# The Remediation Technologies Program
# Great Lakes 2000 Cleanup Fund

## TECHNICAL REPORT

Environmental Protection Branch - Ontario Region
Environment Canada

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# 1. INTRODUCTION

The Great Lakes have been negatively impacted by the discharge of industrial, agricultural and municipal pollutants over the past few decades. The governments of Canada and the United States have recognized that the accumulation of pollutants within bottom sediments and the water column has had a detrimental effect on the Great Lakes ecosystem.

In the 1970s, Canada and the United States entered into the *Great Lakes Water Quality Agreement*, which established common water quality objectives and confirmed their intent to preserve and protect the Great Lakes ecosystem. In 1985, the International Joint Commission, a binational agency designated to watch over the shared resources of the Great Lakes, identified 43 Areas of Concern where impaired water quality prevented full beneficial use of rivers, bays, harbours and ports. The *Great Lakes Water Quality Agreement*, amended in 1987, committed both countries to concentrate remediation efforts in these 43 Areas of Concern[1]. This led to the development of Remedial Action Plans (RAPs) to assess and remediate contamination problems.

## 1.1 The Problem

Sediment contamination problems have been identified in most Areas of Concern. Although the technology for dredging sediment is well established, contaminated sediment poses additional challenges. Conventional dredging technologies (including mechanical and hydraulic dredges) are not acceptable for the removal of contaminated sediment because of the potential for resuspension of material and sediment bound contaminants into the water column. The resuspended sediment may settle on fish spawning beds, affect the integrity of a wetland or be caught by water intakes. The sediment bound contaminants can even be assimilated by aquatic organisms and bioconcentrated in the food chain.

In addition to the environmental effects, contaminated sediment in our lakes and rivers can also have economic implications. When contaminated sediment is dredged for navigation purposes, extensive and expensive mitigation measures are often required to minimize the sediment dispersion from conventional dredging practices. There are several North American examples where port authorities have found themselves unable to complete navigational dredging due to the extent and magnitude of sediment contamination. This situation, leading to restrictions on port usage and significant loss of revenue, will not be resolved until environmentally acceptable alternatives to conventional dredging techniques are developed.

[1] In 1994, Collingwood Harbour, Ontario was the first Area of Concern to be delisted reducing the number to 42.

## 1.2 Cleanup Fund Programs

It became evident in the mid 1980s that if beneficial uses of water and biota in Great Lakes Areas of Concern were to be restored, remedial actions would have to be developed and implemented for contaminated sediment. Annex 14 of the 1987 *Great Lakes Water Quality Agreement* committed the United States and Canada to study the nature and extent of sediment contamination in the Great Lakes and to investigate opportunities for remediation.

In 1989, the Canadian government created the five-year $125-million Great Lakes Action Plan in support of the *Great Lakes Water Quality Agreement.* Of this, $55 million was allocated to a Cleanup Fund with a focus on the Canadian and binational Areas of Concern. A portion of the Cleanup Fund dollars was designated for the development and demonstration of technologies for assessment, removal and treatment of contaminated sediment. Consequently, three distinct programs were created by the Cleanup Fund:

- Contaminated Sediment Assessment Program (CoSAP)
- Contaminated Sediment Removal Program (CSRP)
- Contaminated Sediment Treatment Technology Program (CoSTTeP)

The latter two were established in order to encourage the development of innovative technologies for the remediation of contaminated sediment.

From 1989 to 1994, several innovative remediation technology demonstrations were performed by the CSRP. The success of those demonstrations led to merging CSRP with CoSTTeP to form the Remediation Technologies Program (RTP). Funded by the Great Lakes 2000 Cleanup Fund, the RTP is responsible for the management of innovative technology demonstrations for the remediation of contaminated sediment.

The establishment of partnerships was an integral part of each of the demonstration projects conducted by the CSRP and, later, the RTP. Financial contributions from the Great Lakes 2000 Cleanup Fund represented 33% or less of the total cost of a demonstration. The remainder came from other project partners.

Partners usually included municipalities, industries and other users of the Area of Concern; the provincial government; the Remedial Action Plan Team and/or Public Advisory Committee; the local conservation authority; the technology vendor and environmental consultants. These partners contributed financially and/or provided technical expertise or services as an in-kind contribution to the project.

Initially, the primary objective of both the CSRP and RTP was to identify and demonstrate innovative technologies for the removal, handling, transport, storage, pretreatment, and *in situ* management of contaminated sediment, which could eventually be used for full-scale cleanups in Canadian Areas of Concern. In 1994, commercialization was added to the RTP agenda as a second objective.

This Remediation Technologies Program Report has been prepared to describe the achievements of the RTP and its predecessor, the CSRP.

### 1.3 Organization of Report

The report provides an overview of the issues associated with the development and demonstration of sediment remediation technologies, with particular emphasis on sediment removal technologies.

Section 1.0 provides an introduction to the program and the issues. Overviews of the demonstration projects are described in Section 2.0. Environmental assessment requirements for the demonstrations are described in Section 3.0. Section 4.0 contains the monitoring and auditing procedures followed for assessment of the technologies. Section 5.0 describes the opportunities for application of these technologies, including commercialization. Conclusions about the success of the demonstrations and recommendations for future work are outlined in Section 6.0.

# 2. TECHNOLOGY DEMONSTRATIONS

## 2.1 Identification of Technologies

Given the environmental concerns associated with conventional dredging technologies, the goal of both the CSRP and RTP was to identify technologies to remove sediment from lake or river bottoms in an environmentally efficient manner. The identified technologies were assessed through field demonstrations at selected sites with contaminated sediment problems and results then incorporated into an inventory of sediment removal technologies.

The focus of the CSRP was on Areas of Concern with zones of sediment contamination that could potentially be handled by removal and treatment. These zones of contamination were termed "hot spots" due to the threat the contaminants posed to the health of the ecosystem.

In order to identify a preliminary list of innovative technologies for removing contaminated sediment, in April 1991, Environment Canada invited vendors to respond to a Request for Proposals (RFP). Criteria identified in the RFP outlined the parameters that constituted an innovative technology:

- Minimal resuspension
- Maximum solids content
- Good maneuverability
- Accurate positioning
- Mobile equipment
- Suitable for a variety of hydrodynamic conditions

Approximately 125 responses to the RFP document were received. This included 60 detailed proposals for removing, handling, transporting, pre-treating and treating of contaminated sediment. About one dozen of the respondents were manufacturers of innovative removal technologies.

As a result of this proposal call, a variety of equipment and technologies suitable for removing contaminated sediment were identified, categorized and inventoried. In addition, equipment from other sectors (e.g., mining, forestry, and agriculture) with potential applicability for environmental dredging was also identified.

In 1991, a team of officials from Environment Canada, Public Works Canada, the Ontario Ministry of Environment and other government agencies selected appropriate Areas of Concern for demonstration of the innovative technologies. Collingwood Harbour, Hamilton Harbour and Port Hope Harbour Areas of Concern were chosen as the first demonstration sites. These areas had a range of sediment problems and were geographically diverse.

After extensive discussions with potential partners, the Port Hope Harbour demonstration was deferred. This decision was largely due to ongoing federal Siting Task Force activities relating to the historic low-level radioactive wastes at that location.

Hamilton and Collingwood demonstrations were carried out in 1991 and 1992, respectively. Relying on insights gained from the proposal submissions and these two demonstration projects, additional demonstrations were carried out. Technology vendors for demonstration projects were identified either through unsolicited proposals or in response to further RFPs. Annual workshops were also held in order to facilitate information exchange on technological developments and to promote commercial and public sector participation in the CSRP and RTP.

By 1996, 10 remediation demonstrations had been completed in various Canadian Areas of Concern. These demonstrations, listed in Table 1, involved five unique removal technologies and one *in situ* management approach. In some instances the demonstrations involved only the removal components while others included transportation and treatment of the material.

**Table 1: Technologies and Demonstration Locations (1991–1995)**

| Location | Cable Arm | Mud Cat | Pneuma Pump | Visor Grab | Amphibex | Capping |
|---|---|---|---|---|---|---|
| Hamilton | ✓ 1991<br>✓ 1992 | | | | | ✓ 1995 |
| Welland | | ✓ 1991 | | | ✓ 1995 | |
| Toronto | ✓ 1992 | | | | | |
| Collingwood | | | ✓ 1992<br>✓ 1993* | | | |
| Penetanguishene | | | | ✓ 1994 | | |
| Scarborough | | | | | ✓ 1995 | |

* *Commercial operation observed by CSRP.*

A map of the locations has been included as Figure 1.

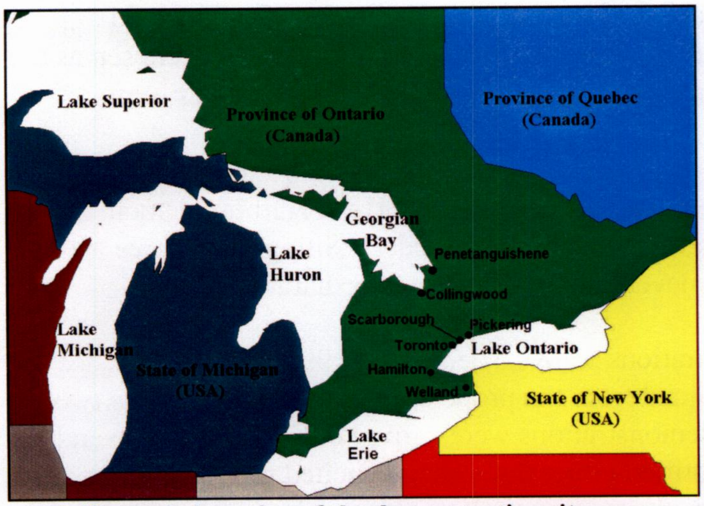


**Figure 1: Location of the demonstration sites**

In some cases, the demonstrations resulted in the commercial use of the technologies on the Great Lakes. For example, Ontario Hydro selected the Cable Arm Environmental Bucket for use at the Pickering Nuclear Generating Station.

The following sections provide descriptions of the different technologies identified either as a result of unsolicited proposals or through the Request for Proposal process described earlier.

## 2.2 Cable Arm Environmental Bucket

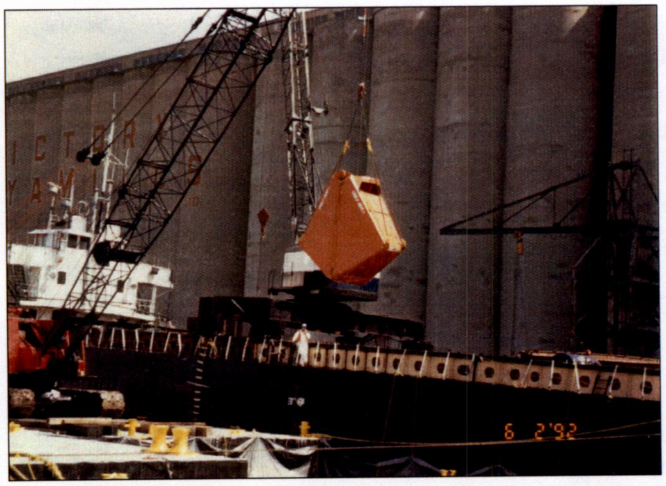

**Figure 2: View of Cable Arm Environmental Bucket**

The Cable Arm Environmental Bucket, manufactured by Cable Arm (Canada) Inc., is a precision clamshell aggregate bucket, which removes contaminated material with less disturbance than a conventional bucket. The Cable Arm was the first innovative dredging technology demonstrated by the CSRP. A distinctive characteristic is the use of cables anchored at the four corners of the bucket as opposed to the traditional winch and pulley system common to conventional dredging buckets. Additionally, the closing profile of the bucket results in a unique level cut instead of a pothole, typical of conventional buckets. A photograph of the Cable Arm Environmental Bucket is given as Figure 2.

### 2.2.1 Hamilton Harbour

The first demonstration was carried out in Hamilton Harbour, Ontario. Hamilton Harbour serves a large heavily industrialized urban area. Like other major cities on the Great Lakes, the harbour receives contaminants and sewage discharge from many sources. Some of the sediment found on the bottom of the harbour contains toxic organic compounds, such as Polycyclic Aromatic Hydrocarbons (PAHs).

The demonstration site was located at the south end of the harbour. This demonstration had two objectives: to test the effectiveness of the Cable Arm Environmental Bucket, and to obtain 8 cubic metres ($m^3$) of sediment with very high levels of PAH for use in the demonstration of a treatment process developed and owned by Eco Logic.

Although the Cable Arm performed as expected, it became apparent from the evaluation that modifications would improve the operational performance. The demonstrated technology was an open bucket, similar to conventional open clamshell buckets. Observations showed spillage of material from the top opening of the bucket. This created a visible plume of suspended sediment in the water. It became evident that a closed bucket would be more effective at containing the dredged material, thus reducing sediment resuspension.

### 2.2.2 Toronto Harbour

As a result of the Hamilton Harbour demonstration, owners of the Cable Arm enclosed the bucket. In addition, they incorporated vents into the sheaves to permit the decanting of water trapped above the sediment after the sheaves were closed. Rubber seals around the sheaves were also added to prevent the loss of sediment due to improper closure around trapped debris.

The CSRP did not pay for these modifications but agreed to pay one-third of the cost of demonstrating this innovation. The Parliament Street Slip in Toronto Harbour, Ontario, was chosen as a demonstration site for evaluating the enclosed bucket for the following reasons:

- The slip contained sediment that had marginal to moderate contamination levels of heavy metals
- Sediment in the slip did not have high concentrations of organics
- The slip could be closed off from the harbour if spillage of sediment occurred

In June 1992, 250 $m^3$ of marginally contaminated sediment was removed at approximately 49% solids (dry weight). The cycle time averaged 17 cycles per hour, in approximately 8m of water. The sediment, in the form of sludge, was treated at the Toronto Harbour Commission's Soil Recycling Pilot Plant.

The demonstration indicated the significant potential of the Cable Arm. The percentage of solids in the 250 $m^3$ of removed sludge demonstrated that this bucket had the capability to remove sediment at approximately the *in situ* water content.

Results also indicated a long cycle time throughout the demonstration. It is believed that with proper operator training, the cycle time could be reduced to anywhere between 1–1.5 minutes. As a result of this demonstration, it was concluded that further testing in an open water area with greater sediment contamination would be beneficial.

Additional modifications to the Cable Arm Environmental Bucket were identified:

- Addition of neoprene and gasket seals to provide a positive seal during closure
- Use of inner side plates to reduce the lateral movement of sediment
- Use of an external reeving system to eliminate sediment contact
- Addition of an epoxy coating on the bucket to reduce coal tar adhesions
- Use of independent seal ports to maximize solids content for different sediment cuts

### 2.2.3 Hamilton Harbour

In the summer of 1992, an area with very high PAH concentrations was identified in Hamilton Harbour. Black tarry material was found on the surface of sediment in the study area. As a result, the CSRP co-ordinated the removal of the top 20 centimetres (cm) of sediment. The demonstration assessed the ability of the Cable Arm Environmental Bucket to dredge in deeper waters and to perform "horizontal cuts" or "surgical dredging" in highly contaminated sediment. The demonstration was also used to obtain harbour sediment for the Grace Dearborn bioremediation demonstration in Hamilton Harbour.

The Cable Arm successfully achieved horizontal level cuts of ±5 cm deviation from the vertical. In total, this demonstration resulted in the removal of 150 $m^3$ of sediment from Hamilton Harbour's Randle Reef. Contaminated sediment was removed, transported in lugger boxes and off-loaded to the treatment facility. The Cable Arm proved particularly impressive in its ability to minimize sediment disturbance and handle the off-loading of material.

The solids content ranged between 44%–48%, while cycle times averaged approximately 2.5 minutes. Site evaluation and monitoring showed that the bucket met, and in some cases surpassed, operational and performance standards established by the program for field testing of the technology.

The Hamilton Harbour and Toronto Harbour demonstrations highlighted the commercial suitability of the Cable Arm for environmental use. It was also concluded that the Cable Arm could compete favourably with conventional dredging technologies for navigational and recreational dredging projects.

Based on the positive results of these demonstrations, the Cable Arm Environmental Bucket was selected by Ontario Hydro for use at the Pickering Nuclear Generating Station in Ontario. The Cable Arm was used to remove sediment from the cooling water intake channel. The technology is now being commercially marketed.

### 2.2.4 Mud Cat

**Figure 3: Modified MC 915-ENV**

The Mud Cat dredge, manufactured by Ellicott International (Ellicott) of Baltimore, Maryland, was designed to operate in shallow marine environments. It features an effective sediment removal system consisting of a boom-mounted horizontal auger and a centrifugal slurry pump. The specially prepared MC-915 ENV dredge incorporated modified components designed to minimize the resuspension of contaminated sediment while maximizing the solids content of the dredged material. The dual convergence of the horizontal auger head, with an enclosed housing for the auger, is the principal component to minimize sediment resuspension. Other mechanical components included hydraulic vibrators to supplement the excavation, and removable front screens to restrict oversized material from obstructing the system. The hydraulic forward tilt and manual transverse tilt of the truss boom and ladder are useful for accommodating sloped lake or river bottoms. Figure 3 is a photo of the modified MC 915-ENV.

### 2.2.5 Welland River

In June 1991, Atlas Specialty Steels of Welland, Ontario approached Environment Canada to work together under the CSRP to remediate contaminated sediment in the Welland River. The demonstration involved the controlled removal of 127 $m^3$ of industrial mill scale and contaminated sediment, using a modified Mud Cat MC 915-ENV.

The remediation of river bottom sediment poses different challenges than that of lake bottom sediment. Removal operations must tackle not only an uneven bottom surface, but also the turbidity and sediment resuspension caused by river currents and fluctuating water flow.

The solids content of the pumped slurry was initially quite low (2.1%). This was largely due to the nature of the dredged material, which necessitated frequent starts and stops to flush the pipeline. In addition, a generally cautious approach was adopted to the dredging to minimize environmental impacts. The removal of the intake screen increased the average solids content to 3.7%; however, it also resulted in frequent blockages of the dredge intake or pump. The removal of the dredge head shroud resulted in the highest overall average solids content of 4.4%.

The demonstration showed that the Mud Cat technology can meet operational and performance specifications developed by the RTP for river sediment removal. The successful performance of the Mud Cat dredge in the Welland River contributed to its selection by the Province of Nova Scotia for a multi-million dollar long-term project for the removal of contaminated sediment in the Sydney Tar Ponds in Nova Scotia.

## 2.3 Pneuma Pump

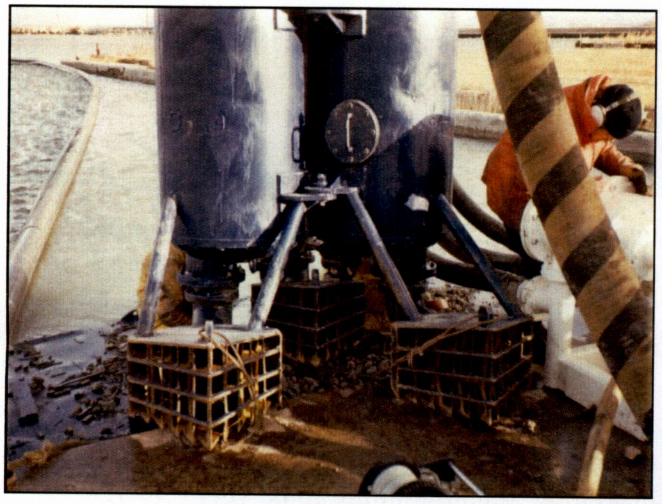

**Figure 4: Pneuma Pump used in Collingwood**

The Pneuma Pump is manufactured by Pneuma s.r.l. It uses static water head and compressed air inside special cylinders. When the cylinders are full, the sediment is forced up a delivery tube by compressed air. As the cylinder empties, the compressed air is discharged, thus releasing the internal pressure of the cylinder. The vacuum is once again applied causing the cylinder to refill with the slurry as the procedure repeats again. The pump has no rotating parts or mechanisms in contact with the sediment, minimizing resuspension problems. A photograph of the Pneuma Pump is presented in Figure 4.

### 2.3.1 Collingwood Harbour

In the summer of 1991, the Collingwood Harbour Remedial Action Plan Team approached the CSRP to conduct a sediment removal demonstration in Collingwood Harbour. The intent was to follow the demonstration project with a full-scale cleanup that would ultimately result in the delisting of Collingwood Harbour as an Area of Concern. In response to the request, the CSRP selected the Pneuma airlift pumping system (Pump #150/30) for the demonstration/cleanup of Collingwood Harbour in 1992.

During the two week demonstration, 1,800 $m^3$ of sediment was removed from the west slip of the harbour. The solids content in the slurry varied from 15%–30%.

Medium and large sized debris from historical ship building activities caused numerous and lengthy down times for cylinder cleanups. It was concluded that the Pneuma Pump was successful in removing contaminated sediment in areas where there is limited debris.

### 2.3.2 Collingwood Harbour Cleanup (1993)

In 1993, after a public tendering process, Voyageurs Marine Construction Co. Ltd. of Dorion, Quebec, used the Pneuma Pump for the cleanup of approximately 10,000 $m^3$ of contaminated sediment in Collingwood Harbour. The removal operation was carried out from November 24–December 8, 1993.

The barge-mounted dredge was set up with guide cables extending across the harbour channel. The dredge was advanced across the channel at an average speed of approximately 4–5 m per minute using a winch system. The material was pumped to a confined disposal facility approximately 1 km from the removal site.

Although the project was of a commercial nature, the CSRP observed the Pneuma Pump operation. Sediment resuspension was monitored by the project manager. The performance and water quality results showed the Pneuma Pump to be very effective at removing contaminated sediment.

After cleanup, Transport Canada used the Pneuma Pump to supply fill and cap material for a confined disposal facility in Collingwood Harbour, with excellent results achieved ahead of schedule. This operation played an important role in the delisting of Collingwood Harbour as an Area of Concern, the first to be delisted in North America, and paved the way for a return to recreational use of the harbour.

## 2.4 Visor Grab

**Figure 5: Visor Grab used in Penetanguishene**

HAM Dredging (The Netherlands) developed the Visor Grab, an innovative sealed bucket. The Visor Grab consists of a standard backhoe bucket with a controlled visor, operated by hydraulic cylinders located on each side of the bucket. The bucket can be used on standard excavators such as a Caterpillar 235 (or larger) and Hitachi 300 (or larger). The bucket has a capacity of 1.5 $m^{3.}$ The cycle time is dependent on the driving machine, the operator and the water depth. Figure 5 is a photograph of the Visor Grab.

### 2.4.1 Severn Sound

Severn Sound, located in the southeastern portion of Georgian Bay, is composed of a group of bays including Penetang Bay, Midland Bay, Hog Bay, Sturgeon Bay and Matchedash Bay. In 1989, the Severn Sound RAP team conducted a survey of nearshore fish habitat in Penetang Bay. An area of shoreline in the south end portion of the bay was identified as providing poor habitat and requiring restoration. In 1993, a rare wind-induced water level change lowered the water level by one metre, exposing several hectares of degraded fish habitat (approximately 300 m x 200 m) in the shallow nearshore area of the bay. Logs, wood slabs and sawdust covered the area.

In early 1994, a partnership was established between the Town of Penetanguishene, the Severn Sound RAP team and the Great Lakes 2000 Cleanup Fund's RTP, to provide funding and expertise to help restore valuable fish and wildlife habitat to a section of Penetang Bay.

Approximately 4000 $m^3$ of wood wastes were removed. Ninety per cent of the waste was removed using a grapple fork, while the remaining wastes were removed as part of a Visor Grab demonstration. The Visor Grab was used in Penetanguishene to test its applicability at removing sediment while minimizing sediment resuspension.

In total, 19 hours were devoted to the removal of approximately 375 $m^3$ of sawdust and clay. In that 19-hour period, approximately five hours were devoted to transport and off-loading of material. Therefore, the total duration of the removal period was 14 hours. The average production rate was approximately 27 $m^3$/hr. The average cycle time was approximately 55 seconds, with the solids content averaging approximately 40%.

Even though most of the large debris was removed from the area with the grapple fork prior to using the Visor Grab, some pieces of wood were still present. These leftovers prevented the Visor Grab from sealing completely. In fact, approximately 70% of the bucket loads were not sealed because of debris.

Sawdust and fine particles, such as clay, tend to resuspend easily and remain in suspension longer than coarser particles, such as sand and gravel. An accumulation of easily resuspended material occurred in the confined area throughout the duration of the project. The results indicated that this resuspended material took approximately one week to settle. Also, very little material exited the confined area since the turbidity immediately outside the silt curtain[2] was always comparable to ambient conditions.

[2] A silt curtain is a geotextile fabric that hangs in the water on floating tubes, effectively enclosing the dredging area. This provides a barrier, isolating any resuspended sediment from the water body outside of the immediate dredging area.

The demonstration proved that that the Visor Grab, with some minor modifications, has the potential to be used to clean up other Areas of Concern.

## 2.5 Amphibex

**Figure 6: Amphibex dredge used in Scarborough**

Normrock Industries' Amphibex is a barge equipped with spuds, stabilizers and an excavator. The hydraulic arm has pumps located on its bucket. This unusual position of the pumps allows the Amphibex to hydraulically dredge sediment without requiring any negative pressure (suction). Only positive pressure is applied to the slurry, resulting in higher solids content and less excess water brought to the treatment site. A photograph of the Amphibex is shown as Figure 6.

### 2.5.1 Scarborough

In May 1995, the Amphibex dredge was used for a demonstration at Bluffers Park in the City of Scarborough, Ontario. This area is part of the Metropolitan Toronto and Region Area of Concern. The dredging site, Bluffers Park embayment, covers an area of approximately 200 m x 125 m (25,000 $m^2$).

The demonstration project involved the excavation of 35,000 $m^3$ of unconsolidated bottom material consisting mainly of loose clayey silt overlying fine to coarse sand.

The project was evaluated under three different scenarios:

- At the early stage of the project when an old hydraulic bucket was used
- After 188.5 hours when a hydraulic bucket was placed on the Amphibex and used at high rotations per minute (RPM)
- After 200 hours with low RPM pumping

The results indicated that with the old bucket the production rate and solids content in the slurry were 16.2 $m^3$/hr and 11.7%, respectively. With the new bucket at a high RPM, the production rate and solids content in the slurry were 46.7 $m^3$/hr and 33.6%, while at low RPM they were 49.5 $m^3$/hr and 35.6%.

This demonstration proved the versatility and the great potential of the Amphibex. As a result, it was selected for use in the Welland River later the same year.

### 2.5.2 Welland River

In the fall of 1995, the RTP partnered with Atlas Specialty Steels, the Ontario Ministry of Environment and Energy, the City of Welland and the Regional Municipality of Niagara to perform a full-scale removal and treatment demonstration.

The sediment to be removed was located offshore from the McMaster Avenue municipal sewer outfall and about 0.5 km downstream at an industrial outfall. Past discharges have resulted in accumulations of reef-type deposits of oily, black, granular metallic industrial mill-scale.

The dredged material was transported in a slurry form via pipeline to an in-line screening system. The in-line screening system was the first of a two-part treatment train, selected as the preferred treatment option. The screened slurry was then discharged into settling basins. Final treatment of the effluent from the settling basins took place at Atlas' North Water Filtration Plant prior to discharge to the river.

Approximately 10,000 $m^3$ of sediment was removed. The production rate varied from 13 to 120 $m^3$/hr as a result of three main factors:

- Quantity of man-made debris
- Quality and thickness of the sediment
- Pumping distance and total head

Extensive debris such as shopping carts, bicycles, cans and steel rods were found near the outfalls. This material had to be removed using a long reach excavator. Once the bulk of the debris was removed, production increased.

The quality of the material greatly contributed to the production rate. Pumping of heavy mill-scale required the addition of excess water in order to provide the necessary velocity for transport to the treatment plant.

Distance was also a contributing factor to the production rate. The McMaster Avenue area was located 1.5 km from the treatment plant, while the sewer outfall area was located 1 km from the plant. The results indicated that the production rate was lower at the McMaster Avenue site.

Turbidity was measured on site to establish shut-down criteria for the dredging operation. Results indicated that the ambient level fluctuated greatly with weather conditions. The ambient turbidity level was generally below 40 FTU. Turbidity measurements downstream of the dredge indicated only one instance of the guideline being exceeded (an increase of approximately 30 FTU from ambient level). During the final six weeks of the project, the weather conditions varied greatly, having an effect on river currents which in turn affected the silt curtain.

The Amphibex was less expensive than conventional technologies, met all regulatory requirements, and satisfied operational and performance standards identified by the RTP, making it attractive to other potential users.

### 2.6 Capping

Most of the demonstrations performed through the RTP involved removal. An alternative procedure for the remediation of contaminated sediment is *in situ* capping. Sediment capping has been performed in Japan, Europe and the United States; however, it has had limited use in the Canadian Great Lakes. Advantages to this procedure are numerous, compared to dredging. Capping eliminates the need for treatment or disposal, making it a less expensive option. Water depths, ship movement, bottom disturbance and currents restrict suitable environments for *in situ* capping.

#### 2.6.1 Hamilton Harbour

**Figure 7: View of capping operations**

In 1995, Environment Canada carried out a sediment capping demonstration off the north shore of Hamilton Harbour. A photograph of the capping operations is shown as Figure 7. A zone measuring 100 m x 100 m was delineated for the demonstration.

Water depths ranged from 12– 17m at this location. Sediment consisted of 30 cm of very soft black silty clay, with elevated levels of metals, underlain by natural harbour sediment (very soft grayish brown silt and clay).

Water quality was monitored during cap placement. Turbidity results during operations indicated the presence of plumes associated with the sand cap material.

Sediment capping is a long-term solution and therefore requires evaluation over several years. Only preliminary results were available at the time of this report.

Preliminary results suggest that the sand cap was successfully placed in the targeted area. It is expected that the cap will maintain its effectiveness for many years.

# 3. ENVIRONMENTAL ASSESSMENT AND PUBLIC CONSULTATION ACTIVITIES

## 3.1 Environmental Assessments

In order to determine the potential for environmental effects, technology demonstrations required assessment before implementation. Prior to 1995, assessments were conducted under the Environmental Assessment and Review Process (EARP). In January 1995, EARP was replaced by the Canadian Environmental Assessment Act (CEAA).

Environmental assessment requirements were triggered because of federal initiatives and dollars and, in some instances, because federal lands and permits were involved in the demonstration projects. Assessments under EARP and CEAA involved the compilation of site and project information, an evaluation of predicted effects of the project, appropriate mitigation measures and an assessment of the significance of any effects remaining following the implementation of these measures. The assessment documents also served as background information to seek approvals under other applicable legislation.

## 3.2 Public Involvement

Partnerships with the RAP teams from the respective Areas of Concern were established for each demonstration project. All RAP teams have Public Advisory Committees (PACs) which are composed of community members. The PAC members played an important role in the review of each demonstration. Communication with the general public was achieved through ongoing RAP and PAC activities and through special events. Open houses were held in advance of each of the demonstrations to disseminate information and to provide a forum to address questions and concerns. Following each of the open houses, a 15-day comment period was provided to allow the public to raise any subsequent related issues.

# 4. MONITORING AND AUDITING

Operational and performance criteria were developed by the CSRP to evaluate the success of each demonstration project. These criteria were applied to ensure that the technologies operated in compliance with environmental regulatory agency requirements related to water quality protection, and fish and wildlife habitat losses.

## 4.1 Water Quality Monitoring

**Figure 8: Remotely operated vehicle used to survey study sites**

In order to assess the technologies against operational and performance criteria and environmental standards, a water quality monitoring program was implemented for each demonstration. This included both water sampling and *in situ* measurements. Figure 8 shows the use of a remotely operated vehicle used to survey the demonstration sites.

Water quality monitoring at each site was customized to account for variables such as:

- Weather (precipitation and wind)
- Current and flow
- Seiches
- Bathymetry
- Existing water quality
- Existing sediment quality

Water quality monitoring was initiated prior to the commencement of each demonstration in order to establish ambient water quality conditions, and continued throughout. The number of monitoring stations was specific to each demonstration location. Water sampling stations were established 10 m, 25 m and 100 m from the dredge head and 10 m outside the silt curtain.

Turbidity was the most regularly monitored water quality parameter. Real-time turbidity measurements were obtained through use of electronic sensors, providing a quick, regular measurement of the quantity of material resuspended during dredging operations.

## 4.2 Operational and Performance Criteria

Operational and performance criteria were developed for each of the three phases of the demonstration projects:

- Sediment removal
- Sediment transport
- Pre-treatment

These criteria, presented in Table 2, provided guidelines during the audit of each of the demonstration projects.

## 4.3 Technology Evaluation

The operational and performance criteria noted above were used to evaluate the various removal technologies. This evaluation was both site- and technology-specific. Comparing pre- and post-dredging depth sounding results also assessed effectiveness of the technology. These soundings allowed for the estimation of the volume of material removed as well as the rate of removal (or production rate).

For mechanical dredges, production rates were also calculated by estimating bucket capacity, truck loads and/or barge loads.

## Table 2: Operational and Performance Criteria

| | |
|---|---|
| **1. Sediment Removal Phase** | |
| Turbidity: | Turbidity beyond a distance of 25 m of the actual removal location shall not exceed ambient levels by more than 30%. |
| Suspended Solids: | Beyond 25 m from the actual removal location, suspended solids shall not exceed ambient levels by more than 25 mg/l. |
| Total Organic Carbon: | Total Organic Carbon (TOC) content should be within the range of 0.4 to 27 mg/l in surface water beyond 25 m of the removal operation. TOC shall not exceed background levels by more than 30% when background concentrations are greater than 27 mg/l. |
| No Overflows or Leaks: | A minimum freeboard of 1 m must be maintained in the hopper after placement of the excavated sediment. The hopper must be sealed for transport to the pre-treatment and/or disposal site. |
| Removal Efficiency: | The solids content of the excavated material should be at least 30% by volume. For mechanical dredges, this involves sampling. For hydraulic dredges in-line sensors measured the density of the slurry. |
| Effluent Quality: | Maximization of solids removal is paramount. Solids suspended in the slurry mixture must be removed by either mechanical or chemical means. If the extracted material is fine-grained, provision should be made to treat the effluent. |
| Production Rate: | The production rate of the sediment removal equipment should be adjusted to allow for sufficient settling such that the effluent can meet the Provincial Water Quality Objectives (PWQOs). Therefore, the feed rate of the excavated material to the holding facility should be adjusted to ensure adequate settling time. |
| **2. Transport Phase** | |
| No Overflows or Leaks: | No overflows or leaks of excavated material shall be allowed during transport to the disposal or pre-treatment area. Use of pipelines or other fully closed transport media is encouraged. |
| Transport Rate: | The rate of material being transported must be adjusted to meet the handling capacity of the pre-treatment or disposal facility. |
| Contact: | No contact is permissible between the contaminated sediment and human, bird and aquatic life. |
| **3. Pre-Treatment Phase** | |
| Effluent Quality: | Effluent quality of the supernatant water and effluent from the pre-treatment process should meet applicable federal and provincial standards and guidelines. |
| Waste Handling: | All wastes from the pre-treatment process should be handled and disposed of in accordance with appropriate federal and provincial regulatory requirements. |

# 5. COMMERCIALIZATION

In 1994, the federal government launched the Canadian Environmental Industry Strategy to promote, facilitate and encourage the commercialization of the Canadian environmental industry.

In 1993, the CSRP emphasized its support for commercialization of tested remediation technologies by matching appropriate technologies to specific problems. As a result, several technologies were awarded contracts by industry and government both domestically and internationally. An overview of these successes follows.

## 5.1 Cable Arm Environmental Bucket

The Cable Arm Environmental Bucket, manufactured by Cable Arm (Canada) Inc. of Pickering, Ontario, evolved from a grab bucket used for the loading and unloading of bulk cargoes. The environmental principles incorporated into the bucket design allow for increased efficiency and minimal environmental impact.

**Figure 9: View of Pickering operations**

As a result of the successful demonstration in Toronto and Hamilton Harbours in 1992, the Cable Arm Environmental Bucket won significant commercial dredging contracts. These have included sediment removal at Pickering Nuclear Generating Station in Ontario (Figure 9); a commercial contract for a demonstration by Ford Motor Company, in Michigan's Rouge River; and for the cleanup of an accidental spill in the St. Clair River at the Dow Chemical facility in Sarnia, Ontario. In 1996, Reynolds, in Massena, New York decided to remediate their section of the Massena Superfund Site. The project, still under development (1998), has chosen Cable Arm as the preferred dredging option. Cable Arm has also been used in Ohio, Georgia and San Francisco Bay. The Vancouver Port Corporation has recognized the capabilities of the Cable Arm Environmental Bucket by including the technology in their dredging specifications.

## 5.2 Pneuma Pump

The Pneuma Pump dredging technology, developed by a consortium of three companies (two Canadian and one Italian), was demonstrated successfully in Collingwood Harbour in 1992. As a result, the technology was then used in a full-scale removal project in Collingwood, managed by Environment Canada, and funded by a group of participating partners. Transport Canada has subsequently used the pump commercially in Collingwood to supply fill and cap material in the harbour. A similar pumping system has been used by the City of Santa Barbara, California, to maintain water levels in Gibraltar Lake, which supplies the city with water. The Pneuma Pump has also been awarded a contract involving sediment removal at the Three Gorges dam on the Yangtze River, China.

## 5.3 Amphibex

The Amphibex amphibious excavator was developed and manufactured by Normrock Industries Inc., of Terrebonne, Quebec. It is a combination backhoe and hydraulic suction dredge, giving it both hydraulic and mechanical capability. The Amphibex has proven to be less expensive than conventional technologies, and also more versatile.

In 1995, Environment Canada conducted successful demonstrations of the Amphibex in the Welland River and at Bluffers Park in Scarborough, Ontario. The Amphibex has been used for debris removal in the South Nation River, Ontario and for navigational dredging at Pigeon Hill, New Brunswick. A Northern Ontario mining company is using the Amphibex for secondary recovery of gold from tailings pond sediments.

## 5.4 Mud Cat

The Mud Cat dredge, used in the 1991 Welland River demonstration, is owned and operated by Auburn Contractors Incorporated, Sudbury, Ontario. The successful demonstration in the Welland River led to the Government of Nova Scotia using the technology for the multi-year cleanup of the Sydney Tar Ponds.

The manufacturers are considering incorporating the successful principles, demonstrated by the removal program, into their production models. The demonstrated innovations are not only environmentally friendly and economically sound, but also have commercial application here and abroad.

## 5.5 SEDTEC – Sediment Technology Directory

As noted earlier, a specific objective of the CSRP and the RTP was to develop an inventory of available remediation technologies for managing contaminated sediment. Environment Canada has used this knowledge and expertise to produce **SEDTEC**, a commercial directory of contaminated sediment removal and treatment technologies (Figure 10).


**Figure 10: Presentation screen from SEDTEC**

**SEDTEC** is a user-friendly computer software product, listing hundreds of technologies for the removal and treatment of contaminated sediment. In addition, **SEDTEC** documents treatment technologies for contaminated soil and sludge. **SEDTEC** is specifically designed for the environmental community and related industries, domestically and globally.

Based on a worldwide inventory of manufacturers and vendors, **SEDTEC** is used to identify technologies for site-specific remediation initiatives. It outlines:

- Costs and operational efficiencies of specific technologies
- Lists contacts for technology auditors
- Project funding agencies
- Technology manufacturers and vendors worldwide
- Case studies of completed projects

This directory includes photographs and schematics of many innovative technologies. **SEDTEC** is the first computer software product available worldwide to include such detailed information on both removal and treatment technologies.

**SEDTEC** was released as a commercial product on CD-ROM and diskette in the summer of 1996. It is a highly effective tool for those who need information on sediment remediation. It is also beneficial for people in industry keen to gain a competitive advantage by accessing up-to-date data on advancements in their field.

### 5.5.1. Beyond SEDTEC

Environment Canada, through CSRP and RTP, has become a worldwide leader in the provision of information on sediment remediation. In recognition of this national and international interest, Environment Canada provides the following services:

**Project Management:**

RTP specialists are available to provide project management related to:

- Problem delineation
- Data analysis
- Remedial options identification
- Cost evaluation
- Definition of project goals
- Funding negotiation and partnership
- Technology selection
- Environmental assessment
- Public consultation
- Formulation of scope of work documents
- Technology audits for implementation
- Follow-up

**Workshops and Seminars:**

RTP specialists are available to conduct general or site-specific workshops and seminars to address:

- Pollution prevention initiatives
- Regulatory and corporate liability issues
- Phased remediation strategies
- Financial management of projects
- Implementation issues for remedial activities (including communication strategies)

# 6. CONCLUSIONS AND RECOMMENDATIONS

Environment Canada's demonstration projects, carried out by the Contaminated Sediment Remediation Program and Remediation Technologies Program, clearly illustrate that innovative solutions exist to remediate sediment contamination problems in ports, harbours and degraded fish and wildlife habitats.

The Programs' achievements to date demonstrate that the development of innovative technologies is economically viable in Canada and internationally. The Cable Arm Environmental Bucket is considered the most advanced in the world and one of the preferred options for environmental dredging. The Amphibex has proven that innovative technologies can be productive, versatile and less expensive than conventional technologies. The Visor Grab is used worldwide for various dredging projects. The Pneuma Pump is capable of working at great depths and of pumping large distances. The Mud Cat dredge is one of the most popular portable hydraulic dredges. All the above technologies meet Environment Canada's environmental and performance criteria.

Now that new, progressive technologies are available to assist in the remediation of contaminated sites, the information gathered and expertise gained through demonstrations will benefit the global scientific community. An ideal way to reach this constituency is to ensure that **SEDTEC** has the widest possible distribution and by marketing the consultant services of the RTP team. To restore impaired areas, it is essential that remediation specialists have access to the best technology and expertise.

By tackling these issues of remediation and restoration, Environment Canada's Great Lakes 2000 Cleanup Fund is working to fulfil the 1994 Canadian Environmental Industry Strategy to promote environmental technologies, products and services as a major component of Canada's vision for healthy, sustainable economic growth.