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Minimun Riparian Buffer Width for Maintaining Water Quality and Habitat Along Stevens Creek

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MINIMUM RIPARIAN BUFFER WIDTH FOR MAINTAINING WATER QUALITY AND HABITAT ALONG STEVENS CREEK

By

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ABSTRACT

Riparian buffer zones are important sites of biodiversity, sediment trapping, pollutant removal, and hydrologic regulation that have significant implications for both people and wildlife. Urbanization's influence on and need for adequate water quality increases the need for careful planning in regards to riparian areas. Wildlife are key components in the ecosystem functions of riparian zones and require consideration in peri-urban planning as well. This study reviews relevant literature to determine the recommended minimum riparian buffer width for maintaining water quality and habitat along Stevens Creek in Lincoln, Nebraska. Only sources that listed a specific purpose related to water quality and habitat for their buffer width recommendations were considered. The study found that the baseline buffer width recommended for Stevens Creek that would be adequate for both water quality maintenance and basic habitat is 50 ft (15 m) per side. This number may be modified based on other factors such as slope, soil particle size, adjacent land use, the presence of certain wildlife communities, stream size, and stream order.

INTRODUCTION

The purpose of this thesis is to use a literature review to determine the necessary riparian buffer width for maintaining water quality and habitat along Stevens Creek. Riparian zones are defined as linear strips of vegetation directly adjacent to bodies of water (Whitaker and Montevecchi, 1999). They are important regulators of the flow of organic material, water, nutrients, and organisms between and within landscape elements (Vince et al., 2005). Riparian zones perform many important ecological and biological functions through the interaction of their hydrology, soils, and biotic communities, which have important social benefits as well (Klapproth and Johnson, 2009). Continuous, ecologically functioning riparian corridors have been found to positively affect water quality and habitat in addition to improving aesthetic properties of the landscape (Forman and Godron 1986). The services that riparian zones provide are numerous, but this paper will focus on water quality and habitat.

Degraded water quality poses serious threats to humans and wildlife (Changhua, 1999). Riparian buffers improve or maintain water quality by trapping sediment and debris, stabilizing stream banks and reducing erosion, and promoting the infiltration of runoff (Palone and Todd, 1998). There is substantial scientific evidence indicating that riparian buffers are cost-effective tools for mitigation of water quality problems, and can be integrated into stormwater management in urban areas (Buffler et al., 2005; Palone and Todd, 1998). Riparian forests are able to capture, absorb, and store 40 times more rainfall than disturbed soils. Fairfax County, Virginia estimated stormwater reduction benefits of $57 million annually from its riparian buffers. Riparian wildlife and ecosystems are also affected by water quality, as water quality is a primary determinant of the plant and animal species existing in and the ecological interactions of riparian systems (Palone and Todd, 1998). Riparian areas provide a sheltered environment for many different species of wildlife to feed, drink, rest, and reproduce, and serve as movement corridors between larger habitats (Palone and Todd, 1998).

The Stevens Creek watershed is located immediately east of Lincoln, Nebraska, and drains approximately 55 square miles (142 sq km) to its confluence with Salt Creek (Fig. 1). It was selected as the site of this study because of the potential risk to the quality of the creek and its adjacent habitat from the significant near-future urban growth and agriculture in the basin (Fig. 2)(CDM, 2005).

The importance of riparian zones for habitat and water quality makes studying the conditions required for the provision of these services essential to riparian planning and management. It is particularly significant for Stevens Creek because of the expansion of the city of Lincoln into the Stevens Creek watershed in the relatively near future. The water quality of the creek affects not just people living within the watershed, but all water users downstream as well. If habitat is not provided for riparian species or species travelling between larger tracts of habitat, the loss or degradation of the riparian zone could result in habitat fragmentation and loss of biodiversity. This study may also be used as a model for the planning of other riparian systems for water quality and habitat.

Specific research questions addressed in this paper include 1) what are the minimum riparian buffer widths recommended in order to maintain water quality? 2) what are the minimum riparian buffer widths recommended in order to preserve adequate riparian habitat for various wildlife species guilds? and 3) what characteristics of the surrounding landscape change width requirements for water quality and habitat purposes? The study is limited by a lack of current water quality data, an inventory of wildlife species and their habitat needs, and the inherent assumption that water quality and wildlife around Stevens Creek are important to people living in Lincoln (Koehler-Cole, 2008). It should also be noted that all buffer widths mentioned in this paper refer to buffer width on one side of the stream.

The first section of this thesis will detail the methods used to collect information, followed by a section that details and summarizes the results of the study. The discussion section will explore the variability in the results and possible adjustment factors for buffer width. Finally, the conclusion section will make recommendations for Stevens Creek and summarize the study.

METHODS

A literature search of books, peer-reviewed journal articles and publications was conducted to determine minimum riparian buffer width recommendations for habitat and water quality purposes. The recommendations were then summarized and applied to Stevens Creek as the width that would likely protect water quality and habitat based on those recommendations.

ArcGIS Version 9.0 software was used to visually represent the future land use of the watershed. The land use data layer was provided by the City of Lincoln's Planning Department. The land use data layer included the entire county, but was clipped to only include the Stevens Creek watershed. This information illustrated potential nonpoint sources of pollutants and sediments and the relative scale of impact on water quality of Stevens Creek.

RESULTS

Literature Review

Water Quality

Water temperature is important for aquatic communities and processes. Increasing temperature stimulates growth of algae, which remove oxygen that is needed by water-dwelling species. The shading of streams by forested riparian buffers decreases the temperature in the summer and lessens the temperature reduction in winter. Forested buffers as narrow as 15 ft (5 m) have been found to provide adequate shade for reducing the temperature extremes of small streams (Palone and Todd, 1998).

Large amounts of water-soluble nitrates can be intercepted by tree roots when shallow groundwater flows through the root zone. Woody plants are particularly effective at nitrogen removal through relatively aggressive nitrogen uptake and moisture retention. Leaf litter from woody plants also contributes to surface organic matter that increases infiltration. Soils high in organic matter remove nitrates through denitrification by bacteria. Studies show that nitrogen removal can be 25 to 90% effective in buffers as narrow as 35 ft (11 m) if environmental conditions for vegetative uptake, water storage, and denitrification are ideal (Palone and Todd, 1998).

Buffers of 45 ft (14 m) have been found to be effective at reduction of stream contamination by pesticides. The use of the term "pesticides" here excludes herbicides, as there is a lack of sufficient data on removal of herbicides in runoff and groundwater by riparian buffers. Most organic pesticides are subject to the processes of microbial breakdown in the surface organic material of riparian zones. Riparian buffers also help protect streams from pesticides by shielding them from chemical drift (Palone and Todd, 1998).

Phosphorous is a common water pollutant, but it is not considered separately for this study because 90% of phosphorous carried in runoff is attached to soil particles or organic matter. While many other pollutants also become adsorbed to soil particles, with phosphorous the amount is particularly high. Managing for reduction of sediments transported in runoff, therefore, would reduce the phosphorous load to streams (Palone and Todd, 1998). Sediment trapping functions of buffers must be considered by soil particle sizes: sand, silt, and clay. Research shows that a 10 ft (3 m) buffer is adequate for most sand-sized particles and 50 ft (15 m) is adequate for silt-sized particles, but smaller clay-sized particles would require a buffer that is at least 300 ft (91 m) wide (Wilson, 1967).

Wildlife

Studies of wildlife can be separated into guilds based on their use of resources (Croonquist and Brooks, 1991). This paper considered edge species, aquatic communities, large mammals, bird communities, and semi-aquatic reptiles and amphibians.

Of the guilds evaluated in this paper, edge species have the smallest requirement of 25 ft (8m) (Croonquist and Brooks, 1991). Edge species prefer the boundaries between patches or habitats of differing qualities, such as a riparian forest and a pasture (Ries and Sisk, 2004).

Aquatic communities are influenced by riparian forests in a number of ways: through effects on food availability, stream flow, light intensity, habitat diversity, and water chemistry. These factors are major determinants of the variety and productivity of plants, microorganisms, fish, and invertebrates that occur in a given stream. A riparian buffer width of 50 ft (15 m) is recommended for the benefit of aquatic communities in small streams (Klapproth and Johnson, 2001).

A study by Croonquist and Brooks (1991), as cited by Klapproth and Johnson (2009), found that large mammals require wider buffers of at least 100 ft (30 m). Klapproth and Johnson (2009) also found that many studies that have attempted to determine riparian buffer width requirements for small mammals have yielded conflicting results, and therefore small mammals are not considered in this paper. The use of riparian buffers by small mammals is possibly related to vegetation structure and habitat quality (Klapproth and Johnson, 2009). This is also an important factor influencing effectiveness of riparian buffers in addition to buffer width, and will be discussed in the following section.

In a study that evaluated bird use of riparian areas in Pennsylvania, Croonquist and Brooks (1991) found that a buffer of 82 ft (25 m) provided adequate breeding and dispersal opportunities for bird communities, including area-sensitive species (Croonquist and Brooks, 1991). Birds are also sensitive to habitat vegetation structure. Their needs vary between breeding, nesting, and other life stages, and may require a diverse species mix to create structural diversity of vegetation for different purposes (Schultz et al., 2004).

Semlitsch and Bodie (2003) performed an extensive literature review examining terrestrial habitat use by many different amphibian and reptile species associated with wetlands. This study determined that the minimum buffer width requirement that would account for the essential terrestrial life stages of semi-aquatic reptiles was 417 ft (127 m), and 522 ft (159 m) for semi-aquatic amphibians. Terrestrial habitats adjacent to wetlands and streams were used by amphibians for foraging, overwintering sites, and refuge. The study found that some amphibians only moved about 65 to 100 ft (30 m), whereas others moved 3,200 to 5,200 ft (975 to 1585 m). However, the authors believe that 522 ft (159 m) is adequate for maintaining amphibian diversity in riparian habitats (Semlitsch and Bodie, 2003).

Reptiles use terrestrial habitats adjacent to wetlands for basking, hibernating, nesting, and burrowing. Again, the distance moved from water in the study varied widely. Some reptile species rarely moved more than 100 ft (30 m), whereas others moved 415 to 950 ft (126 to 290 m) from their home wetlands. Although there is a wide range in movement and wetlands vary greatly in characteristics, the data suggests that a single minimum width of 417 ft (127 m) is sufficient to encompass the riparian areas that are biologically necessary for all reptilian life stages (Semlitsch and Bodie, 2003).

Table 1. Summary of Findings

Category	Minimum Width		Additional notes	Source
	ft	m		
Water Quality				
Water temperature	15	5	For small streams; forested	Palone and Todd, 1998
Pollutants				
Nitrates	35	11		Palone and Todd, 1998
Pesticides	45	14		Palone and Todd, 1998
Sediment				
General	25	8	On slopes <16%; Expand by 5 ft for each 1% increase in slope	Palone and Todd, 1998
Sand	10	3		Wilson, 1967
Silt	50	15		Wilson, 1967
Clay	300	91		Wilson, 1967
Wildlife				
Edge Species	25	8		Keller et al., 1993
Aquatic Communities	50	15	Depends on stream size	Klapproth and Johnson, 2001
Bird Communities	82	25	Includes area-sensitive species	Croonquist and Brooks, 1991
Large Mammals	100	30		Croonquist and Brooks, 1991
Semi-aquatic Reptiles	417	127		Semlitsch and Bodie, 2003
Semi-aquatic Amphibians	522	159		Semlitsch and Bodie, 2003

DISCUSSION

A buffer that is only wide enough for sand (10 ft; 3 m), water temperature (15 ft; 5 m), edge species (25 ft; 8 m), nitrates (35 ft; 11 m), or pesticides (45 ft; 14 m) would be inadequate for the sediment trapping function of an area with soil surface layers high in silt or clay sized particles. A riparian buffer width of 50 ft (15 m) would encompass all of the previously listed categories, as well as trapping of silt-sized sediment and habitat maintenance for aquatic communities. While it would fulfill all water quality recommendations and some of those for wildlife, the wildlife guilds not accounted for in a 50 ft (15 m) buffer are bird communities, large mammals, and semi-aquatic reptiles and amphibians. However, the benefits of a complete riparian buffer around Stevens Creek of 522 ft (159 m) so as to encompass all wildlife guilds in addition to water quality considerations would likely become uneconomical for private landowners adjacent to the creek.

It is possible that a variable width buffer design may be more effective for Stevens Creek. A variable width design includes a baseline width that is reduced or expanded based on certain landscape features or species of interest. The baseline width provides acceptable levels of all needed benefits at a reasonable cost (Dosskey et al., 1997). Actual buffer widths should be adjusted to fit the site (Schultz et al., 2009). Some bodies of water, riparian zones, and their adjacent upland areas have different characteristics that require individual consideration in order for management objectives to be met. Even along the same water body there is variability in landscape features such as presence of wetlands, width of the floodplain, slope, and soil type (Palone and Todd, 1998). Based on the fulfillment of the majority of water quality and wildlife needs, I suggest that 50 ft (15 m) would be an adequate baseline riparian buffer width for Stevens

Creek. The following is a discussion of the variables that could influence the adjustment of this baseline width.

Adjustment Variables

There may be portions of the creek along which higher clay contents exist, which according to Wilson (1967) would require a significant increase in buffer width, up to 300 ft (91 m) for clay dominated surface soils. Areas with low soil organic material would also indicate the need for a wider buffer because of reduced denitrification by bacteria in organic material (Palone and Todd, 1998). Stream size is also a factor, and it is recommended that minimum buffer width for aquatic communities be increased from 50 to 60 ft (15 to 18 m) in larger streams (Klapproth and Johnson, 2001).

The increase of impervious surfaces through urbanization could increase the pollutant or sediment loads of runoff, which may lead to more concentrated flows. Concentrated flows, in turn, will reduce the ability of riparian zones to trap the sediment and filter pollutants out of runoff before reaching the stream. Increased urban growth in the Stevens Creek watershed in coming years will require careful planning of filter strips. Additional practices such as swaths of stones to spread the runoff, and biofiltration swales and wetlands for runoff and stormwater retention which allow for greater infiltration may be required (Palone and Todd, 1998). Wetlands adjacent to streams and riparian zones are sinks for sediments, nutrients and pollutants, and sites for denitrification functions (Johnson and Buffler, 2008).

Vegetation type and design can also influence the effectiveness of buffer zones. More complex structural diversity of vegetation provides habitat for a greater range of wildlife species (Palone and Todd, 1998). Trees are important for establishment of the aquatic food web with leaf matter as a food base (Palone and Todd, 1998). A study of 14 riparian buffer sites in Europe showed similar efficiency of nitrate removal for herbaceous and forested buffers, but after a few years of sediment build-up, grass buffers became overwhelmed and lost their effectiveness (Sabater et al, 2003).

The traditional three-zone design includes an unmanaged forest along the stream bank to provide shading, a managed forest for a nutrient sink, and a grass or grass/forb filter strip that intercepts and spreads runoff to allow sediment settling and slower movement of water through the buffer (Schultz et al., 2004). The grass filter strip is very important to buffer effectiveness. Studies show that forested buffers without filter strips exhibit gully erosion and reduced effectiveness at nutrient removal. Stiff stemmed, native grasses such as switchgrass (*Panicum virgatum*) are recommended over introduced species such as smooth brome (*Bromus inermis*) and Kentucky bluegrass (*Poa pratensis*) that are easily laid down and allow water to pass over. However, a filter strip of switchgrass (*Panicum virgatum*) alone does not provide bird habitat as well as a more diverse species mix. A strip of switchgrass (*Panicum virgatum*) upslope of a more diverse grass/forb mix is recommended to provide both runoff treatment and habitat functions (Schultz et al., 2004).

The most significant adjustment variable for this study is that of wildlife guilds that require buffer widths wider than 50 ft (15.2 m). In portions of the stream where such wildlife guilds or species of interest may be expected, baseline buffer width should be expanded to the width appropriate for bird communities (82 ft; 25 m), large mammals (100 ft; 30 m), and semi-aquatic reptiles (417 ft; 127 m) and amphibians (522 ft; 159 m).

Additional Considerations

Important considerations to buffer effectiveness are continuity and point source pollution. Fragmentation of riparian buffer systems reduces the pollution control ability of buffers and isolates wildlife by removing movement corridors (Schultz et al., 2009). Pollution carried by structures such as tile drains and industrial waste pipes that input water directly into the stream cannot be treated by buffers, which reduces the influence of buffers on water quality (Johnson and Buffler, 2008). In order for buffers to remain effective, point sources need to be eliminated and continuity of buffers maintained along the entire stream.

In addition to the needs of wildlife habitat and water quality functions, economic and social factors should also be considered when discussing riparian planning and management. Landowners along Stevens Creek currently use much of the land for agriculture, and it is important not to completely override their needs in favor of ecosystem functions. At the same time, the use of the land for agriculture can have adverse impacts on a wide range of ecosystem functions and services of the riparian zone, such as the provision of quality freshwater. There must be a balance between meeting the needs of the landowners and protecting ecosystem functions (DeFries et al., 2004). Riparian zones can either take some land out of agricultural production, or it can generate income through government program payments or by providing specialty crops like nuts, fruits, and woody florals (Fox et al., 2005; Dillaha et al., 1988).

The USDA (United States Department of Agriculture) Farm Service Agency offers payments to landowners enrolled in the Conservation Reserve Program for riparian buffers. This program provides economic benefits to private landowners with riparian buffers, which can offset the economic losses of keeping that land out of other kinds of production. In Nebraska, payments are determined on a site specific basis, according to soil series. Certain soil series receive higher payments than others, but all buffers receive a 20% bonus on top of the payment recommended for soil type. An additional sign-up bonus of $10 per acre is offered for riparian buffers, and fencing for the exclusion of livestock is also paid. All buffers are designed under the technical guidance of the NRCS (Natural Resource Conservation Service). The NRCS uses a plant species mix that includes 60% native grasses in the filter strip and always includes species for wildlife to achieve multiple benefits of the buffer (D. Weber, personal communication, 2010).

CONCLUSION

The purpose of this thesis was to evaluate minimum riparian buffer width recommendations using a literature review in order to determine a buffer width to maintain water quality and habitat along Stevens Creek. Water quality is important to the health of people and wildlife, and riparian buffers are important tools for managing water quality and providing habitat. A variable buffer width design with a baseline width of 50 ft (15 m) was recommended for Stevens Creek, to be altered according to landscape features and species of interest. Additional considerations for the implementation and effectiveness of riparian buffers include fragmentation, point source pollution, and equitable management for both natural resources and landowners.

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FIGURES

Fig. 1 Location of Stevens Creek watershed

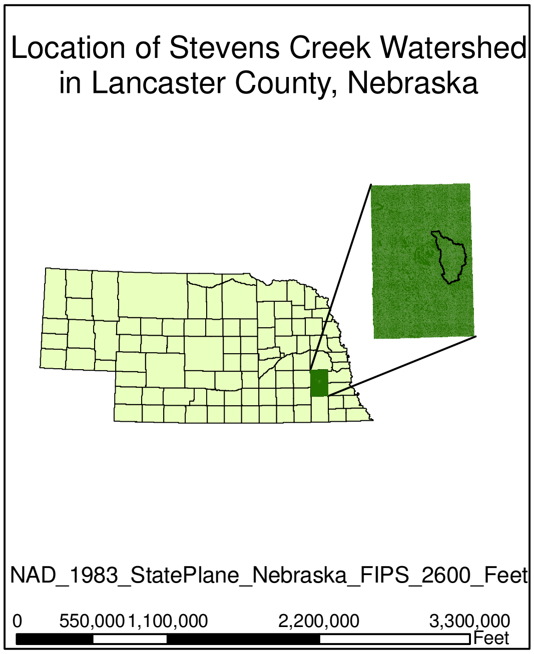

Fig. 2 Future land use plan of the Lincoln/Lancaster County Planning Department