PROPOSALS FOR THE REHABILITATION OF GRENADIER POND, WENDIGO CREEK AND ASSOCIATED WETLANDS

PREPARED FOR:
CITY OF TORONTO PARKS AND RECREATION DEPARTMENT

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EXECUTIVE SUMMARY

As part of the High Park planning study, the City of Toronto put forward a number of proposals for the restoration and management of the Park, including the rehabilitation of the Grenadier Pond system having regard for such matters as water quality and quantity, nutrient loading, sediment quality, and habitat and species diversity among others.

Park users have expressed a growing concern over such issues as the degradation of water and sediment quality, the abundance of nuisance waterfowl and the loss of habitat for fish and wildlife.

In September of 1993, Gartner Lee Limited was retained by the City of Toronto to prepare a rehabilitation plan for Grenadier Pond, Wendigo Creek and associated wetlands, collectively referred to as the pond system.

This study essentially had four objectives:

1. To improve the understanding of the physical chemical and biological conditions in the pond system;

2. To identify and quantify factors which have contributed to changing environmental conditions in the pond system;

3. To identify options for the rehabilitation of the pond system, within the context of the existing park setting and public uses; and

4. To develop a monitoring program to assess the future effects of the rehabilitation on the pond system.

The consulting team was assisted by a Technical steering committee which included members from the City of Toronto, Metropolitan Toronto and Region Conservation Authority, Ministry of Natural Resources, Ministry of Environment and Energy, Environment Canada, Toronto Field Naturalists and members of the public.

In meetings with the Parks staff, Natural Environment Work Group and the Technical Resource Group, the following desirable characteristics of the pond were defined:

a) that a more natural balance of plants and animals be restored, such that algae is reduced as well as the overabundant population of Canada Geese and game fish populations and diversity are increased;
b) that water quality be improved in the pond, particularly water clarity and oxygen conditions;
c) that species diversity should be enhanced within the pond system, specifically a greater variety of shoreline vegetation, amphibians and birds; and
d) that recreational opportunities for park users be maintained or enhanced.

In order to address these concerns, it was important first to define the existing conditions in sufficient detail to allow options to be developed from which to provide a framework for the rehabilitation of the pond. Using a combination of existing information and field studies, a context of past and present conditions was developed.

Context

Up until 1853, the pond was a wetland connected with Lake Ontario through a barrier beach. Water and animals were freely exchanged and water levels reflected those in the lake. Northern pike were historically present, likely moving into the pond to spawn in the spring and moving out to the lake as the water became warmer. The shoreline was a rich wetland, alive with a variety of plants, frogs, turtles, and a host of water birds.

But with settlement in the area, over the next 100 years the shoreline between the beach and the pond was filled and east-west transportation corridors developed. These actions had a profound effect on the pond resulting in a highly altered shoreline, limited water exchange and loss of wetlands and associated fish and wildlife communities.

How Does Grenadier Pond Get Its Water Today?

The Grenadier Pond watershed is situated within an area of highly permeable sands associated with glacial Lake Iroquois. As a result of the generally high permeability of soils in the watershed, precipitation readily infiltrates and there remains a significant potential for ground water input to the pond despite about a 50% reduction in the surface drainage area over historical conditions.

Previous monitoring programs carried out by the Department of Public Works and the Environment in 1992 indicated that there was a significant inflow to Grenadier Pond from another source besides the storm flows from developed portion of the Grenadier Pond watershed.

The water budget analysis undertaken for this study for the Department of Parks and Recreation estimated that ground water, which is clean, cool and flows consistently throughout the year, contributes about 50% of the total water flow to the pond . Historically we have calculated the contribution may have been closer to 65% of the total inflow to the pond. Field studies carried out by Gartner Lee in 1993/94 confirm that ground water is actively entering through the sides of the pond but the data suggested that fine sediments may be preventing the full volume from entering. Some further hydrogeological work is needed in this area of study to quantify ground water contributions.

Much of the surface water in the Grenadier Pond watershed is captured and delivered to the pond via an extensive storm sewer system. Two sewers discharge directly to the pond at the north end at Clendenan Avenue and at Valleymede Avenue. Several other storm sewers feed into West Pond (also known as Catfish Pond) which discharges to Grenadier at the south west corner only a short distance from the outlet, also in the same corner of the pond.

These storm sewers deliver precipitation rapidly to the pond. This results in rapid increases in water level within the pond. Water level observations during this study over the fall of 1993 and summer of 1994 noted fluctuations in the order of approximately 30 cm but the increases only lasted several days. Seasonal fluctuations were not observed as would have historically been the condition prior to outlet controls.

Originally, the pond was approximately 1.3 m lower when connected to Lake Ontario. The pond elevation was altered with considerable filling of the shoreline during the construction of the Queensway. We calculate that restoring the connection with the lake would result in a loss of pond area in the order of 40% given the existing of shoreline configuration.

The present size of the pond is 18.9 ha with a maximum depth of 6.5 m and mean depth of 2.98 m. The pond flushes, or in other words, the water within the pond is exchanged, roughly 2.76 times per year.

What is the Quality of the Water In Grenadier Pond?

Through existing information and some limited sampling as part of this study we have found significant phosphorus (average 0.2 mg/L) and nitrogen (average 2.38 mg/L) levels within the water column which fuels excessive algal growth. The algal growth eventually dies and settles to the bottom of the pond where it decays and uses up oxygen in the process. As a result, there is no oxygen in the bottom waters over a considerable portion of the year, including winter and summer. This is a condition which has been found consistently by all investigators over many years. Hydrogen sulphide, taken by the Ministry of Environment and Energy in 1994, also appears to be present in the bottom waters at toxic levels.

The clarity of the water is typically poor in the summer time, largely related to the algal blooms. Secchi disc readings (measures the distance under water that a disc can be observed) as low as 0.5 m were recorded in this study which appear to be marginally worse than those observed in other years, but that could be a factor related to weather conditions. More frequent and longer term monitoring will assist in determining the average water clarity.

What is the Quality of Sediment in Grenadier Pond?

The sediments of the pond were found by this study to be slightly contaminated with metals, likely related to storm runoff. Few samples were taken and more information would be required to define the extent and quality of the sediments.

What causes the Water Quality Problems in Grenadier Pond?

A significant component of this study was developing a water and nutrient budget to account for the inputs and outputs and identify the most important contributions of each to the pond. We concentrated on phosphorus as it provided significant insight into the mechanisms controlling the pond quality

Our results of the sampling and nutrient budget for this study indicate that the pond experiences significant water quality problems due to:

a) **incoming storm water from the watershed (external loads or contributions) which carries with it nutrients (e.g., from fertilizers), metals (e.g. from road runoff), sediment (e.g., from eroding soil) and bacteria (e.g., from pet waste). In fact, 25% of the total annual phosphorus loadings come from the storm sewers;**

b) **contributions of nutrients from feces of Canada geese abundant around the shoreline which account for 40% of the phosphorus loadings; and**

c) **nutrients contained within the bottom sediments (internal loads) which account for 32% of the total phosphorus loadings.**

Therefore, storm water, geese and the sediments within the pond are significant contributors to the observed problems and need to be addressed.

What is the Aquatic Habitat and Fish Community Structure of the Pond?

The fish community in the pond has changed over time with the alterations of connections and habitats. Over 45% of the shoreline now is concrete curb and steep slopes having replaced the former wetland edge. The habitat is poor for species such as largemouth bass and northern pike which were historically very important in the pond. While both species are present in the pond today, their populations are small, and in the case of pike, cannot be sustained without significant habitat improvements. Sunfish have gained a foothold in the pond and are competing with the bass for resources.

Are There Any Wetlands Left Around the Pond?

Only remnant areas of wetland remain around the pond. Small areas at the north and south west of the pond have limited plant diversity and consequently associated wildlife habitat. Some significant species are present in the pond which can be incorporated into future wetland development. Aquatic plants (macrophytes) are limited in the pond, partially because of the slopes and substrates present on the bottom of the pond, but also are influenced by the poor water clarity.

How Do We Fix The Pond? A Framework for Rehabilitation

Based on the findings of this study there is a better understanding of the past and present conditions in the pond associated with water and sediment quality and habitat degradation. From this a planning framework for rehabilitation options was developed to address the conditions. The framework was developed under the headings of:

a) **external load reduction;**
b) **internal load reduction;**
c) **waterfowl control;**

d) habitat alteration;
e) fish community imbalance;
f) lack of wildlife diversity; and
g) human access and education.

A number of actions were found to satisfy more than one requirement, would result in long term correction of the problem, and therefore were selected on that basis. There are a number of options to deal with the internal loading within the pond and this is where the dilemma lies still. More information and investigations are required to determine the best method to deal with the nutrient rich water or sediments. Nevertheless, a recommended proposal for rehabilitation has been outlined, which in part will be confirmed or altered with new information.

The framework has four main elements:

1. reduction of nutrient loadings from the watershed through public education and voluntary action, increased infiltration in the watershed to enhance cleaner ground water flow through the pond, as well as end of pipe storm water treatment facilities at the end of the Clendenan outfall and West Pond drainage;

2. removal and treatment of sediments within the pond to reduce nutrient loads from the sediment, improve their consistency to foster plant growth and invertebrates, and enhance the ground water flow to the pond;

3. reduction in nutrient loadings from the large population of Canada Geese resident in the park through the restructuring of the habitat surrounding the pond to eliminate the availability of lawn-water connections; and

4. habitat improvements through the restoration of wetland edges and larger wetland blocks and instituting seasonally fluctuating water levels to benefit fish and wildlife.

These actions can be carried out within the park setting to provide improvements to the water quality and natural environment of the pond, pond aesthetics and existing recreation activities, ie. fishing, birdwatching, etc.

Feeding of the waterfowl should be discontinued to discourage the presence of the birds at the pond. Some trail relocation will be necessary to accommodate the new habitats and reduce the effects of people on the wildlife, but in all, the effects on the park user are expected to be minimal.

A community education and communications program is a necessary adjunct to the rehabilitation efforts as actions are needed within the watershed as well as in the pond. During the implementation of the investigations and treatments there will be some inconvenience of the park users and there needs to be a spirit of understanding and cooperation fostered to ensure successful completion of the pond system's rehabilitation.

Ongoing annual monitoring is essential to document the success of the measures or to apply other actions to deal with other problems should they arise. It must be understood that lake rehabilitation is not a precise science

in that there are many interactions that take place in the system of which we may only understand a few. Through careful monitoring changes can be observed and corrected to ensure that management is having the desired effect. Demonstration projects will allow us to try certain actions on a small area of the pond prior to implementation at a larger scale and will be useful in persuading both the park user and the regulatory agencies of the value in larger scale application.

It is important to begin the work as soon as possible. Every day that we wait increases the magnitude of the problem and makes it more difficult and more expensive to achieve our goal of a sustainable aquatic ecosystem in the heart of one of Toronto's greatest resources, High Park.

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1.0 CONTEXT

The Past

Its not hard to imagine what John and Jemima Howard would have seen as they stood atop the high hills overlooking Grenadier Pond during the mid–1800s. Before them lay the pond stretching out to meet Lake Ontario, although a constant bar of sand almost always separated the two. Oaks and grasslands covered the steep hills, offering shade and making it relatively easy to reach the pond's edge.

On occasion, John would take advantage of a sunny day and head to the pond to catch a fish for supper. As he made his way down the hill, leopard frogs would leap through the grasslands ahead of him, a shy fox would peer out from a hillside den, and maybe he would see a large snapping turtle travelling back to the pond having laid its eggs in the sandy slopes. Small springs may have bubbled out of the side of the hill and trickled down to the pond.

The pond's edge was not so easily seen. Dense masses of sedges, willow, cattails and sweet flag surrounded the shoreline, while other varieties of underwater plants grew in the shallow nearshore area. Here, lazy pike lounged waiting for dinner to pass by, or perhaps a largemouth bass minded its nest of young. Turtles sunning on logs, ducks dabbling in the shallows, and marsh birds nesting in the reeds would all have been common sights.

The Present

What would John Howard think if he stood atop the same hill under the same shady oak tree and looked down at the pond today? First he would be proud to see that his legacy to the people of Toronto, made in 1873, remains a reality – while at the same time overwhelmed at the numbers of people who come to use the park. He would soon notice the changes that urbanization and park demands have brought to the pond. The Lake is so far away from the pond now, separated by lanes of roads and rail lines; the densely vegetated edge now replaced in large part with abrupt concrete and lawn; the clear water now an emerald green obscuring views of underwater life. The frogs that once were abundant are now nowhere to be seen. What could have led to these changes?

Though John Howard was a land surveyor, even he may have been surprised by the density of houses which now form the neighbourhoods of High Park and Swansea. Originally part of the lands that fed the pond with water, a network of sewers has replaced the natural drainage patterns and cleansing processes of these lands. For years Grenadier Pond has acted as a receiver of drainage from properties, roads and periodically, domestic waste.

The gradual filling of the shoreline to allow access across what was once a natural physical barrier to the west has removed the connections between the pond and the lake. The exchange of materials is now one–way only through a pipe which outlets to the Humber River almost a kilometre away.

The demands of parks users over the years have also taken their toll. More and better access to the edge of the water has been the result of gradual filling and restructuring of the shoreline. Shoreline alterations have brought about changes in the ability of the system to produce fish – particularly the pike and bass, key to keeping the system in balance. The number of geese, gulls and ducks has expanded to nuisance proportions with few predators to keep their numbers in check, and abundant food brought by visitors to the ponds and supplied by the expanses of manicured lawn (a delicacy for Canada Geese).

High Park is a recognized jewel in the heart of a sprawling metropolis. Although there are no rigorous surveys documenting the frequency, duration or type of human activity that occurs within the park, anyone visiting on a sunny day could attest to the park's popularity. Spring, summer and fall bear witness to the hundreds of people coming daily to explore, bike, fish, bird watch or exercise the family dog along the shores of Grenadier Pond. Winter months are popular with skating on the pond and cross country skiing. Year round events include the nature walks and, unfortunately, also the feeding of the waterfowl. Without doubt, people are a part of the rehabilitation equation and are intrinsic to the successful return of a healthy pond ecosystem.

Within an overall context of improvements to High Park's natural environment, safety, traffic circulation and public communications, the City of Toronto initiated a High Park study in 1988 to review the problems in the system and to develop a management philosophy and approach for, among other things, the pond, Wendigo Creek and the remnant wetlands. Proposals for the restoration and management of the Park were put forward to the public for comment in 1992. The City recommended Grenadier Pond be rehabilitated having regard for such matters as water source, quality and quantity, nutrient loading, sediment quality and biotic integrity, among others.

In the summer of 1993, as a first step, the City of Toronto retained Gartner Lee Limited to undertake a rehabilitation study for Grenadier Pond, Wendigo Creek and associated wetlands (hereafter referred to as the pond system). The study had essentially four objectives:

1. To improve our understanding of the physical, chemical and biological conditions in the pond system;
2. To identify and quantify factors which have contributed to changing environmental conditions in the pond system;
3. To identify options for the rehabilitation of the pond system, within the context of the existing park setting and public uses; and
4. To develop a monitoring program to assess the future effects of the rehabilitation actions on the pond system.

An essential component of the project has been the involvement of the City of Toronto Parks and Recreation Department, the High Park Citizens' Advisory Committee, the High Park Natural Environment Work Group (NEWG) and the High Park Technical Resource Group. Meetings with all groups were important in helping to define the information available, the issues of concern, and the future vision for the pond system.

The Future

Restoring, or in other words, returning the pond to the way it was in John Howard's time is not possible given today's urban setting. However, those elements of his vision – water, wildlife, shoreline habitat and connections between the land and water – are still essential components of the pond system today.

Rehabilitation, or regeneration of each of these components is possible to ensure that the pond system remains sustainable for future generations of park users. But, what should a regenerated Grenadier Pond system look like in the future?

In meetings with the Parks staff, Natural Environment Work Group and the Technical Resource Group, the same question was asked and the following desirable characteristics were defined:

a) restore a natural balance between the plants and animals:

- reduce over abundant algal population;
- establish self–sustaining populations of predator fish, including largemouth bass and pike, zooplankton and phytoplankton; and
- reduce nuisance bird populations.

b) improve water quality in the pond:

- improve water clarity to at least 2 m Secchi depth; and
- improve the oxygen content of the bottom waters (above 2.0 mg/L in winter and above 5.0 mg/L in summer).

c) improve species diversity and habitat diversity within the pond system:

- establish more vegetation around the pond margins and in the pond; and
- amphibians and benthic invertebrates should be enhanced in the system.

As is recognized, people remain a very important component of the Grenadier Pond system. Any of the actions taken to attain the desirable characteristics noted above must also address the effects on the park users, therefore consideration of a fourth characteristic would be:

d) maintain and enhance recreational opportunities for park users.

At closer inspection of the conditions that have been identified as desirable, it is clear that they are not in isolation of each other. Sufficient oxygen, proper food and appropriate habitat are all implicit in maintaining a healthy, thriving fishery. Measures set to improve water quality will automatically benefit aquatic organisms, but the overall goal of a self–sustaining population would not be met if appropriate spawning habitat did not also exist. Remediation in one area must, in turn, be supported by enhancement of other aspects.

Similarly, through water quality improvements, the nutrient levels would be reduced which is often associated with a decline in nuisance algal populations and increased opportunity for macrophytes to become established. These linkages within the aquatic ecosystem should be reflected in the choices made for rehabilitation, as one option would, to some extent, affect many overlapping areas.

Armed with the guidance provided above, the process of developing a framework for rehabilitation of the Grenadier Pond system began. The first stage involved defining the existing conditions along with their historical context. Next, an assessment of how the various present day conditions are interrelated was made. From that assessment, the issues and opportunities around the pond were identified. A number of options were developed for the pond system. No one solution will be sufficient to achieve the rehabilitation. While some have a number of alternatives to accomplish the same thing, others have only one. The recommended framework for rehabilitation presented in the document identifies the need for further data to support the rehabilitation, preferred rehabilitation options, and a monitoring program to measure the effects of the various actions.

2.0 REVIEW OF PAST AND PRESENT CONDITIONS

2.1 DRAINAGE AREA DESCRIPTION

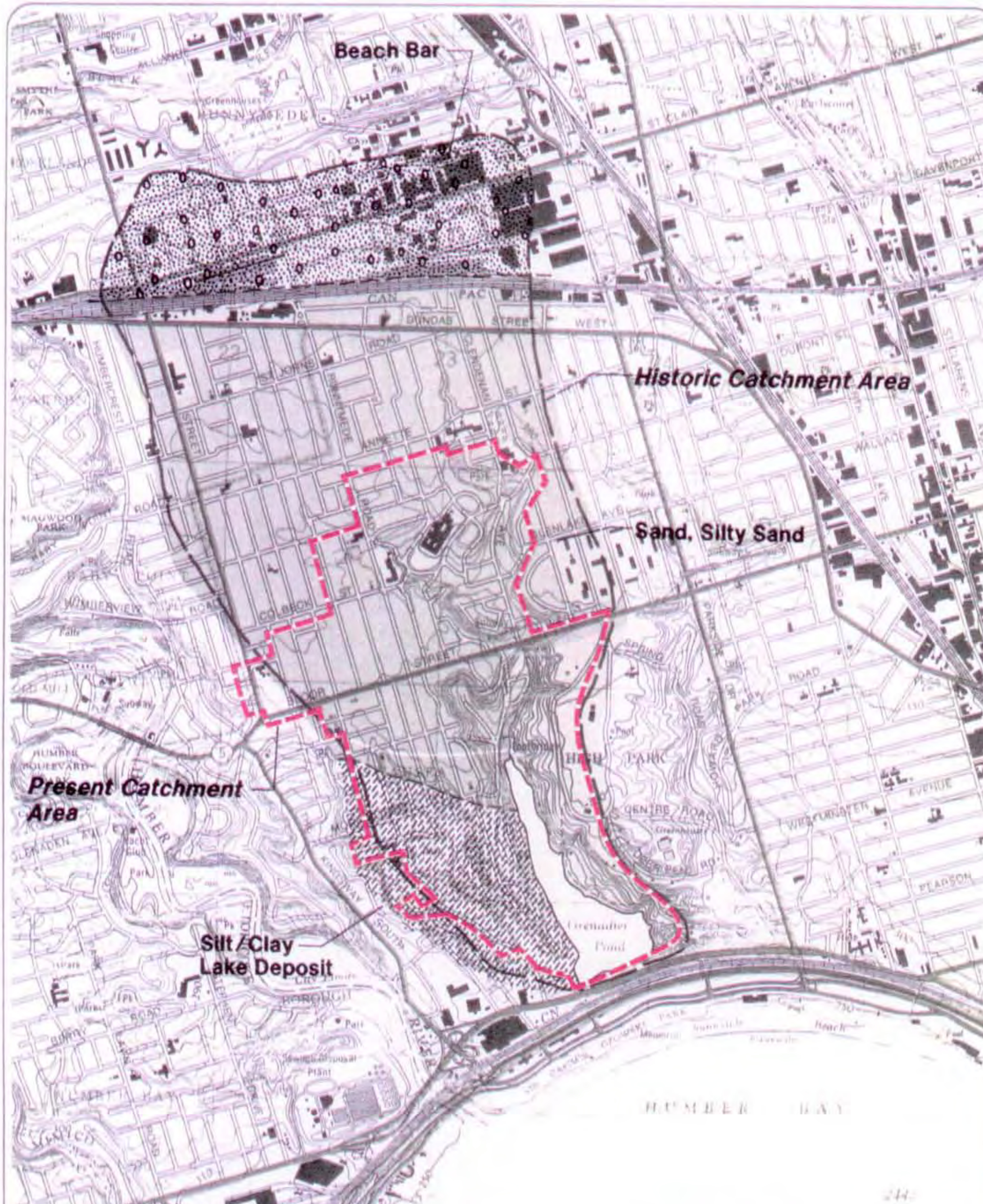
Grenadier Pond is located at the west end of the City of Toronto and adjacent to Lake Ontario. The pond is located within the western boundaries of High Park. On the west side is older residential development within the community of Swansea. Directly south of the pond lies the Queensway and Lakeshore Boulevard, separating Grenadier Pond from Lake Ontario. Water from the pond exits from the southwest corner and travels via a pipe to the Humber River, eventually discharging to Lake

Ontario. Historically, only a sandy beach bar divided the two water bodies. During periods of high water (e.g., spring snow melt), it is expected that Lake Ontario waters would flood over the bar and mix with Grenadier Pond. This action would both result in periodic flushing of the pond with lake water as well as seasonally affecting water levels in the pond.

The Grenadier Pond watershed is situated within an area dominated by glacial Lake Iroquois deposits (OMNR, 1980). These deposits are mostly highly permeable sands and silty sand materials. The upper portion of the historical catchment area, as shown on Figure 2.1, contains a major beach bar deposit of sand and gravel. The area west of the pond, including most of the drainage area to Catfish Pond, consists of deeper water deposits where less permeable silty–clay material is dominant. This westerly area has a lower infiltration capacity than the remainder of the basin. These key physiographic units are shown on Figure 2.1. As a result of the generally high permeability of the catchment, there has been historically high infiltration capacity and is potential for significant ground water input to the pond even today, despite extensive urbanization.

The historical surface catchment area for Grenadier Pond was much larger than the present area. Based on historical mapping sources, it appears that the original drainage area was about 477 ha and extended as far north as St. Clair Avenue where the beach bar deposit exists (Figure 2.1). The catchment area has undergone several changes associated with historical development of the area and separation of combined sewers. The drainage area to Grenadier Pond today is extensively channelized into storm sewers and has been reduced by about 50% from historical conditions to 245 ha based on City of Toronto sewer drawings. The area of most significant change was between Annette Street and St. Clair Avenue where the storm sewer drainage from hard surfaces (about 35% of the area) was diverted out of the catchment during urbanization of these lands. In addition, as building roof areas were typically connected to the storm system, both roof and road runoff were diverted out of the Grenadier Pond watershed. As a result of these changes, the surface water catchment has been reduced to about half its original size and the annual volume of water directed to the pond substantially reduced. The catchment area for ground water has also been affected, but to a lesser extent. (Note that the ground water catchment is larger than the surface water catchment as infiltration outside the surface catchment will still reach Grenadier Pond through the ground water system.) It is expected, however, that much of the ground water flow from the historical catchment as far north as St. Clair Avenue, still moves towards Grenadier Pond since the sandy soil conditions are deep and continuous within the catchment. Although much of the area has storm sewers, these services are relatively shallow and are not expected to intercept significant amounts of infiltrated water either into the pipe or along service trenches. Similarly, the TTC subway line along Clendenan Avenue is shallow or at surface in this area and does not intercept ground water flow.

Specific analyses for the ground water and surface runoff contributions to Grenadier Pond are discussed in the next sections. These factors are key components of the water balance for the Grenadier Pond.



Gartner Lee
Scale 1: 25,000

Present and Historical Watershed Boundaries and Surficial Soil Types

Grenadier Pond

FIGURE
2.1

Project 94-205

2.2 HYDROLOGY

The preparation of a water budget (or balance) is critical to understanding present conditions within the pond and the effectiveness of rehabilitation measures. Water balance components include precipitation, evapotranspiration and the annual surplus. The annual surplus is further divided into the proportions of runoff and infiltration which are dependent upon the soil permeability and land use. To better understand the contributions of ground water and surface water under past and present conditions, a spreadsheet was prepared for the Grenadier Pond watershed to quantify ground water and surface water sources based on land use and soil type. The data are further compared to empirical data collected within the study area.

2.2.1 Ground Water Contribution

Prior to this study, there had been limited data to confirm the potential or quantify the amount of ground water entering into Grenadier Pond either from the side banks or through the base of the pond. City of Toronto data (1992) on inflow and outflow points at Grenadier Pond showed that only 50% of the pond outflow could be accounted for at storm sewer inlets. The reports suggest that much of this difference may be ground water inflow. Through the water budget analysis, we have tried to define the relative contribution of ground water to the system.

An average annual evapotranspiration amount of 450 mm per year with an annual surplus of 300 mm precipitation has been assumed in Table 2.1 based on the Clendenan Avenue meteorological station. In addition, it has been assumed that any infiltrated water within the catchment will reappear in Grenadier Pond due to the steep gradients to Wendigo Creek and the pond and generally uniformly permeable and deep soils. Ground water gradients between Grenadier Pond and Lake Ontario are generally lower than those in the upper part of the basin, resulting in the pond and Wendigo Creek acting as a regional discharge point for ground water.

The percentage of annual infiltration (column 4 in Table 2.1) is based on long–term modelling of daily temperature and precipitation data using the model WATBUD. This model is based on the HELP infiltration model (U.S. Army Corps of Engineers) and uses soil type and land use (imperviousness) to determine annual infiltration values. Data in Table 2.1 suggests that the historical ground water inflow was likely in the order of 30 L/s while it is presently about 15 L/s. The amount of ground water inflow appears to have decreased significantly while the amount of surface inflow has decreased only slightly. This is because the increase in surface runoff due to urbanization has been offset by the loss of drainage area north of Annette Street. The infiltration percentage in Table 2.1 has been adjusted between historical and present conditions to account for the increase in impervious area (roof and road area) for each of the sub–catchment areas as compared to undeveloped conditions. Historically, the ground water inflow was likely about 65% of the total inflow to the pond while it is in the range of 50% presently.

TABLE 2.1
GROUND WATER AND SURFACE WATER CONTRIBUTIONS TO GRENADIER POND

HISTORICAL CONDITIONS

OUTFALL	DRAINAGE AREA NO.	DRAINAGE AREA (HA)	ANNUAL SURPLUS * (MM)	INFILT%	ANNUAL INFILT (MM)	ANNUAL GW VOL (M^3)	ANNUAL RUNOFF (M^3)		
Clendenan Ave.	1.0	336.0	300.0	0.8	225.0	756000.0	252000.0		
Valleymede Rd.	2.0	16.4	300.0	0.7	195.0	31960.5	17209.5		
Into Catfish Pond	3.0	46.5	300.0	0.4	120.0	55740.0	83610.0		
Catfish Pond Drainage	4.0	15.5	300.0	0.4	120.0	18576.0	27864.0		
Into Catfish Pond	5.0	7.2	300.0	0.4	120.0	8676.0	13014.0		
Parkland Drainage	6.0	32.8	300.0	0.7	210.0	68964.0	29556.0		
Direct Precipitation	7.0	21.1	275.7	0.0	0.0	0.0	63328.3		
Direct Precipitation	8.0	1.87	24.3	0.0	0.0	0.0	5581.7		
								RUNOFF=	492163.5 m^3
		477.4 AREA				939916.5 m^3	492163.5 m^3		
				GROUND WATER ESTIMATE =		29.8 L/S			

* – Bloor Street meteorological data for precipitation.

EXISTING CONDITIONS

OUTFALL	DRAINAGE AREA NO.	DRAINAGE AREA (HA)	ANNUAL SURPLUS (MM)	INFILT%	ANNUAL INFILT (MM)	ANNUAL GW VOL (M^3)	ANNUAL RUNOFF (M^3)		
	1A	232.0	300.0	0.30	90.0	208800.0	0.0		
Clendenan Ave.	1.0	104.1	300.0	0.45	135.0	140481.0	171699.0		
Valleymede Rd.	2.0	16.4	300.0	0.45	135.0	22126.5	27043.5		
Into Catfish Pond	3.0	46.5	300.0	0.25	75.0	34837.5	104512.5		
Catfish Pond Drainage	4.0	15.5	300.0	0.25	75.0	11610.0	34830.0		
Into Catfish Pond	5.0	7.2	300.0	0.25	75.0	5422.5	16267.5		
Parkland Drainage	6.0	32.8	300.0	0.70	210.0	68964.0	29556.0		
Direct Precipitation	7.0	21.7	275.7	0.00	0.0	0.0	63328.3		
Direct Precipitation	8.0	1.87	24.3	0.00	0.0	0.0	5581.7		
								RUNOFF=	452818.5 m^3
		246.0 AREA				492241.5 m^3	452818.5 m^3		
				GROUND WATER ESTIMATE =		15.6 L/S			

* – Bloor Street meteorological data for precipitation.

In order to confirm the presence of ground water flow through the pond bottom, two nests of three mini–piezometers (small tubes inserted below the ground surface and extending above which allow measurements of the ground water elevation to be taken) were installed along the pond edge in September 1993. The two locations for these nests are shown on Figure 2.2. At each site, three mini–piezometers were installed at varying depths below the bottom of the pond. These depths were in the range of 2.5, 2.0 and 1.0 m below the pond bottom and at a distance of 1.0 to 2.0 m from shore. While detailed soil stratigraphy data are not available for these sites, it is reasonable to assume that the upper 0.5 to 1.0 m depth is fine sediment while the soils below 1.0 to 1.5 m are compacted sand. This configuration was noted in test pits at the south end of the pond in 1995. Water level data in these piezometers were collected during the fall of 1993 and once in 1994 and are summarized in Table 2.2.

Table 2.2: Summary of Mini–Piezometer Readings – Depth Above / Below Pond Surface Elevation (m)

Date	*South Nest (MP1)*			*North Nest (MP2)*		
	2.5 m	2.0 m	1.0 m	2.5 m	2.0 m	1.0 m
September 24, 1994 (new)	–	–		–	–	–
November 4, 1993	+0.04	+0.10	+0.05	+0.15	+0.59	+0.01
November 5, 1993	+0.01	+0.05	+0.01	+0.01	+0.61	+0.02
November 8, 1993	+0.04	+0.11	+0.03	+0.21	+0.79	+0.11
June 22, 1994	+0.15	+0.13	+0.09	+0.14	+0.38	+0.07

Table 2.2 data shows that all readings were positive (i.e., ground water piezometric surface above pond elevation). This means that there were upward gradients (movement) suggesting active ground water discharge in all mini–piezometers during the late fall of 1993 and early summer of 1994. In many cases, the deeper monitors yielded a higher piezometric surface meaning that the ground water gradient was greater at depth (i.e., in sands) and lower in shallow probes. The June 22, 1994 data are particularly significant as they were preceded by 10 days of hot, dry weather. Other evidence confirming significant ground water inflows included visible seepage and standing water at the surface along the east bank, cattails growing along the adjacent slope near the northerly mini–piezometer nest and a measured flow increase in Wendigo Creek of about 5 L/s between the Clendenan Avenue outfall at Clendenan Avenue and the existing sediment pond at the north end of Grenadier Pond on June 22, 1994.

The flux or measured discharge rate of ground water into the pond was not physically measured for this study as it would require many measurements to obtain an accurate flow reading. However, a rough estimate of ground water discharge to the pond was made using D'Arcy's Law, hydraulic conductivity (K) in the order of 10^{-7} m/s for the pond sediments and assuming a pond bottom area of about 5.0 ha (25% of the pond area) around the edges contributes ground water flow through the sediments. The pond bottom area which contributes discharge to the pond was assumed to be an area which is 1.5 m deep or less. This rough calculation suggests that ground water flow to Grenadier Pond is in the order of 50 L/s. Given the uncertainty with the hydraulic conductivity values and a number of assumptions made, this compares favourably with the 15 L/s contribution calculated in Table 2.1.

2.2.2 Surface Water Contributions

The Grenadier Pond basin shown on Figure 2.3 has been about 85% developed since about 1940 with the only large open area being High Park itself and Remie Park which includes Catfish Pond. The addition of impervious surfaces such as roads and roof tops and sewer systems has changed the way water is proportioned between the surface and ground, or in other words, the natural hydrological cycle. Even the park area has been altered through road ditching, grading and manicuring practices. Minor redevelopment and infilling has also taken place in the catchment, particular to the immediate north and south of the Clendenan Avenue corridor.

Where, prior to development, we can assume virtually 0% impervious within the watershed and a significant proportion (65%) of the rainfall entered (infiltrated) the ground, today that amount of infiltration has shifted to approximately 50% (Table 2.1).

Within the present 245 ha catchment area, there are five (5) primary storm sewer outfalls to Grenadier Pond. Prior to 1990, combined sewer overflows (CSOs) were experienced in the catchment area but there were no overflows to Grenadier Pond. Roof runoff entering the Clendenan sewer still runs into the combined sewer system, which does not enter Grenadier Pond. Diversion of roof area into the storm system will only occur with redevelopment. All remaining sanitary and storm sewer systems are now separated in this area with storm water only from the area north of Bloor Street draining to Grenadier Pond. The five outfalls are summarized in Table 2.3 in addition to other non-sewered catchment areas to the pond with all locations marked in Figure 2.3.

Table 2.3: Summary of Key Outfall Locations (see Figure 2.3)				
		Pipe Size	***Drainage Area***	***Catchment #***
Outfall Location	Clendenan Avenue Valleymede Road Ellis Avenue Rennie Park Coe Hill Drive	1,350 x 1,350 mm box 900 mm 600 mm 900 mm 600 mm	104.1 ha 16.4 ha 15.9 ha 46.5 ha 7.2 ha	1 2 4 3 5
Other Catchment Areas	High Park drainage Grenadier Pond Catfish Pond		32.8 ha 21.1 ha 1.9 ha	6 7 8
Total			***245.9 ha***	

In addition to the five sewered drainage areas, there are about 32.8 ha of parkland which drain directly to the pond and the two pond surface areas themselves. These areas and their respective imperviousness (hard surface) levels were utilized in estimating the water budget for Grenadier Pond presented later (Section 2.6).

Surface water inflow points were not extensively measured for this study. However, past continuous flow measurements were taken for the period of April to October 1992 by the City of Toronto at key outfalls to the pond. These data were used to estimate the amount of surface inflow on an annual basis.

Using data obtained in 1982 from the Quantity Quality Simulation Computer model for the area's sewer network, 373,484 m^3 of runoff were estimated to have drained into Grenadier Pond over the period April to October 1992. (This excludes unsewered areas such as High Park itself and direct precipitation to the pond areas). During this seven month period, 622 mm of rain fell at the Clendenan Avenue meteorologic station which is the nearest to the study area. The average rainfall for this period is about 477 mm based on 30 years of data resulting in the 1992 rainfall being about 30% above average. The total runoff recorded was reduced to account for the abnormally high rainfall conditions in 1992 and then extended to account for the entire calendar year based on the average distribution of precipitation over all months. The average annual surface water inflow to Grenadier Pond was estimated by this method to be about 491,000 m^3, of which only a minor component is expected to be ground water inflow infiltrating into the storm sewer systems.

Dry weather flows from outfall points to both Grenadier Pond and Catfish Pond were measured on June 22, 1994 following 10 days of hot, dry conditions. The measured flow was 15 L/s to Grenadier Pond from the Clendenan Avenue sewer (SW4) and 2 L/s to Catfish Pond from catchment area #3 on Figure 2.3. The total dry weather flow of 17 L/s compares very closely to past City of Toronto data with an average dry weather flow of 19 L/s (City of Toronto, 1992). These are approximate estimates as some of the storm sewer flow on June 22, 1994 was noted to be sourced from lawn watering and dewatering activity at watermain construction activity in the Grenadier Pond catchment area north of Clendenan Avenue.

Additional flow data had been collected from outfalls to Grenadier Pond on October 7, 1993 and February 21, 1994. October 7 was representative of dry weather conditions with measured flows of 9.2 L/s at the base of Wendigo Creek (SW3) (which includes the Clendenan outfall); and 1.0 L/s at the outfall from Catfish Pond (SW5). A total of 10.2 L/s was measured. Flows measured on February 21, 1994 were 15.7 L/s at SW3, 0.2 L/s from the Valleymede culvert (SW7) and 11.0 L/s at SW5. The winter flow data was collected directly following a period of atypically warm weather (10°C) resulting in early snowmelt that was still occurring on February 21.

2.2.3 Grenadier Pond Water Levels

Limited data on seasonal water level fluctuations in Grenadier Pond were available for this study. A stage recorder was installed at the lookout deck (barge area) in October 1993 with readings taken during field visits and periodically by City of Toronto Parks and Recreation staff. Data from these readings are summarized in Table 2.4 with station location noted on Figure 2.2.

Table 2.4: Summary of Water Level Readings at Grenadier Pond

Date	Reading
September 21, 1993	0.980 m
September 22	0.965 m
September 24	0.970 m
October 26	1.100 m
October 28	1.100 m
November 2	0.994 m
November 3	1.090 m
November 5	1.020 m
November 8	1.000 m
December 1*	1.090 m
May 16, 1994	1.020 m
May 18	0.995 m
May 20	0.980 m
May 24,	0.975 m
May 26	0.985 m
May 27	1.035 m
May 30	1.000 m
June 1	1.030 m
June 3	1.005 m
June 22	0.970 m

* *Note: high water debris line at 1.20 m around shoreline was evident in response to 54 mm rainfall on November 29, 1993*

As noted in Table 2.4, the water levels in Grenadier Pond are relatively constant and respond primarily to major runoff events (rainfall or snowmelt) and seasonal peaks in precipitation. The increases in water level appear to last only a few days at most with maximum fluctuations likely in the order of 0.30 m given the present outlet configuration. This information is useful in understanding how water levels fluctuate along the nearshore zone and what implications this may have on renaturalizing shoreline conditions.

As noted previously, historic conditions allowed Lake Ontario to periodically flush Grenadier Pond when water levels were high as there were no significant differences in pond–lake elevations in the past (pre–1900). Likewise, Grenadier Pond drained into the lake during runoff periods. Road and railway construction between Grenadier Pond and Lake Ontario has cut off the hydraulic connection between these two water bodies and resulted in the water levels in Grenadier Pond being regulated by an outlet weir with variations resulting from major runoff events. Even under severe storm conditions, fluctuations in the pond water level appear to be relatively low due to the large surface area relative to the catchment area.

Topographic maps indicate Grenadier Pond is situated at about 76.3 m above sea level and the average water level of Lake Ontario, from data collected by the Army Corp of Engineers from 1982–1993, is at 75.0 m above sea level. Therefore, Grenadier Pond appears to be on average, 1.3 m higher than the lake. Recent test pits (January 1995) dug along the southern shore of Grenadier Pond noted organic deposits at about 1.8 m deep, consistent with Lake Ontario water levels. The test pits were done in anticipation of future shoreline alterations along the southern shore.

If the existing outlet structure were to be removed and the "free–flow" of water between Lake Ontario and the pond restored, the result on water levels in the pond would be dramatic. Based on an equalized elevation of about 75.0 m, approximately 2.4 x 105 m3 of water or 40% of the pond's present volume would be lost. This would result in exposed, dry land around the present pond shoreline and the exposure of mud flats at the north end. Given the already large are of the pond which was lost with the shoreline alterations, this result is clearly not consistent with long–term rehabilitative efforts.

2.2.4 Outlet Structure

Up until 1853, Grenadier Pond was connected directly to Lake Ontario via a channel which would cut through the sand bar which separated the pond from Lake Ontario. Today, the outlet consists of a 1.68 m wide concrete overflow weir (top draw) located at the southwest corner of the pond. The pond outflow, under normal flow conditions, discharges to the Humber River via a storm sewer along the north side of Lakeshore Road while there is a direct overflow to Lake Ontario (see Figure 2.3) under high flow conditions. As the outlet weir is enclosed, it is very difficult to take flow measurements at this point. Dry weather flows on three occasions in 1992 by the City of Toronto determined an average flow of 41 L/s, however, the data set is insufficient to use in the water balance. During the course of this study, water could be heard continuously flowing over the weir on dates when water level readings at the barge lookout site were collected.

2.3 GENERAL LIMNOLOGY

The limnology of Grenadier Pond has been studied and is described to varying degrees in Wainio *et al.* (1976) and Zimmerman *et al.* (1986). University of Toronto studies of pond characteristics have been undertaken since the late 1970s.

The general morphometry of Grenadier Pond is described in Table 2.5 and depicted in Figure 2.2. The pond has a surface area of about 18.9 ha (21.1 ha including the shallow wetland areas at its northern end). It has a relatively shallow mean depth of 2.9 m (maximum depth of 6.5 m), giving the pond a total volume of 5.52×10^5 m^3.

Table 2.5: Grenadier Pond Morphometry (from Zimmerman et al., 1986)

Variable	*Grenadier Pond*
Area	18.9 ha
Volume	5.52×10^5 m^3
Maximum Depth	6.5 m
Mean Depth	2.98 m
Mean Depth / Max. Depth	0.4
Perimeter	2.9 km
Shoreline Development	1.88 km
Flushing Rate	2.76/yr*

* *Gartner Lee calculations indicate a flushing rate of 1.8 to 2.3 times per year.*

A water budget has been constructed for Grenadier Pond and is more fully described in Section 2.6. Based on volumes calculated by Gartner Lee Limited, the flow out of the pond is estimated to be about 986,000 m^3/yr. Based on several measurements at the pond outfall (City of Toronto, 1993), the average out flow from the pond was 1,260,000 m^3/yr. These flows result in turnover rates within the pond of between 1.8 and 2.3 times per year. A turnover rate of 2.76 times per year has been previously estimated for the pond (Zimmerman *et al.*, 1986). Grenadier Pond and Catfish Pond together represent about 8.5% of the catchment area which is high compared to typical southern Ontario basins. It results in an effective trap for sediment derived from inflow points and a large active storage volume resulting in relatively low water level fluctuations even during large storms or snowmelt events.

2.4 WATER QUALITY

Water quality within Grenadier Pond and from storm outfalls to the pond has been described by Zimmerman *et al.* (1986) and the City of Toronto (1993). Additional information has been collected by Gartner Lee Limited in 1993 and 1994. This additional water quality data was collected (at 0.5 m intervals) using a portable YS1 model 58 dissolved oxygen meter mainly at sampling station SW1 (Figure 2.2). The parameters recorded were temperature (°C) and dissolved oxygen (mg/L). Limited shallow water sampling of these parameters were done at SW8.

Gartner Lee water samples were collected using a Kemmer bottle at discreet depths (near–surface and near–bottom) at sampling stations SW1 and SW9. On–site samples were placed in plastic jars and acidified with 1 mL of 30% H_2SO_4. These samples were submitted to Barringer Laboratories for analysis. Gartner Lee collected supplementary information on inputs and outputs, including some data on the quality of ground water discharging into the system.

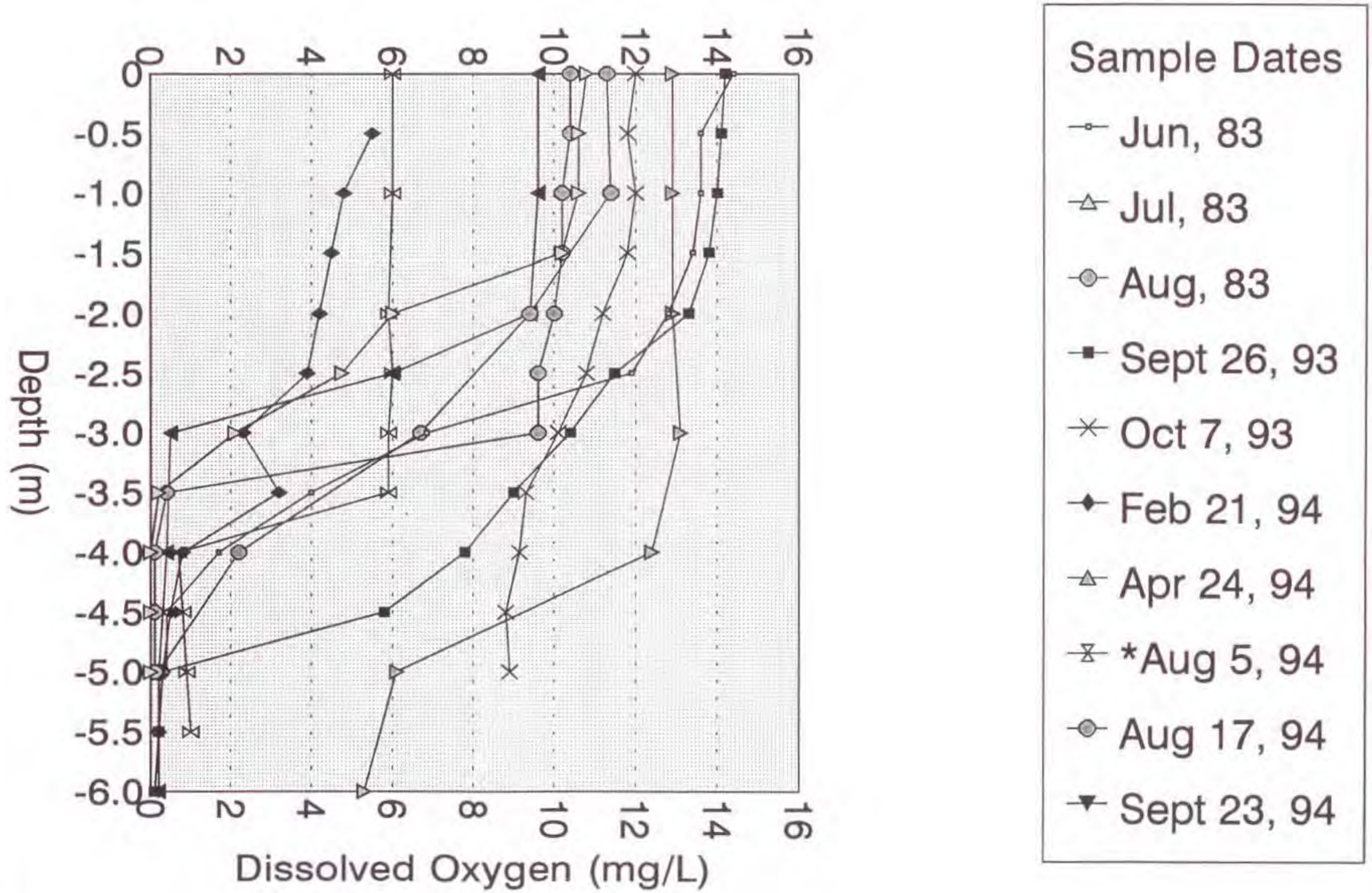
Water quality data are summarized in Tables 2.6 and 2.7. Laboratory results for Gartner Lee data are provided in Appendix B.

2.4.1 Temperature and Dissolved Oxygen Levels

Representative temperature and dissolved oxygen profiles for Grenadier Pond are provided in Figures 2.4 and 2.5; sampling station locations are indicated on Figure 2.2. These include profile information collected in the summer months by Zimmerman *et al.* (1986) in 1983, supplemented with information collected in the fall, winter and spring (1993–1994) by Gartner Lee and the MOEE. These data indicate that the deepest portions of the pond (depths greater than 3 m sampled at SW1) shows some temperature stratification throughout the summer. As stratification prevents mixing of the bottom waters with aerated surface waters, the oxygen supply is soon used up by the bacteria working to decay plant matter resulting in little to no dissolved oxygen (hypoxic to anoxic conditions) in these bottom waters. As fish require oxygen, this portion of the pond becomes unavailable for their use throughout the period when summer oxygen concentrations are less than 5.0 mg/L. Warmwater fish are most active typically during the spring and summer, concurrent with spawning and continual feeding. At this time, the biological oxygen demand of the fish is at its highest as is the need for cool temperature refuges, normally associated with deeper water. During the fall, the pond destratifies, with mixing of water (and dissolved oxygen) occurring through the water column. It restratifies under winter conditions, again resulting in the development of hypoxic to anoxic conditions at depths greater than 4 m when oxygen concentrations drop below 2.0 mg/L. Serious concern for fish survival in the winter is most pronounced when oxygen concentrations are less than 2.0 mg/L. The greater range of

Figure 2.4: Oxygen Profiles for Grenadier Pond

1983 - 1994

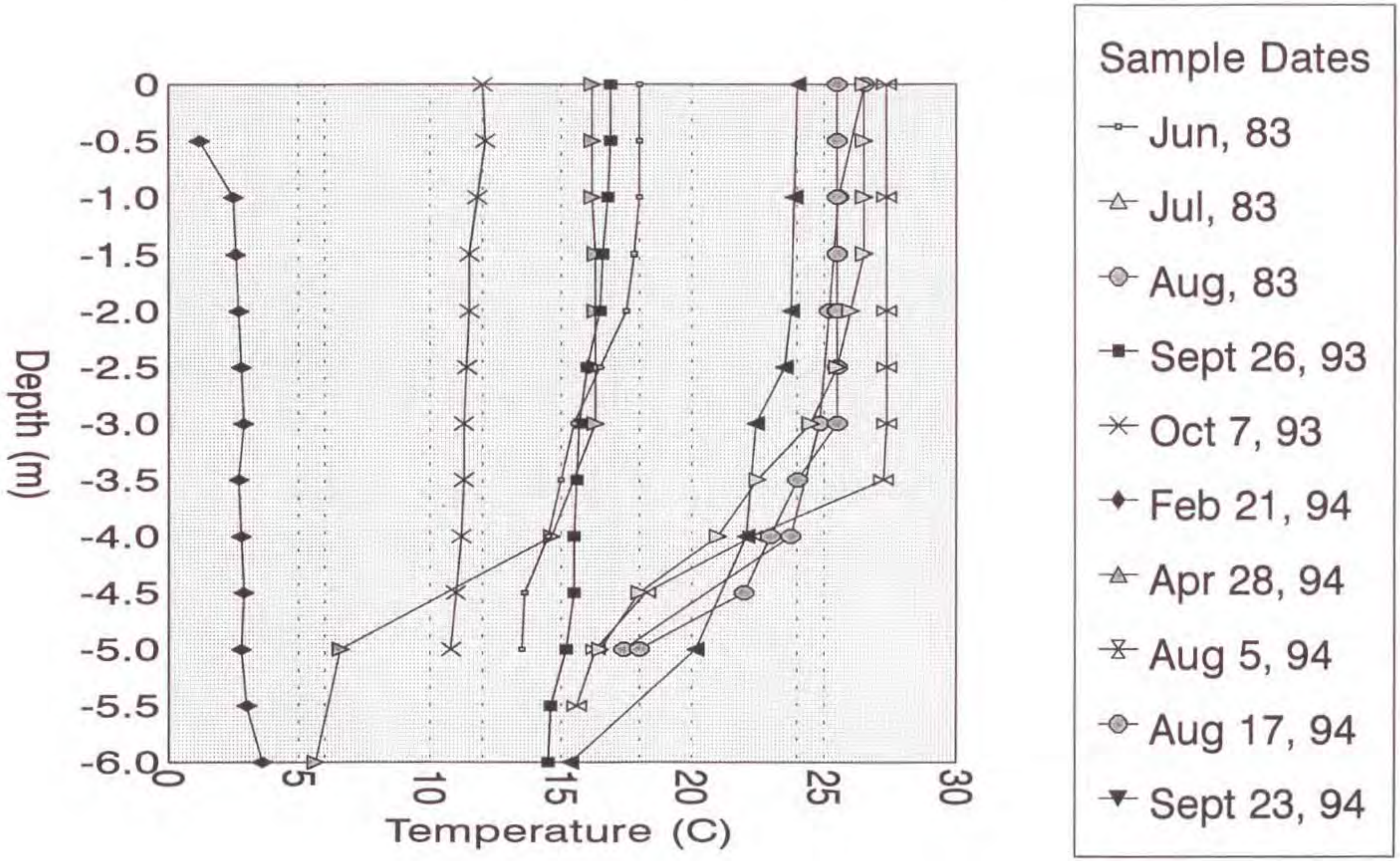


All samples taken from SW1

*Rainstorm occurred August 4, 1995

Figure 2.5: Temperature Profiles for Grenadier Pond

1983 - 1994



All samples from SW1

Table 2.6. Water Quality of Grenadier Pond – Nutrient and Routine Indicator Parameters

A. In–Pond

Date	Sampling Station	pH	TTS	Fe (mg/L)	Total P (mg/L)	NH4 (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TKN (mg/L)	Total N (mg/L)
1986*	SW1	7.9[1]		0.99	0.086	0.27	<0.06	0.12	0.82	1
1986*	SW8			0.29	0.087	0.38	<0.02	0.01	0.86	1.04
July 23/92**	SW1		4.5	<1	0.13				0.75	
July 23/92**	SW9		8	<1	0.23				2.01	
July 23/92**	SW11		2	<1	0.14				0.48	
Aug 13/92**	SW1		5	<1	0.38				0.5	
Aug 13/92**	SW9		5	<1	0.04				2.01	
Aug 13/92**	SW11		8	<1	0.36				0.48	
Sept 17/92**	SW1		4	<1	0.32				1.56	
Sept 17/92**	SW9		210	2	0.04				3.01	
Sept 17/92**	SW11		7	<1	0.35				2.01	
Oct 7/93***	SW1A[2]	8.84	26	0.09	0.18	0.08	0.07	0.029	2.5	2.599
Oct 7/93***	SW1B[2]	8.44	13.9	0.12	0.124	0.34	0.17	0.035	1.81	2.015
Feb 21/94***	SW1A	7.7		0.04	0.087	0.7	0.65	0.024	1.41	2.084
Feb 21/94***	SW1B	7.4		0.165	0.22	1.62	0.84	0.24	2.5	3.58
Feb 21/94***	SW9A	7.58		0.04	0.086	0.75	0.68	0.022	1.39	2.092
Feb 21/94***	SW9B	7.57		0.47	0.156	1.36	1.73	0.104	2.5	4.334
April 28/94***	SW1				0.4					
April 28/94***	SW9				0.065					
April 28/94***	SW11				0.093					
Aug 5/94****	SW1A			<0.02<W	0.062	0.268	0.04	0.011	1.14	1.191
Aug 5/94****	SW1B[4]			<0.02<W	0.8	5.68	0.02<T	0.003<T	7.8	
Aug 5/94****	SW8			<0.02<W	0.06	0.38	0.09	0.018	1.2	1.308
Aug 5/94****	SW9			<0.02<W	0.06	0.288	0.75	0.009	1.1	1.184
Aug 5/94****	SW11			<0.02<W	0.06	0.26	0.04	0.01	1.26	1.31
Provincial Water Quality Objectives				0.3	0.02[3]	0.02				

[1] mean value for pond for 1983

[2] A=near surface sample; B=near bottom sample

[3] no firm objective has been developed for this parameter – 0.02 mg/L is a guideline to prevent nuisance algae conditions in lakes

* Zimmerman et al. – Site A and B

[4] the extreme values suggest region sampled was greater than 5 metres and was likely contaminated by flocculent sediment, therefore not representative of in–pond conditions

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Table 2.6. Continued.

B. Pond Inlet

Date	Sampling Station	pH	TTS	Fe (mg/L)	Total P (mg/L)	NH3-N (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TKN (mg/L)	Total N (mg/L)
Sept 3/92*	SW4		129	8	0.9					
Sept 3/92*	SW7		18		0.2					
July 26/93*	SW4		106	3	0.3					
Aug 8/93*	SW4		95	2	0.2					
Oct 7/93**	SW2	8.76	18.3	0.1	0.135	0.1	0.18	0.025	1.94	2.145
Oct 7/93**	SW3	7.9	6.9	0.63	0.06	0.26	4.22	0.03	0.39	4.64
Oct 7/93**	SW4	8.09	<0.01	0.08	0.067	0.05	5.22	0.026	0.13	5.376
Oct 7/93**	SW5	7.95	8.9	0.17	0.126	0.58	0.45	0.49	2.3	3.24
Feb 21/94**	SW3	7.79		1.02	0.124	0.25	3.76	0.066	0.7	4.526
Feb 21/94**	SW4	7.78		0.32	0.155	0.93	3.53	0.11	1.74	5.38
Feb 21/94**	SW5	7.53		0.48	0.36	1.76	0.94	0.12	4.1	5.16
Feb 21/94**	SW7	7.78		0.74	0.079	0.21	2.96	0.024	0.51	3.494
Provincial Water Quality Objectives				0.3	0.02[3]					

[3] no firm objective has been developed for this parameter – 0.02 mg/L is a guideline to prevent nuisance algae conditions in lakes

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C. Pond Outlets and Groundwater

Date	Sampling Station	pH	TTS	Fe (mg/L)	Total P (mg/L)	NH3-N (mg/L)	NO3 (mg/L)	NO2 (mg/L)	TKN (mg/L)	Total N (mg/L)
Oct 7/93	SW6	8.72	29.9	0.1	0.2	0.04	0.05	0.027	2.2	2.277
Oct 7/93	GW1	7.93	3.5	0.08	0.008	<0.02	0.65	0.002	0.06	
Oct 7/93	GW2	7.74	<0.01	<0.01	<0.002	<0.02	13.6	0.008	0.08	
Feb 21/94	SW6	7.67		0.1	0.186	1.06	0.57	0.05	2.5	3.12

SW=surface water samples

GW=groundwater samples

Table 2.7. Water Quality of Grenadier Pond – BOD, Metals and Fecal Coliform

A. BOD and Metals

Date	Sampling Station	BOD (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Mn (mg/L)	SO4 (mg/L)	SiO3 (mg/L)	Cd (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Pb (mg/L)	Zn (mg/L)	Hg (ug/L)	Ni (mg/L)
1986*	SW1		22.7	176.5	3.68	0.114	71.6	3.07	0.0002	0.002			0.005	0.0087	0.05	
1986*	SW8		22.8	176.4	3.6	0.075	73.6	2.73	0.0002	0.002	0.014			0.004	0.06	
July 23/92**	SW1	1.75	20.5	176	3	0.14										
July 23/92**	SW9	2.3	19	174	3.97	0.1										
July 23/92**	SW11	1.8	20	184	3.99	0.1										
July 26/92**	SW4	57	6	13	6	0.4			–	0.05	0.06		0.1	0.2		0.02
Aug 8/92**	SW4	26	23.2	190.2	5.8	0.1			–	0.05	0.01		–	0.03		0.03
Aug 13/92**	SW1	1.35	20.5	167.5	3.91	0.08										
Aug 13/92**	SW9	1.8	21	169	3.91	0.06										
Aug 13/92**	SW11	1.6	21	173	3.97	0.06										
Sept 3/92**	SW4	7	4	6	4	0.2			–	0.02	0.03		–	0.2		0.02
Sept 3/92**	SW7	6	4	10	2	0.1			–	0.007	0.01		–	0.09		0.01
Sept 17/92**	SW1	5.05	19	173.5	3.82	0.05										
Sept 17/92**	SW9	6.6	19	172	3.66	0.06										
Sept 17/92**	SW11	7.9	22	188	3.96	0.15										
Oct 7/93***	SW1A											0.09				
Oct 7/93***	SW1B											0.12				
Feb 21/94***	SW1A											0.04				
Feb 21/94***	SW1B											0.16				
Feb 21/94***	SW9A											0.04				
Feb 21/94***	SW9B											0.47				
Aug 5/94****	SW1A		20.76	211.7	3.787	0.013	59.68									
Aug 5/94****	SW1B		21.06	306	4.594	0.095	58.25									
Aug 5/94****	SW8		20.64	206.28	3.677	0.0017	60.81									
Aug 5/94****	SW9		20.94	211.32	3.796	0.0083	60.94									
Aug 5/94****	SW11		20.94	214.2	3.742	0.0052	60.26									
Provicial Water Quality Objectives									0.002	0.1	0.005		0.005–0.025	0.03	0.2	0.025

* Zimmerman et al. – A=near surface, B=near bottom

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TABLE27A.wk3 16–May–95 93–251

Table 2.7. Continued.

B. Fecal Coliform Levels

	INLET			IN POND				OUTLET
Date	SW3	SW4	SW5	SW1	SW8	SW9	SW11	SW6
1986*				20	350			
July 7/92**	1500	840	160					100
July 16/92**	2900	4100	100					100
July 23/92**				32		28	76	
July 24/92**	770	830	1100					32
Aug 13/92**	7800	1120	740	1120		28	16	1090
Sept 17/92**	33000	4100	700	82		8	800	3000

Provincial Water Quality Objective: 100 (#/100 ml)

* Zimmerman et al. 1986 – Site A and B

** City of Toronto

low–oxygen tolerance in winter as compared to summer conditions relates to the dramatic decline in fish activity. However, oxygen is still required to maintain a base metabolism and minimal locomotion. Destratification occurs again in the early spring. Data collected on April 28, 1994 indicates that the system had already restratified by this time with a decline in oxygen occurring below 4.0 m.

The temperature stratification patterns exhibited in these data are typical of lakes that only mix twice per year (dimictic) which are common in temperate regions. Density differences between surficial and deeper waters become sufficient to prevent the mixing of these waters under both summer and winter conditions. However, as surface water temperatures decrease in the fall and increase in the spring, the difference in water density between the two layers is reduced to the point where wind–induced mixing can occur. There is some argument as to whether Grenadier Pond is truly dimictic. Based on the morphometry of the pond and temperature data, Nürnberg (see Appendix A) has predicted that the system should only weakly stratify and may be susceptible to wind–induced mixing several times during the summer months and not just once in spring and again in the fall (i.e., it is polymictic). This is supported by observations by Wainio *et al.* (1976) who found mixing did occur during one summer season. However, Zimmerman (1991) data suggests that the system undergoes weak stratification but that it typically remains stratified throughout the summer. Additional recent data collected by Zimmerman (pers. comm.) further suggests that the pond is normally dimictic. Zimmerman has never observed polymixis within the system and suggests treatment options should consider the system as being dimictic. The amount of temperature data collected to date is insufficient to resolve the issue of polymictic vs. dimictic. Therefore future monitoring programs will need to incorporate temperature profiles as a key parameter to be measured.

Figure 2.4 indicates that Grenadier Pond reaches a maximum summer temperature of 26°C. This temperature is typical of warmwater lakes. While temperatures remain near 18°C at the bottom, the low dissolved oxygen concentrations restrict the use of this area by fish. These conditions indicate that the pond is only suitable for warmwater fish species.

2.4.2 Water Clarity

Water clarity in Grenadier Pond is poor. Secchi disk depth measurements of Zimmerman *et al.* (1986) range between 4.0 and 0.8 m. The secchi disk depth approximates the depth to which 10% of incident light penetrates (Zimmerman *et al.*, 1986). It provides an indication of the depth to which plants and algae can grow. Secchi disk depth is reduced by both suspended sediments and algae. Gartner Lee measurements of secchi disk depth at SW1 (Figure 2.2) ranged from 0.5 m (October 7, 1993) to 0.6 m (April 28, 1994) to 0.9 m (September 23, 1994).

Data collected by the MOEE on August 5, 1994 measured a secchi depth of 1.6 m at SW1 (Figure 2.2). The summer of 1994 was atypically dry, receiving less precipitation than an average year. Under these dry conditions, less surface runoff to the pond would be expected, directly reducing the amount of phosphorus reaching the pond as well as suspended sediments . In summary, the increased water clarity this past year is unlikely due to improved conditions within the watershed or pond but more to yearly climatic variation. However, data limitations require additional and more frequent monitoring of water quality to assess any improvements.

2.4.3 Bacterial Levels

Fecal coliform levels within Grenadier Pond are provided in Table 2.7. Fecal coliform organisms are not pathogens but an indicator of the presence of fecal matter from warm blooded animals. Their presence indicates a potential for the presence of pathogenic organisms. Elevated fecal coliform levels are associated with high nutrient loading and could signify another source of contamination that should not be ignored. Levels occasionally exceed 100 organisms per 100 mL within the pond, the limit established for body contact recreation (MOE, 1984). Levels of as high as 1,120 fecal coliform/100 mL had been observed within the pond but are typically between 20 and 300. Probable sources are pet feces contributed from storm water runoff and bird feces contributed by direct runoff and/or defecation directly into the pond.

Levels of fecal coliform bacteria in the storm water inputs and surface water drainages entering the pond routinely exceed 100 organisms per 100 mL. Values of up to 4,000 fecal coliform/100 mL have been recorded in Wendigo Creek. The routinely high levels of fecal coliform in storm water indicates that this is a major source of bacterial contamination to the pond. The high levels suggest a potential for sanitary cross connections.

The high levels of fecal coliform bacteria observed within Grenadier Pond restrict the use of the park for body contact recreation such as swimming or windsurfing, but do not represent a concern for fish and wildlife.

2.4.4 Nutrient Levels

There is limited data on phosphorus concentrations in discharges to Grenadier Pond. For the purposes of this discussion, there are three main discharges: the Clendenan Avenue sewer, which outlets Clendenan Avenue and provides most of the flow within Wendigo Creek; the Valleymede Road sewer, a smaller sewer outletting the north end of Grenadier Pond, and drainage from Catfish Pond, which is fed by storm sewers, direct runoff and ground water discharge to Catfish Pond. Based on two dry weather samples collected by Gartner Lee Limited and average values seen in three wet weather events samples by the City of Toronto (Table 2.6b), the mean concentrations of phosphorus is 0.324 mg/L in the Clendenan Avenue sewer. A mean phosphorus value of 0.140 mg/L was observed at the Valleymede Road sewer (based on one dry weather sample and one wet weather sample). A mean phosphorus value of 0.243 mg/L was seen at the outlet of Catfish Pond in two dry weather samples collected by Gartner Lee Limited. Under dry weather conditions, phosphorus concentrations within the Clendenan Avenue and Valleymede Road sewers were 0.11 and 0.079 mg/L respectively (Table 2.6b) which were typically as low or lower than trends seen within Grenadier Pond (Gartner Lee results, Table 2.6a). However, phosphorus concentrations from these drainage areas are much higher during storm events (0.47 mg/L from Clendenan sewer and 0.20 mg/L from Valleymede sewer), the periods during which most of the flow from these sources occurs (City of Toronto results, Table 2.6b). Phosphorus levels within the Catfish Pond drainage, under dry weather conditions, appear to be typically higher than levels within Grenadier Pond itself, which is consistent with previous observations of higher phosphorus levels in Catfish Pond than in Grenadier Pond (Zimmerman *et al.*, 1986).

Total phosphorus concentrations within Grenadier Pond are provided in Table 2.6a. Total phosphorus concentrations within the pond range from 0.04 to 0.4 mg/L. Zimmerman *et al.* (1986) found the average concentration to be 0.086 mg/L. Results obtained by Gartner Lee Limited, the City of Toronto (1993) and the MOEE (1994) suggest that the average concentration is now 0.20 mg/L (mean value based on 22 samples ranging between 0.04 and 0.4 mg/L). These phosphorus concentrations put Grenadier Pond in the eutrophic (.03 to .1 mg/L) to slightly hypereutrophic (>0.1 mg/L) category (Zimmerman *et al.*, 1986).

Phosphorus concentrations averaged 0.19 mg/L in two samples collected at the pond outlet by Gartner Lee Limited on October 7, 1993 and February 21, 1994 (Table 2.6c) while this is consistent with the average phosphorus levels observed in the pond in Gartner Lee Limited, City of Toronto and MOEE samples, it was higher than the average pond concentration of 0.14 mg/L observed on these two dates. This suggests that there could be some short circuiting of nutrients from Catfish Pond drainage and possibly from birds congregating at the southern end of the pond to the pond outlet. The concentration of total phosphorus in the Catfish Pond drainage was found by GLL to be 0.243 mg/L which is substantially higher than the in–pond values found.

Very low concentrations of phosphorus were found in two ground water samples collected by Gartner Lee Limited (Table 2.6c), with detectable levels (0.008 mg/L) found in only one of the two samples.

Another trend in the phosphorus data appears when comparing near–surface and near–bottom samples at station SW1 (Table 2.6a). Data collected in February 1994 and August 1994 indicate higher concentrations of phosphorus in the bottom waters as compared to the near–surface water. On both dates, the pond was thermally stratified and had hypoxic bottom waters, that is, less than 2.0 mg/L of dissolved oxygen (Figures 2.4 and 2.5). Under very low or no oxygen levels, phosphorus can be released from the sediments into the water column, a process called internal loading. The winter and summer data suggest that internal loading occurs seasonally in Grenadier Pond but the exact timeframe for internal loading needs to be determined.

However, data collected on October 7, 1994 at SW1 (Table 2.6a) indicates the reverse phosphorus pattern, that is, a higher concentration of phosphorus was found in the near–surface water than in the deeper water. By this date the pond was no longer thermally stratified (Figure 2.5) and the mixing of aerated surface water with bottom water had increased dissolved oxygen concentrations in the bottom water to above 8.0 mg/L (Figure 2.4). Further release of phosphorus from the sediments was likely suppressed due to higher oxygen concentrations, and the higher hypolimnetic phosphorus may have risen up into the epilimnion during the fall turnover which in part explains the high concentrations of phosphorus at the surface (an increase in external loads must also be considered). It is not clear if this phosphorus is biologically available for uptake by algae. Studies suggest upwelling phosphorus availability depends on the degree of dilution of anoxic water as well as iron and oxygen concentrations (Nürnberg, 1985).

Nitrogen forms a major nutrient that affects the productivity of lakes. There are inorganic forms of nitrogen (nitrate, nitrite, ammonia) organic nitrogen compounds and molecular nitrogen (N_2). Total nitrogen (TN) refers to only the sum of inorganic and organic forms. Total nitrogen levels within drainages to Grenadier Pond averaged 5.38 mg/L for the Clendenan Avenue sewer and 4.20 mg/L for the Catfish Pond drainage for two dry weather samples collected by Gartner Lee Limited (Table 2.6b). A value of 3.49 mg/L was observed in a single sample collected from the Valleymede Road sewer. These discharges serve as a major source of nitrogen to the pond. Total nitrogen values are not available for storm event sewer sampling undertaken by the City of Toronto, however, total kjeldahl nitrogen (TKN) values (organic nitrogen and NH_3) are available and were similar to those seen in dry weather samples collected by Gartner Lee Limited. TKN values do not contribute that significantly to total nitrogen levels. More than 80% of the total nitrogen from the Clendenan Avenue sewer and Valleymede Road sewer samples collected by Gartner Lee Limited was in the form of nitrate. Common sources of nitrate found in the watershed are lawn fertilizers and animal waste that wash into the storm sewers. Nitrogen within the Catfish Pond drainage was divided between organic nitrogen (48%), ammonia (28%) and nitrate (20%), similar to the ratio seen within Grenadier Pond itself. Levels of nitrogen, in particular nitrate, were high in ground water samples (Table 2.6c). However, limited data on ground water chemistry makes it difficult to assess the significance of this source.

Total nitrogen levels within Grenadier Pond averaged 2.38 mg/L in eight samples collected by Gartner Lee Limited and the MOEE, compared with an average of 1.02 mg/L in samples collected by Zimmerman *et al.* (1986) (Table 2.6a). On average, organic nitrogen (TKN minus NH_3 values) contributes 43%, ammonia contributes 29% and nitrates contribute 25% to the total nitrogen values observed by Gartner Lee Limited. Contributions from nitrite are very minor. This is reasonably consistent with the results of Zimmerman *et al.* (1986), although negligible levels of nitrate were seen in their samples. Organic nitrogen values averaged 0.515 mg/L in samples collected by Zimmerman *et al.* (1986) and 1.21 mg/L in samples collected by Gartner Lee Limited and the MOEE. According to Zimmerman *et al.* (1986), this also puts Grenadier Pond in a marginally hypereutrophic productivity class (organic nitrogen concentration between 0.7 and 1.2 mg/L).

The high levels of phosphorus in Grenadier Pond, in combination with high levels of nitrogen, relate directly or indirectly to many of the problems within the pond. High nutrient levels encourage the growth of both macrophytes (rooted plants) and algae. In general, algae and aquatic macrophytes utilize nitrogen in the form of nitrate (ammonia can also be used, but is pH dependent). Some blue-green algae have the ability to use molecular nitrogen as well, although this ability is enzymatically suppressed when concentrations of inorganic nitrogen are high (Wetzel, 1975). A single analysis of the type of algae growing in Grenadier Pond was conducted by the MOEE in August 1994. Approximately 87% of the algae in the pond were blue-greens (mainly *Aphanizomenon sp.*), a less desirable food source of most zooplankton and only 6% were found to be green algae, which are readily consumed by zooplankton, with the remaining species a collection of diatoms and brown algae. *Aphanizomenon sp.* is known to be nitrogen fixer, however, it should be noted that their presence in the pond is not evidence that they are actually fixing nitrogen (Zimmerman, pers.comm.); appropriate testing would have to be conducted to confirm the biological activity of this algae. The general implication of this is that the system currently favours the growth of blue-green algae over other species.

Studies suggest that blue-green algal blooms can occur when epilimnetic TN:TP ratios drop below approximately 7:1 by concentration, (mg/L) (Zimmerman, pers.comm.). When the ratio is higher than this value, the growth of blue-green algae is less common, consistent with higher concentrations of nitrogen other than the molecular form. The TN:TP ratio for surface waters in Grenadier Pond was 11.6 according to Zimmerman data (1986) and the average values found by GLL (1992/93) and MOEE (1994) was 20.5 (see Table 2.6a). Based on the latter values, Grenadier Pond is not likely a nitrogen limited system, although caution must be taken in light of organic nitrogen being included in this ratio. A large portion of TN in lakes is comprised of organic nitrogen which must be converted into inorganic forms in order to be up taken by algae and plants. This conversion takes place through various biochemical processes, such as, decomposition and nitrification. Further study would be required to detail the eventual availability of organic nitrogen to the productivity in Grenadier Pond.

Systems experiencing blooms of blue-green algae exhibit a collection of strongly autocorrelated limnological conditions that it is difficult to isolate one factor as the cause for blue-green dominance. The dominance of blue-green algae is likely a combination of high nutrient availability (of both phosphorus and nitrogen), selective grazing on green algae by zooplankton and, perhaps more importantly, the fact that blue–greens are able to regulate their position in the water, inhabiting the very surface of the water, creating a mat, as opposed to green algae which inhabits the upper region of the water column where light penetrates, also called the euphotic zone (1 to 2 m). The competition for light can be a significant factor in blue–green algae dominance over other algae and larger rooted plants. Blue–green algae are able to photosynthesize at very low light levels (below 0.1%) as opposed to the 1% of most other algae (A. Zimmerman, pers.comm.). In addition, the abundance of algae increases at the water's surface, plants in the water column are shaded out and water clarity decreases to the point where blue–green algae are advantaged and rooted vegetation has a difficult time surviving. This is presently the situation within the pond. Algae blooms can result in unsightly and odourous accumulations of dead algae within the pond and along its shoreline. Decaying algae settles to the pond bottom. Through bacterial action, the process of decay continues releasing ammonia and consuming oxygen, contributing to the creation of low oxygen levels and, as a result, poor fish habitat, within the deeper waters of the pond. The accumulation of partially decomposed algae on the pond bottom also limits the production of benthic invertebrates (a food source for fish and some other wildlife), adds to pond turbidity when disturbed (with impacts on sight–feeding fish) and further reduces the potential for rooted macrophytes given its flocculant and oxygen demanding nature. The overall process of nutrient enrichment can gradually result in a system which has a poor diversity of animal and plant life, limited recreational opportunities and which is aesthetically unpleasant.

A monitoring program should be set in place to better understand the seasonal dynamics of nitrogen in Grenadier Pond. It would also be important to concurrently monitor biological responses to nutrient changes, for example, chlorophyll concentrations in the epilimnion.

2.4.5 Metal Levels

Iron concentrations were measured as a general indicator parameter in Gartner Lee Limited samples. Values have been compared to the Provincial Water Quality Objective (PWQO), an objective developed to protect aquatic life. Levels are typically below the PWQO of 0.3 mg/L within the pond (Table 2.6a). However, levels of iron within storm sewer discharges often exceed the PWQO. An increase in iron concentrations within Wendigo Creek, between its source at a storm sewer outlet at Clendenan Avenue (SW4: 0.032 to 0.08 mg/L) to above its confluence with the pond (SW3: 0.63 to 1.02 mg/L) suggest that ground water seepage along the creek may be the source of this metal. The presence of iron–staining along the creek banks supports this. Iron is commonly found at naturally high concentrations in ground water, although may also indicate the presence of leachate from landfill materials which are reported to have been historically deposited along the west side of Wendigo Creek (Decommissioning Consulting Services Limited, 1992). Iron can also be an important factor affecting the phosphorus cycle. Iron binds with phosphorus to precipitate it out of suspension. Lake Wilcox is considered an iron limited system with only 0.036 mg/L of iron in the hypolimnion as compared to Grenadier Pond which ranges between 0.12 to 0.47 mg/L of iron in the deep water. While extensive testing was not undertaken, it appears that metal levels were not elevated in a sample of suspected leachate collected along the banks of Wendigo Creek (Decommissioning Consulting Services Limited, 1992).

Results of other metal analyses conducted by Zimmerman *et al.* (1986), the City of Toronto (1993) and the MOEE (1994) are provided in Table 2.7. There were occasional minor exceedances of the PWQO for copper and nickel. All other parameters met their respective PWQOs.

As activities that result in direct body contact with the water of Grenadier Pond, such as swimming, are not presently practiced, human health risks are considered through indirect pathways for contamination, such as consuming fish. According to the Guide to Eating Ontario Sport Fish (MOEE and MNR, 1991) there are no restrictions to eating pumpkinseeds, black crappie or white perch which were all tested for mercury and other metal contamination.

The limited data on metal levels within Wendigo Creek and Grenadier Pond suggests that these contaminants are present in only small quantities which would not be toxic to either fish or wildlife.

2.4.6 Organic Contaminant Levels

There are no data on concentrations of organic contaminants within Grenadier Pond. Samples of suspected leachate were previously collected along the banks of Wendigo Creek and analyzed for volatile organic compounds, gasoline and middle distillate petroleum hydrocarbons (Decommissioning Consulting Services Limited, 1992). Phenols and benzene were both detected. Benzene was found at a concentration of 0.06 mg/L, below the PWQO of 0.1 mg/L. Phenols were found at concentrations of 0.0025 mg/L, above the PWQO of 0.001 mg/L. However, the PWQO has been established to prevent unpleasant taste in fish flesh, not because of the toxicity of phenols. Trace levels of petroleum hydrocarbons were also noted. The presence of such compounds could also be related to storm water discharges.

The limited data on organic contaminants within Wendigo Creek suggest that these contaminants are present in only small quantities which would not be toxic to either fish or wildlife at Grenadier Pond.

Similar to concerns of metal contamination, human exposure to organic contaminants would be indirect. According to the "Guide to Eating Ontario Sport Fish" (MOEE and MNR, 1991), there are no restrictions to eating pumpkinseeds, black crappies, white perch or brown bullheads which were all tested for PCB and pesticide (Ontario use) contamination.

2.4.7 Other Parameters

A summer concentration of hydrogen sulphide in the bottom waters (SWIB) was measured by the MOEE (1995). The concentration was found to be 11.7 mg/L which is significantly above the Provincial Water Quality Objective for undissociated hydrogen sulphide of 0.002 mg/L to protect aquatic life. The high concentration of hydrogen sulphide in the bottom waters precludes fish habitat. The narrow interface between the warm surface waters and the chemically toxic bottom waters provides very limited fish habitat.

2.4.8 Summary

In summary, Grenadier Pond has a problem with elevated nutrients and does receive some low–level contamination of a few organic chemicals and metals. Storm water discharging from the Clendenan Avenue sewer is the greatest source of surface water drainage into the pond. Treatment of this water before it enters the pond is being emphasized through the future installation of a sediment settling pond as the base of Wendigo Creek by the Department of Public Works and the Environment. Another significant source of surface water to the pond, together with phosphorus and contaminants, is the outfall from Catfish Pond. Fortunately, the water received from this source lacks much opportunity to mix with the majority of the pond as the main discharge from Catfish is located adjacent to the Grenadier Pond outlet (Figure 2.2). Remediation efforts will focus on further limiting the dispersal of Catfish Pond drainage with the rest of Grenadier. The third main source of phosphorus contamination is the sediments. Methods of reducing the internal load of phosphorus is required in order for the rehabilitation plan to be effective.

2.5 SEDIMENT QUALITY

Sediment quality data for Grenadier Pond has been collected by Zimmerman *et al.* (1986) and M.M. Dillon Limited (1993). Additional data was collected by Gartner Lee Limited in 1993 using an Ekman grab sampler. These samples were transported to Barringer Laboratories for analysis. These data are summarized in Table 2.8. Ontario Provincial Sediment Quality Guidelines (Persaud *et al.*, 1992) and Urban Residential Fill Criteria (MOEE, 1992) are provided in Table 2.8 for comparison. The Sediment Quality guidelines define three levels of ecological effects, based on the chronic, long–term effects of these contaminants on benthic organisms. The no–effect level defines a concentration at which no toxic effects have been observed in aquatic organisms and at which no biomagnification through the food chain is anticipated. The lowest–effect level represents a level of contamination that can be tolerated by the majority of benthic organisms. A severe–effect level indicates a level of contamination which is likely to be detrimental to the majority of benthic species and have a

Table 2.8 Sediment Quality for Grenadier Pond, 1992 to 1993

Date	Sampling Station	pH	As (mg/kg)	Se (mg/kg)	Sb (mg/kg)	Hg (mg/kg)	Total CN (mg/kg)	Ag (mg/kg)	Ba (mg/kg)	Be (mg/kg)	Cd (mg/kg)	Co (mg/kg)	Cr (mg/kg)
1986*			8.31			0.16					1.7	3.1	18
1992**	SED2	7.5	2.1	<1		0.05	0.05	<0.5			0.4	2.9	9.6
	SED3	7.3	1.4	<1		<0.05	0.05	<0.5			0.2	2.1	9.5
	SED4	7.4	4.3	1		0.1	0.41	<0.5			0.8	2.7	10
1993***	SED1												
	SED2												
	composite	7.5	2.5	2.2	0.4	0.183	<0.05	<0.3	96.4	0.38	1.2	<2	12.1
MOEE Sediment	No Effect		–	–		–					–	–	–
Quality Guidelines[1]	Lowest Effect		6			0.2					0.6		26
	Severe Effect		33			2					10		110
Urban Residential Fill Criteria[2]		3.1	17	1.3	0.43	0.18	0.05	0.33	180	1.1	0.84	17	62

Date	Sampling Station	Cu (mg/kg)	Mo (mg/kg)	Ni (mg/kg)	Pb (mg/kg)	P (mg/kg)	TKN (mg/kg)	NH3-N (mg/kg)	NO2-N (mg/kg)	NO3-N (mg/kg)	TOC (mg/kg)	Fe (mg/kg)	Zn (mg/kg)
1986*		44		12	290	800	5600				61000	12000	260
1992**	SED2	8.9		5.5	75.7	320	580						
	SED3	4.5		4.2	46.3	350	140						
	SED4	10.9		7.6	115	740	650						
1993***	SED1					620	6050	670	<0.5	0.9			
	SED2					570	6330	670	<0.5	1			
	composite	45.3	<3	<2	163								
MOEE Sediment	No Effect	–		–	–	–	–						
Quality Guidelines[1]	Lowest Effect	16		16	31	600	550					20000	120
	Severe Effect	110		75	250	2000	4800					40000	820
Urban Residential Fill Criteria[2]		65	1	38	98								

ppm = mg/kg dryweight

* Zimmerman et al.

** M.M. Dillon Limited

*** Gartner Lee Limited

[1] Persaud et al. 1992

[2] MOEE 1992

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pronounced effect on the sediment–dwelling community. The Urban Residential Fill Criteria have been taken from the Proposed Policy for Management of Excess Soil, Rock and Like Materials (MOEE, 1992). It should be noted that this document was distributed for technical consultation only and, as such, these criteria may be revised. They do, however, provide an indication of the quality of pond sediments in relation to soils of typical urban parks and have implications for sediment disposal (if any of the parameters are exceeded, then sediments could not be used as park or urban residential fill).

2.5.1 Nutrient Levels

Observed phosphorus concentrations in Grenadier Pond sediments fall between 320 and 800 mg/kg on a dry weight basis (Table 2.8). Some of these values exceed the low–effect level of 600 mg/kg. These phosphorus concentrations measured in the sediment of Grenadier Pond were generally lower than the concentrations found in another urban waterbody, Lake Wilcox (650 to 1,070 mg/kg).

Concentrations of TKN range of between 140 and 650 mg/kg were observed by M.M. Dillon Limited (1993) (Table 2.8). Results of Zimmerman *et al.* (1986) and Gartner Lee Limited are approximately ten fold higher, with a maximum value of 6,330 mg/kg observed. These values exceed the severe effect level. The reason for the discrepancy between result is not known (sampling locations were generally similar). It is recommended that further sediment sampling be done to confirm the depth, distribution and chemical characteristics for sediment remediation options.

Results suggest that sediment nutrient levels would be toxic to many benthic organisms.

2.5.2 Metal Levels

One or more of the sediment samples which have been collected at Grenadier Pond exceeded the low–effect level but were less than the severe effect level for arsenic, cadmium, copper, lead and zinc (Table 2.8). For lead, all samples collected exceeded the low–effect level and one sample slightly exceeded the severe–effect level. Results suggest that these sediments would be toxic to many benthic organisms.

Levels of selenium, mercury, total cyanide and cadmium exceeded the proposed Residential Fill Criteria in one or more samples (Table 2.8).

As mentioned earlier, iron can play an important role in keeping phosphorus bound in the sediments. Grenadier Pond sediments measured 12,000 mg/kg of iron as compared to an iron–limited system such as Lake Wilcox which has only 1,100 mg/kg of iron in the sediments.

2.5.3 Organic Contaminant Levels

Sediment samples collected by M.M. Dillon (1993) were analyzed for PCBs and organochlorine pesticides. These results are provided in Appendix B. Trace levels of DDT and its metabolites were seen in one of the three samples collected (the one collected at the north end of the pond). Measured concentrations were in excess of the low–effect level but less than the severe effect level (MOEE, 1992). PCBs and all other organochlorines analyzed were not detected in any of the samples.

2.6 WATER, SUSPENDED SOLIDS AND NUTRIENT BUDGETS

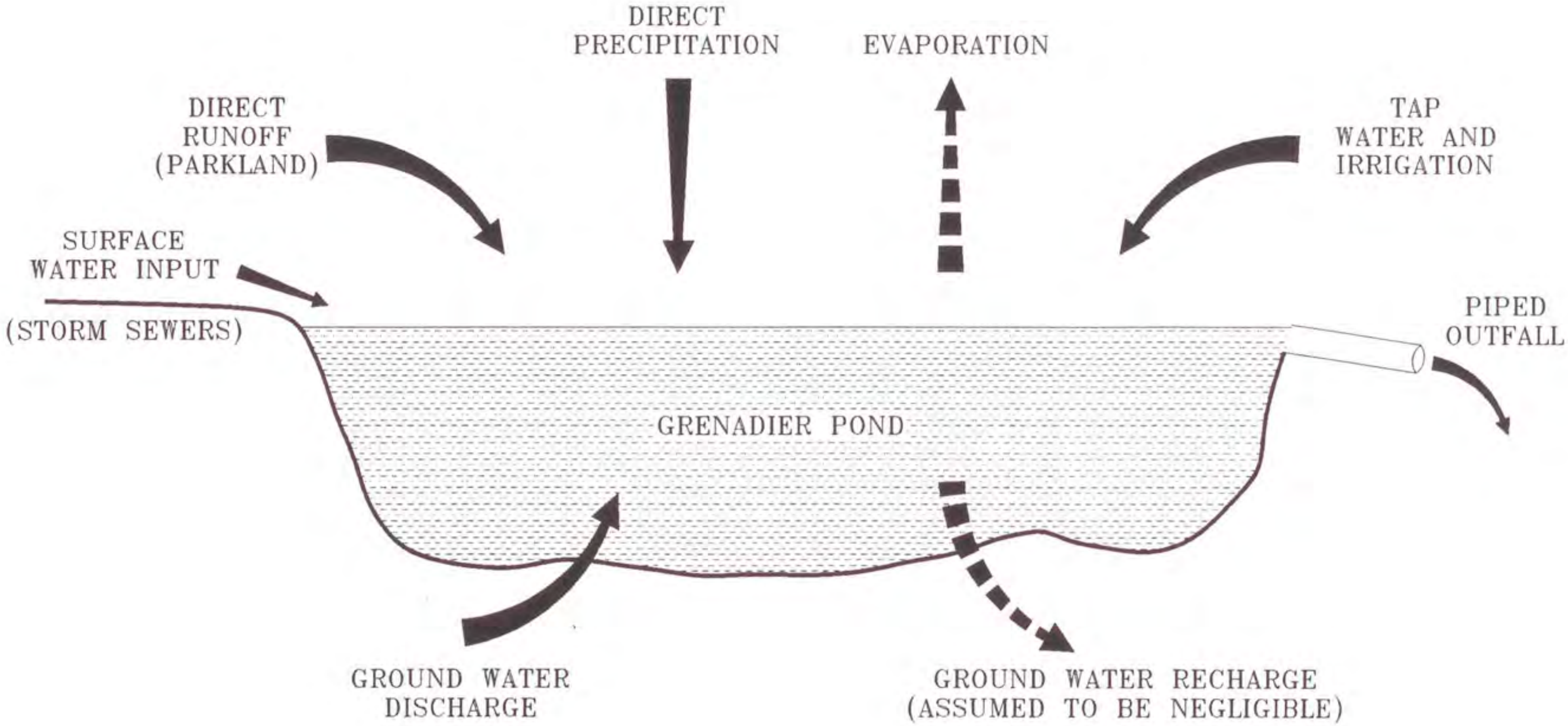
2.6.1 Water Balance

In order to assess the performance of the pond under existing conditions as well as evaluate the benefits of remedial options, a water balance was prepared. This analysis uses the best available data for rainfall evaporation, surface runoff and ground water inflow to estimate the actual and relative contribution of each component. The use of measured data are preferred over calculated or deduced values for the water balance. A generalized schematic of the components of the water balance is provided in Figure 2.6 and the data summarized in Table 2.9.

Table 2.9: Water Balance for Grenadier Pond (Existing Conditions)

Inputs	*	Direct Precipitation *(average 820 mm per year)*	155,000 m^3
		Ground Water Inflow *(15 L/s)*	492,000 m^3
Surface Inflow	*	Clendenan Avenue Outfall	172,000 m^3
	*	Valleymede Road Outfall	27,000 m^3
	*	Catfish Pond Drainage *(3 outfalls)*	138,000 m^3
		Direct Runoff *(High Park)*	46,000 m^3
	*	High Park Irrigation/Tap Water *(2.0 L/s over 6 months)*	32,000 m^3
Total Annual Input			**1,062,000 m^3**
Outputs	*	Lake Evaporation *(400 mm per year)*	76,000 m^3
		Pond Outflow	986,000 m^3
Total Annual Output			**1,062,000 m^3**

* *measured values*



Site Name:
File Name: FG01AF26.DWG

Gartner Lee

GENERALIZED SCHEMATIC OF WATER BALANCE FOR GRENADIER POND

Project No. 93-251
Date Issued: MAY 1995

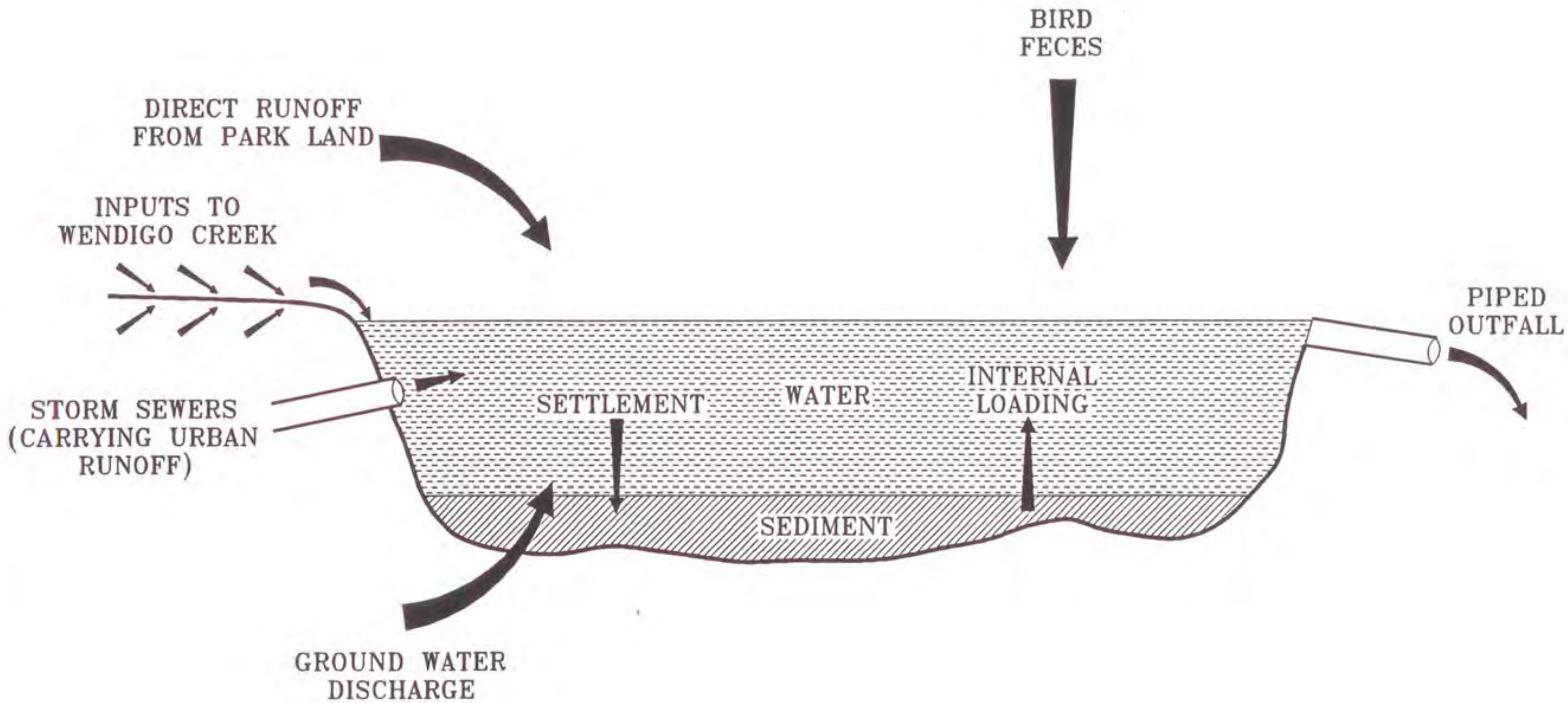
Figure 2.6

The water balance shows that in the order of 1.06 million m^3 per year flows through the pond from surface runoff and ground water inflow. This results in an annual retention time of about 0.5 years or turnover time of 2 times/year. The City of Toronto data for pond outflows showed about 40 L/s for four measurements in 1992. This would imply an annual outflow of about 1.3 million m^3. This estimate, however, is based on very limited data collected during a wet year. The nature of the pond outfall prohibited further measurements during this study. It was felt that the sum of total inputs to the pond provided a more reliable estimate of the total output. Of the 1,062,000 m^3 estimated, a total annual output, 76,000 m^3 can be partitioned to lake evaporation and the remaining 986,000 m^3 to the pond outfall. This later value agrees reasonably well with the 1.3 million m^3 estimated during a wet year. Given the limited data on outflows this compares reasonably well with the 1.06 million m^3 estimated for the water balance. The balance also assumes that ground water recharge under the pond is zero based on the constant upward gradients as previously noted in Table 2.2.

The water budget formed the basis for the construction of the suspended sediment, total phosphorus and total nitrogen budgets. Concentrations of these parameters were determined through water sampling or from literature values for each of the sources of water to the pond. Multiplied by the annual volume of water, these provided annual loading values. Other sources of loadings which are not contributed from discharges to the pond were bird feces and internal loadings. As empirical data was generally quite limited, several assumptions have had to be made. A generalized schematic outlining nutrient and contaminant sources and pathways is provided in Figure 2.7. Model results are provided in Tables 2.10 and 2.11. Model results and underlying assumptions are discussed in the following paragraphs.

2.6.2 Suspended Solids

Storm sewer discharges are a major source of suspended solids. A literature value of 125 mg/L has been predicted for the major storm sewers outletting to Grenadier Pond (the outlet to Catfish Pond has been treated as a storm sewer based on general water quality at this location). The concentration of 125 mg/L is the mean concentration for urban sites calculated by the U.S. EPA (MOE and MNR, 1991). This value is generally conservative in comparison to mean urban suspended sediment concentrations calculated in other jurisdictions (MOE and MNR, 1991). It is reasonably consistent in comparison with the limited data that has been collected by the City of Toronto (1993) for storm sewers outletting to Grenadier Pond (during storm events) (Table 2.6c). Average values observed during storm events monitored by the City of Toronto ranged from 18 to 129 mg/L, with a mean value of 87 mg/L. A peak value of 865 mg/L was observed at the Clendenan Avenue outfall. An average concentration of 87 mg/L has been used by Dillon (1994) in their evaluation of storm water treatment options for the north end of Grenadier Pond, a project recently completed for the City of Toronto. Collectively, these storm sewers are calculated to account for 46,904 kg of suspended solids per year (Table 2.10), representing 87.1% of the total loadings to the pond (Table 2.11).



Site Name:	
File Name:	FG02AF27.DWG

Gartner Lee

GENERALIZED SCHEMATIC OF CONTAMINANT SOURCES AND PATHWAYS FOR GRENADIER POND

Project No.	93-251
Date Issued:	AUGUST 1994

Figure 2.7

Table 2.10 : Grenadier Pond Mass Balance For Water, Suspended Solids And Nutrients

	Water	TSS		Total P		Total N	
	m^3/annum	mg/L	kg/annum	mg/L	kg/annum	mg/L	kg/annum
Inputs							
Direct precipitation	155,000	0	0	0	0	0	0
G.W. contributions	492,000	0	0	0	0	1	492
Clendenan Ave.	172,000	125	21,500	0.3	51.6	5.38	925
Valleymede Rd. Culvert	27,000	125	3,375	0.2	5.4	3.49	94
Catfish pond drainage	138,000	125	16,000	0.3	41.4	4.20	580
Direct runoff to pond	46,000	25	1,175	0.125	5.9	2.5	118
Tap water (assume 1L/s)	32,000	0	0	0	0	0	0
Birds			4,854		159		240
Internal loadings			0		124.4		441
Total	1,062,000		46,904		387.7		2,890
Outputs							
Evaporation	76,000	0	0	0	0	0	0
Settlement within pond (R = 0.686)			33,600		180.6		252
Pond outfall	986,000	15	14,700	0.21	207.1	2.7	2,638
Total	1,062,000		48,300		387.7		2,890

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Table 2.11 : Grenadier Pond Mass Balance (% Contributions)

	Water	TSS	Total P	Total N
Inputs				
Direct precipitation	14.6%	0%	0%	0%
G.W. contributions	46.3%	0.0%	0.0%	17.0%
Bloor Street culvert	16.2%	45.8%	13.3%	32.0%
Culvert entering below Wendigo Ck.	2.5%	7.2%	1.4%	3.3%
Catfish pond drainage	3.0%	34.1%	10.7%	20.1%
Direct runoff to pond	4.3%	2.5%	1.5%	4.1%
Tap water (assume 1L/s)	3.0%	0.0%	0.0%	0.0%
Birds		10.3%	41.0%	8.3%
Internal loadings		0.0%	32.1%	15.3%
Outputs				
Evaporation	7.2%			
Settlement within pond (R = 0.686)		70.0%	46.6%	8.7%
Pond outfall	92.8%	30.0%	53.4%	91.3%

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It should be noted that Dillon (1994) estimated that 63,000 kg of sediment enter Grenadier Pond annually from storm water drained to the north end of the pond and through direct runoff along the Wendigo Creek ravine slope. While this agrees quite closely with our total estimated loading to the pond of 46,904 kg annually, it is higher than our data would predict from the sources analyzed in Dillon's study.

It has been assumed that direct precipitation, ground water and tap water do not serve as sources of sediment to the pond. It has also been assumed that there are no net internal loadings of sediment within the pond. While bottom sediments within the shallow areas of the pond are routinely stirred up by wind and wave action, birds, fish, pets and human activities, it is assumed, based on the size of the pond and only localized resuspension, that these resettle and do not contribute to the sediment being exported from the system.

The concentration of suspended solids in direct overland runoff is predicted to be lower than levels in urban storm drainage given that much of the area contributing runoff is gently graded, with the exception of hills directly surrounding the pond, and covered by lawn or dense vegetation. Some active erosion exist, especially along Wendigo Creek. A concentration of 25 mg/L has been assumed and is consistent with the increase in suspended solids levels which were observed in Gartner Lee Limited samples collected near the upstream and downstream portions of Wendigo Creek (Table 2.6). Direct runoff is estimated to result in 1,175 kg of suspended solids loadings to the pond per year (Table 2.10), or 2.5% of the total loadings (Table 2.11).

Birds are another source of suspended solids to the pond. A bird count was conducted at Grenadier Pond on October 6, 1993. Results are provided in Table 2.12. A total of 513 birds were found in the pond and on its banks. General observations at other times of the year suggests that this is primarily a resident population and numbers remain quite consistent throughout the year. Based on the average weight of these birds, this represents 1,114 kg of bird biomass. Based on literature information for waterfowl (Scherer *et al.*, 1994), these birds are estimated to produce a total of 9,707 kg of solids per year of which we have assumed 50% (4,854 kg) will end up in the pond (Table 2.13).

Settling within the pond is a major source of suspended solids removal. Settlement can be calculated by predicting the retention co–efficient for the system (Dillon, 1974). This value is a function of pond size and flushing rate. For Grenadier Pond, a retention co–efficient of 0.686 (or 68.6% of total inputs) has been estimated. It should be noted that Nürnberg predicted the retention coefficient of Grenadier Pond using another model and estimated it to be 0.65 (see Appendix A), which is consistent with our estimate. A total of 33,600 kg of suspended sediments are estimated to settle in the pond each year (Table 2.10).

There is only one TSS reading at the outlet from the pond of 29.9 mg/L (Table 2.6c). Based on the size of the pond and expected sedimentation effectiveness, a TSS concentration of 13.5 mg/L has been estimated for the pond outfall to balance inflow data. This is predicted to result in the export of 13,300 kg of suspended solids per year (Table 2.10). Additional monitoring is required at the outlet from the pond.

2.6.3 Total Phosphorus

As with suspended solids, storm sewers are a major source of total phosphorus to Grenadier Pond. There is limited available data on TP concentrations to Grenadier Pond from sewer outfalls. Existing data from this study ranges from 0.07 mg/L to 0.36 mg/L but is insufficient to establish average values. Based on existing more comprehensive sewer sampling studies undertaken in the Toronto area, empirical values for total phosphorus in urban storm water, range from 0.33 to 0.41 mg/L (MOE and MNR, 1991). For this report, average values of between 0.2 and 0.3 mg/L of phosphorus have been used for storm inputs from Valleymede, Catfish Pond and Clendenan catchments depending on the level of imperiousness (0.2 mg/L for >25% and 0.3 mg/L for >25%). While these values are higher then values measured under low flow conditions during the study, they are within the same range as the City of Toronto's measurements under storm conditions (City of Toronto, 1993). Using these averages phosphorus concentrations in storm sewer drainage, this source accounts for loadings of 98.4 kg per year (Table 2.10), or 25.4% of the total annual loadings to the pond (Table 2.11).

Direct precipitation, ground water and tap water are not considered as significant sources of total phosphorus to the pond. While phosphorus was detected in one of the two ground water samples collected by Gartner Lee, it was still very low compared to the surface water concentrations. Phosphorus is typically low in ground water and the one elevated result could be an anomaly as suspended solids were also elevated in this sample. Sediment disturbance within the piezometer tube could account for observed phosphorus levels.

A total phosphorus concentration of 0.125 mg/L is estimated for direct runoff. This value is supported by observed increases in phosphorus along the course of Wendigo Creek (Table 2.6). Based on this estimate, direct runoff accounts for 5.9 kg of phosphorus into the system per year (Table 2.10), or 1.5% of the total annual loadings (Table 2.11).

The waterfowl population of Grenadier Pond is estimated to account for 159 kg of phosphorus loadings to the system per year, or 41.0% of the total annual loading. This prediction is based on an estimate of 1,114 kg of waterfowl as previously described, producing 182 kg of phosphorus per year, of which 159 kg is assumed to end up in the pond (Table 2.13; see footnote 3). Loading rates are based on measurements undertaken by Scherer *et al.* (1994). In their study of a small (105 ha) eutrophic urban lake in Seattle (Green Lake), birds were estimated to contribute 217 kg of phosphorus to the lake annually. This represented 52% of the total phosphorus load to the lake. In another study, Manny *et al.* (1994) found that 6,500 Canada Geese and 4,200 ducks (most of these birds were migratory) contributed 88 kg of phosphorus per year, a full 70% of phosphorus derived from external sources to Wintergreen Lake, a small (19 ha) eutrophic lake in southwestern Michigan.

Internal loadings of phosphorus, also previously discussed in Section 2.4, have been predicted from estimates or measurements of all other inputs and outputs (internal loading + external loading = settlement + pond outfall). A value of 124.4 kg/year (Table 2.10), equalling 32.1% of total loadings, is predicted (Table 2.11). Nürnberg predicted an internal load of phosphorus to Grenadier Pond of between 129 and 186 kg/year (Appendix A). However, some refinement has been made to the estimates of external load (she used a value of 219 kg/year, which has been refined in our model to 263.3 kg/year), explaining much of the differences between these estimates. Nürnberg concluded that these internal load estimates are plausible given considerations of the extent of anoxia, sediment phosphorus concentrations and phosphorus release rates under anoxic conditions (see Appendix A).

Loss of phosphorus to settlement within the pond is estimated to occur at a rate of 180.6 kg/year (Table 2.10), based on a calculated gross retention coefficient (R) of 0.686 which does not consider the effects of internal loading. Using a different model, Nürnberg predicted a retention coefficient of 0.65 for this system. Loss of phosphorus through the pond outfall is estimated to be 207.1 kg/year (Table 2.10), based on measured levels of phosphorus at or near the outfall. This estimate is higher than the calculated gross R would suggest because internal loading affects the nutrient mass balance by adding P to the system which can be measured in the outflow. Nürnberg also determined a net R that was only 0.06 kg/yr. This is an actual retention value based on subtracting the outflow loading from the external loading and also accounts for settlement minus internal loading. However, the net R is close enough to zero to imply no (or very minimal) retention of phosphorus in the sediments which is not accurate as 68.6% of external phosphorus loadings continue to settle in the pond. In this case, internal loading is very significant.

In summary, Grenadier Pond likely fluctuates between behaving as a net sink versus a net source of phosphorus, depending on the intensity of the internal load and the time of year. When internal loading is very high, concomitant with seasonal hypoxia of bottom waters (summer and winter, see Sections 2.4.1 and 2.4.4), Grenadier is more likely to be a source of phosphorus. Conversely, less intense internal loading would likely occur during periods of oxic conditions in the bottom water where phosphorus is removed to the bottom sediments. Therefore, rehabilitation efforts should consider both scenarios, as they occur, on a seasonal basis.

2.6.4 Total Nitrogen

A simplified model has been constructed to estimate the nitrogen budget of Grenadier Pond. This model does not take the processes of nitrogen fixation or denitrification into account. Model results are provided in Tables 2.10 and 2.11.

Total nitrogen concentrations have been measured at each of the storm sewer outlets to Grenadier Pond and ranged between 3.49 and 5.38 mg/L. These estimates are higher than literature estimates for urban storm water which range from 1.54 to 2.9 mg/L (MOE and MNR, 1991). On the basis of Gartner Lee estimates, storm sewers account for loadings of 1599 kg of total nitrogen per year (Table 2.10), or 55.4% of total loadings to the pond (Table 2.11).

It has been assumed that direct precipitation and tap water are not significant sources of nitrogen. A value of 1.0 mg/L has been applied to ground water inputs, based on limited site-specific measurements and concentrations typically seen in ground water. On this basis, this source accounts for 492 kg of nitrogen per year (Table 2.10), or 17.0% of total loadings (Table 2.11).

Waterfowl are estimated to produce 274 kg of nitrogen per year, 240 kg of which is assumed to enter the pond (see Table 2.13). This is equivalent to 8.3% of total loadings (Table 2.11).

Internal nitrogen loadings have been estimated based on theoretical or empirical measurements of all other sources and outputs (in the same way that internal phosphorus loads were estimated). A total of 441 kg of nitrogen (Table 2.10), or 15.3% of the total loadings to the pond (Table 2.11), is estimated to be introduced from this source. This estimate may be conservative, however, as losses to denitrification have not been considered in the mass balance.

In estimating nitrogen losses to sediments, it has been assumed that only organic nitrogen is subject to settlement and that this loss is governed by the rate of sedimentation within the pond ($R = 0.686$). Based on approximately 15% of the total nitrogen from external loads being organic, 252 kg of nitrogen are estimated to be lost in this manner (Table 2.10). Losses via the pond outfall are estimated to be 2,638 kg/year, based on measured concentrations at or near the pond outfall.

With concerns regarding the role of nitrogen in controlling the growth of blue-green algae and preventing Grenadier Pond from becoming a nitrogen limited system, attention should be paid towards obtaining a better understanding of the nitrogen budget. Monitoring nitrogen levels along with phosphorus concentrations will provide the data required for a more detailed assessment of the nutrient dynamics and help guide pond management strategies.

2.7 AQUATIC HABITAT

The existing aquatic habitats in Grenadier Pond and Wendigo Creek are best understood in terms of the historical condition of the shoreline and how they have changed over time. Historical habitat conditions in the pond have been documented by Wainio *et al.* (1976). Originally, the margins of Grenadier Pond were largely shallow with wetland vegetation extending along a shallow gradient from the land surface to under water. As early as 1853 changes to the pond began which altered the shoreline permanently. The sand bar across the mouth of the pond joining it to Lake Ontario was widened with fill to locate the Grand Trunk Railroad across this barrier to the west. By 1888, Lakeshore Road also occupied this area to the south of the pond resulting in more fill between the pond and the lake.

Wainio *et al.* (1976) provide a detailed account of the alterations to the pond based on airphoto interpretation. In the earliest photos (1947) approximately 75% of the pond margin was in a natural state. By 1956, the south shore of the pond had been extensively filled to make way for the Queensway which was completed in 1960. The filling raised the level of the pond by upwards of 1.8 m resulting also in the need to reform the shoreline which was accomplished with a concrete border and associated steep riprap slopes along the treated edge. Wainio *et al.* (1976) notes that this concrete border reduces the natural shoreline extent by about 50% which agrees with Zimmerman *et al.* (1986) who determined shoreline development to be 1.88 km or 64.8% of the pond edge, leaving only 35.2% in a natural state. Not only did these changes affect the character of the shoreline, but they also removed the interaction with the lake. The pond now drains via a pipe to the Humber River, maintaining a water level which is about 1.8 m higher than historical levels.

A number of alterations also occurred to the wetland areas on the north of the pond. These changes will be discussed further in Section 2.7 – Wetlands.

Today, the pond outlets via a top draw weir and culvert which diverts the drainage to the Lower Humber River. The shoreline alterations of the 1950s remain in place, although in varying states of disrepair. But aquatic habitat also includes that which extends into the water. There are three aspects of habitat that affect aquatic habitat for fish and other aquatic organisms. These are:

a) physical and chemical water conditions;
b) physical habitat features (including sediment physiochemistry); and
c) water level fluctuations;

a) Water Quality

Water quality changes as they affect aquatic habitat have already been discussed in the previous Sections 2.3 and 2.4. The lack of oxygen in the bottom waters results in approximately an area of 9 ha (45%) being unsuitable for fish throughout most of the summer and winter months. While the remainder of the pond generally has suitable oxygen concentrations for fish, these waters are shallow or associated with the upper 3 m of the surface in the open pond, and are typically warm (the maximum surface water temperature is approximately 26°C). It should be noted, water quality data collected by the MOEE on

August 5, 1994 (Figure 2.4) suggests surface water may also be oxygen–poor following major storm events. The depths of a pond are often used by larger fish seeking cooler water temperatures or as resting habitat through the winter season. With this area unsuitable for large portions of the year, there is a lack of good habitat for the larger individuals of the community.

Of the water chemistry parameters measured in the hypolimnion, oxygen and ammonia were found to be at levels lethal to fish and other aquatic organisms.

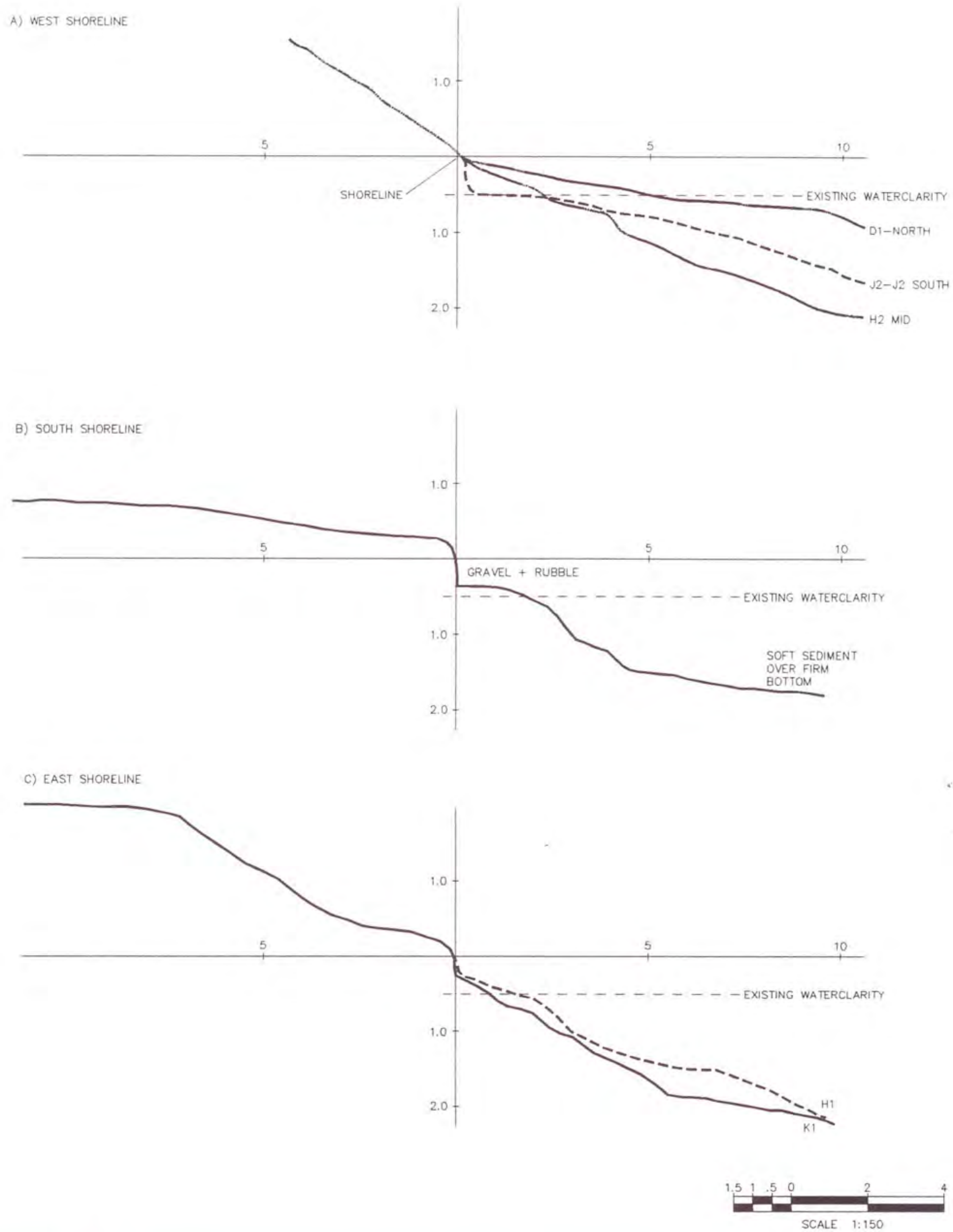
The nutrient levels associated with the pond produce abundant algal growth in the water column which limits the transmission of light through the water. The poor water clarity in turn limits the ability of fish to see in the water for feeding purposes, and compounds the difficulties rooted aquatic plants have in becoming established at depths around the shoreline (see Section 2.9). The lack of physical structure around the pond will be discussed further in item b).

b) <u>Physical Habitat Features</u>

Physical habitat features include the bottom substrates, plant growth both in the water and on the shoreline, and other structures which may provide cover such as logs or rocks.

The bottom of the pond provides the habitat for attached or burrowing aquatic organisms, such as aquatic insects, and is the surface on which some of the fish spawn. There are two main types of habitat along the Grenadier Pond shoreline. The first is a gravel and small boulder zone in the nearshore which was artificially placed when the shoreline alterations were undertaken in the late 1950s (Figure 2.8). This type of substrate extends approximately between 5 and 10 m offshore becoming covered with a layer of fine organic material with increasing depth, believed to be associated with the decay of the plant matter in the pond. Approximately 45% of the entire shoreline has this type of substrate. While this type of shoreline offers some diversity, the size range of materials is not well suited to the type of species that would be using it for spawning purposes. As well, the slopes of the altered shoreline area are steep, typically in the range of a 3:1 or 4:1 (H:V) (Figures 2.9b and 2.9c) compared with those of the natural west shoreline which were more variable and in the order of 12:1 or flatter (Figure 2.9a).

The other dominant type of substrate is a soft organic muck, found over approximately 55% of the shoreline, a large proportion of which (28%) is considered to be a fine "floc" (Figure 2.8). This is believed to be the result of the decay of the abundant algae in the pond. This material is readily disturbed, is typically over 1 m in depth and is expected to have a high



Site Name:

File Name: 93251F28.DWG

Gartner Lee

EXISTING SHORELINE CROSS-SECTIONS

Project No. 93–251

Date Issued: MAY 1995

Figure 2.9

oxygen demand. This type of substrate also occurs coincidentally with approximately 40% of the limited area of littoral zone around the pond and typically have slopes more suited to fish production. It is estimated that the littoral area (between 0.5 and 1.0 m depth) comprises only 8% to 22% of the pond; therefore, based on the above substrate distribution, only 4.8% to 13.2% of the littoral zone is considered suitable habitat. In other words, where light transmission in the pond is expected to be greatest, as well the area which is typically used by fish for spawning, there are very poor substrates for the rooting of vegetation or spawning. (For further discussion on limited macrophyte growth, see Section 2.9.)

Other physical habitat structure in the form of logs, overhanging vegetation, and in water vegetation is dominant on the west shoreline of the pond where trees and emergent vegetation remain. The majority of the east and south shorelines has limited cover provided by underwater aquatic vegetation and virtually no shoreline vegetation, the original marshy, low gradient shoreline having been replaced with a concrete curb over 45% of the entire ponds perimeter. This curb creates an abrupt edge which does not allow a connection with the shoreline. For many fish species this is not a necessary element for their life cycle. However, for pike which were historically important in the pond, it is essential. They spawn on the flooded margins of lakes or streams, laying their eggs atop matted grasses. Without this habitat feature in the pond, there can be no spawning of pike. Only the marsh area to the north offers the potential for this type of habitat but its size limits the available spawning area and presently it is elevated above the water. Without water level fluctuations in the pond, the potential to innundate the wetland is not realized.

The area to the north of the location of the former boathouse on the east side and incorporating the northern tip of the pond has discontinuous patches of shoreline vegetation as well as extensive areas of submergent vegetation, extending across the width of the pond at this point (Figure 2.10). The vegetation is dense and has limited diversity (see Section 2.9)

The habitat associated with Wendigo Creek is highly altered, not just from water quality contributed by the storm sewer system, but from channel alterations undertaken to provide a more direct path for the drainage to the pond, as well as to stabilize the channel against erosive storm flows. The lower section of the Creek has no structural habitat features. Further upstream, outside the wetland area, the stream has armour stone banks with rock rubble in the bottom of the creek bed. While the rock provides good cover for small fish, it offers limited diversity. The "dam" for the sediment pond provides an effective barrier to further upstream movement of fish within the creek. Habitat was not assessed upstream of this.

c) <u>Water Level Fluctuation</u>

As noted in Section 2.2.3, the water levels in Grenadier Pond are controlled by an outlet structure which maintains a fairly consistent level, with the exception of temporary higher elevations associated with storm events. Therefore water levels in the spring are usually similar to those observed throughout the rest of the year. For most fish, this does not pose a problem, but for pike which were historically significant here, the lack of water level fluctuations limits their ability to reproduce. As noted above, they require flooded margins of lakes or rivers to spawn in the early spring. The lack of vegetation along the majority of the shoreline, combined with abrupt edges and relatively small water level fluctuations further limits the potential for pike to spawn in the pond, as well as limiting potential amphibian and vegetation reproduction.

2.8 FISH COMMUNITY

The fish community, like the habitat in Grenadier Pond has undergone considerable change. Once open to Lake Ontario, the community no doubt reflected those that would enter into the marsh to feed and return to the lake for some or all of their life cycle (e.g. salmon, sturgeon, pike, suckers, minnows). With the connection to the lake gone, the species are locked into the pond, relying on it for all of their life cycle requirements. Table 2.14 provides an annotated listing of the fish species known to be or have been in the pond.

Since 1960, 21 species of fish have been recorded in the pond, some of which have been placed there by stocking. Consistently present are species such as pumpkinseed (*Lepomis gibbosus*), bluegill (*Lepomis macrochirus*), carp (*Cyprinus carpio*), golden shiner (*Notemigonus crysoleucas*), brown bullhead (*Ameirus nebulosus*), largemouth bass (*Micropterus salmoides*) and white perch (*Morone americana*). There has not been a detailed survey of the fish community since 1976 when Wainio *et al*. (1976) undertook an inventory using seine and hoop nets.

In the Wainio survey, as well as observations and sampling results in more recent years, the pumpkinseed and bluegill, collectively referred to as sunfish, are the most abundant fish species, suggesting that these populations have increased disproportionately. This may be in part related to the abundant habitat for these species that is available in the pond and the typically low fishing pressure that these species would receive. Sunfish can eat a variety of organisms present in the pond but are expected to consume a number of zooplankton which are present in the water column, such that they may depress their populations. Zooplankton, such as *Daphnia*, consume phytoplankton (microscopic algae) from the water column and may help control algal blooms and corresponding water clarity.

Table 2.14: History of Fish in Grenadier Pond

(tab-2-14/93251/0595)

Fish Species (Common & Scientific)	**Evidence of Spawning**	**Year of Study**	**Type of Study**	**Spawning Habitat Requirements**	**Dietary Needs**
Longnose Gar *Lepisosteus osseus*	– no evidence – 1976 – rare	1976 – Wainio	1976 – Sampling	– build nests, 2 ft below surface on bottom covered with short stems of aquatic plants – warmwater in shallows of lakes or large streams over vegetation – some mature upstream spawning – weedy spawning beds *Adults:* quite weedy shallows of warm water lakes or fairly larger rivers	– invertebrates (larvae) becoming pisivorous (frogs, crayfish)
Bowfin *Amia calva*	– no evidence – 1976 – rare	1976 – Wainio	1976 – Sampling	– spring spawner – shallow, vegetated water to build nest in 1 to 2 ft water can be under logs, stumps or bushes – bottom of nest has cut roots of vegetation – 16°C to 19°C for spawning and nest building *Adults:* swampy, vegetated bays of warm lakes – can survive in stagnant water	– piscivorous (frogs, crayfish) – also some aquatic insects and vegetation
Gizzard Shad *Alosa* sp.	– "now breeding successfully" – p.145 Wainio 1976	1976 – Wainio	1976 – Sampling	– spring and summer, various temperatures – no nest – sand, gravel boulder bar, 2 to 4 ft water 17.2°C to 22.8°C – temp. very important for initiation & continuation of spawning *Adults:* return to deeper water	– plankton (animal) – minute algae – phytophlankton & algae
Northern Pike *Esox lucius*	– rare – 1976 – no evidence	1836 – Wainio 1960 – Wainio 1969 – Tough 1976 – Wainio * Stocking has occurred by MNR in 1990s	1836– Historical Account 1969– Observed 1976– Sampling & Creel Census	– water temp.: 4.4°C to 11.1°C (at ice melt) – heavily vegetated floodplains of marshes, rivers and bays – 178 mm deep water is sufficient – fry – remain in vegetation (sometimes attached) *Adults:* clear, warm, slow, heavily vegetated rivers, or warm, weedy lakes or bays – top 15 ft of water	– large zooplankton and aquatic insects becoming pisivorous (small fish, frogs, crayfish, rodents, etc.)
White Sucker *Catostomus commersoni*	– no evidence reported	1976 – Wainio 1985/86 – DMD	1976 – Sampling 1985/86 – Creek Census	– gravelly streams, 10°C or lake margins, quiet areas in river mouth – shallow water, gravel bottom (can be in rapids) – no nests *Adults:* warm shallow lakes, tributary rivers	– plankton and small inverts – bottom feeders (chironomid larvae molluscs)

Table 2.14: History of Fish in Grenadier Pond

(tab-2-14/93251/0595)

Fish Species (Common & Scientific)	***Evidence of Spawning***	***Year of Study***	***Type of Study***	***Spawning Habitat Requirements***	***Dietary Needs***
Goldfish *Carassius auratus*	– no evidence reported	1976 – Wainio 1985/86 – DMD	1976 – Creel Census 1985 – Creel Census 1986 – Creel Census	– spring spawning – May or June – warm, weedy shallows 18°C to 25°C – eggs spread over submerged aquatic plants or willow roots – ponds with healthy population of aquatic vegetation	– (omnivorous) larvae and adult aquatic insects, molluscs, crustaceans, worms, vegetation
Carp *Cyprinus carpio*	– observed mating behaviour (north end) 1976 – observed – 1969 (east shore – south end)	1969 – Tough 1971 – Wainio 1976 – Wainio 1986 – DMD 1985/86 – DMD	1969 – Netting 1971 – Creel Census 1976 – Sampling & Creel Census 1986 – Netting 1985 – Creel Census 1986 – Creel Census	– spring, early summer – warm, weedy shallows – minimum water temperature: 17°C for spawning to start – maximum 29°C – eggs attached to submerged weeds, grasses or roots	– same as goldfish – many types of plant tissue, bottom ooze, floating algae or organisms
Golden Shiner *Notemigonus crysoleucas*	– abundant – 1976	1976 – Wainio 1986 – DMD	1976 – Sampling & Creel 1986 – Sampling 1976 – Sampling	– aquatic vegetation required – will resort to filamentous algae or rooted aquatic plants – water temperature: 20°C *Adults:* clear, weedy, quiet water, extensive shallow areas	– cladocera, flying insects, chironomid pupae, algae, molluscs
Common Shiner *Luxilus cornutus*	– rare – 1976	1976 – Wainio	1976 – Sampling	– stream or gravelly shoals – minimum water temperature range: 15.6°C to 18.3°C – gravel beds / flowing water / head of gravel riffle – nests of other fish – at shores of clear water lakes	– aquatic insects (adults and larvae) – algae, aquatic plants – protozoan, desmids, small fish (less common)
Brown Bullhead Catfish *Ameirus nebulosus*	– fry caught – 1976 – spawning observed – 1969	1960 – Wainio 1969 – Wainio 1976 – Tough 1986 – DMD 1993 – DMD	1976 – Sampling & Creel Census 1986 – Sampling 1993 – Sampling	– water temperature: 21.5°C – shallow nest, mud, sand, roots of aquatic vegetation near protection: rock, stump, tree – nest burrows also built in hollow stumps, tires, under boards – shallow sites: > 6 inches deep 3 ft shoreline mainly coves, bays, river mouths	– omnivorous (offal, molluscs, insects, zooplankton, worms, algae, fish)
Channel Catfish *Ictal rusuctatus*	– no evidence – 1976	1960 – Wainio	1960 – Stocked * none found in 1976 survey	– water temperature: 23.9°C to 29.5°C (25°C optimum) – secluded, semi–dark, nests built in holes, undercut banks, log jams or rocks * will not spawn in transparent ponds *Adults:* cool, clear deeper water, sand, gravel or rubble bottoms, holes, protective rocks and logs	– aquatic insects chironomids, molluscs, algae, plants, fish

Table 2.14: History of Fish in Grenadier Pond

Fish Species (Common & Scientific)	Evidence of Spawning	Year of Study	Type of Study	Spawning Habitat Requirements	Dietary Needs
Banded Killifish *Fundulus diaphanus*	– no evidence reported	1969 – Tough 1971 – Wainio	1969–MNR Sampling 1971 – Observations	– water temperature: 21°C to 23°C – quiet water, weedy pools *Adults:* quiet water, sand, gravel, detritus bottoms, patches of submerged aquatic plants	– (versatile) chiromid larvae ostracods, zooplankton, amphipods, flying insects, nymphs, molluscs
Brook Stickleback *Culaea inconstans*	– no evidence reported	1969 – Tough	1969 – Observations	– spawning inhibited above 19°C (water temperature); must obtain minimum – water temperature of 8°C before spawning begins – shallow water nests built on stems of reeds or grasses close to the bottom – grass fibres and green algae used to build nests *Adults:* clear, cold, densely vegetated streams and spring fed ponds and swampy marshing of beach ponds	– a variety of aquatic insect larvae and crustaceans – eggs and larvae of other fish – molluscs, worms, algae
Rock Bass *Ambloplites rupestris*	– no evidence reported	1969 – Tough 1985/86 – DMD 1987 – DMD	1985/86 – Creel Census 1987 – Creel Census	– water temperature: 15.6°C to 21.1°C – make shallow nests in swamps – gravel shoals *Adults:* rocky areas in shallow water, lower warm reaches of streams	– aquatic insects, crayfish, small fish (e.g., yellow perch
Pumpkinseed *Lepomis gibbosus*	– abundant – 1976 – All YOY – 1993	1969 – Tough 1971 – Wainio 1976 – Wainio 1984 – DMD 1985/86 – DMD 1993 – DMD	1969 – Observed 1971 – Creel Census 1971 – MNR Sampling 1976 – Sampling and Creel Census 1986 – Sampling 1993 – Sampling	– nests in shallow ponds, lakes of shallow streams – water depth 15.2 to 30.5 cm near shore – water temperature: 20°C to 28.8°C – nests built in subaquatic vegetation – clean hard bottom	– variety of aquatic insects (nymphs) – ants, worms, mulluscs – zooplankton – small fish – eggs of other fish
Bluegill *Lepomis macrochirus*	– abundant – 1976 – observed spawning – 1969	1969 – Tough 1971 – Wainio 1976 – Wainio 1985/86 – DMD 1986 – DMD 1987 – DMD	1969 – Observed 1971 – Creel Census 1971 – MNR Sampling 1976 – Sampling and Creel Census 1985/86/87 – Creel Census 1986 – Sampling	– nests: firm bottom – sand, gravel, mud – maximum water temperature: 24°C – shallow, weedy warm water *Adults:* seek cooler refuge in deeper water during hot summer days	– insects, zooplankton, plant material

Table 2.14: History of Fish in Grenadier Pond

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(tab-2-14/93251/0595)

Fish Species (Common & Scientific)	***Evidence of Spawning***	***Year of Study***	***Type of Study***	***Spawning Habitat Requirements***	***Dietary Needs***
Smallmouth Bass *Micropterus dolomieu*	– no evidence of spawning – 1976 – observed nesting sites – 1987	1971 – Wainio 1976 – Wainio 1987 – DMD	1971 – Creel Census 1971 – MNR Sampling 1976 – Creel Census 1987 – Creel Census (1969 – last stocking date)	– water temperature: 12.8°C to 20°C (nest building & spawning) – 16.1°C to 18.3°C egg laying – sandy or gravel bottom – rocks and logs for protection (nests) – sensitive to water temperature, water levels, wind, nest desertion, bass tapeworm – sudden change sin temperature can kill eggs *Adults:* seek cool refuge, protection	– insects, fish, crayfish – plankton and inspects as juveniles – crayfish fish, frogs, tadpoles, fish eggs and plants as adults
Largemouth Bass *Micropterus salmoides*	– Young Fry caught prior to 1976 stocking – Young Fry caught – 1969 – "Successfully spawning" – 1987	1947 – Wainio 1969 – Tough 1971 – Wainio 1976 – Wainio 1978 – June, report 1985/86/87 – DMD 1986 – DMD	1969 – Observed 1971 – MNR Sampling 1971 – Creel Census 1976 – Creel Census 1976 – Sampling 1985/86/87 – Creel Census 1986 – Sampling	– nest building – 15.6°C (water temperature) – spawning – 16.7°C to 18.3°C (water temperature) – shallow, protected areas, emergent vegetation – spawning ground range sand (rare) to marl and soft mud in reeds, bullrushes or water lilies – bottom of nests: exposed roots of emergents	– plankton and insects as juveniles – fish, crayfish and frogs, worms, molluscs, large insect nymphs
Black Crappie *Pomoxis nigromaculatus*	– abundant – 1976 – observed spawning – 1969	1960 – Wainio 1969 – Tough 1971 – Wainio 1976 – Wainio 1985/86/87 – DMD 1986 – DMD	1969 – Netting 1971 – Creel Census 1971 – MNR Sampling 1976 – Sampling and Creel 1985/86/87 – Creel Census 1986 – Sampling	– water temperature: 19°C to 20°C – nests: sand, gravel or mud – 10 inches to 2 feet of water, some vegetation	– zooplankton – invertebrates – small fish
Yellow Perch *Perca flavescens*	– rare – 1976 – "successfully spawning" – 1976	1969 – Tough 1971 – Wainio 1976 – Wainio 1985/86/87 – DMD 1986 – DMD	1969 – Observed 1971 – Creel Census 1971 – MNR Sampling 1976 – Sampling and Creel 1985/86/87 – Creel Census 1986 – Sampling	– water temperature: 6.7°C to 12.2°C – shallows in lake, river tributaries – rooted vegetation, submerged brush, fallen trees – sand and gravel (rare) – no protection *Adults:* warm cool temperature, open water, moderate vegetation, mucky sandy bottom	– immature insects, larger invertebrates, fishes – zooplankton
White Perch *Morono americana*	– no evidence reported	1976 – DMD 1986 – DMD 1993 – GLL	1976 – Sampling and Creel 1986 – Sampling	– water temperature: 11°C to 15°C – shallow water – no bottom preference – eggs adhere to rocks, vegetation, bottom objects	– microplankton – aquatic insects – piscivorous

Largemouth bass are a top predator in the system and can still be seen in small numbers. They typically nest on the west side of the pond and therefore may have a limited distribution throughout the rest of the pond. No young bass were caught when sampling was undertaken in the fall of 1993 on the east side of the pond, although limited effort was expended. Habitat alteration combined with fishing pressure and poor water quality no doubt contribute to low population numbers. The number of sunfish no doubt also influence the population. Sunfish are a predator on bass nests. When the male bass, who guards the nest during the incubation and rearing periods, is removed from the nest by fishing, the contents of the nest may be eaten by the sunfish, further reducing their spawning success. Some bass stocking efforts have occurred in the past by MNR.

Pike were historically present in Grenadier Pond (Wainio *et al.* 1976) and recently efforts have been made by MNR to stock them. As noted in Section 2.7, the habitat is not suitable for pike spawning and therefore the expectation of their continued presence in the pond is low unless suitable habitat alterations are made.

Data are limited on the populations of benthic invertebrates within Grenadier Pond. However, the combination of fine flocculant sediments with high biological oxygen demand and little aquatic vegetation provides poor habitat for benthos. Under these conditions, desparate populations of both micro and macro benthic fauna are likely to exist throughout Grenadier Pond. Future sampling is recommended as another measure of pond health.

2.9 WETLAND VEGETATION

The marsh vegetation of Grenadier Pond has been significantly reduced in area since earlier times. Wainio *et al.* (1976) have shown the incremental reduction in this habitat from 1947 until the 1970s. Formerly, emergent marsh vegetation formed a wide continuous band along the entire south end of the pond but this was drowned and filled in with the construction of the Queensway in the late 1950s. The elevation of the shoreline was raised at that time over 1 m in height which necessitated the reconstruction of the shoreline. The concrete curb and riprap edge now rimmed the pond, removing marsh vegetation from these portions and making conditions unfavourable for reestablishment, due to the lack of a gradually sloping nearshore area. Historically, the entire north arm of the pond would have been wetland (Figure 2.11), given that the original surface water elevation would have been approximately 1.8 m lower than at present (see bathymetry of Figure 2.2).

The extent of emergent vegetation has remained much the same from the late 1960s until the present, being essentially confined to the mouth of Wendigo Creek in the north and near the outlet of Catfish Pond in the southwest. The latter is all that remains of the formerly extensive south marsh.

Photograph 1: Historical shoreline and vegetation (north end of pond).

Photograph 2: Present condition (spring 1994).

Figure 2.11
Historical and Present Wetland and Shoreline Conditions.

The north marsh covers about one third of the extent found in the mid–1950s. It has been strongly influenced by Wendigo Creek and the silt that it carries and deposits. Goodwin (pers.comm.) notes that until the mid to late 1960s, Wendigo Creek did not have a well defined channel but formed a swampy bottomland north of the marsh. The creek was channelized allowing a more rapid flow during runoff and greatly increasing sedimentation in the north end of Grenadier Pond. Wainio *et al.* (1976) note that sediment deposits in this area first become apparent in the 1968 airphotos.

Marsh vegetation has been described by Wainio *et al.* (1976) and Varga (1989). In this study, vegetation was examined during field investigations on September 28, 1993. The existing vegetation communities are described below and shown on Figure 2.10.

a) Cattail Marsh

Broad–leaved Cattail (*Typha latifolia*) dominates the two marshes. Purple loosestrife (*Lythrum salicaria*) is frequent along the pond edge, but more abundant in the north marsh than in the southwest. Other less common species are mixed in, including European Water–horehound (*Lycopus europeaus*), Red–stemmed Aster (*Aster puniceus*), Beggar–ticks (*Bidens cernua*), Nodding Smartweed (*Polygonum lapathifolium*) and Giant Redtop Grass (*Agrostis gigantea*). Again these are more prevalent in the north. Much of the cattail marsh on the west side of Wendigo Creek is elevated about 10 cm above the waterline, whereas elsewhere it occurs in standing water.

b) Sweet Flag Marsh

A narrow (0.5 to 1.0 m wide) of marsh consisting primarily of Sweet Flag (*Acorus americanus*) occurs almost continuously along the west shoreline of Grenadier Pond and discontinuously along the northeast shoreline. Yellow Iris (*Iris pseudacorus*) is described as codominant with Sweet Flag by both Wainio *et al.* (1976) and Varga (1989). While present in 1993, Yellow Iris was much less abundant than Sweet Flag suggesting that it may have declined since then.

Sweet Flag is a regionally rare plant species within the Regional Municipality of York and Metro Toronto (Riley 1989), consequently a community where it is dominant is a highly significant feature.

c) Waterlily Marsh

Two rather dense patches of White Waterlily (*Nymphaea odorata*) occur, one in the southwest and a more extensive stand in the north. A single patch of Yellow Pondlily

(*Nuphar variegatum*) grows in the southwest which was also reported by Wainio *et al.* (1976). Fahey (pers.comm.) commented that the waterlily patches have expanded since paddle boats were removed from Grenadier Pond approximately five years ago.

d) Submerged Vegetation

Submerged aquatic vegetation grows in the shallow littoral zone to a depth of about 1 m. The algae blooms which typically occur in Grenadier Pond during the summer severely restricts light penetration which in part limits the depth to which aquatic vascular plants can thrive.

In September 1993, aquatic vegetation was discontinuous but where present was dominated by Coontail (*Ceratophyllum demersum*) with Sago pondweed (*Potamageton pectinatus*) and Nuttall's Waterweed (*Elodea nuttalli*). Varga (1989) described the submerged community as dominated by Sago Pondweed, Crispy Pondweed (*Potamageton crispus*) and Nuttall's Waterweed with a lesser amount of Coontail. Wainio *et al.* (1976) considered all four species as codominants. These variations suggest that the relative abundance of the species present can change from year to year or perhaps over the course of one growing season. Crispy Pondweed is known to senese in June or July (Madsen *et al.*, 1993) and consequently timing of observations may yield different conclusions. The Nuttall's Waterweed is a rare species within the Regional Municipality of York and Metropolitan Toronto (Riley 1989).

Goodwin (pers.comm.) has commented that marsh areas dominated by Water–willow (*Decodon verticillata*) lined some of shoreline in the north marsh until the later 1960s. By the mid–1970s, only a few plants remained (Wainio *et al.*, 1976) and there does not appear to be any at present. Wainio *et al.* (1976) list at least 25 species of wetland plants which occurred formerly but not at present indicating the species impoverishment which has occurred here.

Aggressive non–native plant species appear to be outcompeting some native plants, and hence be contributing to declining diversity. At least three non–natives; Purple Loosestrife, European Water–horehound and Yellow Iris are abundant along marsh shorelines. Although Purple Loosestrife has been present since at least the late 1960s, Yukich (pers.comm.) has observed dramatic increases in its population within the past 10 years.

Barren mudflats appear at the surface in the northern area of the pond resulting from sediments carried by Wendigo Creek during storm events or spring runoff. Wainio *et al.* (1976) noted a rather luxuriant growth of four species of bulrushes (*Scirpus* spp.) and Toad Rush (*Juncus bufonius*). This was not apparent in September 1993 when mudflats were devoid of any vegetation. In addition, the bay among the north marsh consisted of shallow clear water (about 10 cm depth) with a firm bottom. No submersed aquatic vegetation was present in an area where it would be expected.

2.10 WILDLIFE

Wildlife use has changed in and around Grenadier Pond which corresponds to vegetation changes. Generally, as available marsh habitat has decreased, nesting opportunities were no longer available for some species. Because of High Park's strategic location along the Lake Ontario shoreline, and since it is a habitat "island" surrounded by urbanization, the area, including Grenadier Pond, continues to provide a stopover area for migratory birds.

Waterfowl

The most obvious wildlife present are the feral flocks of waterfowl. Hundreds of Canada Geese (*Branta canadensis*) and Mallards (*Anas platyrynchos*) are regularly present on and around the pond. The greatest numbers occur during the summer moulting period. These birds are part of the attraction to High Park for some members of the public who provide bread, cereal and grains for food, thereby helping to maintain artificially high populations throughout the year. In addition, open areas of lawn immediately adjacent to waters edge provide opportune foraging sites for these two species. At the southwest corner of Grenadier Pond, where public waterfowl feeding is concentrated, the birds activity is so intense that the ground is compacted and completely devoid of vegetation.

Many of these birds nest around Grenadier. On April 26, 1994, one Mute Swan (*Cygnus olor*) nest and several Canada Geese nests were found in each of the two marsh areas. Undoubtedly a number of mallards were also nesting here as there were several sentinel males present nearby. It appears that the semi–feral waterfowl are the only ones breeding here how. Blue–winged Teal (*Anas discolor*) and Black Ducks (*Anas rubripes*) formerly nested (Wainio *et al.*, 1976).

Grenadier Pond provides staging area for migratory waterfowl during spring and autumn. A total of 26 species have been recorded (Goodwin, 1988). Small numbers of staging waterfowl of several species were observed near the marsh areas on both September 1993 and April 1994 field visits.

Other Waterbirds

Many other species of waterbirds have been recorded at Grenadier Pond including six species of herons, three grebes, four rails, 17 shorebirds, seven gulls and three terns (Goodwin, 1988). Almost all of these are migrants and some are very irregular visitors. A few of these such as Black–crowed Night–Heron (*Nycticorax nycticorax*) and Belted King Fisher (*Ceryle alcyon*) are summer residents. Several species were formerly summer residents and likely bred here. Both Virginia Rail (*Rallus limicola*) and Sora (*Porzana carolina*) were regularly encountered in summer and likely nested through the 1960s (Goodwin, pers.comm.). Marsh Wren (*Cistothorus palustris*) and Swamp Sparrow (*Melospiza georgiana*) were common prior to that (Wainio *et al.*, 1976) and they too likely nested here. These species disappeared because of insufficient or degraded habitat. The highly adaptable Red–winged Blackbird (*Agelaius phoeniceus*) is one of the only species which still commonly breeds in the cattail marsh.

Marsh species continue to use Grenadier Pond for migration, particularly those which use open water such as grebes, and American Coot (*Fulica americana*). During visits in 1993 and 1994, the smaller marsh at the southwest was more favoured by marsh birds than the north marsh. The configuration of the southwest marsh makes it less visible to pedestrians and therefore offers better seclusion. In addition, there is deeper water immediately adjacent to emergent vegetation giving better interspersion. The shallow water surrounding the north marsh may have limited food and provide suboptimal habitat. Goodwin (pers.comm.) noted that bird activity declined in the north marsh when the trail was installed along the east side.

Goodwin (pers.comm.) found that the mudflats near the mouth of Wendigo Creek are used by staging shorebirds during the autumn migration. None were observed on September 26 or 28, 1993, however, Yukich (pers.comm.) found significantly higher numbers of shorebirds using the mudflats prior to construction of the small sedimentation pond upstream on Wendigo Creek in 1983.

Mammals

A small population of Muskrat (*Ondatra zibethica*) occurs within the pond. Muskrat trails are frequent in the north marsh, and scats were apparent at several localities. A freshly used Beaver (*Castor canadenses*) trail was noted to the northeast on April 26, 1994. This species may have moved in recently from the nearby Humber Marshes. It could effect surrounding woodland and shoreline vegetation if it becomes established here. Raccoons (*Procyon lotor*) and their tracks were noted around the pond.

Norway Rats (*Rattus norvegica*) have been reported at the southwest corner of the pond by local residents. These are likely attracted to the food which the public leaves for ducks and geese (large piles of breakfast cereal were observed here on the evening of April 26, 1994). Yukich (pers.comm.) has also seen rats elsewhere around the pond including the marsh at the north.

Turtles

Grenadier Pond has always had a fairly large population of Painted Turtles (*Chrysemys picta*) (Goodwin, pers.comm., Wainio *et al.*, 1976). On September 26, 1993, approximately 30 Painted Turtles and another 30 Red–eared Sliders (*Pseudemys scripta*) were observed sunning just south of the north marsh. The majority of the turtles were concentrated on a fallen tree trunks on the west side. It appears that turtle activity is concentrated here in the spring and autumn, and the turtles disperse in the wider pond through the summer. They make little use of the shallow water immediately adjacent to the north marsh.

Red–eared Slider is the familiar pet store turtle that is not–native to Ontario. The species was obviously released and the large number of adults observed suggests that it is now successfully breeding here. Grenadier Pond may represent one of the largest population in Ontario. Wainio *et al.* (1976) did not report the species which indicates that they may have increased dramatically since then. Red–eared sliders may be displacing the Painted Turtle since the two species are ecologically similar. Turtles need to lay their eggs on land, preferably in areas of sandy soil exposed to sun. The slopes of the adjacent parkland are sandy and offer opportunities for nesting. However, trails and dense ground cover may be limiting the habitat availability. Savanna restoration efforts may increase potential nesting areas.

Snapping Turtles (*Chelydra serpentina*) are also present but they rarely sun and are therefore less conspicuous. Newly hatched snapping turtles were observed making their way to the water in late September 1993 in the north section of the pond. Wainio *et al.* (1976) also recorded Blandings Turtle (*Emydoidea blandingi*) and Map Turtle (*Graptemys geographica*) from Grenadier Pond. These probably represent specimens which were released from elsewhere, for it is unlikely that there are a sufficient number of individuals to maintain viable populations of these species.

Amphibians

The virtual lack of frogs in Grenadier Pond may be related to poor water quality or habitat conditions. Wainio *et al.* (1976) also commented on lack of frogs. Johnson (pers.comm.) found an adult Green Frog (*Rana clamitans*) in the southwest marsh about 1990 and O'Hara (pers.comm.) found a slightly deformed adult Leopard Frog (*Rana pipiens*) along the east side of the pond in October 12, 1993. The entire shoreline was surveyed for calling amphibians on the evening of April 26, 1994, a warm night when Leopard Frogs should have been calling if they were present. None were heard. The two frogs found indicate that some breeding must be occurring unless they were released individuals. Apfelbaum (pers. comm.) suggests that elevated chloride levels in marshes related to road salt inputs has caused a decrease in frogs in areas of the United States. Since the north part of the marsh is near several storm water outfalls, which likely contribute significant concentrations of chloride, this may be a factor limiting frog numbers.

There is no indication when frogs were abundant here but presumably when the marshes were more extensive, they provided optimal amphibian habitat. Leopard Frogs require open meadows adjacent to the wetlands which they inhabit. Oak savana restoration efforts are expected to improve habitat conditions for this species. The American Toad (*Bufo americanus*) is present in small numbers along the northeast shore and Wendigo Creek. This species is more adaptable to urban conditions than other amphibians, probably due to its more terrestrial lifestyle and shorter larval period.

3.0 ASSESSMENT OF EXISTING CONDITIONS

There are many relationships which we must clearly understand in order to ensure that the rehabilitation options to be developed achieve the maximum benefit and do not cause harm to one part of the ecosystem while attempting to help another. While several of these relationships are already described or alluded to in the previous sections, we have reiterated them here in a simple format.

Water Quality

Many of the problems which Grenadier Pond faces are related directly or indirectly to the high levels of nutrients within the pond. Both nitrogen and phosphorus are utilized by algae and plants (not to the exclusion of the physiological needs of all animals). As the concentration of these nutrients increases (generally phosphorus is most limiting, although this may not always be the case in Grenadier Pond), it causes a proliferation of algae and plant growth. As algae becomes more abundant, light transmission (measured by secchi depth value) is reduced and submerged aquatic vegetation becomes shaded out. Eventually, excessive amounts of nutrients will result in large amounts of algae and a reduction in submerged aquatic vegetation. This has occurred within Grenadier Pond.

Algae is constantly dying and being replaced by new algae. Dying algae can decay on the surface of the pond and on its shorelines, producing aesthetic problems. It also falls to the bottom of the pond. As oxygen is required as part of the decay process, this has resulted in large areas of oxygen deficient water during both the winter and summer months. The decaying algae also form accumulations of loose, nutrient–rich sediments within Grenadier Pond. Under low oxygen conditions, the nutrient–rich sediments can re–release phosphorus back into the water column (internal loading) where it once again becomes available for algal (and other plant) growth. In addition to providing an internal source of nutrients, such sediments create poor habitat for fish and invertebrates, can add to pond turbidity when disturbed by waves or animals and they provide an inappropriate substrate for rooted vegetation.

Aquatic Plants and Wetlands

The types and distribution of plants within the pond environment has been influenced by both water quality and physical changes to the pond. Like all plants, rooted aquatic plants need light to survive, and as light is reduced so too is the limit of where their growth can be successful. The result is that there are scattered patches of plant growth in the water, some of which appear to die back in the summer, potentially as a result of being weighed down by algal growth over their surface or progressively declining light levels, as well as from natural senescence (i.e., seasonal decline). Animals may also influence the success of the vegetation. Carp may up–root aquatic plants as they feed, although the significance of their presence in the pond is not known. On the terrestrial side, Canada geese keep the lawns closely cropped and trampled such that there are areas of the manicured shoreline with virtually no grass remaining.

Similarly, the alteration of the shoreline from a naturally sloping edge to a concrete and manicured lawn has further reduced the natural plant growth, both on the banks and as it extends into the water at the edge. This alteration has reduced the area of the pond which was historically part of the marshes connected to Lake Ontario. Presently, small remnants of the marsh occur to the south, west and north within the pond. The marsh to the north of the pond has been altered through the deposition of sediment from upstream drainage areas, as well as redirection of the flow from Wendigo Creek into a defined channel along the side of the marsh leaving the marsh higher than the water level. The size of the marsh area also becomes a factor in how much diversity of plant and animal life can be expected. It has also been suggested that the lack of water level fluctuation further limits the productivity of the aquatic plant community, particularly, the emergents. Invasive species such as Purple Loosestrife are now gaining a foothold among the native plants.

The alterations to Wendigo Creek extend throughout its length, not just in the marsh area. Originally it was probably a series of springs which came together at the base of the slopes and trickled into the marsh at the north end of the pond, providing a steady and clean source of water. With the need to drain storm water from the residential neighbourhoods to the north of Clendenan Avenue, Wendigo has become an open storm sewer channel, armoured with large stone against the erosive forces of the sudden flashes of flow associated with rain events. Although it still contains some cleaner ground water, this storm drainage is of very poor quality. In recognition of this a sedimentation pond was installed on the creek to try and capture some of the particulate matter prior to its discharge to Grenadier Pond by damming the water flow. The result is an artificial "creek" of limited value for aquatic organisms.

The change in the water quality and the plant community in the pond further influences the aquatic habitat features. Fish and other aquatic organisms utilize plant material for cover, as spawning surfaces or to stabilize bottom sediments for spawning purposes, and serve as attachment surfaces for a variety of aquatic invertebrate life forms. Limiting the plant growth limits the ability of the system to produce pike and largemouth bass in particular.

The lack of significant water level fluctuations or water flow through the wetland also results in less open water among the wetland plants which limits the habitat for amphibians. Water quality contributed through the storm system is also suggested to be further limiting the production of frogs in the north end of the marsh.

Animals

Just as there are relationships between the physical, chemical and biological components of the pond system, there are also relationships between animals. Some need each other for food while others compete for food and resources. This is particularly evident between bass and sunfish. Sunfish are likely the dominant food source of the bass in the pond given their abundance and the lack of other minnow species. However, the abundant sunfish population also impacts on the bass as they prey on their eggs and young in the nest.

Sunfish eat a variety of foods within the pond in addition to bass eggs. It is expected that they also prey heavily on the zooplankton and other invertebrates within the pond which eat algae, such that there may be insufficient numbers of these organisms to crop the dense algal growth.

Exotic species now present in the pond, such as carp, goldfish and Red–eared Slider, may be competing with the native species for resources. The large population of waterfowl, including Canada Geese, Mallards and farm ducks, have taken over the pond perhaps to the exclusion of migratory waterfowl which could nest in the area.

The large populations of Canada Geese in particular, have a rather interesting relationship with the park users and residents of the area which is quite aside from the role that the birds play in the nutrient enrichment of the pond. People feed the geese which maintains artificially high numbers in the park. The feeding ranges from a few slices of bread to large bags of bakery leftovers deposited on the shoreline. The abundant food left for the birds attracts other animals, rats in particular. Much of the feeding takes place beside Ellis Avenue, where the birds remain close to the pond and there is easy access for people and delivery trucks. Ellis Avenue stands between Grenadier Pond and Catfish Pond to the west. The geese readily move between the two ponds taking advantage of lawns and food along the way. Complaints of geese on roads and residential properties are numerous.

Domestic animals and urban wildlife (e.g. raccoons, rats) may be preying on or disturbing nesting birds such that the numbers of marsh birds are limited. Further, human presence in the area and ready access to the shoreline and marsh habitats no doubt influences the success of reproduction of both aquatic and terrestrial species.

4.0 IDENTIFICATION OF ISSUES AND OPPORTUNITIES

An analogy for the rehabilitation of the Grenadier Pond system could be the renovation of a house. Before you proceed you have to define what you want in the way of desirable characteristics, the existing components that you have to work with and what you can have with the budget available.

If we were to carry this analogy further, we begin by looking at the structural elements of the house first – is the foundation of the house structurally sound and if so, what type of building will it support.

Through the course of this study we have been defining both the desirable characteristics of the renovated Grenadier Pond system and assessing the structural elements of the existing environment upon which we will build the new systems.

Members of the public, City of Toronto staff, government agencies and the Technical and Natural Environment Working Groups have assisted in the definition of the desirable characteristics of the pond system over the course of the past year. There was consistent agreement that it was necessary to:

a) Restore a more natural balance of plants and animals in the pond through:

- i) improving the populations of predator species, including largemouth bass and pike;
- ii) limiting the populations of waterfowl; and
- iii) reducing the abundance of algal growth to improve water clarity and enhance the growth of aquatic macrophytes.

b) Improve water quality in the pond through:

- i) reducing nutrient concentrations to limit algal production, increase water clarity and improve dissolved oxygen concentrations;
- ii) transferring nutrients from algae into animal biomass through the food chain; and
- iii) reduce the loading of suspended solids.

c) Improve species diversity and habitat diversity within the pond system through:

- i) increasing the area of marsh coverage in the pond;
- ii) establishing more aquatic vegetation around the edge of the pond to improve habitat;
- iii) limiting the influence of exotic species and humans;
- iv) improving water quality;
- v) creating habitat for specific species of interest or of past abundance in the system (e.g., amphibians, marsh birds); and
- vi) fluctuating the water levels.

d) Maintain opportunities for recreational activity that is consistent with the restoration of the natural environment.

These desirable characteristics then guide us to our assessment of how to work with or change the structural elements of the existing pond system in order to achieve the preferred condition.

4.1 OPPORTUNITIES

While in any house it may be desirable to tear it down and start over, that is not always possible. While the preceding sections have elaborated on the myriad of problems that plague the pond, we must look past these to critically evaluate the components that provide us with the greatest opportunities to build on. The opportunities identified through the evaluation include:

a) ground water contribution;
b) the west shoreline natural habitat features;
c) the existing marsh areas;
d) the existing diversity of plants and animals; and
e) public interest.

a) Ground Water

The Grenadier Pond watershed is located in the Lake Iroquois Beach, an area of sand deposited by glacial Lake Iroquois. This sand is very permeable and was identified as contributing a substantial amount of ground water to the pond system. The quality of ground water was shown to be cleaner than the surface water. It was also shown that the amount of ground water contributed by the drainage area has declined over the past century through the actions of collecting storm water from roads and rooftops in sewers and piping it directly to the surface waters of the pond or diverting it entirely from the catchment. Enhancing the quantity of ground water to the system would contribute to cleaner water to the pond which would increase the flushing rate thereby lowering nutrient concentrations, assuming no change in loading.

b) The West Shoreline

Structurally the pond has been "renovated" many times in successive waves of development, particularly on the eastern and southern shorelines. In fact the entire pond has undergone transformation from its original configuration as a marsh on Lake Ontario. Nevertheless, the existing natural condition of the west shoreline provides us with a strong building block on which to extend to other areas of the pond. Slopes are more representative of natural habitats, habitat features are diverse and offer good cover and linkages to the offshore, and the seclusion offered by private ownership has protected the shoreline and associated wildlife from excessive disturbance.

c) **The Existing Marsh Areas**

Remnant marsh areas exist in the north portion of the pond and to the south west. While the diversity of plants and associated biota may be reduced over that which was there originally, there are still native plant species and potentially seed stock available to the build upon. Further these two marsh areas are connected via the west shoreline which remains continuous from north to south.

d) **Existing Diversity of Plants and Animals**

While many species appear to be on the decline, they are still present providing both a brood stock as well as specific genetic characteristics that may enable them to live in the urban environment. Specifically, there are largemouth bass, a predator species of interest to be enhanced in the pond, painted and snapping turtles, a variety of marsh birds including black–crowned night heron, grebes and rails.

Several significant plant species, such as Sweet Flag and Nuttals Waterweed, provide an existing diversity of species on which to build.

e) **Public Interest**

No renovation would ever be undertaken if the owner did not feel the need for the action to take place. Even repairs by landlords to tenant properties are welcome when pipes are leaking or heaters broken. Both the owners (the City of Toronto), and the "tenants" (the park users), are both in agreement, the pond ecosystem needs to be fixed. The smells, the colour, the masses of algal growth, the hundreds of birds, are now at nuisance proportions.

4.2 ISSUES

Our renovation must now look at the items that needs to be fixed, or that we are happy to have changed in order that we will have a successful project. These items, or issues, for the pond system include:

a) nutrient loadings from external and internal sources;
b) lack of oxygen in the bottom waters;
c) excessive algal growth;
d) poor water clarity;
e) abundance of waterfowl;
f) abundance of sunfish and decline of predators;
g) habitat alteration;

h) lack of aquatic macrophytes;
i) lack of wildlife diversity;
j) steady water level within the pond; and
k) human access and education.

It was shown in Section 3.0 that each of these issues or problems within the system is integrated. Without exception, each contributes to a problem observed in another component of the ecosystem. The problems have been described in preceding sections and it is not our intention to further elaborate on them here. Rather, the problems are listed as they now become the basis for the development of options for the rehabilitation – or in other words – how do we solve the problems. Just as in our analogy of the house renovation, there are several ways to tackle the problem. Our objective may be to have three bedrooms when the project is completed, however, the layout and the materials used can be combined in a number of different ways. There is likely one option that is preferred from the standpoint of effectiveness in providing the solution, blending with the existing conditions and cost, as well as personal preference. In the following sections we will evaluate options which provide solutions to the problems faced by the pond system. Some of these have been costed out for comparison purposes where several options will achieve the same or similar results.

5.0 OPTIONS FOR REHABILITATION

Section 4.0 identified the issues and opportunities for the Grenadier Pond system. Each is presented in a series of tables (Table 5.1). It soon becomes apparent that the sqlution to many of the problems in the pond system lies with improvements to water quality and it is here that we have placed the greatest emphasis.

5.1 NUTRIENT LOADINGS

The plant nutrients nitrogen and phosphorus are the main factors contributing to poor water quality within Grenadier Pond. These are derived from both external and internal sources. The major external sources are storm water and birds.

Before dealing with specific measures to reduce external and internal nutrient loadings, it is useful to examine the potential for water quality improvements that could be achieved if either external or internal nutrient loads are reduced. Therefore, we have developed a series of general management scenarios and roughly evaluated the resultant phosphorus concentration, as shown on Table 5.2.

Table 5.1: Evaluation of Measures to Address Issues Identified in Grenadier Pond

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Issue	*Measures*	*Evaluation*	*Cost*
a) External Loading of Nutrients	1. Storm water retention facilities at storm outfalls	– reduction of proportion of storm contributions – maintenance required for continued effectiveness	
	2. Reduce nutrient and other contaminant contributions from watershed	– difficult to quantify or control effectiveness – public awareness and participation needed – source control ideal	
	3. Reduce numbers of waterfowl through habitat alteration & feeding reduction	– should be very effective – needs public cooperation	
	4. Buffer strip development through shore–line habitat alterations and mowing restrictions	– vegetative strips effective at filtering nutrients and sediment – inexpensive – attractive addition to pond	
b) Internal Loading of Nutrients	1. Precipitate with chemical (e.g., alum, calcium hydroxide)	– short term – may add undesirable chemical (aluminum)	$800/ha
	2. Hypolimnetic removal	– polymictic; insufficient stratification – downstream implications – tertiary treatment facility required	–
	3. Hypolmnetic aeration	– more effective for winter use – energy efficient techniques available – required for long term	
	4. Artificial circulation aeration	– prevents stratification – winter use conflict with ice skating – required over long period – energy efficient methods available	$1,800/ha (windmills)
	5. Increased flushing with water from Lake Ontario or ground water	– effects displace TP to Lake Ontario – long term requirements – doesn't treat problem – retention time of external loadings reduced – ground water enhancement can contribute small volumes of additional clean water	?
	6. Food Web Alteration (also see h) (stock bass and pike)	– long timeframe – complimentary – cannot treat whole problem	$200/ha

Table 5.1: Evaluation of Measures to Address Issues Identified in Grenadier Pond

(tab-5-1/93251/0595)

Issue	***Measures***	***Evaluation***	***Cost***
b) Internal Loading of Nutrients (continued)	7. Capping (dirt; geosynthic)	– difficulty in making even – inhibits ground water inflow – sediment displacement – only effective if pond is a phosphorus source	
	8. Dredging – Nearshore Area	– removes problem – extensive removal required – difficult to made it even – aids in ground water improvements – could aid in plant growth and habitat – require specialized equipment – quick response	$225,000/ha (dredging only) disposal 1,500,000/ha (@ $1,000/truck load)
	9. Chemical Treatment – Pond Aid – Biologic	– sediment characteristics must be determined	 $1,800/ha $26,500/ha
	10. Sediment injection with calcium nitrate	– reduces volume of sediment	$15–25/$m^3$
c) Lack of Dissolved Oxygen	See a) and b)		
d) Excess Algal Growth	See a) and b)		
	1. Maintenance to physically remove accumulations	– labour intensive – improves aesthetics but not major contribution to nutrient reduction	
e) Poor Water Clarity	See a) and b)		
f) Abundant Waterfowl	1. Physical removal of birds	– large population in Toronto area makes this ineffective	
	2. Habitat alteration by barrier plantings, reduction in lawn area adjacent to pond (see a3)	– should be effective and long term solution	
	3. Limit feeding by education and barrier plantings	– may be unpopular and require public communication program – should be effective	

Table 5.1: Evaluation of Measures to Address Issues Identified in Grenadier Pond

(tab-5-1/93251/0595)

Issue	*Measures*	*Evaluation*	*Cost*
g) Habitat Alteration	1. Change slopes along altered shoreline by cut and fill	– involves moving considerable material – can be undertaken	
	2. Change substrates (see b))	– will be assisted by measures to improve sediment quality decaying algae – may also improve ground water flow into the pond	
	3. Increase abundance and diversity of macrophytes (see g.1, g.2; a) and b))	– can be undertaken but needs concomitant improve–ments in clarity, slopes and substrates – reduction in purple loosestrife needed	
	4. Water level fluctuation	– investigate water rights issues – can be undertaken inexpensively with existing structure (potential 0.3 m higher or 0.3 m lower) – change in shore slope and vegetation required for full effectiveness	
h) Fish Community Imbalance	1. Stock predators (see b.6)	– effective but sustaining predators requires habitat improvements	
	2. Improve water quality (see a) and b))		
	3. Reduce fishing pressure through enforcement, creation of sanctuary zones, closed seasons and public education	– enforcement is labour intensive – sanctuaries likely most effective – education needed regardless	
	4. Habitat improvement (see g))	– likely effective	
i) Poor Wildlife Diversity	1. Improve marsh habitat by increasing size and water interspersion (see g))	– amphibians and waterbirds need deeper water interspersion	
	2. Reduce competition from non–native species & predation by cats and raccoons	– red–eared sliders may compete with painted turtles – cats and raccoons may prey on marsh birds and/or eggs	
	3. Improve connections with land habitats such as meadows	– oak–savannah restoration will compliment habitat improvements for amphibians	

Table 5.1: Evaluation of Measures to Address Issues Identified in Grenadier Pond

(tab-5-1/93251/0595)

Issue	*Measures*	*Evaluation*	*Cost*
j) Human Access and Education	1. Redirect trails (see i))	– should reduce interference with wildlife	
	2. Barrier plantings around edge (see f.2)	– requires incorporation of viewing areas	
	3. Educate park users about their role (see a.1, f.3, h.3)	– cooperation from public is necessary	
	4. Modification of recreational activities	– public support required – enforcement	

To simplify the evaluation of the potential for water quality improvements, only phosphorus concentrations have been predicted. Phosphorus is generally the most limiting of plant nutrients, although there is some controversy as to whether this holds true for Grenadier Pond.

The existing condition is based on measured water quality at the outfall. Under each of the future scenarios, external loadings, internal loadings and settlement have been calculated. Losses to the pond outfall are then calculated using the relationship:

external loading + internal loading = settlement + losses to the outfall

The water quality at the pond outlet = the annual loss to the outfall ÷ the annual flow through the outfall (note that while the flow remains the same under most scenarios, it is increased under Scenario 5). Water quality at the pond outfall is considered indicative of water quality throughout the pond.

To provide some additional insight into the biological significance of the predicted changes in phosphorus, we have also estimated a secchi disk depth under each of the loading reduction scenarios. Carlson (1973) developed a simple relationship between phosphorus concentration and light transparency:

$$SD = 48\ (1/TP)$$

(where TP is measured in µg/L and SD is measured in m)

Using this relationship, a secchi disk depth of 0.25 m would be predicted for Grenadier Pond based on existing phosphorus concentrations. Actual measurements suggest that it is at least twice this value (0.5 m). We have therefore predicted the secchi disk depth as:

$$2 \times 48\ (1/TP)$$

It should be noted that this relationship only provides a rough approximation of the increased water clarity that might be achieved with Grenadier Pond. A suitable target for secchi disk depth would be 2.0 m or greater, corresponding to a target phosphorus concentration of 0.05 mg/L or less.

Two main conclusions can be drawn from the predicted results of the various load reduction scenarios described in Table 5.2:

a) no one action to reduce phosphorus concentrations can achieve the target of 0.05 mg/L phosphorus and increase light transparency to over 2.0 m. Reductions in external and internal loads are both required as well as increases in clean ground water contributions; and

b) internal load reductions should be more effective than external load reductions in reducing phosphorus concentrations and increasing light transparency.

Table 5.2: Modelled Results of Phosphorus Reduction Potential within Grenadier Pond		
Modelled Scenario	***Phosphorus Concentration of Outfall***	***Approximate Secchi Disk Depth***
Existing Condition	*0.21 mg/L*	*0.5 m*
Future Scenarios		
a) External Load Reductions		
1. reduce storm water loadings by 25%	0.20 mg/L	0.5 m
2. reduce storm water loadings by 50%	0.19 mg/L	0.5 m
3. reduce waterfowl loadings by 50%	0.18 mg/L	0.5 m
4. reduce waterfowl loadings by 75%	0.17 mg/L	0.6 m
5. increase ground water flows by 25%	0.19 mg/L	0.5 m
b) Internal Load Reductions		
6. reduce internal loadings by 25%	0.18 mg/L	0.5 m
7. reduce internal loadings by 50%	0.15 mg/L	0.6 m
8. reduce internal loadings by 75%	0.11 mg/L	0.9 m
c) Combined Strategies		
9. 2 + 4 + 7	0.09 mg/L	1.1 m
10. 2 + 4 + 5 + 7	0.08 mg/L	1.2 m
11. 2 + 4 + 5 + 8	0.05 mg/L	1.9 m
12. 1 + 4 + 5 + 8	0.06 mg/L	1.6 m

It should be noted that the change in phosphorus concentrations and light transparency predicted in Table 5.2 are what might be expected in the short term following load reductions. Over the long term, these are very conservative estimation of the improvements that could be achieved; just as the course of eutrophication within Grenadier Pond has started several processes in motion which collectively have led to a deterioration in water quality, a reversal of this situation will result in a number of improvements which will have synergistic effects on water quality. For example, as water quality begins to improve, increased light transparency will encourage macrophyte growth which will compete with algae for plant nutrients and increase the stability of bottom sediments. Both of these processes will result in further water quality improvements that cannot be adequately quantified. Similarly, the effects of food web alterations have not been quantified but are also expected to contribute to improvements over time.

A variety of specific measures to reduce nutrient loads are discussed in the following sub–sections.

5.1.1 External Nutrient Loads

Phosphorus loads from external sources have been estimated to contribute approximately 68% of the observed phosphorus concentrations in the pond system (Table 2.11). These sources include three drainage outfalls, two at the north end of the pond and the Catfish Pond drainage which carries other storm water outfalls, runoff from the parkland, and loadings from the waterfowl feces directly or from runoff into the pond. Of these sources the waterfowl are potentially the greatest source estimated at 41% of the total loads, followed by the Wendigo Creek outfall (13%) and the Catfish Pond drainage at 11%.

A number of options have been identified to deal with these sources and are shown on Table 5.1. Specifically, point source outfalls can be treated through the addition of storm water treatment facilities designed to retain storm runoff and settle out solids carrying nutrients as well as other urban contaminants. Given that these facilities only retain runoff from a given storm magnitude (usually 25 mm or less) and work on the principles of sedimentation, they cannot be expected to be fully effective at eliminating this source. However, they could be expected to remove 40 to 50% of the nutrient load from storm sewers as well as sediment which has been accumulating at the north end of the pond in recent years (MOE, 1991).

A new sedimentation facility is proposed to capture storm drainage from the Wendigo Creek outfall which will contribute to improvements in the northern end of the pond and Wendigo Creek (M.M. Dillon 1994). A similar treatment facility on the Catfish Drainage is unlikely to be possible given the lack of area available. However, an on–line wetland developed for treatment purposes may provide sufficient treatment as well as being compatible with the existing surroundings.

Watershed reductions of phosphorus can be achieved by encouraging homeowners to reduce or eliminate the use of fertilizers and other household and garden chemicals on their property. To this end, education programs for watershed residents may assist in this effort. The effectiveness of this option is difficult to assess for the participation level of residents cannot be measured. High Park is also within the watershed and here control over fertilizer and other chemicals can be exercised. However, Table 2.11 notes that direct runoff to the pond from adjacent parkland accounts for only 1.5% of the problem and therefore, while contributing to the overall objective, will not be effective in improving the nutrient loads.

The largest source of external phosphorus is from waterfowl resident on the pond. It has been estimated that approximately 300 Canada Geese and numerous other ducks and seagulls contribute 41% of the phosphorus. Clearly, limiting their numbers will provide a significant reduction to this source. While this number has been derived from a variety of sources using a number of assumptions (see Section 2.6) fecal matter littering the shoreline is very evident and can readily make its way to the water during rain events or directly as the birds swim on the surface. Other studies have also found birds to be a significant source of nutrient contamination (Scherer *et al.*, 1994; Manny *et al.*, 1994).

The presence of fecal matter on the shoreline both contributes to the nutrient problems observed in the pond but also is aesthetically unpleasing and prevents park users from using the shoreline for sitting, except on benches. Maintenance actions to remove the material could be undertaken but is a never ending task, labour intensive, and would not do anything to reduce the number of birds or eliminate the problem.

Given the large populations of birds in the Toronto area, physical removal will not be effective for any period of time. Similarly, the success of deterrents such as predator decoys (inflatable crocodile, sand dead bird decoys) is limited to the duration of use; the birds will return if decoy is removed or damaged. Alternately, habitat alteration is available to reduce the numbers. This can be accomplished by providing barrier plantings of shrubs or wetland vegetation around the perimeter of the pond, thus eliminating their preferred lawn surfaces, a quick escape route to the water and a food source. The barrier plantings can serve a dual function as a buffer strip to filter the runoff from the land surface. As a corollary to this action, must come public education to reduce the artificial feeding which occurs, particularly at the south west corner of the pond. This feeding maintains large numbers of the birds which would otherwise be more widely distributed on the Toronto waterfront. Barrier plantings at the south west corner of the pond will serve to discourage both birds and feeders at this location, but unless carried out across the shoreline, it will just shift the birds elsewhere. Some plantings were undertaken in the summer of 1994 in an effort to begin changing this area.

5.1.2 Internal Nutrient Loads

Over the years nutrients contributed to the pond have been removed either through discharge from the pond at the outlet or through sedimentation to the bottom of the pond. The sedimentation may occur after the nutrients have been assimilated by algae in the water column, which eventually die and decay on the bottom. In the presence of oxygen, phosphorus is bound into the sediments and effectively removed from further interaction in the system. Where there is abundant nutrients and resultant algal growth, the process of algal decay depletes oxygen in the bottom waters such that under these anoxic conditions, phosphorus is released from the sediments to be available for more plant growth. Today it is estimated that 32% of the phosphorus in the pond is contributed by the internal load from the sediments. Further Nürnberg (1991) noted that the phosphorus released from bottom sediments is usually in the form of phosphate which is biologically available and therefore can contribute immediately to plant growth. Clearly it is necessary to deal with this load if rehabilitation efforts are to be successful.

There are essentially three types of options to deal with the internal phosphorus loads from the sediments (Table 5.1):

1. removal or treatment of the sediment;
2. removal or treatment of the bottom waters; and
3. transfer of the nutrients into animal biomass.

Within each of these categories there are number of different mechanisms available. Only those which are believed to have a reasonable chance of success are described here. Other options are shown on Table 5.1.

1. Sediment treatment methods

Dredging

The complete removal of sediments from the bottom by dredging provides a potential to eliminate the problem for an extended period of time. There are methods available which would cause minimal disturbance to the water column, a common complaint of dredging being the turbidity and potential release of contaminants with disturbance of the sediments.

Dredging, however, is likely a very expensive option, especially given the volumes of sediment estimated to be present in the pond (150,000 m^3). Some contamination is present in the sediments which could result in a requirement to dispose of them in a landfill at an even greater cost, although additional testing would be required to confirm this. Alternative disposal options may be available other than landfilling, such as use of the dredgate as a soil amendment which could be used to rebuild the wetlands, sold, or replace top soil and fertilizer purchases by the Park's department.

An advantage of some sediment removal is to improve the ground water transfer into the pond. It was suggested by this study that the layer of fine sediments in the nearshore appears to be creating a barrier to the movement of ground water into the pond although further investigation or trial plots would confirm this. Further, these sediments are a fine flocculant which is readily disturbed and appears to have a high oxygen demand which may be limiting the growth of some plants and animals.

Segmental dredging may be used in part to achieve the objectives at considerably less cost than whole pond treatment.

Insitu Treatment of Sediment

Phosphorus can be inactivated by chemical treatment of the sediments using alum, calcium hydroxide or calcium nitrate to create a stable phosphorus mineral apatite (Murphy *et al.* 1993). Calcium nitrate treatment has been used experimentally by Environment Canada on contaminated sediments in Hamilton Harbour with some success both to bind the phosphorus and to oxidate the sediments. These treatments are considerably less expensive but may not provide a long term solution, needing to be repeated in time. Calcium nitrate is also reported (Murphy pers comm) to reduce the volume of sediment by consolidating flocculates which would be beneficial in the Grenadier Pond situation.

Capping of the sediments with clean material could be undertaken to reduce the interaction with the water column. However, capping is likely to be relatively expensive and of variable effectiveness given the difficulty to ensure even treatment throughout the lake bottom.

Several alternative treatment chemicals were suggested by manufacturers during the course of this study. While none had been tested for the purposes of lake remediation, there were promises of a "miracle cure". One, "Biologic SR2", appears to be able to breakdown sediments through micronutrients which stimulate bacterial action. They range in price and the effectiveness cannot be commented upon with the information provided to us. It would be of interest to test some of these products on the sediment to determine the potential for their use. In all cases, sediment treatment may not be 100% effective given disturbance, uncertainty of coverage and the requirement to eventually repeat the treatment. Therefore the maximum expected effectiveness has been given at 75% on Table 5.2.

2. Water Treatment Methods

There are several options that have been tried which treat the water leaving the sediments in place. These include aeration of the hypolimnion or whole water column, hypolimnetic withdrawal or increased flushing with clean water.

Aeration

To treat the water air is pumped into the water either through the whole column or by injection below the thermocline into the hypolimnion to maintain oxic conditions at the sediment interface. There is some debate as to the stability of the stratification that occurs in the pond. Given its relatively shallow depth and observed occurrences of summer destratification it is expected that the lake only weakly stratifies and would be considered unsuitable for hypolimnetic oxygen treatments. Aeration of the whole water column thermally warms the water, mixes higher hypolimnetic phosphorus concentrations and destratifies the pond which is not generally considered desirable.

Aeration can be achieved at relatively low cost using windmills although the effectiveness of treatment is dependent on wind conditions. Power units which appear less intrusive on the surface can be used which require a greater investment in electricity and potentially capitol costs to install servicing. This method requires a long–term commitment for operation given the amount of phosphorus in the sediments. Seasonal aeration to maintain oxic conditions longer can be considered.

Hypolimnetic Withdrawal

This technique essentially relies on withdrawal of phosphorus laden anoxic hypolimnetic waters during stratification. This is done by changing a surface draw system to a bottom draw system and discharging the waters down gradient, or capturing and treating them if downstream pollution is an issue. While it has been shown to be effective in reducing phosphorus concentrations significantly in the first few years (>11% per year; Nürnberg 1987) it is a slow process and may have two disadvantages for use in Grenadier Pond. First, as noted above, the pond may be weakly stratified and therefore the withdrawal could result in a breakdown of stratification. Secondly, these bottom waters are likely to be very odourous with high levels of hydrogen sulphide which would be undesirable in a park setting. The discharge of nutrient rich water downstream to the Humber River is unlikely to be regarded favourably by the approvals agencies given this area's status as an Area of Concern. While the Humber Sewage Treatment Plant is close by, capitol costs would increase significantly if treatment for the water was sought there. There are a number of biological treatment options available to treat these waters on–site, such as Algal Turf Scrubbers (Jensen, K., pers.comm., 1995) and the Living Machine (Todd and Josephson, 1994) which have the potential to provide educational opportunities as well as effective water treatment. Neither of these two technologies are inexpensive, requiring both unique designs and a large location to be set aside. Given the length of time for hypolimnetic withdrawal to be effective, the approvals required and expense of water treatment, this option is likely to be relatively expensive to undertake.

Increased Flushing

The flushing rate of lakes has long been associated with the degree of eutrophy in lakes (Dillon 1975). Those lakes with a high flushing rate tend to have a low retention co–efficient and lower productivity. Grenadier Pond has a flushing rate in the order of 2 to 3 times per year. While this rate could be increased, it too would result in a transfer of the problem from Grenadier Pond to the lower Humber River, where the pond outlets, and eventually to Lake Ontario. This technique would be of uncertain effectiveness and would require capitol expenditure to provide servicing to exchange the water. Lake Ontario is the only potential source of this kind of volume of water. While it would mimic the historical condition before the pond was cut off from the lake, there are now a number of concerns, such as zebra mussels, that would need to be addressed, if it was reconnected to the lake.

Improvement in flushing rate should be encouraged, however, through the enhancement of ground water contributions to the pond. This water is clean and can be obtained at relatively low cost. Drainage from roofs in the watershed is primarily connected to the sewer system (M.M. Dillon, 1994). The City of Toronto has a program to disconnect roof leaders from the sewers and allow them to discharge onto lawns (Marich, pers. comm.). This program was initiated in 1994. Given the sandy soils in the area it is expected that there will be a significant increase in the ground water flow to the pond. We would not be able to quantity the effectiveness of this program until it was known how many residences were participating.

Ground water recharge could also be improved within the park area. The area to the east of the pond consists largely of steep–sloped manicured lawn. Much of the precipitation falling within the area enters the pond as runoff. Shallow infiltration trenches along the bottom of the slope, gravel ditches along roads or depressions to detain drainage would minimize direct runoff while encouraging infiltration.

With additional encouragement of the roof leader disconnection program and measures to improve infiltration in the ponds, a 25% increase in ground water contributions to Grenadier Pond is considered realistic. This represents an approximate 12% increase in flushing rate within the pond.

3. Transfer Into Animal Biomass

This treatment relies on the food chain to reduce the phosphorus concentrations. The principle is that phytoplankton are eaten by zooplankton who are in turn eaten by small fish who are eaten by large fish. When there are too many planktivorous fish then they exert pressure on the zooplankton cropping them to numbers too low to exert an effect on the algae. Predator species are often in low abundance or absent from such systems and, as such, do not keep planktivorous fish in check. Food web alteration (also referred to as biomanipulation) has been investigated by many (Hosper and Meijer 1993, Boers *et al.* 1991, DeMelo *et al.* 1992, Carpenter and Kitchell 1992, Agusti and Canfield 1992) and while it has merit, there are cautions about our ability to understand and measure food web interactions.

While food web alteration can be tried in Grenadier Pond it is unlikely to be effective at reducing phosphorus levels by itself given the internal loads, poor habitat characteristics for producing predator species and fishing pressure. However, this, in combination with other phosphorus reduction mechanisms, will contribute to the removal of phosphorus as well as achieving other recreational and fish community objectives at relatively low cost.

5.2 LACK OF DISSOLVED OXYGEN

Large areas of anoxia develop in the bottom waters during both the summer and winter periods. The anoxia is related to the high oxygen demand of the sediments as the algal biomass decays. The options discussed in Section 5.1 to deal with external and internal phosphorus loading will also improve the oxygen conditions of the bottom waters. No further actions would be specifically required to deal with this problem.

5.3 EXCESS ALGAL GROWTH

Abundant algae grows in the water column and attached to surfaces in the pond. This growth is fueled by the excessive nutrients available in the pond. Options noted in 5.1 to reduce the concentrations of phosphorus in the water column will result in the reduction of algal growth in the whole pond. Maintenance measures such as harvesting and removing algal mats from the surface of the pond will improve the appearance of the water but will not effectively contribute to the whole pond objectives of algal reduction.

5.4 POOR WATER CLARITY

The abundant algal growth is contributing to poor water clarity which limits the transmission of light to water depths beyond 0.5 m during the summer months. This contributes to poor growth of aquatic macrophytes. The options developed in Section 5.1 to reduce the external and internal loads of nutrients will also contribute to improved water clarity. There are no other actions that should be taken to specifically alleviate this problem.

5.5 ABUNDANT WATERFOWL

The abundant waterfowl on the pond have been shown to be contributing significantly to the problem of nutrient enrichment (Section 2). In addition, they trample lawns, cover shoreline areas with feces, and present a threatening front to park users. It has been suggested that the feeding of the birds that takes place, particularly at the southwest corner, maintains artificially high numbers of these birds throughout the season. As well, lawns adjacent to water provide an ideal habitat for the geese. The left over food poses other problems including its contribution to the nutrient loading in the pond (unquantifiable) and the attraction of other nuisance animals, such as rats, reported by residents.

Options to control the geese or the results of their presence include:

1. removal of the birds;
2. alteration of habitat; and
3. limiting feeding opportunities.

1. <u>Removal of the Birds</u>

Reductions in the number of birds using the pond can be achieved through physical removal of the animals, destruction of the eggs, or through the use of deterrents such as acoustic techniques and decoys which scare the birds away. All of these require labour intensive measures and are unlikely to be highly effective given the number of birds present in the Toronto area. Additionally, they may be unpopular techniques with the public and subject to considerable debate prior to implementation. These options are only recommended as compliments to other actions initiated.

2. **Alteration of Habitat**

To reduce the number of birds which use the pond habitat alteration is presented as an option. Lawn surrounding the shoreline offers a food source and a quick escape route to the open water. Planting of vegetation unsuitable for the waterfowl, such as shrubs or high grasses, along the waters edge can be undertaken at relatively low cost and requires little or no maintenance over time. This option is likely to be the most effective at reducing the bird numbers, but will also require the alteration of much of the existing shoreline access to accomplish this. A trial area of plantings has already occurred at the south west corner of the pond beside Ellis Avenue in an effort to deter the birds from crossing the road to Catfish Pond and to reduce the area available for feeding and resting. Early reports suggest that there are fewer birds now to the west of Ellis Avenue.

3. **Limiting of Bird Feeding**

Feeding of the waterfowl has become a popular pastime for park users. However, some of that feeding has gotten out of hand with bakery leftovers being dropped off by the truck load, usually at the south west corner of pond beside Ellis Avenue. As has been previously noted the feeding maintains artificially high numbers birds and supplants their natural food source with bread and doughnuts. Public education to help them understand the consequences of their actions on the pond system and potentially the health of the birds is an option that can be undertaken coincidentally with habitat change. While in itself feeding reductions are unlikely to be effective enough to reduce numbers to target ranges, it will be an important adjunct to the habitat changes needed, in order to gain public acceptance of the future directions.

5.6 HABITAT ALTERATION

Section 2.7 noted the extent of habitat alteration that has occurred in the pond, both related to water quality and physical habitat change. To improve species diversity habitat must be improved. Options to improve habitat, not related to water quality which was discussed in Sections 5.1 through 5.4, include:

1. changing the slopes of the shoreline;
2. changing the substrates;
3. increasing the abundance and diversity of aquatic macrophytes; and
4. controlling water levels to fluctuate seasonally.

1. <u>Shoreline Slope</u>

Shoreline slopes were shown in Section 2.7 to vary between 3:1 and 18:1. Slopes adjacent to the altered shoreline have the steepest slopes, which when combined with substrates and poor water clarity offer limited opportunity for macrophyte development (Duarte and Kalff 1986) and spawning areas. Further, the shoreline in this area does not gradually move upland but abruptly stops at a concrete curb.

Options to correct the shoreline slope are to remove the concrete curb allowing a more gradual transition between the land and waters edge and to regrade/fill the nearshore and backshore to establish a more gradual profile, in the order to 10:1. The extent of slope alterations will in part be dictated by adjacent uses, underlying materials and cost.

2. <u>Substrates</u>

Section 2.7 noted that there are essentially only two types of substrates along the shoreline of the pond, both of which may present problems for macrophyte development and spawning. Coarse substrates such as sands, gravels and boulders are poor mediums for macrophyte rooting and offer poor nutrition. On the other hand, the fine organic sediments may also limit macrophyte growth as they have low density (Barko and Smart 1986). Options to change the substrate characteristics include the addition of inorganic matter to the fine organics, treatment with calcium nitrate to consolidate the sediments, and regrading, removing or filling the areas of coarse or fine sediments. Leaving some of the coarse sediments in place will be beneficial to controlling macrophytes in areas where growth is discouraged.

Removing some of the fine sediments may also be beneficial as indicated earlier in Section 5.1.2 to enhance the ground water movement into the pond. This may be undertaken at an experimental level on the east side of the pond where ground water inflow has been measured.

Regrading or filling of other substrates is complimentary with objectives to reduce the slope along the edge of the pond.

3. <u>Improve Abundance and Diversity of Macrophytes</u>

Macrophytes can provide a considerable amount of cover for fish, amphibians and reptiles and provide attachment surfaces for invertebrates (food organisms) as well as nesting habitat for birds and a substrate for spawning fish. Plants stabilize sediments on shore as well as in the water from disturbance. A variety of plant species are already present around the pond but their distribution has been limited by substrates (see above), shoreline structure and poor water clarity.

To increase the macrophyte diversity and abundance, options noted to improve slopes and substrates are required. Some planting can be undertaken to begin a shift to more desirable species from a food or cover perspective. For example, broad leave submergents (e.g wild celery, pond weeds) provide better cover than dense, fine–leave submergents such as coontail and *Myriophyllum* (Engel, 1995). Floating water lilies are attractive and also provide excellent cover.

Shoreline macrophytes can be established to restore some of the historic marsh edge of the pond and wetland. Species include arrowhead, sedges, bulrushes, and cattails. Diversity of species along the shoreline can provide for different wildlife communities including nesting birds, barrier plantings for waterfowl control, pike spawning, and amphibians. While pike require slender leave emergents along the shoreline which readily matt down over the winter, such species may not be as successful at controlling waterfowl or providing for nesting waterbirds. Therefore, careful planning designs must be developed to maximize opportunities for pike while minimizing opportunities for geese.

Macrophyte development will be an effective mechanism to improve habitat, remove nutrients from the sediments, stabilize shoreline substrates, reduce waterfowl presence, and filter runoff from the surrounding parkland. The extent of planting will be dependent on funds available.

4. Water Level Fluctuations

Aquatic macrophytes will decline or increase in abundance based on water level fluctuations (Busch 1983, Blindow 1992) and some have suggested that without water level fluctuations marsh communities will decline (Varga, Pers. Comm.). As described in Section 2.1, water levels in Grenadier Pond only fluctuate in relation to storm flows and these fluctuations appear to be of short duration. Seasonal fluctuations were also identified as being necessary for northern pike reproduction. Even the fluctuations observed have limited opportunity to contribute to spawning opportunities for the pike given the relatively abrupt and manicured shoreline around much of the edge of the pond.

Only one option is presented to improve water level fluctuations. The outlet structure can be modified to a stoplog format which would allow the water level to be raised or lowered for extended periods of time. It is possible to lower the water level approximately 0.3 m during the summer months over normal levels and raise it 0.3 m over normal levels in the spring resulting in a 0.6 m fluctuation seasonally. It is expected to be a fairly inexpensive option to implement but is necessary to contribute to the enhancement of pike populations and the expansion of the marsh to the north. There would be a need to communicate plans with landowners on the west shoreline.

5.7 FISH COMMUNITY IMBALANCE

Although detailed fish community structure sampling has not been undertaken for many years, indications are that the pumpkinseeds are very abundant in the system, potentially to the detriment of the largemouth bass. Predators, such as the largemouth bass and to a lesser extent, northern pike which are poorly represented in the pond, undergo heavy fishing pressure, some of which is out of season and during the spawning period. While the fish may be caught and returned to the pond, during their absence from the nest, pumpkinseeds may prey on the eggs or young reducing the reproductive success (Kieffer *et al.*, 1995).

Habitats for largemouth bass and pike have been affected by past actions of shoreline alterations and water level controls to the point that pike cannot spawn in the existing pond environment and bass spawn largely on the western shoreline. Inskip (1982) noted in the Habitat Suitability Index for Pike that the minimum ratio of spawning habitat area to summer habitat area is 0.25 although ratios may vary with the quality of the habitat present. This ratio is based on egg deposition rates and average fecundity of female fish. Historically, 38.6% of Grenadier Pond was wetland area with extensive northern and southern wetlands and vegetation along the shorelines (Wainio *et al.*, 1976) representing an approximate ratio of 0.35. Presently, wetland areas have decreased dramatically through infilling and shoreline alteration to only 10% of the pond. There are small pockets of wetland plants at the north end of the lake but because water level fluctuations are so small, these areas are not suitable for pike spawning. Therefore, there is virtually no spawning habitat available for pike presently.

Water quality has also affected the fish in the form of poor oxygen concentrations in bottom waters and low water clarity reducing visibility for sight feeding fish. All of these factors put together serve to put the fish community out of balance.

Options to improve the fish community include:

1. stocking of additional predator species;
2. improving water quality;
3. reducing fish fishing pressure; and
4. improving habitat.

1. **Stocking of Predators**

Until such time as the predator population can be more productive it may be necessary to stock predator species, largemouth bass and northern pike in particular, to prey on sunfish. This option is consistent with that presented for food web control of water quality in Section 5.1.2. Trial programs to implement this option were undertaken during the summer of 1994.

2. **Improving Water Quality**

Options to improve water quality described in Section 5.1 will further assist the fish community and should also be undertaken in support of this issue.

3. **Reducing Fishing Pressure**

Although limited information exists on the number of bass caught and removed from the pond relative to other species, fishing is a popular pastime in the pond and we can infer that there is sufficient pressure on this species. It is expected that most of the impact of fishing comes from anglers who fish during spawning season for the bass, typically in May through early June. Although fishing for bass out of season is prohibited under provincial fishing regulations they are not enforced. There are options available to limit fishing pressure including establishing sanctuary zones, closed fishing periods, public education and enhanced enforcement.

Sanctuary Zones

Currently the west shoreline of the pond acts largely as a sanctuary as it is in private property and supports the majority of the spawning activity. However, some anglers are still observed on this shoreline fishing out of season. This area could be officially designated as a sanctuary zone by the Ministry of Natural Resources and access further restricted. Other zones may be established once habitat improvements are undertaken. Enforcement of the zone will be required to ensure compliance.

Closed Fishing Seasons

On almost any of the week and any time of the day there are anglers along the shores of Grenadier Pond. It is one of the most popular urban fishing holes and has been promoted as such. Closing fishing until the finish of bass spawning is an option to improve spawning success, although will likely meet with opposition and require considerable enforcement. The concept of sanctuary zones will likely meet with greater success. Closed seasons may be necessary for a few years while we try to increase the predator abundance for biomanipulation purposes. Consultation with the Ministry of Natural Resources should be undertaken to determine the feasibility of implementing this option.

Public Education

Like all of the options to be undertaken at the pond, public understanding and acceptance of the action will be key to its success. Programs to inform anglers of their relationship with the pond are important, as well as to inform them of changes that are being implemented. Anglers can also assist rehabilitation and monitoring efforts through information collection on the types and numbers of fish that they catch, reporting tags if marked fish are released, and education of other anglers. They can fish responsibly with barbless hooks, clean up line and hooks so that other animals are not trapped, and treat the resource with respect by caring for the fish caught properly. Display cases are already available at the pond for use in education and trial materials will be installed in the summer of 1994.

Further consultation actions are necessary to ensure maximum effectiveness and participation of the anglers.

Enhanced Enforcement

Enforcement of fishing regulations is the responsibility of the Ministry of Natural Resources. However, budget cutbacks have affected the number of staff that they have available to undertake this activity and consequently limited enforcement takes place on Grenadier Pond. Enforcement, however, should be viewed as a last resort mechanism, preferring instead to look for angler cooperation in achieving objectives for fish protection.

4. **Habitat Improvement**

Habitat improvement was described in Section 5.6. These actions will improve habitat for fish and should be undertaken to improve predator abundance as well as achieving other objectives of improving species and habitat diversity.

5.8 LACK OF WILDLIFE DIVERSITY

It has been noted that all levels of amphibians, reptiles, mammals and birds have experienced a decline in diversity. This has been attributed to changes in habitat, disturbance by people and pets, competition with non–native species and potentially, environmental contamination.

Improvements in habitat have been discussed in Section 5.6. No further actions are required on the pond side. It should be noted that many of the marsh animals also rely on terrestrial environments for part of their life cycle. Improvements to habitats on the land site should also benefit the aquatic species.

Other measures to improve wildlife diversity include removal of interference by people, predators and non–native species. It was noted that the trail along the north marsh may reduce the success of breeding marsh birds by enhancing human access to the area, as well as their pets. Moving people further away by altering the trail location may reduce interference.

Controlling cats and raccoons is a difficult task. However, increasing water interspersion in the marsh may reduce intrusion by cats, at a minimum.

Some management of exotic species, such as the Red–eared Slider, may be necessary to ensure that native turtles remain successful.

It is assumed that if conditions are improved, species diversity will naturally increase. Monitoring for target or indicator species will assist in determining success.

5.9 HUMAN ACCESS AND EDUCATION

The presence of people in the park has both contributed to the importance of improving this environment as well as contributed to the problems experienced by the pond system. It is necessary in part to reduce the influence of people on the habitats and species in the pond system through restricting access and educating them as to the role they play in the success of this project.

At present people have access to virtually every inch of the shoreline with the exception of the west shore which is held in private ownership. Even here, there is human access but it is limited to a few individuals. It has been suggested that the presence of people and pets may limit the success of nesting by marsh birds given the proximity of the trail to the marsh at the north end of the pond. Shoreline trails around the remainder of the pond provide easy access for fishing. Therefore, it is desirable to limit some of the access to the ponds edge in order that other objectives related to fish and wildlife habitat development, waterfowl control and fish community protection can be realized. As this process evolves, it is also necessary to continue to educate and inform the public about the changes that are coming and the reasons why.

A trial program of public education and awareness was undertaken in the summer of 1994 as implementation projects on the pond began.

Other options to move trails are shown on the preferred framework described in the next section.

6.0 PREFERRED FRAMEWORK FOR REHABILITATION

Based on the information presented in the preceding sections there are several options that fall out as being more desirable or satisfying a number of objectives. Details of each recommended option are not repeated here, unless additional detail is provided. The attached concept (Figures 6.1 and 6.2) provides a graphic illustration of the locations and options which are being proposed to achieve the rehabilitation of the Grenadier Pond system.

As with any plan for ecological improvement, a long–term monitoring program should be set in place. Similarly, public eduction and cooperation will also be essential for a successful plan. Finally, an action plan to guide the implementation and advise on the priority of projects would also be necessary. Each of these programs will be discussed in detail in Section 7.0.

6.1 WATER QUALITY

Water quality improvements will be achieved through a combination of actions including:

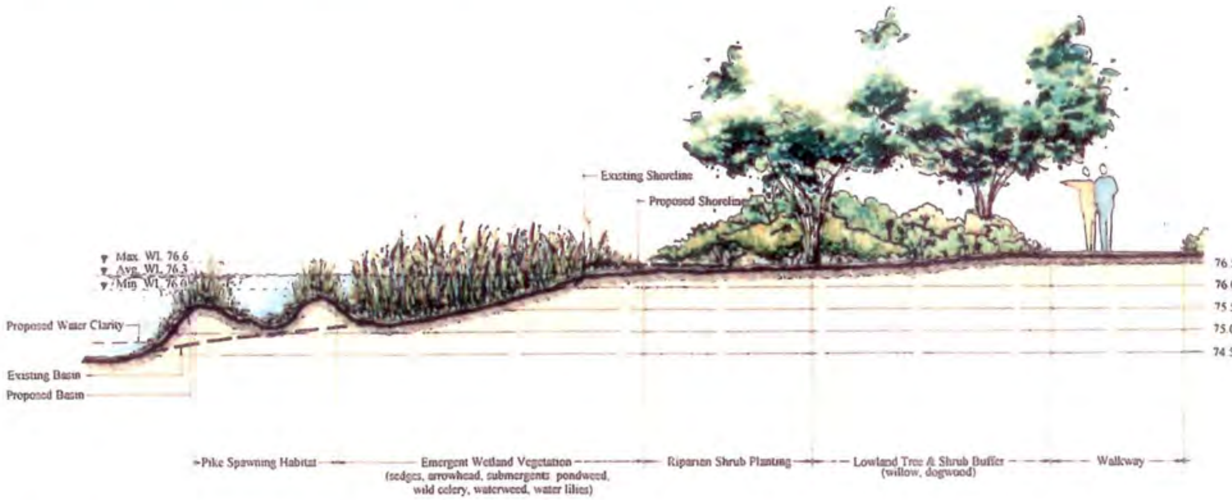
a) reduction of the internal phosphorus load by selective sediment removal, sediment treatment, macrophyte establishment and food web alteration; and
b) reduction of external phosphorus loads through waterfowl reduction, watershed actions, and storm water treatment facilities.

Each option will be discussed in more detail in the following section. Water quality improvements are sought which will improve water clarity to the 2.0 m level. To do this would require phosphorus concentrations within the pond to be reduced from the present 0.21 mg/L to approximately 0.05 mg/L.

6.1.1 Internal Loading Reduction

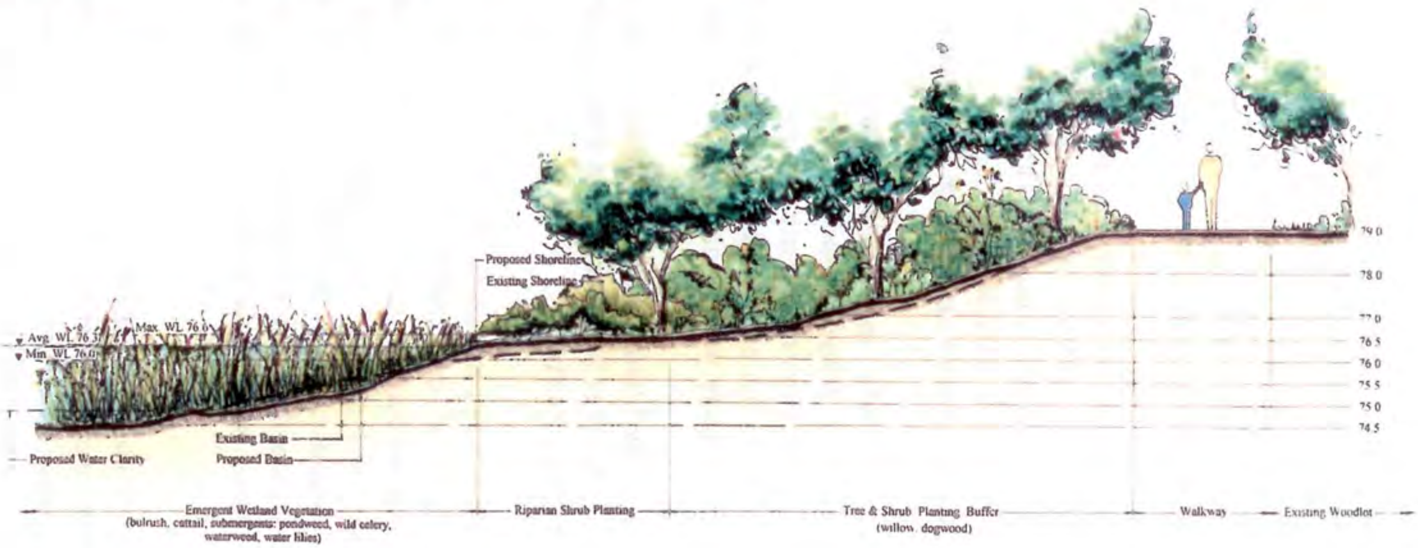
While there are many ways to rehabilitate the sediments in Grenadier Pond, there are only a couple that could or should be pursued further. Those options that are associated with correcting the problem in the pond are given greatest consideration. While others, such as aeration may be cheaper in the long run, they are not going to fix the problem and will need to be continually applied over a very long time frame.

Those options that will be viewed as being successful by the park users are those that will result in visible differences in the pond environment in a short period of time. Many other aspects of the



Section A-A
South Shoreline 1:50

Gartner Lee No to Scale	**GRENADIER POND SYSTEM REHABILITATION CONCEPT PLAN** A Plan for the Rehabilitation of Grenadier Pond Wendigo Creek and Associated Wetlands for The City of Toronto	FIGURE **6.2a** Project 93-251



Section B-B
East Shoreline 1:50

Gartner Lee

No to Scale

GRENADIER POND SYSTEM REHABILITATION CONCEPT PLAN

A Plan for the Rehabilitation of Grenadier Pond Wendigo Creek and Associated Wetlands for The City of Toronto

FIGURE
6.2b

Project 93-251

rehabilitation framework, such as the wetland development and fish habitat improvement, are also dependent on the improvement in the sediment quality and resulting oxygen demand and therefore a rapid improvement in water quality is required for these elements to be successful.

Finally, given the setting in a regionally significant park, the mechanism chosen should be least intrusive to the park users and allow them to see the rapid progression toward the desired goal.

There are only two methods that may achieve these needs to varying degrees. The first is dredging and the second is selective withdrawal and treatment of the hypolimnetic (bottom waters). Both are relatively expensive options, require further investigations and approvals.

Dredging has the advantage of resulting in a more rapid recovery of the system and it has been suggested that it may also improve the flow of ground water into the pond. The requirement to dewater and dry the dredgate prior to disposal or use results in the need to set aside a large area of land on a temporary basis. The flat area on the south shore of the pond could be used prior to restructuring of the shoreline. It is also away from the main concentration of park users.

The dredgate may be contaminated with metals which limits its use for certain applications. Additional testing will be required to delineate contaminant zones and depths of material to be removed. However, newer technologies may be able to bind metals such that the dredgate can be used as a soil amendment and not require special disposal. It will be rich in nutrient and therefore could be considered a resource rather than a liability, which could be selectively used in controlled situations.

Dredging will require permits from the Ministry of Natural Resources and the Conservation Authority as well as approvals from the Ministry of Environment and Energy related to the Sediment Quality Guidelines and the Material Management Policy.

The costs for this option are based on an anticipated 15 ha (150,000 m^3) area with 1 m of sediment removed on average. This would need to be confirmed in the field. Assuming a $10.00 per cubic metre cost to remove and process, we have calculated a cost of approximately $1,500,000 plus about $150,000 for additional studies and permits. The wildcard in terms of cost are the costs or requirements associated with disposal or use of the sediments. Until further work is undertaken we will not be able to determine whether there would be additional costs. These costs would be over the course of a one to two year period and result in an immediate benefit to the pond, allowing other projects to begin.

Hypolimnetic withdrawal relies on the selective removal of the bottom waters for discharge downgradient of the site. With operation over an extended period of time, nutrients are gradually depleted from the bottom sediments. This process can take years to produce significant results and therefore may not be as effective as dredging at meeting the anticipated needs of the park users.

Given the concentrations of nutrients in the bottom waters, treatment of the water post withdrawal is likely to be a requirement. The act of removing the bottom waters is not difficult, however, the treatment of the withdrawn water is likely to more complicated and expensive. The simplest and least expensive option to treat the water would be to direct the discharge to the sanitary sewer system for treatment at the Humber Treatment Plant. However, the feasibility of this option has not been pursued.

There are other insitu treatment technologies being offered today which take advantage of biological processes to treat the water. They include algal scrubbers and multi–chambered bacterial and plant systems (Living Machine). There are few examples of their application in Ontario to treat water but experience in other jurisdictions reports effective treatment capability. Either of these types of technologies would have to be specifically designed to meet the needs of the regulatory agencies and likely would require a Certificate of Approval (C of A) from MOEE to operate. On going requirements for maintenance and monitoring to meet the likely requirements of a C of A are in addition to the initial capitol expenditures for such technologies.

The costs for this option are not that different from those related to dredging. The capitol expenses relate to the studies required for approvals of a facility, building of a pump house to withdraw the bottom waters, and the construction of a treatment facility and are estimated in the order of $750,000, bearing in mind that the various treatment technologies have very different capitol costs associated with them. In addition, there will be ongoing monitoring and maintenance costs associated with the use of hypolimnetic withdrawal and the treatment systems. These costs are estimated to be about $30,000 per year which, if extrapolated over the 20 year time frame anticipated for treatment could amount to $600,000 or more.

While new technologies can be an interesting educational opportunity in the park, they will also take up park space over a very long period while the withdrawal is operating.

At this time it is difficult to firmly recommend a preferred option for the treatment of the internal load. There is additional work required to allow the development of detailed plans for carrying out the preferred action. We should also not preclude the potential of interesting opportunities which present themselves.

Having said that, it our opinion that dredging represents the option with the potential to elicit the most rapid response and be the least intrusive into the park land over the long term, and at a cost that, while substantial, is likely comparable to that for hypolimnetic withdrawal.

In addition to the above, there are a few areas of the pond where dredging should not be carried out as habitat of reasonable quality remains. Specifically, the western shoreline should be left alone.

However, the sediments in this area may benefit from some treatment to reduce the flocculant nature and expected high oxygen demand. Therefore, chemical treatments injected into the sediments should be investigated for their effectiveness at improving the sediment quality through the use of test plots.

Macrophyte establishment around the shoreline is necessary to stabilize the sediments and prevent their continued resuspension into the water column.

Food web alteration should be pursued in combination with these options to ensure that algae populations are controlled in part by zooplankton. Efficiency of this option in treating the problem is not known but will contribute further to the objectives at low cost.

Alone, the sediment treatment should be able to achieve a 75% reduction in the internal loadings. Additional measures including food web alteration and macrophyte development will also contribute to this goal.

6.1.2 External Loading Reductions

Loads from the waterfowl and storm outfalls should be controlled to improve water quality. We propose to proceed with a program to alter the habitat for waterfowl around the perimeter of the pond in order to discourage their presence and feeding activities. This habitat alteration should be accompanied by a program of public education about the birds and feeding.

We have targeted a 75% reduction in nutrient loadings from birds in order to be able to achieve a suitable water clarity objective. This means that either the population of Canada geese is reduced to approximately 75 individuals and/or that a substantial part of the shoreline has a buffer strip planting to reduce the runoff of feces into the pond. As noted previously, a reduction in birds is only achievable through barrier plantings and feeding reductions. Figure 6.1 outlines areas of barrier plantings and buffer strip development.

Storm water outfalls from Clendenan Avenue and entering Grenadier via the Catfish Pond drainage should be controlled using quality control sedimentation facilities. The Valleymede outfall was not shown to be a significant source of nutrients to warrant specific treatment, although enhanced wetland development at its junction with the pond may improve the quality contributed slightly.

The Clendenan Outfall is currently undergoing design at the direction of the City of Toronto Department of Public Works and the Environment for a new sedimentation facility which will assist in meeting Grenadier Pond objectives. M.M. Dillon (1994) predicts that 73% of the annual suspended sediment load will be trapped by the sedimentation facility. Total phosphorus is often associated with suspended sediment and a corresponding maximum reduction in phosphorus by 50% is expected (MOEE, 1992). Therefore a nutrient load reduction to Grenadier is expected to be in the order of 7%.

An on–line wetland treatment facility could be installed at the south west corner of the pond to treat the drainage from Catfish Pond. While it may be of only moderate effectiveness in treating the water, this water would no longer mix with the pond water prior to discharge through the outfall. It could be considered completely removed (reduction of 11%) for the purposes of assessing the potential pond improvement.

These two treatment options reduce nutrient loadings by approximately 18%. This is still substantially under the 50% storm runoff target reduction to achieve desired water clarity. Therefore, it is necessary to look at further improvements within the watershed by residents and businesses to reduce contributions of contaminants in the storm water to improve the quality of water being contributed to the pond. Reductions in the use of chloride (deicing salt) and garden fertilizers and chemicals, as well as stooping and scooping are simple actions that can be encouraged of the watershed residents. However, the success of this is unknown and cannot be quantified. Therefore, a target of 25% reduction in storm water contributions may be more realistic but may not result in desired water clarity (see Table 5.2). Everything possible should be done to educate watershed residents and seek their participation.

Residents can also cooperate in the disconnection of their roof leaders when approached by the City of Toronto Department of Works and the Environment. This will enhance clean ground water contributions to the pond. Similarly, infiltration can be enhanced in the park for example by putting gravel in the road ditches, and creating shallow depressions in the tablelands. The added advantage is that erosion could be reduced where runoff is moving down the slope.

Using the previously developed ground water and surface budget (Table 2.1) future conditions under modified infiltration options were predicted and are shown on Table 6.1. Infiltration in the park only contributes approximately 0.5 L/s to the pond. However, roof leader disconnection (assuming 50% participation) combined with park infiltration options could provide an additional 4 L/s over current levels. This meets the target of an increase of 25% of ground water flows to the pond shown on Table 5.2.

6.2 FISH AND WILDLIFE HABITAT AND COMMUNITY DIVERSITY

Improving the diversity of fish and wildlife habitat will be achieved by undertaking a number of actions including those related to water quality improvements as described in Section 6.1, as well as restructuring the shoreline, and increasing the area of marsh vegetation available through habitat enhancement activities.

As a first step in deciding the type and extent of habitat alterations required lists of existing species or those that were once known to be common to the pond area were reviewed. A number of species of birds, mammals, amphibians and fish were selected as targets for restoration activities. They are shown on Table 6.2 along with their habitat requirements.

TABLE 6.1
FUTURE GROUND WATER AND SURFACE WATER CONTRIBUTIONS TO GRENADIER POND

FUTURE CONDITIONS–with recharge in park

AREA NO	DRAINAGE AREA (HA)	ANNUAL SURPLUS (MM)	INFILT%	ANNUAL INFILT (MM)	ANNUAL GW VOL (M3)	ANNUAL RUNOFF (M3)		
1A	232.0	300.0	0.30	90.0	208800.0	0.0		
1.0	104.1	300.0	0.45	135.0	140481.0	171699.0		
2.0	16.4	300.0	0.45	135.0	22126.5	27043.5		
3.0	46.5	300.0	0.25	75.0	34837.5	104512.5		
4.0	15.5	300.0	0.25	75.0	11610.0	34830.0		
5.0	7.2	300.0	0.25	75.0	5422.5	16267.5		
*6	32.8	300.0	0.85	255.0	83742.0	14778.0		
7.0	23.0	300.0	0.00	0.0	0.0	68910.0		
							RUNOFF=	369130.5 m^3
	245.4 AREA				507019.5 m^3	438040.5 m^3		
		GROUND WATER ESTIMATE =			16.1 L/S			

FUTURE CONDITIONS–roof leader disconnection (50%)+recharge

AREA NO	DRAINAGE AREA (HA)	ANNUAL SURPLUS (MM)	INFILT%	ANNUAL INFILT (MM)	ANNUAL GW VOL (M3)	ANNUAL RUNOFF (M3)		
1A	232.0	300.0	0.40	120.0	278400.0	0.0		
1.0	104.1	300.0	0.55	165.0	171699.0	140481.0		
2.0	16.4	300.0	0.55	165.0	27043.5	22126.5		
3.0	46.5	300.0	0.30	90.0	41805.0	97545.0		
4.0	15.5	300.0	0.30	90.0	13932.0	32508.0		
5.0	7.2	300.0	0.30	90.0	6507.0	15183.0		
*6	32.8	300.0	0.85	255.0	83742.0	14778.0		
7.0	23.0	300.0	0.00	0.0	0.0	68910.0		
							RUNOFF=	322621.5 m^3
	245.4 AREA				623128.5 m^3	391531.5 m^3		
		GROUND WATER ESTIMATE =			19.8 L/S			

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Table 6.2: Target Fish and Wildlife Species and Their Key Habitat Requirements

(tab-6-2/93251/0894)

Target Species	*Key Habitat Requirements*		
	Reproduction	*Feeding*	*Cover*
Fish			
▪ Northern Pike	submergent and emergent vegetation; inundated floodplain (>10 cm) in early spring)	predator – small fish, birds, amphibians	young in vegetation, adults deeper water with or without cover
▪ Largemouth Bass	soft or fine gravel substrates; shallow water usually less than 1 m; with submergent vegetation or log cover	predator – small fish, amphibians	young in vegetation, adults deeper weed beds and at depths
Mammals			
▪ Muskrat	Cattail Marsh with adjacent open water	Cattail roots and aquatic vegetation – Cattail	Cattail Marsh adjacent to moderate deep water, also stream bank
Amphibians			
▪ Leopard Frog	pond/marsh – clean shallow water area with aquatic vegetation	adults – aquatic and terrestrial invertebrates; larvae – algae	adults use meadows, near pond if possible; tadpoles – clean shallow water
▪ Green Frog	permanent pond/marsh clean shallow water with aquatic vegetation	adults – aquatic and terrestrial invertebrates; larvae – algae	adults use marsh along pond edge; tadpoles – clean shallow water with aquatic vegetation
▪ Gray Tree Frog	pond/marsh – clean shallow water with aquatic vegetation	adults – aquatic and terrestrial invertebrates; larvae – algae	adults in deciduous forest in summer
Waterbirds			
▪ Virginia Rail	Cattail or Sedge marshes with interspersion of shallow water	invertebrates	same as reproductive habitat
▪ Sora	Cattail or Sedge marshes with interspersion of shallow water		
▪ Marsh Wren	moderately dense Cattail Marsh	insects	
▪ Swamp Sparrow	cattail marsh or willow–alder thickets	insects	
▪ Moor Hen	cattail marsh interspersed with open water	aquatic vegetation	

The habitat requirements for the target species then formed the basis for determining the type of habitat restoration needed. Habitat improvements for these species will also be suitable for a variety of other species and therefore should contribute to the overall goal to increase species diversity. Habitat designed for these species should also be suitable for a number of other species. In future monitoring efforts we can gauge the success of habitat rehabilitation efforts by the presence of some or all of these species .

Shoreline alterations include those necessary to remove the existing concrete curb, as well as those necessary to change slopes and substrates off shore. Two example cross sections (Figure 6.2a,b) are provided which depict the typical existing and proposed depth profiles, plant zonation, and targets for water level fluctuations and water clarity. Figure 6.1 outlines the locations of where the shoreline alterations should occur.

While the alteration of the shoreline is a relatively expensive effort, some of the materials salvaged can be used to create habitat elsewhere in the pond. Specifically we propose to create an island extending offshore from the existing wetland at the south west corner of the pond. This will increase the perimeter of the pond and enhance opportunities for fish and wildlife habitat. It also serves to barrier the far south west corner from interaction with the pond to make treatment of the Catfish Pond drainage more effective. This area can be designed with a greater degree of open water interspersion making it attractive habitat for a variety of species, including muskrat, pike and marsh birds.

The wetland at the north end of the pond is also in need of rehabilitation and enhancement. The marsh is now elevated above typical water levels reducing the amount of open water which occurs within it. Many animal species associated with the wetland depend on water interspersion. Restoring a connection with Wendigo Creek may improve that condition. As well it is necessary to extend the wetland southward into the area of mudflats to create a larger area of wetland and gradual transition into the open water.

Gibbs *et al.* (1991) noted that species richness of non–game waterbirds increased in wetlands of increasing size. Wetlands of between 1 ha and 10 ha were observed to provide a reasonable diversity of water birds. Increasing the wetland area from its current 0.4 ha to an area in the order of 1.2 ha as shown on Figure 6.1, should improve the species diversity.

To improve water interspersion in the north marsh areas of deeper water will be required. This can be accomplished through selective dredging or blasting to create deeper 'holes' or pockets of water. The impacts of re–distributing the bottom sediments would need to be investigated given the presence of contaminants. The placement of sunning logs for turtles and under water boulders and stumps for fish should also be valuable additions to the habitats.

Improving the shoreline and wetland habitats, and combined with water clarity improvements should increase the habitable area of the littoral zone which roughly ranges between 4.8% and 13.2% of the pond to approximately 20% which is considered optimal for lakes (Mikalski *et al.*, 1987).

To reduce human influence in these areas we propose to relocate the trail in the north east of the pond and discontinue the use of the shoreline trails in the south of the pond.

Stocking of fish would take place to augment the existing population and to introduce more pike into the system, primarily for food web alteration purposes. Other wildlife transfers may also be tried if, through monitoring, it is determined that the species have not become established on their own.

Some wildlife management may also be deemed necessary to remove or limit the influence of non–native species such as Red–eared Slider turtles and predators such as cats and raccoons from the marsh.

6.3 PARK USER ACTIVITIES

The rehabilitation plan changes very little of the park user activities. Trails are still provided around the pond with access points to the water's edge. Swimming and boating are activities that presently do not occur in the pond and both have the potential for more harm than good. Boating on the pond could be offered by Parks and Recreation as an educational tool, to watch "an experiment in progress". There are many swimming opportunities both in the park and at nearby waterfront beaches and therefore we have not considered it here.

Fishing is, and shall remain, a favoured pastime of urban anglers – both adults and children alike. Maintaining this activity on the pond is important to providing a quality of life for many Toronto residents and to achieving objectives of the Ministry of Natural Resources. However, we would advocate the delineation of sanctuary zones throughout the pond which are actively "enforced" by Parks staff, Metro Police and/or MNR. Education of anglers to catch and release and fish in season will also be an important component of the successful rehabilitation of the pond.

Feeding of the birds is a pastime on the pond which must be reduced. The Duck Pond to the east within the park offers opportunities to feed the birds. Although the odd piece of bread thrown by children can be tolerated, bakery drop offs by well meaning bird lovers must be discontinued. Through habitat alterations along the south and east shorelines, a program to inform the public of the changes, and identification and communication with the offending bakeries, the objective for bird control should be achievable.

Winter activities such as skating on the pond would not be affected by the water treatment options with the exception of aeration. Aeration would result in limited areas of open water which would be dangerous to park users, but at this time it is an option that has not been recommended. Clearing of snow in the ice may benefit winter oxygen production by increasing light availability to the water column.

Educational opportunities at the pond could be increased through the addition of an interpretive centre at the shoreline. This could both serve as a living classroom but provide washroom facilities and be used as a safety office during winter ice skating use.

7.0 IMPLEMENTATION PLAN

7.1 PRIORITIES

A number of action items and regulatory approvals requirements were identified throughout the previous section outlining the recommended framework for rehabilitation. However, in order to get the job done there needs to be a clearer direction on the actions to be undertaken and the priority of each. While implementation of all aspects of the rehabilitation scheme at once is ideal, this is unlikely to be realistic. In that event, certain actions have to be begun first, forming the building blocks for the next action. Referring back to our house analogy, the windows can't go in without the walls to hold them in place. Table 7.1 provides a listing of the rehabilitation items, partners, specific action items and a priority. Those items that have a high priority should be begun first followed by moderate to low priority items.

The first priority in the successful implementation of this plan, although not shown on Table 7.1, will be the assignment of a Project Manager, whose primary responsibility it is to ensure the timely implementation of each component through securing funding, managing staff resources and seeking the input of experts as required.

Monitoring and a community education and information plan are action items that are essential throughout the course of this rehabilitation plan. Although noted with specific action items, they should be considered as an ongoing annual requirement. The monitoring program is described in more detail in the following section as are the elements of a community information plan.

The following summarizes in more detail the specific actions required. Some of these actions have been begun as part of demonstration projects and are recognized throughout as appropriate.

TABLE : 7.1 IMPLEMENTATION PLAN OF PREFERRED OPTIONS TO ADDRESS ISSUES IDENTIFIED IN GRENADIER POND

ISSUE	OPTION	EASE OF IMPLEMENTATION	WHO WILL IMPLEMENT	ADDITIONAL WORK REQUIRED	PRIORITY
A. **External Loading of Nutrients**	1. Stormwater Detention Facilities a) North End	– Major Construction – Long term maintenance – Expensive	– Public works and the Environment	– Detail design – Construction	Proposed for 1995
	b) South End (Wetland Development) at Catfish Pond outfall	– Feasible over small area (See Nearshore Dredging) – required	– Parks and Rec.	– Class EA – confirm need; undertake – Detail design – Construction	Moderate
	2. Reduce nutrient and other contaminant contributions from watershed; increase ground water contribution a) Surrounding area	– Infiltration combine with roof leader disconnection program – Educational program easy to develop and implement with roof leader, but very difficult to enforce / regulate	– City of Toronto – Public Works and Environment – Public Utilities	– Devise strategy for the development, and delivery of Educational Program	High
	b) Adjacent Parkland	– Highly feasible	– Parks and Rec.	– Exercise control over the use of fertilizer and other chemicals within the park – Combine with other infrastructure changes	Moderate
	3. Reduce # of waterfowl a) Limit feeding by education	– Initial implementation completed	– Parks and Rec. – Local Environmental groups eg. Environmental Dialogue High Park Foundation – MNR	– Develop public communication program to encourage cooperation/ support signage.	High
	b) Habitat alteration – Barrier Plantings	– Technically feasible – Small scale planting complete – Easy to implement – Large cost; may require phasing	– Parks and Rec.	– Public communication – Detail design for entire shoreline restructuring – Tender specifications – Construction in segments	High – Moderate

TABLE : 7.1 IMPLEMENTATION PLAN OF PREFERRED OPTIONS TO ADDRESS ISSUES IDENTIFIED IN GRENADIER POND

ISSUE	OPTION	EASE OF IMPLEMENTATION	WHO WILL IMPLEMENT	ADDITIONAL WORK REQUIRED	PRIORITY
B. Internal Loading of Nutrients	4. Foodweb alteration (Stock Large Mouth Bass and Northern Pike)	– Highly feasible – One stocking completed	– MNR – City of Toronto – Canadian National Sportsmen's Show	– Water quality improvements (see 6) – Habitat improvements (see 8,9) – Monitoring fish populations	High
	6. Dredging (Nearshore sediments) or Sediment Treatment	– Feasible but involves more information and approvals – Expensive	– Parks and Rec.	– Sediment testing – Site selection for removal – Develop disposal/treatment options – Monitoring	High
C. Habitat Alteration Improvement	8a. Change: – nearshore slopes – substrates b. Increase diversity and abundance of macrophytes and wetlands	– see 3b – Feasible to implement but will require some approvals – Large cost; may require phasing	– Parks and Rec.	– Sediment and substrate testing for quality/quantity – Detailed survey information – Detail design – Tender – Monitoring (demonstration areas)	High – Moderate
	9. Water level fluctuation	– Technically feasible * should <u>Follow</u> options for habitat improvement – Simple but requires approvals	– Public Works and Environment	– Study impact of fluctuation on existing shoreline – Investigate details surrounding water rights (Stelco) – Public discussions with landowners – Design structure – seek permits from MNR and CA	Moderate
D. Human Access and Education	10. Educate park users about their role (extend to watershed)	– Signage (complete) – Enforcement difficult	– City of Toronto – Local Environmental groups e.g., Environmental Dialogue	– Continue to monitor waterfowl populations vs. feeding tendencies – Signage for live–release fishing practices	High
	11. Redirect Trails	– Highly feasible * Done in conjunction with shoreline changes	– Parks and Rec.	– Detail design – Public communication	Moderate
	12. Education Centre	– Unknown	– Parks and Rec. – Board of Education – Sportsmen's Shows	– Detail Design	Low

A. Phosphorus Reduction of External Sources

There are several actions relating to the reduction of external loads of nutrients, in particular phosphorus, two of which maintain high priority for completion: improvements within the watershed to reduce phosphorus inputs to storm water and increase ground water contributions should be implemented by the municipal government in co–operation with individual residents. The success of these actions relies on effective communication and education of the public on their role in watershed management, therefore it is important to have community outreach programs in progress with watershed management actions. Bird control measures are also a high priority as waterfowl significantly contribute to the high external phosphorus loading. As the bird control measures rely in part on the alteration of shoreline habitat, both shoreline and backshore alteration should be undertaken concomitantly to reduce the potential for later disturbance to already treated areas. Shoreline plantings along the south–west corner have already been completed.

Other activities would also include the implementation of the Clendenan outfall storm water treatment facility, proposed for 1995 by the Department of Public Works and the Environment, and investigating the needs for further approvals to create a storm treatment wetland in the pond at the southwest corner to capture and provide some treatment for the Catfish Pond outlet.

B. Phosphorus Reduction of Internal Sources

The internal loading of phosphorus is one of the main sources of phosphorus contamination and therefore, all actions to remediate this loading are considered to be high priorities. Food web alteration can be applied through the stocking of the historically present predator fish, northern pike and largemouth bass. Funding from the Canadian National Sportsmen's Show has allowed for the stocking of 200 largemouth bass and five northern pike in September 1994. Additional stocking of northern pike is scheduled for May 21, 1995. Although fish stocking will assist in the recovery of ecosystem balance, the successful reproduction of pike will likely not be observed until such time as the water levels are altered seasonally and shorelines are naturalized (see part C). Bass spawning can be enhanced by installing 50 spawning boxes along the south shore until such time as water quality improvements are realized.

More importantly, though, is the need to deal directly with the sediments in the pond. More information is required to allow a final determination of how to deal with the internal load. Specifically, additional information is required to delineate the depths, quality and consistency of the sediments to determine appropriate handling, as well as to obtain necessary permits or approvals. Trial plots for different sediment treatments could be undertaken to examine different alternatives prior to whole scale implementation.

C. Habitat Alteration Improvement

Habitat alterations can be undertaken in stages. Great Lakes Clean–Up Funding has been received for Spring 1995 and designated towards naturalizing approximately 40 m of the south end shoreline as a demonstration project that will focus on restoring a section of shoreline into a wetland. A boardwalk will also be designed and constructed to enhance on–site educational opportunities. Eventually, additional sections of the shoreline will be naturalized. This staged approach would also allow time for completing detailed designs, obtaining the necessary permits and for ongoing monitoring of the success of different measures in order that design modifications can be made prior to completion of the works. Early habitat alterations will not have the advantage of the clear water that is expected once the nutrient control measures have begun to work, and as such may require further improvements as rehabilitation progresses.

Once new habitat areas are developed and steady improvements to the water clarity and quality are achieved, water levels can be manipulated to alter the seasonal fluctuations. With water level fluctuations it is expected that the north marsh area will now expand, both naturally and with some assistance. Permits and approval will need to be sought from the Metro Region Conservation Authority and the Ministry of Natural Resources.

Marsh improvements should also incorporate alteration of the Wendigo Creek outlet/configuration to direct more water into the existing and new marsh areas and movement of the current walking trail away from the edge of the marsh, if deemed desirable.

At this time, the wetland to the south west can also be expanded. Alterations to the shoreline will have yielded materials to be used in the construction of an island. The creation of a wetland treatment facility for the Catfish Pond drainage would also be completed at this stage. Assuming that it would also need to undergo a Class Environmental Assessment, there would be sufficient time intervening to have the studies and design completed.

D. Human Access and Education

As referred to earlier in part (A), creating an educational community outreach program on the role of residents and park users in the rehabilitation of Grenadier Pond should be designed and coordinated as the earliest date. Educational signage along the south west shore of the pond has already been erected by the City of Toronto in an effort to control unwise bird feeding.

Other opportunities exist to provide an interpretive facility on the shores of the pond. While it can be constructed at ant time during the rehabilitation process, it would have a lower priority than the need to fund the sediment and habitat improvements.

7.2 PARTNERSHIPS

A summary of the activities in the implementation plan is provided in Table 7.1. Most of the activities outlined fall under the mandate of the City of Toronto Parks and Recreation Department. The exceptions are those that may be undertaken by the Department of Works and the Environment related to storm treatment and roof leader disconnection. Some of these projects are already under way.

The Ministry of Natural Resources can assist with the implementation of sanctuary zones and angler education. As well, waterfowl control falls under their mandate. It is a larger problem than just what is occurring at Grenadier Pond and there should be consideration given to larger scale activities to reduce their populations.

And last but not least, it is also the responsibility of each watershed resident and park user to assist in the efforts to rehabilitate the pond system.

8.0 MONITORING PROGRAM

8.1 PROJECT RATIONALE

As the Grenadier Pond Framework for Rehabilitation becomes finalized and the implementation of various rehabilitation strategies becomes feasible, a monitoring plan is required top assess improvements resulting from these management strategies. The timeline for such monitoring is chiefly dependent on the type of rehabilitation actions applied to the system. For example, dredging is a relatively fast procedure often yielding end results within five years. Alternatively, methods of bottom water/sediment treatment, such as hypolimnetic withdrawal, have a considerably extended period of operation, perhaps as long as 20 years. To be of practical use, any monitoring should occur coincidentally with a rehabilitation project and continue beyond completion for a minimum of 1 to 2 years, with periodic monitoring intervals thereafter, in order to confirm patterns indicative of success or otherwise. Bear in mind this relationship between implementation and monitoring, the following outlines essential monitoring practices that would measure and evaluate ongoing changes within Grenadier Pond, helping to guide management actions towards a successful rehabilitation.

Through the information collected to date, the ecosystem dynamics affecting Grenadier Pond are becoming better understood, but there is still a need to acquire more detailed information on the seasonal physicochemical behaviour of the pond, as well as sediment characteristics and various watershed impacts. Pond Managers can decide to have monitoring projects begin before rehabilitation plans are implemented, thereby adding to the existing baseline data collection or have the two projects run concurrently. In the case of Grenadier Pond, it is recommended to proceed with additional data collection as early as possible.

8.2 WATER QUALITY AND QUANTITY MONITORING

8.2.1 Project Rationale

The following parameters are the essential ones to assess improvement within the system. A full range of chemical testing would add valuable insight to the overall workings of the pond, but is not absolutely required for practical monitoring. If the appropriate agency, such as MOEE, is involved at this stage, it becomes more economically feasible to conduct complete water chemistry evaluations.

Through frequent measurements of the phosphorus, temperature and oxygen profiles in the deep region of the pond (sampling station SW1), our present understanding of seasonal stratification patterns and time frames for bottom water anoxia would be significantly improved.

N.B. Winter profiles may not be practically obtainable due to ice cover, but should be pursued throughout the winter as opportunity presents.

As a component of the water balance, water volumes at the pond outlet would provide an indication of any increasing ground water inputs.

8.2.2 Monitoring Practice

As a first measure, the pond's inputs and output flows as well as the shallow and deep in–pond station should be sampled for the following parameters:

- Total Phosphorus (TP)
- Phosphate (PO_4)
- Nitrogens (NH_3, NO_2, NO_3)
- Hydrogen Sulphide (H_2S)
- Chlorides
- Secchi Depth
- Field pH, Temperature and Dissolved Oxygen
- Chlorophyll

In addition to taking discrete samples, water column profiles for phosphorus, oxygen and temperature at the deep station (SW1) should be continually developed, taking measurements at 1 m intervals.

Ground water quality and quantity entering the pond should be measured in conjunction with measuring water volumes at the pond outlets. All monitoring should be done, at a minimum, on a monthly basis, preferably every two weeks.

8.3 SEDIMENT QUALITY MONITORING

8.3.1 Project Rationale

The need to reduce internal loading of phosphorus from the sediments has been identified as critical to the rehabilitation, being directly related to water quality, nutrient enrichment, algal growth and habitat. Techniques involving sediment removal and/or treatment must be supported by a clear understanding of the chemical attributes making up the sediments in Grenadier Pond, therefore, the monitoring of sediment quality must be undertaken both before and after project implementation.

8.3.2 Monitoring Practice

Sediment core samples can be taken to determine:

a) sediment density;
b) phosphorus concentrations; and
c) heavy metal contamination.

Samples should be from various depths and locations within the pond to determine distribution of sediment characteristics. As mentioned above, pre– and post–project monitoring is required at frequency of once per year.

8.4 FISH MONITORING

8.4.1 Project Rationale

As part of the overall rehabilitation scheme, establishing self–sustaining populations of largemouth bass and northern pike would imply a shift in the present biophysical conditions of the pond towards a more balanced and historically similar ecosystem.

8.4.2 Monitoring Program

Three aspects of fish sampling are recommended: a) whole lake populations; b) spawning surveys; and c) young–of–the–year surveys (to estimate spawning success), all of which can be done with assistance from the MNR.

a) Whole lake populations of fish can be sampled at representative habitats throughout the pond. Two days of intensive sampling for population size and composition is recommended to be done on a biannual basis at the beginning of the summer and then again in late summer/early fall. In order to properly understand the fish population dynamics in Grenadier Pond, initial monitoring should continue for at least two years at which time whole pond monitoring should be continued at 5 year intervals. Sampling methods would employ a combination of hoop nets, seining and electrofishing as well as documentation of localized habitat improvements.

b) Spawning surveys of largemouth bass nests should be conducted along the shoreline. Largemouth bass spawning occurs in late spring to early summer. Two to three nest counting events should be done, generally in mid–late May through mid–June (peak spawning period), but determined by weather conditions.

With the stocking of pike, areas of spawning activity (if any) should be identified and mapped. As spawning habitat is created, the success (illustrated by the degree of pike use) of these areas would also need to be documented. Once spawning locations are found, the number of actively spawning adult pike should be counted. Pike are known to spawn in the early spring, after ice out. Spawning counts should be focused on late March to mid April, approximately every three days, but determined by weather and water temperature conditions.

c) Sampling for young–of–the–year pike and bass would occur at and around identified spawning grounds. This sampling must be done following the spawning season for each respective fish. Techniques would involve electrofishing and seining.

Creel surveys should also be conducted throughout the fishing season to document fishing pressure and harvest. MNR typically conducts these inventories, but park staff could assist with this effort.

8.5 BIOMONITORING

8.5.1 Project Rationale

All of the following issues can provide direct feedback on the net effectiveness of the rehabilitation strategies. Similar to the water quality parameters, these are all biological indicators of the health status of Grenadier Pond and therefore essential to assessing improvement.

8.5.2 Monitoring Program

Monthly sampling of zooplankton and phytoplankton is recommended. One integrated sample should be taken from the surface to a maximum of 3 m for both zoo– and phytoplankton coinciding with water sampling periods, concentrating on spring, summer and fall periods.

Seasonal sampling of macrophyte density, species and distribution would be required on a monthly basis starting in April and continuing through to October.

Spring surveys of herpetile mating calls would help verify the presence or absence of these creatures. Frequent visits throughout the spring spawning season would be advised. Future monitoring can be expanded to determine population sizes, species identification and fecundity.

Population counts of waterfowl combined with recorded incidence of human feeding practices should be conducted on a bimonthly basis throughout the year. Volunteers from local environmental/ community groups may be interested in organizing this effort.

9.0 COMMUNITY EDUCATION AND INFORMATION

A number of the options outlined in the recommended rehabilitation strategy rely on the cooperation and active participation by watershed residents, park users and businesses. Without their involvement it is unlikely that the targets for nutrient reduction in the watershed will be met and as a result the pond improvements will not be as successful.

A number of specific action items can be identified as requiring community cooperation. They include:

a) lot level drainage controls (e.g., roof leader disconnection);
b) revegetating and naturalization of the shoreline;
c) stooping and scooping after pets;
d) reduction or elimination of fertilizer and other chemical use in the watershed and along the adjacent parklands;
e) the role of aquatic macrophytes; and
f) monitoring of water quality, plants (including algae) and animals.

Materials prepared and activities undertaken should attempt to address these items first.

Education cannot just take the form of a flyer dropped in a mailbox or utility bill. The education program should also include elements of:

a) direct contact for discussion purposes and to provide more detailed information through "town hall" meetings or the establishment of a "hotline";
b) demonstrations by experts in water quality monitoring or plant and animal surveys, for example;
c) public work days to assist in the pond remediation process, such as work on the shoreline plantings or monitoring activities;
d) signage at specific locations around the pond where activities are being undertaken;
e) a regular newsletter to provide updates on progress and upcoming events;
f) the development of a regular report card to communicate the progress at meeting objectives; and
g) presentations to schools, ratepayers associations, and clubs, for example.

This program should be undertaken promptly, as a first priority in the action plan. There are number of changes coming that could ultimately affect the residents and park users and they need to be given ample warning and opportunity to input to these changes.

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10.0 REFERENCES

Agusti, S. and D. Canfield, Jr., 1992:
"Self–regulation, bottom–up and top–down control of phytoplankton communities: A reply to the comment by Kamenir" Limnol. Oceanogr. Volume 37(3):683–687.

Apfelbaum, S., 1994:
Personal Communication. Applied Ecological Services, with D. Martin–Downs, Gartner Lee Limited.

Atmospheric Environmental Service, 1990:
Summary of Meteorologic Data for Clendenan Avenue Station (1840–1990)

Barko, J.W. and R.M. Smart, 1986:
Sediment–related Mechanisms of Growth Limitation in Submerged Macrophytes. Ecology V67(5):1328–1340

Blindow, I., 1992:
Long– and Short–term Dynamics of Submerged Macrophytes in Two Shallow Eutrophic Lakes. Freshwater Biology V28:15–27.

Boers, P., L. Van Ballegooigen and J. Unk, 1991:
"Changes in Recycling in a shallow lake due to food–web manipulations" in Freshwater Biology Volume 25.

Busch, W.D., 1983:
Lake Ontario/St. Lawrence River Wetland Inventories: Impacts of Water Level Regulations. Presented to the Great Lake Fishery Commission Annual Meeting, by U.S. Fish and Wildlife Service.

Carlson, R.E., 1977:
A Trophic State Index for Lakes Limnology and Oceanography 22(2) 361–369.

Carpenter, S. and J. Kitchell, 1992:
"Trophic cascade and biomanipulation: Interface of research and management – A reply to the comment by Demelo *et al.*" Limnol. Oceanogr. Volume 37(1):208–213.

City of Toronto, 1993:
1992 Grenadier Pond Survey of Inflows and Water Quality. Prepared by Department of Public Works and Environment.

Decommissioning Consulting Services Limited, 1992:
Letter report re: Wendigo Creek leachate Spring Remediation, High Park, Toronto, Ontario. Prepared for City of Toronto, Parks & Recreation Department.

DeMelo, R., R. France and D. McQueen, 1992:
"Biomanipulation: Hit or Myth" Limnol. Oceangr. Volume 37(1):192–207.

Department of Energy, Mines and Resources, 1974:
Map Sheet 30M/11e at scale 1:25,000

Dillon, P.J., 1975:
The Phosphorus Budget of Cameron Lake, Ontario: The Importance of Flushing Rate to the Degree of Eutrophy of Lakes. limnology and Oceanography V20(1):28–39.

Dillon, P.J., 1974:
A Manual for Calculating the Capacity of a Lake for Development. Ontario Ministry of the Environment.

Duarte, C.M. and J. Kalff 1986:
Littoral Slope as a Predictor of the Maximum Biomass of Submerged Macrophyte Communities. Limnol. Oceanogr. V31(5):1072–1080

Fahey, T., 1993:
Personal communication. Landscape Architect for City of Toronto with James Kamstra, Gartner Lee.

Goodwin, C., 1988:
A preliminary checklist of High Park birds. Unpub. 5 pp.

Goodwin, C., 1994:
Birdwatcher who formerly lived near High Park.

Hosper, H and M. Meijer, 1993:
Biomanipulation, Will it Work for Your Lake? Ecological Engineering V2:63–72

Johnson, B., 1993:
Personal communication. Curator of Reptiles, Metro Toronto Zoo with James Kamstra, Gartner Lee Limited.

Kieffer, J.D., *et al.*, 1995:
Effects of catch and release angling on nesting smallmouth bass. Trans.Am.Fish.Soc. 124:70–76.

Loehr, R.C., 1974:
Pollution Control for Agriculture. Academic Press Inc., New York.

Gibbs, J., J.R. Longcore, D.G. McAuley and J.K. Ringelman, 1991:
Use of Wetland Habitats by Selected Non–Game Water Birds in Maine. U.S. Fish Wildlife Services, Fish Wildlife Res. 9, 57 pp.

Manny, B.A., W.C. Johnson and R.G. Wetzel, 1994:
Nutrient Additions by Waterfowl to Lakes and Reservoirs: Predicting Their Effects on Productivity and Water Quality. Hydrobiologia 279/280:121–132.

M.M. Dillon Limited, 1993:
Grenadier Pond Sedimentation Control Study. Public Information Centre #2 – Sediment Sampling Program. Prepared for City of Toronto, Department of Public Works and the Environment.

M.M. Dillon Limited, 1994:
Grenadier Pond Sedimentation Control Study. Final Environmental Study Report. Prepared for City of Toronto, Department of Public Works and the Environment.

Michalski, M., D.R. Gregory and A.J. Usher, 1987:
Rehabilitation of Pits and Quarries for Fish and Wildlife. Prepared for the Aggregate Resources Section Land Management Branch, Ontario Ministry of Natural Resources.

Ministry of the Environment, 1991:
Stormwater Quality Best Management Practices. Queens Printer, Ontario.

Ministry of the Environment (MOE) and Ministry of Natural Resources (MNR), 1991:
Interim Stormwater Quality Control Guidelines for New Development. Water Resources Branch, Central Region.

Ministry of the Environment (MOE), 1984:
Water Management: Goals, Policies and Implementation Procedures of the Ministry of the Environment.

Ministry of the Environment and Energy, 1992:
Proposed Policy for the Management of Excess Soil, Rock and Like Materials. Prepared by Materials Management Policy Committee.

Murphy, T, A. Moller, H. Brouwer, M. Fox and J. Babin, 1994:
Review of Insitu Sediment Treatment (Draft). Publication of the National Water Research Institute, Environment Canada, Burlington, Ontario.

Murphy, T, E. Prepas, J. Babin, K. Hall and P. Manning, 1993:
Developments in Lake Restoration in Western Canada. Canadian Water Resources Journal V18(3):299–306

Nürnberg, G., 1987:
Hypolimnetic Withdrawal as Lake Restoration Technique. Journal of Environmental Engineering V113(5):1006–1017

Nürnberg, G., 1991:
Phosphorus from internal sources in the Laurentian Crest Lakes, and the concept of threshold external load. J. Great Lakes Res. V17(1):132–140.

O'Hara, D., 1993:
Personal Communication. City of Toronto.

Ontario Ministry of Natural Resources, 1980:
Quaternary Geology for Toronto and Surrounding Area, Preliminary Map P. 2204, Ontario Geological Survey

Persaud, D., R. Jaagumagi and A. Hayton, 1992:
Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario. Ontario Ministry of the Environment.

Riley, J.L., 1989:
Distribution of Status of the Vascular Plants of Central Region. Ontario Ministry of Natural Resources, Open File Ecological Report SR8902, Richmond Hill, Ontario. 110 pp.

Scherer, N.M., H.L. Gibbons, K.B. Stoops and M. Muller, 1994:
Nutrient loading of an Urban Lake by Bird Feces. Lake and Reservoir Management.

Varga, S., 1989:
A botanical Inventory and Evaluation of the High Park Oak Woodlands Area of Natural and Scientific Interest. Ontario Ministry of Natural Resources. Open File Ecological Report 8907, Richmond Hill, Ontario. 48 pp.

Wainio, A., J. Barne, J. Roswell and K. McIntosh, 1976:
An Ecological Study of Grenadier Pond and the Surrounding Areas of High Park– Toronto.

Yukich, R., 1994:
Personal Communication. Birdwatcher who lives near High Park with James Kamstra, Gartner Lee Limited.

Zimmerman, A.P., 1991:
Letter report re: Comments on limnos Reports on Aquatic Management Options, High Park. Written to Mr. J. Belan, Department of Parks and Recreation.

Zimmerman, A.P., L.A. Warren and S.G. Smith, 1986:
The Comparative Limnology of Grenadier and Catfish (West) Ponds, High Park, Toronto, Ontario.