

The Riparian Setback Matrix Model



Prepared for:

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March 31, 2010

Mr. Spencer Croil
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Dear Mr. Croil,

Re: The Riparian Setback Matrix Model

Aquality is pleased to present you with the Riparian Setback Matrix Model, which has been adapted for use within the MD of Foothills. With this tool in hand, the MD of Foothills will be better prepared to manage riparian areas and protect water quality for the future enjoyment of all residents and visitors to the area. The Model will also complement any future policies or bylaws that the MD adopts in order to further protect environmentally sensitive and significant areas.

In this document you will find an introduction to the importance of riparian areas, how we developed the Matrix, the Matrix Model, how to use it, and further considerations. References that support the science of the model are provided. We have also included a companion document, the Developer's Guide for distribution to those who wish to develop in areas adjacent to watercourses within the MD.

We would like to thank you for the opportunity to work with you on this project. If you have any questions or concerns regarding the RSMM, please feel free to call the undersigned at (780) 757-5530.

Yours truly,

AQUALITY ENVIRONMENTAL CONSULTING LTD.

Per: _____
Jay S. White, M.Sc., P.Biol.
Principal

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1 Introduction

1.1 Purpose

Facing immense development pressures, the need to protect and restore the riparian areas in the Municipal District of Foothills has become increasingly apparent. The Riparian Setback Matrix Model is a tool that was developed in 2007 by Aquality for Lac La Biche County (formerly Lakeland County) and has subsequently been incorporated in their municipal bylaws. Aquality has modified the model to meet the development needs and conservation objectives of the MD of Foothills. The Riparian Setback Matrix Model creates unique, defensible Environmental Reserve setbacks based on slope, height of bank, groundwater table level, soil type and texture, and vegetation/ground cover. These development setbacks will help to protect riparian lands¹ and maintain the ecological goods and services that healthy and functional riparian areas provide for future generations' benefit.

The purpose of this document is to help municipalities and developers determine the appropriate area of an Environmental Reserve (ER) to maintain healthy and functional riparian areas free from pollution² while providing public access that will not impede natural functions. In addition, the Riparian Setback Matrix Model can be used to determine appropriate development setbacks and land uses for all private lands located adjacent to environmentally sensitive and or significant lands within a municipality.

1.2 Environmental Reserves

During subdivision of a parcel of land, under conditions prescribed in the *Municipal Government Act* (MGA), a municipality may acquire "reserve lands". Reserve lands include "environmental reserves" which are essentially "undevelopable" lands that must be left in their natural state or used as a public park, and "municipal reserves", "school reserves", or "municipal and school reserves", which are dedications of up to 10% of the remaining "developable" lands in the parcel after the removal of environmental reserves and any lands required for roads and public utility lots. If insufficient land is available, the developer may provide a monetary payment equivalent to the market value of up to 10% of the developable lands (cash in lieu). Dedicated reserves become property of the municipality in which

¹ "Riparian land" means the lands adjacent to a watercourse where the vegetation and soils show evidence of being influenced by the presence of water. Riparian areas are the green zone around a watercourse. They are the vital transitional zone between surface water and the drier uplands and play a vital role in the healthy functioning of both.

² "Pollution" means any non-point source impacts on the environment from substances such as sediments, nutrients, pesticides, bacteria, parasites or toxic chemicals that reach a watercourse by surface or subsurface flow through adjacent land, and the unauthorized release of any "deleterious substance" as defined in the *Fisheries Act* (Canada), or the unauthorized release of any substance whether non-point or otherwise that may cause an adverse effect under provisions of the *Environmental Protection and Enhancement Act*.

they are located. A municipality is not required to compensate the landowner for any lands taken as “reserve” during the subdivision process.

As stated in the MGA, a municipal council may require the dedication of ER if the lands proposed for subdivision consist of: a) a swamp, gully, ravine, coulee or natural drainage course, b) land that is subject to flooding, or land that is unstable, or c) a strip of land, not less than six metres in width, abutting the bed and shore of any lake, river, stream or other body of water (Figure 1). If the lands adjacent to the minimum required 6 meter strip are also subject to subsidence, flooding, contain swamps and natural drainage courses, the required dedication of ER may result in a much wider strip than 6 meters. The strips of land abutting a lake are taken for two purposes: to prevent pollution, or to provide public access to and beside the bed and shore (Stewart, 2006).

ER is dedicated to protect provincially owned beds and shores and water resources from "pollution". Therefore, the definition of "pollution" that a municipality adopts in its Land Use Bylaw must specify what constitutes "pollution" in their community. For prairie lakes already high in nutrients such as phosphorus and nitrogen, added nutrients may impair water quality causing noxious algal blooms, taste and odour problems, anoxic conditions and even fish kills. Phosphorus has been identified in several recent studies as causing water quality problems across the Province (Hamilton 1985, Mitchell 1998, Mitchell 2000, Mitchell 2001, Schindler et al. 2004, White and Prather, 2004). Nutrients, therefore, can be defined by the MD of Foothills as pollution and steps will be taken to protect aquatic systems from additional nutrients making their way into watercourses via point and non-point source discharges. One of the most effective ways to protect aquatic ecosystems and prevent pollution is to ensure that riparian areas are intact, healthy and functional.

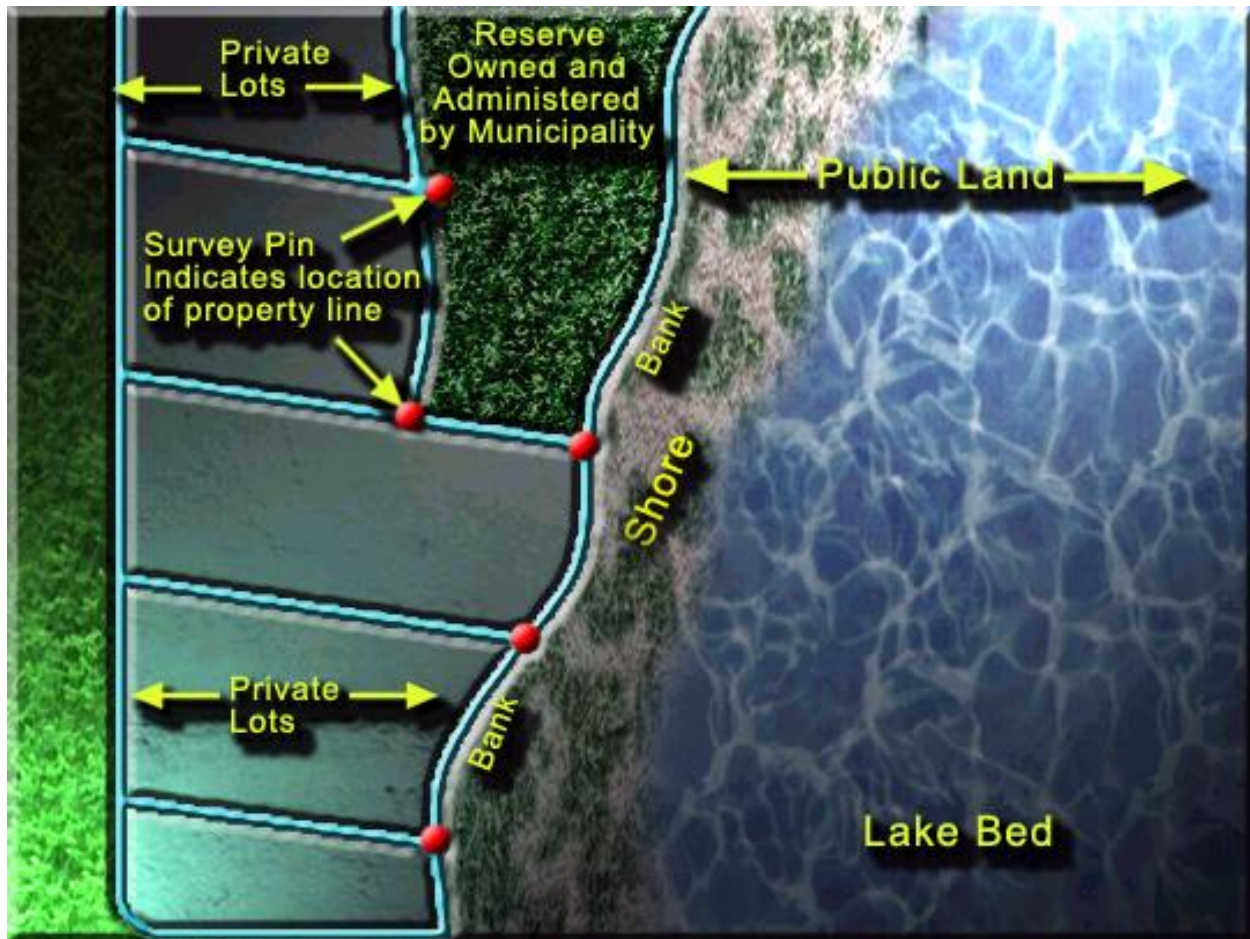


Figure 1. Illustration of lake bed and bank which is public land and owned by the Province and the Environmental Reserve land that is owned by the Municipality.

Sometimes, residents think that their property rights allow them to use adjacent ER parcels for exclusive, private purposes. They landscape, cut down trees, mow vegetation along streams, and plant gardens outside their lot lines with invasive species of flowers, shrubberies and trees. ER shore lands are often fenced or barricaded or restricted against the natural flow of people and floodwaters even when ER strips lie between their property and the bed and shore of a river or lake. Environmental Reserves are sometimes littered with lawn clippings, leaves, tree branches stumps and other debris, while ravines and river valleys are littered with garbage wastes that are non-biodegradable and do not readily decompose in the natural environment.

People compete with wildlife for ER adjacent to rivers and lakes which act as wildlife corridors or migratory bird habitat, and provide shade, shelter, food and water for flora and fauna. Some citizens consider ER private playgrounds to walk dogs, cycle, and ride all terrain vehicles. These activities create *ad hoc* pathway systems, adversely affecting the natural ground cover and vegetation, pollution, erosion of escarpments and ravines, and sedimentation of adjacent watercourses and bodies of water. When conflicts arise among ER users with different values, complaints are made directly to the municipality about erosion, fencing, litter, illegal dumping, off-leash dogs and pet wastes. As the owner of ER, a

municipality has the responsibility to control access and use to ensure that these sensitive landscapes are sustained for current and future generations. This can be done through a Reserve Bylaw or policy sanctioned by the municipality.

ER can also be required to provide public access to the beds and shores and the water, creating an inherent conflict between users who value ER for equally important, but competing functions. Riparian development setbacks should have as few channels and walking paths as possible. Channels and walking paths will increase the amount of surface runoff that reaches surface waters and decrease the effectiveness of the setback. Surface runoff from adjacent lands, depending on the land use, may contain sediment, nutrients, pesticides, bacteria, parasites, toxic chemicals and other pollutants. Functional and intact riparian areas remove these pollutants and prevent them from entering a waterbody, but paths through these areas decrease their effectiveness. The role of ER and riparian land protection is particularly important around waterbodies that serve as a drinking water source for communities.

Community access points to provincial beds and shores can minimize cumulative detrimental effects. Communal beach, dock and swimming areas are recommended as alternatives to allowing multiple points of access. Communal access in areas with the least environmental sensitivity, with the lowest quality riparian or wildlife habitat (i.e. non-fish spawning habitat) or land that is already disturbed will help protect intact, sensitive and healthy habitat. Developers and regulators should work together to identify areas that are more suited for public access such as boat launch or dock that will minimize habitat loss or environmental damage.

1.3 Environmental Reserve Easements and Conservation Easements

It is important to recognize that since 1994 when the current MGA was enacted, a municipality may enter into an agreement with an owner of a parcel of land that is subject to a proposed subdivision to create an "environmental reserve easement" for the lands that would otherwise be dedicated as ER for "protection and enhancement of the environment". An ER easement is registered under the *Land Titles Act* and is a covenant on the land ensuring that lands are left in their natural state, and the easement is enforced by the municipality.

Under the *Environmental Protection and Enhancement Act*, landowners can voluntarily enter into a legal agreement called a conservation easement to preserve habitat while retaining title to the property. The landowner relinquishes certain ownership rights in order to protect the landscape's natural character. Qualified easement holders include land trusts, municipalities or conservation groups such as Ducks Unlimited Canada or the Nature Conservancy of Canada.

1.4 Development Setbacks for Buildings

A municipality is responsible for the planning and development of private lands within its geographical boundaries. Through provisions in the Land Use Bylaw (LUB), a municipal council can control the development of "buildings" on land that is subject to flooding or subsidence, or that is low lying, marshy or unstable; or, land that is adjacent to or within a specific distance of the bed and shore of any lake, river, stream or other body of water ("environmentally significant lands"). What constitutes a "building"

is defined in the MGA to include all structures except highways and bridges. Controlling development of buildings within prescribed development setback areas can be done through policy statements and land use bylaw provisions. The opportunity to create appropriate development setbacks and land uses in riparian areas is underutilized by municipal governments. The Riparian Setback Matrix Model presented here will assist the MD of Foothills to create a defensible “natural environmental reserve” land use designation with associated permitted and discretionary land uses. The natural riparian function of each landscape that a municipality wishes to preserve will determine the extent of the development setback required. The Riparian Setback Matrix Model will assist municipalities to adopt appropriate development setback policy and enact appropriate Land Use Bylaw provisions inclusive of Area Structure Plans or Watershed Management Plans, integration of policies and directives.

1.5 Riparian Areas

Vegetation in riparian areas is different from that of uplands. Riparian areas stay green longer and produce more biomass than uplands, partly due to soil types but mostly due to an elevated water table. The types and abundance of vegetation can help to identify riparian areas. The vegetation is different and tends to attract livestock, wildlife and humans. Riparian areas are highly productive and can be reliable producers of forage, shelter, fish, wildlife and water. These areas are especially useful when drought or flooding occurs by attenuating flood waters and reducing erosion (Alberta Riparian Habitat Management Society, 2006).

Riparian zones act as buffers that function to protect water quality. Contaminants are absorbed onto sediments, taken up by vegetation and transformed by soil microbes into less harmful forms (Klapproth and Johnson 2000). They have long been proven effective in reducing nutrients, sediments and other anthropogenic pollutants that enter surface waters via overland and subsurface flow (Klapproth and Johnson 2000; Lee and Smyth 2003; Mayer et al 2006).

In addition to protecting surface waters, riparian areas are valuable wildlife and plant habitat. They provide nesting sites for several bird species, habitat for reptiles and amphibians and safe corridors for several species of mammals such as deer and moose (Wenger 1999). Although riparian areas make up only a small fraction of our landscape, they are disproportionately important to fish and wildlife, recreation, agriculture, and society in general. As much as 80% of Alberta's wildlife relies in whole or in part on riparian areas to survive (Alberta Riparian Management Society, 2006). The health and functioning of riparian areas can be influenced by human activities including road construction, resource extraction, agriculture, urban or rural development, and recreation. Unfortunately, most riparian lands are privately owned and therefore difficult to protect unless a municipality enacts development setbacks in riparian lands from a body of water such as a river or lake.

Defining a riparian area (riparian buffer strip) that is far enough from a receiving water body to effectively protect the water and the aquatic ecosystem has been the subject of much debate. A “one size fits all” approach has traditionally been used by provincial regulators and is still being used today. However, it is becoming increasingly apparent that water bodies require a unique set of guidelines to define appropriate riparian buffer widths and development setbacks. It is essential that municipalities establish appropriate land uses adjacent to bodies of water, including wetlands, to avoid or minimize

development impacts of our valuable water resources, as provided in the provincial *Land Use Policies*. The importance of establishing and protecting a properly-sized buffer strip is extremely important for source water protection.

1.6 Environmental Legislation

The MGA and *Environmental Protection and Enhancement Act* are not the only pieces of legislation that protect environmental reserves and riparian buffers. There are at least twelve municipal, Provincial and Federal bylaws and acts that serve to protect these sensitive areas (Table 1), some with very broad powers of application (Figure 2). Several Provincial policies and strategies are also in place to protect the aquatic environment including the *Strategy for the Protection of the Aquatic Environment*, *Water for Life Strategy* and others that are consistent with *Alberta's Commitment to Sustainable Resource and Environmental Management* and *Strategy for the Protection of the Aquatic Environment*. The new *Framework for Watershed Management Planning* should provide municipalities with a suite of mechanisms to work with partner stakeholders, landowners and other jurisdictions to ensure that water resources are protected for future generations. Our common challenge will be to understand and implement these various pieces of legislation for the benefit of environmental protection within long term development integration.

Table 1. Legislation and policy involving riparian land management.

Legislation/policy	Description
Federal <i>Fisheries Act</i> - Fisheries and Oceans Canada (FOC)	Regulates and enforces on harmful alteration, disruption and destruction of fish habitat in Section 35.
Provincial <i>Water Act</i> - Alberta Environment (AENV)	Governs the diversion, allocation and use of water. Regulates and enforces actions that affect water and water use management, the aquatic environment, fish habitat protection practices, in-stream construction practices, storm water management.
Provincial <i>Environmental Protection and Enhancement Act (EPEA)</i> - AENV	Management of contaminated sites, storage tanks, landfill management practices, hazardous waste management practices and enforcement.
Provincial <i>Alberta Land Stewardship Act (ASRD)</i>	This legislation supports implementation of the Land-use Framework. It creates the seven land-use regions, establishes the Land-use Secretariat and gives authority for regional plans, creation of Regional Advisory Councils and addresses the cumulative effects of human and other activity.
Provincial <i>Agricultural Operations Practices Act (AOPA)</i> - Natural Resources Conservation Board (NRCB)	Regulates and enforces on confined feedlot operation and environment standards for livestock operations.
<i>Historical Resources Act</i> - Culture and Community Spirit	Concerns any work of humans that is primarily of value for its prehistoric, historic, cultural or scientific significance, and is or was buried or partially buried in land or submerged beneath the surface of any watercourse or permanent body of water.
Provincial <i>Municipal Government Act (MGA)</i> - Municipal Affairs	Provides municipalities with authorities to regulate water on municipal lands, management of private land to control non-point sources, and authority to ensure that land use practices are compatible with the protection of aquatic environment.
Provincial <i>Public Lands Act</i> - Sustainable Resource Development (ASRD)	Regulates and enforces on activities that affect Crown-owned beds and shores of water bodies and some Crown-owned uplands that may affect nearby water bodies.
Provincial <i>Safety Codes Act</i> - Municipal Affairs	Regulates and enforces septic system management practices, including installation of septic field and other subsurface disposal systems.
<i>Regional Health Authorities Act</i> - Alberta Health	RHA have the mandate to promote and protect the health of the population in the region and may respond to concerns that may adversely affect surface and groundwater.
<i>Wildlife Act</i> - ASRD	Regulates and enforces on protection of wetland-dependent and wetland-associated wildlife, and endangered species (including plants).
<i>Provincial Parks Act & Wilderness Areas, Ecological Reserve and Natural Areas Act</i> - ASRD and Community Development	Both Acts can be used to minimize the harmful effects of land use activities on water quality and aquatic resources in and adjacent to parks and other protected areas.

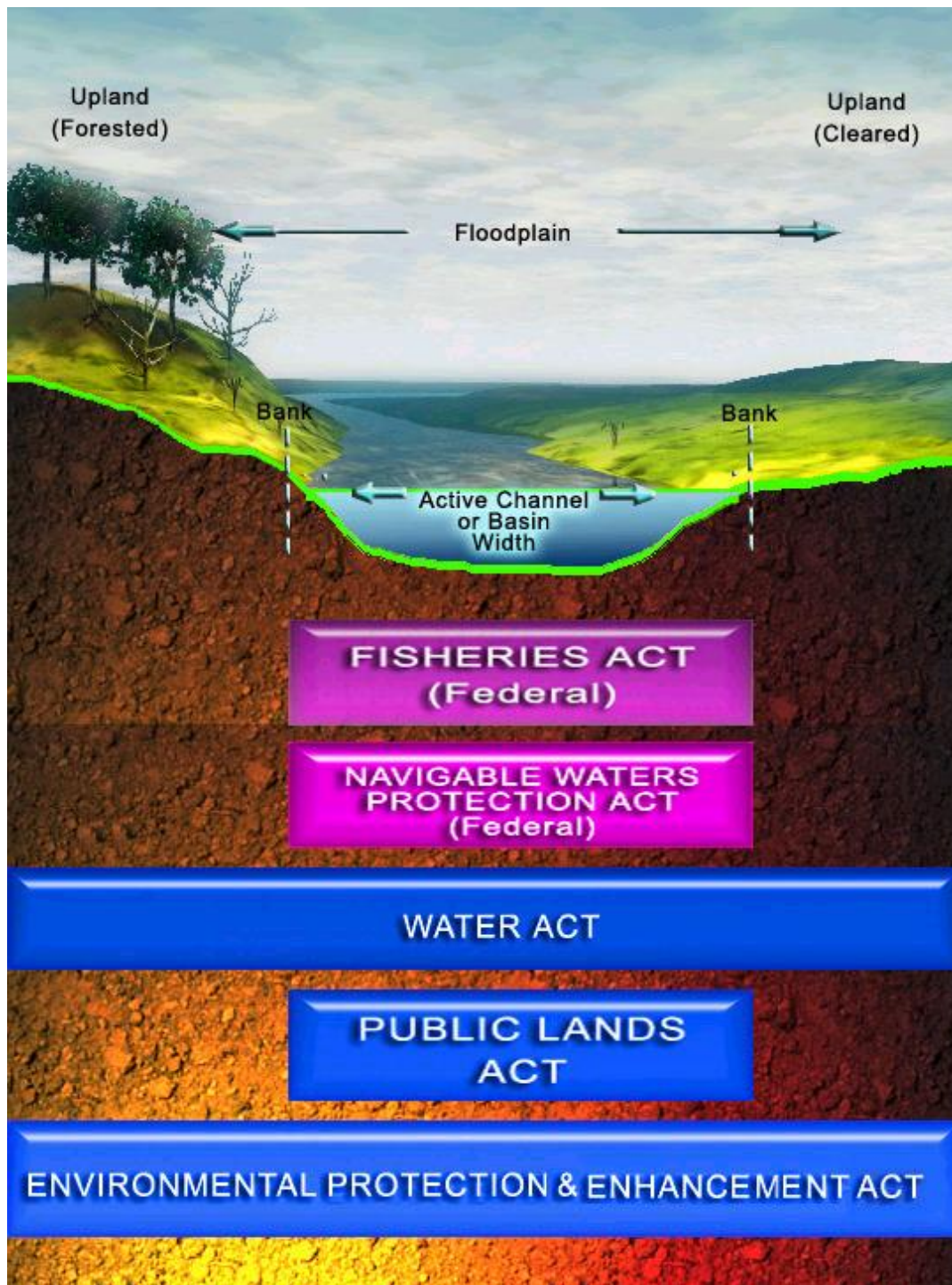


Figure 2. Federal and Provincial legislation that can be used to protect riparian habitats.

2 Development of the Riparian Setback Matrix Model

Internet and library searches were undertaken to survey the scientific and grey literature for sources of riparian information. With a focus on peer-reviewed primary literature, we reviewed riparian development setback documents looking for recommendations on slope, vegetation, bank height, and groundwater influence. Additionally, the properties of riparian zones and different vegetation types were reviewed in relation to nutrient and other pollutant attenuation.

Based on the review of the literature and other documents, a matrix was designed to include slope, bank height, groundwater influence, soil characteristics and vegetation type. For each category, setback distances were recommended for different properties of each category. Additionally, a table was established as a 'double check' to the matrix. Based on a review of the literature, the table presents recommended riparian development setback distances for effective nutrient (nitrogen and phosphorus) and sediment attenuation. This table acts to ensure that the development setback distance determined by the matrix will be sufficient for nutrient and sediment removal.

3 The Riparian Setback Matrix Model

3.1 Riparian Setback Matrix Model - Setback Determinations

The Riparian Setback Matrix Model (RSMM) is meant for all types of waterbodies in the Municipal District of Foothills. Parameters or measurements that may lead to intervention or modification of the prescribed setbacks by municipal administrators are highlighted in yellow; parameters or measurements requiring special surveys or other technical considerations are highlighted in red.

Table 2. Riparian Setback Matrix Model for the Municipal District of Foothills #31.

Waterbody Name:

Waterbody Location:

Waterbody Type (circle one):

Lake/Pond

River/Stream

Wetland

STEP 1	Slope Category (%)	Slope (%)	Distance Adjustment
	0 - 4.9		10 m
	5 - 9.9		10 m + 1 m per % of slope over 5%
	10 - 14.9		Same as above†
	≥ 15		Requires a geotechnical survey††

SLOPE SETBACK

STEP 2	Height of Bank	Bank Height (m)	Distance Adjustment
	< 5 m	_____	10 m
	5 to 30 m	_____	2x height of bank
	≥ 30 m	_____	60 m
	BANK HEIGHT SETBACK	_____	

STEP 3	Groundwater Influence	Select one:	Distance Adjustment
	Distance to water table	_____	
	0 - 9.9 m	_____	30 m
	10 - 19.9 m	_____	15 m
	≥ 20 m	_____	10 m
	GROUNDWATER SETBACK	_____	

STEP 4	Vegetative Cover Type	% Cover	Distance Adjustment (m / % cover type)
	Forested	_____	0.15
	Shrub	_____	0.25
	Grass and Herbaceous Plants	_____	0.30
	Bare Ground	_____	0.50
	Impermeable surfaces	_____	0.60†††
	VEGETATION SETBACK	_____	

STEP 5	Soil Texture/Type	Select one:	Distance Adjustment (multiplier) ++++
	Peat (minimum 50% organic matter in soil)	_____	1.0
	Sand, Sandy Loam, or Loamy Sand	_____	1.0
	Loam, Silty Loam, or Silt	_____	1.1
	Clay Loam, Sandy Clay Loam, Silty Clay Loam, Sandy Clay, Silty Clay, or Clay	_____	1.25

Rock and gravel (more than 50% rock and gravel) _____ 1.25

SOIL SETBACK MULTIPLIER _____

STEP	Overall Setback Calculation
6	
	Determine maximum setback from Steps 1-4 above _____
	Multiply baseline setback by soil texture multiplier _____
	TOTAL CALCULATED SETBACK: _____

† - Sites with slopes of 10 – 14.9% may require a geotechnical survey, decided on a site by site basis at the discretion of the administration.

†† - Sites with slopes of >15% require a geotechnical survey in all circumstances, to be carried out by a qualified professional (see *Professional Requirements for Site Assessments*).

††† - for survey points with impermeable surfaces (concrete, asphalt, etc.) as a component of the ground cover, the established setback distance is subject to special approval by municipal administrators. It is recommended that the setbacks be long enough that the impermeable surfaces make up at maximum 5% of the setback distance. For instance, if 2 m of the survey site are covered by impermeable surfaces, then the recommended setback at that site would become $2 \text{ m} \div 0.05 = 40 \text{ m}$.

†††† - Soil texture serves as a modifier of the distances calculated from the previous steps, and are not included in the most-sensitive-parameter approach of the preceding calculations. A multiplier of 1.0 means that the soil texture does not change the setback determined previously, while multipliers greater than one increase the setback proportionally. For instance, a setback of 36 m calculated for a site based on vegetation, slope, bank height, and groundwater depth would remain at 36 m if on a sandy loam ($36 \text{ m} \times 1.0 = 36 \text{ m}$), while on a silty clay it would increase to 45 m ($36 \text{ m} \times 1.25 = 45 \text{ m}$).

Table 3. Recommended Riparian Setbacks for Nitrogen, Phosphorus and Sediment Control.

Parameter	Riparian Vegetation	Recommended Setback (m)	Notes
Nitrogen	Grass	50+	-Will remove ~90% of nitrate from surface and subsurface runoff.
	Grass/Shrub or Forest	30+	
	Forest	30+	
Phosphorus	Grass	20+	-Will reduce soluble phosphorous by ~90%. -See recommendations for sediment for the removal of total phosphorus (most phosphorus enters a buffer attached to the sediments).
	Grass/Shrub or Forest	20+	
	Forested	20+	
Sediment	Grass	30+	-Will remove ~90% of sand and silt particles. -100m is required for the effective removal of clay particles. - For long term retention of sediments the setback should be 30 – 100m.
	Grass/Shrub or Forest	30+	
	Forested	25+	

3.2 How to use the Riparian Setback Matrix Model

The amount of Environmental Reserve to be taken will be determined by using the Riparian Setback Matrix Model. Environmental Reserve will be determined at several sites along the water's edge, and as such the area dedicated as ER will vary throughout the site; some areas will require more Environmental Reserve and others will require much less. The dedicated Environmental Reserve will vary throughout the parcel of land depending on slope of the land, height of any banks present, groundwater influence, soil type and vegetative cover.

The amount of property bordering the water's edge will also affect how Environmental Reserve is determined. To start using the Riparian Setback Matrix, setback points will need to be established. The number of points used to determine Environmental Reserve will vary based on the area to be developed.

1. Establish the number and location of setback points required.

1.1. Whereas the location of the point will be:

1.1.1. At the point where vegetation (living or dead) characteristic of an aquatic environment end changes to that of upland vegetation. This vegetation includes but is not limited to; Sedges, Bulrushes, Cattails and Willows.

1.1.2. If no vegetation exists, the setback point will be determined from the current edge of water.

1.1.3. Whereas the length of land bordering the water body, stream or wetland is:

1.1.3.1. **Greater than 200 meters** – The outside setback point will be no more than 100 meters from the property line along the water body, stream or wetland. The subsequent setback points will be equally spaced no more than 200 meters apart.

1.1.3.2. **200 meters to 50 meters** – Two (2) setback points will be required equal distance apart and equal distance from each property line.

1.1.3.3. **Less than 50 meters** – One (1) setback point will be required at the discretion of the Municipal District of Foothills. Please contact the MD of Foothills administration to determine the location of this setback point.

2. Slope of the land must be determined by a legal land surveyor at each of the setback points. From each setback point, determine the slope of the land perpendicular to the water body, stream or wetland. The setback distance for slope is calculated as follows:

2.1. If the slope is **<5%**, the setback distance requirement is 10 m.

2.2. If the slope is **5-9.9%**, the setback distance will be 10 m + 1 m for every 1 % increase in slope after the minimum.

- 2.3. If the slope is **10-15%**, consult with MD of Foothills administration to determine if a geotechnical survey will be required.
- 2.4. If the slope is **≥ 15 %**, then a geological survey is required. The total setback required for this site will be determined by a registered professional. The determined setback must take into account the slope, height of bank, groundwater influence, soil type and vegetative cover. Setback requirements will be subject to the approval of the subdivision authority.
- 2.5. Record slope, under measured slope in Step 1 and enter the calculated distance adjustment in the TOTAL Box in Step 1.
- 2.6. If the determined setback is greater than or equal to 75 m, skip to step 6; otherwise, continue to step 3.

3. **Height of Bank** must be determined by a legal land surveyor at each of the setback points. From each setback point, determine the height of bank perpendicular to the water body, stream or wetland. NOTE: Height of bank will be determined at the same time as slope by the surveyor.
 - 3.1. Put a check mark next to the appropriate bank height in Step 2.
 - 3.2. Identify and enter the required distance adjustment in the TOTAL Box in Step 2.
 - 3.3. If the required distance adjustment is 75 m you can stop here. The required distance adjustment for this site is 75 m. The Environmental Reserve allocation will be determined horizontally, perpendicular to the water body, stream or wetland from the setback point.
 - 3.4. If the determined setback is greater than or equal to 75 m, skip to step 6; otherwise, continue to step 4.

4. Determine the **depth to the water table** for the site. This information can be obtained from a geotechnical report, or from local well data by a qualified hydrogeologist.
 - 4.1. Put a check mark next to the appropriate groundwater depth in Step 3.
 - 4.2. Identify and enter the required distance adjustment in the TOTAL Box in Step 3.
 - 4.3. If the determined setback is greater than or equal to 75 m, skip to step 6; otherwise, continue to step 5.

5. Determine the **vegetation cover of each type** for the site.
 - 5.1. From each setback point, determine the vegetation type perpendicular to the water body, stream or wetland, by creating a 1 m x 10 m plot.
 - 5.2. Determine the percent of the plot that is grass, shrub, forested, impermeable and cleared.
 - 5.3. Multiply the percentage of each vegetation cover class by the respective distance adjustment for each type.
 - 5.4. Put the required adjusted distance beside the respective vegetation cover.
 - 5.5. Add up the setback requirements from all vegetation cover types to obtain the total vegetation cover setback.

5.6. Continue to step 6.

6. **Determine the baseline setback** based on slope, bank height, groundwater depth, and vegetation cover.
 - 6.1. If any of the setbacks calculated from steps 2 – 5 are equal to 75 m, the baseline setback for that point is 75 m.
 - 6.2. Otherwise, the baseline setback is the maximum of the setbacks determined in steps 2 – 5.
7. Determine the **soil type and texture** for the site.
 - 7.1. The soil type and texture with respect to proportions of sand, silt, clay, organic material (peat), rocks and gravel should be determined by a qualified professional.
 - 7.2. Based on the percentages of each soil particle fraction, determine the soil texture category that the soil at the site falls into, and use this texture/type to determine the setback soil multiplier.
8. Multiply the distance obtained in step 6 by the soil multiplier determined in step 7. This is the final setback for the site.
9. **To establish Environmental Reserve**, determine setback distances from each setback point. Connect setback points. Setback to the property line will be done perpendicularly from the nearest determined setback point. (See diagram on Page 9 for clarification).

See the attached Riparian Setback Matrix Model SAMPLE for more clarification (Appendix B).

3.3 Slope and Bank Height

Slope and bank height are important factors in determining an appropriate riparian setback width. Steeper slopes are more susceptible to erosion and can increase the velocity of overland flow (runoff) and reduce buffer contact time (Wenger 1999; Li et al 2006). Dillaha et al (1988, 1989) found that as buffer slope increased from 11 % to 16%, sediment removal efficiency declined by 7-38%. Li et al (2006) also found that as slope gradient increases, that loss of nutrients also increases. Fox and Brown (1999) found that flow velocities increased with increased slope, with the rate of increase following an approximately linear relationship over the range of slopes considered by this model. The Connecticut Association of Wetland Scientists (2004) suggested a minimum buffer width of 25 feet with a width increase of 3 feet (~1m) for every degree of slope. Others have suggested that there be minimum buffer of 30 m with an increase of 0.61 m for every 1 % increase in slope (Wenger 1999; Sasson 2003). The City of Calgary (2006) recommends that the development setback distance should increase by 1.5 m for every 1% increase in slope after 5%. Based on these and other documents, the minimum setback for slope was established at 10 m, with a linear increase in the setback distance of 1 m for every degree in slope over 5%.

Bank height was addressed in the Draft Watershed Management Plan for the Nose Creek Watershed (Palliser, 2005), modified slightly here to extend the upper limit of the bank height setback to 75 m. It was suggested that where there is $\geq 15\%$ slope, an additional setback from the top of the bank should be added to the riparian development setback. This would provide a stable slope allowance (Palliser, 2005). These recommendations were adopted into our matrix model by requiring that there be a geotechnical survey conducted when the slope is $\geq 15\%$. Slopes between 10 and 15% may require a similar survey, to be determined at the discretion of the administration on a case by case basis in order to adequately protect especially sensitive areas. The slope and height of bank should be determined by a legal land surveyor in order for the model to be legally defensible.

3.4 Groundwater Influence

Groundwater and subsurface flows can also contribute nutrients and pollutants to surface waters (Figure 4), and groundwater itself can become compromised when polluted runoff infiltrates through the soil. For the protection of the surface and groundwater, it is recommended that shallower water tables have larger development setback distances. Devito *et al* (2000) found that a lake located in a regional recharge or local discharge area received proportionally greater phosphorus inputs from surface and near-surface flows, and were therefore more susceptible to disturbances in the watershed. It was also found that in deeper water tables with primarily subsurface flows, phosphorus is more readily absorbed to the soil and taken up by plant roots. However, in shallower water tables where soil is often waterlogged, overland flow is more common and there was little phosphorus removal (Devito *et al*, 2000). There is very little reference in the literature to groundwater influence when determining effective riparian setback distances. Therefore, this category of the model was developed with the knowledge that deeper groundwater has generally had a longer residence time in the soils (Li *et al*, 2006) and allows for more water to absorb to soil particles (Devito *et al*, 2000). Water that has longer contact with soil has more time for physical, chemical and biological breakdown of pollutants. Shallower water tables are more likely influenced by the immediate surroundings and the water will have had a shorter residence time; additionally, it is more likely to discharge into the surface waters of concern.

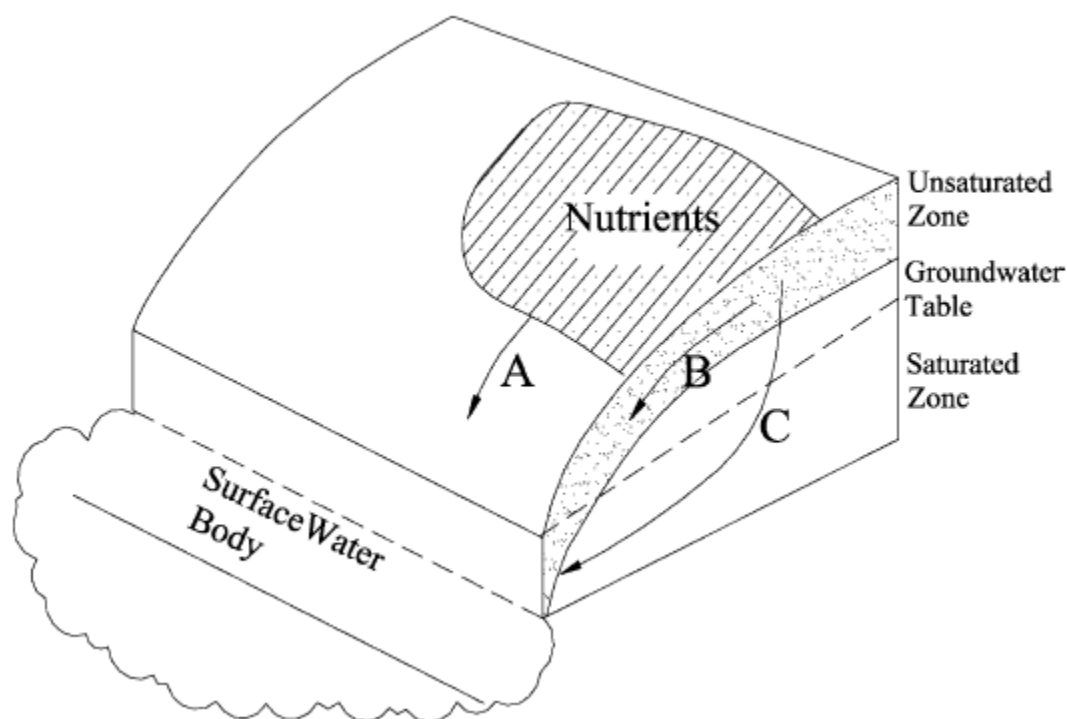


Figure 3. Potential pathways for nutrient and pollutant input from sloping lands to surface water: (A) surface runoff, (B) subsurface flow, and (C) groundwater (Taken from Li *et al* 2006).

3.5 Vegetation Type

Vegetation slows the velocity of overland water flow and allows increased infiltration and sediment deposition (Connecticut Association of Wetland Scientists 2004). Once in the soil, chemical, biological and physical processes remove pollutants through filtering and absorption (Connecticut Association of Wetland Scientists 2004). Plants and microflora also remove nutrients and pollutants through absorption (Connecticut Association of Wetland Scientists 2004). In an extensive review of the literature, Mayer *et al* (2005) found that grassed buffers were the least effective at removing nitrogen from surface and subsurface flows, whereas forested buffers were the most effective (Figure 3). Wenger (1999) reported that both grass and forested buffers were effective for sediment and nutrient removal, but that shrub or forested buffers were more effective for bank stabilization and decreasing erosion. Gilliam (1997) reported that forested buffers were more effective than grass for sediment and nutrient removal, and that a combination of grass and forest was the most effective buffer. The presence of emergent vegetation enhanced the effectiveness of the riparian setback. Based on these and other documents, we designed the matrix so that grass buffers would have the largest distance adjustment.

The matrix was designed with vegetation of different types having additive effects. The aim of the model is to remove a specified percentage of pollutants from runoff. Since each vegetation cover type is capable of removing pollutants at a different rate, the use of an additive model with different weights

for each vegetation class will ensure the removal of a consistent percentage of pollutants regardless of cover type at a given location.

Although certainly not as effective as vegetation cover at slowing and removing pollutants from surface runoff, bare ground does still allow infiltration into the shallow groundwater, where such pollutants may adsorb onto soil particles or eventually be removed by plant growth. However, impermeable surfaces such as asphalt and concrete pavement confer no such advantage. When impermeable surfaces are present within the vegetation plot, it is recommended that the determination of the setback distance be subject to approval by MD of Foothills administration. In such cases, we recommend that the setback distance for vegetation be extended so that at most, 5% of the length of the setback is covered by impermeable surfaces, to maintain as best as possible the protection provided by the vegetated buffer.

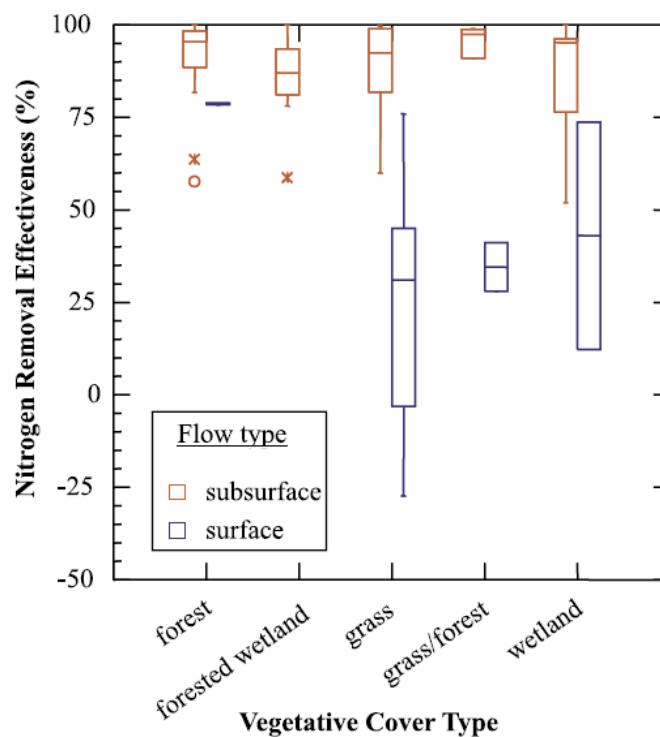


Figure 4. Nitrogen removal effectiveness in riparian buffers by buffer vegetation type and water flow path. The center vertical line of the box and whisker plot marks the median of the sample. The length of each box shows the range within which the central 50% of the values fall. Taken from Mayer *et al* (2005). We do not use wetland or forested wetland cover type in our model.

3.6 Soil Texture and Type

The type and texture of soil present at a site may have a strong influence on the ability of a riparian habitat to remove pollutants from surface runoff. Soil type is determined by the “parent” material, i.e. the original substrate that the soil developed on (e.g. bedrock of various types, glacial till, ancient river or

lakebeds), while texture is determined by the relative proportions of sand, silt, and clay that are present in the soil.

Two important aspects of soils that are determined by texture may have the potential to strongly influence pollutant loadings into adjacent waterbodies: erodibility and hydraulic conductivity. Low erodibility can be beneficial because it reduces loadings of solids and other potential pollutants into waterbodies; high hydraulic conductivity can be beneficial because it allows rapid infiltration of surface water into shallow groundwater. Soils that are high in clay content tend to be less erodible than those dominated by sand or clay (White, 2006), because the chemical and physical bonds between the particles are stronger and are more resistant to the physical action of water. However, a tradeoff exists, because soils with higher sand and silt contents have generally higher hydraulic conductivities (United States Department of Agriculture, 2008), meaning that they are better at allowing surface water to infiltrate into shallow groundwater.

This implies that high clay soils might be preferred near waterbodies (or at least allow for shorter setback distances). However, if otherwise healthy riparian areas are left undisturbed by human activities, vegetation will establish rapidly and reduce rates of erosion across all soil types (Morgan and Rickson, 1995). For longer-term protection of waterbodies, hydraulic conductivity will be the more important component to consider. Since the effectiveness of groundwater infiltration depends upon the slowing of surface runoff by reduced slope and the presence of established vegetation, soil texture and type are included in the model as a parameter that modifies the original setback, akin to a “soil texture tax.” For soils textures with high hydraulic conductivity, there is no tax imposed, but soil textures that do not permit easy groundwater infiltration (e.g. clay-dominated soils) are heavily “taxed” to allow increased infiltration time and distance.

While the determination of soil texture excludes the fraction of soil comprising rocks, gravel, and organic matter, these factors can have important influences on hydraulic conductivity, erodibility, and the ability of a soil to support plant life. Naturally formed peat deposits can be highly beneficial in riparian zones, due to their high capacity for absorbing water and nutrients and supporting plants (Cohen, 1997). Rocks and gravel, on the other hand, tend to have a negative influence on pollutant removal, because they may act as an impediment vegetation establishment (McBride and Strahan, 1984) and can form natural “pavements” that allow surface water to rapidly run over them (Huggenberger et al., 2002), without allowing sufficient contact time with soil particles or plant roots for the removal of sediments and nutrient pollutants.

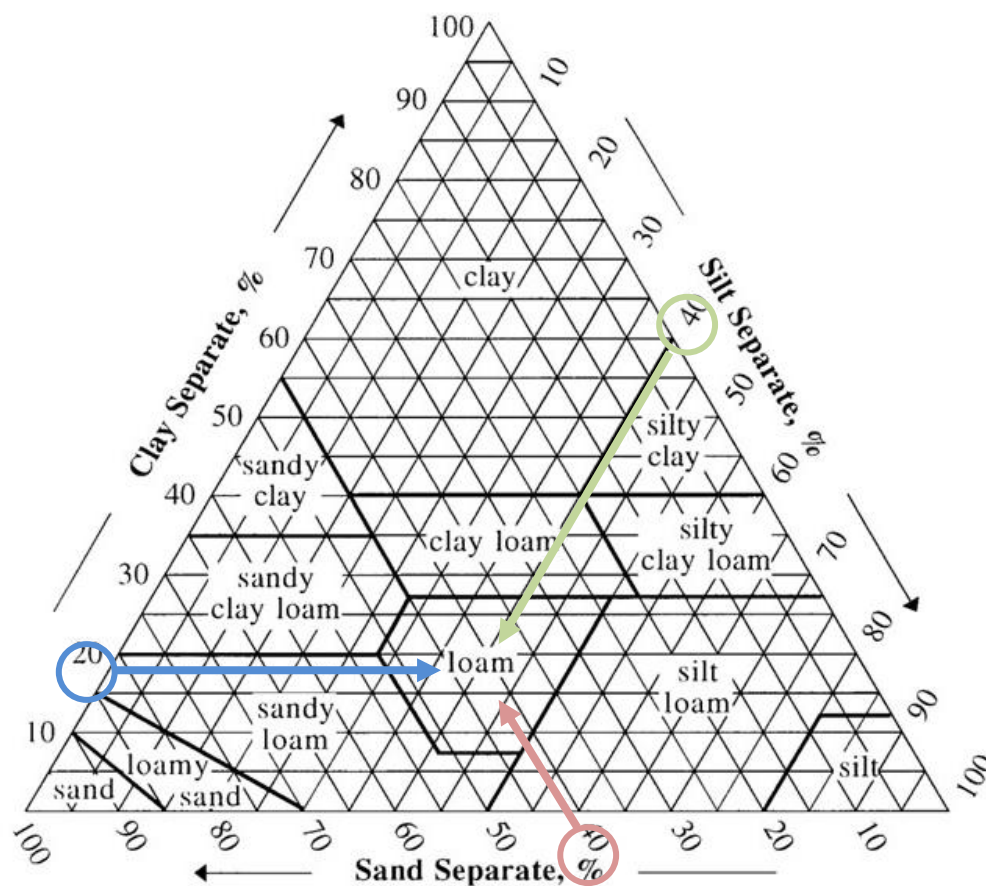


Figure 5. Soil texture as determined by the relative proportions of sand, silt, and clay present in the soil sample. The texture of a given soil (with known sand, silt, and clay contents, is determined by moving directly to right from the appropriate percentage on the clay (left) axis, down and left from the appropriate percentage on the silt (right) axis, and up and left from the appropriate percentage on the sand (bottom) axis. The determination of the texture for a soil with 20% clay, 40% sand, and 20% silt (a loam soil) is shown by the coloured lines on the figure.

4 Professional Requirement for Site Assessments

Although every effort has been made to make the Riparian Setback Matrix Model accessible to as wide an audience as possible, the determination of setbacks should not be undertaken without enlisting the assistance of a professional(s) with qualifications appropriate for the conditions and complexity of the site.

Condition	Professional Requirements for setback determination
Low slope, obvious transition from aquatic to upland vegetation, groundwater table known from nearby wells	Professional biologist
Complex vegetation communities with no obvious transition from aquatic to upland vegetation	QAES/QWAES

Moderate slopes (5-15%)

Legal land surveyor

Steep slopes (>15%)

Geotechnical professional (Geological engineer, hydrogeologist)

Extensive river meander or presence of floodplain

QAES/QWAES + Geotechnical professional

Unknown water table depth

Hydrogeologist

5 Summary and Conclusions

Riparian setbacks are useful in reducing the amount of pollutants that reach surface waters. However, they are not perfect, and in storms and floods their effectiveness will be reduced. Therefore, every step possible should be taken to reduce pollutants at their source, and sources should be restricted from floodplains whenever possible, regardless of development setback distance (Wenger 1999). Certain land uses, such as storage of toxic chemicals should never occur adjacent to ER lands or within riparian development setbacks. The cumulative effects of urbanization adjacent to bodies of water and in riparian areas requires careful monitoring and adaption to ensure seemingly innocuous development activities are not polluting our waters. Determining appropriate land uses in environmentally sensitive lands is an important policy consideration for Municipalities that want to ensure long term community and environmental sustainability.

This Riparian Setback Matrix Model was designed using information and recommendations from several pieces of literature and other academic and government documents. There is continuous research on this subject, and new recommendations are continuously being made so future revisions may be required. There are several other categories that may additionally be considered, especially with soils. These include vegetation density and percent cover and for soils, soil type and texture, organic content, pH, and conductivity. However, we feel that this model will be an effective method for determining an effective riparian development setback. As the RSMM is used and more information comes available, adjustments can be made to suit different requirements and needs, depending upon municipal suitability and environmental integrity.

5.1 Remote Sensing and the RSMM

The determination of riparian setbacks as formulated in the above model is based on on-the-ground surveys of potential development or subdivision sites. As such, determining setbacks for large numbers of parcels or over large areas may require a large temporal and financial commitment. However, if sufficiently high resolution remote sensing or other spatial data are available, it may be possible to extend the RSMM to a GIS platform where setbacks could be determined as a desktop exercise, possibly in a semi-automated fashion. However, the resolution for the required data would need to be very high, so unless they are already available or required for other purposes, it may not be fiscally worthwhile to do so. At minimum, the required data would include digital elevation models with 1-2 m lateral and 0.5 m or less vertical resolution for slope and bank determination, 1:5,000 or 1:10,000 aerial photos for

vegetation cover determination, and 1:20,000 scale soil texture and groundwater depth maps. The cost associated with purchasing or producing such data currently are high, so unless they are required or would be highly useful for other purposes, it would likely not be fiscally worthwhile to obtain them.

5.2 Other Considerations

The riparian development setback should have as few disturbances such as channels and walking paths as possible. Channels and walking paths will increase the amount of runoff that reaches surface waters and decrease the effectiveness of the development setback. Community pathway systems should be developed using permeable construction materials with naturescaping around the edges. Community access points to provincial beds and shores and communal beach development are recommended to minimize cumulative detrimental effects instead of allowing many access points or private beach development on reserve lands.

We believe that the Riparian Setback Matrix Model will be of great value to the MD of Foothills and other municipalities across Alberta that are serious about protecting their Environmental Reserve lands and sensitive riparian lands. The model is scientifically-based, legally defensible and will allow municipalities to take adequate Environmental Reserve to prevent the most common forms of pollution in Alberta, instead of guessing, using a pre-determined arbitrary setback or simply requesting the 6 m minimum. Identifying and protecting Environmental Reserve supports two of the main goals of Alberta's *Water For Life* strategy of ensuring safe, secure drinking water supplies and healthy aquatic ecosystems. Municipalities that adopt this approach will benefit from source water protection within their jurisdiction and will ultimately save thousands of dollars on long term water treatment costs.

6 References

6.1 *Riparian Setback Matrix Model References by Category*

Parameter	References
<u>Vegetative Cover Type</u>	Mayer et al, 2005 Connecticut Association of Wetland Scientists, 2004 Chargin River Watershed Partners Inc., 2001 Wenger, 1999 Gilliam et al 1997 Klapproth, 2000
<u>Slope</u>	Connecticut Association of Wetland Scientists, 2004 Calgary City Council, 2006 City of North Royalton, 2005 Fox and Brown, 1999 Sasson, 2003 Wenger, 1999
<u>Height of Bank</u>	Palliser Environmental Services Ltd., 2005
<u>Soil Texture and Type</u>	United States Department of Agriculture, 2008 White, 2006 Morgan and Rickson, 1995 Cohen, 1997 McBride and Strahan, 1984 Huggenberger et al., 2002
<u>Groundwater Influence</u>	Li et al, 2006 Devito et al, 2000

6.2 References

- Alberta Riparian Management Society. Cows and Fish Website. <http://www.cowsandfish.org/> [accessed 25 January 2007].
- Atwill, E.R., Hou, L., Karle, B.M., Harter, T., Tate, K.W., and Dahlgren, R.A. 2002. Transport of *Cryptosporidium parvum* Oocysts through vegetated buffer strips and estimates filtration efficiency. *Applies and Environmental Microbiology* 68: 5517 – 5527.
- Bechtold, J.S. and Naiman, R.J. 2006. Soil texture and nitrogen mineralization potential across a riparian toposequence in a semi-arid savanna. *Soil Biology & Biochemistry* 38: 1325–1333.
- Cappiella, K., Schueler, T. 2002. Crafting a lake protection ordinance. [http://yosemite.epa.gov/R10/WATER.NSF/840a5de5d0a8d1418825650f00715a27/159859e0c556f1c988256b7f007525b9/\\$FILE/Crafting%20a%20Lake%20Protection%20Ordinance.pdf](http://yosemite.epa.gov/R10/WATER.NSF/840a5de5d0a8d1418825650f00715a27/159859e0c556f1c988256b7f007525b9/$FILE/Crafting%20a%20Lake%20Protection%20Ordinance.pdf) [accessed 25 January 2007].
- Chargin River Watershed Partners Inc. 2001. Why Riparian Setbacks? <http://www.3vct.org/lid/resources/Why%20Riparian%20Setbacks.pdf> [accessed 31 January 2007].
- City of Calgary. 2006. Environmental Reserve Setback Guidelines Discussion Draft. http://www.calgary.ca/docgallery/bu/water_services/water_quality/environmental_reserve_setback_guideline.pdf [accessed 30 January 2007].
- City of North Royalton. 2005. Chapter 1492: Controlling riparian setbacks and wetland setbacks, Exhibit A. <http://www.northroyalton.org/Council/Legislation/2005%20Ordinances/05-172%20Exhibit%20A.pdf> [accessed 25 January 2007].
- Cohen, R. 1997. Fact Sheets: Functions and Values of Riparian Areas. Massachusetts Department of Fisheries, Wildlife and Environmental Law Enforcement.
- Connecticut Association of Wetland Scientists. 2004. Vegetative buffers for water quality protection: An introduction and guidance document, Draft Version 1.0. <http://www.ctwetlands.org/Draft%20Buffer%20Paper%20Version%201.0.doc> [accessed 11 Jan 2007].
- Devito, K.J., Creed, I.F., Rothwell, R.L. and Prepas, E.E. 2000. Landscape controls on phosphorus loading to boreal lakes: implications for the potential impacts of forest harvesting. *Can. J. Fish. Aquat. Sci.* 57: 1977 – 1984.
- Fox D.M. and R.B. Brown. 1999. The relationship of soil loss by interrill erosion to slope gradient. *Catena* 38:211–222.
- Gilliam, J.W., D.L. Osmond, and R.O.Evans. 1997. Selected Agricultural Best Management Practices to Control Nitrogen in the Neuse River Basin. North Carolina Agricultural Research Service Technical Bulletin 311, North Carolina State University, Raleigh, NC

- Government of Alberta. 2006. Standard Sustainable Resource Development Recommendations to Municipal Subdivision Referrals Including Recommended Minimum Environmental Reserve Widths DRAFT. Sustainable Resource Development.
- Hamilton Conservation Authority. 2005. Planning & Regulation, Policies and Guidelines. http://www.conservationhamilton.ca/Asset/iu_files/Planning-Regs-and-Policies.pdf [accessed 25 January 2007].
- Hamilton, H.R. 1985. Impact assessment of sewage discharges to Field Lake, Alberta. HydroQual Consultants report. 33 pp.
- Huggenberger, P., E. Hoehn, R. Beschta, and W. Woessner. 2002. Abiotic aspects of channels and floodplains in riparian ecology. *Freshwater Biology* 40(3):407-425.
- Klapproth, J.C. and Johnson, J.E. 2000. Understanding the Science Behind Riparian Forest Buffers: Effects on Water Quality. Virginia Cooperative Extension. <http://www.ext.vt.edu/pubs/forestry/420-151/420-151.html> [accessed 11 Jan 2007]
- Lee, P. and C. Smyth. 2003. Riparian forest management: paradigms for ecological management and practices in Alberta. Report produced by the Alberta Research Council (Vegreville, Alberta) and the Alberta Conservation Association (Edmonton, Alberta) for the Northern Watershed Project Stakeholder Committee. Northern Watershed Project Final Report No.1. 117 pp.
- Li, Y., Wang, C., Hongliang, T. 2006. Research advances in nutrient runoff on sloping land in watersheds. *Aquatic Ecosystem Health & Management* 9: 27–32.
- Mayer PM, Reynolds, SK Jr., Confield, TJ. 2005. Riparian Buffer Width, Vegetative Cover, and Nitrogen Removal Effectiveness: A Review of Current Science and Regulations. U.S. Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory. <http://www.epa.gov/ada/download/reports/600R05118/600R05118.pdf> [accessed 11 Jan 2007]
- McBride, J.R. and J. Strahan. 1984. Establishment and survival of woody riparian species on gravel bars of an intermittent stream. *American Midland Naturalist* 112(2):235-245.
- Mills, B. 2005. An assessment of the health and integrity of riparian management zones of Moose Lake and Lac La Biche, Alberta. Data Report (D-2005-001) produced by Alberta Conservation Association, St. Paul, Alberta, Canada. 18 pp.
- Mitchell, P. 1998. The impact of aerated sewage lagoon effluent on water quality in Field Lake. Alberta Environmental Protection report. 21 pp.
- Mitchell, P. 2000. Effect of Field Lake outflow on water quality in Red Deer Brook. Alberta Environmental Protection report. 22 pp.
- Mitchell, P. 2001. Lac la Biche: water quality and phosphorus sources. Patricia Mitchell Environmental Consulting report. 18 pp.

- Morgan, R.P.C. and R.J. Rickson. 1995. *Slope stabilization and erosion control: a bioengineering approach*. Chapman and Hall, London, United Kingdom.
- NC State University. 2002. Riparian buffers and controlled drainage to control agricultural and nonpoint source pollution. http://www.soil.ncsu.edu/lockers/Osmond_D/web/RiparianBuffers.pdf [accessed 11 Jan 2007]
- Palliser Environmental Services Ltd. 2005. Draft Watershed Management Plan for the Nose Creek Watershed. Nose Creek Watershed Partnership. <http://www.airdrie.com/Content/environment/nosecreek/images/Draft%20WMP%20-%20November%207.pdf> [accessed 30 January 2007].
- Province of British Columbia. 2004. Flood Hazard Area Land Use Management Guidelines. Ministry of Water, Land and Air Protection. http://www.env.gov.bc.ca/wsd/public_safety/flood/pdfs_word/guidelines.pdf [accessed 30 January 2007].
- Province of Ontario. 2001. Understanding Natural Hazards. Queen's Printer http://www.mnr.gov.on.ca/MNR/pubs/nat_haz1.pdf [accessed 30 January 2007].
- Polyakov V, Fares A, and Ryder MH. 2005. Precision riparian buffers for the control of nonpoint source pollutant loading into surface water: A review. *Environ. Rev.* 13: 129-144.
- Riparian Land Conservation & Management Project: Phase I Final Report. 2007. Riparian Land Conservation and Management Project, Riparian Multi-stakeholder Committee Report, 76 pp, unpublished paper.
- Ritter, M.E. 2006. The Physical Environment: an Introduction to Physical Geography. http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/title_page.html [accessed 30 January 2007].
- Polyakov V, Fares A, and Ryder MH. 2005. Precision riparian buffers for the control of nonpoint source pollutant loading into surface water: A review. *Environ. Rev.* 13: 129-144.
- Sasson, A. 2003. Points to include in determining riparian buffer requirements for Big Darby Environmentally Sensitive Development Area. <http://utilities.ci.columbus.oh.us/project/docs/031120%20Points%20to%20include%20in%20determining%20riparian%20buffer%20requirements%20for%20the%20Big%20Darby%20ESDA.doc> [accessed 25 January 2007].
- Schindler, D.W., R. Freed, A. Wolfe, S. Neufeld and R. Vinebrooke. 2004. Water Quality in Lac la Biche: A Preliminary Assessment of Past and Present Conditions. Unpublished report submitted to the Lac la Biche Watershed Steering Committee. 27 pages.
- Stewart, J. 2006. Ownership and Conservation of Wetlands and Riparian Lands in Alberta's Municipalities. (Unpublished paper).
- Stewart, J. 2007. Sharing governance of a modern commons: Managing access and use of urban municipal environmental reserves. (Unpublished paper).

- Sutton, D. 2004. Agricultural Region of Alberta Soil Inventory Database (AGRASID) Version 3.0. Government of Alberta, Department of Agriculture and Food. [http://www1.agric.gov.ab.ca/\\$department/deptdocs.nsf/all/sag5173](http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/sag5173) [accessed 25 January 2007].
- Town of Cochrane. 2005. Land use Bylaw 01/2004. [http://www.town.cochrane.ab.ca/municipal/cochrane/cochrane-website.nsf/AllDoc/0EBC6A8CAA5CD3388725700E00636D1E/\\$File/LUB%20with%20maps-first%20reading-mar-05.pdf](http://www.town.cochrane.ab.ca/municipal/cochrane/cochrane-website.nsf/AllDoc/0EBC6A8CAA5CD3388725700E00636D1E/$File/LUB%20with%20maps-first%20reading-mar-05.pdf) [accessed 30 January 2007].
- Ulén, B., Carlsson, C., Lidberg, B. 2004. Recent trends and patterns of nutrient concentrations in small agricultural streams in Sweden. *Environmental Monitoring and Assessment* 98: 307–322.
- United States Department of Agriculture. 2008. Saturated Hydraulic Conductivity in Relation to Soil Texture. Soil Survey Guides and References, Natural Resources Conservation Service. Accessed online at <http://www.usda.gov>
- Urban Systems. 2006. Lakeland County Municipal Development Plan. Draft July 2006. Urban Systems Planners, Edmonton, Alberta.
- Valastin, P. 1999. Caring for Shoreline Properties: Changing the way we look at owning lakefront property in Alberta. Report published by the Alberta Conservation Association (Edmonton, AB) and Fisheries and Wildlife Management Division, Natural Resources Service, Alberta Environmental Protection (St. Paul, AB). 32pp.
- Vermont DEC River Management Program. Defining River Corridors Fact Sheet 2. http://www.anr.state.vt.us/dec/waterq/rivers/docs/rv_definingrcfactsheet.pdf [accessed 30 January 2007].
- Welsch, David J. 1992. Riparian Forest Buffers: Function and Design for Protection and Enhancement of Water Resources. NA-PR-07-91. Radnor, PA: USFS Forest Service, Northeastern Area.
- Wenger S. 1999. A Review of the scientific literature on riparian buffer width, extent and vegetation. Institute of Ecology, University of Georgia, Athens, Georgia. http://64.233.167.104/search?q=cache:8ZQTRzNpLZQJ:outreach.ecology.uga.edu/tools/buffers/lit_review.pdf+riparian+buffer+width+and+phosphorus+removal&hl= [accessed 11 Jan 2007]
- White, J.S. and C.M. Prather. 2004. State of the Lac la Biche Watershed 2004: Summary of Current Information. Report prepared by AQUALITY Environmental Consulting Ltd., Edmonton, August 2004. 43 p.
- White, R.E. 2006. *Principles and Practice of Soil Science: The Soil as a Natural Resource*, 4th ed. Wiley-Blackwell, Malden, Massachusetts.

7 Appendix A – Vegetation Definitions

Grass & Herbaceous Plants: Any grass or non-woody vegetation (including grasses, forbs, rushes, sedges).

Shrub: Shrubs will be defined as woody plants differing from a tree by its low stature (>2m) and by generally producing several basal shoots instead of a single trunk. Tree seedlings (saplings) <2m will also be considered as shrubs.

Forested: A tree or group of trees with an average height of 2 m and an associated understory.

Cleared: An area where the soil is exposed. There may be sporadically occurring plants present.

Aquatic Vegetation: Plants that grow in water or in saturated soils (i.e. bulrushes, sedges, cattails, rushes, willows).

Upland Vegetation: Plants that grow away from the water in drier soils (i.e. aspen, birch, white spruce and pine trees; shrubs such as rose, mountain ash, juniper and Saskatoon; grasses such as fescue, common grass, wild rye and wheat grass).

8 Appendix B - Example Worksheet

EXAMPLE SHEET WHEN MODEL IS FINALIZED