Comparison of Soil Bioengineering and Hard Structures for Riverine and Shoreline Erosion Control in Ontario:

Costs and Effectiveness

FINAL DRAFT

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Timothy S. Patterson

ABSTRACT

Within recent years, the use of vegetation and soft structures for erosion control, known as soil bioengineering, has become popular for use in riverine and lakeshore environments. Bioengineering is often used in conjunction with, or instead of hard structures such as concrete channels and shorewalls. A cost comparison between the use of bioengineering and hard structures is conducted, with reference to overall effectiveness of each technology. The area of research is within Southern Ontario, from which case studies are extracted. Bioengineering projects in Ontario are usually implemented by either a Conservation Authority or municipality. The cost structure for bioengineering projects often varies between these two levels of governments, as can the reasoning for implementation. When bioengineering is not chosen for erosion control along a watercourse, it is often due to uncertainty of its performance or effectiveness, due to lack of knowledge. The use of bioengineering instead of, or in conjunction with hard structures in a riverine environment can significantly reduce costs for erosion control. Bioengineered sites, when vegetation is established, tend by nature to strengthen over time, whereas hard structures either remain as strong as when they were constructed, or become weaker.

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Tim Patterson

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EXECUTIVE SUMMARY

The objective of this report is to compare the costs and effectiveness associated with both soil bioengineering and hard structures. The common principles and materials used in bioengineering was researched. An investigation of how these principles were applied to various sites across Southern Ontario was then conducted. This included visitation of the sites and interviews with people involved. Findings from these sites are listed as Case Studies

Manufactured "hard" structures designed to prevent erosion will often become cracked and damaged as they age. Since they are "dead" materials, they cannot maintain or repair themselves as plant materials can. Hard structures do, however, provide immediate effective erosion control against severe elements that would wash away newly placed plant materials. This is especially true for lake front lands. For this reason, some constructed bioengineered sites incorporate hard structures.

The main thrust of bioengineering involves the harvesting and planting of dormant cuttings or branches from tree and plant species in order to provide a natural basis for erosion control. These cuttings are arranged into individual stakes (live stakes) and/or put into bundles. These bundles can be arranged in a variety of ways. The most common arrangements are called fascines, brush layers, and brush mattresses. Cuttings are usually taken from dogwoods and/or willows. This is mainly because the cut branches of these species are able to take root and grow on their own. As the cuttings grow and extend their root structure, the soil becomes more stable.

Bioengineering is used as a natural, long term solution to erosion control. A bioengineered site is considered to be successful when there is little or no evidence of human intervention, years after planting. The site should become better protected with time. For example, cuttings planted into a bank beside a watercourse can go through additional stages of erosion control for the bank. The cuttings add a bit of protection against soil sliding down the bank, immediately after being planted. Roots from the cuttings begin to hold the soil together more as they grow and inter-connect with each other. Eventually, some of these roots will likely extend out into the watercourse, slowing down flows and creating fish habitat. As the trees mature more, the thicker roots in the watercourse are able to partially deflect flows away from the bank, decreasing erosion. During flooding conditions, these roots not only help protect against erosion, but can trap soil, sand and small stones which add to the bank material.

For the majority of applications in bioengineering, the only types of tree cuttings that may be successfully used are those that can grow on their own after being cut (when dormant). There are three common types of trees in Ontario that can provide such cuttings: Willows, dogwoods, and poplars. Willow and dogwood cuttings are the most commonly used for bioengineering projects. Although these species are used to establish a firm root structure in the soil, native plants tend to invade a bioengineered site over time, mixing in

with the willows and dogwoods. These invading species usually do not harm the integrity of the bioengineered site, and are often beneficial in aiding to the root structure.

The technique of bioengineering is becoming more popular among municipalities and Conservation Authorities (CAs) in Ontario. Where most municipalities and CAs did not incorporate bioengineering techniques only 10 years ago, most do today for at least some of their erosion control projects.

There are two main reasons municipalities and CAs choose bioengineering over concrete and steel. The first reason is that it is considered to be more environmentally friendly. The second reason is financial. For most sites, it is actually cheaper to implement bioengineering, than it is to create a hard structure, especially for the long term. Material, transportation and labour costs are generally more expensive for hard structures.

The main reason some local governments do not choose to utilize bioengineering is because they are unsure of its effectiveness. Bioengineering principles are relatively unknown (although not unproven), and thus an uncertain solution to erosion in the minds of many. Limits to the ability of bioengineered sites to resist erosion are even less certain, and very site specific.

Because municipalities typically have larger budgets than CAs, some of the best combinations of bioengineering techniques can be found at projects paid for by cities. Often, these techniques are in combination with hard structures.

Costs vary for different types of bioengineering techniques. There is often no cost for labour and/or materials. Labour is sometimes done by volunteers. Materials, such as cuttings for live stakes, fascines and brushlayers, are sometimes found either on or off site, or are donated.

Hard structures have a specific design life to them, but bioengineering designs typically do not. This may be partly because bioengineering was little used in North America 10 years ago compared to its use now, so there are few projects older than 10 years to compare with (except for sites in Europe). While this may be true, the theory behind bioengineered designs is that they are living and self repairing. Once established with a good design, they increase in strength, and after a period of 2 to 3 years, they should be capable of resisting high stream flows. They should also be capable of self-repair. Branches or roots that become broken or dead are gradually replaced with more growth. Since hard structures cannot repair themselves, they require long term maintenance. This means that the gap in costs between a hard structure and a bioengineered site will continually grow.

Most of the case studies detailed have successfully achieved stable erosion control using bioengineering. Proper planning and adaptation to site conditions played a big role in these successes. This included knowing the limitations to each type of planting or soft structure, and deciding on if and where they should be used. Recognizing where rip-rap or rocks should be used instead of, or in conjunction with a soft structure was also very important.

Although careful planning went into most of the case studies, unforeseen or unanticipated problems have occurred at some sites, resulting in partial or complete failures in the bioengineering designs. There are many problems that can occur due to the combined complexities of factors such as the characteristics of tree species used, soil conditions, local climate, random storm events, immediate and surrounding land use, area wildlife, pedestrian traffic, skill of the labourers, and the project design, among other things.

The success of a bioengineered site can only be conclusively determined after the first 2 or 3 years. Live stakes, fascines, brushlayers and brushmattresses are very vulnerable to poor site conditions, erosion and vandalism during this time while their root structures are growing. It is essential that the required amount of sunlight and soil moisture necessary for the species of cuttings used be a part of the site conditions, as this was the main reason for failed areas of sites in the case studies.

Natural channel design goes well with bioengineering. Because this involves the removal or relocation of soil, this adds to the cost considerably.

Bioengineering could still use more public and municipal support. Although it is becoming a popular alternative to hard structures, there are still some municipalities that seldom or never use bioengineering designs. This support should come gradually, as the overall effectiveness of bioengineering projects become better known and understood.

Bioengineering is much more widely used in riverine environments over lake shores. This accounts for the fact that few case studies involve lake shore sites. Where bioengineering is used at such sites, it is often in combination with hard structures such as armourstone or boulders. This is because the erosive force of waves along a shoreline is frequent, and is usually too overpowering to allow tree cuttings to grow, even if aided by geotextiles and cribwalls. For adequate erosion control in many low flow creeks, however, hard structures may be limited or avoided altogether in favour of bioengineering.

Comparing costs taken from the case studies, live stakes, fascines, brushlayers, brushmattresses, root wads and log jams are the lowest costing components of bioengineering, followed by geotextiles, rip-rap, and live cribwalls. Natural channel design is above these costs. Hard structures cost even more.

Bioengineering in a riverine environment is usually significantly less expensive than hard structures on a per metre basis. Comparing natural channel design case studies with large concrete channels, the difference is about threefold. Comparing case studies using basic bioengineering designs with those using large concrete channels, the difference is even more, depending on site conditions.

In addition to the cost benefits of bioengineering, the environmental benefits, which are not as easily measured, are an important factor. Wildlife habitat, green space and aesthetic qualities are in high demand. This is apparent by the number of citizens' and special interest groups that have made contributions to several sites listed in the case studies

1.0 INTRODUCTION

The use of vegetation for erosion control, known as soil bioengineering, has been around for centuries. With the introduction of concrete and heavy lifting equipment, hard structures became the normal product used for erosion control, especially in North America. It has only been in the last 10 years where a noticeable use of bioengineering principles has been applied to numerous sites across the continent.

The objective of this report is to compare the costs and effectiveness associated with both bioengineering and hard structures. The common principles and materials used in bioengineering was researched. An investigation of how these principles were applied to various sites across Southern Ontario was then conducted. This included visitation of the sites and interviews with people involved. Findings from these sites are listed as Case Studies (Section 9.0).

The basic nature of hard structural designs is detailed in addition to vegetation and materials used in bioengineering. An attempt was made to grasp the attitudes towards the use of each, both by governments and the public. This led to understanding some of the reasons why bioengineering is, or is not chosen in certain cases.

Cost comparisons are based on existing reports and interviews with those involved in the case studies.

2.0 EROSION CONTROL USING "HARD" TRADITIONAL MEASURES

2.1 Overview

Much literature exists on the detailed, technical applications to traditional erosion control structures listed in this section. For this reason, only a brief explanation of the nature of each structure will be provided. The structures are mentioned so that it may be understood what they are and what they do.

Manufactured "hard" structures designed to prevent erosion will often become cracked and damaged as they age. Since they are "dead" materials, they cannot maintain or repair themselves as plant materials can. Hard structures do, however, provide immediate effective erosion control against severe elements that would wash away newly placed plant materials. This is especially true for lake front lands. For this reason, some constructed bioengineered sites incorporate hard structures.

2.2 Concrete Channels

Concrete channels consist of a protective lining of concrete for the entire bottom and all or part of the banks for a watercourse. They are designed so that the usual flow of water does not come into contact with soil.

Often, the unprotected soil around the edge of the concrete channel will erode away due to rain, slumps, or overflow from the concrete channel when its flow capacity is exceeded. Where unprotected soil at the base of the watercourse exists at either end of a concrete channel, some water will often flow around the concrete channel causing it to be undermined.

2.3 Shorewalls

Shorewalls are designed primarily for lake shorelines. They are built right against the bank or bluff, flush with the soil. They usually extend from the top of the bank, down to the base of the bank at or below the water level. They can be vertical or set at an angle leaning against the bank. They are commonly made of concrete, concrete blocks, or steel sheet piling (often in combination with concrete).

Shorewalls are expensive to build, and must be designed well for the site, since they need to withstand tremendous force from waves during storms. They are susceptible to being undercut.

2.4 Breakwaters

Breakwaters are the most expensive erosion control method for shorelines. They are offshore walls, set back several to hundreds of metres into the lake from the shore. They can be made of the same materials as shorewalls, and also be vertical, or be sloped on both sides. Breakwaters break down the erosive forces of waves before they hit the shoreline, and may even encourage accretion (build up of sediments) between the breakwater and the shore.

2.5 Armourstone

Armourstone, as the name implies, is like armour for shorelines. Armourstone consists of large cut rocks (usually limestone) that can weigh about 5 tonnes each. The rocks can be densely placed together on a sloping bank, or stacked on top of each other to form a wall or revetment.

2.6 Concrete Blocks

Concrete blocks can be used for both watercourse and shoreline environments. They are placed in line, and are usually piled on top of each other in several rows. They are held together by their own weight.

2.7 Gabion Baskets

Gabion baskets consist of wire baskets filled with rocks (usually limestone). They are rectangular, and like concrete blocks can be stacked on top of each other. They are better suited to erosion control on dry land than along a watercourse, since the soil they sit on can be washed away from between the individual rocks that fill the baskets. Shifting of loose rocks within the baskets can encourage the baskets to slump over. Since the baskets are held together by wire, which can rust or be cut, they are easily vandalized. They are one of the least expensive of the "hard" applications for erosion control.

2.8 Boulders/Rip-rap

Boulders provide the most "natural" look of all the "hard" applications for erosion control. They are usually rounded and can be many different types of rock. They can appear to have originated from the soil at the site, and in some cases they have. Boulders are used along creeks or rivers where peak flows are deemed to be high. For some shoreline sites, they are used as an alternative to armourstone.

"Rip-rap" is a term used for a collection of small boulders, stones, and pebbles. It may be natural, with rounded features (known as "river run stone"), or it could be from cut stone. Rip-rap may be placed along the bottom of a watercourse, along a shoreline, and on banks. It can provide the resistance necessary for high erosive areas that newly planted vegetation may not be able to withstand. Live stakes (discussed in Section 3.2) may also be planted between the boulders and stones of riprap, and be better protected than if planted along bare soil.

2.9 Groynes

Groynes are long, narrow structures that protrude out and perpendicular to shorelines. They are commonly made of rocks or armourstone, and extend out from shorelines at various lengths. Usually, groynes are constructed in a series along a stretch of shoreline, collectively making a "groyne field". They are designed to trap eroded sediment moving along the shoreline. Since there is usually an overall net movement of sediment in a particular direction (littoral drift), the sediment will collect along the updrift side of the groyne where it meets the shoreline. This gradual accumulation of sediment will form a small, crescent shaped beach. The formed beach builds up, and thus protects that portion of the shoreline.

Groynes help the immediate area they protect at the expense of areas downdrift from the groyne. The sediment that is trapped on the updrift side of the groyne will not be supplied to downdrift areas accustomed to receiving littoral drift. The downdrift side of the groyne that does not receive the littoral drift may actually erode faster.

3.0 EROSION CONTROL USING BIOENGINEERING MEASURES

3.1 Overview

The main thrust of bioengineering involves the harvesting and planting of dormant cuttings or branches from tree and shrub species in order to provide a natural basis for erosion control. These cuttings are arranged into individual stakes (live stakes) and/or put into bundles. These bundles can be arranged in a variety of ways. The most common arrangements are called fascines, brushlayers, and brushmattresses, which are often installed beside each other in various combinations, along with live stakes. Cuttings are usually taken from dogwoods and/or willows. This is mainly because the cut branches of these species are able to take root and grow on their own. As the cuttings grow and extend their root structure, the soil becomes more stable.

Bioengineering is used as a natural, long term solution to erosion control. A bioengineered site is considered to be successful when there is little or no evidence of human intervention, years after planting. The site should become better protected with time. For example, cuttings planted into a bank beside a watercourse can go through additional stages of erosion control for the bank. The cuttings add a bit of protection against soil sliding down the bank, immediately after being planted. Roots from the cuttings begin to hold the soil together more as they grow and inter-connect with each other. Eventually, some of these roots will likely extend out into the watercourse, slowing down flows and creating fish habitat. As the trees mature more, the thicker roots in the watercourse are able to partially deflect flows away from the bank, decreasing erosion. During flooding conditions, these roots not only help protect against erosion, but can trap soil, sand and small stones which add to the bank material.

3.2 Live Stakes

Live stakes are simply short, straight, cuttings from dormant trees and shrubs. Most are cut into lengths between 25 to 50 cm. In contrast to "dead" wooden stakes, live stakes are cut from living trees or bushes. Thicknesses of live stakes usually vary from about 2.5 cm to 7.5 cm. They are usually pushed or tamped into the ground (cut end down) with a "dead blow" hammer or mallet (e.g. plastic head hammer filled with lead shot).

Care is taken not to sever the top of the stake, in order to insure proper growth. If the top of a live stake becomes damaged in the installation process, it is sheared off.

3.3 Willow Posts

Willow posts are long, thick cuttings that are used to provide slumping control for steep banks. They are much longer and thicker than live stakes, being about 2 to 3.5 m long, with a top diameter of 10 cm or more (Grillmayer, 1998). Preparation for installing the post usually involves creating a long, narrow hole with a steel ram or an auger. The post is then placed in the hole and buried. One third or less of the post is usually left unburied. Several posts are used throughout the bank, to increase the overall slope stability.

3.4 Fascines

Fascines are bundles of long, thin cuttings or branches from young trees. The branches are tied together in the same orientation, and often overlapped to increase the length of the fascine. The bundles can vary in thickness and length, but are usually about 20 cm in diameter at the centre, and between 1 to 6 m long. They are planted on bank slopes parallel to the length of the bank, usually with about 80% of the fascine buried. Dead or live stakes are used to secure the fascines into place. Often, a terrace or trench is cut into the bank, allowing the fascines to be better secured into position. Growth should occur along the entire length of the fascine.

3.5 Brushlayers

Brushlayers consist of horizontal rows of tree cuttings or branches planted into a bank. Installation of a brushlayer is done by digging a terrace into the bank. The terrace is made to be almost as deep as the cuttings are long, so that the cuttings can be easily placed on the terrace, and will be well secured into the bank when planted. The terrace is sloped so that the growing ends of the cuttings, facing outward, are slightly higher than the cut ends planted. The cuttings are placed in a criss-cross pattern. This insures the full growth and integration of the root material. Spaces in the growth from the brushlayers is also minimized, which helps to slow rainwater runoff and stop sliding soil.

3.6 Brushmattresses

Brushmattresses are live cuttings placed in long, flat continuous layers on a bank, often with criss-crossing branches. This provides for continuos soil surface protection. The brushmattresses may also slow velocities during periods of high flows, collecting debris and sediment during such times. Brushmattresses are usually only used on low sloping banks, with a slope ratio of 4:1 being about the steepest (Dave Rogalsky, personal communication).

The cuttings or branches in brushmattresses may alternate in orientation, so that growth occurs on both ends. Another technique aligns all the cuttings so that the growing tips face upslope, or towards the top of the bank. The opposite, or cut ends are then planted into the bank.

3.7 Live Cribwalls

Live cribwalls are constructed into, or against banks and house layered horizontal rows of brushlayers. The face of a cribwall is made of horizontal rows of untreated timber logs aligned parallel to the bank, which lay on perpendicular logs that extend into the bank. This creates gaps between the parallel logs. During construction of the wall, willow and/or dogwood brushlayers are planted between layers of soil inside the wall, so that the tips extend out through the gaps of the wall.

Live cribwalls provide a temporary vertical surface for the bank, and hold the brushlayers in place. Over the years, well before the wall rots away, the brushlayers should establish themselves and grow enough to be capable of remaining in place, as their root structure holds the soil of the bank together.

There is no standard design for cribwalls. They may be constructed into an existing bank, or may be constructed beside an eroding bank and filled with soil, so that some or all of the land lost to erosion is reclaimed. They may be any dimension high or long. The timbers can be cut square, or left in their natural rounded state (as is usually done).

Cedar and pine timbers are commonly used for cribwalls. Cedar timbers tend to last in the ground for many years without rotting (30 years is not uncommon). Pine timbers may rot away after about 5 years (Dave Rogalsky, personal communication). After 5 years, however, the brushlayers within the cribwall should be established enough to maintain soil stability on their own.

3.8 Live Rock Revetment

A live rock revetment is the term used for the combination of rip-rap or boulders on a bank with live materials placed between, such as live stakes. The rock helps to protect the live stakes or plantings as they grow, in addition to providing for immediate erosion control.

3.9 Root Wads (Tree Revetments)

Root wads are the stump and base roots of a mature tree. They are placed along the edge of banks. The roots slow the velocity of water, which helps protect the bank from erosion. The stump side of the root wad usually leans against, or faces the bank. In addition to slowing velocities, root wads may also effectively deflect floating ice, reducing scouring of the bank.

Root wads are often placed in single rows along the edge of banks. Sometimes they are placed in two or more layers extending from the surface, down into the watercourse, where depth allows. In some cases, they are only placed below the surface of the watercourse, where they are intended more for fish habitat.

3.10 Log Jams

Log jams comprise of a bundle of small logs and/or thick branches that are wrapped together and secured to the side of a watercourse bank. The rough surface of the log jams, as with root wads, help break up the erosive flow forces of the watercourse, and can also collect sediment and debris, building up the bank where erosion once occurred. Log jams are often bundled together by aircraft wire, and secured to the bank by tying the aircraft wire to steel bars anchored into the bank.

Log jams are best suited to smaller creeks, and are intended as a temporary measure to reduce erosion and provide fish habitat.

3.11 Geotextiles

Most geotextiles used for bioengineering are comprised of fabricated, biodegradable materials. This allows them to break down and rot into harmless components after surrounding vegetation can take root and replace the need for the geotextile. Geotextiles typically cover over a newly landscaped, or severely eroded area bare of mature vegetation, and are used in conjunction with live stakes and other bioengineering techniques.

3.11.1 Netting/Matting

Biodegradable netting is often made up of jute or coconut fibres. Matting can be entirely composed of biodegradable fibres such as jute, coconut, straw and cotton, or it may also incorporate plastic to better hold the netting material together. Both netting and matting are usually used on bare earth berms or banks after regrading is completed. Live stakes are often used to hold the material in place.

Filter fabric matting is sometimes used underneath rocks or boulders placed along a bank to prevent undercutting of the rocks from rainwater runoff or watercourse flows. Alternatively, specifically graded stones or pebbles may be used for this purpose (Dave Rogalsky, personal communication).

3.11.2 Coir Logs

Coir logs are rolled mats of coconut fibres (about 20 cm thick), usually held together by jute webbing ("coir" is the term used for coconut husk fiber). They are usually placed within a watercourse, parallel to the bank, being partially or entirely submerged. They are held inside the watercourse by dead stakes on both sides of the roll. When the log is placed in such a manner, it can serve two purposes. First, it may be seeded with wetland plants. Second, if the log is only partially submerged within a small creek during normal flows, it may be used to alter the existing course of the creek. Sediments and debris from the creek during higher flows fill in the area between the roll and the bank, creating an eventual narrowing of the creek channel. In the meantime, low flows are confined by the log, which speeds up the flow velocity. The purpose of this is to encourage cool or cold water fish habitat. The higher velocity will sweep away finer material in the creek, exposing coarser material (sand and stones). The clarity of the water will improve and the average temperature will lower, creating the preferred habitat of coldwater fish species. This second method of coir log use is subject to specific geomorphologic conditions of the watercourse being met. There would otherwise be a risk of "blow-outs" (rapid erosion of banks) downstream with the higher velocities (Glenn Harrington, personal communication).

Coir logs may also be placed along the base or the top of a bank. When placed along the base of a bank at the normal flow level, they provide temporary erosion control from creek flows. When placed along the top of a bank, they provide protection from rainwater runoff. In both instances, they may be seeded with a variety of grass or shrub seeds.

3.11.3 Bio-Carpets

Bio-carpets contain natural fibres and are thick (approx. 5 cm) wide mats that are very porous. They are used to hold seedlings and are especially good for wetland species. Before site placement, bio-carpets are seeded and kept moist. After the seedlings have just begun to grow, it is rolled up like a carpet, transported to the site, and rolled out on it's predetermined location. They can be secured into place with live or dead stakes.

3.12 Vortex Weirs

Vortex weirs are an arrangement of rocks within a watercourse, designed to alter the main flow towards its centre. Individual rocks are arranged together to form a wide "U" or V-shape, with the point of the "V" pointing against the flow. This draws the flow from the edges of the watercourse towards the centre as it flows over the rocks, creating a vortex. The rocks tend to blend in well with the natural "look" of bioengineered sites.

A series of vortex weirs will provide grade control for the watercourse. They can provide for a more even distribution of flow velocity, as the weirs act as a series of miniature dams and waterfalls.

3.13 Hydraulic Mulch

Hydraulic mulch is a spray that is composed of grass and plant seeds, recycled paper, and other organic fibres. It is sprayed over bare soil from a hose, so that the seeds it contains will quickly take root and stabilize the soil. Hydraulic mulch is often the only use of organic material for newly constructed sites that rely primarily on "hard" erosion control. The mulch, however, can easily be incorporated into bioengineered sites.

3.14 Natural Channel Design

Natural channel design is an attempt to reshape the route a watercourse takes in a "natural" pattern that incorporates meanders, and allows for floodplain areas. Where there is an emphasis on increasing the capacity of the floodplain, much soil usually needs to be removed in order to deepen and widen the floodplain. The greater flow capacity will insure that the banks are not as easily overflowed. This helps prevent flooding of lands above the banks, which often contain roads and private dwellings. A widened floodplain allows for wider meanders which slow down the flow of the watercourse, decreasing its erosion capability. In reshaping the meander pattern of a watercourse, there is some allowance for guiding the flow and selecting the areas that will be the most susceptible to erosion (i.e. bank on an outside bend, or meander).

Some of the best bioengineered designs are constructed at sites that have undergone natural channel design. This is because the new design of the channel can be created in such a way to easily incorporate bioengineered products. For example, bank slopes may be terraced as they are regraded, so that they can easily incorporate fascines and brushlayers.

Natural channel design can be very expensive. Reworking a channel involves construction on a large area. The removal of large volumes of soil, and the grading of a wide surface area add to the cost of placing bioengineered products.

4.0 VEGETATION USED

4.1 Overview

For the majority of applications in bioengineering, the only types of tree cuttings that may be successfully used are those that can grow on their own after being cut in their dormant state. There are at least three types of trees in Ontario that can provide such cuttings: Willows, dogwoods, and poplars. Willow and dogwood cuttings are the most commonly used for bioengineering projects. Although these species are used to establish a firm root structure in the soil, other native plants tend to invade a bioengineered site over the years, mixing in with the willows and dogwoods. These invading species usually do not harm the integrity of the bioengineered site, and are often beneficial in aiding to the root structure.

Consideration is made in the selection of willow and/or dogwood species at bioengineered sites. Native species are preferred, especially where non-native species do not exist in the area. The planting of non-native species runs the risk of affecting the local eco-system (e.g. native plants may be choked out by introducing non-native species, which in turn may affect wildlife habitat). Species suited to the weather and soil conditions at the site are also preferred.

4.2 Willows

There are over 75 species of willows in North America, most of which grow no larger than a shrub (MNR, 1995). Hybrids of various species are quite common. Some native, non-invasive species used for bioengineering projects in Ontario are listed:

Autumn Willow (*Salix serissima*). Shrub.
Beaked Willow (*Salix bebbiana* Sarg.). Shrub.
Black Willow (*Salix nigra* Marsh.). Tree.
Diamond Willow (*Salix eriocephala* Michx.). Shrub.
Peachleaf Willow (*Salix amydaloides*). Tree
Pussy Willow (*Salix discolor* Muhl.). Tree.
Sage Willow (*Salix candida*). Shrub
Sandbar Willow (*Salix exigua* Nutt.). Shrub.
Shining Willow (*Salix lucida* Muhl.). Shrub.
Slender Willow (*Salix petiolaris* Sm.). Shrub.

Sources: John Fischer, personal communication; Environment Network, 1998; Dave Rogalsky, personal communication; Grillmayer, 1995.

Willow cuttings are ideal for bioengineering. They grow rapidly, producing thick, long branches and an extensive root system. This enables them to quickly stabilize banks, providing the banks with greater strength in resisting erosion from slumping and washout. Willows suit the usually moist soil conditions found near a watercourse.

Tree form willow cuttings may not be desirable for smaller streams. This is because the aggressive growth of willow roots may eventually congest the watercourse (Grillmayer, 1998).

4.3 Dogwoods

Dogwoods also provide good cuttings, being more shade tolerant, but having a slower growth rate than willows. This can result in their being suppressed by the faster growing willows. Dogwoods provide a good aesthetic appearance, often bearing red berries and broader leaves that can vary in colour, depending on the species used. Common, non-invasive species are:

Gray Dogwood (*Cornus racemosa* Lam.)
Red Osier Dogwood (*Cornus sericea* L.)
Silky Dogwood (*Cornus amomum* Mill.)

4.4 Others

A large variety of other plants can be used at bioengineered sites, although these are usually installed as individual plantings and not grouped as cuttings. Examples of species used are cedar, alder, and poplar. Where a wetland styled area is created, aquatic plants such as bulrushes are planted.

4.5 Harvesting and Placement

Harvesting and placement of cuttings is done during the dormant season. The dormant season varies a bit for different regions of Ontario, but it generally covers the time between mid October to mid April (Grillmayer, 1998). The most common time bioengineering projects are started is in the fall, at the start of the dormant season. Early spring is the next most common time, prior to budding. Some projects have, however been conducted during winter.

5.0 ATTITUDES, PRIORITIES AND BUDGETS

5.1 Why Bioengineering is Chosen

The technique of bioengineering is becoming more popular among municipalities and Conservation Authorities (CAs) in Ontario. Where most municipalities and CAs did not incorporate bioengineering techniques only 10 years ago, most do today for at least some of their erosion control projects.

There are two main reasons municipalities and CAs choose bioengineering over concrete and steel. The first reason is that it is considered to be more environmentally friendly. Watercourses protected by plants, cribwalls, and natural channel design are aesthetically pleasing, and attract birds and wildlife. They become peaceful, enjoyable areas that are accessible. The public is a little more aware of the benefits of environmental stewardship today, than they were over a decade ago. More citizens seem to appreciate seeing greenspace as a result of the new environmental awareness, and today there is more greenspace in urban areas to compare with concrete designs of the past. The public thus tends to favour natural looking areas. This public demand eventually has to be reflected by local governments.

The second reason is financial. For most sites, it is actually cheaper to implement bioengineering, than it is to create a hard structure, especially for the long term. Material, transportation and labour costs are generally more expensive for hard structures. Concrete is heavy and requires special trucks to get it on site. Placement of concrete must be precise. More engineering equations and measurements are required. Generally, a hard structure must be repaired or replaced within a shorter time frame, than vegetation at a bioengineered site. Vegetation within a bioengineered design is self repairing, especially with mature growth. If a few branches are broken off, more will grow to take their place. In some cases, the new growth will be thicker and stronger than before. If a hard structure is damaged in any way, it cannot repair itself. Finances must be set aside for repairs.

CA's tend to favour bioengineering more than municipal governments, for it falls within their policy of conservation - setting aside greenspace. Municipalities tend to go more with public demand, although they may also favour bioengineering for the financial reasons explained.

Public demand sometimes has an influence on whether bioengineering is used. In one instance, a small group of landowners wanted the creek that ran through their backyards protected from existing erosion without the use of concrete channels. The city proposed to build a concrete channel against the wishes of the landowners. The landowners took the city to court and won the case. The site was successfully bioengineered, incorporating natural channel design. Since then, the city has willingly made it their policy to implement bioengineering where possible, using natural channel design, to control erosion along a watercourse.

5.2 Why Bioengineering is Not Chosen

The main reason some local governments do not choose to utilize bioengineering is because they are unsure of its effectiveness. The traits of concrete channels and other hard means of erosion control are well known. There are plenty of modelling equations and data in existence which are easily accessed for hard designs. There are plenty of existing hard structures of varying age for referral. The advantages and disadvantages, strengths and limitations for hard structures are well known. In other words, they are familiar, comfortable things to create with a reasonably known performance level. They are ingrained in the minds of many planners and engineers, as not only the traditional approach, but the recommended, *practical* approach. Bioengineering principles are relatively unknown (although not unproven), and thus an uncertain solution to erosion in the minds of many. Limits to the ability of bioengineered sites to resist erosion are even less certain, and very site specific. As a result, the more valuable the property that needs to be protected, the less likely bioengineering will be implemented.

Certain advantages that bioengineering provides are often not considered. Some individuals or local government bodies simply do not have an appreciation for the aesthetic qualities bioengineering provides. When faced with an erosion control problem, they look at numbers. Erosion and erosive forces are deemed to be measured and quantified. The appearance of the structure, how it blends in with the surrounding environment, and how people feel about it may not be as important in the decision making process as to how practical the design is in overcoming the erosion problem.

In some cases, bioengineering on its own may not be practical. This is often true for areas of shoreline that are subjected to waves produced by storms. New plant material may not be able to withstand the erosive forces at the site. Mature plant material may be able to in many cases, but the frequency of storm events at the site may not provide enough time for newly planted vegetation to grow strong enough to withstand the erosive forces. This may also be the case along narrow watercourses that often carry great velocities of water. In most cases, however, bioengineering may be applied at any given site in combination with a minimum of hard surface structures. For example, the top of bank at most watercourse and shoreline sites may be bioengineered, even if regrading is required.

The survival of vegetation used in bioengineering may be threatened at some sites. Water fowl feed on most young vegetation along banks, especially during spring. Certain tree and plant species planted in mainly shaded areas often do not survive for more than a year. Soil and weather conditions may be unsuitable for most vegetation. Bioengineered sites that have a lot of pedestrian or even animal traffic may get trampled on too often. Bioengineering may not be feasible for sites with the above conditions.

Public groups may look unfavourably towards bioengineering, especially if they are not fully informed about how it works. One such group spoke out against a proposed project in London, involving the upgrade of a drainage ditch in a park, using bioengineering. Staff in the city's engineering department supported the plan, but it was turned down (Brad Glasman, personal communication).

In rare instances, some forms of bioengineering may not fit in with the community use of a site. In St. Catharines, a proposed cribwall was shortened along a bank beside a pond that a local rowing club uses (Case Study #20). Although the cribwall would only have protruded a few metres into the pond along that section, this was considered to be too close to a boat route used by the rowing club. Rip-rap was instead placed on the bank beside the shortened cribwall (Cindy Toth, personal communication). At a harbour park in Hamilton (Bayfront Park), the use of bioengineering was rejected in favour of having greater public access to the water (Warner Plessl, personal communication). The past limitation of public access to the harbour was a big community issue before the park opened. The park's shoreline was covered with rip-rap on a low sloping bank from the water line to the top of the bank. A long walking path winds along the perimeter of the park, just above the rip-rap.

5.3 Conservation Authorities and Municipalities

CAs have a mandate to conserve public lands in their care (conservation areas), restrict development in floodplains, and review proposed changes to watercourses. With such a charge, CAs naturally tend to favour the use of bioengineering as much, or more so, than municipalities who use bioengineering. Individual CAs, however, do not all play the same role in bioengineering projects. Some CA's not only implement their own large scale bioengineered projects, they also have their own nurseries to supply material. Other CAs do not conduct any projects involving bioengineering, although they are responsible for the approval of many such projects. Some only stick to small projects, involving no more than 10 or 20 metres of bank protection.

CAs vary greatly in annual budgets. This is perhaps the most driving force for how involved CAs get towards bioengineering projects. Typically, CAs do not have as much money to spend for erosion control as the average sized city government. As a result, CAs will often produce the most cost efficient bioengineered sites. Tree cuttings are often free, being found on site, or harvested from road ditches. Labour is sometimes done by volunteers, or paid for by government work programs outside the budget of the CA. Depending on the project size and materials used, some of these projects can cost as little as a thousand dollars or less.

CAs usually conduct projects on their own conservation areas, but often will work on private land when requested. Private land owners often enjoy the benefits of having erosion control projects on or affecting their property subsidized by the local CA (where assistance programs exist).

Because municipalities typically have larger budgets than CAs, some of the best combinations of bioengineering techniques can be found at projects paid for by cities. Often, these techniques are in combination with hard structures. Where a large city government accepts the concept of bioengineering, there will usually be several bioengineering projects existing, and a few more planned. In other words, there will usually be more than just a few modest projects completed and planned. Once a city government is sold to the idea of bioengineering, they usually implement it as often as is practical. Some bioengineered projects may, however, still exist within a community where the municipal government and/or the public it serves does not look favourably towards bioengineering. This will often be on account of the local CA and possibly some private land owners, who request help from the CA.

6.0 COST COMPARISONS: HARD STRUCTURES VS. BIOENGINEERING

Cost comparisons between different sites are hard to do because each is "site specific". Not only do the site conditions vary, but the combinations of bioengineering techniques used, each with their own associated costs, also vary. In addition, labour is sometimes voluntary, and materials are sometimes free. General comparisons between different techniques used for erosion control, however, can be made.

6.1 Steering Committee Report

Costs in this sub-section are taken from the steering committee report *Assessment of Benefits of Subwatershed Planning and Naturalizing Stream Systems* (1994). This report looked at the costs associated with natural channel design and concrete channels in addition to subwatershed studies. A committee of staff from CAs, municipalities, provincial ministries and consultants completed the report.

The following table is taken from information the report cited from the *Halton Channel Lining Maintenance Study (1992)*, comparing natural channel design with concrete channel costs. Concrete lined channels were reported to require repair or replacement within a 13 to 25 year time frame.

Table 1. Milton Channel Cost Comparisons

	Natural Channel Design	Concrete
Land Required (width)	30.5 m	80 m
Capital Cost	$ 550/m	$ 2,740/m
Replacement Cost	unknown	$ 1,750/m
Annual Maintenance Cost	$ 1.00/m	$ 6.25/m

Comparisons of the "typical construction costs" per metre for four different channel lining materials, with a design flow rate of 20 m^3/s were as follows:

Grass	$ 180
Riprap	$ 230
Gabion	$ 400
Concrete	$ 600

Citing the report: *Maintenance & Implementation (1994)*, by J. Tran, costs for roadside drainage types for the City of Etobicoke are listed as:

	Cost per metre	
	Capital	Maintenance
Roadside Ditches	$ 250	$1.10
Curb and Gutter	$ 500	$1.60

6.2 Costs From Case Studies

Table 2 lists the costs for bioengineering projects from selected case studies. In order to provide a more accurate measurement of bioengineering costs on a linear basis, each case study selected had either most or all work done on one bank. None of the sites in Table 2 incorporated hard erosion control structures, with the exception of riprap and/or vortex rock weirs at some sites. Natural channel design was not conducted on any of these sites.

Table 2: Costs Per Metre of Selected Case Studies Using Bioengineering

Site	Labour Charge?	Materials Charge?	Cost	Length (m)	Cost /m
Harrington Cribwall	No	Yes	$ 1,000	25	$ 40
Peace Park	No	Yes	$ 3,000	70	$ 43
Cairns Blvd.	No	Yes	$ 1,561	30	$ 52
Lake Victoria	No	Yes	$ 2,000	24	$ 83
Harbour Square Park	Yes	Yes	$ 8,600	65	$ 132
Morrison Property	Yes	Partial	$ 8,000	55	$ 145
Mimico Creek Estuary	Yes	Yes	$ 4,964	30	$ 165
Spring Creek	Yes	Yes	$ 5,000	30	$ 167
Black Ash Cribwall #2	Partial	Partial	$ 6,197	34	$ 182
Fundale Park	Yes	Yes	$ 15,690	80	$ 196
Farewell Park Cribwall	Yes	Partial	$ 12,000	40	$ 300
Black Ash Cribwall #1	Yes	Partial	$ 4,443	13.5	$ 329
Binbrook Lake	Yes	Partial	$ 30,000	80	$ 375
				Average:	**$ 170**

As can be seen, costs vary considerably, ranging from $40 to $375 per metre for bioengineering applications. The reason for such discrepancy is due mainly to two aspects:

1. As shown, there is often no cost for labour and/or materials. Labour is sometimes done by volunteers. Materials, such as cuttings for live stakes, fascines and brushlayers, are sometimes found either on or off site, or are donated.
2. Costs vary for different types of bioengineering techniques (e.g. Live stakes, cribwalls, and coir logs all vary in expense).

The following table lists three projects in an urban setting that have incorporated natural channel design in addition to basic bioengineering. The quantities of soil removed (per m) at each site, which is a major factor in the project costs, all vary considerably.

Table 3: Costs Per Metre of Selected Case Studies Using Natural Channel Design

Site	Cost	Length (m)	Cost /m
Little Etobicoke Creek	$ 300,000	1,000	$ 300
Cedarbrook Park	$ 430,000	630	$ 683
Maple Hill Creek	$ 250,000	300	$ 833
		Average:	**$ 605**

Note that the *maximum* cost per metre for the basic bioengineering case studies listed in Table 2 ($375/m) is less than both the cost quoted for natural channel design in Table 1

($550/m), and the average cost for case studies using natural channel design found in Table 3 ($605/m). These costs are in turn less than the capital cost quoted for concrete channel linings in Table 1 ($2,740/m). This last figure is considerably higher than the others, as is the cost associated with Colonial Creek (Case Study #12), where a 280 m concrete channel (later removed) was constructed for $1,786/m.

The following table lists three case studies in Mississauga that have used a good portion of both bioengineering techniques and hard structures such as boulders or cut stone walls. The average cost for these three projects is more than the average cost for projects using natural channel design, but much less than costs associated with concrete channels.

Table 4: Costs Per Metre of Case Studies Using Both Soft and Hard Structures

Site	Cost	Length (m)	Cost /m
Cooksville Creek	$ 435,000	800	$ 544
Sawmill Creek	$ 350,000	500	$ 700
Loyalist Creek	$ 615,000	400	$ 1,538
		Average:	**$ 927**

6.3 Costs for Bioengineering Materials

The following table lists sample costs for particular items used in bioengineering, if they are not found on site or donated. Taxes and transport costs are extra for most items.

Table 5: Sample Costs for Bioengineering Materials

Item	Cost
Live stakes (each)	$ 0.50
Geotextile netting (per m^2)	$ 1.46
Geotextile filter material 270R (per m^2)	$ 1.74
Aquatic plants (each)	$ 2.00
Cuttings for brush layers and brush mattresses (bundle of 50, 1-3 m long)	$ 8.50
Rip-rap (per tonne)	$ 14.40
Cedar poles for cribwalls (3 m each)	$ 20.00
Fascines (5 m length)	$ 35.00
Root wads (each)	$ 35.00
Coir logs (per metre)	$ 80.00
Constructed cribwall (per metre)	$182.26

Sources: City of Mississauga (Cooksville Creek Tender Contract); Environment Network; Grillmayer, 1995; Belton Industries, Inc.; Brad Glasman, personal communication.

Costs are available on a square metre basis for some cribwalls, bioengineered slopes, and stone material such as rip-rap. Comparisons using square metres are more accurate than linear metres since exact dimensions are known for all material compared. Table 6 compares the areas protected by cribwalls, cuttings (used in live stakes, brushlayers and fascines), and stone material for various projects.

Table 6: Costs Per Square Metre of Cribwalls, Cuttings and Stone Material

Project	Area (m^2)		Cost /m^2
Stone Material			
Colonial Creek (river run stone)	766		$ 6
Scott's Plains Pk. (river run stone)	320		$ 22
Cooksville Creek (recycled gabion stone for gabion mats)	150		$ 33
Colonial Creek (rip-rap)	5		$ 50
		Average:	**$ 28**
Cuttings for Slope Protection			
Duffin's Marsh, Pickering*	337.5		$ 16
Mimico Creek	150		$ 33
Harbour Square	182		$ 47
		Average:	**$ 32**
Cribwalls			
Farewell Park	100		$120
Black Ash Creek #2	40.8		$152
Black Ash Creek #1	20.25		$219
		Average:	**$164**

* Not a Case Study

Sources: City of Mississauga (Cooksville Creek Tender Contract); City of Waterloo (Colonial Creek Tender Contract); Grillmayer, 1995; Otonabee Region CA (Scott's Plains Park Tender Contract); Dave Rogalsky, personal communication; Carole Seysmith, personal communication.

6.4 Costs for Hard Structure Materials and Labour

Due to the skill, labour, and machinery required for the installation of hard structures, labour costs are associated with the materials and quoted as one price. It should be noted that for rock material, such as armourstone, the costs for transport vary considerably throughout Ontario, depending on site location. This cost has a significant effect on the total cost for installation. The table below lists sample costs at time of construction for hard structure materials and labour, following the year of completion:

Table 7: Sample Costs Per Metre for Hard Structures

Item	Cost
1996 Rip-rap - 400 to 900 mm diameter	$ 656
1997 Concrete storm sewer extension - 750mm diameter	$ 797
1996 Armourstone wall on Binbrook Lake	$ 984
1985 Armourstone average cost for Lake Ontario 20 year design	$ 1,225
1993 Armourstone wall on Lake Superior	$ 1,500
1994 Shorewall on Lake Ontario	$ 1,981
1998 Shorewall on Lake Ontario	$ 3,364

Sources: Ken Cullis & Jake Vander Wal, personal communication; Joe Hollick, personal communication; MNR, 1986; Otonabee Region CA (Scott's Plains Park Tender Contract); R.V. Anderson Associates Ltd., 1992.

6.5 Costs of Bioengineered Sites vs. Existing Hard Structures

The following table and figure show the comparative difference in costs between soft and hard structures.

Table 8: Average Costs Per Metre of Erosion Control Projects

Project		Cost /m
Basic Bioengineering (cuttings only)		
Duffin's Marsh, Pickering*		$ 121
Harbour Square Park		$ 132
Mimico Creek		$ 165
	Average:	**$ 139**
Cribwalls		
Black Ash Creek Cribwall #2		$ 182
Farewell Park Cribwall		$ 300
Black Ash Creek Cribwall #1		$ 329
	Average:	**$ 270**
Natural Channel Design		
Average from Table 3		**$ 605**
Boulder Bank Protection (400-900 mm)		
Binbrook Lake* (outside of case study area)		**$ 656**
Armourstone Wall		
Binbrook Lake* (outside of Case Study area)		$ 984
Red Rock, Lake Superior		$ 1,500
	Average:	**$ 1,242**

Concrete Channel

Colonial Creek		$ 1,786
From Table 1		$ 2,740
	Average:	**$ 2,263**

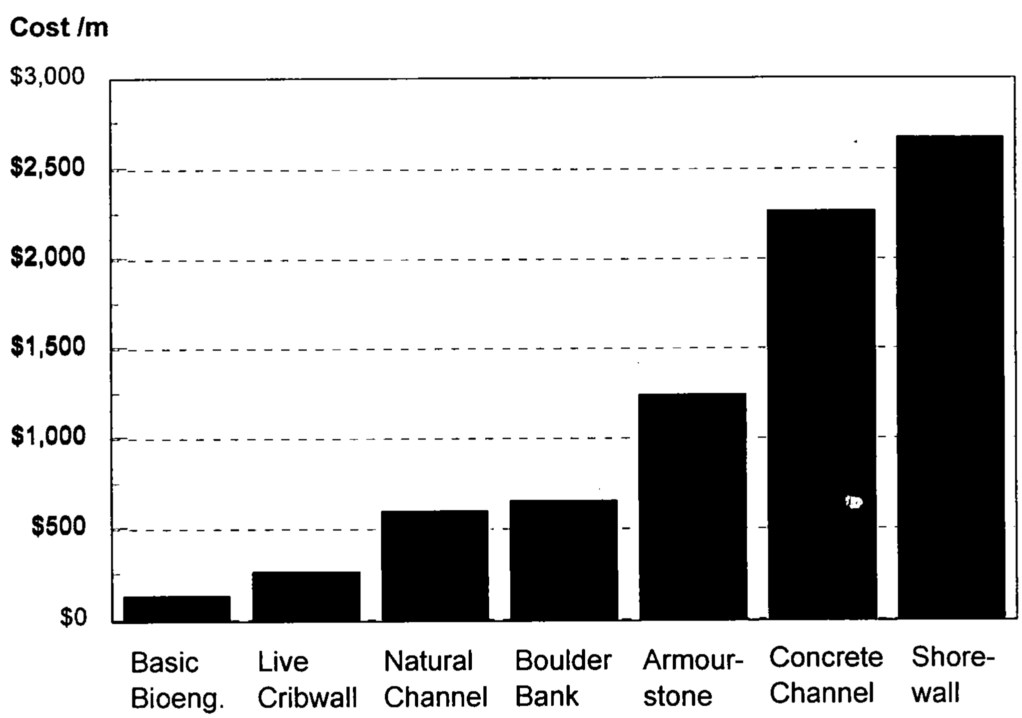
Shorewalls

Burlington, Lake Ontario* (1994)		$ 1,981
Burlington, Lake Ontario* (1998)		$ 3,363
	Average:	**$ 2,672**

* Not a case study

Sources: Ken Cullis & Jake Vander Wal, personal communication; Grillmayer, 1995; Joe Hollick, personal communication; Dave Rogalsky, personal communication; Carole Seysmith, personal communication; David Watson, personal communication.

Figure 1 **Bioengineering vs. Hard Structures**
Cost Comparison / m



6.6 Design Life

Hard structures have a specific design life to them, but bioengineering designs typically do not. This may be partly because bioengineering was little used in North America 10 years ago compared to its use now, so there are few projects older than 10 years to compare with (except for sites in Europe). While this may be true, the theory behind bioengineered designs is that they are living and self repairing. Once established with a good design, they increase in strength, and after a period of 3 to 5 years, they should be capable of resisting high stream flows. They should also be capable of self-repair. Branches or roots that become broken or dead are gradually replaced with more growth.

Since hard structures cannot repair themselves, they require long term maintenance. This means that the gap in costs between a hard structure and a bioengineered site will continually grow.

7.0 SUCCESSES, BENEFITS AND FAILURES

7.1 Successes and Benefits

Most of the case studies detailed have successfully achieved stable erosion control using bioengineering. Proper planning and adaptation to site conditions played a big role in these successes. This included knowing the limitations to each type of planting or soft structure, and deciding on if and where they should be used. Recognizing where rip-rap or rocks should be used instead of, or in conjunction with a soft structure was also very important. Some case studies, such as Harbour Square Park, Little Etobicoke Creek and Black Ash Creek Cribwall #2 owe their present improved design to mistakes made in the past.

Environmental benefits, in addition to erosion control, have been noted at some of the larger scale case studies. An improvement in fish populations was noted at Hall's Creek and Scott's Plains Park, where the latter disproved a concern that erosion control would remove fish habitat (Mark Peacock, personal communication). Monitoring showed that the constructed North Flood Plain Pool at Snyder Flats was used by pike, largemouth bass and minnow species as a nursery habitat (GRCA, 1996). LaSalle Park and Grenadier Pond now have better habitat for fish and waterfowl. The Morningside Tributary is to be re-stocked with redside dace, and will have an ongoing subwatershed monitoring program of fish and benthic communities.

An important indicator of successful projects, particularly in urban areas, is the acceptance and satisfaction that the public and neighbouring residents have for resulting site conditions.

7.2 Failures

Although careful planning went into most of the case studies, unforeseen or unanticipated problems occurred at some sites, resulting in partial or complete failures in the bioengineering designs. There are many problems that can occur due to the combined complexities of factors, such as the characteristics of tree species used, soil conditions, local climate, random storm events, immediate and surrounding land use, area wildlife, pedestrian traffic, skill of the labourers, and the project design, among other things.

Riverine processes are dynamic, and naturally tend to change over time. The route of the watercourse, shape of the floodplain, seasonal flows, and the area vegetation are some factors that can change over the years. Natural changes to a riverine system are not regarded as failures. Rather, it is the lack of being able to compensate for these changes in a bioengineering design that causes failure.

The following table lists the case studies that have experienced some form of failure:

Table 9: Case Studies Where Failure Occurred

Case Study	Suspected Causes
Harbour Square Park	Toe of slope undermined by wave action due to higher than expected lake levels.
Little Etobicoke Creek	High flow velocities due to un-natural channel shape and lack of energy dissipation.
Colonial Creek	Debris accumulating on vortex weir, re-routing flow. Lack of adequate vegetation on banks. Soil conditions.
Black Ash Creek	Too much shade due to vertical face cribwall facing north.
Cribwall # 1	Discontinuous brushlayers inside cribwall.
Findlay Mill Rd.	Constricted channel because of added boulders. Lack of filter cloth under placed boulders.
Cairns Blvd.	Constricted channel because of added boulders. Vandalism. Soil Conditions.
Highland Creek	High flow velocities from storm event. Soil conditions. Delay in planting cuttings.
Binbrook Lake	Too much shade (north facing section with steep bank). Delay in planting cuttings.

8.0 CONCLUSIONS

The success of a bioengineered site can only be conclusively determined after the first 2 to 3 years. Live stakes, fascines, brushlayers and brushmattresses are very vulnerable to poor site conditions, erosion and vandalism during this time while their root structures are growing. It is essential that the required amount of sunlight and soil moisture necessary for the species of cuttings used be a part of the site conditions, as this was the main reason for failed areas of sites in the case studies. The cribwalls, when properly designed, were usually found to be quite effective in providing protection for cuttings, without inhibiting light and moisture conditions available on site. The use of biodegradable geotextiles provided good temporary erosion control where needed. Vandalism or human activity was a main factor in contributing to the demise of at least two case studies.

Rip-rap and vortex rock weirs appear to go well with bioengineering designs. Although they may arguably be considered to be hard materials, they provide good erosion protection along areas exposed to running water, while still blending in with the natural features of the site. This is especially true if well rounded rocks are used, consistent with rocks that naturally exist along many creeks and rivers. Rip-rap appeared to be very successful in the sites visited. Vortex rock weirs often were as well, but in some cases they were blocked with debris, moved, or had become dislocated from the centre of flow in the watercourse, where they should be. Vortex weirs should thus be inspected periodically.

Root wads and log jams are for temporary erosion control and fish habitat only. Although they appeared quite effective in providing for these things at the sites visited, these sites were newly developed. Root wads and log jams are not living structures and thus can only break down. The overall bioengineering design incorporating these can only be successful if their eventual collapse is accounted for.

Natural channel design goes well with bioengineering. Because this involves the removal or relocation of soil, this adds to the cost considerably, as seen in the Highland Creek case study. The Maple Hill Creek case study, which used natural channel design, was successful. This is significant because it is one of the oldest projects studied (1990), and was completed in a city easement with a narrow width that restricted the full potential of the natural channel design.

Bioengineering could still use more public and municipal support. Although it is becoming a popular alternative to hard structures, there are still some municipalities that seldom or never use bioengineering designs. This support should come gradually, as the overall effectiveness of bioengineering projects become better known and understood.

Bioengineering is much more widely used in riverine environments over lake shores. This accounts for the fact that few case studies involve lake shore sites. Where bioengineering is used at such sites, it is often in combination with hard structures such as armourstone or boulders. This is because the erosive force of waves along a shoreline is frequent, and is usually too overpowering to allow tree cuttings to grow, even if aided by geotextiles and cribwalls. For adequate erosion control in many low flow creeks, however, hard structures may be limited or avoided altogether in favour of bioengineering.

Comparing costs taken from the case studies, live stakes, fascines, brushlayers, brushmattresses, root wads and log jams are the lowest costing components of bioengineering, followed by geotextiles, rip-rap, and live cribwalls. Natural channel design is above these costs. Hard structures cost even more.

Based on the findings listed in Section 6, bioengineering in a riverine environment is usually significantly less expensive than hard structures on a per metre basis. Comparing natural channel design case studies with large concrete channels, the difference is about threefold. Comparing case studies using basic bioengineering designs with large concrete channels, the difference is even more, depending on site conditions.

In addition to the cost benefits of bioengineering, the environmental benefits, which are not as easily measured, are an important factor. Wildlife habitat, green space and aesthetic qualities are in high demand. This is apparent by the number of citizens' and special interest groups that have made contributions to several sites listed in the case studies.

9.0 CASE STUDIES

Each case study site documented was inspected by the author between August and December, 1998.

Case Studies Listed Under Conservation Authority Jurisdiction

Central Lake Ontario Conservation Authority

1. Farewell Park, Oshawa

Credit Valley Conservation Authority

2. Brault Property, Credit River
3. Cawthra Creek, Mississauga
4. Cooksville Creek, Mississauga
5. Lornewood Creek, Mississauga
6. Loyalist Creek, Mississauga
7. Sawmill Creek, Mississauga

Ganaraska Region Conservation Authority

8. Cobourg Creek Golf Course, Section A, Cobourg
9. Cobourg Creek Golf Course, Section B, Cobourg
10. Peace Park, Cobourg

Grand River Conservation Authority

11. Bechtel Park, Waterloo
12. Colonial Creek, Waterloo
13. Grofmill Creek, Cambridge
14. Maple Hill Creek, Waterloo
15. Mill Creek, Cambridge
16. Snyder Flats, Bloomingdale

Halton Region Conservation Authority

17. LaSalle Park, Burlington

Hamilton Region Conservation Authority

18. Spring Creek, Dundas

Niagara Peninsula Conservation Authority

19. Binbrook Lake, Binbrook
20. Martindale Pond, St. Catharines

Nottawasaga Valley Conservation Authority

21. Black Ash Creek Cribwall #1, Collingwood
22. Black Ash Creek Cribwall #2, Collingwood
23. Black Ash Creek Gully Stabilization, Collingwood
24. Cairns Blvd., Willow Creek, Midhurst
25. Findlay Mill Road, Willow Creek, Midhurst
26. Glen Huron Cribwall, Glen Huron
27. Harbourview Park, Collingwood
28. Morrison Property, Nottawa

Otonabee Conservation Authority

29. Scott's Plain Park, Peterborough

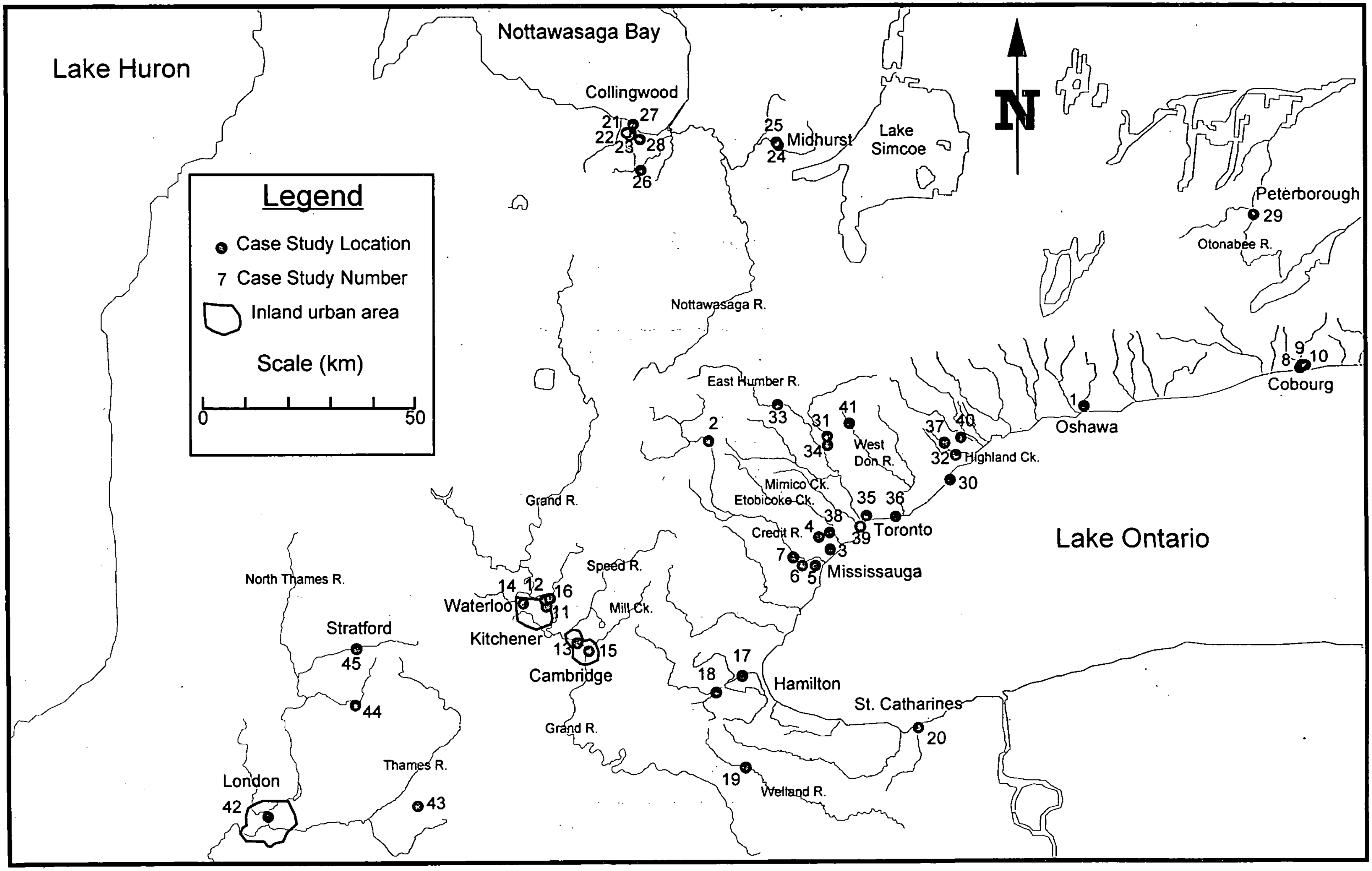
Toronto Region Conservation Authority

30. Bluffer's Park, Scarborough
31. Boyd Conservation Lands, East Humber River
32. Cedarbrook Park, Scarborough
33. Cold Creek, Bolton
34. Fundale Park, Woodbridge
35. Grenadier Pond, Toronto
36. Harbour Square Park, Toronto
37. Highland Creek, Scarborough
38. Little Etobicoke Creek, Mississauga
39. Mimico Creek, Etobicoke
40. Morningside Tributary, Scarborough
41. Rupert's Pond, West Don Greenway, Maple

Upper Thames River Conservation Authority

42. Gibbons Park, London
43. Hall's Creek, Ingersol
44. Harrington Conservation Area, Harrington
45. Lake Victoria, Stratford

Figure 2: Map of Case Studies



1. <u>Farewell Park, Oshawa</u>

Location: Farewell St. and King St. East
Dates of Construction: Aug 25 - 29 and Nov. 3, 1997
Approximate Project Cost: $12,000
Funded By: City of Oshawa (50%), Friends of Second Marsh (50%).

Description:
A 40 m cribwall was constructed along Harmony Creek within a municipal park. The cribwall was built into a steep bank about 2 metres high, where the watercourse is relatively straight and about 3 m wide. At the top of the bank there is a public walking trail that was threatened by the eroding bank. Due to the close proximity of the trail to the stream, space did not allow for grading of the bank. It was considered to be too costly to relocate the paved trail away from the bank, so a live cribwall was thus selected for the site. The lower portion of the cribwall was constructed in the summer to avoid disrupting fish habitat. The upper portion of the cribwall was constructed in November, when the cuttings used for this section were dormant.

The cribwall was built into an excavated space in the bank. The timbers used in the wall were donated, being raw timber hydro poles 20 cm in diameter and about 2.5 m long. The lower portion of the cribwall was excavated so as to be 0.5 m below the creek bed, and was filled with 5-20 cm diameter rock backfill. Evergreen boughs extend out from this section into the watercourse. Willow and dogwood cuttings were used for the upper sections of the cribwall, which slopes back slightly away from the creek. Fascines anchored with live stakes spaced 1 m apart were planted along the top of the cribwall.

Comments:
Five city staff completed the project. A backhoe was used to excavate the bank.

Downstream of the site for several hundred metres there is a "buffer area" of planted coniferous trees on both creek banks.

Friends of Second Marsh are monitoring for species occurrences. Invertebrate sampling occurred prior to construction and is scheduled to continue for at least two years after the completion date, to monitor water quality conditions above and below the site.

Contacts: Dave Brady, City of Oshawa, Public Works (905) 725-7351
Carole Seysmith, Friends of Second Marsh (905) 723-5047

2. <u>Brault Property, Credit River</u>

Location: Near Inglewood
Started: 1995
Duration: Unknown
Approximate Project Cost: < $1,000
Funded By: MNR - Community Fisheries Involvement Program

Description:
A live cedar cribwall about 15 m long was built along a bank on the Credit River, located on private property in a forested area. Fascines and brushlayers were placed along the slope above the cribwall. The cribwall was built external to the bank, so about 2 m of land was reclaimed. Some cedars are planted along the bank in specially constructed squares built along the top of the cribwall. The cribwall includes an overhanging cover for fish habitat. Rip-rap was added along the base of the bank. The watercourse is wide with a relatively high flow velocity.

Downstream from the site is a log jam about 5 m long, which was built in one day with a group of 5 people. The log jam is made of thick branches and small logs all bound together by aircraft cable. The cable is fastened to a steel T-bar stuck in the ground.

Comments:
Volunteers worked a total of 180 hours on the site.

Contact: Mark Heaton, MNR, Aurora District (905) 713-7406

3. Cawthra Creek, Mississauga

Location: Delwood Place (West of Cawthra Rd., between Arbor Rd. and Atwater Ave.)
Started: December, 1996
Duration: Five days
Approximate Project Cost: $15,000
Approximate Bioengineering Cost: $13,500
Funded by: City of Mississauga

Description:
The site is in a small, residential park, spanning about 100 m of Cawthra Creek. The creek itself is small, being only about 2 to 3 m wide. The project was given high priority and done quickly due to the creek threatening to damage a sanitary sewer. Fascines and brushmattresses were used during construction from dogwood cuttings harvested on site. Thick vegetation now exists on both sides of the creek. Natural channel design was used, involving the re-alignment of the watercourse to create meanders, point bars, and the addition of small pools.

Comments:
To the north of the site, within the park, exists a small, old concrete channel that is now separated from the bank and sits within, rather than holds the flow of water. About 50 m to the north of this channel exists a larger channel beside two storm sewer outflows. Within this channel is a set of concrete pillars acting as energy dissipaters. Although the channel and dissipaters are intact, graffiti is on both.

Contacts: Bob Levesque, City of Mississauga (905) 896-5144
Mississauga Recreation and Parks (905) 896-5384

4. Cooksville Creek, Mississauga

Location: East of Hurontario St., between Burnhamthorpe Rd. and Central Parkway East
Started: May, 1998
Duration: Two months.
Approximate Project Cost: $435,000
Approximate Bioengineering Cost: $39,000
Funded by: City of Mississauga

Description:
The site spans about 850 m of Cooksville Creek, running through Mississauga Valleys park. Various forms of erosion control using both hard and soft materials were used at different sections of the creek. The hard materials included wire mesh placed along sections of creek bed that were shallow and flat, boulders used as energy dissipaters (also placed along the creek bed at certain sections), rip-rap along banks and bottom of the creek, and cut armourstone walls along some banks. Gabion baskets from previous works were left along some banks. Soft materials included vegetation growing between rip-rap on lower banks, live stakes, and geotextile matting. The geotextile matting consisted of organic material attached to black plastic netting and was held in place by live stakes. A walking path exists along the entire length of the site.

Comments:
Stones from old, existing gabion baskets were reused for both rip-rap and new gabion baskets (1.0 m x 0.5 m).

This case study uses a wider variety of erosion control techniques than most projects examined. All forms of bioengineering and hard structures appeared to be holding up well.

The park is well used by people of all ages, yet no damage or vandalism was noted (August 1998) to the work carried out.

Contacts: Bob Levesque, City of Mississauga (905) 896-5144
Mississauga Recreation and Parks (905) 896-5384

5. Lornewood Creek, Mississauga

Location: South of Springhill Dr.
Started: October, 1997
Duration: One week
Approximate Project Cost: $40,000
Approximate Bioengineering Cost: $20,000
Funded By: City of Mississauga

Description:
The site is on a small section (about 60 m) of a small creek (about 3 to 4 m wide), bordering private property on either side, in a residential neighbourhood. Natural channel design was incorporated with the creation of new meanders, pools, riffle sections, and point bars. Fascines and brushmattresses were placed along both banks. Rip-rap was used along the base of the creek in some sections.

Comments:
This project was done in conjunction with pond rehabilitation works done further downstream. The work was required due to erosion threatening a sanitary sewer and a house.

Contact: Bob Levesque, City of Mississauga (905) 896-5144

6. Loyalist Creek, Mississauga

Location: Mississauga Rd. at Seven Oakes Dr.
Started: January, 1997
Duration: Two months
Approximate Project Cost: Three Phases: Phase 1 $325,000
Phase 2 $290,000
Phase 3 Ongoing
Funded By: City of Mississauga

Description:
The site spans about 450 m of Loyalist Creek in a winding section on public land bordering residential property. The channel is about 8 m wide in some sections. Rip-rap of varying sizes was placed in generous quantities at different sections of the creek bottom. This was done to form "rocky ramps" or step pools to help control flow velocities. Steep banks were protected by a variety of hard and soft structures. The hard materials protecting banks are either rip-rap, boulders, or cut vertical armourstone walls. Vegetation was noted to be growing through the rip-rap bank protection in some areas. The soft materials used were live cribwalls, live stakes, fascines, and geotextile matting. The cribwalls were set high on the banks on a base of cut armourstone, and incorporated willow cuttings. Fascines were placed above the cribwalls, held by live stakes, to provide for stabilization. Live stakes were often used in conjunction with geotextile netting, which was used to hold up certain smaller sections of the bank near the cribwalls. Vortex weirs of rocks were used throughout the site, often with geotextile matting which was found to be both over and under rocks. The west end of the creek contains two different types of concrete energy dissipaters. The smaller one, outside of a storm sewer outlet, uses raised rectangular concrete blocks about 20 cm high. The other, at the western border of the site, is within the main flow of the creek and uses vertical concrete slabs about 90 cm high.

Comments:
Supplemental landscape planting of nursery stock was added to sections of the site in November 1997.

Project works involves three phases. Phases 1 and 2 were completed at the time of inspection (August, 1998). Phase 3 commenced in December, 1998.

A good mix of hard and soft structures at a large scale are used. The channel appears to be well protected and capable of handling large flows as a result. Most of the creek is not easily accessible and may account for the fact that the vegetation used for the project is largely undisturbed.

Contact: Bob Levesque, City of Mississauga (905) 896-5144

7. Sawmill Creek, Mississauga

Location: North side of Burnhamthorpe Rd. West, east of Erin Mills Pkwy.
Started: Fall, 1996
Duration: Six weeks
Approximate Project Cost: $350,000
Approximate Bioengineering Cost: $52,000
Funded By: City of Mississauga

Description:
The site spans about 500 m of Sawmill Creek in parkland bordering on residential properties. A walking path follows most of the creek. Cribwalls incorporating willow cuttings were put on both banks along part of the site. Extensive planting of live stakes was done in the flood plain areas. Rip-rap is used extensively, and on certain sections of the bank it is covered with wire mesh. Cut armourstone and layered gabion baskets were placed along parts of the western area of the site. Large vortex weirs of armourstone are also used in this section.

Comments:
The project appears to be successful.

Contact: Bob Levesque, City of Mississauga (905) 896-5144

8. Cobourg Creek Golf Course, Cobourg. Section A

Started: September, 1998
Duration: About 8 days
Approximate Project Cost: $4,000 (includes labour)
Funded By: Land Owner

Description:
This site (unfinished at time of inspection) runs along an outside bend in the creek for about 40 m. The bottom layer of a cribwall extends out into the creek, reclaiming about 2 m of the eroded bank, leaving about a 3 m width of watercourse. The base of the cribwall is covered with riprap. Along the inside middle of the cribwall, a row of logs runs parallel to the face of the cribwall, for extra support. Cedar boughs extend out from the base of the cribwall into the watercourse. The new bank is to be lower sloping than the original eroding bank, being designed for a 3:1 slope.

Comments:
At the time of inspection, 2 days work had been completed; an estimated 4 more days work was required for completion, scheduled to be done the following week.

The work for both Section A and Section B (following) was designed by the Ganaraska Region CA.

9. Cobourg Creek Golf Course, Cobourg. Section B

Started: Fall, 1997
Duration: About 8 days
Approximate Project Cost: $4,000 (includes labour)
Funded By: Land owner

Description:
This site is very close to Section A of the same golf course, along a similar shaped bend in the creek. The cribwall design is of the same type, blending into the landscape well, and has a thick growth of dogwoods. Cedar boughs were also added to the base of this cribwall, as with the one in Section B, which were not visible and are expected to die within a year. These boughs were added for temporary protection as the dogwood cuttings took root.

Comments:
Since Sections A and B have very similar conditions, but are one year apart in construction, it is expected that Section A will have similar appearance and success as Section B, after one year.

Contact: Scott MacNeill, Ganaraska Region CA (905) 885-8173

10. Peace Park, Cobourg

Location: Cobourg Creek
Started: September, 1998
Duration: Three days
Approximate Project Cost: $3,000 (materials)
Funded By: Ganaraska Region CA (provided materials), Town of Cobourg (provided labour - not included)

Description:
The site runs along 70 m of the east side of Cobourg Creek. The creek is about 15 m wide and is used by coldwater fish, including salmon. About 3 metres of bank was reclaimed along a 2 m high bank with a continuous cribwall. The cribwall was built with cedar posts (bark left on) and covered with root wads along its face. The cribwall was filled with sand and rocks, and covered over with geotextile matting held down by rip-rap.

Comments:
The cribwall was unique, in the sense that it was lined with root wads, rather than filled with willow and/or dogwood cuttings.

The root wads were donated, since they were ripped out of a site proposed for development and were not wanted.

Contact: Scott MacNeill, Ganaraska Region CA (905) 885-8173

11. <u>Bechtel Park, Waterloo</u>

Location: South-east corner of Hwy. 86 and University Ave.
Started: 1992
Duration: Two phases done over two years
Approximate Project Cost: $750,000
Funded By: City of Waterloo

Description:
About 400 m of Laurel Creek runs through Bechtel Park. An area of the park, including much of where Laurel Creek flows, is the site of an old landfill. Prior to the start of this project, the creek was eroding certain sections of the landfill, exposing garbage on both banks. This erosion was threatening a sanitary sewer pipe running through the old landfill, approximately 3 metres or less parallel from the edge of the creek. A concrete cradle was built for the pipe, and protected with cribwalls. In the first phase of remediation (1992-1993), the creek surface area was narrowed to speed up the flow velocity. This was done because the creek was so wide that stagnant areas developed, producing a bad odor with the eroding banks of garbage. Cribwalls using willow cuttings were placed on the west bank on the north (upstream) section, and vortex weirs of rocks were placed in sections of the creek. For the second phase (1993-1994), fascines were placed on the west bank in the south section, the remnants of which still remain. At the south end of the site, a pond was created a few metres away from the creek, in order to create a mini-wetland environment and to take flows during flooding events.

Comments:
The section of Laurel Creek running through the park is still relatively wide (about 5 to 6 m), and has a slow velocity after being narrowed. Stagnant water, is however, no longer a problem. Vegetation along the banks of the creek is growing well. There is no visual indication that the site is on an old landfill.

A 22 month subwatershed study was conducted for the entire length of Laurel Creek. This study cost $840,100, funded 35% by the city of Waterloo, and 65% from provincial monies. In 1993, a Watershed Plan was adopted and incorporated into the municipality's Official Plan. Forty-four watershed recommendations were produced by the Study, most of which were incorporated into the Official Plan. These recommendations involved considerations such as flood and erosion control, groundwater infiltration, water temperature, sediment loadings, and bioengineering (Steering Committee Report, 1994).

Contact: Paul Eichinger, City of Waterloo (519) 747-8748

12. <u>Colonial Creek, Waterloo</u>

Location: Malabar Dr.
Started: 1997
Duration: One year
Approximate Project Cost: $391,000
Approximate Bioengineering Cost: $28,000
Funded By: City of Waterloo and a developer

Description:
The site is along a 660 m span of Colonial Creek. The creek is small, being only about 3 m wide. The site formerly contained a 280 m long concrete channel (2 m by 2 m) which was removed last year at a cost of $52,000. The concrete channel had been installed approximately 10 years ago at a cost of about $500,000. There is a high berm on the north side of the watercourse, but the area immediately beside both sides of the watercourse is relatively flat. Fascines and rock vortex weirs on geotextile fabric were placed after the concrete channel was removed. Rip-rap was also put along the base of the creek. Trees more than 2 m high were planted beside the creek, which includes cedars and deciduous species (cost of $46,300). A small eroding section on one of the low banks exists. Much of the geotextile fabric placed under rocks in this section has been swept into a small pile around a large rock, rendering the fabric useless. A pond exists at the west side of the site, which is used to contain storm flows.

Comments:
The reason for the erosion on a small section of bank is uncertain. It is possible that debris backed up on some rocks in the channel, diverting more flow towards the bank. It is also possible that not enough vegetation was put on the bank, since little more than grass is growing on that section.

The total project cost also includes creation of a stone pathway ($15,800), habitat enhancement ($2,500) and a contingency allowance of $15,000.

The concrete channel removed was in good condition. The ideology of the city government towards a natural approach to flood and erosion control was strong enough for them to have a $500,000 concrete channel in good working order removed. This case study shows how government attitudes towards hard structures are changing towards natural channel design.

Contact: Sunda Siva, City of Waterloo (519) 747-8634

13 Grofmill Creek, Cambridge

Location: Hwy. 8 (Coronation Blvd.) between Coronation Blvd. and the railway tracks on
the west boundary of Dumfries Conservation Area.
Started: May 3, 1993
Duration: Six weeks
Approximate Project Cost: $57,800
Funded by: City of Cambridge

Description:
The site spans along 300 m of Grofmill Creek, on a narrow strip of land between residential back yards to the west, and railway tracks to the east. Live stakes and a cribwall were installed at the site, in addition to vortex weirs, rip-rap and plunge pool energy dissipaters. Mulch was also added to the site.

Comments:
Evidence of human intervention is difficult to see, after more than five years since completion of the project. A thick growth of weeds and small trees makes access difficult through the site. Stands of willow trees grow several metres high next to the watercourse. The project thus appears to have been successful.

Contact: Kirit Patel, City of Cambridge (519) 740-4682

14. Maple Hill Creek, Waterloo

Location: Culpepper Pl., north of University Ave.
Started: 1986
Duration: Stages of development over five years
Approximate Project Cost: $ 250,000
Funded By: City of Waterloo

Description:
The site is 300 m long and is along a city easement which runs through several backyards on private lots in a residential neighbourhood. It is downstream from a gabion channel, and upstream from a concrete channel. The usual watercourse is very narrow (< 1 metre), but a large urban drainage area significantly increases the storm flows. While no live stakes, fascines, or brushlayers were used, natural channel design was incorporated. Meander patterns exist, although constrained by space. Dogwood and cedar trees were planted along some banks. A gazebo exists above such a bank, which could only remain there due to remedial measures taken, incorporating the natural channel design. Rip-rap exists within the low flow channel of the watercourse.

Comments:
Erosion along Maple Hill Creek has been a problem for the past 20 years, when much urban development took place. Local residents wanted the erosion problem solved using an alternative, more natural approach than a hard structure. The city instead proposed to install a concrete channel. The residents took the city to court over the issue and won the case. Commencement of the existing design then started in 1990 and is considered to be successful.

Downstream of the site, an old concrete channel still exists. The watercourse widens out significantly at the downstream end of this channel to about 5 m or more. The banks here are steep and eroding. This portion of the creek is scheduled to be remediated using natural channel design.

According to a government report, there has been extensive funding towards rehabilitating sections of Maple Hill Creek. Prior to 1994, about $2 million (1994 dollars) was spent within the previous 10 to 15 years. This was to remediate sections presumably damaged by increased runoff from uncontrolled development. It was determined that had a Subwatershed Plan been in place before development occurred around the creek, approximately $1.6 million in costs could possibly have been avoided (Steering Committee Report, 1994).

Contact: Paul Eichinger, City of Waterloo (519) 747-8748

15. Mill Creek, Cambridge

Location: Hwy. 8 (Dundas St.) and Beverly St.
Started: August, 1997
Duration: Three months
Approximate Project Cost: $118,000
Approximate Bioengineering Cost: $25,000
Funded By: City of Cambridge

Description:
The site spans 412 m of Mill Creek, mainly downstream of Soper Park. Along most of this stretch, the creek is wide (about 6 m) with a low flow. The banks are protected by a variety of bioengineered structures. Some sections use root wads along the waterline and geotextile matting on the bank, some use fascines, and some use planted trees. Deeper areas of the creek, designed for low flow conditions, were created and are separated from riffle sections with a straight weir.

Comments:
Mill Creek supports coldwater fish species, found in creeks with granular sediment. Past development had increased fine sediment loadings. The objective of the work on the creek was thus to improve the fishery habitat as well as control flows.

A $420,000 subwatershed study was conducted on Mill Creek, funded 40% by the municipality and 60% from provincial funds (Steering Committee Report, 1994).

Contact: Kirit Patel, City of Cambridge (519) 740-4682

16. <u>Snyder Flats, Bloomingdale</u>

Location: Snyder's Flats Rd.
Started: 1992 or 1993
Duration: Two weeks
Approximate Project Cost: $10,000
Funded By: Grand River CA with royalties from Preston Sand & Gravel

Description:
Snyder Flats is a 96 hectare (237 acres) property located on a U-shaped bend beside the Grand River, and is owned by the GRCA. A privately run gravel quarry exists on the east side of the site. There are four ponds on the property, totaling 17 hectares (42 acres) in area. Two of these ponds (the north and south floodplain pools), are within an extensive floodplain beside the river, and are connected to a channel that runs parallel to the river for 530 metres. Along this channel, close to the north floodplain pool are two cribwalls about 15-20 m long, brushlayering about 2 m high and 20 m long, and two rows of fascines about 15 m long. A sunken, steel weir controls some of the flow. A beaver dam also exists just upstream from the weir, opposite the cribwalls.

Comments:
The large, extensive floodplain was created and financed with royalties from the gravel company on site. Royalties from this company also go to restoring and protecting other lands owned by the GRCA. All bioengineered work appears to be in good condition.

In 1969, as part of a land acquisition program, the GRCA purchased the flats to create a publicly owned river corridor to reduce flooding and erosion risk. The area was also meant to be recreational. The GRCA and gravel company have worked together since 1979 to extract gravel and create habitat along the river.

With the extraction of gravel, five main aquatic zones were created:

> Cool water habitat - 3.6 ha. pond, with maximum depth of 6 metres to be eventually used as rearing area for cool water fish
>
> Warm water habitat - 9.6 ha. pond, with max. depth of 7 metres, designed to allow flooding during spring and fall through the backup of water from the river.
>
> North floodplain pool - shallow, 3.8 hectare pool. Seasonal flooding has introduced many species of fish.
>
> South floodplain pool - shallow depression in the floodplain, that is covered with water during the spring runoff. During summer it remains damp and provides habitat for wetland plants and animals.

Connecting channel. - riffles and pools along the 530 m channel increases oxygen in water and provides spawning habitat.

Source: GRCA pamphlet on Snyder Flats.

Contacts: Joe Farwell, Grand River CA (519) 621-2761
Jennifer Hawkins, Grand River CA (519) 621-2761

17. LaSalle Park, Burlington

Location: LaSalle Park Rd. and North Shore Blvd.
Started: January, 1994
Duration: Over a year
Approximate Project Cost: $1.6 million
Funded By: GLCUF, Fisheries & Oceans Canada, provincial and municipal funds, Harbour Commissioners, and other sources

Description:
LaSalle Park is on Hamilton Harbour, having about 500 m of shoreline. Along this section of shoreline, extensive fish and wildlife habitat restoration was done. Angular cut rocks have been placed along the waterline, to about 2 or more metres up the bank. Above this, a wide variety of trees and plants were planted for a few metres up the bank. Along some of the shoreline, wetland species were planted on low sloping banks. Off-shore islands were built near a shoreline section and have provided protection from waves, creating wetland like conditions. Fish habitat structures of wood and branches extend out from this stretch of shoreline. A boardwalk, complete with benches and look out areas between the trees and shrubs, stretches along the shoreline. Educational signs are located at certain spots along the boardwalk.

Comments:
The LaSalle Park project was done primarily to enhance fish and wildlife habitat. By necessity, however, the shoreline is protected from erosion by rip-rap, and the banks are stabilized by vegetation. The offshore habitat islands are a form of erosion control in the sense that they are a first line of defense against wave action.

Contact: John Hall, Halton Region CA (905) 336-1158 Ext. 317

18. Spring Creek, Dundas

Location: Old Ancaster Rd. & South Rd.
Started: About 4 years ago
Duration: Four days
Approximate Project Cost: $5,000
Funded By: Hamilton Region CA

Details:
This small site spans about 30-40 m on land owned by the CA. It is located beside a path in a small valley bordered by residential lots on both sides. The creek at the site is about 2 m wide and has a sharp bend. Fascines, live stakes and a rock vortex weir were installed at the site. A high bank on the outside of the bend exists opposite a low lying bank. Three rows of fascines were installed on the high bank, with willow and dogwood stakes placed randomly throughout the fascines. The fascines and live stakes are growing well where there was previously bare earth. The vortex weir was not working properly, due to a build up of debris. Erosion is thus occurring on both banks beside the weir.

Comments:
Just upstream of the site on the higher bank, the channel slope is considered to be changing due to low flow conditions. Sediments falling from the bank that would be swept away by a high flow are settling onto one side of the base of the watercourse. This raises the usual watercourse bottom, decreasing the volume of the water channel. Higher flow events thus tend to over spill the channel and rise higher on the banks, increasing erosion.

This site was remediated because erosion was threatening adjacent private property. Just downstream of the site, there is a 1 m high eroding bank on the opposite side of the creek from the high bank where fascines were installed. This bank was not included in the remedial project because the slope of the valley on this side of the creek is back further from the bank. The private property at the top of the valley slope is thus not immediately threatened by creek bank erosion.

Contact: Tony Horvat, Hamilton Region CA (905) 648-4427 Ext. 138

19. Binbrook Lake

Location: Harrison Rd., near Hwy. 56, south of the Town of Binbrook
Started: Two or three years ago
Duration: About three weeks
Approximate Project Cost: $30,000
Funded By: Niagara Peninsula CA and Provincial funding under Section 25

Description:
Binbrook lake is narrow and about 5 km long. Lake levels are controlled by a dam operated by the NPCA. These levels have been kept about 90 cm lower than normal over the past three years, in order to decrease erosion along the shoreline. The site remediated is about 80 m long on a conservation area. A steep bank (1.5:1 slope) of clay about 5 m high stretches across the site in a gentle curve, following the contour of the shoreline. The bank at the site suffered slumping prior to being remediated. Private property is only several metres away from the top of the bank.

Oversized rip-rap was placed along the base of the bank. Brushlayers and fascines using dogwood and willow cuttings were planted throughout the bank face. The willows were harvested on site, but the dogwood cuttings came from the Long Point Marsh in Lake Erie. Spruce trees were planted along the top of the bank. Wild Goldenrod is now growing among these, which is expected to aid in the soil stabilization process. Slumpage of the slope occurred over the first winter since the project completion, but no movement has been noted since. It was speculated that the bank slumped due to heavy farm machinery moving close to the top of the bank.

Some wetland plant species are growing wild along the water's edge at the site, but only in limited numbers. This is due to the carp population in the lake, feeding on the plants.

Comments:
The east section of the project was a success; the west section failed. The dogwood cuttings on the west section were the last ones to be planted. They were not planted until about 5 days after being cut, which was likely what killed off many of the cuttings. The bank on the west side faces more towards the north than the east section, so lack of adequate sunlight was likely a factor too. The afternoon sun tends to shine only on the east section.

Only three people were needed to complete this project (one excavator and two labourers).

Contact: David Watson, Niagara Peninsula CA (905) 227-1013 Ext. 237

20. Martindale Pond, St. Catharines

Location: North-west St. Catharines
Started: 1996
Duration: Ongoing
Approximate Project Cost: $600,000
Funded By: GLCUF, City of St. Catharines, Green Ribbon Trail

Martindale Pond is about 2.4 km long and 0.6 km wide, being almost entirely enclosed within an urban area. It is used by a rowing club, and will be hosting an international rowing competition in 1999. Ontario Hydro controls the flows to the pond, and St. Catharines Hydro controls the pond water levels. Several parks exist at various locations around the pond, many of which have undergone various forms of bioengineering. The largest park, Henley Island (700 m by 200 m) is made of landfill around a small native island. Rennie Park (200 m by 100 m), located at the north end of the pond, is also made of landfill. Both of these parks each have 3 small islands of mud beside them, which were pushed up to the surface as a result of the weight of the landfill berm material pushing the soft mud away from it. These "mud waves" as they are called, have been planted with bulrushes and dogwoods, and have been protected at their bases with rip-rap. Rootwads, mainly submerged, were placed in between these islands. Several live cribwalls were constructed on some of the parks around the pond. Four sites have cribwalls, and a fifth site at Rennie Park is scheduled for one.

Rennie Park previously had sheet piling along the edge of the landfill. The sheet piling was covered, and the landfill is now lined with rip-rap, planted bulrushes and dogwoods. No willow species were planted because of their tendency for spreading and fast growth. Snow fencing was put up to keep geese from eating the new plantings.

On the west side of the pond, there is an inlet known as Richardson's Creek. The west end of this inlet contains a circular bay about 90 m in diameter, connected to the inlet by a narrow channel. This bay is almost divided in half by a strip of land with a narrow channel mid-way. Richardson's Creek flows through this bay and into the inlet of the same name. Strong flows had previously pushed through this bay. These flows were slowed by the construction of two long berms (60 m and 40 m), one in each half of the bay, both of which cross the old flow route of the creek. This has caused flows to slow significantly. The berms were planted with red osier dogwoods, pussy willows, and common cattails among other species. Wild water lilies, typical of clear water and low flows, are abundant. The edge of the berms were covered with rip-rap (lined with geotextile) and root wads. A footpath runs through the small bay. A blue heron and waterfowl inhabit the area, and a mix of cold and warm water fish are in the bay (including carp).

Many cribwalls were placed at different sites throughout Martindale Pond. These were constructed of coniferous logs, notched together, and housed willow and dogwood cuttings above the low waterline. Below the waterline, evergreen boughs were used. The cribwalls were placed beside the bank and filled with gravel below the low water line, and compacted backfill above it. The top of the backfill was seeded with buckwheat and annual rye. Beside one cribwall, at Royal Henley Park, heavy rip-rap was used for shore protection instead of extending the cribwall. This was because the extra few metres the cribwall would extend into the pond would have cut into the rowing course used by the local rowing club.

Existing Cribwall Locations:
- Henley Island Bridge
- St. George's Point
- Royal Henley Park
- Estates Park

Other Bioengineered Locations:
- Henley Island - mudwaves
- Rennie Park - landfill shoreline, mudwaves
- Richardson's Creek - berms

Comments:
The fact that there are seven different bioengineered locations in Martindale Pond, makes this a complex site. All projects, however, appear to have been successful, and have greatly enhanced the overall aesthetic quality of the pond while maintaining erosion control.

Contact: Cindy Toth, City of St. Catharines (905) 688-5601 Ext. 2193

21. Black Ash Creek Cribwall #1, Collingwood

Location: South branch of Black Ash Creek, at Concession 10 and Poplar Side Road (45 m upstream of Case Study 23)
Started: Debris removal - October/November 1992
Cribwall site preparation - November, 1992
Finished: Cribwall construction - December 9-11, 1992
Approximate Project Cost: $4,400 (Detailed costs listed in Grillmayer, 1995)
Funded By: Collingwood Harbour RAP stakeholders

Description:
An eroding bank of silty sand existed along Black Ash Creek at the site, measuring 13.5 m long and 5 m high. This bank was stabilized by a cribwall built from cedar logs found in debris within the watercourse channel. Flow values along the creek were measured to be as low as 0.32 litres per second and estimated to be as high as 4 m^3/second.

The cribwall was installed with two rows of brushlayers 13.5 m long, and 0.75 - 2 m deep, using beaked willow and red osier dogwood cuttings, which were used within 2 days of being cut. The face of the cribwall was kept vertical. The back of the cribwall was put against the toe of the eroded slope, so fill material of sandy soil was used to fill up the cribwall. The brushlayers were placed so that the cut ends would be against the native soil on the bank, allowing the roots to grow into the bank, increasing the strength of the cribwall.

Comments:
The cribwall frame is in good shape, but the growth of the brushlayers was only partially successful. The willow cuttings grew well, but the dogwood cuttings did not. The lower brushlayer did not grow too well. There were three reasons attributed for the poor growth from the cribwall:

1. The cribwall face was vertical, and thus the top brushlayer created too much shade for the lower brushlayer.
2. The cribwall faces north, so little direct sunlight reached the brushlayers.
3. The brushlayers were not continuous. Some spaces were left between cuttings within the two rows of brushlayers. These spaces were considered to be weak spots in the uniform growth of the brushlayers.

Debris removal from the site was considered to have increased erosion of the streambed observed below the base of the cribwall, lowering the streambed about 0.5 m The cribwall itself, however, was not undercut.

Source: Grillmayer, 1995

Contact: Rick Grillmayer, Nottawasaga Valley CA (705) 424-1479

22. Black Ash Creek Cribwall #2, Collingwood

Location: Collingwood city limits at Concession 10 and Poplar Side road (100 m upstream of Case Study 21)
Started: Preparation of cribwall site - November 8, 1993
Construction of wall - November 22 - 26, 1993
Finished: Final landscaping - December 4, 1993
Duration: Seven days
Approximate Project Cost: \$6,200 (Detailed costs listed in Grillmayer, 1995)
Funded By: Collingwood Harbour RAP stakeholders

Description:
The project site is a deep road ditch (about 2.5 m) at the side of the road, which is a channelized length of the south branch of Black Ash Creek. A long cribwall of jack pine logs with bark (34 m long, 1.2 m high, 2 m deep) was built into the bank, opposite from where a taller concrete block wall (road side) was later built. The cribwall is on private property, whereas the concrete block wall was built beside the road, and thus on a township road allowance. The downstream end of the cribwall bends around a curve, joining the channelized section of the creek to its natural flow path. Flows in the ditch vary greatly. The site carries the runoff from an area of about 15 km^2. There is often no flow, yet peak flows are estimated to be at 3 to 4 m^3 per second. The bank soil is silty sand.

The cribwall was built into the bank, due to space limitations. Excavation of the bank allowed for the cribwall face to be located at about the same place as the original bank. The bottom of the cribwall was constructed so that its base would be slightly below the creekbed. This was to prevent undercutting of the cribwall. The face of the cribwall was sloped slightly to allow more sunlight to the lower brushlayers growing from the crib, and to allow greater flow capacity. The horizontal logs on the face of the cribwall were overlapped at the cross-logs (positioned into the bank), such that the cut ends of the logs faced downstream. This prevented water from flowing directly against the cut ends of the logs, which would have increased strain on the cribwall. Willow and dogwood cuttings (sandbar willow, shining willow, and red osier dogwood) used in the cribwall were harvested from various locations and were all 1 to 3 years old. The cuttings were used within a day of harvesting.

A single brushlayer was installed 0.5 m above the top of the cribwall. Remaining exposed soil above the cribwall was seeded with a rye/oat seed mixture and covered with a geotextile netting.

Source: Grillmayer, 1995

Comments:
Vegetation growing from the cribwall is thick and in good condition.

The concrete wall opposing the cribwall was constructed in 1995, and is made of thick concrete blocks five layers high. Being on the road allowance, it was designed by the Town of Collingwood, whereas the cribwall was designed by the NVCA. Erosion of the concrete wall is evident on many of the block faces. It has also become partially undercut at its downstream corner and along the mid-section, despite the placement of rip-rap along the bottom of the ditch after the wall was built. Fragments from the concrete blocks are apparent and some of these have been swept into the brushlayers growing out of the cribwall. Storm flows have been strong enough to carry fragments and stones of up to 25 cm into the cribwall. Some of the soil within the cribwall has been eroded away, however the overall integrity of the cribwall is considered to have been unaffected.

Of all the case studies documented, this site contains the best comparison of the independent uses of bioengineering and hard structures. This is because the two walls face each other in close proximity and are responsible for protecting against virtually identical erosive forces. Although the live cribwall was constructed before the concrete wall, the concrete wall appears to be in more danger of failing.

Contact: Rick Grillmayer, Nottawasaga Valley CA (705) 424-1479

23. Black Ash Creek Gully Stabilization, Collingwood

Location: South branch of Black Ash Creek, at Concession 10 and Poplar Side Road (45m downstream of Case Study #21)
Started: December 4, 1992
Duration: 1.5 days
Approximate Project Cost: Unavailable
Funded By: Collingwood Harbour RAP stakeholders

Description:
The site is on a large private lot along 8 m of the south branch of the Black Ash Creek. Surface runoff from 0.25 ha. of a farm field had eroded one bank of the creek, forming a small gully. Three rows of brushlayers spaced 2 m apart were planted into the gully. Fascines secured by live stakes were planted between the brushlayers and angled down towards the centre of the gully to channel the runoff. Live stakes were also placed in bare soil between the brushlayers. All live stakes used were shrub willows. All live materials were cut one day before installation (Grillmayer, 1995).

Over two years after this project was completed, it was considered to have been successful. In the summer of 1995, the site was set up to examine the depth of the willow roots. Heavy rip-rap was placed on the lower half of the gully, and some of the old upper brushlayers were put under a high pressure spray of water. The soil around the roots was intentionally washed out, and the root depth was measured. It was found that the root structure went as far down as 1.5 m into the soil.

Comments:
This is the only case study to document measurements made on the root structures of live materials used in bioengineering, years after planting. The fact that willow tree roots of a common species (shrub willow) can grow 1.5 m into the soil within the third growing season indicates that willows can be a powerful soil stabilizer after just a few years. This assumption can be made when comparing the high success rate of younger brushlayers that have more shallow root structures.

The lower bank, with the rip-rap protection, was not significantly affected by the high pressure water spray. The quantity of riprap used was considered to be greater than required.

Contact: Rick Grillmayer, Nottawasaga Valley CA (705) 424-1479

24. Cairns Blvd., Willow Creek, Midhurst

Location: Cairns Blvd.
Started: Fall, 1996
Duration: Unknown
Approximate Project Cost: $1, 561
Funded By: Half was funded by the Springwater Township. The other half came from funding for 20 different projects under the NVCA Land and Water Program. This includes the following groups: GLCUF, Ontario Federation of Anglers & Hunters, Barrie Hunters, Canada Trust, North Simcoe Environmental Watch, Nottawasaga Region Dinner Committee

Description:
This site spans about 30 m of Willow Creek in a residential neighbourhood. A small park runs along this stretch, starting at a pedestrian bridge. Fascines exist underneath the bridge. Just downstream from the bridge, the creek takes a sharp bend. At this bend is a high sandy bank which is partially on private property. Sparsely growing brushlayers, comprising a mix of willow species remain on this bank. Layers of fieldstone protect the base of this bank. An interpretive sign was put up beside the bridge, explaining the basic concept of bioengineering done at the site, and the project partners involved (listed above).

Comments:
The sign gives a brief history of the project. In April 1996, a large section of the sandy bank collapsed. This collapse was a result of stone protection put at the base of the bridge. Rocks had been placed at the base of the bridge abutments to protect against erosion, but this rock protection had constricted the flow route under the bridge. This in turn accelerated the flow of the creek, causing the increase in flow at the base of the sandy bank. The rocks were removed and were replaced with brushmattresses.

At the time of inspection (October, 1998) brushmattresses were no longer underneath the bridge, although fascines were there. Live stakes were also planted during construction, and these have disappeared as well. The brushmattresses and live stakes were lost to vandalism. The willow brushlayers on the large sandy bank are in poor condition and have been damaged by pedestrian traffic. It is important to note that willow trees grow best in moist soil, and the bank that they were planted on is sandy and well drained. The brushlayers, in their present condition, do not appear to be strong enough to prevent the bank from slumping or sliding, even with the fieldstone protection at its base.

Of all the case studies, this site has perhaps undergone the most damage as a result of vandalism. This is in spite of an on site explanatory sign on bioengineering. The NVCA intends to fence off similar future projects in urban areas.

Contact: Rick Grillmayer, Nottawasaga Valley CA (705) 424-1479

25. Findlay Mill Rd, Willow Creek, Midhurst

Location: Watte Rd. and Findlay Mill Rd.
Started: Fall, 1996
Duration: Unknown
Approximate Project Cost: $12,000
Funded By: Springwater Township Roads Department (50%) and the NVCA Land and Water Program (GLCUF, Ontario Federation of Anglers & Hunters, Barrie Hunters, Canada Trust, North Simcoe Environmental Watch, Nottawasaga Region Dinner Committee)

Description:
This site is in the same residential neighbourhood as Case Study #24. It is situated along Willow Creek below a public walking path, where the watercourse flows about 4 m wide. A steep sandy bank about 10 m high was stabilized along a stretch of about 25 m, using fascines, brushlayers, and live willow stakes. Overall, alternating rows of brush layers and fascines, both with mild growth, are effectively stabilizing the bank. Thick live willow stakes were planted randomly among the fascines and brushlayers, but these have failed to grow.

Comments:
Boulders were originally placed at the base of the bank. Erosion of the base of the bank occurred after this, and the boulders have since become displaced. The original design called for a combination of root wads and smaller rock (about one quarter of the size of the boulders used).

A pool was formed at the base of the boulders in the spring of 1997. Previously, a shallow riffle had existed there. Some of these boulders have since slumped into the pool, which is increasing in size.

Although the steep bank has been well stabilized using bioengineering techniques, the base of the bank has apparently not been adequately protected, which may jeopardize the upper bank with undercutting. Growth of the brushlayers and fascines has not been as extensive as typical bioengineered sites, which may be due to the well drained, poor nutrient content of the sandy soil. As a result, the bank does not appear to be strong enough to resist undercutting from the creek, even though the growth of the brushlayers and fascines may be strong enough to keep the soil from sliding down the bank.

Contact: Rick Grillmayer, Nottawasaga Valley CA (705) 424-1479

26. Glen Huron Cribwall, Glen Huron

Location: A few kilometres south-east of Glen Huron, on the Mad River
Started: Fall, 1993
Duration: About a month
Approximate Project Cost: $35,000
Funded By: Township of Clearview

Description:
Bank erosion was occurring within a road right of way along a bend in the Mad River. In response to this, a cribwall was built along the bend at the base of a deep bank, located between the road clearance and private property. Brushlayers of willows and dogwoods were planted along much of the bank. Fascines were installed along the top of the cribwall.

Comments:
Armouring of the bank was considered to be too expensive, so bioengineering was chosen.

The brushlayers are growing well. Some local plant species have started growing among them.

In the fall of 1995, a section of the bank needed repair due to drainage from a road culvert eroding the brushlayers. The culvert was not taken into consideration in the design process because its existence was unknown to those responsible for the bioengineering design. A small channel was installed for the culvert.

Flooding of the river occurred in the spring of 1996. The water level rose over the cribwall and onto the bank, yet no major damage was done to the site.

Contact: Rick Grillmayer, Nottawasaga Valley CA (705) 424-1479

27. Harbourview Park, Collingwood

Location: Collingwood harbourfront
Started: October, 1996
Duration: About four months
Approximate Project Cost: $80,000
Funded By: Action 21

Description:
Harbourview park is a large park in Collingwood with about 1 km of shoreline on Nottawasaga Bay. Prior to becoming a park, three industries existed by the site. These industries used the area as a landfill, leaving the area covered in waste materials by-products. This area was later covered over with soil, before becoming a public park. About 500 metres of the shoreline was bioengineered.

The main feature for erosion control at the park was the installment of rounded, natural looking boulders along the edge of the low-sloping shoreline. These serve as both erosion control and fish habitat. Behind these were planted brushmattresses and live stakes. Jewel weed, a native species, has grown up among the brushmattresses.

Comments:
The boulders lining the shoreline are considered to have been effective in reducing erosion, particularly from ice scouring. Growth from the brushmattresses is thick and healthy.

Previous bioengineering work done in Harbourview Park was done under the Collingwood Harbour Habitat Enhancement program sponsored by the GLCUF. This included the planting of a 50 m by 10 m bush lot within the park, and plantings of over 10,000 trees along a shoreline section of the harbour for habitat enhancement Also under the project, a small bay was excavated at the mouth of a canal (Oak Street canal) to establish a wetland. A geotextile mat of coir (coconut husk) was installed on the bank using live willow stakes. The bay was created by the Collingwood Harbour Habitat Team (GLCUF web page).

Contacts: Rick Grillmayer, Nottawasaga Valley CA (705) 424-1479
Jim Collis, Environment Network (705) 446-0551

28. <u>Morrison Property, Nottawa</u>

Location: East side of Hwy. 24 on the north side of Nottawa.
Started: Mid-November, 1996
Duration: Three days with three people
Approximate Project Cost: $8,000
Funded By: The land owner (50%) and the NVCA Land and Water Program (GLCUF, Ontario Federation of Anglers & Hunters, Barrie Hunters, Canada Trust, North Simcoe Environmental Watch, Nottawasaga Region Dinner Committee)

Description:
This site is entirely on a private farm lot, along a 55 m bend of the Pretty River (which drains an area of 78 km^2). The river at the site is below a steep clay bank (about 4 m high) beside a service road on the lot. The bend at the site is quite sharp. This feature in combination with high flow velocities resulted in the natural riverbed at the bend being washed away, exposing the clay. Erosion of up to 1 metre per year was occurring on the nearly vertical bank.

The bank slope was taken back towards the service road just enough to allow the placement of small boulders along the base of the bank. Willow posts and stakes were planted at varying angles among these boulders, creating a "live rock" revetment. A small natural stand of dogwoods at the base of the bank was left undisturbed. A small vortex weir was installed upstream of the live rock revetment to reduce and redirect the velocities away from the toe of the bank.

Comments:
All the live posts and stakes used were taken from directly across the creek, where a natural stand of young willow trees exists. It only took two days to gather the required amount of willow cuttings, and only one day to put the boulders, posts, and live stakes in with a work crew of three people.

A mature willow tree at the downstream end of the site is successfully diverting some flow away from the bank by its root structure. It is expected that the willow stakes and posts placed at the site will eventually do the same.

Due to the heavy cohesiveness of the clay bank, it was considered to be too expensive to install a cribwall. The project has, however, so far been successful in stabilizing the bank. The rocks have stayed in place and are still protecting the cuttings. The riverbed at the bend has been re-established since the project completion.

Contact: Rick Grillmayer, Nottawasaga Valley CA (705) 424-1479

29. Scott's Plains Park, Peterborough

Location: Otonabee River at Charlotte St.
Started: November, 1997
Finished: February, 1998
Approximate Project Cost: $335,000
Approximate Bioengineering Cost: $35,000
Funded By: City of Peterborough

Description:
The site is in a park in an urban area, and runs along 380 m on the west bank of the Otonabee River in Peterborough. The river is about 180 m wide by the site. The site had a history of erosion problems. Around the turn of the century, the site was filled in twice by garbage dumps which were eroded by the river over the years. When it was decided to stop the erosion, there were fears that this would remove fish habitat. A design incorporating extensive underwater root wad layers was used to maintain this habitat. The root wads were held in place by underwater log structures filled with rip-rap. Large riprap was placed along the lower bank above the root wads. Above this rip-rap, brushlayers were planted.

Comments:
Prior to the start of construction, field analysis of the site commenced in December, 1996. A series of specific inventories were conducted on the following areas:

Dec. 1996 to June, 1997	Bank vegetation
May to June, 1997	Hydraulic / hydrology
June to July, 1997	Fisheries
July to August, 1997	Fluvial geomorphology
August, 1997	Geotechnical / soil chemistry

The final design was completed in September, 1997. Monitoring is scheduled to commence in the spring of 1999, and continue through 2000.

The project appears to have been successful. The brushlayers are growing well, and the rip-rap is successfully protecting the bank.

Contact: Mark Peacock, Otonabee CA (705) 745-5791

30. Bluffer's Park, Scarborough

Location: Brimley Ave., at the lakeshore
Started: Early 1980's
Duration: Unknown
Approximate Project Cost: $6 million
Funded By: Various levels of government

Description:
Very high and steep shear faced bluffs of clay meet Lake Ontario on parkland. The parkland has an area of 42 hectares, including 32.4 hectares of lakefill (Metro Services web site). The bluffs are partially protected by an extension of lakefill, which is in turn protected by armourstone. The land extension bends so that some parts are parallel to the shoreline, creating a protected, artificial bay. Planted trees thrive along the extension. The artificial bay has been closed to the public, and left as a natural regeneration area. Young trees are growing up along the shoreline of this bay, and a variety of birds and waterfowl inhabit the area. The site includes a public boat launch and marina, scenic look-out points, and a restaurant.

Comments:
While no brushlayers, fascines or live stakes have been used at Bluffer's park, a natural approach to erosion control is incorporated into the design, outside of the fact that lakefill was used to create protective headlands. It is significant to note that the site is exposed to wave action from a long fetch in Lake Ontario, yet no concrete shorewalls exist. Above the protective layering of armourstone, many tree species have been planted, combining deciduous with coniferous trees. Good public access to the lake exists throughout the park. A path goes along the lakefill.

Much of the expense for this project went into park facilities such as the marina, washrooms, and pathways, which contributed to making the cost as high as it is.

Contact: Toronto Economic Development, Tourism, and Culture (416) 392-8186

31. Boyd Conservation Lands, East Humber River

Location: Boyd Conservation Lands (Rutherford Rd., south side).
Started: 1995
Duration: Ongoing
Approximate Project Cost: $70,500
Funded By: GLCUF, Ontario Streams (MNR-Community Fisheries Involvement Program), TRCA, Canadian Highways International Corp., Friends of the Environment Foundation, Ontario Federation of Anglers and Hunters.

The site is within a large conservation area, administered by the Toronto and Region CA. The Humber River meanders greatly through the site, where high eroding bluffs exist, winding for 5.8 km. Project objectives were for rehabilitating coldwater fish habitat while improving water quality. This was done through riparian tree planting and the bioengineering of eroding slopes. Seven cabled log jams and two lunkers (fish habitat structures) were placed in addition to cribwalls placed along various meander bends throughout the area. Triangular shaped log deflectors (wing deflectors) have been placed along some banks of the river, which serve to deflect flows and produce scour pools (granular bottom good for fish habitat). These deflectors are simply extensions of logs from the bank, which protrude about one third into the river along the surface of the water, in the shape of a triangle. Along the banks where cribwalls have been placed, trees were often planted, being coniferous varieties combined with balsam poplar. Burlap matting was placed along the base of some of these banks, with seeds of various varieties of plants. On one L-shaped bank, several metres of land was reclaimed at the toe of a steep slope, where a log jam was created.

Comments:
Some bluffs in the area are over 25 m high.

Contact: Mark Heaton, MNR, Aurora District (905) 713-7406

32. Cedarbrook Park, Scarborough

Location: East Park Blvd.
Started: September, 1996
Finished: Summer, 1997
Approximate Project Cost: $430,000
Funded By: City of Scarborough (now City of Toronto - Scarborough District)

Description:
This site is in a municipal park in a residential neighbourhood, spanning 630 m of the West Highland Creek. The creek was reshaped so that a natural meander pattern would exist. A wide flow path was used (about 5 m), so flows are low. The banks are low sloping. Rip-rap was placed at the edge and to a lesser extent, along the base of the watercourse. River run stone and geotextile matting was used along some bends. Live stakes were also placed throughout the site, by the watercourse.

Comments:
The site has good public exposure being in a large park with a walking trail and community centre. The live stakes appear to be growing well, and the banks are stable.

Contact: Mark Schollen, Schollen & Company Ltd. (416) 441-3044

33. Cold Creek, Bolton

Location: Hwy. 50 and King St.
Started: May, 1997
Duration: Within five months (included in road improvement project)
Approximate Bioengineering Cost: $36,000
Funded By: Region of York

Description:
The site is on the Humber River, beside a secondary highway. An eroding slope of clay included in a span of about 30 m along the river was bioengineered. In a fenced off area, 20 root wads were placed along the base of the eroding bank. Filter fabric was used on the slope to prevent silt from getting into the stream. A coir fabric mat was placed on the slope and used as an alternative to mulching. Live stakes of willow and red osier dogwood trees and shrubs were put into the bank.

Comments:
Work on Cold Creek was incorporated into a bridge replacement and road improvement project, with an overall cost of about $580,000. The project was delayed for a season, allowing erosion to significantly increase in the first part of 1997.

Contacts: Mark Heaton, MNR, Aurora District (905) 713-7406
Lennard Ng, Region of York (905) 895-1200 Ext. 5073

34. Fundale Park, Woodbridge

Location: Islington Ave., north of Hwy. 7.
Completed: January, 1997
Duration: Three weeks
Approximate Project Cost: $17,410
Approximate Bioengineering Cost: $15,690
Funded by: TRCA and the Town of Vaughan

Description:
The East Humber River runs through Fundale Park, being about 500 m from its confluence with the Humber River. The site spans about 80 m along a bank that was being eroded. River boulders were toed in along the base of the bank to prevent serious ice scouring and undercutting of the structure during establishment. A cribwall stocked with shrub willows and dogwoods was built into the bank above the boulders. A coir log, held by dead stakes, was then placed above the cribwall to prevent sediment from entering the watercourse. The upper portion of the bank was regraded to a lower slope (about 4:1). The regraded portion of the bank was seeded and planted with riparian shrubs in the spring of 1997.

Comments:
The cribwall was made from 150 mm diameter pointed cedar fence posts. These posts were driven into the bank by a backhoe, providing the advantage of not having to excavate the native soil. Some foot traffic exists along the top of the bank, causing minor hindrance to the growth of vegetation.

Contact: Dave Rogalsky, Toronto Region CA (905) 851-2809

35. Grenadier Pond, Toronto

Location: High Park
Started: 1994
Duration: Ongoing
Approximate Project Cost: $1.5 million
Includes:
Shoreline Softening: $400,000
North Wetland: $200,000
Sedimentation Pond: $900,000
Funded By: GLCUF, Toronto RAP, Toronto and Region CA, Ducks Unlimited Canada, Canadian National Sportsmen's Shows, Toronto Economic Development, Tourism, and Culture.

Description:
Grenadier Pond is in an urban park, and is about 1.5 km long with a total pond area of about 19 ha. Residential subdivisions flank the west side of the pond. High Park is on the east side, with a footpath and boardwalk along the shore. The north section of the pond narrows considerably, and this location has been rehabilitated to support a wetland environment. Approximately 500 m of the pond has been revegetated along its banks. These banks have been regraded to a lower slope. A weir was installed at the south (draining) end of the pond to lower water levels on a seasonal basis, which exposed mud flats. This was to encourage natural seed germination and habitat restoration. The south-west shore of the pond is fenced off to the public, and has received much of the bioengineering for shoreline softening, which is ongoing.

The project for Grenadier Pond (excluding an existing sedimentation pond) was designed to re-introduce native wetland and meadow plant material such as water lilies, sweet flag and native grasses. The west and north shores of the pond already have these species. Fish, turtle, and bird habitat was also to be improved. Wetland areas created as a result of the project are expected to filter and improve water quality. Fish stocking was carried out in 1994.

At the north end of the pond, there is a small sedimentation pond which was bioengineered and re-graded to a 3:1 bank slope in 1996. This pond is separated from Grenadier Pond only by a narrow extension of land no wider than a foot path. The sedimentation pond collects sediment from Wendigo Creek and 104 ha of road storm sewers north of Bloor Street. The pond is designed to collect about 330 tonnes of sediment over 5 years before dredging is necessary (Toronto Parks and Recreation, 1996). It has, however, needed dredging after just two years (David Stonehouse, personal communication). A concrete bypass exists beside the pond for storm events. All around the pond's circumference, there are new plantings of live willow stakes and fascines. Along one section there is a live cribwall stocked with willow cuttings.

Comments:
The North Sedimentation Pond has been in existence for over 14 years. It was created to catch and trap contaminated sediments, including algae producing salines from storm sewer runoff that would otherwise have gone into Grenadier Pond (Hall, 1984). The storage volume of the original pond was 150 m^3. It was estimated that 4,600 m^3 storage was required, due in part to the build-up of sediments that reduce the holding capacity of the pond. Since the pond could not hold nearly the estimated volume of water to prevent overflow, it threatened the adjacent lands, which included a children's playground. The new capacity of the pond with the removal of concrete and sediment is now about 2,600m^3 (Murray Boyce, personal communication). Although this is still not the required amount of volume, it is a big improvement, and the children's playground was not lost.

All bioengineering designs at Grenadier Pond and the North Sedimentation Pond appear to have been successful.

Contact: Murray Boyce, Toronto Parks and Recreation (416) 392-0584

36. Harbour Square Park, Toronto

Location: Queens Quay and York St.
Started: Spring, 1998
Duration: Five days with a workforce of two.
Approximate Project Cost: $ 9,840
Approximate Bioengineering Cost: $ 8,600
Funded by: City of Toronto

Description:
A 65 m long, by about 2.5 m high bank exists at the shore of Toronto Harbour in an urban setting. The site is protected from extreme wave action by the Toronto Islands, and a boardwalk just above the water, following the length of the site. The base of the 1:1 bank slope contains small rip-rap stone. The slope contains alternating rows of fascines and brush layers (five layers of each), containing shrub willows (primarily on the lower slope) and red osier and gray dogwoods (primarily on the upper slope). The top of the bank has planted red osier dogwood and several alder trees measuring about 3 m high. The soil at the site is a mix of imported sand and gravel, and was tamped down for aeration to speed the growth of the vegetation.

Comments:
A condominium complex exists beside the site. Area residents wanted a soft approach to the shoreline stabilization, so a bioengineering design was incorporated. This project was originally started in the spring of 1997, but failed because the toe of the slope was undermined by wave action due to higher than expected lake levels. The TRCA was called in to reconstruct the project incorporating rip-rap toe protection to compensate for these high lake levels. The project was successfully re-done in the spring of 1998. Occasional trimming of the vegetation may be necessary to thicken future growth, since bare soil still exists around the plantings.

The variety of trees used are not only are good for soil stability, but are also aesthetically pleasing. All the willow and dogwood cuttings and fascines needed for the project were carried on one truck load.

Contacts: Dave Rogalsky, TRCA (905) 851-2809
Bob Duguid, City of Toronto Parks (416) 392-1925

37. Highland Creek, Scarborough

Location: Large area south of Hwy. 401, and west of Markham Rd.
Started: 1997
Duration: Ongoing
Approximate Project Cost: $2.9 million
Removal of soil: $975,000
Engineering and preparation: $700,000
Approximate Bioengineering Cost: $400,000
Funded By: City of Scarborough (now City of Toronto - Scarborough District), Co-operators Insurance, Friends of Highland Creek, MNR.

Description:
Highland Creek underwent a major natural channel design with very extensive bioengineering. The length of the site goes for 1.5 km between commercial lots, and crosses three main roads (Corporate Dr., Progress Ave., and Bellamy Rd.). The site itself is on public property. A wide open channel (3:1 slope) was created in a large natural channel design shape incorporating meanders and riffle sections, with the excavation of 135,000 m^3 of soil. Many forms of bioengineering were used, including an extensive use of brushmattressing and fascine combinations. River run stone is used throughout the site, mainly at the base of the watercourse and floodplain. Vortex rock weirs are also used along some sections. Armourstone walls start at the east site boundary. The watercourse varies in width, narrowing at riffle sections, but is generally about 4 m wide.

A floodplain was created beside the watercourse. This floodplain is expanded along the west section of the site, in order to contain a designed flow route from a large storm sewer outfall, which in turn discharges into the main watercourse. A half circle of fascines held by dead stakes was created near the discharge of this flow route. In the eastern section, the floodplain contains a pond lined with river run stone, attached to a narrow wetland styled channel. Both the west and east ends of the floodplain contain habitat features that consist of a single log positioned across the designed flow path, held firm at both ends by rounded boulders.

A large variety of plant species were planted at the site. In addition to usual willow and dogwood cuttings, many individual trees were planted along the upper banks. Some sumac and scotch pine trees, several years old, were planted. Buckwheat rye was also planted. Some trees were planted in the floodplain in biodegradable pots. The wetland styled area beside the pond was lined with cattails. Most of the site has been hydroseeded with mulch. Some weeds have taken root, especially in the west floodplain area.

The bioengineering combinations are unique at this site. The brushmattresses were lain in long rows, entirely on the surface of the bank near the watercourse. The branches were staggered so that growth existed at both ends of the rows. Two lengths of rope, tied onto dead stakes, held down each end of the brushmattress. The fascines were held down by dead stakes and sometimes were in rows of two. Growth from the fascines was moderate at best, and many were dead.

Cribwalls were placed on some of the outside bends in the meander pattern. These were low lying with only two horizontal log rows from which willow cuttings grew out between. All the cribwalls were in good shape and contained good growth.

Erosion is still a problem throughout the site. The soil is very sandy and is easily swept away. Many of the brushmattresses and fascines were swept away before they could firmly root into the soil. About as much as one third of all the brushmattresses were washed out. Erosion even exists in the western floodplain, along the flow route from the storm sewer outfall. This is despite wild weeds and planted trees that exist along this section.

Comments:
This is the largest project of its kind in Ontario, and possibly includes the largest number of interest groups. It's the most expensive riverine site of all the case studies. There is an active citizens' group, "Friends of Highland Creek" who have met once a month since the spring of 1997, for discussions on the creek and the project. It is likely that through this group, so many side projects have been funded. These projects include a small snake hybernacilum ($2,000 grant from the MNR and donation of sumac, cedar and raspberry plantings), fundraising through the Co-Operator's for trees and aquatic plantings ($16,000), and a future video to be produced by the municipality ($15,000). A public trail is scheduled to go along the creek within the project site. Three consultants aided the former City of Scarborough in design and preparation for the creek.

The poor growth that some of the cuttings had were considered to be due to the planting methodology combined with the past winter. The cuttings may not have been handled properly (e.g. they may not have been planted in time). The past winter provided very little snow cover for the brushmattresses and fascines. This lack of cover may have killed off some of the cuttings.

The severe erosion that has occurred at this site appears to be due to the soil and flow conditions. There were difficulties with inserting the dead stakes holding down the brushmattresses, due to the density of the sandy soil which has a high clay content. Some dead stakes may not have been inserted deep enough into the ground as a result. The high erodibility of sandy soil makes it easier for newly planted cuttings to become uprooted and swept away when the cuttings are exposed to high flow velocities, as has happened. The large quantity of soil that was removed for natural channel design (135,000 m^3) made it possible to decrease flow velocities with the creation of meander patterns and a wider floodplain. This, however, did not change the fact that the site drains a large urban area, which has larger associated flows and less groundwater retention than rural lands, thus creating larger variations in flow velocities. Some of the brushmattresses lost to erosion will be replaced.

Mulch from hydroseeding had been recently added to the site prior to inspection (September, 1998), in an attempt to quickly stabilize the bare sandy soil. Some of the planted scotch pines along the slope were killed by this, as they were sprayed as well.

A maintenance and frequency report on Highland Creek should eventually be available from the municipality.

Contact: Grant Taylor, City of Scarborough (416) 396-7689

38. Little Etobicoke Creek, Mississauga

Location: West of Dixie Rd. between Burnhamthorpe Rd. East and Bloor St.
Started: January, 1996
Duration: Two months
Approximate Project Cost: $300,000 (Phase 1)
Approximate Bioengineering Cost: Not separated out
Funded by: City of Mississauga

Description:
About 1 km of the creek, all flowing through public land, within a residential area was re-constructed using natural channel design, and to a lesser extent, bioengineering using root wads, sod matting, brushmattresses, fascines and live stakes (north section). Ducks were spotted in this section. A large berm exists on the west side of the creek, (south portion of site) which is used as a walking path, but also protects property around an apartment building. Beside this, large willow trees are in the floodplain.

Comments:
An original attempt to utilize natural channel design did not succeed. This was considered to be due to the fact that the first project had an oversized channel with no plunge pool or sections to dissipate the flow energy, and undersized vortex rock weirs. As a result, the second attempt documented corrected these features (at the above cost), and the project now appears to be successful.

Immediately south of Bloor Street, the creek was remediated along a 600 m stretch in the early part of 1997 (Phase 2). This section incorporated cut stone rows (rock vanes), on the west bank, that slope down at opposing angles to the flow of the creek (i.e., the south, or downstream end of the rows of rocks are on the bank, whereas the north end of the rows are in the creek). The cost for this work was similar to that of Phase 1.

Little Etobicoke Creek is within the watershed of a fish survey being conducted by the Toronto and Region CA. The areas surveyed are the two watersheds of the Etobicoke and Mimico Creeks.

Contacts: Bob Levesque, City of Mississauga (905) 896-5144
Mississauga Recreation and Parks (905) 896-5384

39. Mimico Creek Estuary, Etobicoke

Location: Humber Bay Park (East flank)
Started: December 11, 1998
Duration: Three days
Approximate Project Cost: $5,000
Funded by: Toronto Region CA

Description:
A 30 metre long bank curves out into the Mimico Creek Estuary at Humber Bay Park, facing upstream. A foot bridge exists at the west end of the site, linking the east and west flanks of Humber Bay Park. Several rows of fascines and brushlayers, containing a mix of willow and dogwood cuttings, were planted along the slope which has a width of 5 m with a maximum slope of 4:1. The fascines used were about 5 m long, placed in a shallow dug trench, and were secured with live willow stakes.

Comments:
A crew of two (sometimes three) people worked on the site, with one operating a backhoe. The lower two brushlayers were placed in a dug terrace and placed mainly parallel to each other. The third row of brushlayers were criss-crossed to allow for better soil stability, and were placed in a series of spaces made by the bucket of the backhoe. The bucket was aligned perpendicular to the bank, dug into the soil then lifted up just enough to allow the placing of cuttings. After the cuttings were placed, the soil in the bucket was dropped. This method insured that the original topsoil remained mainly in place. The upper two brushlayers contained red osier dogwood cuttings exclusively.

Rip-rap toe protection at the base of the bank existed before the project began. The total project cost ($4,964) thus reflects costs associated with bioengineering using soft materials exclusively (including labour).

Contact: Dave Rogalsky, Toronto Region CA (905) 851-2809

40. Morningside Tributary, Scarborough

Location: Metro Zoo, south property (behind asphalt plant)
Started: 1997
Duration: Ongoing
Approximate Project Cost: $41,200
Funded By: GLCUF, Fisheries and Oceans Canada, Rouge Park Alliance, Ontario Streams (MNR), Metropolitan Toronto Zoo, Metro East Anglers, Save the Rouge Valley System, Friends of the Rouge

Description:
The site is on a tributary of the Rouge River, on the Metropolitan Toronto Zoo property. The watershed of the tributary is 21.4 km^2 and supports warm, cool, and cold water fish species. The project objective is to restore 4.5 km of cool water fish habitat, and to control erosion (GLCUF web site). This includes an attempt to re-connect fragmented aquatic habitats. The site comprises two locations visited on the tributary, about 80 m apart.

The first location is a log weir (one of four to go in), made of cedar. It was to act as a fish ladder with the other three log weirs to be completed.

The second location is on a bank that was severely eroded. Pine Christmas trees were placed along the bank to slow flows and collect sediments. Sediments were collected by the trees. Live stakes are to be inserted into the sediment, so that they reach the water saturated sediment beneath. Log deflectors are also to go into this site.

Comments:
A few high school students and one MNR supervisor provided the labour for the work done at time of inspection. Volunteers have so far worked for over 298 hours. A large pile of rocks beside the log weir were scheduled to be put into the tributary by volunteers, to further aid erosion control.

Other work conducted for the overall area included debris/garbage cleanup, fish habitat lunkers, step pool fishways and 50 m of naturalized channel within an existing box culvert.

Contacts: Doug Forder, Ontario Streams (416) 678-8792
Mark Heaton, MNR, Aurora District (905) 713-7406

41. Rupert's Pond, West Don Greenway, Maple

Location: North-east of Rutherford Rd. and Keele St.
Started: Spring, 1998
Duration: Unfinished
Approximate Project Cost to date (August, 1998): $141,000 (includes: excavation, grading, stream channel naturalization, bioengineering, pathways, and plantings).
Approximate Bioengineering Cost: $3,000
Funded by: GLCUF, Town of Vaughan, and Toronto Region CA.

Description:
The Rupert's Pond watercourse is a tributary to the West Don River. This 500 m long reach is bordered by residential subdivisions on either side of the West Don Greenway. Due to the fact that the watercourse had been channelized (geo-web lined) during the residential development phase, the watercourse provided little in the way of habitat potential and was susceptible to fast flow events. Prior to 1990, about the only vegetation around the watercourse was cut grass. Through an ongoing partnership, the City of Vaughan and the TRCA initiated a riparian naturalization project in this reach which saw the establishment of new mowing limits and extensive tree and shrub plantings.

In 1998, the floodplain was expanded, providing for greater flood water capacity. This involved the excavation of about 2 m of soil within the eastern side of the floodplain, which was relocated on site to form a large berm. The first phase of a natural channel design was implemented, creating a meandering channel between two excavated open water marsh habitat cells in order to control the flow velocity and quantity for storm events. The new river stone channel is flanked by berms separating it from the two marsh cells. Grade control is achieved by stone weirs and habitat enhancements including rootwad installations. The berms are protected with a geotextile, live stakes and other shrub plantings. The shoreline around the ponds was vegetated with a native marsh basin seed mix and plantings on top of the banks. Two cribwalls incorporating shrub willows and dogwoods were created along a section of the pond during March, 1998.

Comments:
The Greenway is a fine example of how public green space can also be used as a floodway for major storm events. Floodplain reconfiguration and channel design provides additional buffering to the surrounding neighbourhood from potential high water levels and flows. The Greenway is highly accessible, as it can be entered from side streets and backyards. A pathway made up of recycled concrete stones winds it's way through the Greenway, inside the floodplain. Mallard ducks and herons are now a common sight.

Additional phases are planned for implementation.

Contacts: Dave Rogalsky, Toronto Region CA (905) 851-2809
Gary Misumi, Toronto Region CA (416) 661-6600 Ext. 293

42. Gibbons Park, London

Location: Gibbons Park on the North Thames River
Started: Fall, 1996
Duration: About 5 weeks
Approximate Project Cost: $250,000
Funded By: City of London

Description:
A long cribwall about 80 m long and 1.5 m high was built along one bank on the North Thames River in Gibbons Park. The cribwall was filled with mainly willow, but some dogwood cuttings as well. Square fir timbers were bolted together to form the cribwall, built beside the bank, and filled with sandy/gravelly soil. To help keep the soil inside the cribwall in place, a geotextile blend of woven and unwoven polypropylene and some cotton lined the base of the placed soil. Due to the gentle bend of the river, no bioremediation was considered necessary on the bank opposite the cribwall.

Comments:
Hydraulic studies were done for this site, prior to construction, which is included in the quoted cost of $250,000. A private contractor completed the project.

Contact: Brad Glasman, Upper Thames River CA (519) 451-2800 Ext. 251

43. Hall's Creek, Ingersol

Location: About 5 km south of Ingersol
Started: 1994
Duration: Three years
Approximate Project Cost: $25,000
Funded By: Wetlands/Woodlands/Wildlife (WWW) of Canada's Green Plan

Description:
The site is part of a 4 km reach of Halls Creek that was used as a demonstration project. The project was started in late 1994 to maintain drainage and encourage fish and wildlife habitat. The north section visited, incorporated two vortex weirs, live stakes, brushlayers, brushmattresses, root wads, and a coir log. The area around the creek is agricultural, with clay loam soils.

Live stakes were from shrub willow cuttings less than 1 m long with a maximum diameter of 25 mm. Shrub cuttings from different tree species used for the brushlayers and brushmattresses were 15 to 50 mm in diameter, being about 1 m long for the brushlayers, and up to 2 m long for the brushmattresses. The brushmattresses were placed in a trench with the tops facing upwards, and staked at 1 m intervals with dead and live stakes. Dutch white clover was used for immediate erosion control until tree cuttings could become better established. The root wads were from large diameter trees taken from a tree widening project. Trunk lengths were at least 3 m long and anchored into the stream bed with timber, boulders and earth. These have helped to improve fish populations (WWW, 1997).

Comments
The brushlayers, live stakes and brushmattresses were hard to identify because of the growth that had occurred since they were placed. The most successful tree species used were determined to be red osier dogwood, sandbar willow and pussy willow. Willow trees that grew from live stakes grew at varying rates, with a common growth of more than 1 m in the first growing season. The Dutch white clover was considered to have provided good temporary erosion protection, and did not impede tree growth. Wild growth was mixed with that growing up from plantings (WWW, 1997).

One main goal for the project was to improve cold water fish habitat. This was done in part by preventing cow crossings on the creek. Cows disturb the sediments in the creek, which discourages cold water fish habitat. Beginning in the Fall of 1996, 20 acres of land was put off limits to cows. Another method used to improve fish habitat was the placing of a coir log about a metre away from a bank, narrowing the watercourse channel by about 30% (WWW, 1997) This almost doubled the flow velocity, which swept away about 20 cm of fine sediment. This exposed coarser material (sand, gravel) and provided better cold water fish habitat. The shade from growing vegetation planted helps to cool the water temperatures. Wild watercress is abundant through the creek, which is a good indicator of cleaner water conditions. It was not growing before the project started.

As part of an educational event, high school students provided the majority of the labour involved for the Hall's Creek project. While the exact number is not known, several hundred students were estimated to have contributed over three years.

Creek flows were so low, that attempts were made to increase, rather than decrease the flows. Even when erosion is not a problem due to low flows, fish habitat can suffer. This project shows that bioengineering can work both to decrease, and increase stream flow velocities as needed.

Contact: Brad Glasman, Upper Thames River CA (519) 451-2800 Ext. 251

44. Harrington Conservation Area, Harrington

Location: Harrington (about 14 km south of Stratford)
Started: November, 1997
Duration: 1.5 days
Approximate Project Cost: $1,000 (all for materials)
Funded By: Harrington Social Club, Katimavik

Description:
The site is on a small lake within the Harrington Conservation Area. A small piece of shoreline was protected by a cribwall about 25 m long. The cribwall was made of round cedar timbers, and stocked with both willow and dogwood cuttings. About 2.5 m of land was reclaimed as a result of the cribwall construction beside the bank. Some brown eyed Susan's were planted along the top of the cribwall.

Comments:
The funding for this project was unique. All materials were paid for by a local club with an interest in conservation. Labour was provided by Katimavik, a Federal program allowing young people to travel and do community work. Only supervision was provided by the UTRCA, using a few staff members.

Contact: Brad Glasman, Upper Thames River CA (519) 451-2800 Ext. 251

45. Lake Victoria, Stratford

Location: Lake Victoria on the Avon River
Started: Summer, 1997
Duration: One day
Approximate Project Cost: $2,000
Funded By: Upper Thames River CA

Description:
The site spans a 24 m stretch along the north shore of Lake Victoria. Work on the shoreline was done for demonstration, rather than remedial purposes. A coir log, seeded with wetland species, was placed along the shoreline below the water level, and held in place by dead stakes. The coir log was placed to trap natural sediments, which would build up the shoreline and allow a protected base for the wetland plant species to grow. The coir log is also expected to keep carp away from the plants. A wood and rock fish habitat structure (about 3 m^2 of White Ash hardwood) extends out from the shoreline.

Iris plants were added to the shoreline at the site. The iris species is known to be unpalatable to waterfowl. Some of the iris plants, however appeared to have been eaten.

Comments:
The project was completed in one day by about 6 volunteers from the Upper Avon Conservation Club, and two UTRCA staff members. The main cost was the coir log, which was about $25 per foot (30 cm).

Since this was a demonstration project focusing on encouraging natural buildup of the shoreline, rather than erosion control, it will take a few years measurement of the overall success of the project.

Contact: Brad Glasman, Upper Thames River CA (519) 451-2800 Ext. 251

ACRONYMS

CA	Conservation Authority
CVCA	Credit Valley Conservation Authority
GLCUF	Great Lakes 2000 Cleanup Fund
GRCA	Grand River Conservation Authority
MNR	Ontario Ministry of Natural Resources
NPCA	Niagara Peninsula Conservation Authority
NVCA	Nottawasaga Valley Conservation Authority
RAP	Remedial Action Plan
TRCA	Toronto Region Conservation Authority
UTRCA	Upper Thames River Conservation Authority
WWW	Wetlands/Woodlands/Wildlife

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