MITIGATING IMPACTS OF SEWER CONSTRUCTION THROUGH WETLAND RESTORATION AND HABITAT CREATION: THE DEVIL'S CREEK TRUNK SEWER PROJECT

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ABSTRACT

In Canada, one of the major challenges associated with infrastructure development has been the need to maintain a balance between planned urban growth and expansion of services without compromising the commitment to protection of significant environmental features. With technologically advanced construction techniques, ecologically sustainable solutions with minimal impacts to environmental features are now more feasible economically and technically. For example, the Devil's Creek trunk sewer project was a sewer construction project that gradually evolved into a major ecological enhancement and restoration endeavour that persisted despite seemingly insurmountable constraints. The Devil's Creek project is the first Canadian microtunnelling application and sewer construction project to cross a provincially protected significant wetland and a regional environmentally sensitive area with full approval from all levels of government.

The Devil's Creek Valley is composed of a wetland and adjacent mature growth forest that is well-recognized for its size, quality, and rare species it supports. Its many significant features include a natural cold-water trout fishery and provincially significant plants and wildlife. Despite the need to protect the valley's natural features and functions, planning studies conducted as early as the 1970s indicated a need for sanitary sewer servicing to accommodate growth at Cambridge's west end. The most attractive alternative available in terms of minimizing cost, maintenance, and social disruption was a gravity sewer line along the natural valley system, with a potentially significant impact to the environment.

This paper presents the restoration measures used to reduce the level of impact from gravity sewer construction through 1.3 km of construction easement. A combination of restoration techniques and the results of two years of post-construction monitoring are presented to provide insight on the application of restoration measures for similar projects.

Introduction

The Devil's Creek Valley is situated along the west side of the City of Cambridge (population approximately 100,000) located 100 km west of Toronto, in an agricultural area of Ontario. The valley is comprised of a large 100-acre wetland and adjacent upland mature growth forest, which have undergone a minimal degree of human disturbance in the past. The valley is renowned for its flora and fauna occurring in a relatively pristine environment within the city limits. Because of these attributes, the area was designated as a provincially significant wetland and an environmentally sensitive policy area by both regional and provincial planning authorities. The

City of Cambridge is committed to protecting the wetland from the cumulative effects of development and human encroachment.

While the City of Cambridge owns a great deal of the property encompassed by the wetland, a significant portion of the remaining woodland and smaller wetlands are owned privately. Many of these private lands are currently undergoing development. The city's west end was experiencing rapid growth, placing a huge demand for sanitary sewer services. Development was also threatening to affect adjacent lands that are integral to the future sustainability of the wetland ecosystem. Much of the original hardwood forest that once lined the Devil's Creek Valley has been cleared, resulting in fragmentation. Along its remaining wetland communities, signs of urban encroachment are evident.

The location of the Devil's Creek Valley and the valley's floral and faunal attributes are shown on Figure 1.

The Need for Sanitary Sewer Servicing in the City of Cambridge

Because of increasing development pressure associated with westward expansion of the City, the need for sanitary sewer servicing was the primary constraint in limiting growth.

An aging pumping station, constructed as a temporary facility in 1967, had failed in one instance, resulting in a bypass of raw sewage to Devil's Creek. With this system in need of replacement, the only other alternatives were to construct a gravity sewer down a valley parallel to and crossing Devil's Creek at various points, including the wetland, or to pump the wastewater out with new or rebuilt pumping stations. Construction through city streets would incur major associated capital and continual operating costs.

When construction through the Devil's Creek Valley was presented as a feasible alternative, the potential impacts to the provincially significant and environmentally sensitive area became a controversy among local government agencies, public interest groups, and concerned citizens. These parties had to be satisfied that no long-term ecological damage to the valley would occur. The proposed sewer line could not change the wetland's water table, destroy mature woodlands, reduce wetland or function area, or disturb the habitat of endangered creatures. The planning process for the Devil's Creek project stretched from four months to four years because of public opposition, environmental restrictions and constraints placed on the project, and changing provincial legislation during the process (i.e. the Ministry of Natural Resources' Wetland Policy was enacted during the project).

Evaluating Alternatives

In accommodating the demand for future growth, the City of Cambridge and CH2M Gore & Storrie Limited, the project consultant, examined a number of servicing alternatives in great detail. These alternatives included two different pumping scenarios along city streets, each with a new pumping station or a gravity sewer. This evaluation indicated that all available options to upgrade existing infrastructure were costly in terms of construction as well as increased maintenance and risk of potential failure in the long term. The most attractive solution was the gravity sewer line along the natural valley system, but this option presented a potentially significant impact to the environment.

Three different scenarios for gravity sewer servicing were examined. The first involved a combination of open-cut and microtunnelled sections under a sensitive wetland and stream crossing. The second scenario was the worst-case variant of this approach assuming that the microtunnelling equipment could not be advanced due to an in situ obstruction, requiring it to be excavated and retrieved. The third approach involved an open-cut method with all efforts to minimize the extent of disturbance.

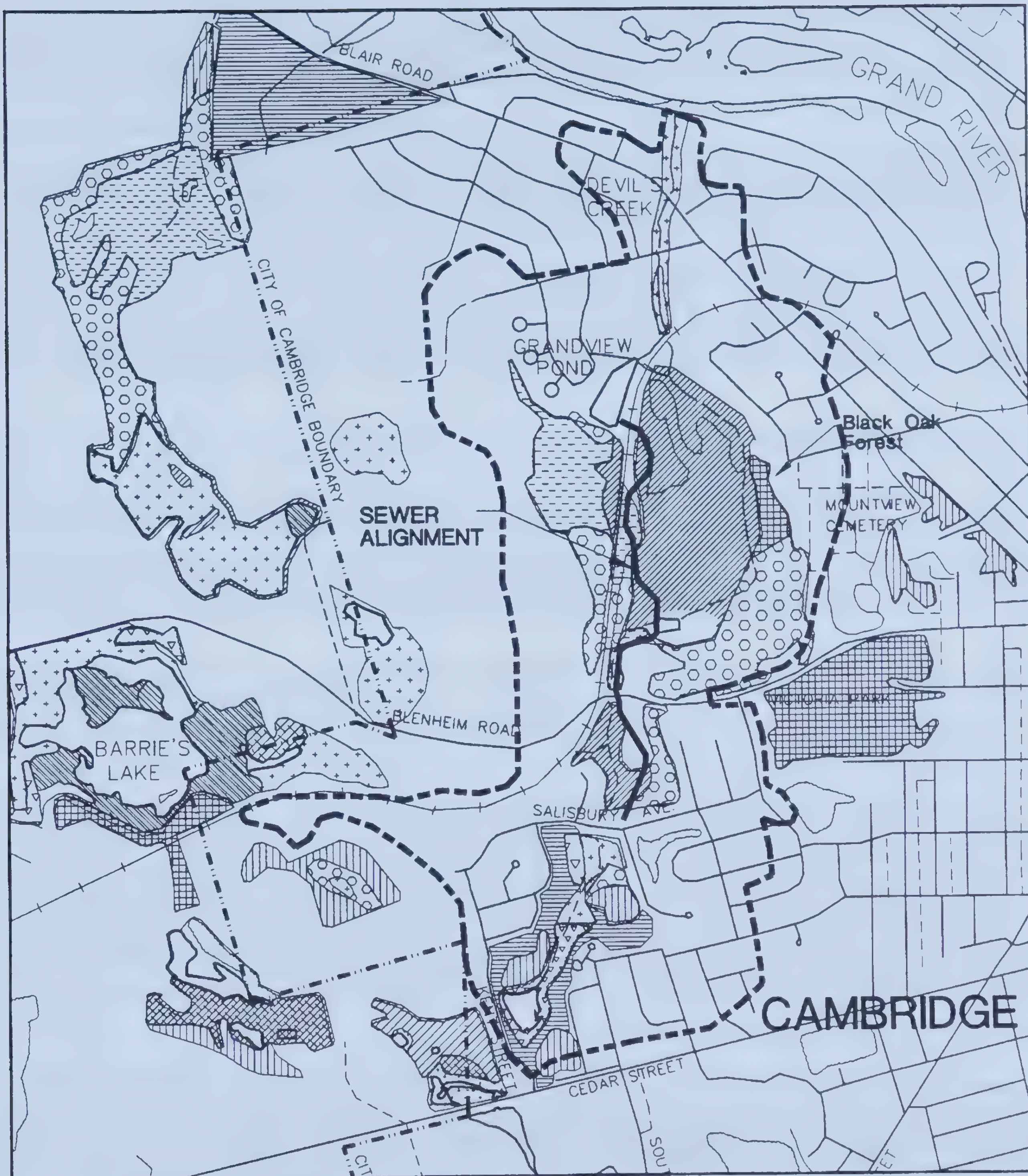

Figure 1

PLAN VIEW OF SANITARY SEWER ALIGNMENT THROUGH DEVIL'S CREEK WATERSHED

LEGEND

- Pine/Oak Forest
- Oak Forest
- Maple-Beech Forest
- Poplar/Manitoba Maple Forest
- Pine Plantation
- Black Cherry/Pine/Oak
- Old Field
- Tamarack/Leatherleaf Fen
- Deciduous Swamp
- Grass-Herb Marsh
- Willow/Buckthorn Shrub Swamp
- Leatherleaf/Carex Lasiocarpa Fen
- Devil's Creek Subwatershed Boundary

SOURCE (BASE) Ministry of Natural Resources Surveys and Mapping Branch, Ontario Base Map, 1983

0 100 200 300 400 500 METRES

The main differences among the alternatives were:

- The extent of habitat disturbance and potential loss to the wetland for the open-cut sewer, which ranged from 0.0 ha (pumping) to 0.53 ha

- The uncertainty that microtunnelling posed. Microtunnelling could reduce ecological damage, but the nature of the geological materials (gravels, tills) meant that there was a risk of having to excavate and retrieve the tunnelling equipment, causing significant damage

- The major cost differences – from $1.6 million to $3.0 million

Because of the strong views generated by the public and agencies against any loss of ecological features, an integrated strategy was developed, which neutralized opposition to the project and led to acceptance by all stakeholders.

The Preferred Alternative

The gravity sewer method was recommended as the preferred alternative, if steps were taken to minimize all possible environmental risks, from an operational and cost perspective. If the environment could be further improved with cost savings realized from this project (i.e. savings realized by constructing a gravity sewer instead of the more expensive pumping station), the chances of gaining public acceptance and agency approval were greater. The gravity sewer approach required approximately 1,500 m of 750-mm diameter sewer.

The city believed that a minor intrusion through the least sensitive and most disturbed portion of the valley parallel to an existing railway line and along an existing horse trail could be approved if the construction/ restoration plan could demonstrate no long-term impact to the wetland would occur and if the project could significantly improve the existing area over time.

Part of the savings that were accrued from choosing the gravity sewer method instead of the pumping station alternative were specifically set aside for environmental restoration and enhancement on a watershed scale. This $550,000 budget was established by Cambridge City Council to ensure the long-term viability of the Devil's Creek Valley following inevitable development after the construction and hookup of the sanitary sewer. Some of these funds (approximately $200,000) were used in 1996 to acquire private properties, which enhanced the important hydrological and biological connections beyond the immediate area impacted by sewer construction. The balance of the budget was to be spent on a watershed ecological enhancement program.

Easement Construction and Restoration Plan

A restoration plan was developed to address impacts from construction at the site level. The objective of the plan was to ensure that the habitat area affected by construction was retained as close to its original state as possible (with no net loss in habitat) and to enhance it by creating new habitat for wildlife.

In the development of the best routing for the sewer, all stakeholders from both government agencies and the general public were asked to indicate the location that would minimize their concerns, based on an ecological study of the wetland area. The composite route that was identified meandered around most of the sensitive wetland features (Figure 2). For this project, the usual "straight line" approach for engineering projects of this type was abandoned.

Ecological damage to the wetland was kept to a minimum by routing the line around significant flora and fauna and scheduling construction to avoid sensitive periods of the year.

The composite route was 20 percent greater in length and would disturb 21 percent less natural habitat than a comparable straight-line route, which had been recommended in an earlier engineering study. By scheduling construction during the winter, impacts to the wetland were minimized.

Vegetation Communities Before Construction

Vegetation along most of the proposed sewer route was classified as swamp (i.e. wooded wetland). A major portion of the route was dominated by wetland shrubs such as shining and pussy willow (*Salix lucida* and *S. disidor*, respectively) and red-osier and gray dogwoods (*Cornus stolonifera* and *C. racemosa*). Other parts were dominated by wetland trees such as hybrid willow (*Salix* x *rubens*), balsam poplar (*Populus balsamifera*), and elm (*Ulmus americana*). The understory was patchy, consisting of a variety of shrubs, herbs, and grass-like plants (graminoids), which were primarily native (76 percent). However, common and glossy buckthorn (*Rhamnus cathartica* and *R. frangula*, respectively) occurred abundantly throughout the swamp and formed a monoculture in some places.

A section at the south end of the route was vegetated by mature deciduous forest. At the north end of the deciduous forest, the route went through a pond with surrounding marsh vegetation, before proceeding through an adjacent sawmill (which was denuded of vegetation). This pond was degraded by deposition of sediments and heavy growths of green algae but, nonetheless, served as breeding habitat for yellow-spotted salamanders.

One other section was characterized as a transition zone between an area of successional upland vegetation and adjacent swamp. This area was cut to allow the sewer to pass and then filled and re-formed as a steeper slope after construction.

Wildlife Habitat Before Construction

The route was selected to follow existing openings along a horse trail, where bird species were typical of woodland edges and small patches of thicket or swamp — species that are ubiquitous in southern Ontario, such as Northern Cardinal, American Robin, and Rose-breasted Grosbeak. Mammals included species common of small woodlands or woodland edge, such as white-tailed deer and eastern chipmunk. Because little standing water was present along most of the route to provide breeding habitat for frogs and salamanders, few amphibian species existed. Breeding habitat for significant species of salamanders had been identified along some of the alternatives originally proposed for the sewer route. Amphibians noted along the route north of the deciduous forest were American toad and leopard frog. The pond at the north end of the deciduous forest provided breeding habitat for mole salamanders, though not the significant Jefferson's Complex salamanders, which were identified as a constraint along other alternative routes. The only reptiles noted were snapping and painted turtles.

Construction Methods

The preferred construction method consisted of closely regulated open-cut trench construction along the disturbed wetland portions of the route and trenchless microtunnelling through more sensitive areas, such as the deciduous forest.

The open-cut trench used a minimal construction easement width of no more than 11 m to allow for trench, spoil pile, and equipment movement along a vehicular access road beside the excavation. This easement was pinched in to approximately 6 m in specific areas to avoid specific features. It also required a few wider turning points along the route and an offsite storage area. By controlling all vehicular and construction width through this easement area, the area disturbed was minimized.

Figure 2

LOCATION OF THE DEVIL'S CREEK WATERSHED IN THE CITY OF CAMBRIDGE AND SIGNIFICANT SPECIES AND PLANT COMMUNITIES

LEGEND

SIGNIFICANT SPECIES

K1–5 Ambystoma Salamander 1991–1995
2 Smooth Solomon's Seal
3 Smartweed
4 Fringed Gentian
5 Hemlock Parsley
6 Black Mountain Rice
7 Clearweed
8 Thin-leaved Sedge
9 Golden Alexander
10 Pignut Hickory
11 Hill's Oak(tentative location)
12 Blue-leaved Willow
13 Hairy-fruited Sedge (widespread in fen)
14 Area-sensitive Bird Species
15 Necklace Sedge
16 Arrow-leaved Tearthumb
17 Water Shield (widespread in open water marsh)
18 Olive Spike-rush (widespread in fen)
19 Hard-stemmed bulrush (widespread in fen)
20 Water Dock
21 Carpenter's Square Figwort
22 Significant Marsh Bird Species

A1–A4 Ambystoma Salamander location only (1995)

Devil's Creek Subwatershed Boundary

SIGNIFICANT COMMUNITIES

Open Black Oak Forest

Leatherleaf/Carex Lasiocarpa Fen

SOURCE. (BASE) Ministry of Natural Resources Survey's and Mapping Branch, Ontario Base Map, 1983.

0 100 200 300 400 500

METRES

The use of high-strength pipe during construction was beneficial because it eliminated the need for bedding materials (i.e. clear stone) along the entire trench for pipe support. This pipe reduced material handling requirements and avoided the risk of lowering the natural water table through longitudinal water migration along the pipe.

Before the open-cut excavation, biologists conducted a detailed botanical survey of the construction easement. Plugs of significant plant material were identified for transplanting and saving. Native seed material was collected from plants indigenous to the wetland. During the winter construction period, this native plant material was grown and cultivated in a greenhouse for easement restoration in the spring. The remaining plant material along the easement was cut close to the ground surface in preparation for open-cut construction.

After vegetation was cleared along the easement, the area was intentionally made unattractive to wildlife by removing various cover materials. Herbaceous flora on one side of the easement was covered with geotextile cover, which was used as a base for the gravel roadway for construction vehicles. The use of geotextile cover allowed for optimum protection during construction.

During construction, topsoil was stripped from the subsoil and stockpiled separately. As sections of pipe were laid along the trench, soil was put back in the order that it was excavated. Excess soil was trucked offsite. This activity ensured that the characteristics of the original soil properties both physically and chemically were retained, which preserved the natural seedbank and reduced the chances of invasive plant species recolonizing the site. Upon grading the original topsoil material, entire soil plugs containing plant material were returned to their general locations.

Groundwater levels were closely monitored throughout the initial phases of construction to ensure that the new sewer line did not alter the water table and change the hydrological regime of the wetland.

During open-cut trench construction, sediment runoff was controlled by constructing large sedimentation ponds along the easement to control the large amount of silt-laden water generated. Because silt was considered detrimental to the sensitive wetland and cold fisheries habitat in the area, great care was exercised in controlling the extent of siltation as much as possible. In addition to constructing ponds along the easement, the newly constructed sewer line sections were used as a conduit to an offsite sedimentation pond. These ponds were then converted to amphibian habitat after construction.

Microtunnelling was used in sections of mature woodland and to cross a rail embankment without disruption to the active rail services. The main disadvantage of this technique was the cost, which exceeded $2,100 per metre, including jacking and exit pits. In contrast, the cost for the open-cut method was $750 per metre, which included pipe.

Approximately three-quarters of the open-cut work was completed by late February 1996 before microtunnelling was used on the remaining segments. In total, three microtunnelling drives were completed: the first bored a length of 32 m beneath a railway embankment through silty sand and cobbles. The second drive was through a 144-m section beneath a creek bed and deciduous forest through silty sand and sandy clay. This section was considerably more difficult because of the length and small boulders within the sand layers. The final drive was completed through a 39-m section of wet sand under a highway embankment.

Easement Restoration

After construction, the trees and shrubs were planted in the replaced soils suitable for the post-construction soils and moisture regimes along the top of the sewer trench. The 4-m vehicular access road was left and not re-vegetated because of the possibility that a trail might be approved along its length. Trees and shrubs were chosen for planting because of the concern that non-native plants might invade the disturbed soils. Initially, the wetland portions of the route were planted as quickly as possible in the early spring with cuttings from the adjacent shrub swamp, mainly red-osier dogwood and shrub willows. The cuttings were taken in March, before the shrubs had leafed out. Plugs of herbaceous wetland plants were removed from the adjoining wetland and planted along the route.

The transition area between upland and wetland, which was cut and re-formed as a steep slope after construction (one of the few areas of upland soils along the route), was also planted with trees and shrubs, in order to limit the growth of non-native plants. The deciduous forest at the south end of the route was not significantly affected, because the sewer route was tunnelled underneath, and planting was concentrated mainly around the transition area between the pond and the forest. The few impacts in this area resulted from fears of liability: a few large beech trees along the easement showed signs of mortality and were cut down by the City of Cambridge. One of these trees may have been killed by tunnelling, others were already dead.

Intrusion of invasive weed species was kept to a minimum partly by the establishment of the newly planted ground cover and controlled by chemical and physical means at the construction entry point at the wetland periphery. Remaining exposed soils in drier portions of the easement were seeded with an annual rye ground cover, which acted as "nurse crop" for the native herbaceous material in the forthcoming seasons.

Following the establishment of plant material, amphibian habitat was created from sedimentation ponds that were used during construction. Concept plans for three ponds aimed at target amphibian species, such as rare salamanders and frogs, were designed based on specific habitat requirements. The remaining wetland plant material that was propagated specifically for pond use was used to create a natural-looking littoral zone in each habitat.

Pond Reconstruction

The pond was reconstructed from a shallow marsh community to a permanent pond to deepen and improve its water retention and to exclude fish species, which could prey on salamander eggs or larvae. The transition from upland to wetland around the pond between the sawmill and the deciduous forest is more abrupt than prior to construction because of difficulties associated with maintaining a reasonable depth in such a small area. In addition, the topsoil and subsoil separation south of the pond was poor. The pond edges were planted mainly with adaptable tree and shrub species characteristic of transition zones between upland and wetland, such as eastern cottonwood (*Populus deltoides*) and nannyberry (*Viburnum lentago*). These species have generally survived, but there has been some influx of non-native species in the area. There is very little growth in the area where subsoil and topsoil were mixed.

Post-Construction Vegetation Communities

The vegetation community along the proposed sewer route can still be classified as wetland, two years after construction and planting, but the type of wetland vegetation has changed somewhat. The success of the shrub planting was variable. The red-osier dogwood generally did not root as well as expected and is now found only in small quantities. The success of the willows was variable. However, herbaceous and grass-like plants from the seed bank in the stockpiled wetland soils and planted plugs, and possibly the seed rain from the adjacent wetland, have produced a dense mat of herbs, grasses, rushes, and sedges along the entire wetland portion of the route. Many shrub willows have germinated from cuttings but are overshadowed by other vegetation.

The dominant plants in any given portion of the route vary. Swamp aster (*Aster puniceus*), soft rush (*Juncus effusus*), cattail (*Typha angustifolia*), stinging nettle (*Urtica dioica* var. *procera*), black bulrush (*Scirpus atrovirens*), boneset (*Eupatorium perfoliatum*), and various sedges (*Carex vulpinoidea*, *Carex stipata*) are the most common dominants and occur in patches throughout the route. Along one small portion of the route, planted willows have become dense enough, though still small, to dominate other vegetation, which may be related to the shade produced by trees that overhang both sides of the route in that location. Willows likely are more shade-tolerant than plants of open marshes. The patchiness of the vegetation appears to be determined mainly by subtle differences in the type and moisture of the soils along the route. The differences in microhabitat that were most obvious after construction were:

- variations in groundwater seepage and surface flows in different areas, caused mainly by impoundment by the access road

- variations in the separation of topsoil and subsoil along the route, with consequent variations in soil fertility and drainage

In some areas along the route, plants usually associated with drier soils, such as tall goldenrod (*Solidago altissima*), are almost as common as plants more traditionally associated with wetlands, indicating that some parts of the route may become classified as upland as vegetation dynamics proceed.

Non-Native Plant Invasion

The restored sewer route is dominated by native plants, except in one section where purple loosestrife (*Lythrum salicaria*) is one of the dominants, but it has not become a monoculture as in some wetlands. The loosestrife was already abundant in the soils of the immediate area; it was the dominant plant around an adjacent pond. Two other highly invasive non-native species common in the Devil's Creek wetland, common and glossy buckthorn, are found in one small area of the wetland portion of the restored route, where they can be controlled. These individual plants probably originated from roots or stems that were inadvertently left in the soils along the route during the restoration.

Post-Construction Wildlife

Breeding bird species noted in the monitoring survey two years after construction (1998) were essentially the same as had been noted in 1994 prior to construction. The Ovenbird, the only species noted in 1994 that is an indicator of forest interior habitat, was not noted in 1998 surveys. However, another species indicative of forest interior habitat, Scarlet Tanager, was noted in 1998. Two species of open marsh, Common Yellowthroat and Swamp Sparrow, have colonized the marsh habitat now found along the route. They were not noted in the swamp habitat that characterized the route prior to construction.

Mammal, reptile, and amphibian species along the restored route are also essentially the same as those noted in 1994. One "new" species of open marsh, chorus frog, was noted in the portion of the route primarily dominated by cattail. A pond created for amphibians along the route appears to be unsuitable for amphibian breeding because of heavy algal growth. However, this pond has the potential to improve as planted vegetation at its edge becomes taller and shades out the algae.

Approximately 15 breeding adult yellow-spotted salamanders were noted in 1997 and 1998 spring surveys in the reconstructed pond at the north end of the deciduous forest. Though these numbers have never been seen before in this pond, they must have always been there, because this type of salamander is generally faithful to prior breeding habitat. The present configuration of the pond likely allows the salamanders to be seen more easily. Bullfrogs, green frogs, and small fish have been noted in the reconstructed pond and, because these can be predaceous species known to prey on salamander eggs and larvae, it is not certain whether this habitat is now a "source" or a "sink" for these salamanders.

Summary and Concluding Comments

Results from the project during the first and second years were largely successful as evidenced by the rapid regrowth of vegetation and re-colonization of the disturbed area by wildlife. Evidence of the disturbance through open-cut construction has largely been diminished, although the access road is still evident. This road is likely to be modified or removed, pending the decision on the trail. Except for the mortality of one tree that was close to the tunnelling shaft, no changes in the vegetation community in the microtunnelled portions of the route have occurred. Groundwater monitoring showed no change in water level fluctuation before and after construction. Public involvement and support for the project has also increased, and plans are underway to develop the construction access road into a community trail.

Although public and agency skepticism of the project was initially high during the planning stages of the project, the care that was taken to ensure no damage to the wetland habitat and the habitat restoration effort instilled a greater amount of public acceptance for the project. Involvement by school groups, community volunteer organizations, and the local conservation authority helped to raise the profile of the project.

With the methods used (tunnelling in part, routing, and restoration), a consensus was reached by all parties on the preferred location, method of construction, and mitigation. The final cost of the project, which was $2.4 million (which included costs for numerous studies as well as construction) was substantially less than original cost estimates for replacement of pumping stations and existing sewer lines. Funding for the entire project was provided from development charge fees assessed by the municipality on all new development projects. The gravity sewer option was a superior engineering design because it followed the natural hydrological gradient of the valley terrain and this option was only possible through the use of recently developed technology, micro-tunnelling. The project also relied heavily on the understanding of ecosystem processes at the watershed and site-level scale to develop a plan for restoring disturbed areas to ensure retention of environmental characteristics and qualities of the former vegetative cover.

Reclamation and Restoration of Settled Landscapes

September 27th – 30th, 1998
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