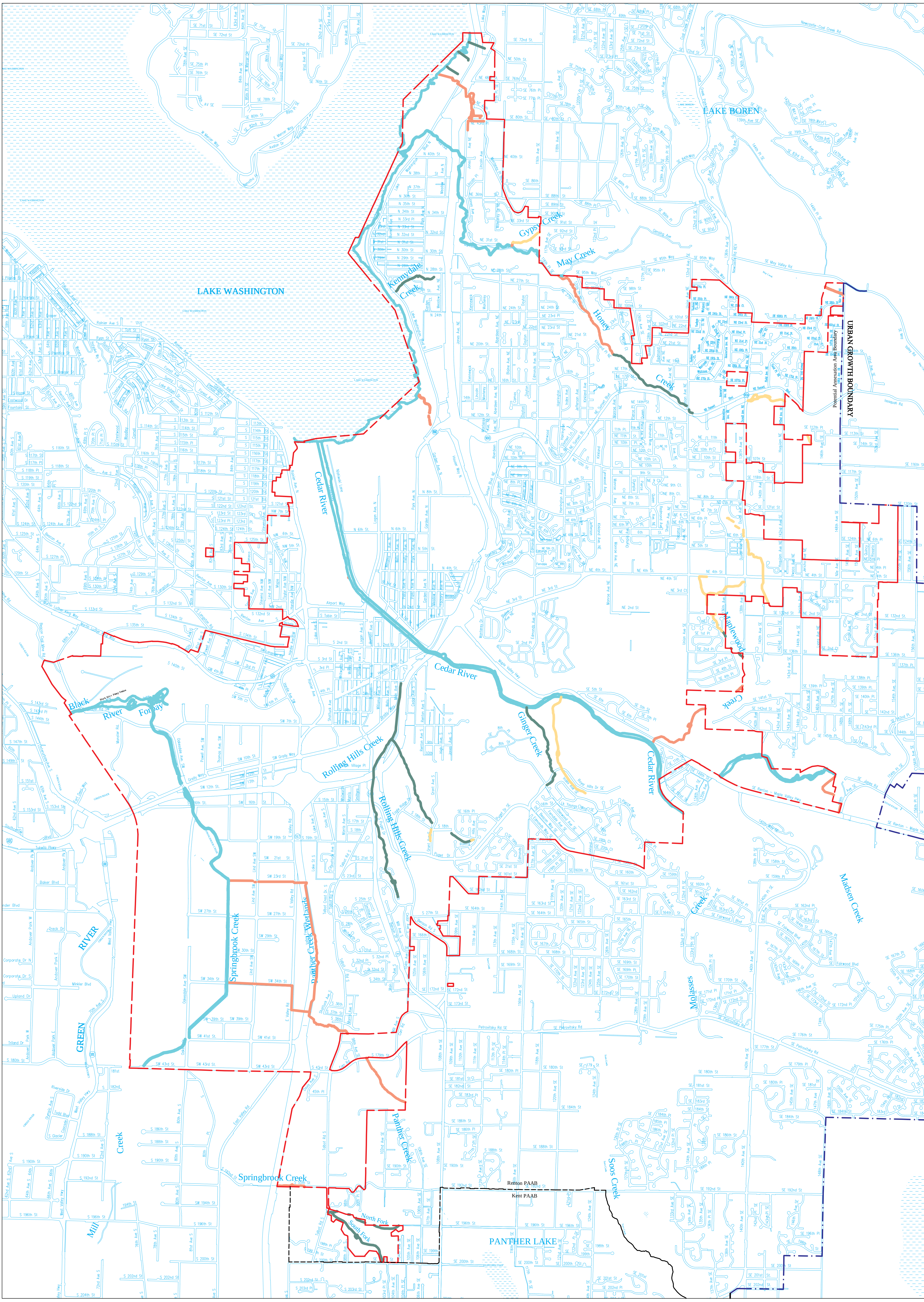
Citation	Notes
May 2000 (cited in King County 2002) and 2002	Literature Review; Adequate shade (36-141 ft. or minimum of 98 ft.)
Knutson and Naef 1997	Literature review (35-151 ft.)
Brosofske *et al.* 1997	Harvesting effects western Washington; Natural temperature regulation (148 ft.)
Spence *et al.* 1996	Literature review; Natural temperature and shading (Cascade and Coast range) (100 ft.)
Murphy 1995 (cited in Spence *et al.* 1996)	Shade (100 ft.)
Castelle *et al.* 1994 (cited in City of Portland 2001)	Literature Review; Shade and water temperature (76 ft.)
FEMAT 1993 (cited in King County 200; City of Portland 2001; May 2002)	Forest ecosystem management; mature forest; Shade (100-150 ft.)
Johnson and Ryba 1992 (Cited in Knutson and Naef 1997; Levitt 1998; Spence *et al* 1996)	Literature Review; 50-100% shade (100 ft.)
Jones *et al.* 1988 (Cited in Knutson and Naef 1997; May 2002)	Urbanization effects; 80% shade (100-141 ft.)
Beschta *et al.* 1987 (also cited in Knutson and Naef 1997; May 2002; Spence *et al* 1996)	Forestry interactions / harvesting; Minimum shade to level of old growth forest (50-100%) shade (100 ft.)
Corbett & Lynch 1985 (cited in May 2002; Knutson and Naef 1997)	Municipal watersheds; 60-80% shade (39-100 ft.)
Lynch *et al.* 1985 (cited in Knutson and Naef 1997; May 2002)	Mature forested watersheds; 50-100% shade (100 ft.)
Steinblums *et al.* 1984 (cited in May 2002; Knutson and Naef 1997)	60-80% shade (75-92 ft.); 80% shade (151 ft.)
Hewlett & Fortson 1982 (cited in May 2002)	60-80% shade (50-100 ft.)
Brazier and Brown 1973 (cited in Knutson and Naef 1997 and May 2002; Spence *et al* 1996)	Old growth stands conifer forests s. cascades and Oregon Coast range; 60-80% shade (35-125 ft.)

Human Disturbance Literature Review

Citation	Notes
Schuler 1995	Protects physical and ecological integrity (25 to 50 ft.)
Cooke 1992	Mixed use residential; 50 ft. or greater buffers recommended to protect from human disturbance.

General Riparian Buffer Recommendations

Stream Type	Citation/Study
General	Fischer *et al.* 2000 (50-325 ft.)
Headwater / mid-section streams	Metro (OR) 1999 (150 ft.)
General	Oregon Division of State Lands, 1998 (20-120 ft.)
Perennial streams	Pollock and Kennard 1998 (250 ft.)
General	Metro (OR) 1997 (50-200 ft.)
General (Type 1 –Type 5)	WDFW 2001 (Knutson and Naef 1997) (150-250 ft.)
General	Johnson and Ryba 1992 (cited in Knutson and Naef 1997) (50-100 ft. to protect stream functions)
General	May *et al.* 1997 (100-325 ft.)
General	Schueler 1995 (100 ft.)
General	Castelle *et al.* 1994 (50-100 ft.)
General	Spence *et al.* 1996 (100-170 ft.)
General	FEMAT 1993 (150-300 ft.)
General • Fish bearing streams • Perennial (non-fish) • Intermittent	U.S. Forest Service 1993; Reeves and Sedell 1992 (cited in Knutson and Naef 1997) 2 SPTH (300 ft.); 1 SPTH (150 ft.); and 100 ft.
General	Erman *et al.* 1977 (100 ft.)



City of Renton - Water classes

Economic Development, Neighborhoods & Strategic Planning
Alex Pietsch, Administrator
G. Del Rosario
15 October 2003

DRAFT

- Renton City Boundary
- PAA Boundary
- Class 1
- Class 2
- Class 3
- Class 4
- Culvert

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