ENVIRONMENTAL REVIEW
BEDROCK RESOURCES, INC.
PERMIT APPLICATION FOR
AGGREGATE DREDGING
IN LAKE ONTARIO

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PROJECT TECHNICAL SUMMARY

Title	ENVIRONMENTAL REVIEW: BEDROCK RESOURCES, INC. Permit Application for Aggregate Dredging in Lake Ontario
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Principal Investigators	Gillian M. Booth, Trevor J. Chandler, Chris Fraikin, Paul G. Anderson, with contributions from Bruce Kilgour MAWSA, and Milo Sturm and Rob Nairn of Shoreplan Engineering Limited.
Report Period	January 1991 - January 1992 Draft Report for Client Review: November 2, 1992
Objective	B.A.R. Environmental Inc. was retained by Bedrock Resources, Inc. to investigate the ecological impacts resulting from a proposed dredging operation for aggregates, 1.5 - 4.0 kilometres offshore the Scarborough Bluffs in Lake Ontario. The concerns voiced by the Ministry of Natural Resources, the Ministry of the Environment and the Department of Fisheries and Oceans were to be addressed.
Technical Perspectives	Environmental concerns which arise from the proposed project include impacts to fish, fish habitat, benthic invertebrate, water quality and human users. The physical features of the site are described using field data, literature and unpublished reports together with selected field sampling of sediments and biota. As requested by the Ontario Ministry of Natural Resources, we investigated the use of the site by fish to determine which species and life stages would be most likely to be affected. Gore and Storrie limited was asked to apply their models of Lake Ontario circulation patterns to determine the levels of turbidity which could be expected from the dredge overflow plume. We reviewed the literature regarding turbidity and sedimentation so that we could estimate their impacts to fish and invertebrates. Examination of MNR creel data and the local charter boat operations were used to determine whether there would be any conflict with local fishermen.
Results	Dredging is expected to take 145,900 m^3 of sand from the deposit annually for at least the first 3 years and perhaps double that in the future. Based on single and double shift rates, the deposit will remain productive for 195 and 97.5 years, respectively. At single shift rates, the dredge will suction the top 15 cm off 6.9% (0.973

km^2) of the site each year. In a worst case scenario (which is based on the fine sediment found at only one sampling station, the resulting sedimentation from the overflow will amount to an estimated maximum accummulation of 2.5 mm per year, deposited over 6 million m^2. Based on the average sediment particle size, an anticipated accumulation of 0.7 mm yr^{-1} (deposited over 6 million m^2) is predicted. Suspended sediment concentrations of the turbidity plume will be extremely localized and have maximum concentrations less than 1600 ppm. The plume will be formed for 8-10 hours a day and is expected to dissipate quickly by advection and sedimentation. In the vicinity of the R.C. Harris Water Treatment Facility concentrations are projected to not exceed 0.1 mg L^{-1}. Lake herring and rainbow smelt are the only fish with spawning habitat at any risk from the operation. Other fishes found in the offshore zone do not use sandy substrate in depths of 10 - 40 metres for spawning. Some of the fishes in this zone may use the site for feeding. In the short term, the benthic invertebrate community will be removed from the 6.9% of the area dredged that year. The impact to the overall benthic invertebrate community of the site will be minor due to projected rapid recolonization.

Project Implications

The applicant has recognized that environmental impacts can be avoided in the most part by staying out of the shallow nearshore zone that is the most biologically active. By limiting this application to depths greater than 9 m and avoiding gravel substrates that are useful as fish habitat, or silt deposits that are potentially contaminated and create turbidity, environmental impacts have been kept to a minimum. Potential to fish habitat is limited to marginal lake herring and rainbow smelt spawning habitat and to marginal feeding habitat for other bottom feeding fishes of the open lake, such as round whitefish and sculpins. None of the sport fishes use this type of fine sand at these depths for spawning.

The dredging zone is at the edge of prime sport fishing waters which lie along the lakeward (southerly) boundary of the permit application zone. There is potential for perceived conflict of interest as the two zones lie in close proximity. Fishing boats based at Bluffer's Park or Ashbridges Bay will have to cross the dredging zone to reach the fishing grounds. However, in practical terms, a single dredge operating within 14 km^2 of open lake is unlikely to interfere with fishermen.

1 INTRODUCTION TO THE PROJECT

Bedrock Resources, Inc. is proposing to mine sand from the lake bottom 1.5 to 4.0 km offshore from the eastern Toronto waterfront. The aggregate would be processed onshore and provided to the Toronto building market as concrete sand. The area originally outlined on the aggregate permit application filed with the Ontario Ministry of Natural Resources (MNR) in 1990, has been revised after consideration of the environmental factors reviewed in this report, the location of the R. C. Harris Water Filtration Plant intake pipes and field sampling of the substrate. Both the original and the revised proposed permit areas are shown in Figure 1. The northern, inshore edge of the permit area is 1.5 to 2.5 km offshore. The southern offshore boundary approximates the edge of a steep shelf at a point about 4 km offshore. The proposed permit area runs east-west for 7.8 km from offshore Ashbridges Bay to east of the Scarborough Bluffs for a total surface area of approximately 14 km^2. At no point is the permit area within 1 km of the shoreline. The average depth of water in the permit area is 18 m and ranges from 10 to 40 m. The substrate in the permit area is generally featureless fine to coarse sand, 1.5 m to 5.25 m thick, overlying the silt and clay deposits of the Scarborough Formation and Sunnybrook Till (Sharpe 1980). Martin-Downs (1988) reports that this area is poor fish habitat, used primarily as a transition zone for fish passing through, due to its featureless nature and to the large, sudden summer water temperature changes caused by wind-induced upwellings of cold water from mid-lake.

The proposed project is to dredge the surface sand from the permit area using a suction dredge. An average of approximately 1.0 cm of the surface of the substrate would be dredged each year, at single shift dredge rates. Bedrock Resources, Inc. (Bedrock) is committed to carrying out an environmentally sound project. The equipment and techniques proposed by Bedrock are the best available technology in the world today. The president of Bedrock visited several major international dredging operations to discover the most environmentally sound operating techniques. These techniques will be applied to this project to ensure that there will be minimal impacts to the local environment and other users of the area. The dredging operation is described in more detail in Section 4.

1.1 Study Objectives

B.A.R. Environmental Inc. was hired to assess the environmental impacts of the proposed project, to carry out studies to ensure that these impacts can be reliably predicted, and to recommend mitigation strategies, if appropriate, for preventing impacts. We reviewed existing data respecting the fisheries, benthos and water and sediment chemistry at the site. Milo Sturm of Shoreplan Engineering Limited was asked to

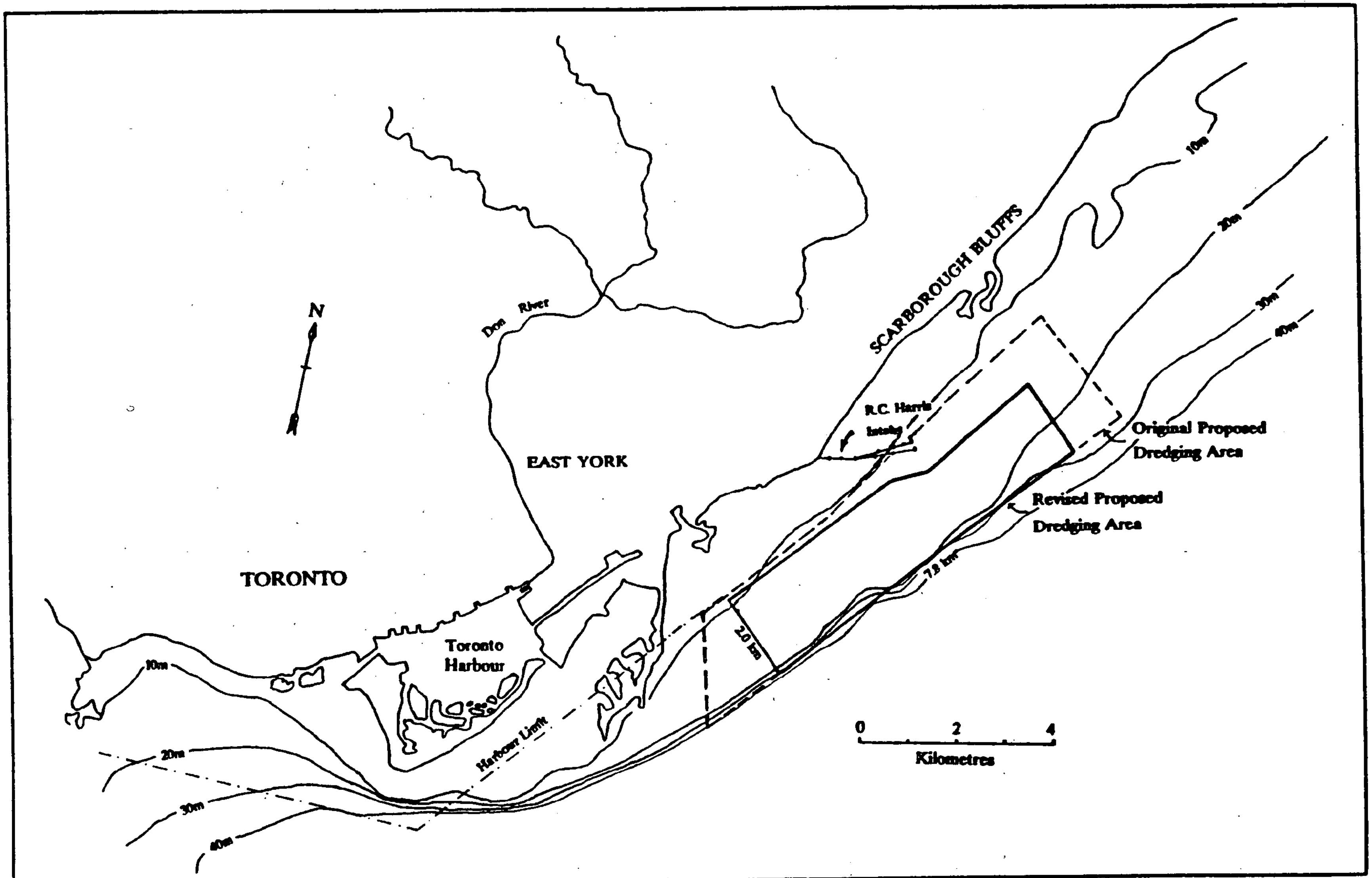

Figure 1 Map of the study area showing the original and revised licence application areas and bottom depths (m).

address the concerns regarding impacts to the littoral regime and shoreline erosion. Gore & Storrie Limited were retained to model Lake Ontario circulation patterns in the vicinity of the permit site and to project the magnitude of turbidity plumes resulting from dredging operations. We used the turbidity data, generated by Gore & Storrie Ltd., and estimates of sedimentation to predict the potential impacts to the biota. We also reviewed Ontario Hydro data on currents, sediments and fisheries from the Pickering Generating Station studies to the east of the permit site. We sampled the benthic invertebrate community at the site to assess its importance to feeding fishes and we carried out a survey during whitefish spawning to determine whether whitefish were using the site for spawning. Bedrock Resources, Inc. examined the physical aspects of the substrate itself, including grain size and depth of the deposits.

1.2 Alternatives to the Project

There are other locations in Ontario that could provide similar aggregate resources to the Toronto market. However, given the prohibitive haulage costs, the only viable reserves to supply the downtown Toronto construction market, are in the Greater Toronto region. Barge or boat and railway haulage, although cheaper than trucking, can only provide a feasible alternative where several conditions are present: suitable rail beds and routes, appropriate handling facilities, and aggregate resources of sufficient volume and suitable locations to make the project feasible (McLellan 1983). Distant reserves (not in the Toronto area) and their economic constraints have been reviewed in the separate report prepared by the client.

The Oak Ridges Moraine, within the Toronto hinterland north of the city, extends from the Niagara Escarpment eastward to the Trent River. This extensive feature contains several distinct sections containing as much as 200m of overburden (Chapman and Putnam 1984). Much of this material contains sand and gravel and, consequently, has been one of the chief sources of aggregate for the Toronto market (McLellan, 1983). However, there are concerns that gravel extraction has had negative effects upon the hydrogeological, ecological and aesthetic characteristics of the region (OEAAC, 1990). A complete assessment of these impacts does not exist (OEAAC, 1989), although Intera Kenting (1990) identifies three potential impacts of aggregate extraction to the hydrogeological regime. These effects include the drawdown of local water tables, especially if the pit is dewatered; ground compaction which reduces the permeability of the ground surface; and siltation. Siltation ponds may plug the porosity of the ground and impede infiltration and silty wash water discharged into streams can increase stream turbidity resulting in the destruction of fish habitat. Although progressive rehabilitation may lessen these impacts, aggregate extraction will permanently change the physical appearance of this provincially significant landform. For these reasons, an alternative to mining the moraine could provide significant environmental benefits.

1.3 Benefits from the Project

McLellan (1983) warns against establishing new pits in hinterland areas, such as in the Oak Ridges Moraine because of potential transportation difficulties and land use conflicts. The Lake Ontario aggregate deposits, located within 10-15 kilometres of downtown Toronto, make them ideally suited for use within this market. The main reasons are: 1) eliminating the environmental impacts associated with aggregate mining in the Oak Ridges Moraine, an environmentally sensitive area; 2) heavy, expensive and environmentally damaging truck haulage can be avoided, thereby minimizing further congestion of local highways; 3) keeping costs and prices lower for local users of aggregate materials; and 4) as recommended by the Royal Commission on the Future of the Toronto Waterfront (Crombie 1990), industries like Bedrock Resources that require access to Lake Ontario, should be encouraged to locate along the waterfront.

2 POTENTIAL ENVIRONMENTAL CONCERNS

The following is a list of the potential concerns which have been raised by Bedrock Resources, Inc., B.A.R. Environmental Inc., the Ministry of the Environment, the Ministry of Natural Resources and the Department of Fisheries and Oceans.

Potential impacts to fish and other biota:

- eggs and larvae of lake trout, lake and round whitefish, rainbow smelt, lake herring and sculpins may be smothered or entrained;
- substrate required for spawning fish may be removed;
- forage base may be damaged by entrainment or smothering;
- important habitat for sculpins may be destroyed;
- the texture of the substrate may be altered and no longer suitable for fish habitat;
- inplace pollutants may be redistributed into the water column; and
- turbidity plume may affect biota.

Potential impacts to other users of the site:

- water quality and protection of the intake pipes at the R.C. Harris Water Treatment Plant may be affected;
- removal of aggregate from the site may influence erosion patterns along the waterfront;
- salmon fishing, particularly the Toronto Star Derby, may drop off if the dredging interferes with fishing; and
- public enjoyment of on-shore activities may be affected by the un-aesthetic view of the dredge and the turbidity plume.

In this report we review the information available about the physical environment in which the operation is proposed, describe the dredging operation itself and review the potential impacts of the operation on the environment, the fishes potentially using the site and the public use of the area.

3 THE PHYSICAL ENVIRONMENT

3.1 Water Currents

The offshore currents of western Lake Ontario have been well documented (Saylor *et al* 1981; Farooqui 1991). Currents are typically wind-driven and parallel to the shore, except in summer when wind stress is low and the geostrophic effect (earth rotation) is the dominant force affecting current direction. Farooqui (1991) found that the current flow direction is bimodal along the northwest shore of Lake Ontario, either to the east or the west. In addition, there is a seasonal preference to current direction: westward in summer, eastward in fall and winter and an even mix of east and west during the spring.

In Lake Ontario, the coastal currents that affect surface waters extend approximately 10 km offshore (Saylor 1981) and the proposed permit site lies entirely within this zone. Figure 2 illustrates the predominant current directions in Lake Ontario.

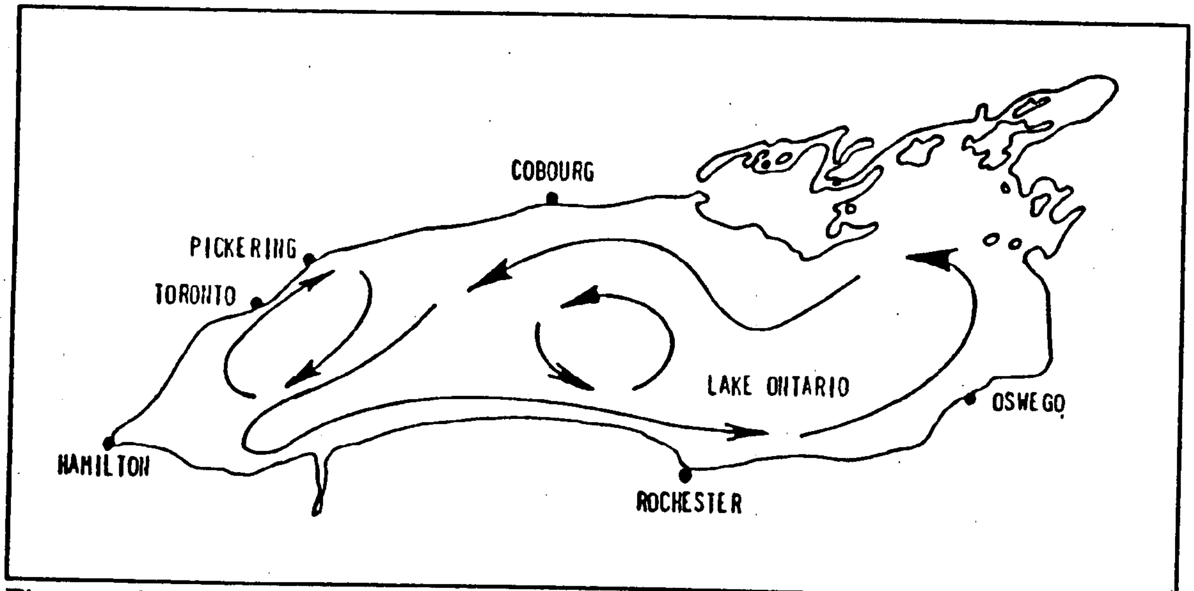

Figure 2 Vector averaged currents from June to October, adapted from Pickett and Mermick 1977.

Current speeds at the water surface are generally slow, averaging 10 cm sec^{-1}, during most of the open water season but as high as 36.3 cm sec^{-1} in fall and early winter when wind speeds are greater (Ontario Hydro 1979). Hydro monitored current and wind velocities at a site 1.3 km offshore from Pickering NGS (Figure 3). Currents velocities were measured at three stations, at depths of 8m in 13m of water. These studies reveal a high frequency of wind reversals along the northwestern shore which induce current reversals that often lag behind the wind change by about 6 hours inshore and 12 hours offshore (Farooqui, 1991).

3.2 Sediment Transport

The information in this section was provided to Bar Environmental Inc. by Milo Sturm and Rob Nairn of Shoreplan Engineering Limited. The proposed permit site lies within the littoral cell that extends from East Point, Scarborough to Leslie Street Spit (Reinders 1988; Philpott 1988, 1991; Sandwell, 1989). The net sediment movement in this area is from east to west but substantial movement in both directions occurs. The wave climate in this area is bi-directional, (Reinders 1988) therefore sediment can be transported in both westerly or easterly directions. However, the dominant drift direction is from the east because of the much greater fetch that lies in this direction and the subsequently higher wave energies during fall and winter storm events (Rukavina 1976). These waves erode the Scarborough bluffs which contribute 100,000 cubic metres of sediment to the littoral regime (Philpott 1988; Sandwell 1989).

The direction that this eroded material moves can be expressed in two ways: *alongshore* transport, parallel to the shoreline and either to the east or west, or *cross-shore* referring to the movement of sediment perpendicular to the shoreline. Over the past several thousand years, most of the littoral sediment has been transported alongshore to the west, and this transport process has been responsible for the production of such features as the Toronto Islands (Rukavina 1976). However, it is the cross-shore transport that is key to this project. Analysis of cross-shore transport will indicate if the deposits within the proposed dredging area are acting as a source or sink for littoral material. If these sediments act as a source or temporary storage area, the removal of this material could impact coastal processes and shoreline stability.

Philpott (1991) estimated cross-shore transport during the severest storm event over a 20 year period (1964-1983) for a grain size of 0.2 mm. His analysis showed that cross-shore transport in the offshore zone was virtually non-existent at depths greater than nine metres. This result indicates that, in depths greater than nine metres, sediment is not transported toward (or away from) the shore and, hence is not a factor controlling shoreline stability. Philpott (1991) also performed sensitivity analyses to determine the effect of sediment size and water depth on cross-shore transport. The results indicated a rapid decline in cross-shore transport when either variable was increased. The median grain size of the bottom deposits in the permit area ranges from 0.18 mm to 3.89 mm (Bedrock 1991), and all but one of the sediment sampling stations had a median grain

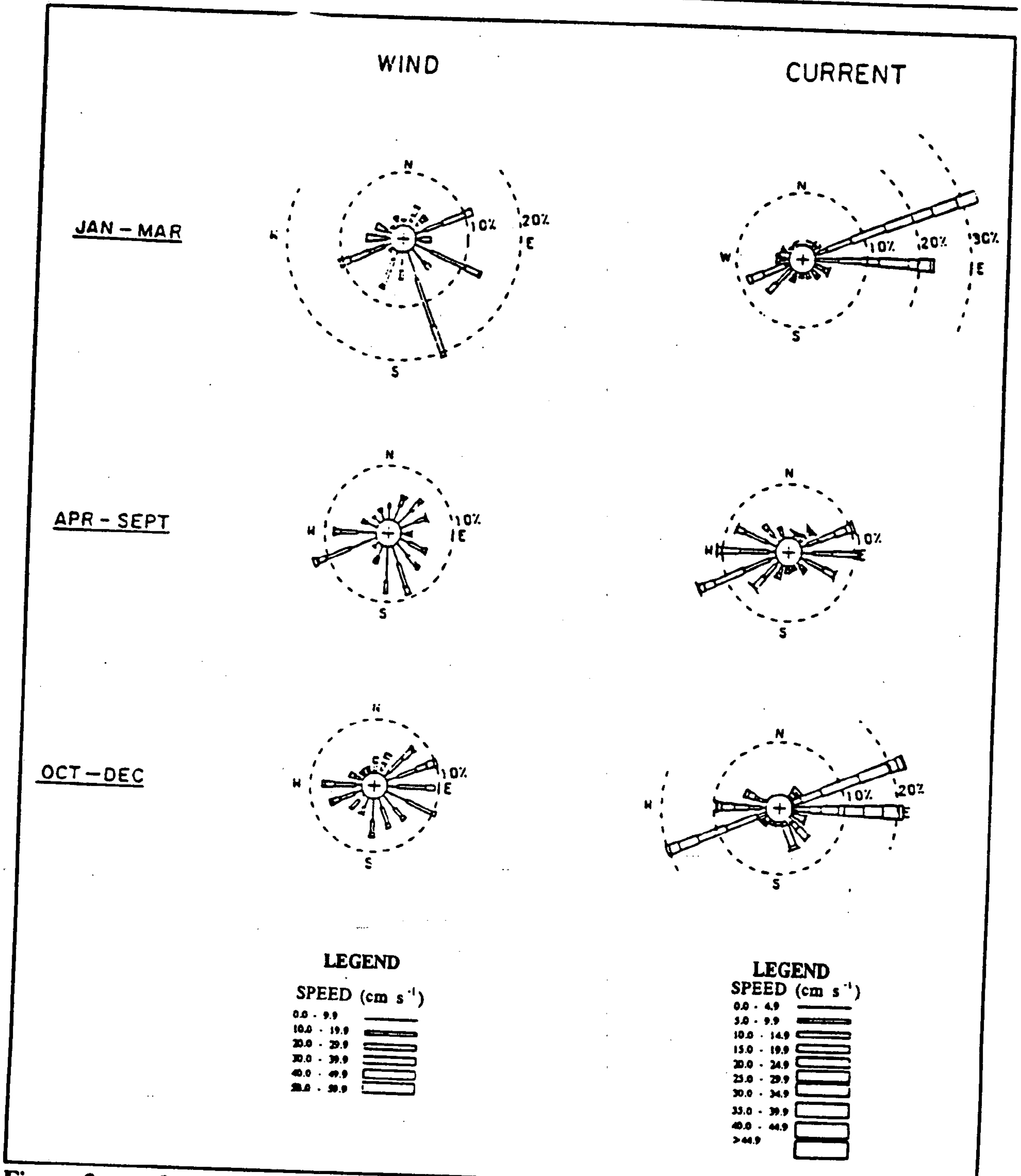

Figure 3. Seasonal distribution of wind and currents at 8 m, 1.3 km offshore Pickering NGS in 1979 (from Farroqui 1981).

size greater than 0.50mm. In addition, depths exceed nine metres in all of the proposed dredging area. As a result, based upon the work of Philpott (1991), the larger grain sizes and depths within the proposed dredging area should preclude cross-shore transport. Since the deposits in this area are not a significant source of sediment for beach building, dredging activities are not expected to aggravate shoreline erosion.

3.3 Temperature Regime

The most detailed data for lake temperature in this area are the ten years of continuous temperature records at surface, 8 m and 12 m collected by Ontario Hydro offshore from the Pickering NGS. These data are reviewed by Lawler (1990) and summarized in Figure 4. Not evident from these data, because of the monthly averaging, is the strong effect of fluctuating temperatures caused by local upwellings and downwellings. This turbulence is a function of the displacement of inshore water by changes in the direction of strong, along-shore winds. Offshore displacement of the top 10 to 20 m of water occurs when the wind shifts direction to come from the west. Upwelling from below the thermocline results, causing substantial temperature drops of up to 17C°, a condition which often lasts over a few days (Farooqui and Lawler 1983). From 1986 to 1988, major fluctuations in the surface water temperature occurred 3 to 6 times per year (Lawler and Schauffert 1990). These upwellings and consequent temperature changes occur predominantly in the summer when there is a large difference in the temperature above and below the thermocline. In general, summer currents from the east are associated with warmer surface water whereas currents from the west result in cold upwellings. An example of a cold upwelling in August 1972 (Figure 5) is shown in Bull and Kaiser (undated) using wind, water temperature and current data at a 10 m depth station 3 km offshore in 25 m of water near Oshawa, Ontario (a few miles east of the proposed permit site).

We had some concern that dredging would disrupt the thermocline by suctioning cold water from the bottom and returning it to the surface of the lake. At the 10 to 40 m depths of the proposed site, the bottom will usually be below thermocline (Bull and Kaiser undated). In this area of the lake the thermocline is very unstable because of the frequent spring and summer upwellings as discussed above. When a thermocline does form, frequently in August, it extends to a maximum depth of 8 to 12 m (Stewart and Robertson 1990). In order to minimize the possibility of introducing cold water to the surface, the overflow water will be returned to near bottom depths. Furthermore, it is unlikely that the relatively small volumes of water suctioned by the dredge would have any impact on the variable and unstable temperature regime that already exists in the offshore zone.

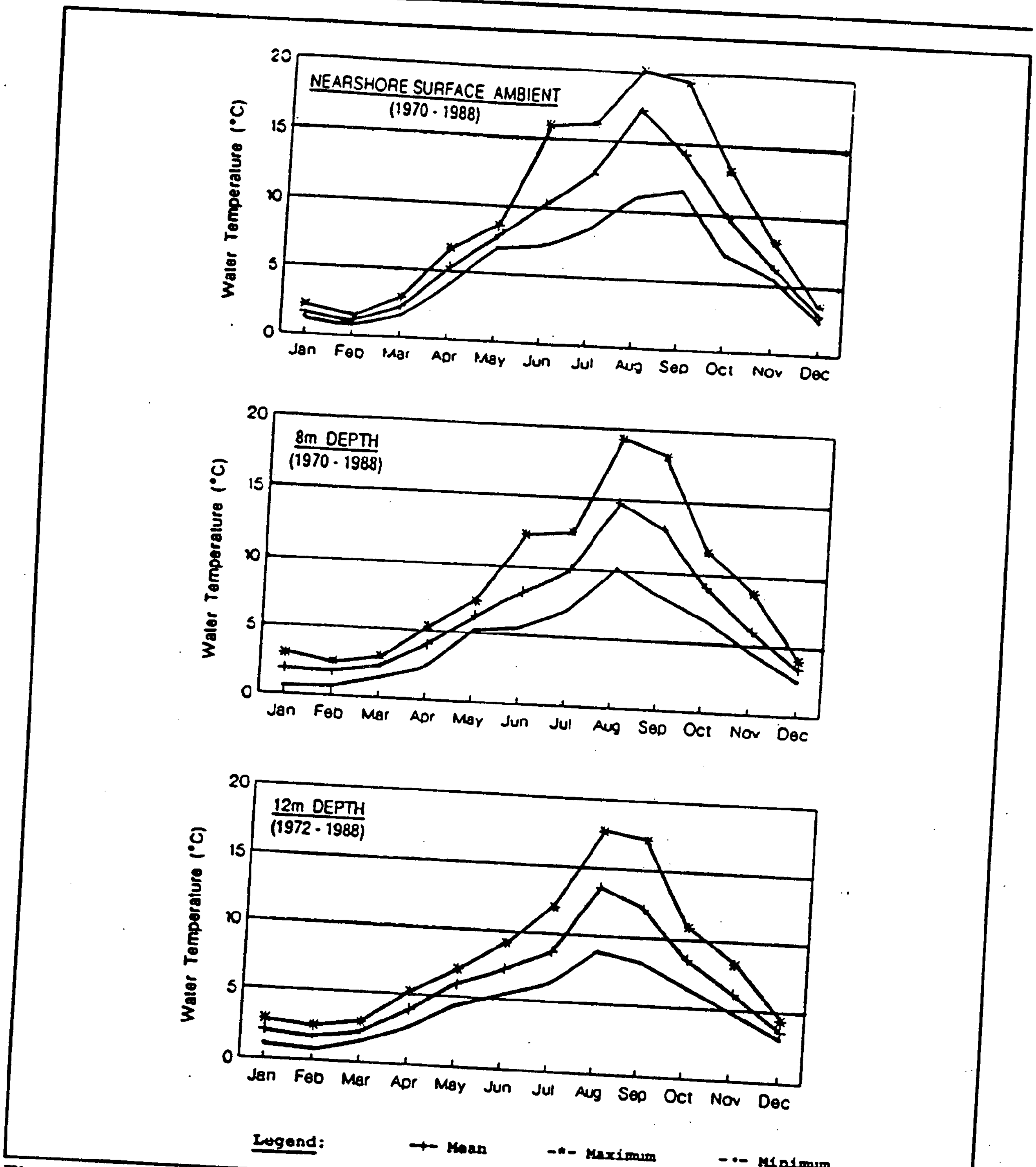

Figure 4 Mean monthly temperatures at 3 depths offshore the Pickering NGS from 1970-1988 (from Lawler 1990)

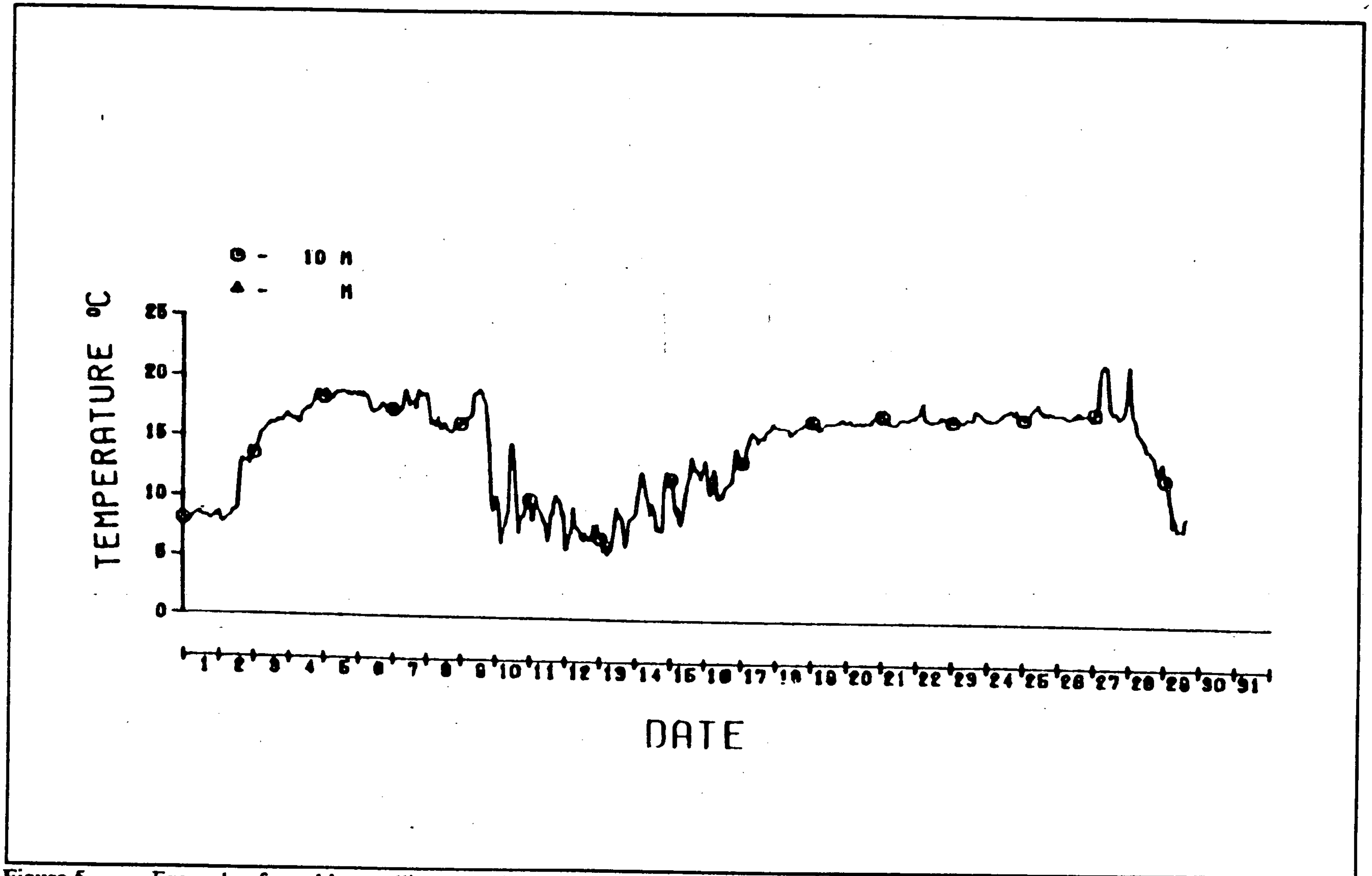

Figure 5. Example of a cold upwelling at a 10 m deep station 3 km offshore Oshawa, Ontario in 25 m of water in August 1972 (Bull and Kaiser undated).

The ambient temperature regime is suitable for cold water fishes, based on mean July temperatures that are below 15°C (Christie and Regier 1988; Scott and Crossman 1988). The large and sudden fluctuations in water temperature in the nearshore zone are two of the factors which lower the value of the area as fish habitat (Martin-Downs 1988). Stewart and Robertson (1990) used surface water temperatures to model the potential for fish use for various regions of Lake Ontario. Their work indicates that cool mean July surface temperatures (13-15°C) are associated with a very low probability of the water column stratifying. This situation reflects the high frequency of cold water upwellings which lowers the average temperature and disrupts any nascent stratification, as suggested by the high coefficient of variation associated with the temperature means.

3.4 Sediment Substrate

Within the context of sediment transport, there are two components of the sediment substrate: the nearshore and offshore deposits. Nearshore deposits are defined as sediments subjected to continuous or episodic motion induced by wave action (Whittow, 1984). As mentioned, sediment at depths less than nine metres are potentially transported cross-shore and, hence, can be defined as nearshore substrate. Nearshore sediments, in the vicinity of the proposed dredging site, consist of deposits of postglacial sand representing accumulations of littoral drift from the east (Rukavina 1976; Thomas *et al* 1972). This drift pattern is ascribed to the effect of net easterly storms in this part of the lake (Rukavina 1976). The three main sources of postglacial deposits in this area are from erosion of shoreline bluffs, subaqueous erosion of glacial deposits exposed on the lake bottom in the nearshore zone and sediment discharge from rivers and creeks. No portion of the proposed permit site lies within the nearshore substrate zone.

The offshore sand deposits within the proposed permit site are in water that exceeds depths of nine metres and, thus, are not subject to cross-shore transport. This sediment is 1.5 to 5.25 metres thick and caps the silty-clay Scarborough Formation and Sunnybrook Till (Sharpe 1980). The offshore superficial sediments are believed to be "fossil" deposits, originating from processes that are no longer active within this part of the lake. The surface substrate is thought to have originated from local bluff erosion which has occurred since the last glaciation over 12,000 years ago (Rukavina 1976; Thomas *et al* 1972). Since this time, lakes in the Ontario basin have undergone drastic water level fluctuations. During the draining of glacial lake Iroquois, lake levels fell rapidly to about 100 metres below present lake levels (Muller and Prest 1985). Since 11,400 years B.P. (before present), isostatic rebound has raised the St. Lawrence outlet and, consequently, lake levels also slowly increased. By 5000 to 6000 years B.P., waters levels rose to a elevation that coincided with the elevation at the proposed dredging site (Sly 1983; Anderson and Lewis 1985). At that time, the deposit may have been reworked as the rising water levels and wave action sorted and removed the fine sediments. The

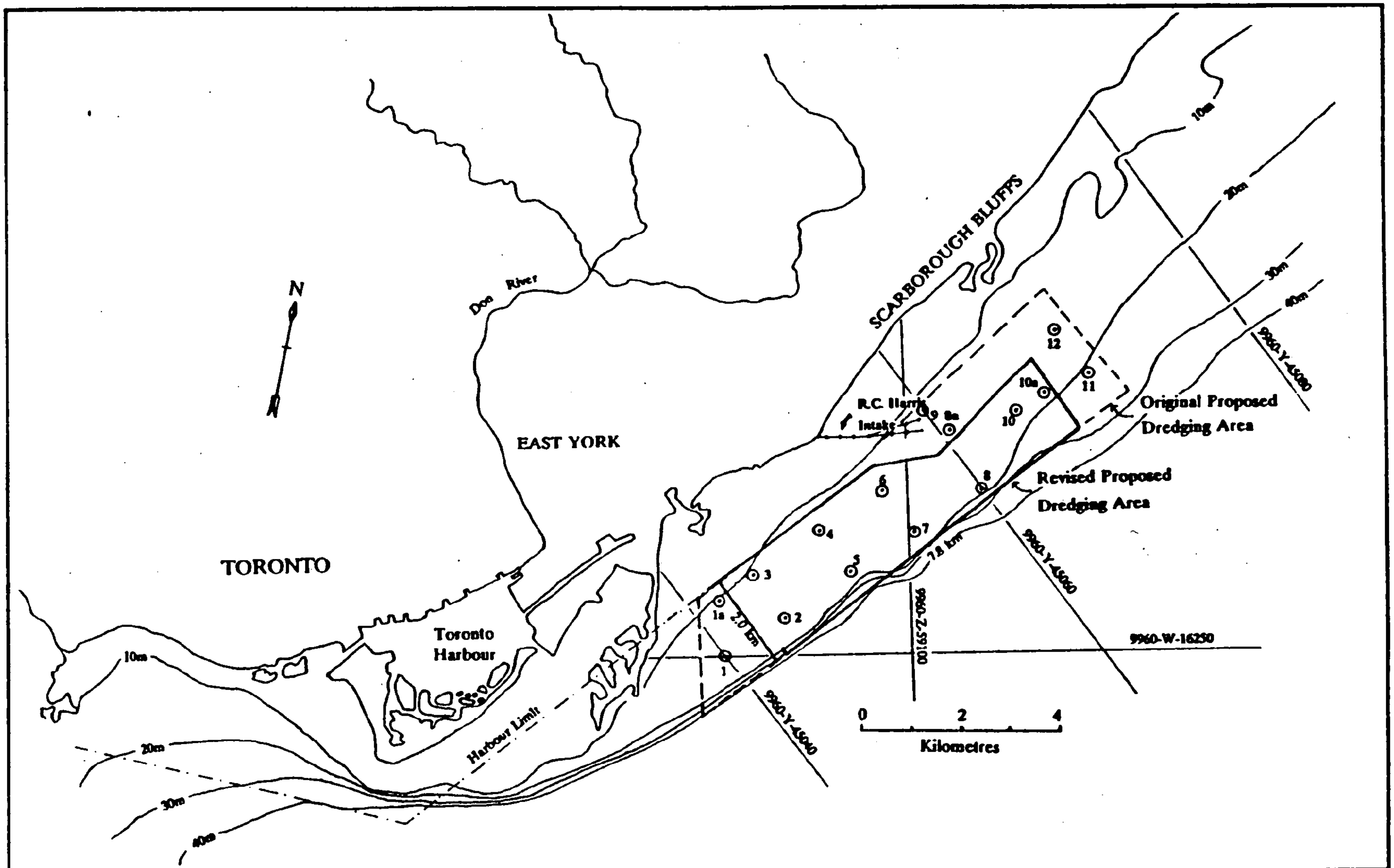

Figure 6 Locations of sediment and benthic invertebrate samples. Location numbers correspond to the sampling done by Bedrock Resources Inc.

Table 1. Concentrations of contaminants (ppm) in sediments collected from the proposed licence area. Values exceeding the Guidelines for Open Water Disposal (MOE 1992) are highlighted, while those exceeding the lowest effect level of the Fill Quality Guidelines for Lakefilling in Ontario (Hayton *et al* 1992) are underscored.

Contaminant	Guideline		Sampling Location								
	MOE 1992	Hayton *et al* 1992	2	3	4	5	6	7	8	10	10a
As*	8	6	0.9	1.3	0.7	1.3	3.3	8.3	5.4	2.0	1.3
Cd*	1	0.6	0.7	0.4	0.3	<0.3	<0.3	<0.3	<0.3	0.7	0.6
Cr*	25	26	9.8	8.7	8.4	7.4	13.6	14.0	13.5	11.4	9.1
Co	50	na	6	5	5	4	7	9	8	4	4
Cu*	25	16	3.2	4.6	5.6	5.2	14.5	15.3	11.7	7.3	6.7
Fe (%)	1	2	1.31	0.78	0.60	0.50	0.83	1.04	0.90	0.52	1.25
Pb*	50	31	7	9	6	7	13	17	14	10	8
Hg*	0.3	0.2	0.008	0.013	0.008	0.013	0.028	0.025	0.023	0.015	0.015
Mo	na	na	<3	<3	<3	<3	<3	<3	<3	<3	<3
Ni*	25	16	6	6	5	5	8	9	8	7	8
Ag	0.5	na	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Zn*	100	120	11.8	20.3	14.2	15.5	32.8	35.2	29.5	20.7	20.2
TKN	2,000	550	120	230	280	280	680	560	560	450	340
TP*	1000	600	500	810	250	250	340	360	380	320	390
NH_4	100	na	120	50	170	170	230	170	170	230	170
PCB*	0.05	0.07	0.05	0.05	0.03	0.05	0.04	0.04	0.04	0.06	0.04
TCN	0.1	na	<.05	<.05	<.05	<.05	0.05	0.05	<.05	nd	<.05
O&G	1500	na	<100	<100	<100	100	545	110	120	235	<100
LOI(%)	6%	na	0.25	0.48	0.78	0.78	1.85	1.70	1.74	1.05	0.90

* - Mandatory test for unconfined fill (Hayton et al 1992).
na - Not available.
nd - Not determined.

The effects of high concentrations of heavy metals such as cadmium, copper, mercury and zinc on aquatic biota can be detrimental to certain communities (Klaverkamp *et al* 1984). Two samples contained cadmium at a level slightly higher than the lowest effect level. All values for cadmium were below the Open Water Disposal guideline and the average concentration over all samples (< 0.4 ppm) was well below the Fill Quality guideline level. One sample contained an arsenic level that was higher than guideline levels; however, this concentration is within the range of background levels found in the Great Lakes (Allan *et al* 1991b), and the average concentration of arsenic at the site (2.7 ppm) is well below the Fill Quality Guidelines' value. Three stations had levels of iron above the Open Water Disposal Guidelines' value; however, all samples had iron concentrations under the lowest effect level of the more recent Fill Quality Guidelines. One station had PCB levels above the Open Water Disposal guideline level but was below that of the Fill Quality guideline.

All contaminant concentrations that exceeded the Fill Quality Guidelines' values were close to the lowest effect level, which indicates a level of sediment contamination that can be tolerated by the majority of benthic organisms (Persaud *et al* 1991). Moreover, these levels were well below those at which pronounced disturbances of the sediment-dwelling community is expected (Persaud *et al* 1991). The above-mentioned lowest effect levels do not address ammonia; however, according to Long and Morgan (1990) these concentrations are not in a range that would be considered as having significant potential for biological impacts as these ammonia levels do not exceed the lowest effects levels for ammonia.

The reported concentrations are those of *in situ* sediments and not those of dredgate overflow. These represent the background levels to which the dredgate overflow will be returned. If current action moves the overflow plume downstream (downwind in this case), movement will be westward during the summer (see Section 2.1) toward a zone of much higher contamination where the plume will not have a negative impact (Persaud *et al* 1985). During the fall the net movement will be eastward where the fine silts and clays will eventually deposit in the deep lake basin (Thomas *et al* 1972).

Moreover, contaminant concentrations were determined from near-surface sediment samples only, and they do not necessarily represent concentrations present in the deeper, older strata of the sand deposit.

4 THE DREDGING OPERATION

4.1 The Dredge

Bedrock Resources, Limited has chosen to renovate an existing barge into an environmentally sound and economically effective dredging vessel. A conventional hopper barge will be transformed into a trailing suction hopper barge similar to that illustrated in Figure 7. The proposed barge is approximately 60 m long, with a loaded draft of 3.6 m and a cargo capacity of 1,800 tonnes (950 m^3). Note that this vessel is substantially improved over the stationary aggregate dredges currently working in Ontario. The dredge will trail a 1 m (front/back) x 1 m (side to side) suction head which takes a 15 cm (deep) x 1 m (wide) swath of sand as the barge moves continuously across the permit site. Unlike existing operations in Ontario which leave holes where stationary dredges clam or suction a small area, the proposed operation will vacuum up to 15 cm from the surface of the shoal, representing 6.9% of the surface of the entire permit site each year. This practise will leave the bottom contours unchanged except for removing the top 15 cm over 1 km^2 of the proposed site each year, affecting a particular area on average once every 14 years (at the anticipated single shift production rates of 277,200 tonnes per year).

The dredge would be based at one of several available sites along the Toronto waterfront. Initial plans are to have one 11 hour shift a day which would be able to dredge 277,200 tonnes (145,900 m^3) per year based on an April 1 to Nov 30 period when prevailing weather conditions would allow operation. Based on this scenario, the deposit would provide sand for the Toronto building industry for 195 years. A double shift would boost production to 554,000 tonnes yr^{-1} and reduce life of the deposit to 97.5 years.

4.2 The Overflow Plume

The dredge will require 5.29 hours to fill at 90% loading efficiency. Since approximately one hour will pass before turbid water begins to overflow the hopper, the duration of plume discharge will be about 4.5 hours per day. Even after overflow begins, sediment entering the hopper will still have an opportunity to settle prior to discharge. As the hopper is filled to its capacity, material larger than approximately 160μ will be retained and the overflow water from the dredge will contain only material with grain sizes finer than 160μ. This outflow will generate a turbidity plume and its projected extent and suspended sediment concentrations have been modelled by the firm of Gore & Storrie (G&S 1992, appended). One of the chief input variables for the modelling was the calculation of the suspended sediment concentration in the outflow, calculated with the

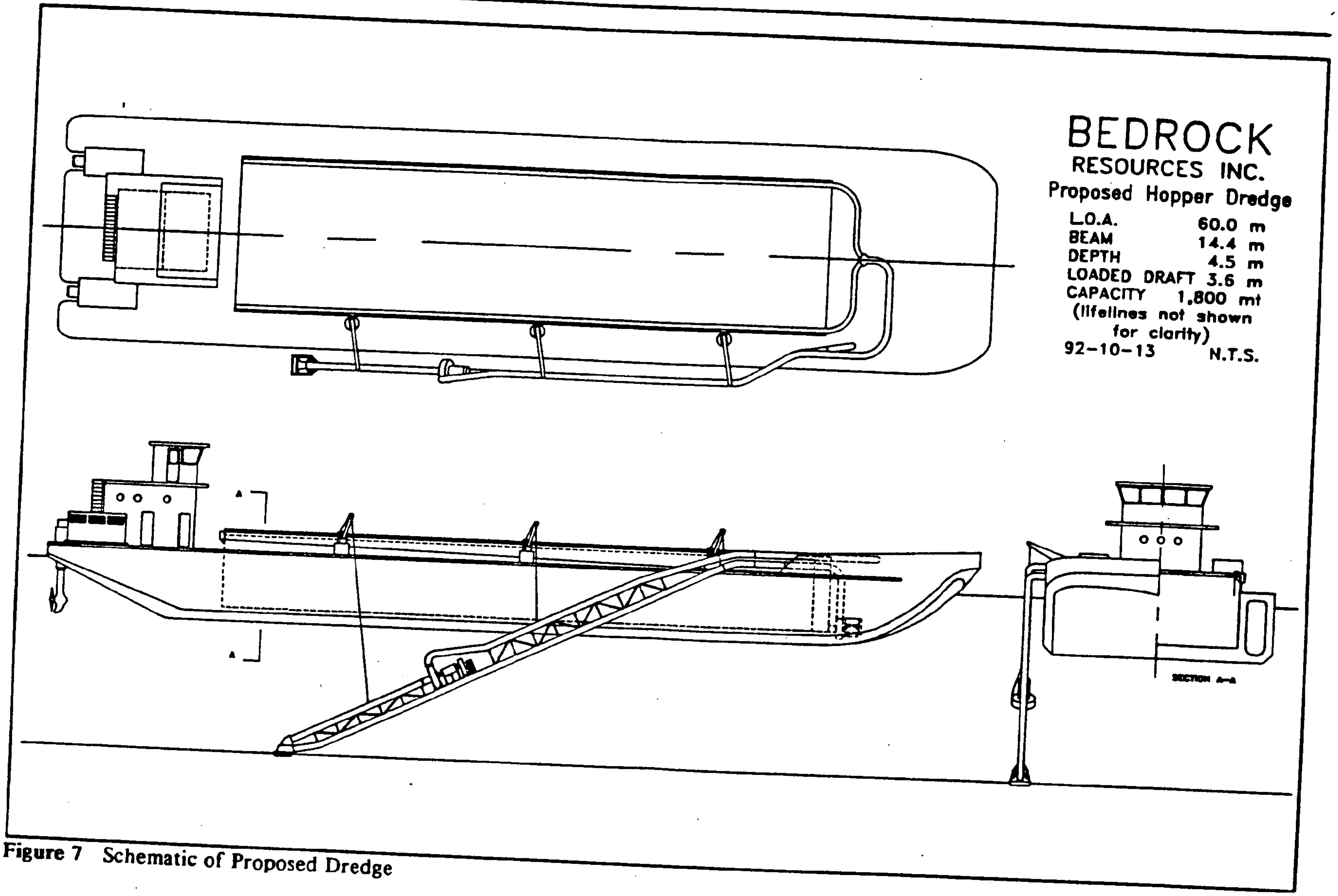

Figure 7 Schematic of Proposed Dredge

equation 1:

$$C = \left(\frac{S_i \, \rho_s \, S_p}{W_o}\right) 1000$$

Where:

C = Suspended sediment concentration of outflow (mg L^{-1})
S_i = volume of sediment entering hopper (0.0388 $m^3 s^{-1}$)
ρ_s = density of sediment (2,650 kg m^{-3})
S_p = percentage of solids finer than 150μ
W_o = volume of water exiting hopper (0.245 $m^3 s^{-1}$)

The key variable in this equation is S_p; the smaller this percentage, the lower the concentration of suspended solids in the discharge. This percentage depends on the amount of fines encountered in the bottom sediment. Outflow concentration, (C), was based on three estimations of S_p, using the particle size data collected by Bedrock (1991) and BAR (1992). We used S_p values of 0.2%, 3.6% and 10.6%, to represent "best", "anticipated" and "worst case" turbidity scenarios, respectively. Of the 66 lake bed samples analyzed, two-thirds had S_p values less than 3.6% (Bedrock 1991). Applying these proportions to the above equation, the resulting outflow concentrations are 800, 15,000 and 44,000 mg L^{-1} respectively. These numbers are used to indicate each of the three scenarios in both this report and in the G&S report. Although these concentrations are initially high, they are very rapidly diluted to background levels.

The worst case scenario (C = 44,000 mg L^{-1}) was based on the fine sediment encountered at sampling station 7 (Bedrock 1991). Nevertheless, even under these worst case conditions, the 0.1 mg L^{-1} isoline of the resulting turbidity plume will remain within 1,100 metres of the hopper; the distance to the water filtration plant from station 7 is 1,800 metres. As a result, the "worst case" turbidity levels related to dredging at station 7 will have virtually no impact on the water intakes.

In addition, the grain size data indicated that about 38% of the sediment at station 3 consists of fine sand between 150μ and 75μ and, therefore, could potentially be discharged as turbidity. To mitigate this situation, we recommend that this area be dredged only while the hopper fills with water before any overflow occurs. This effort will capture the fine sands, a desirable resource, while preventing the discharge of excessively turbid water. Also, despite the high proportion of fine sand at station 3, the proportion of material finer than 75μ is less than 0.7%. If this area is dredged first, then most of the suspended solids between 150μ and 75μ will be able to settle out within the hopper, minimizing the turbidity of the outflow.

The turbidity modelling of G&S indicates that a plume under any scenario will be localized and quickly dissipated by advection. Plume concentrations are expected to fall below 100 and 10 mg L^{-1} after 1.4 and 32 minutes respectively. These modelling results concur with field studies performed by Friebergs (1970), who used aerial photography to examine dredging plumes along the Toronto Waterfront. He also found that plumes were local and quickly dissipated. Based on the pattern of deposition of material eroded from the Scarborough Bluffs, much of the suspended silts and clays will be deposited several kilometres offshore in depths exceeding 20 metres (Arajs 1980). The modelling results of G&S are detailed in a separate, appended report and the sedimentation of fines is discussed in section 4.4.

There are concerns regarding the potential impacts of a turbidity plume upon the R.C. Harris water treatment plant. Originally, the water intakes were included within the proposed permit site. To mitigate potential water quality impacts caused by dredging in this immediate area, the proposed permit boundaries were revised. A 400m buffer zone now exists between the intakes and the nearshore boundary of the proposed permit site and it will prevent excessively turbid water from reaching the intakes. Provincial water quality objectives for turbidity allow an increase within 10% of background suspended sediment concentrations. Raw water data from the plant indicate that historical background levels range from 0.3 - 40 mg L^{-1}, therefore background levels cannot exceed 0.33 - 44 mg L^{-1}. The concentration of a turbidity plume at the intakes is expected to be less than 0.1 mg L^{-1}. The "worst case" concentration of 2.5 mg L^{-1}, as modelled by Gore & Storrie (1992) is not anticipated because particle settling and the coarse sediment near the intakes will help reduce plume concentrations. These considerations, and the 400 m buffer zone, will ensure plume concentrations at the intakes are kept within provincial guidelines.

4.3 Sedimentation

As with any turbidity plume, most of the suspended solids will eventually settle to the lake bed. One of the impacts to spawning habitat and the benthic community is the rate at which this material accumulates. To addresses this concern, sedimentation rates (equation 2) were based on the amount of material to be dredged in a year and the proportion of this sediment which will overflow the hopper.

The estimated single shift dredging rate is 277,200 tonnes per year or, expressed volumetrically, 145,900 m^3. Again, we used S_p values of 0.2%, 3.6% and 10.6% to estimate sedimentation rates.

$$S_y = \left(\frac{V_i S_p}{A}\right) 1000$$

Where:
S_y = Average annual sedimentation rate (mm yr^{-1})
V_i = Total volume of solids entering the hopper (m^3 yr^{-1})
S_p = Proportion of solids expected to overflow the hopper
A = Area of site traversed by the dredge in one year (m^2). Assume 6 km^2.

The area of lakebed dredged each year is projected to be 972,664 m^2 (0.97 km^2). However, the one metre-wide dredge passes will not adjoin each other, rather they will be separated by several metres. The dredge will traverse an area of at least 6 million square metres (6 km^2), in a given year, and much of the sediment settling from the plume will be deposited within this larger area (Table 2). To remain economically feasible the dredging operation will take advantage of the range of grain sizes across the permit site, and will therefore dredge over at least 6 km^2 of the total area in a given year.

Table 2. Average annual rates of sediment deposition resulting from the turbidity plume. Even under worst case conditions, sedimentation does not exceed 3 mm per year.

Outflow Concentration (mg L^{-1})	Percentage of Bed Sediment not Retained by Hopper	Volume of Sediment in Outflow (m^3 yr^{-1})	Average Annual Sediment Deposition Rate (mm yr^{-1})
44,000	10.6%	15,500	2.5
15,000	3.6%	5,250	0.9
12,000	2.9%*	4,200	0.7
800	0.2%	300	< 0.1

* - Mean proportion of sediment particles < 150 μm from the sand deposit site.

The values in table 2 are likely overestimated. The estimations assume that all of the deposition will occur within the 6 km^2 area whereas some of the fines will travel beyond these limits. Also, the deposition rates assume that the hopper is continuously discharging sediment while dredging. One to two hours will elapse before turbid overflow begins and, once started, sediment between 75μ and 160μ will have the opportunity to settle out inside the hopper. Maximum turbidity, as considered in Table 2, will occur only near the end of each shift as the hopper becomes full of aggregate.

5 IMPACTS TO FISH SPAWNING SUCCESS

The proposed licence area has a water depth of between 10 and 40 m and contains a substrate of fine to coarse sand and small amounts of fine gravel. The concerns regarding the impacts of the proposed dredging on fish reproductive habitat are:

- spawning habitat will be harmfully altered by the removal of spawning substrate;
- spawning habitat will be harmfully altered by increases in the sediment deposition rates in the area; and
- entrainment of eggs and larvae will reduce populations.

In order to address these potential impacts, we have identified the fish species that may use the deposit area as a reproductive (spawning and nursery) habitat, and we have compared their preferred habitats to that available at this site. An atlas of spawning and nursery areas for Lake Ontario fishes (Goodyear *et al* 1982) identifies reproductive habitat areas which have historically been used by Lake Ontario fish; however, the areas identified in the atlas may not presently support spawning habitat.

While the inshore fish community is fairly diverse, at least in the areas where there is some protection from upwellings and some cover (Buchanan 1989), the zone we are examining is approximately 1.5 to 4 km offshore with no cover and is fully exposed to cold upwellings. In general, the fishes using the deposit area are those from the deeper offshore waters beyond the coastal shelf that are migrating inshore to feed or spawn, or they are species such as sculpins which may be resident in this area. There are also open water spawning fish that may use the sand and gravel substrate in the area of the proposed dredging site as spawning substrate. These fish species include lake whitefish, lake herring, round whitefish, rainbow smelt, yellow perch, walleye and lake trout. Each fish species of concern has been described in more detail below. Their spawning and nursery habitat requirements, including potential spawning areas, have been related to the proposed licence site.

5.1 Lake Whitefish (*Coregonus clupeaformis*)

In Lake Ontario, the current status of the lake whitefish stocks is unclear (Stewart 1991), although in the Bay of Quinte the stock has increased tremendously in recent years (Bowlby 1990). These fish spawn predominantly on gravel, rock, or honeycombed rock reefs (Goodyear *et al* 1982). Sand is used less frequently as spawning substrate (Scott and Crossman 1973). Spawning takes place in late November or early December in Lake Ontario at depths of between 2 and 20 m (Goodyear *et al* 1982) and somewhat earlier in the Bay of Quinte (Hoyle and Melkic 1991). More generally, whitefish spawn

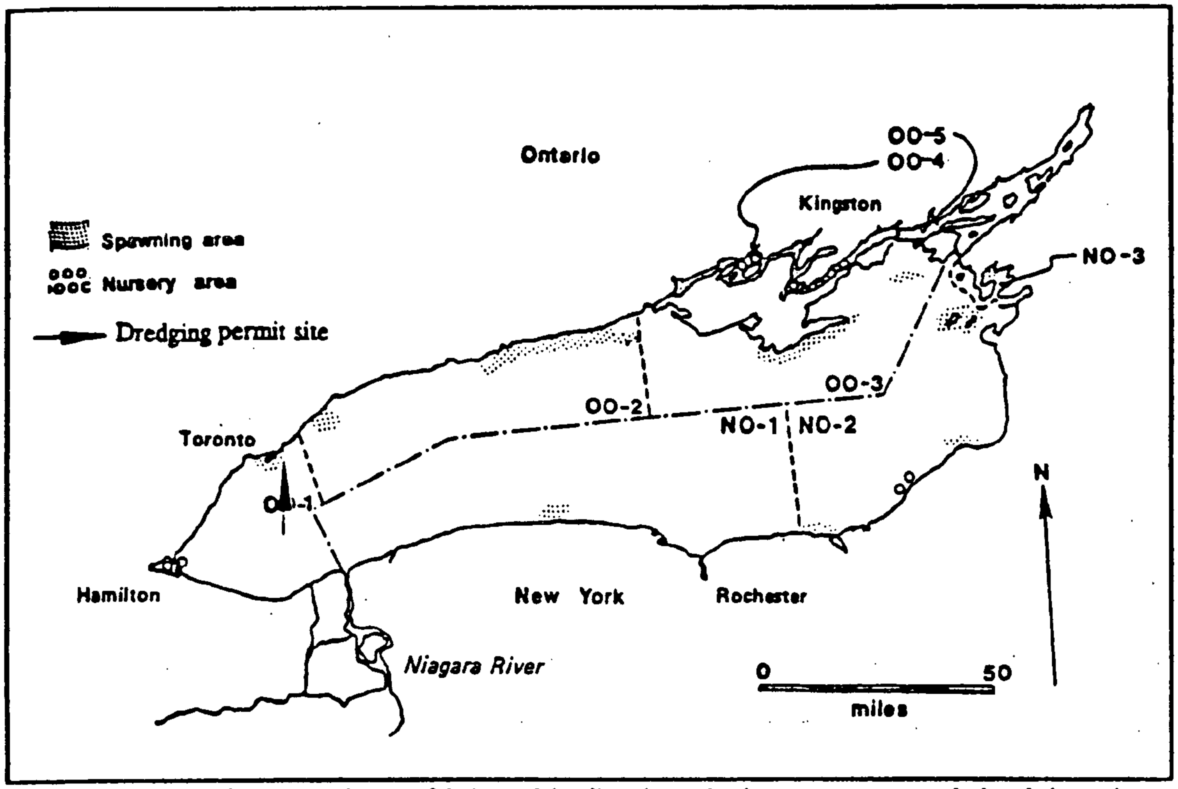

Figure 8 Spawning locations of lake whitefish in relation to proposed dredging site (after Goodyear *et al* 1982).

in lakes and rivers at 0-5 m depth on shoals, windward shores and points (Christie 1982). This was the case in Whitefish Bay of Lake Superior where spawning whitefish were found in < 2m of water at the point of an island over cobble and rubble substrate (John Kelso DFO, Sault Saint Marie, Pers. Comm.). Eggs are broadcast randomly over the spawning substrate, and a large number of eggs are deposited during spawning (Scott and Crossman 1973). Christie (1963) calculated the fecundity of lake whitefish to be 9900 eggs per pound of fish in Lake Ontario.

Lake whitefish are a cool water species which are normally found in schools. They spend most of the year in offshore areas, descending into the cooler waters of the hypolimnion during the summer months (Scott and Crossman 1973). As the water temperatures cool, lake whitefish move inshore to their spawning areas, normally in mid-October.

In Lake Ontario, spawning grounds are concentrated in the eastern end of the lake and along the north shore (Figure 8), and these grounds appear to be in the same general areas used by lake trout (Goodyear *et al* 1982). Lake whitefish spawned in the area of

Toronto Island and adjacent shores until the early 1880's (Whillans 1977); however, no recent lake whitefish spawning in this area has been documented. Fish in spawning condition were netted in the 1970's at several spots to the east of Oshawa in areas where substrate was large gravel to cobble and boulders (Ontario Hydro 1979). Whitefish were not captured during the first week of December, 1991 at a Bowmanville site (see Section 5.9) previously identified as appropriate for whitefish spawning (Ontario Hydro 1987). Moreover, lake whitefish were not detected at the sand deposit site during the fall of 1991 (see Section 5.9). The lack of large grained substrate makes the sand deposit site an unlikely spawning ground for this species.

5.2 Lake Herring (*Coregonus artedii*)

The lake herring or cisco is a pelagic fish species which forms large schools in offshore areas of Lake Ontario. While the depth at which lake herring school is dependant upon season and water temperature, they are normally found in midwater depths. Lake herring spawn in November or early December during times of declining temperatures (Scott and Crossman 1973). Large schools normally migrate to inshore areas to spawn at varying water depths. In the Great Lakes, spawning has been reported to occur in shallow waters, as well as in waters as deep as 64 m, and even pelagic spawning in midwater 9-12 m below the surface has been observed. Eggs are usually deposited on the spawning substrate and abandoned by the parents. Spawning may occur over any type of substrate but is often observed over gravel or stony bottoms (Scott and Crossman 1973).

Because the date of spawning is primarily temperature dependent, the time of spawning is difficult to predict in large lakes where conditions can vary to a large degree in various parts of the lake; thus, optimum spawning conditions will occur at different periods in different areas of the lake. Egg development is slow due to the low winter conditions, and hatching occurs after the spring breakup of surface ice. Larval cisco require light to feed, and they begin to feed the day they hatch while still carrying the yolk sac.

In Lake Ontario, sand, gravel and rubble sized substrates are the most frequently used spawning substrate (Goodyear *et al* 1982). Historically, large schools of lake herring typically used the inshore areas of Lake Ontario to spawn. Spawning would normally take place in mid November, and the adults would return to deeper waters in December, soon after spawning. The herring spawned on shoals and in bays in waters as shallow as 3 m; however, "deepwater" herring, mainly found in the western end of Lake Ontario, were found to spawn at depths of 25 to 55 m and at distances of up to 3 km offshore (Goodyear *et al* 1982).

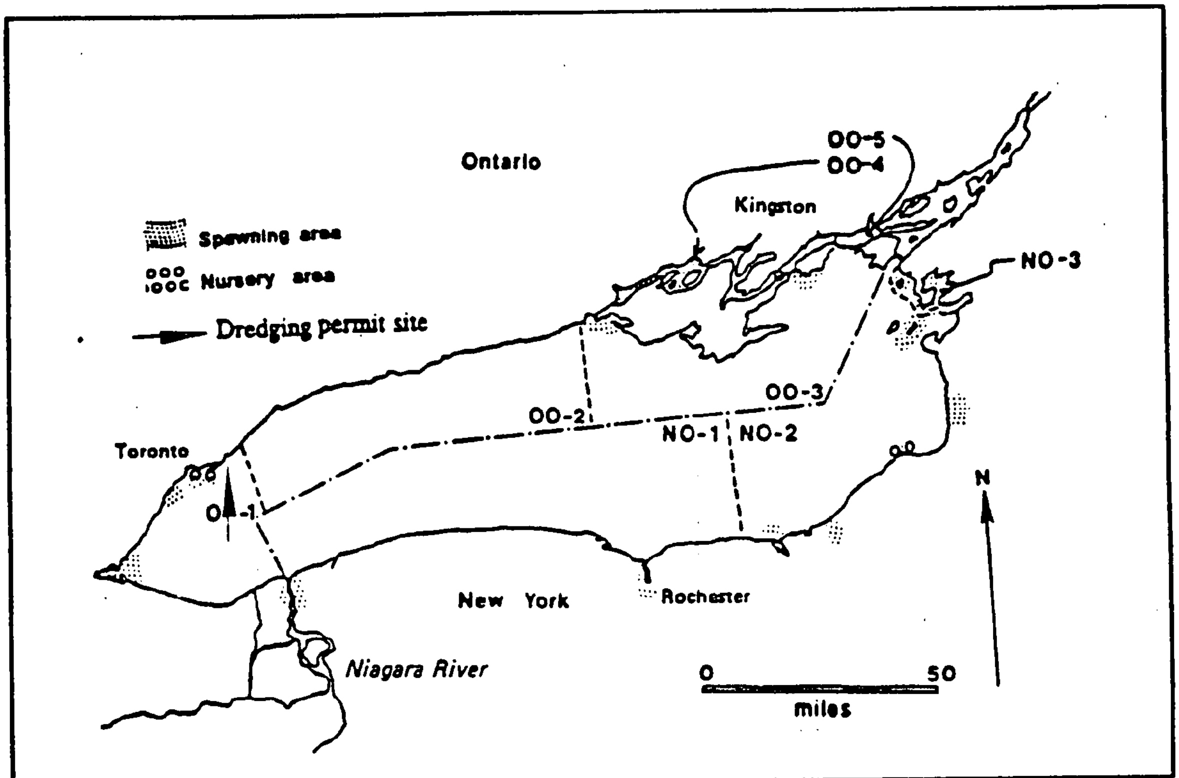

Figure 9 Historical spawning sites for lake herring in relation to the proposed dredging site (after Goodyear et al. 1982).

Historically known lake herring spawning habitats in Lake Ontario (Figure 9) may still have the potential to provide spawning areas for lake herring. The proposed licence site does not offer the most appropriate habitat for lake herring spawning. This area may be suitable for Lake Ontario populations; however, lake herring were not captured during our gillnetting, Dec. 2-4, 1991 (see Table 4, Section 5.9).

5.3 Round Whitefish (*Prosopium cylindraceum*)

Scott and Crossman (1973) identify the spawning habitat of round whitefish to consist of gravelly shallows of lakes, river mouths, or rivers. Spawning substrate for this species was found to consist of gravel at depths of 4 to 15 m in lakes Michigan and Huron and of gravel and rock at a depth of 6.5 m in Lake Superior (Koelz 1929). Spawning fish swim in pairs, and, as in other coregonine fishes, eggs are broadcast over the substrate and abandoned.

Goodyear *et al* (1982) identifies only the area of Raby Head-Bowmanville as having spawning sites for round whitefish in Lake Ontario. Good spawning habitat in this area consists of patches of gravel and rubble in approx. 3 to 12 m of water. According to Goodyear, spawning sites have not been identified near the proposed aggregate removal site.

Ontario Hydro (1987) investigated the use of the inshore areas of Lake Ontario by spawning round whitefish. Gill nets set near the Pickering Nuclear Generating Station captured 97 round whitefish between November 20 and December 11, 1984. Although no eggs were collected by pump sampling for round whitefish eggs, six larvae were collected from 108 benthic sled samples in the spring. This would indicate that at least isolated spawning was occurring in this area (Figure 10). Ontario Hydro (1987) also developed a subjective assessment scheme for the suitability of sediment substrate for round whitefish spawning (Table 3). They rated photographs of the substrate at various locations from 1 to 10, with 10 representing the ideal substrate for round whitefish spawning. According to this rating, the sediments in the western half of the proposed dredging area are rated at < 1 due to the high percentage of fine sand and silt. The somewhat coarser sand substrate in the centre and eastern portions of the proposed site is rated at 0 or 1. The far eastern end of the site, which includes some gravel and cobbles, is rated at 5, although the site is deeper than would normally be expected for round whitefish spawning habitat.

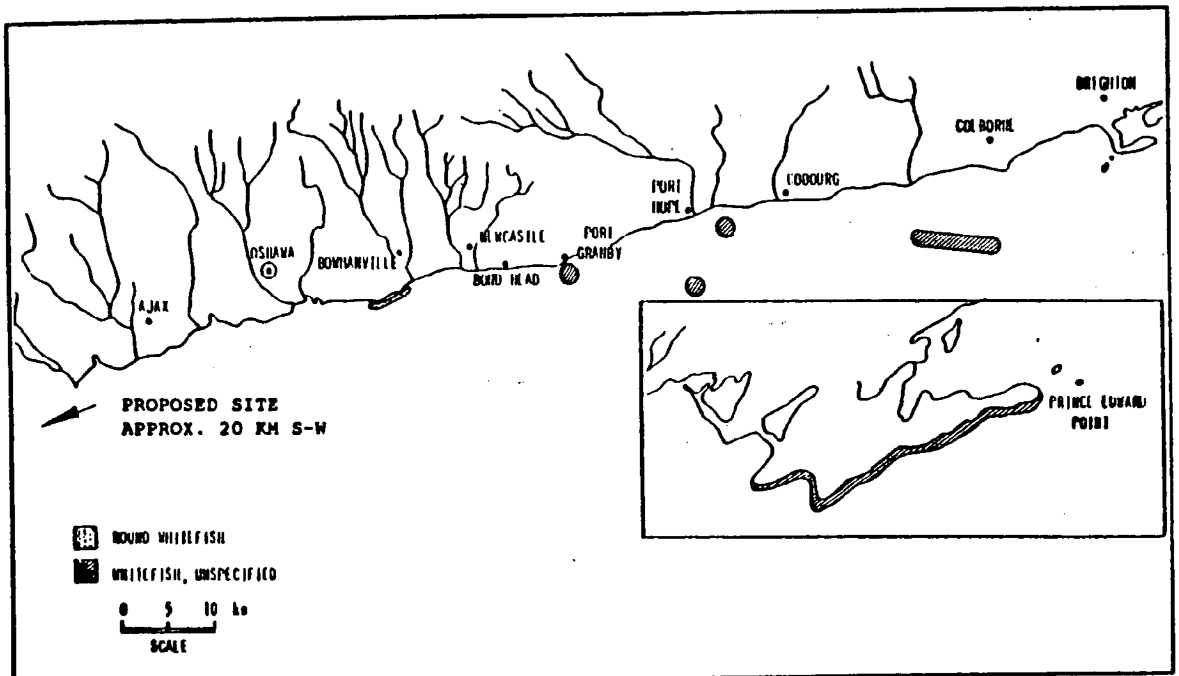

Figure 10. Spawning sites for round whitefish in relation to the proposed dredging site (after Ontario Hydro, 1987).

Table 3 Round whitefish spawning substrate suitability index (after Ontario Hydro 1987).

Rating	Description
0	Pure sand, silt, hardpan clay, or very dense Cladophora
1	small amount of boulder /cobble/gravel embedded in fines
2	boulder/cobble/gravel > 25%, embedded in fines
3	boulder/cobble/gravel > 50%, embedded in fines
4	boulder/cobble > 80%, spaces between filled with fines
5	boulder/cobble with moderate amount of fines in spaces
6	boulder/cobble with only a few fines in spaces
7	boulder/cobble in > 1 layer, a few fines between
8	boulder/cobble in > 2 layers, a few fines between
9	boulder/cobble in > 2 layers, very clean
10	clean cobble or boulder bed, many layers deep, many spaces for eggs to settle into substrate, no fines.

The depth and, in particular, the substrate type in the proposed licence area make it unlikely that round whitefish would be using this zone for spawning. Netting and observations by our crew in December 1991, however, resulted in the capture of fish in spawning condition at the proposed licence site (see Section 5.9). These fish were likely spawning at one of several nearby suitable habitats: inshore on the shallow gravel substrates, at the nearby spawning site identified by Ontario Hydro (Figure 10) or on gravel placed to anchor the water intake pipe for the R.C. Harris plant. We found no evidence of eggs or congregating fish in our video observations of the site.

5.4 Rainbow Smelt (*Osmerus mordax*)

In light of the recent scientific report that confirmed reports of a reduction in the numbers of large smelt found in Lake Ontario (Mathers 1992), the possible impacts of dredging operations on this species was of particular concern. This trend has been attributed to changes in growth of older smelt and an increase in their mortality rate, which is due to predation by the increased numbers of salmonids in the lake. A high yearling abundance has not been observed since 1987 in western Lake Ontario.

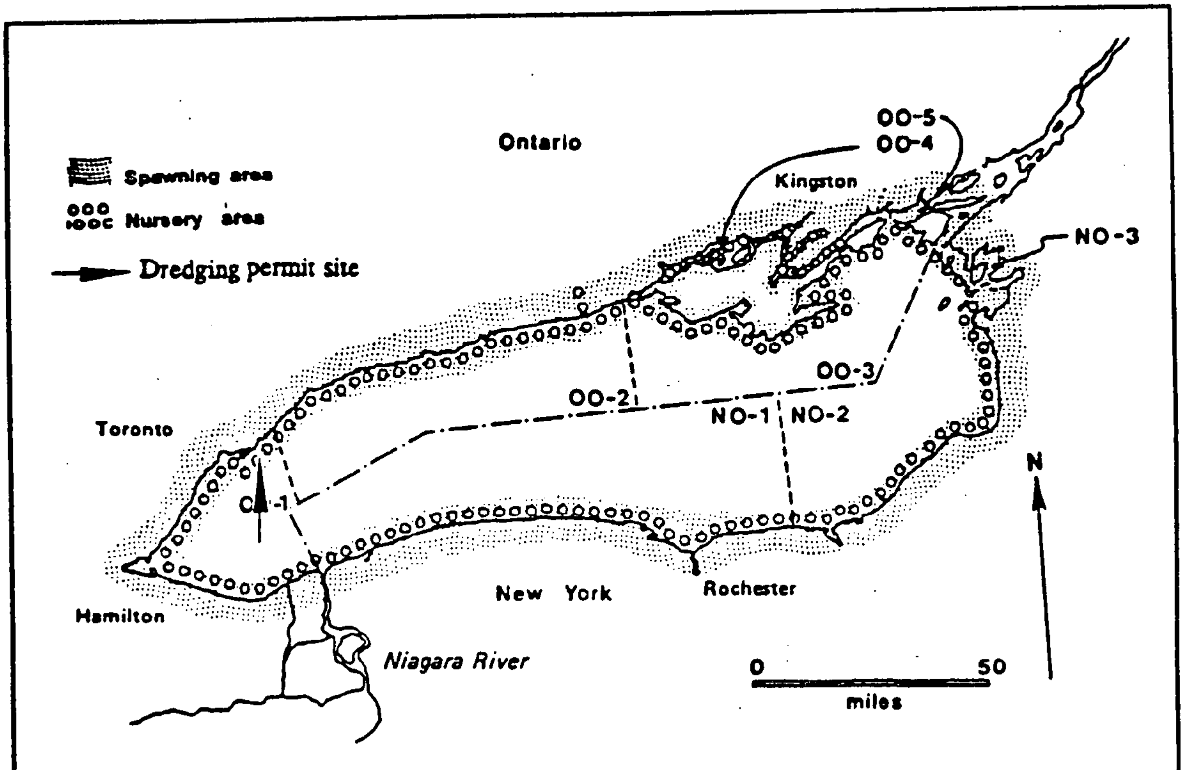

Figure 11 Locations of potential reproductive habitat for rainbow smelt in relation to the proposed dredging site (after Goodyear et al. 1982).

Increased predation on yearling smelt, competition or predation by a changing alewife population, degradation of spawning areas and unfavourable climatic conditions have all been proposed as possible explanations for the low smelt recruitment (Mathers 1992). Rainbow smelt, a commercially important fish, is crucial to the Lake Ontario ecosystem as it is considered to be the second most significant prey species (after alewife) for the economically important salmonid populations (Brandt 1986).

Both marine and freshwater populations of rainbow smelt have historically been known to spawn on gravel substrates in streams (Scott and Crossman 1973, Jilek et al. 1979). Goodyear et al. (1982) state that most Lake Ontario tributaries not blocked by gravel or sand bars support spawning runs of rainbow smelt (Figure 11). However, other spawning habits for freshwater populations have been reported. Rupp (1965), for example, reported smelt populations spawning on shallow shoals or in shallow (< 0.51 m) water near sandy lake shorelines, and in Lake Ontario spawning has also been identified in open waters on gravel and sandy shoals and other areas throughout the lake (Goodyear et al. 1982) (Figure 11). Deep-water spawning has been observed by Legault and Delisle (1968), and further variations of spawning habits by smelt were presented by these authors. Though spawning in most populations generally occurs several days after ice melt, a sympatric population of very large smelt (average length of 22 cm) found in a Québec lake was observed to spawn a month prior to ice melt, under 60 cm of ice and at a depth of at least 6 m (Legault and Delisle 1968). In this same lake , however, a population of "dwarf" (average length of 7.5 to 10 cm) smelt was observed spawning at the end of April on sand and gravel beaches.

Reuter (1883), cited in Legault and Delisle (1968), observed that a "large variety" of smelt found in Finish lakes preferred deep moving waters for spawning whereas a "small variety" showed preference for beaches and shoals in shallow waters. Other authors have further suggested that smelt are deep water spawners in some lakes (Greene 1930, cited in Legault and Delisle (1968)). Plossila (1984) presents evidence that in Lake Champlain smelt will seldom spawn in shallow waters. Depth distribution of gill-net-caught smelt, as well as captures of yellow perch that were found to be feeding on smelt eggs, led Dudones (1975, cited in Plossila (1984)) to conclude that smelt were "primarily deep water spawners".

The collection of smelt eggs at depth has provided further evidence for deep water spawning habits in rainbow smelt. For example, Legault and Delisle (1968) collected 127 embryonic smelt eggs from the bottom of Lake Champlain at a depth of 9 to 12 m. In Lake Erie, to the east of Point Pelee, large numbers of eggs (> 1000) were found at a depth of 16.5 m, some 6 km offshore, and eggs have also been collected from depths of up to 30.5 m in Long Point Bay, Lake Erie (Ferguson, R.G. Pers. Comm., cited in Legault and Delisle (1968)). In another study in Lake Champlain smelt eggs were not found in shallow water or streams, but some eggs were found attached to a gill net set at a depth of 17 m (Plossila 1984). Based on egg deposition rates, Plossila determined that smelt were spawning over a predominantly clay substrate at depths ranging from 14 m inshore to at least 29 m offshore, with the greatest rate of spawning activity occurring between 17 and 23 m. Moreover, spent females were caught in 37 m of water. Other studies presented by Plossila (1984) suggested that egg deposition was restricted to depths of 9 to 27 m in certain areas of Lake Champlain.

Rainbow smelt are considered to be a "common" species along the Toronto waterfront, as they were found to comprise up to 1% of the total catch in a study undertaken in 1989 (Buchanan 1989). Ideal spawning habitat along the Toronto waterfront area, however, has been largely destroyed as a result of human activities (Buchanan 1989). Populations of smelt, known for their extensive spring migrations in the Great Lakes, may compensate for locally disturbed spawning conditions through effective searches for alternatives (Whillans 1979). The substrate type found at the proposed licence site may provide an alternative to spawning rainbow smelt, even though it does not provide typical smelt spawning habitat. More suitable habitat is available, however, to the east of the proposed dredging site. This species was neither caught nor observed during our late fall field survey (see Section 5.9).

5.5 Sculpins (*Cottus spp*)

Two species of sculpins have been reported in the nearshore zone of Northern Lake Ontario near Toronto (Martin-Downs 1988, Buchanan 1989). The slimy sculpin (*Cottus cognatus*) and the mottled sculpin (*Cottus bairdii*) are very similar morphologically, in their choice of habitat and in their biology; however, the slimy sculpin is generally found in deeper waters and further to the north (Emery 1973, Scott and Crossman 1973) and is more likely to be the species found in the depths of the proposed licence site. Both are spring spawners, spawning when water temperatures reach 10°C. Males build nests under rock or ledge, usually on rocky bottoms. After several females have deposited adhesive eggs on the underside of the roof of a nest, the male will guard the eggs until they hatch, about a month later (Scott and Crossman 1973). In Great Bear Lake, sculpins were seen to move inshore into the stony shallows to spawn in early spring (Scott and Crossman 1973).

During the day sculpins will avoid open sand and prefer rocks and weeds; however, at night they are found on sandy bottoms near their daytime habitat, where they feed at dusk and into the night (Emery 1973; Koster 1937; Scott and Crossman 1973). Although there may be pockets where there is enough substrate for sculpins to find cover and build nests on the sandy bottom at the proposed licence site, the habitat is not ideal, and they would be expected to move inshore to spawn in the more protected bays where there is more suitable habitat and cover. Dr. Randy Owens (USFWS, Oswego, NY, Pers. Comm.) suggested that he would not expect many sculpins to be found on a sandy bottom in < 35 m waters. In the bottom trawls conducted by himself on both the north and south shores of Lake Ontario, peak sculpin abundance was found at 70 m and few fish at < 35 m. He also confirmed that preferred sculpin habitat is on rocky or cobble substrates where they can find cover from lake trout predators. The population of sculpins in Lake Ontario has declined dramatically since the beginning of lake trout stocking in the early 1970's in both US (Dr. Randy Owens, unpublished data) and Canadian waters (Casselman *et al* 1991), and this may be due to lake trout predation (Dr. Randy Owens, Pers. Comm.).

5.6 Yellow Perch (*Perca flavescens*)

Yellow perch are spring or early summer spawning fishes that use shallow weedy areas for spawning. Though reported to occur, these fish seldom spawn over sand or gravel (Scott and Crossman 1973). River mouths, bays and marshes are the preferred spawning sites; however, lake shallows may be used for spawning as well (Krieger *et al* 1983). In Lake Ontario yellow perch are reported to also spawn along the lake shore proper (Goodyear *et al* 1982). Open water areas are not preferred habitat since the eggs are deposited in a long gelatinous string, which adheres to submerged vegetation or, at times, to the bottom, and, hence, could easily be cast ashore by wind, waves or currents (Scott and Crossman 1973). Goodyear *et al* (1982) state that ripe yellow perch were collected at Centre Island in Toronto in 1901, and that spawning was documented in Ashbridges Bay in 1891 (Figure 12). It is unlikely that yellow perch would use the plant barren, deep bottom at the proposed licence site for spawning.

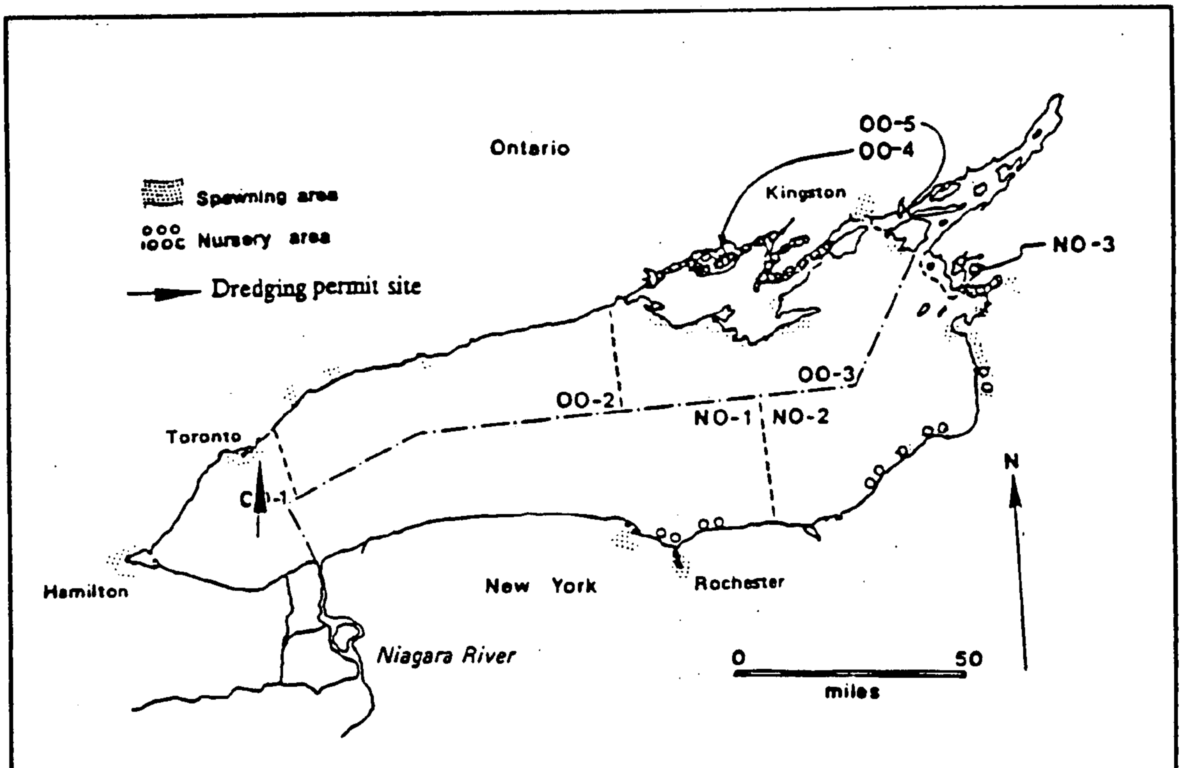

Figure 12 Potential spawning sites for yellow perch in relation to the proposed dredging location (after Goodyear et al. 1982).

5.7 Walleye (*Stizostedion vitreum*)

Like other percids, walleye are spring spawners, moving into spawning areas soon after ice out. Preferred spawning habitats include shallow shoreline areas, coarse-gravel shoals, riffles, locations characterized by fast moving waters due to wave action or currents, and below dam faces and impassable falls with rocky substrates and white water (Scott and Crossman 1973, McMahon *et al* 1984). Preferred water depths for spawning are between 0.5 and 1.5 m and preferred spawning substrates are gravel, cobble and rubble (McMahon *et al* 1984).

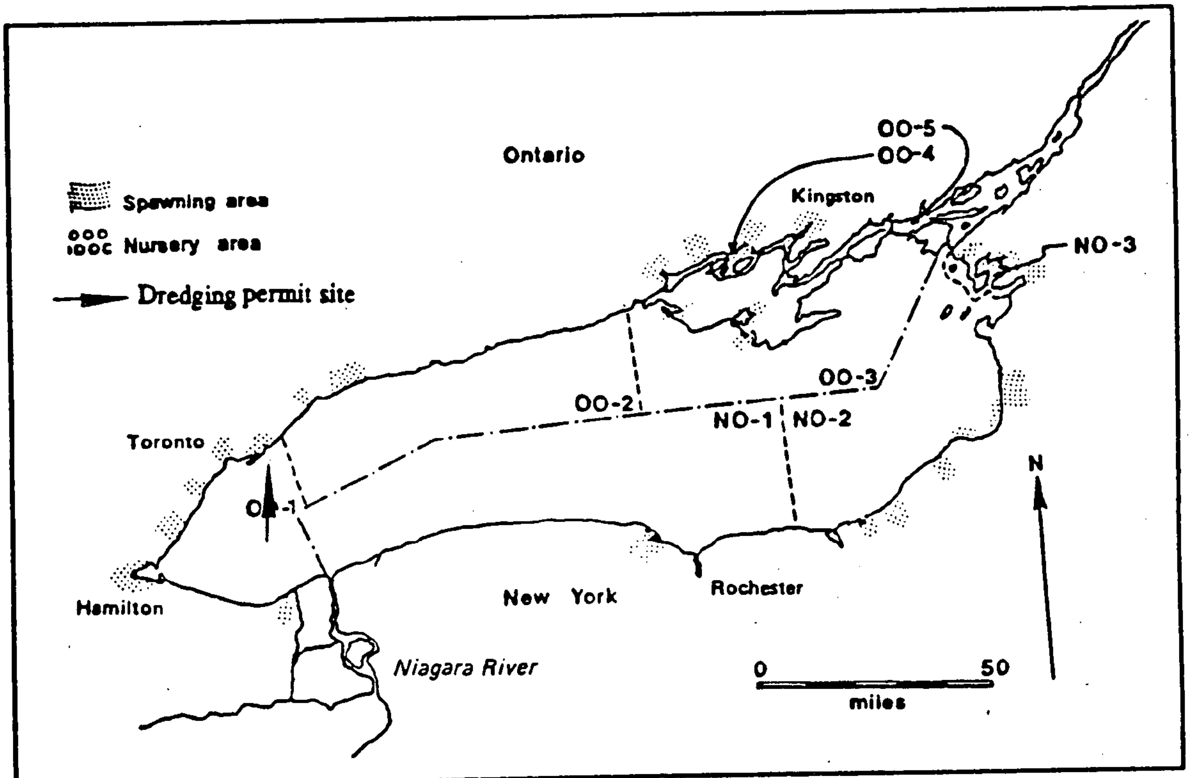

Figure 13 Historical spawning locations for walleye in Lake Ontario in relation to proposed dredging site (after Goodyear et al. 1982)

Historically, walleye moved inshore to spawn in creeks, river mouths and along the shorelines of Lake Ontario in April (Goodyear *et al* 1982). Historical spawning locations for walleye in the area of the dredging site include the Don River, Burlington Bay, Bronte Creek, Rouge River and Duffin Creek (Figure 13). Walleye spawned in these areas of Lake Ontario until the 1930's; however, walleye spawning in these areas no longer exists (Goodyear *et al* 1982). Nests are not built by walleye, and, for protective cover, eggs are dropped into crevices in the substrate (or on mats of vegetation in some areas)(Scott and Crossman 1973); thus, as well as being too deep, the proposed licence site does not provide suitable spawning habitat for this species.

5.8 Lake Trout (*Salvelinus namaycush*)

In the Great Lakes, lake trout spawning occurs between September and November (Marcus *et al* 1984). Spawning occurs most often over a boulder or rubble bottom at depths of less than 40 m, although depths as shallow as 0.3 m (Scott and Crossman 1973) and over 55 m (Marcus *et al* 1984) have been documented. In general, lake trout spawn over a variety of surfaces, from mud to angular boulders; however, ideal spawning habitat is considered to be cobble (2 to 30 cm diameter) in 0.2 to 55 m of water (Marcus *et al* 1984). In Lake Ontario, lake trout usually spawn over boulders or cobbles in 1 to 5 m of water (J. Casselman, pers. comm.), the substrate being 3.5 to 5.4 cm in diameter and several layers deep. Lake trout embryos require interstitial spaces between the rocky substrate as cover to survive (Scott and Crossman 1973).

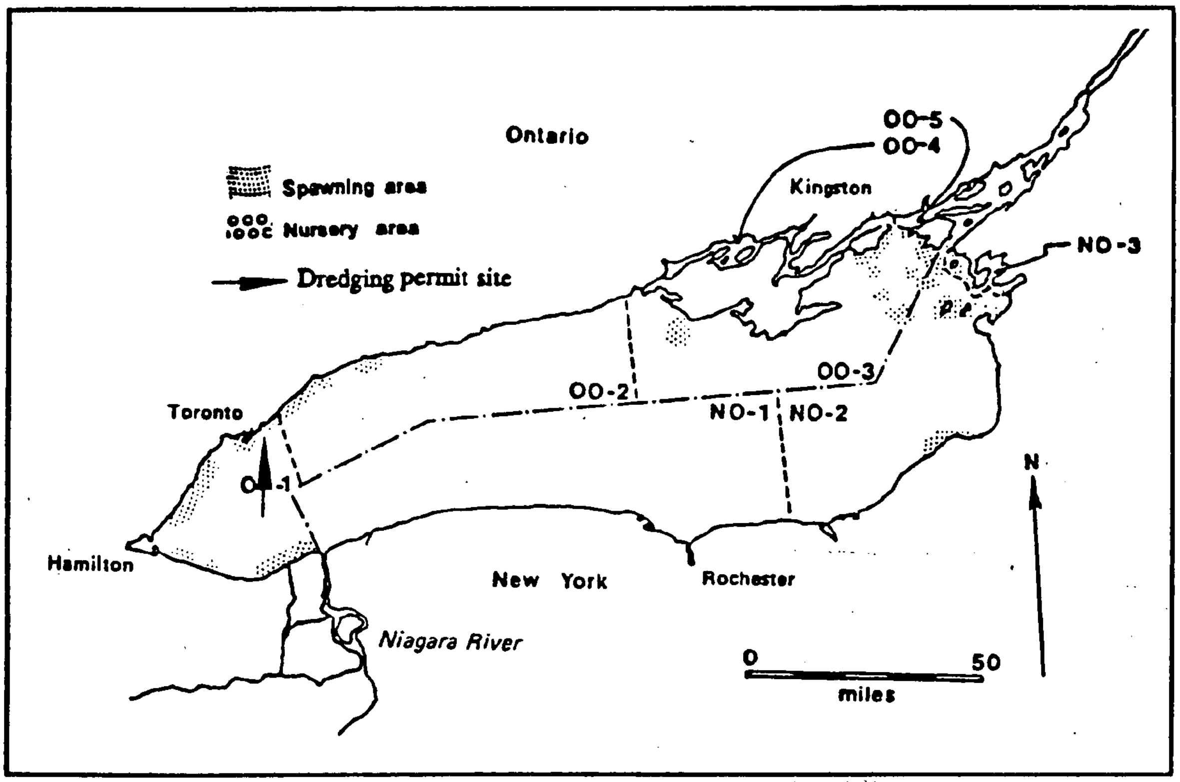

Figure 14 Historical locations of lake trout spawning areas in Lake Ontario (after Goodyear et al. 1982).

Goodyear *et al* (1982) identifies native lake trout spawning sites in Lake Ontario to be on reefs in 3 to 30 m depth at the same sites used by spawning lake whitefish (Figure 14). Most spawning grounds were concentrated in the eastern end of Lake Ontario in Canadian waters. No natural reproduction has been recorded since the 1950's, and they are no longer self sustaining in Lake Ontario (Goodyear *et al* 1982). Lake trout have been stocked in Lake Ontario waters since 1972. All of the above-mentioned factors suggest that the substrate, the major composition of which is sand, in the licence area is unsuitable for lake trout spawning.

5.9 1991 Fall Field Survey

Seasonal occurrence of fish in the Toronto waterfront area is very dependent upon local weather conditions (Martin-Down 1988) and, as a result, may vary from year to year considerably. For this reason our data should be viewed as representative of fall conditions in 1991 and may not represent an average year. In order to assess the potential use of the deposit site by spawning whitefish, B.A.R. Environmental Inc. conducted a gillnetting survey during the spawning period in early December 1991. Ontario Hydro (1987) found that the peak abundance of round whitefish catches at Thickson Point, just to the east of our site, was during the first two weeks of December.

Four 300 m gangs of monofilament gill nets (experimental gangs of 38 to 123 mm stretch mesh) were set for a minimum of 24 hours at the locations shown in Figure 15 on December 2 and 4, 1991. The fish captured in these nets are listed in Table 4. All round whitefish were found dead in the nets; thus, they were weighed and measured and their sex noted (Table 4). No lake whitefish were captured. A total of 9 round whitefish, 5 of which were in spawning condition, were captured at nets 2 and 3. It seems most likely that the fish in spawning condition were spawning nearby and inshore, where appropriate gravel substrate can be found in < 15 m of water. The net set at the Bowmanville site (net #4) was placed in an attempt to capture spawning fish in habitat which had been indicated as appropriate for spawning round and lake whitefish (Ontario Hydro 1987). This was intended to confirm that there were fish in the area in the event that fish were not caught in the nets at the proposed permit site. The absence of whitefish at this site is unexplained.

In order to observe features of the bottom substrate and potential fish spawning zones, as well as to collect samples of fish eggs, we employed an underwater video camera, combined with an airhose suction, over a 1.5 km transect across the site (Figure 15). The 40 minute video (available on request from B.A.R. Environmental Inc.) shows sand ripples several cm high. No other features were discernable. At one point in the video a sculpin can be seen darting away from the camera. Sand samples collected from the airhose contained some *Mysis relicta* but no fish eggs.

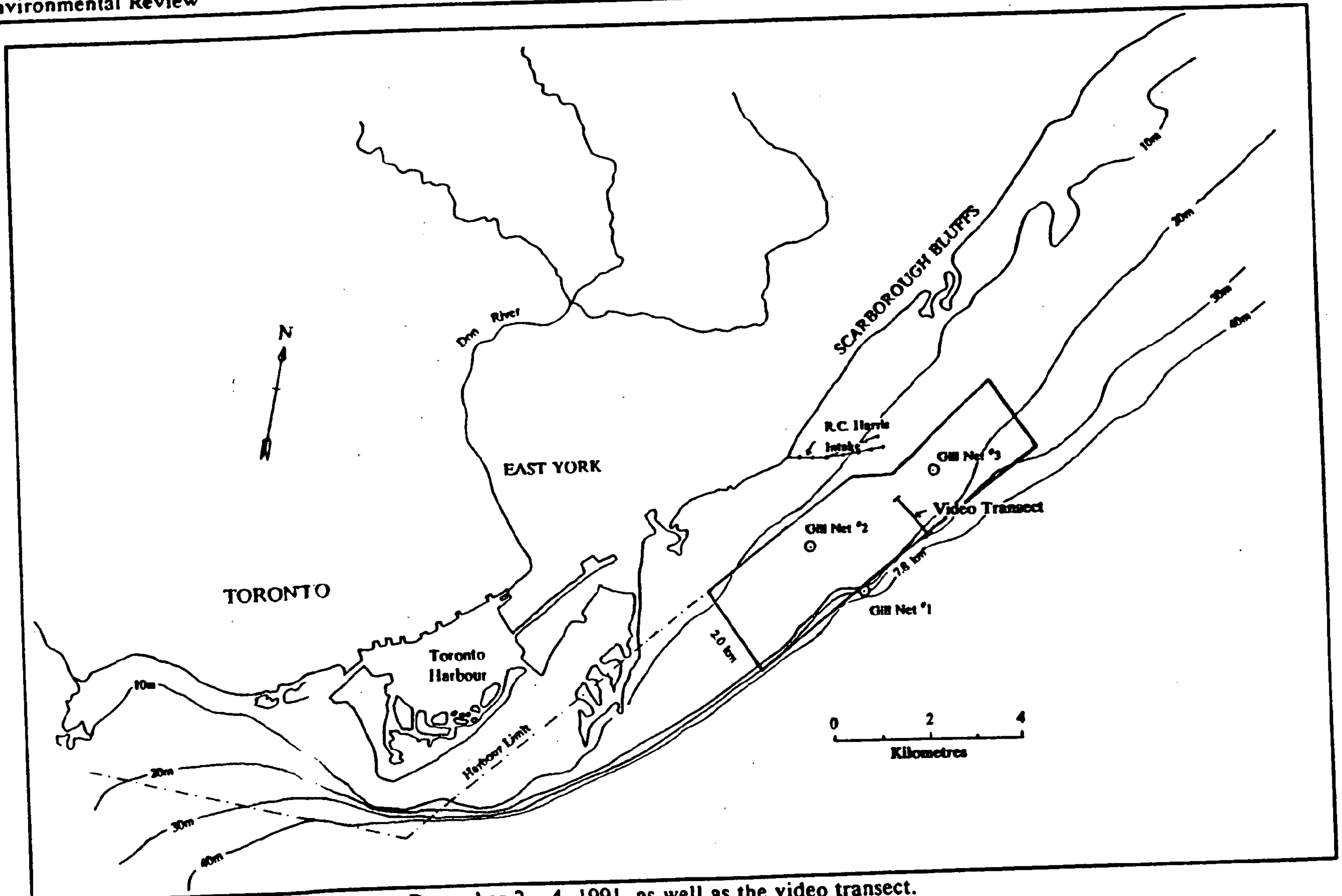

Figure 15. Sites of gill nets set on December 2 - 4, 1991, as well as the video transect.

Table 4. Fish captured in gill nets set December 2 - 4, 1991 at locations shown in Figure 15.

Net # (depth)	Species	TL (mm)	FL (mm)	Weight (g)	Notes
1 (20 m)					no fish captured
2 (15 m)	round whitefish	391	359	460	Ripe male
	round whitefish	323	303	265	Immature male
3 (15 m)	lake trout				Large adult, released
	white sucker				Large adult, released
	white sucker				Large adult, released
	round whitefish	510	470	1320	Ripe female
	round whitefish	500	463	1080	Ripe female
	round whitefish	362	334	365	Immature female
	round whitefish	387	356	480	Unripe female
	round whitefish	382	353	460	Ripe male
	round whitefish	378	350	420	Immature female
	round whitefish	410	375	580	Ripe male
4* (5 m)	Pacific salmon				Large adult, released
	brown trout				Large adult, released
	lake trout				Large adult, released

* - Net 4 was set at the Bowmanville site, which is not shown in Figure 15.

5.10 Conclusions Regarding Impacts to Fish Spawning

Our concerns regarding the impacts of dredging on fish spawning were due to the potential for turbidity from the plume affecting congregating fish, sedimentation from the plume suffocating eggs, changes to bottom substrates altering fish habitat and entrainment of fish and fish larvae. We examined these potential impacts on each of the species known or expected to use this region of Lake Ontario, and our conclusions are presented below.

In the worst case scenario, as described by Gore and Storrie (1992) and reviewed in Section 4.2, a sediment plume with a concentration of 100 mg L^{-1} required 4 h to completely dissipate, though after 34 minutes the concentration had fallen to 10 mg L^{-1}. The effect of such a plume of suspended sediments on fish would be restricted to modified behavioral patterns (Newcombe and MacDonald 1991). Such effects would include modified avoidance response and a reduction in feeding rates, and if fish remained within this worst case plume area for the duration of the plume, the most severe effect would be a reduction in their condition factor. — ??

A more typical scenario would involve a 250 m wide (mostly down current) sediment plume of 10 mg L^{-1}. Such a plume would dissipate to background levels within 32 minutes (see Section 4.2). Most fish would swim the short distance to avoid the turbidity, and little if any serious effect by the sediment plume on spawning fish in this area would be noticeable.

The purifying mechanism of spawning bed interstices, which includes oxygen replenishment and removal of metabolic wastes produced by fish embryos, is critical to the survival of these embryos. The accumulation of sediments has the potential to clog interstices in spawning beds, thus inhibitting this purifying mechanism. Furthermore, sediment deposits may form physical barriers, thus preventing the emergence of the young. The effects of sedimentation on fish spawning as result of the proposed dredging are predicted to be minimal. In a worst-case scenario we predict an average annual sediment deposition rate of 2.5 mm yr^{-1} (see Section 4.4). The species identified as potential users of the sand deposit site for spawning habitat are rainbow smelt and lake herring. Taking into consideration the length of time between for spawning and emergence of young of these species, the developing embryo would be exposed to a considerably smaller quantity of sediment accumulation than that calculated for an entire year. Though the developing process can be prolonged for lake herring, the timing of their spawning activities (late November to early December) coincides with the termination of dredging for the winter season.

Several other species of fish have historically used the northern shore of Lake Ontario, east of Toronto, as a spawning ground. These include lake and round whitefish, lake trout and sculpins; however, none use fine grained sand at depths of 10 to 40 m as their preferred spawning habitat. The sand grain size is such that there are not interstitial spaces large enough to protect fish eggs, and the constant, and often strong, currents would carry demersal eggs away from the site.

Sculpins, which are nest builders, can potentially spawn over sandy substrates; however, an expert on sculpins in Lake Ontario (Dr. Randy Owens) has indicated that the density of slimy sculpins over a sand bottom at these depths is probably low due to lack of cover, as well as to predation by lake trout (see Section 5.5). For these reasons, the dredging operation is unlikely to have serious implications for the sculpin population in this region.

The dredging operation will vacuum 15 cm layers from the surface of the sand deposit and will effect 6.9% of the entire site annually. The bottom substrate will remain unchanged except for the 1 km^2, which will lose 15 cm of its surface layer. Taken over the entire area of the deposit, this is equivalent to a yearly loss of 1 cm of bottom sediment. As the sand deposit depth ranges from 1.5 to 5.25 m, and considering that the nature of the deposit coarsens only very slightly through the depth of the sand, the substrate composition at the deposit site will not change as a result of the dredging. Fish using the site for spawning will not, therfore, be affected by changes in substrate composition of their spawning habitat. Nevertheless, the grain size of the remaining deposit should be monitored to ensure that major alterations to habitat do not occur.

Another potential concern with spawning fish was due to the potential of entrainment of eggs and larvae. As mentioned earlier, 6.9% of the surface of the entire licence site will be suctioned from April 1st to November 30th each year. The timing of spawning for herring is such that it coincides with the winter period when dredging will not occur; hence, only rainbow smelt eggs have any likelihood of disruption by the dredge.

6 IMPACTS TO THE INVERTEBRATE COMMUNITY

The proposed dredging of bottom sediments will result in the temporary destruction of benthos (bottom dwelling organisms). Most of the disturbance will be due to the 1 by 1m suction head, which takes a 15 cm by 1 m swath of sand along the path of the barge. As discussed above, approximately 7% of the surface of the sand deposit area will be dredged each year. Benthic invertebrates constitute an important part of the diet of most fish. In an effort to determine if the impacts from dredging will have substantial effects on benthic feeding fish in the area, we examined the potential impact of dredging on the invertebrate community that inhabits the sediments at the proposed licence site. Invertebrates were collected on August 14, 1991, from each of the 12 stations indicated in Figure 6. These stations were located on a grid across the deposit area, and they corresponded with the sites at which sediment samples were collected. Samples were collected using a 15 x 15 cm eckman dredge on a winch. Triplicate samples from each station were pooled. Samples were sieved in the field through a 250 μm mesh and preserved in 5% formalin. All samples were sorted and identified using a dissecting microscope. Temporary slide mounts, in glycerin, were made to confirm some of the Oligochaetes and Chironomids found. Identification was generally to genus except for Hirundinea and some other common taxa (see Appendix B for taxonomic references used). Results of the benthic community analysis are listed in Table 5, and they show that this community was mostly dominated by Oligochaetes and Chironomids.

In order to determine the importance of the benthic community to benthic feeding fish in the sand deposit area, two factors were examined:

(1) the contribution to the total numbers of invertebrates by each of the major taxa found in the study area; and

(2) the major food items for lake trout (*Salvelinus namaycush*), rainbow trout (*Oncorhynchus mykiss*), chinook salmon (*Oncorhynchus tshawytscha*), lake whitefish (*Coregonus clupeaformis*) round whitefish (*Prosopium cylindricum*), sculpins (*Cottus bairdi, Cottus cognatus, Cottus ricei*), white sucker (*Catostomus commersoni*), and gizzard shad (*Dorosoma cepedianum*), i.e. the fish species most likely to be utilizing the sand deposit area for feeding, as determined by results of both our field and literature surveys.

McCall and Soster (1990) and Soster and McCall (1990) conducted a series of studies in Lake Erie to determine the effects of similar disturbances to the benthos. Their studies indicated that many of the taxonomic groups (chironomids, oligochaetes, ostracods) returned to original numbers within the first two months following the disturbance. For some taxa (e.g., *Chironomus plumosus*) numbers increased by a factor of 2 to 7 fold

Table 5. Benthic invertebrates sampled offshore of the Scarborough Bluffs, Lake Ontario on August 14, 1991.

Taxa	1	1A	2	3	4	5	6	7	8	8A	10	10A
Annelida:Hirudinea:												
Helobdella elongata	-	-	-	-	-	-	1	-	-	-	-	-
Helobdella stagnalis	-	-	-	-	-	-	-	-	-	1	-	-
Piscicola geometra	-	-	-	-	-	-	1	-	-	-	-	-
Annelida: Oligochaeta												
Stylodrilus herringianus	4	26	-	14	2	-	15	81	28	11	82	124
Tubificidae:	7	51	2	81	3	3	-	-	-	2	1	1
Eggs (oligochaeta)	175	11	3	115	4	2	73	70	116	11	82	48
Acarina: Hygrobates	2	-	-	-	-	-	-	-	-	1	-	-
Lebertia	2	-	-	-	1	-	-	-	-	-	-	-
Amphipoda:												
Diaporeia hoyi*	32	-	-	3	2	2	-	30	9	-	1	39
Cladocera: Eurycercus	-	-	-	-	-	-	-	-	-	-	-	1
Ostracoda: Candona	7	-	-	6	1	2	6	4	9	4	24	9
Cytherissa	16	-	-	15	-	-	-	-	-	2	-	-
Diptera:												
Chironomidae												
Chironominae: Chironomini												
Chironomus sp.	-	1	-	-	-	-	-	-	-	-	-	-
Cryptochironomus	5	6	-	2	2	-	-	-	1	5	-	-
Dicrotendipes	-	-	-	-	-	-	-	-	-	-	-	1
Paracladopelma galaptera	6	1	-	1	2	-	-	-	-	4	-	-
Polypedilum poss. laetum	1	3	-	16	8	1	1	1	-	-	2	6
Chironominae: Tanytarsini												
Micropsectra	1	-	5	-	1	2	9	34	-	17	57	3
Orthocladiinae:												
Cricotopus	-	-	-	-	-	1	-	-	-	-	-	-
Heterotrissocladius marcidus-group	35	3	10	49	65	7	21	3	4	85	11	10
Parakiefferiella	-	-	-	-	-	1	-	-	-	-	-	-
Prodiamesinae:												
Monodiamesa tuberculata	4	-	-	6	-	-	-	-	-	4	-	-
Mollusca: Sphaeriidae:												
Pisidium	70	-	1	18	6	-	-	2	7	2	7	89
Nematoda:	2	1	-	6	-	-	-	8	-	1	1	1
Platyhelminthes: (Microturbellaria)	-	2	-	-	-	-	-	-	-	-	-	-

compared to abundances measured prior to disturbance. The first taxa to recolonize disturbed sediments generally have life histories amenable to fast colonization (e.g. short lifespan, many reproductive events per year, short generation time). Other taxa such as sphaeriid clams take longer to colonize (approx. 1 year) because of longer lifespans and a longer generation time (McCall and Soster 1990, Soster and McCall 1990).

Amphipods have a relatively short generation time (approx. 2 weeks; DeMarch, 1977), and should be able to recolonize disturbed areas fairly rapidly.

The benthos in the sand deposit area was dominated by oligochaetes (56%), chironomids (23.5%), sphaeriid clams (9.0%), amphipods (5.2%) and ostracods (4.7%). Annelids (leeches), Acarina (mites), Cladocera, Nematoda, and Platyhelminthes comprised less than 2% of the total numbers of invertebrates (Table 5). Because of the relatively rapid reproduction rates of oligochaetes, chironomids, ostracods, and amphipods which dominated the benthos, recolonization of areas disturbed by dredging should occur fairly rapidly.

Using a conservative estimate for dredging frequency, where dredging occurs at any one site on average once every 14 years, approximately 7% of the sand deposit (0.97 km^2) will be dredged annually. Because the majority of benthic organisms (99%) occupy the upper 6 cm of sediment (Nalepa and Robertson, 1981), the removal of the top 15 cm will effectively remove 100% of the benthos in the dredge path. If two months are required for oligochaetes, chironomids, amphipods, and ostracods to return to normal numbers, then an area representing 1.2% (7% ÷ (12 months ÷ 2 months)) of the deposit would be depauperate of benthos at any one moment, while an area representing 7% would be depauperate of clams and other taxa (which made up 10.6% of the benthos abundance in this area (Table 5)), as they may take up to a year to recolonize the disturbed areas. The annual net loss of benthos as a direct result of dredging may be determined as follows: (1.2% × 100% community) + ((17 - 1.2)% × 10.6% community) = 1.8% of the total benthos abundance at the sand deposit site.

A net annual loss in benthic abundance of 1.8 % should not have a significant impact on benthic feeding fish in the area. Many of the fish identified as potential users of the sand deposit site for feeding are known to consume a number of the benthic organisms found at this site (Table 6). Of these fish, lake trout, rainbow trout, chinook salmon, lake whitefish and sculpins also make use of other feeding strategies (Carlander 1969, Scott and Crossman 1973). For instance, these fish are known to actively seek out regions with more favourable and abundant benthic fauna, and, they are also known to utilize other types of food (e.g. plankton and small fish) in their diet. Young (larvae, juvenile) salmon and trout feed mostly on plankton, while adults often prey upon small fish. Although lake whitefish primarily utilize benthos as a food resource, they can also utilize plankton during all life stages. Sculpins also feed primarily on benthos, but they may also consume small fish if benthic prey are scarce. Round whitefish are primarily a bottom feeding fish, but have been known to consume small fish.

White sucker is the only fish in the vicinity of the sand deposit that has a limited ability to prey on alternative food groups. In the deposit area, the sucker probably feeds

Table 6. The major benthic taxa found at the proposed licence site as well as their known fish predators.

	Fish Species								
Food Group	Lake Trout	Rainbow Trout	Brown Trout	Chinook Salmon	Lake Whitefish	Round Whitefish	Sucker	Sculpin	Gizzard Shad
Annelida: Hirudinea		x						x	
Oligochaetes								x	
Nematoda									
Platyhel-minthes									
Acarina				x					
Amphipoda	x	x		x	x	x			
Cladocera							x		
Ostracoda									
Diptera: Chironomidae	x	x		x	x	x	x	x	
Mollusca: Sphaeriidae					x	x	x		

Fish predators are indicated by "x" (Sources: Carlander 1969, Scott and Crossman 1973).

primarily on chironomids and clams. This fish usually spends daylight hours in deeper waters, coming into shallower waters at night to feed. If the dredging operation disrupts certain feeding areas of the white sucker, a decreased condition factor for this fish would be expected (Munkittrick and Dixon, 1989); however, the condition factor of the white sucker has been shown to vary naturally by as much as 28% (Munkittrick et al., 1990; Kilgour *et al.*, 1991). If a change in condition factor is assumed to be linearly related to a change in abundance of available food, then a reduction in body condition of approximately 1.8% may be expected. This number may be somewhat higher considering that the fish may be obliged to expend more energy than usual to find food; however, a change in condition of over 20% as a direct result of dredging over the sand deposit is unlikely. Hence, a change in body condition would not be detectable in light of the natural variation found in most populations of white sucker. The effects of a 1.8% annual reduction in the abundance of benthic invertebrates on the white sucker population will likely be minimal.

Though we propose a program to monitor changes that may occur to the benthos (Section 10), it is common in benthos surveys to find variations in abundance as much as 20-50% of the overall average (Morin, 1985). Considering the large variation among samples (coefficient of variation = 65%) from the sand deposit site (Table 5), an intensive survey would be required to detect a 1.8% change in benthos abundance. Paine and Kilgour (1991) demonstrated that in order to detect a change of 5% in benthos abundance in the Lesser Slave River, a collection of 8400 samples at each station was required.

These observations suggest that the effects of dredging on the benthic community will be extremely difficult to detect as they will likely be minimal. Any changes in benthos will be small because the majority of the benthic community should be able to recolonize the disturbed bottom fairly rapidly (less than two months). Benthic feeding fishes will not be able to feed in the swath dredged by the draghead for at least two months after dredging; however, various feeding strategies will allow them to obtain their dietary requirements via alternative sources. Two months after dredging, fish should be able to begin feeding in the affected areas following the recolonization by benthos. The predicted loss of benthos (in terms of numbers) is expected to be under 2%, which is a change that is highly difficult to detect, even with a very rigorous sampling regime. The only effects of a reduced abundance of benthic invertebrates may be on the condition factor of the white sucker; however, the predicted changes are within limits that have been shown to occur naturally in other populations.

7 IMPACTS TO FISH FEEDING HABITAT

Despite the fact that the impact to benthic invertebrates is likely to be undetectable, we felt that we should examine each of the fish species which may feed at this site so that we can ensure that adequate alternative sources of food are available when dredging is occurring. In the following section we examine the diet of each of the key fish species that use the site for feeding.

7.1 Lake Whitefish (*Coregonus clupeaformis*) — fed on benthos also

Analysis of the diet of lake whitefish has been studied by several authors. Although the diet varies depending on geographical location, whitefish are considered to be mainly bottom feeders over most of their range (Reckahn 1970, Hart 1931, Koelz 1929). Food items of lake whitefish include a wide variety of bottom living invertebrates (Koelz 1929, Hart 1931), planktonic crustaceans (Clemens *et al* 1923), small fishes (Scott 1967) and even terrestrial insects (Clemens *et al* 1923).

The most common food items of lake whitefish include aquatic insect larvae, molluscs and amphipods (Koelz 1929, Hart 1931). In depth studies on the diet of whitefish from Lake Ontario has not been conducted; however, the diet of whitefish from lakes in Saskatchewan was dominated by amphipopds (*Ponteporia*), fingernail clams (*Pisidium spp*), gastropods, insect larvae (chironomids, trichopterams, and ephemeropterans), leeches, cladocerans and mysids. The primary food items in the diet of young of the year whitefish include copepods (especially *Diaptomus*) and clodocerans (especially *Bosmina*). As the young become larger, their diet resembles that of adults, dominated by insect larvae (especially chironomids), gastropods, amphipods, isopods and ostracods.

7.2 Lake Herring (*Coregonus artedii*) a little

Lake herring is a pelagic fish species, and as such the lake herring is basically a plankton feeder. Dominant food items in the diet include copepods, daphnia, diatoms, and cladocerans (Scott and Crossman 1973). In the Great Lakes crustaceans such as amphipods (*Pontoporeia spp*) and mysids are an important component of the diet, as are immature stages of aquatic insects (such as trichopterans, ephemeropterans, and chironomids) (Pritchard 1931). In Lake Ontario forage fish and fry of other fish species also provide food for the lake herring (Pritchard 1931).

7.3 Round Whitefish (*Prosopium cylindraceum*) also

Round whitefish are bottom feeders. Their diet consists of a variety of benthic invertebrates. Insect larvae and nymphs compose the bulk of the diet, especially ephemeropterans, trichopterans and chironomids (Scott and Crossman 1973). Other food items include molluscs, such as fingernail clams and snails, crustaceans, such as amphipods and isopods, small fish, and fish eggs.

7.4 Yellow Perch (*Perca flavescens*) – also at a certain stage of growth.

The diet of yellow perch is variable depending on season and size of the fish. The diet is composed largely of aquatic insect larvae and nymphs, other large macroinvertebrates and small fish. Yellow perch larvae (6mm) feed mainly on cladocerans, copepod nauplii and cyclodoid copepods (Krieger *et al* 1983), ostracods, and chironomid larvae may also be part of the diet of small perch (Scott and Crossman 1973). Fry survival and year class strength of yellow perch is strongly correlated to the supply of zooplankton at the onset of feeding (Kelso and Ward 1977). As the fish grow their diet shifts to benthic organisms such as immature insects (e.g. nymphs of odonata and ephemeroptera) and amphipods. Adult yellow perch are mainly piscivorous, though other food items for adults include decapods (crayfish), and odonota nymphs (Kelso and Ward 1977). Some authors have suggested that relative availability of different prey types, rather than preference for particular food items, is the most influential factor in the diet of yellow perch (Collette *et al* 1977).

7.5 Walleye (*Stizostedion vitreum*)

During the first six weeks after hatching walleye feed mostly on copepods, cladocerans and, later, on small fish (Scott and Crossman 1973). Walleye fry eat zooplankton, then aquatic insects, and at 1.5 to 2.5 cm in length, they then start feeding on fish (Forney 1966). Juveniles and adults feed mainly on fish; however, invertebrates such as mayfly nymphs or crayfish may also be important food items. Yellow perch are a dominant fish prey, though centrarchids and clupeids may also be eaten.

7.6 Lake Trout (*Salvelinus namaycush*) feed on rainbow smelt, which would be threatened

Lake trout will feed on the most abundant food available. The predominant food items of young lake trout include zooplankton and dipteran larvae, although lake trout will begin to eat fish at 38 mm (Carlander 1969). Mysids are an important food item for lake trout of all sizes. Larger lake trout feed primarily on fish, including slimy sculpins (although in some inland lakes lake trout continue to feed on zooplankton throughout their lives (Marcus *et al* 1984)). In the Great Lakes, alewife and rainbow smelt form a significant part of their diet (Brandt 1986).

7.7 Other Salmonids (*Onchorynchus spp.*)

Other salmonoid species which may be affected by the proposed dredging operation include rainbow trout (*Oncorhynchus mykiss*), chinook salmon (*Onchorynchus tshawytscha*) and coho salmon (*Oncorhynchus gorbuscha*). The impacts of dredging on benthic invertebrates and forage fish species may make the area less suitable for these fish species. Each of these fish species has similar diet requirements. Each is considered to be an opportunistic feeder, and their diet is composed of a wide variety of food items (Raleigh *et al* 1984, Raleigh *et al* 1986). Important food items in the diet of salmonids include aquatic insects, zooplankton, terrestrial insects, and forage fish (Raleigh *et al* 1984). Bottom dwelling invertebrates may comprise a large component of the winter diet (Raleigh *et al* 1984). In Lake Ontario the diet is *likely* largely composed of forage fish.

7.8 Rainbow Smelt (*Osmerus mordax*)

Depending on the stage of their life history, smelt are able to utilize food resources of the lake bottom and the entire water column. Adults occupy the hypolimnion during the period of summer stratification; however, they are known to leave the lake bottom at night and ascend into the water column, often ascending through the thermocline into the epilimnion (Ferguson 1965). Age 0 smelt apparently undergo an opposite diel pattern descending down into the hypolimnion from the epilimnion during darkness, and yearlings are usually found in an intermediate position between adults and YOY smelt (Evans and Loftus 1987). In Lake Ontario nursery areas for this species are known to include the nearshore waters of the entire shoreline (Goodyear et al. 1982).

The diet of smelt is dominated by invertebrates, such as copepods, cladocerans, mysids and insects. Other food items include fish eggs, and even embryonic smelt eggs have been found in adult rainbow smelt (Legault and Delisle 1968). Smelt are also capable of feeding on larger food items, and in some lakes they are reported to be almost entirely piscivorous (Evans and Loftus 1987). In Lake Ontario smelt prey primarily on large invertebrates and fish. Piscivory increases with body size, and in Lake Ontario fish have been found to comprise up to 100% of the food of smelt larger than 200 mm. In fact, piscivory in smelt is, with few exceptions, associated with a high degree of cannibalism (Evans and Loftus 1987).

A decline in abundance of food available to smelt is important because smelt display an opportunistic strategy for larger food items; hence, the degree of piscivory, including cannibalism, by smelt could be affected by the availability of alternate prey. Moreover, O'Gorman et al. (1987) found that year class strength in smelt was more closely related to size of the previous year class than to size of the spawning population, thus, suggesting that intraspecific competition between YOY and yearlings may be an important factor in the survival of YOY smelt. Decreases in food items may also lead to declines in smelt abundances due to competition from other species. Because the staple diet of both alewife and smelt is small invertebrates, competition with alewife may have caused reduced growth rates of smelt in New England Lakes, as well as complete displacements of smelt populations (Evans and Loftus 1987).

Predominant food items in the diet of yearling smelt have been found to consist of Copepoda and Cladocera; however, smelt fry (YOY) and smelt scales have been found in the stomachs of yearling smelt in Lake Erie (Henderson and Nepszy 1989). Other food items found in the diet of yearlings, and that were found in the sand deposit site in Lake Ontario (Table 5), include Dipterans, Mollusca, Amphipoda, Ostracoda and Nematoda (Henderson and Nepszy 1989).

Quote

Changes in the structure of the benthic invertebrate community could lead to a reduction in the availability of prey of sufficient size for optimal growth of certain fish species. Indeed, this was suggested to be the cause of the decline in the size of yellow perch in Lake Erie (Hayward and Margraf 1987). As both smelt and yellow perch could compete for ostracods, chironomids and amphipods (Scott and Crossman 1973, Evans and Loftus 1987), changes in the invertebrate community could affect either of these species; however, because impacts to the benthic community are expected to be of a very small magnitude (see Section 6), changes to the benthos that are a result of the dredging operation, and hence, the effects on smelt, are expected to be minimal. however,

7.8 Sculpins (*Cottus spp*)

Mottled sculpins tend to be somewhat less mobile and live in shallower water than slimy sculpins, which have been found at depths of 100 m in the Great Lakes. Both can bury into the sand for cover, although they prefer stones, rocks or cobble substrate (Emery 1973). Sculpins feed primarily on aquatic insects, including the nymphs and larvae of mayflies, caddis flies, dragonflies, stoneflies and other dipterans, plus smaller fish and occasionally fish eggs and plant material (Koster 1937). Though sculpins may move inshore to feed at night, they are less mobile than pelagic fishes. Thus, sculpins are more likely to be affected by the localized reduction in the benthic community due to dredging, although the density of sculpins using the proposed permit site is likely to be very low (Dr. Randy Owens, USFWS, Oswego NY, Pers. Comm). Quote

Very little is known about the migrational habits of sculpins due to the difficulty of capturing and tagging these small, bottom dwelling fishes (Emery 1973). Emery (1973) found that when approached closely they quickly darted away and this was confirmed in our video transect of the site when the one sculpin that was seen darted away from the camera/dredge head. In our own observations of a 1.0 km transect of the site we observed only 1 sculpin; however, many have been captured in seine netting of the Toronto waterfront (Buchanan 1989).

Any fish present in the dredging area during the dredging season would be susceptible to entrainment into the dredge, although the design of the draghead is such that only the rear of the head is above the surface of the substrate, thus minimizing the chances of entrainment. In light of the low densities of sculpins expected to be using the proposed permit site, as well as the small percentage of the sand deposit area affected, the impact to sculpins would be undetectable.

7.9 Conclusions Regarding Impacts to Fish Feeding

Disturbance of the benthic invertebrate community over a localized portion of the proposed permit site will cause the fishes feeding in this zone to temporarily feed away from the strip dredged by the draghead. However, the impact to the above-mentioned fish will not be large because alternative sources not affected by dredging (such as other fishes, zooplankton and other benthic organisms) are available nearby, and only a minor and undetectable change in the benthos (< 2% loss of abundance) is anticipated (Section 6).

Physical entrainment of fishes is unlikely for any species except sculpins. The drag head is submerged about 15 cm below the surface of the sand and will not entrain pelagic fish. Sculpins are known to bury themselves in the sand when disturbed and may occasionally be entrained into the dredge. As the density of sculpins is likely to be low over the proposed site, the impact to sculpins is not anticipated to be measurable. The effects to fish behaviour caused by the sediment plume are not expected to be serious as fish that may be present would have to swim a short distance to avoid the plume. Physiological effects to fish that remained within the sediment plume would be minimal and short-lived (see Section 5.10).

8 IMPACTS TO OTHER USERS

The R. C. Harris Water Filtration Plant intake pipe ends in the middle of the originally proposed permit application zone. Structures that could be affected by the proposed operation include the two "Y" prongs of the intake pipe, the intake structure itself which is a large concrete structure with a set of vertical bars designed to trap coarse debris. The west intake ranges from 1.5 to 2.75 m off the bottom and the east intake ranges from 0.75 to 1.7 m off the bottom. The proposed pipes which will carry chlorine to the intake pipes for zebra mussel control may also be affected. In addition, regular spring and fall maintenance operations are done at the intake. Turbidity is one of the water quality parameters which is of greatest concern to the Water Filtration Plant. Increased turbidity is a concern due to the implications for operating cost increases at the plant.

The proposed permit site is 1.5 to 2 km offshore from Bluffer's Park in Scarborough, Ontario. This is an area just inside the zone where salmon fishing is concentrated during the Toronto Star Derby each summer. Between 10 and 20% of the summer fishing effort in MNR's Central Region originated from Bluffer's Park, showing that this is an important and active area for anglers. The largest component of the fishing is by daily launch anglers (46% or 635,565 rod-hr) with moored boat anglers and charter boats being about equal components of the fishery with about 27% each (Stewart *et al* 1990).

The major fish species angled from Lake Ontario in Central Region are chinook salmon (64%), rainbow trout (25%), coho salmon (8%), with lake trout and brown trout and Atlantic salmon making up the remaining 3%. There is no commercial fishery in this area at present (Stewart *et al* 1990).

As discussed in Sections 5 and 7, the dredging activity is unlikely to have any impact on the fish species which are of concern to anglers, as none of the species spawn or feed specifically in the area of the sand deposit. Interference between anglers and the dredge is of some concern as anglers are towing projecting lines behind them and could become entangled with the draghead if they pass very close in front of the dredge. Although this is unlikely, we investigated the extent of the overlap between the area fished by anglers and the area of the proposed dredging. In conversations with charter boats that fish this area we were told that the angling fishery is along the offshore side of the steep ledge which marks the southern edge of the proposed permit area. The fish appear to congregate in the deeper water off this ledge and there is very little fishing in less than 30 metres of water. The overlap is therefore minimal, although the perception of overlap may still occur as the dredge and the fishing boats may be within a few hundred feet of one another. In addition, the boats fishing that stretch of shore would most likely originate from Bluffer's Park or Ashbridge's Bay and would therefore have to cross the proposed licence area in order to reach the fishing grounds. As the permit area covers an area of 14 km^2, with only one dredge working the site, it is unlikely that there will be any interference with existing traffic.

9 CONCLUSIONS

The concerns raised in Section 2 have each been discussed above. We have considered the potential physical impacts of the proposed project and examined the implications for local biota and other users of the site.

9.1 Physical Impacts

The substrate consists of a sand deposit ranging from 1.5 to 5.25 metres in thickness. Over the five year permit period, removal of this material from the surface of the permit area will deepen the bottom depth by an average of 1.0 $cm.yr^{-1}$. The life time of the deposit will extend for over 50 years at the potential full production rate of 1 million tonnes per year. Over this time, the relief will be lowered by approximately two metres, on average, and the remaining surface will closely resemble that which exists today. Sediment within the permit site is currently in water that is too deep to permit cross-shore transport, therefore increasing the depths will have no impact upon shoreline stability.

Less than 3.0% of the aggregate in the permit site is composed of fine (< 150μ diameter) silts and clays. These fine suspended solids will overflow the dredge hopper resulting in a plume of turbidity for approximately 4.5 hours of each shift. Based on the modelling of Gore & Storrie, this plume will have a maximum suspended sediment concentration of about 1,600 mg L^{-1} directly behind the dredge and will quickly dissipate to undetectable concentrations. Concentrations of ammonia in the sediments marginally exceeded MOE (1992) guidelines at some sites and may be resuspended with the fine silts and clays in the turbidity plume. These concentrations were not different from background levels in this region.

Based on the volume of aggregate to be dredged and the percentage of fines capable of overflowing the hopper, it was possible to estimate average sedimentation rates within the proposed permit site. The maximum volume of sediment returned to the lakebed is 15,500 m^3 yr^{-1}, assuming single shift production rates. If the hopper traverses an area of 6 km^2, this figure translates into a maximum deposition rate of 2.5 mm yr^{-1}. This rate is based on an initial outflow concentration of 44,000 mg L^{-1}. However, outflow concentrations are likely to be closer to 15,000 mg L^{-1} which would result in deposition rates of less than 1.0 mm yr^{-1}.

9.2 Conclusions Regarding Biota

We have identified fish species which use the site for feeding as being salmonids, lake and round whitefish, yellow perch and slimy sculpins. We also investigated the benthic invertebrate community of the site. We found that the impact of removing the benthic invertebrates from the 7% of the site that may be dredged each year at single shift production rates, is unlikely to be detectable a year later and that the impact will be very localized and unlikely to affect mobile life stages of feeding fishes. As the texture of the substrate does not change appreciably with depth, there will be no changes to the type of physical habitat available to fish and invertebrates.

Sedimentation rates from dredge overflow are small enough to be undetectable in the current swept area of the permit site. The 0.1 cm yr^{-1} of deposited sediments will not smother fish eggs or invertebrates. The only fish species expected to spawn on substrate as fine, featureless and deep as that at the proposed site are lake herring and rainbow smelt. Though the slimy sculpon may feed in this area, the densities of these are thought to be very low.

The turbidity plume which is generated may have sublethal effects to any fish which remained in its influence for a prolonged period. As the plume is mobile and is expected to dissipate overnight, the likelihood of affecting any fish is very small. Plankton which remained in the influence of the plume would experience dampening of light penetration but again the period during which the turbulence affects any one individual will be too short and too localized to be of concern.

9.3 Conclusions Regarding Other Users

Upon the revision of the proposed dredging boundaries, the R.C. Harris intake pipe and proposed chlorination pipe are now separated from the permit area by a 400 metre buffer. This action has eliminated the possibility of the dredge interfering with the pipes or with the maintenance operations at the intake. The facility has historically accommodated background suspended sediment concentrations from 0.3 - 40.0 mg L^{-1}. The plume modelling performed by Gore & Storrie shows that the plume concentration would not exceed 2.5 mg L^{-1} under worst case conditions, but given the coarse nature of the bottom sediment and the fact that the worst case scenario does not take particle settling into account, plume concentrations are not expected to exceed 0.1 mg L^{-1} in the vicinity of the intakes. In addition, plume concentrations, although initially high, will quickly dissipate to background levels by advection and as sediment settles to the bottom.

The sharp drop over a ledge at the southern boundary of the permit application site is an important fishing ground for salmon fishermen, particularly during the Toronto Star Derby each summer. While the fishing ground does not overlap the proposed permit area, the fishing boats based at Bluffer's Park and Ashbridges Bay must pass through the permit site to reach the fishing area. In view of the large surface area of the permit site it is unlikely that there will be any interference with fishermen. However, there may be a perception of interference which should be monitored.

Visual impacts of the dredge on the aesthetics of the waterfront were considered. The dredge is smaller than the lakers that frequently pass through the permit application zone at present. ~~As the essence of the waterfront is~~ its function as a busy harbour, it seems unlikely that the presence of the dredge would be unduly noticeable.

!! They're much further out!!

unbelievable: quote this in ~~to~~ [illegible] section!

10 MONITORING REQUIREMENTS

The application submitted by Bedrock Resources, Inc. is for a five year permit to dredge sand from Lake Ontario. During that period, water quality and the condition of the biological community within the zone of dredging should be monitored. We have designed a monitoring program to collect information regarding these aspects over the five years of the permit.

10.1 Water Quality

One of the main concerns regarding the impacts of the project is the potential for increased turbidity, specifically in the area of the water intakes and, more generally, in the aquatic environment surrounding the dredging. We recommend that a water quality survey, including measurements of turbidity, be conducted during both summer and fall conditions to delineate the influence of the dredging on the lake. Water quality should be measured along a transect which crosses the plume in the area where the dredge makes its 180° turn, an area where the highest potential turbidity should occur. The transect, which would be perpendicular to the direction of dredge movement, should consist of five sampling points, one point in the centre of the plume and 2 points at 25m and 100m on either side of the plume. Water samples should be obtained at the water surface and from a point 1m above the lakebed for a total of 10 water quality samples per transect. Sampling should be performed immediately prior to dredging on any typical day and continue at 0, 2, 6, and 24 hours after the dredge passes across the transect. This will provide information which can be compared to the model developed by Gore and Storrie Ltd. and should indicate the decay rate of the turbidity plume. Sample analysis should include the parameters stipulated in the Ministry of the Environment Guidelines for Surface Water Quality for Biota, and in particular those parameters which are of concern: turbidity, TSS, TKN, NH„ PCBs and a scan for metals. In addition, daily turbidity monitoring data at the R.C. Harris plant could also be used to determine if a statistically significant relationship develops between dredging activities and turbidity levels at the intakes.

10.2 Sedimentation Rates

Sediments traps have been used in many studies to determine changes in the rates of sediment deposition. We recommend that in the first summer of the project, sediment traps be deployed in triplicate at 5 sites along a transect which bisects the permit area (perpendicular to shore) and at 2 control sites with similar bottom characteristics, outside the influence of the dredging. These traps should be examined after 1 month of dredging to determine the rate of sediment deposition compared to the control sites.

Contaminant analysis of the contents of the traps will also determine whether the depositing sediments exceed MOE guidelines.

10.3 Biological Community

10.3.1 Benthic Invertebrates:

The benthic invertebrate community is among the most sensitive to potential environmental damage from this project as it is fairly stationary, localized to the sediments and could be affected if sedimentation rates were large or contamination severe. This is an important trophic level in the ecosystem because of its relevance as fish prey. It is also an easily measured community because large numbers of individuals can be sampled efficiently and the data are amenable to statistical analysis. We therefore recommend that inventories of the benthic community, similar to those performed in 1991 using the same sampling locations, be undertaken in years 1,2 and 4. This would include contaminant sampling of the sediments in which invertebrates are collected. The resulting data can be compared to those collected over the period of the initial permit survey to determine whether there has been damage to this level of the ecosystem.

10.3.2 Fish

Impacts that the project might have on the fish community are more difficult to monitor as the fish populations are mobile and not using the permit site exclusively. As the surface of the deposit is not expected to change in character over the life of the operation, it is difficult to see how the fish community may be affected. Evidence of fish in the cargo hopper may indicate the presence of fish at the site. As well, bottom trawls of the site could be done during the early summer of the first year to determine if fry or adult fish depend on the dredge permit site for some stage in their life cycle. If that is found to be the case, then it may be necessary to consider windows during which dredging could not take place. Dredging will not occur from December 1 to March 31, therefore some protection is already afforded to whitefish and herring eggs and fry.

10.4 Substrate Characterisation

It will be important to monitor the character of the bottom over time to ensure that the sand is not removed to leave silt or clay. It is our opinion that alteration of the substrate towards a slightly coarser, more gravel and rock surface would be an improvement of fish habitat as it would provide more diversity and protection for fish eggs and invertebrates. Alteration towards a finer material would however be detrimental to the aquatic community. During the invertebrate surveys, we recommend that both photographs and cores be taken. Grain size analysis of the cores will determine whether the mean grain size is changing over time.

We suggest that the results of these monitoring studies be provided to the approval agencies by January of each year. In the final year of the permit a summary report should consider the results of all the monitoring studies, to examine the feasibility of extending the permit for a further 5 years.