A LITERATURE REVIEW ON RIPARIAN BUFFER WIDTHS FOR SEDIMENTS, NUTRIENTS AND LARGE WOODY DEBRIS

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Abstract

Riparian buffers play a key role in protecting streams. This essay will look at a number of literature studies on riparian buffer widths concerning sedimentation, nutrients and large woody debris loading and try and identify an optimal range for buffer width design in regards to water quality and aquatic habitat. Sediment is the principal contaminant in most streams. Buffer widths of only 4.6 m have been shown to be successful. Buffer widths of 30 m are sufficient to retain sediments for most circumstances although buffer widths should extend as slope increases. In long-term studies, the recommendation of wider buffers is deemed necessary. Buffers have the ability to be sinks for phosphorous and nitrogen in the short-term. For buffers to be effective in the long-term for nutrients, on-site management will be required. Buffer widths of 30 m will provide sufficient nutrient mitigation and 15 m wide buffers can act as the minimum as it will still provide adequate control under many conditions. Buffers also play a part in maintaining aquatic habitat through large woody debris loading. Buffer widths of 10-30 m with native forest as the vegetation will provide inputs of large woody debris. The extent of buffers should include all perennial and intermittent streams of second order or higher. Vegetation type should consist of native forest and other native vegetation to the riparian area. There are many factors that affect the width of the buffer. These factors include: slope, rainfall pattern and intensity, soil characteristics, floodplains and land use. In general, the greater the width of the riparian buffer is, the greater the security for water quality and aquatic habitats.

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Introduction

Background on Riparian Areas and Buffers

Riparian areas are zones that surround water bodies like streams, lakes and wetlands within a watershed that link water to land. They are composed of streambed, moist to saturated soils, and water-associated vegetation that directly influences aquatic habitats.

Aquatic ecosystems are strongly influenced by riparian zones through the organization, diversity and dynamics of communities connected (Gregory et al. 1991). As a result of the aquatic ecosystem interactions, riparian areas consist of distinct ecological characteristics. These areas are marked out through changes in soil moisture and nutrient regimes, vegetation and various factors that reveal an aquatic-land interaction (Naiman and Decamps, 1997). The complexity within riparian areas illustrates variability of the drainage network, stream channels and the biotic community.

Riparian buffers resulted from better understanding of clearcutting effects and the loss of woody debris in streams (Hall et al. 1987) in order to limit direct impacts of forestry on fish population and stream health. A riparian buffer is "any strip of vegetation between a river, stream or creek and an adjacent upland land use activity, that is maintained for the purposes of protecting or improving water quality, or enhancing the movement of wildlife among habitat patches (Hickey and Doran, 2004)." Like a physical barrier, vegetated riparian buffers act to prevent transportation of sediment and nutrients into streams (Barling and Moore 1994). In addition, they become a source for woody debris and mitigate stream temperature. A riparian buffer can be made up of native vegetation left intentionally intact or re-established vegetative buffers that may include forest or herbaceous plants. Riparian buffers are important as they maintain and protect many ecological services with both economic and social value to humans.

Purpose

The purpose of this essay is to review literature based on buffer widths in regards to sedimentation, nutrients and large woody debris loading in riparian areas. By looking at the effectiveness of buffer widths, this essay will try to identify the optimal range to maintain a healthy and functioning riparian ecosystem. In addition, the extent and vegetation type will be

reviewed for the characteristics of an effective buffer. Water quality and aquatic habitats will be considered as buffer functions. The first two sections of this essay will discuss water quality (sedimentation and nutrients). The third section will discuss large woody debris loading as aquatic habitat requirements. Finally the last section will discuss recommendations for buffer widths while taking into consideration the previously discussed factors.

Sediment

The largest source of contamination in streams is sediment (Cooper 1993). Studies have shown that riparian buffers are effective in the retention of sediments, in so doing limiting sediment to rivers and streams.

Effects

Detrimental effects to water quality and stream biota can occur when excess amounts of sediment are present in streams and rivers. A brief summary of key sediment effects adapted from Wood and Armitage 1997 are as follows:

- Fish habitat and invertebrates which many fish will consume will be reduced from sediment deposition on stream beds;
- Light transmittance will be reduced dude to suspended sediment, thereby reducing algal production;
- Fish mortality will be directly affected due to high concentrations of fine suspended sediments;
- Filter-feeding organisms, like arthropods and molluscs, will have their abundance reduced due to suspended sediments and;
- Sedimentation decreases the capacity and life of reservoirs.

The effects of both suspended and benthic sediment have negative biological effects on the aquatic ecosystem.

Sources

Sediment sources in streams can originate from upland runoff or the stream channel. Examples of upland runoff are agriculture fields, construction sites and logging roads. Examples of sedimentation from the channel are erosion of unstable banks and from stream bed scouring

(Wenger 1999). Sediments from the channel could have originated from upland runoff that have been deposited and remained in the streambed (Wood and Armitage 1997).

Construction Sites

The main source of sediment in urban and urbanizing areas is from construction. Higher sediment loads have been found in streams that drain urban areas as oppose to ones in agricultural and forested watersheds (Wahl et al 1997).

Mines

Severe sedimentation could result from various forms of mining (Burkhead et al 1997); specifically, gravel dredging, as it occurs within the river itself. Sedimentation from these mines can directly impact stream organisms negatively, as well as increase turbidity downstream of the mining site. Furthermore, contaminants bound to sediment may be released in the dredging process (Burruss Institue 1998).

Agriculture

Direct access of riparian areas by livestock can result in bank erosion and water contamination (Wenger 1999). Fertilizers and pesticides may also leach into the streams and cause nutrient loading.

Forestry

Forest operations that disturb the soil will impact riparian areas. Methods of yarding are a large determinant of sediment production.When logs are kept off the ground, partially or completely, there is less soil disturbance whereas skidding creates soil disturbance over a large area. In Toews and Moore (1982), they found that stream bank erosion was over 250% greater after logging in clearcut areas with no buffer strips compared to a clearcutted area with a 5 m buffer strip, stream bank erosion increased only 32%.Logging roads also contribute to sedimentation, especially cut and fill slopes if they are not maintained or become deactivated.

Literature Review:

According to the US ACE 1991, sedimentation among streams can be reduced through riparian buffers in the following ways:

- By relocating events that generate sediment away flowing water;
- By using surface runoff to trap terrestrial sediments;
- By decreasing the velocity of storm flows heavy in sediment and by permitting sediments to be deposited on land as it settles out of water;
- By preventing channel erosion through stabilization of stream banks;
- By reducing bed scour, stream flow moderation would be conducted during the flood season; and
- By retaining and loading coarse woody debris, sediment collection can be trapped for the short term.

The first part of the review will discuss the prevention of surface runoff. The second part will look at the reduction of channel erosion. A review of coarse woody debris will follow in a subsequent section.

Surface Runoff

There have been many studies conducted that show the effectiveness of riparian buffers in regards to retaining sediment from surface runoff. However, the width needed is usually the complicating factor for an effective buffer.

Overall, the width of the buffer and the capacity to retain sediment is a positive correlation. In Desbonnet et al (1994), it was found that with an increase of a 3.5 factor in width, sediment removal was increased by 10%. The most proficient sediment removal buffer width was found to be 25 m by the reviewers. It was also found that a 3.0 factor was needed for an increase of 10% in sediment removal for total suspended solids and 60 m wide buffers offer the best efficiency. However, in this study, these results and data collected were based on studies from different locations using different methods.

Studies with data from the same location with the same methods that compare different buffer widths were also reviewed. The comparison of the effectiveness of two different buffer widths for trapping total suspended solids (TSS) were studied in six reviews: Young et al 1980; Peterjohn and Correll 1984; Magette et al 1987, 1989; and Dillaha et al 1988, 1989. It was found in all circumstances that buffer effectiveness increased with buffer width. The results show a positive correlation between buffer width and removal of TSS while a negative correlation is

shown with slope. Table 1 provides a summary of the results of six studies as complied by Wenger (1999).

Author	Width (m)	% Slope	% TSS Removed
Dillaha et al 1988	4.6	11	87
Dillaha et al 1988	4.6	16	76
Dillaha et al 1988	9.1	11	95
Dillaha et al 1988	9.1	16	88
Dillaha et al 1989	4.6	11	86
Dillaha et al 1989	4.6	16	53
Dillaha et al 1989	9.1	11	98
Dillaha et al 1989	9.1	16	70
Magette et al 1989	4.6	3.5	66
Magette et al 1989	9.1	3.5	82
Peterjohn and Correll 1984	19	5	90
Peterjohn and Correll 1984	50	5	94
Young et al 1980	21.3	4	75-81
Young et al 1980	27.4	4	66-93

Table 1: Results from six studies including buffer width, slope and TSS removed (Wenger 1999).

In Dillaha et al 1988, it was found that for a 4.6 m buffer and 9.1 m buffer, the average TSS reduction was 81% and 91% respectively. Their buffer system consisted of orchardgrass and was downslope of a simulated feedlot. In their study of 1989, the same type of buffer system was used and it was found that for a 4.6 m buffer, the average TSS reduction was 70% and 84% for a 9.1 m buffer. The study by Magette et al 1989 used a similar buffer system and for the 4.6 m buffer, the average TSS reduction was 66% and 82% for the 9.1 m buffer.

In Young et al 1980, it was found that for a buffer of 21.34 m, the average TSS reduction was 78% and 93% for a 27.43 m buffer. On average for the two buffers, slope was four percent and the buffer system was composed of various grasses. In Peterjohn and Correll 1984, for a 50 m

buffer, it was identified that the average TSS reduction was 94% and 90% for a 19 m buffer. The slope was averaged to five percent and the buffer system was in an agricultural catchment.

In Davies and Nelson 1994, it was found that in logged forests, sedimentation was highly reduced due to the buffer width design. According to Davies and Nelson (1994), "all effects of logging were dependent on buffer strip width and were not significantly affected by slope, soil erodibility or time since logging." The study shows that a width of 30 m was required to prevent sediment impacts. Similar to a review by Clinnick (1985), the results are in agreement for mitigating impacts of logging on forest streams as a result of buffers. It stated that "streams with buffers of at least 30 m width exhibited similar channel stability and biological diversity to unlogged streams, whereas streams with buffers less than 30 m showed a range of effects similar to those found where no stream protection was provided (Clinnick 1985)."

Studies by Dillaha et al (1988, 1989) show a decrease in removal of sediment by 7-38% with a slope increase from 11% to 16%. Thus, various factors like soil infiltration and slope can affect the efficiency of a buffer.

The extent of buffers is also very important. The effectiveness of the buffer system can be compromised if gaps or breaks occur along the stream as it can provide direct access of surface runoff into the stream. Smaller headwater streams require riparian buffers as a measure of protection since they form the majority of stream miles in any basin (Lowrance et al 1997). These streams are also important because land-water interaction is most common among these types of streams and thus, there will be a higher chance to accept and transport sediment. Binford and Buchenau (1993) states that "protecting greenways along low-order streams may offer the greatest benefits for the stream network as a whole."

Although riparian buffers are effective in most cases, they become less effective in mitigating sediment transport when the flow is concentrated or channelized (Daniels and Gilliam 1996). Under such circumstances, soil infiltration cannot occur as the flow cannot be slowed enough by the buffers and allow the vegetation to trap the surface runoff. Daniels and Gilliam (1996) also found that during high-flow events, buffers were inadequate to trapping surface runoff. Typically, despite sediment accumulation, vegetation would still persist so the inundation of sediments for buffer vegetation should not decline in effectiveness; although it can create a case

of buffer ineffectiveness (Dillaha et al 1989). Furthermore, the accumulation of sediment can reach a point to where it will form a levee, preventing water flow to the stream from the slope (Dillaha et al 1989).

The construction of logging roads is seen as the single largest source of sediment due to vegetation removal and large exposures of erodible surfaces for cut and fill slopes. This finding is evident in numerous studies and has been modelled as well (Burns 1972, Megahan et al 1986, Burroughs and King 1989). Road construction also triggers mass wasting, which is a major problem. In Megahan et al (1986), it was found that about 66% of landslides are due to road cuts.As a result, mitigating sediment delivery from logging roads through buffers will contribute to reducing sedimentation in streams.

Slope is a main element in controlling sediment transportation. In Trimble and Sartz (1957), it was found that the average slope below the road determined the movement of sediment through the buffer and thus recommended that the width of the buffer should be increased as the average slope between the road and stream increased. Swift (1986) found that on 47% slopes with no buffer, sediment was able to travel to a maximum of 95.7 m with an average distance of 24.7 m. With a buffer, the distances were cut in half. However, there is a discrepancy among studies regarding travel distances of sediments. In general, studies show that buffer widths of 61.0 m to 91.4 m, are effective in sediment control that is not channelized. For example, in Trimble and Sartz (1957), they recommend buffers width ranging from 7.6 m for 0% slopes to 50.3 m for 70% slopes. They also recommend doubling that distance to maintain areas that are to be the highest possible water quality standard. Furthermore, Burroughs and King (1985) compared buffers with different vegetation types and found that dense grass reduced sedimentation by 97% on a fill slope of 67%, wood fiber mulch decreased sedimentation by 91% and woody slash reduced sedimentation by 87%. Overall, it was found that with a given sediment source, non-channelized travel distance will increase with slope and decrease with the amount of buffer width. For non-channelized flow, studies indicate that in general, sediment does not travel more than 91.4 m (Belt et al 1992).

Channel Erosion

Channel erosion plays a key role in stream sedimentation. The stabilization of banks is an essential role that riparian buffers play. In Beeson and Doyle (1995), it was found that of the 748

stream bends, “67% of bends without vegetation suffered erosion during a storm as oppose to only 14% of bends with vegetation.” Bends without vegetation were over thirty times more likely to suffer remarkably severe erosion. The conclusion the review reached was “the denser and more complete the vegetation around a bend, generally the more effective it is in reducing erosion (Beeson and Doyle 1995)”. Similarly, Barling and Moore (1994) have found in riparian zones that are extremely susceptible to erosion, rills and gullies were prevented from forming due to buffers.

The width of a buffer does not pose as a chief factor to preventing channel erosion providing that the stabilization of stream banks is in place and anthropogenic actions are kept at a fair distance of the stream. An important factor to consider is channel migration. Some erosion will occur and is inevitable and thus the stream will eventually move outwards of the buffer boundary. As a result, the buffer width design should incorporate that fact. However, a smaller width is acceptable for a shorter time period. Generally, bank erosion and stream movement are accounted for through various factors that buffer widths are also set out to protect.

In Daniels and Gilliam (1996), it was found that during dry seasons, forested ephemeral channels became sediment sinks but during storm events, became sediment sources. Clinnick et al (1985) states that “during storm events it is often the ephemeral elements of the stream system that act as a source of surface flow to permanent streams. The prevention of sediment accession to streams thus relies primarily on protection of these ephemeral elements.” In order to allow ephemeral channels to “slow water flow, trap sediment and prevent them as sediment sources, it is crucial to maintain these channels in a vegetated condition (Clinnick et al 1985).” Moreover, bank vegetation should be composed of a deep, rooted structure that enables it to hold the soil. In Shields et al (1995), it was found that the vegetation most suited to recolonizing and stabilizing banks are native woody species, particularly willow.

Summary and Recommendations

The mitigation of surface runoff and channel erosion has been proven through riparian buffers. Reviews have shown numerous buffer widths as recommendations; in the short term, widths as small as 4.6 m have been efficient. However, the larger the buffer is, the greater the capture of sediments, in particular on steeper slopes. For long-term management, wider buffers are also recommended. Generally, a width of 30 m is sufficient undermost circumstances to capture

sediments. A minimum width, overall, should be 9 m. There should be buffers for all streams, continuously for the whole stream network. Regular monitoring of stream turbidity would help to ensure the effectiveness of riparian buffers.

Further observations show that buffer widths should be increased on steeper slopes and buffers are not efficient in controlling channelized flows that originate outside of the buffer. The maximum travel distance sediment can flow through a buffer is 91.4 m and removal of riparian vegetation will allow for an increase in travel distance for sediments.

Nutrients

Phosphorus

Effects

The effects of phosphorus have been linked to eutrophication of lakes. The result of eutrophication leads to vast blooms of certain species of algae. Once these algae die and decompose, the consumption of oxygen is so great that fish and other aquatic animals cannot survive. Therefore, phosphorus is one of the main sources of contamination and poses a problem to riparian areas overall (Burruss Institute 1998).

Sources

Possible causes of phosphorous are fertilizers from agriculture and domestic use, animal wastes, septic drain fields, and leaking sewer pipes. Furthermore, forestry operations such as harvesting and slash burning are sources of phosphorous.

Literature Review

The width of buffers used for surface runoff will also be applicable to retaining phosphorus since it is usually attached to sediment or other organic matter (Peterjohnand Correll 1985). Studies have shown that within a short period, buffers trap most of the phosphorus that enters and as buffer width increase, retention also increases.

In Dillaha et al (1988 and 1989) and Magette (1987 and 1989), it was shown that grass buffers have reduced phosphorus levels. Table 2 shows the summary of their results. However, both authors noted that the buffers' effectiveness declined as time passes and total phosphorus reductions were higher than soluble phosphate reductions. In Dillaha et al (1988), it was

illustrated that there was more released phosphorus than the amount entered by the buffer. The increase may be a result of previously trapped phosphorus that became remobilized. However, the other reviews indicate that with an increase in buffer width, there was a decrease in the concentration of phosphorous. This was supported in Desbonnet et al (1993). They found that by increasing the buffer width by a 2.5 factor, phosphorus removal was increased by 10%.

Study	Total P Removal	
	4.6 m buffer	**9.1 m buffer**
Dillaha et al 1988	71.5%	57.5%
Dillaha et al 1989	61%	79%
Magette et al 1987	41%	53%
Magette et al 1989	18%	46%

Table 2: Removal of Total Phosphorus by grass buffers (Wenger 1999).

However, riparian buffers for long term effectiveness are uncertain. Because "phosphorus is either taken up by vegetation, precipitated with metals, or released into the steam or groundwater" (Lowrance 1998), a chance of buffer saturation may occur so any additional inputs of phosphorous will be transferred as soluble phosphate (Daniel and Moore 1997). Therefore, leaching of sediment-bound phosphorous may occur once the buffer is saturated (Osborne and Kovacic 1993). However, that process is slow so the stream will still be protected from extreme nutrient pulses. Factors, like cation exchange capacity and redox, lead to different rates of soil saturation. To permanently remove phosphorus from the riparian system, the harvest of vegetation may be the only practical management technique. However, this technique can lead to destabilization and thus erosion (USACE 1991), so ideally, it should be limited to areas with a reasonable distance away from the stream. Welsch (1991) suggests 4.6 m as a minimum width but 7.6 – 15.2 m will act as a safety measure.

Despite the effectiveness of buffers for phosphorous in the short run, net dissolved phosphorous retention is low (Lowrance et al 1997). Peterjohn and Correll (1984) discovered that total phosphorus and soluble phosphate were retained by 84% and 73% respectively across a 50 m riparian buffer from surface runoff. In Young et al (1980), they found a small difference in reductions for both total and soluble phosphorous across a 21 m buffer. They found that total phosphorus and soluble phosphate decreased by 67% and 69% respectively.

For vegetation considerations, the effectiveness of decreasing total phosphorous can be attained from both grass and forested buffers. Phosphate has been shown to dissipate into the stream through each vegetation type. In Osborne and Kovacic (1993), phosphate seeped faster into streams from forested buffers than grassed buffers. In Mander et al (1997), phosphorus uptake was higher in the early seral stage of forests. Lowrance et al (1985) suggests that to sustain greater nutrient uptake, periodic harvesting of riparian vegetation should occur at 4.6 m from the stream.

Similar to sediment control, continuous buffers for all streams is required for effective nutrient control. Riparian buffers separate direct access of phosphorous to water and allows for the chance of removal.

Summary and Recommendations

Therefore, phosphorous can be trapped effectively by riparian buffers but are not for long-term storage or soluble phosphate. In addition, once the buffer is inundated, trapped phosphorous can seep into the stream. To permanently remove phosphorous from the riparian area, one method would be to do periodic harvests of riparian vegetation (grass and forested). The buffer widths necessary to provide this service would be similar for sediment (15-30 m and an increase with slope). Buffers should extend to all streams within the network. As a result of buffer limitations, effort should be made to control phosphorous loading at its source. These can include: erosion control, restrictions placed on fertilizers, and restrictions on other land use activities. This can prevent the buffer from being quickly saturated and regulate the flow of phosphorous in and around streams.

Nitrogen

Effects

Nitrogen also leads to eutrophication of water.The two most common forms of nitrogen with regards to riparian buffer systems are nitrate and ammonium. To people and wildlife, nitrate (NO_3^-) is toxic at 10 mg/L or more (Wenger 1999). Ammonium (NH_4^+) is also poisonous to numerous water organisms and is taken up by aquatic vegetation and algae (Wenger 1999). Nitrate and ammonium also pose as a drinking water issue.

Sources

Sources for nitrogen are similar to phosphorous sources.

Literature Review

There are numerous studies that show significant nitrate reductions by the use of riparian buffer zones. In Fennesy and Cronk (1997), 20-30 m buffers can almost entirely eradicate nitrate. Gilliam (1994) states "even though our understanding of the processes causing the losses of NO_3^- are incomplete, all who have worked in this research area agree that riparian zones can be tremendously effective in NO_3^- removal." According to Cooper et al (1994), "streams with little or no buffer can have two to three times the nitrate concentration than those riparian areas with buffers." Riparian buffers can remove nitrogen through denitrification and through vegetation uptake.

Denitrification is a process through anaerobic microorganisms that convert nitrate into nitrogen gas. It permanently removes nitrogen and may be a leading cause of nitrogen reduction in riparian areas. Denitrification, at lower rates, also occurs within the stream.

Because of the solubility of nitrate, it has the ability to easily transport itself into shallow groundwater, unlike phosphorus (Lowrance et al 1985). Through subsurface pathways, nitrate makes its way into riparian areas (Dillaha et al 1988). Thus, these pathways account for the extent of nitrogen reduction. For example, if the path is through the root zone of the riparian vegetation then vegetation uptake and denitrification is important. In contrast, less nitrogen less will occur if it goes through an aquifer and skips the riparian area.

There is a positive relationship with riparian buffer width and the reduction of nitrogen. In Dillaha et al (1988), the 4.6 m and 9.1 m buffers were moderately efficient at total nitrogen removal from surface runoff but inefficient in removing nitrate. This result is also supported in Dillaha et al (1989) and Magette et al (1987, 1989). Table 3 summarizes the effectiveness of total nitrogen removal in relation to buffer widths. Young et al (1980) proposed that a buffer width of 36 m is adequate to safeguard water quality. Daniels and Gilliam (1996) states that "grassed buffers of 6 m width and a combination of grass-forested buffers of 13 m and 18 m width retained 20-50% of ammonium and 50% of total nitrogen and nitrate." However, in that study, the sites had different characteristics so width may or may not have been a factor. In addition, only surface runoff was studied and not subsurface flow so it may under- or over-estimate nitrate reduction because nitrate can pass through buffers in interflows. This problem is the same in the Dillaha (1988, 1989) and Magette (1987, 1989) studies. Peterjohn and Correll (1985) determined

that a buffer width of 50 m will reduce all forms of nitrogen from surface runoff. Also nitrate was reduced in shallow ground water but an increase in subsurface flow of various forms of nitrogen was found. Table 4 summarizes Peterjohn and Correll's (1985) findings.

Study	Total N Removal	
	4.6 m buffer	**9.1 m buffer**
Dillaha et al 1988	67%	74%
Dillaha et al 1989	54%	73%
Magette et al 1987	17%	51%
Magette et al 1989	0%	48%

Table 3: Removal of total nitrogen by grass buffers (Wenger 1999).

		Nitrate (mg/L)	Exchangeable NH4+ (mg/L)	Particulate Organic N (mg/L)
Surface Runoff	*Initial*	4.45	0.402	19.5
	Final	0.91 (79%)	0.087 (78%)	2.67 (86%)
Subsurface Transect 1	*Initial*	7.40	0.075	0.207
	Final	0.764 (90%)	***0.274***	***0.267***
Subsurface Transect 2	*Initial*	6.76	0.074	0.146
	Final	0.101 (99%)	***0.441***	***0.243***

Table 4: Nitrogen Reductions (Peterjohn and Correll 1985).

Summary and Recommendations

A correlation of buffer width and nitrogen removal is evident. Studies show that nitrate removal from shallow groundwater was high and nitrate can be removed through denitrification and vegetative uptake. For nitrate reduction, the buffer width depends on path flows. Because denitrification sites vary spatially, wider buffers are generally more important. Overall, a minimum of 15 m is required to reduce nitrogen levels. More extensive buffers, like 30 m, will likely include greater ranges of denitrification and thus offer more nitrogen removal. Buffers should also be continuous alongside all streams, especially on high nitrogen removal sites such as wetlands.

Large Woody Debris

Effects

Large woody debris (LWD) plays a key role in the stream ecosystem. It helps structure fish habitat, trap sediment and shape channels (Gregory and Sickle 1990). Other organic matter, such as leaf litter and terrestrial invertebrates provide inputs of food and energy. It also plays a part in the physical attributes; it can influence channel type, sediment storage and bedform roughness (Bilby and Bisson 1998).LWD creates blocks which in turn manage local channel hydraulics and supply protection against flood scour for vegetation development that persists over time (Naiman et al 2000). LWD creates suitable habitat for the colonization of riparian plants in alluvial rivers. Large logs that are deposited initiate the arrangement of steady woody debris jams that modify the local stream system and thus greatly influence the spatial pattern of scour and deposition (Naiman et al 2000). These blocks remain stable long term; mature riparian forest patches are able to form despite channel migration and frequent disturbance as a result (Naiman et al 2000).

Sources

Riparian vegetation regulates the age and species of large woody debris entering the stream system. The variability of wood size and species has significant ecological implications in regards to the perseverance of LWD within the stream and other successional processes associated (Naiman et al 2000). LWD is deposited into the stream as a tree falls or through upstream transportation or upslope by natural disturbance like floods, storms, fires, landslides or avalanches. However, virtually all LWD originates from riparian trees (Murphy and Koski 1989). There is variation among how LWD enter the stream system depending on bank erosion. For example, windthrow is the predominant mechanism for wood delivery in streams along erosion-resistant banks whereas trees that undergo erosive undercutting are the predominant mechanism for wood delivery in streams along erosion-prone banks (Murphy and Koski 1989). The abundance of LWD inputs depends on tree growth and mortality, longevity of wood and direction of tree fall (Naiman et al 2000). Natural disturbances like wind, fire, floods or landslides is usually the cause of most tree fall resulting in wood delivery in the stream. However, floods play a key part in wood removal. Based on empirical data on probability of fall direction, local topography strongly dictates tree fall direction and thus the chance of a tree falling towards the stream will be significantly greater than falling in another direction(Andrus

1998). Forest harvesting and other management practices that affect stand characteristics like species and stock levels will influence the quantity and timing of LWD contribution.

Literature Review

In Toews and Moore (1982), a comparison of three clearcut areas were observed; one was intensively logged, the second with careful guidelines and the third with a buffer width of 5 m. The first two (without buffers) yielded ample amounts of LWD which resulted in decreased stability of LWD already in the channel in addition to bank instability. The third yielded LWD recruitment levels as natural. In McDade et al (1990), they recommended, for an old-growth coniferous forest, a 30 m buffer would supply 85% of LWD whereas a 10 m buffer would provide less than half the amount of LWD naturally. Furthermore, the quantity and distance of LWD increased with slope. It was also found that in old-growth forests, source distance and LWD size was less than compared in mature stands with shorter trees. This indicates that tree height plays a role in LWD recruitment. In Robison and Beschta (1990), it was suggested that buffer widths equal to one tree height will provide the most quantity of LWD. Similarly, Collier et al (1995) supports a width of at least one tree height. However, for stability reasons, a buffer width of three tree heights may be required.

Salmonid survival is dependent on the amount of LWD in streams.Streams with a buffer width of 15-130 m were comparable in habitat quality to old growth forest areas (Murphy et al 1986). Although in the short term, clear cutting led to increases in salmonid populations during the summer, there is insufficient LWD to provide shelter for fish in the winter. The type and quantity of vegetation varies among different fish populations but native vegetation is critical to a healthy and functioning stream system (Abelho and Graca 1996). Abelho and Garca (1996) also found that other stream organisms are possibly not adapted to non-native trees in regards to leaf fall patterns or chemical features.

Summary and Recommendations

Riparian buffers provide a source of LWD and in turn provide some aquatic habitats and channel morphology characteristics. Without riparian forests, there will be a negative impact on the stream ecosystem. A minimum of 15 m wide buffer will allow for LWD input into the stream (Wenger 1999). Forest harvesting should not occur within 12 m of the stream and native vegetation should remain intact or restored (Wenger 1999).

Discussion and Conclusion

Overall, riparian buffer guidelines for extent and vegetation come with less complication than with width. The extent of buffers should be ideally placed for all perennial (streams with year round flows), intermittent (streams that cease flow yearly during some weeks or months) and ephemeral (streams that form only for a few hours or days succeeding rainfall) streams. This will maximize the effectiveness of placing a buffer around a channel. However, this may not be practical to do but a reasonable goal would be to place buffers for all perennial streams and intermittent streams with second order or higher (Wenger 1999). The buffer vegetation should be native to the riparian area. Native forests along the channel will sustain aquatic habitat. The width of a buffer depends on a variety of factors. For instance, some buffer functions do not require a large width while other functions do. Different studies have found what they deemed as important factors. For example, in Clinnick (1985), it was identified that soil type, slope and cover were the essential aspects whereas in Buchenau (1993), it was identified that catchment size, slope and land use were the important variables. In Fennessy and Cronk (1997), detention time was the most vital factor and in Osborne and Kovacic (1993), variables that affected nutrient removal such as soil characteristics and drainage characteristics were important.

Slope is possibly the primary factor when defining buffer efficiency for retaining sediments and nutrients. Studies have suggested that with a steeper slope, an overland flow will have a higher velocity and sediments and nutrients will require less time to go through the buffer. In both Trimble and Sartz (1957) and Swift (1986), a linear relationship was found between slope and buffer width. Trimble and Sartz make the recommendation that the width should be increased by 0.61 m to 1.22 m for every percent slope increase while Swift recommends an increase of 0.12 m to 0.42 m for every percent slope increase. The reason for the difference between the two studies is that Swift did not take into account small silt and clay particles, therefore resulting in a lower width recommendation. Overall, for every percent increase in slope, a minimum of 0.61 m width should be added to the buffer.

Rainfall pattern and intensity also contribute to buffer effectiveness. In Daniels and Gilliam (1996), it was found that during a single storm, the majority of sediments that goes through the buffer did so in the single event. In Dillaha et al (1988, 1989) and Magette et al (1987, 1989), test plots with simulated rainfall were done but these studies were interim and comparisons of

rainfall intensity were not done. However, in Cooper et al (1987) and Lowrance et al (1988), long term studies, which included large storms, were reviewed for the effectiveness of buffers. The conclusion from those studies show that wider buffers were needed compared to the short term studies. Therefore, buffers should be able to handle runoff from at least a one-year storm event and stream water quality tests can be done to ensure buffer effectiveness. However, due to lack of empirical data, a concrete relationship between buffer width and rainfall patterns cannot be concluded.

Other factors like soil characteristics (pH and soil moisture), floodplain and land use are important but not practical, especially on a large scale. Additional on-site experiments, data collection and studies may also be needed before determining optimal buffer widths. Overall, the larger the minimum width of a buffer is, the larger the security of water quality and habitat preservation for the riparian area.

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