NORTHERN WOOD PRESERVERS SEDIMENT REMEDIATION CASE STUDY

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ABSTRACT
Contaminated sediments are recognized as significant contributors to impaired water quality in the Great Lakes. Thunder Bay Harbour sediment contamination of polycyclic aromatic hydrocarbons (PAHs), chlorophenols, dioxins and furans around Northern Wood Preservers contributed to the International Joint Commission's (IJC) identification of the Harbour as an Area of Concern. A biological assessment study was conducted to establish site specific clean up criteria. Based on measured biological effects related to PAHs, three cleanup zones were identified corresponding to areas of acute toxicity, chronic toxicity and no measurable toxicity. The project, referred to as the Northern Wood Preservers Alternative Remediation Concept (NOWPARC), is a plan to isolate the contaminant source, clean-up the contaminated sediment, and enhance fish habitat. Extensive public consultation was undertaken to ensure public acceptance of the plan.

RÉSUMÉ
Il est reconnu que les sédiments pollués contribuent de façon importante à la dégradation de la qualité de l'eau des Grands Lacs. La contamination des sédiments du Port de Thunder Bay par les hydrocarbures aromatiques polycycliques (HAP), les chlorophénols et les dioxines et furannes près de la Northern Wood Preservers a joué un rôle décisif lors de l'identification de ce port comme secteur préoccupant par la Commission Mixte Internationale. On a effectué une évaluation biologique afin d'établir des critères d'assainissement de ce site. En se basant sur les mesures des effets biologiques associés aux HAPs, on a définit trois zone de nettoyage qui correspondent aux secteurs de toxicité intense, de toxicité chronique et de toxicité non mesurable. Le projet, référé en anglais sous le nom *Northern Wood Preservers Alternative Remediation Concept (NOWPARC)*, consiste en l'isolation de la source de pollution, au nettoyage des sédiments contaminés et à l'amélioration de l'habitat du poisson.

1. INTRODUCTION

Sediments have been identified as a major repository for contaminants that enter our lakes and rivers.

Over the past two decades, elevated levels of polycyclic aromatic hydrocarbons (PAHs), chlorophenols (CP), dioxins and furans (PCDD/F) have been found in sediments adjacent to Northern Wood Preservers in Thunder Bay Harbour. PAHs, CP and PCDD/F are of concern because they are persistent, toxic and can bioaccumulate. In sufficient concentration and with sufficient exposure periods, there is potential to harm a wide variety of life forms, including humans. PAHs (as creosote) and pentachlorophenol are used in wood preserving. PCDD/F are a by-product of combustion reactions and historically, were contaminants formed during the production of some pentachlorophenols.

Contaminated sediments are recognized as significant contributors to impaired water quality in the Great Lakes. Sediment contamination around Northern Wood Preservers contributed to the International Joint Commission's (IJC) identification of Thunder Bay Harbour as an Area of Concern. In order to delist Thunder Bay Harbour as one of the IJC's Areas of Concern, government agencies, industry and the public have partnered to develop a Remedial Action Plan (RAP) that identifies water use goals and initiatives for the remediation of the harbour. The remediation of contaminated sediment at Northern Wood Preservers is a key element of this plan.

A sediment and biological assessment study was undertaken to establish site specific clean up criteria. Based on this study, three zones of distinct biological effects were identified. This finding lead to the finalization of the sediment remediation plan known as Northern Wood Preservers Alternative Remediation Concept (NOWPARC). The plan is to isolate the contaminant source, remediate the contaminated sediment, and enhance fish habitat.

Abitibi Consolidated Inc., Northern Wood Preservers Inc., and Canadian National Railway Co., along with Environment Canada and Ontario Ministry of the Environment (MOE) have funded this remediation project to address contaminated sediment around Northern Wood Preservers.

NOWPARC involves the following components:

- Environmental Monitoring
- Rockfill Containment Berm
- Environmental Dredging
- Sediment Treatment
- Isolation of on site contaminants
- Groundwater Treatment Plant
- Fish Habitat Compensation
- Post Construction Monitoring

The NOWPARC project is directed by a Steering Committee comprised of a senior representative from each of the five organizations. An Implementation Committee comprised of technical specialists from the participating organizations advises the Steering Committee.

The RAP team's Public Advisory Committee (RAP-PAC), has played a key role in the development and refinement of NOWPARC. Their support of NOWPARC was critical for its success. This remediation project is one of many initiatives aimed at achieving many of the Water Use Goals set out by the Thunder Bay Harbour RAP team.

2. BIOLOGICAL ASSESSMENT STUDY

The need for cleanup was based on biological effects determined through a combination of benthic community assessment and laboratory sediment bioassays. The determination of cleanup criteria was based on a three step evaluation:

1. Develop a detailed map of sediment PAH concentrations (96 locations were sampled for chemical analysis)
2. Develop dose-response relationships between organism toxicity and PAH concentrations and determine cleanup criteria based on different levels of toxicity. Verify with benthic community data.
3. Using cleanup criteria and sediment PAH map, outline areas exceeding criteria to define cleanup zone(s)

Sediment PAH and PCDD/F concentrations were mapped on the basis of 96 samples located in a radiating pattern around the site. Sediment toxicity tests were then conducted across a gradient of PAH and PCDD/F concentrations. Total PAH concentrations varied from <2 parts per million (ppm) to over 16,000 ppm. Sediment chemistry showed decreasing PAH concentrations with distance from the site in all directions. A pool of liquid creosote was encountered along the north wall of the site (sampling was not conducted in this pool). Sediment type along all transect lines was similar, and consisted of a thin layer of fine silt overlying a silt/clay mix.

Whole-sediment toxicity tests were conducted using the mayfly nymph, *Hexagenia limbata* (21-day exposure, survival and growth), the midge larva, *Chironomus tentans* (10-day exposure, survival and growth) and the juvenile fathead minnow, *Pimephales promelas* (21-day exposure, survival and chemical bioaccumulation).

Sediment toxicity was related to sediment PAH concentrations through regression analysis for all three organisms. Both lethality and growth were measured as test endpoints. A gradient in toxicity (increased % survival) was apparent with decreasing concentrations of sediment PAH. The highest concentrations resulted in mortality, while intermediate PAH levels resulted only in growth impairment. The lowest concentrations resulted in no observable effects on either growth or survival.

Sediment toxicity testing indicated no effects on either survival or growth at sediment PAH concentrations below 30 ppm. Between 30 ppm and 150 ppm, there was an increase in growth impairment among the mayflies, chironomids and minnows. Survival was affected as concentrations of total PAH exceeded 100 ppm. At 130 ppm total PAH, mayfly mortality reached 50% in the bioassay tests. Chironomid mortality reached 50% mortality at 150 ppm total PAH.

As a result, it appeared from the test results that sediment up to and including 30 ppm total PAH could be left in place with no negative effects on benthic communities.

The sediment toxicity test results were verified in the field through benthic community analysis. Benthic communities at the sample sites consisted primarily of oligochaetes and chironomids. Oligochaete density and diversity did not show any relationship with sediment PAH or PCDD/F levels (benthic samples were not collected in the creosote pool). Chironomid density was found to vary with sediment PAH concentrations, though the correlation was weak ($r=-.6794$ $p<0.05$).

Reductions in the density and diversity of the chironomid community corresponded with lab toxicity results. A simple regression of density versus sediment total PAH suggests that a 50% reduction in chironomid density would correspond to approximately 150 ppm total PAH in sediment. Outside of the heavily contaminated zone, the benthic community as a whole did not show any direct effects of high sediment concentrations of PAH. Since much of the PAH is present as discrete blobs or drops of oil, it would be relatively easy for most organisms to avoid these areas. This could account for the lack of response to higher PAH concentrations by many organisms. No changes were observed on the chironomid community below 30 ppm total PAH.

The results of the biological testing were used to define three cleanup zones (figure 1). Zone 1, was the area of heavy, visible contamination of sediments by creosote (a creosote 'pool'). This area was targeted for cleanup based on visual observation of creosote on the sediment surface.

Zone 2 was defined on the basis of acute biological effects i.e., greater than and including 50% mortality in the test organisms, and coincided with the area of high PAH (>150 ppm) and PCDD/F contamination (>200 ppt total TEQ). The boundary of this zone was the area enclosed within the 150 ppm total PAH isopleth.

Zone 3 was defined on the basis of chronic biological effects and coincided with the sediment area exceeding 30 ppm of total PAH. This area was defined as the area enclosed within the 30 ppm total PAH isopleth. Below this concentration, there was no measurable effect on benthic organisms and this area was considered suitable for natural remediation since existing contaminant concentrations posed little threat to biota.

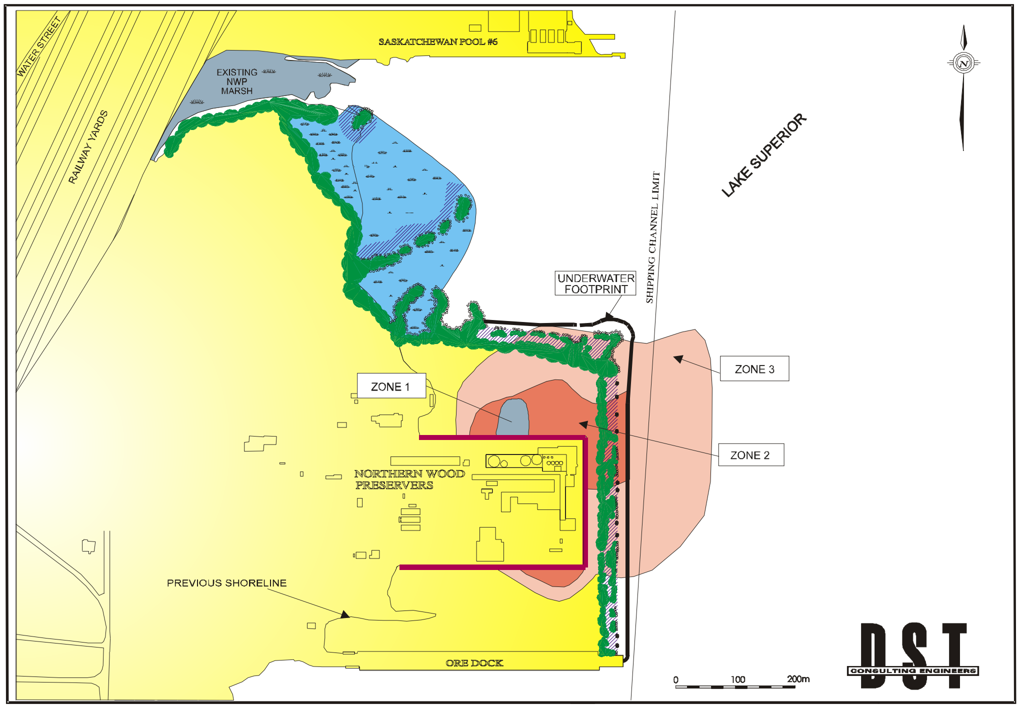

Figure 1: Contaminated Sediment Zones at NWP

NOWPARC identifies the following remedial strategy for each zone:

- Zones 1 & 2 approximately 11,000 m^3 of sediment be dredged and treated to meet the Canadain Council of Ministers of the Environment (CCME) Industrial Commercial Criteria for Soil.
- Zone 3A approximately 21,000 m^3 of sediment (between 30-150 ppm TPAHS) which is inside the footprint of the rockfill containment berm be contained and covered over with clean fill forming a dry cap. Thus, isolating this sediment from the aquatic environment.
- Zone 3B approximately 28,000 m^3 of sediment outside the footprint of the rockfill containment berm be left in place for natal recovery. Nearly 80% of this area was below 50 ppm total PAH and predictive modelling conducted by Beak Consultants indicated that PAH concentrations would continue to decrease as the PAHs decayed. The majority of this sediment is located within the shipping channel.

3. ENVIRONMENTAL MONITORING

The design of the project included mitigative components that served to protect the harbour, its users and the environment from resuspension of sediment or other releases of contaminants from the site.

Monitoring of water quality was undertaken during berm construction, site isolation, fill placement and sediment removal. Air monitoring was undertaken during sediment treatment to ensure compliance with regulatory standards.

During sediment removal, standards were set to mitigate resuspension of contaminated sediments. Total suspended solids (TSS) beyond a distance of 25 m from the perimeter of the removal operation shall not exceed ambient levels by more than 25 mg/L. Background turbidity samples were taken at a fixed location approximately 500m from the work activity. Turbidity measurements were collected as real time data using online monitors. A relationship was derived between turbidity and TSS which was used to estimate TSS concentrations in water based on turbidity field measurements. This site specific relationship was determined prior to the project using sediment from the removal area.

Water samples for total PAHs were collected weekly from inside and outside the containment area and compared to the background location. In addition daily water samples were collected for TSS, turbidity, and conductivity.

Results of the water quality monitoring program showed that there were no adverse effects on the aquatic ecosystem from the sediment remediation operations.

4. ROCKFILL CONTAINMENT BERM

The Rockfill Containment Berm (RCB) was designed to contain Zone 3A around the Northern Wood Preservers (NWP) site. The area (15 hectares) behind the berm was backfilled with approximately 800,000 tonnes of clean fill to provide a dry cap as part of the containment structure for Zone 3A. As part of the compensation for infilling, fish habitat was created under the Department of Fisheries and Oceans Authorization. The berm design allows for site treatments to create embayments and zones of different depths and substrate types for fish habitat.

During construction, shale was end dumped in two stages to allow for consolidation and strengthening of the soft lake bottom materials upon which the RCB was constructed.

Construction of the RCB began on August 28, 1997, and was completed on December 13, 1997. The berm is 850 meters in length and runs parallel to the shipping channel, connecting the old Ore Dock to the northwest corner of the NWP site. During berm construction approximately 1200 m^3 of contaminated sediment in Zone 2 was removed to prepare the lake bottom for berm construction. The RCB is constructed in water depths up to 8.2 meters.

Rip rap was placed on the exterior to provide protection against wave action. The crest of the RCB is 5 metres wide with interior and exterior slopes at 2 horizontal to 1 vertical for long term stability. Approximately of 260,000 tonnes of shale and 22,000 tonnes of rip rap was used during construction.

Because the RCB was constructed on the relatively soft soils of the harbour bottom, a monitoring program was continued throughout the construction to ensure the stability of the RCB. Monitoring included slope inclinometers, which measure movement of a slope, and pneumatic piezometers, which measure the pore pressures in the underlying foundation soils. Results indicated that the RCB was constructed as designed.

5. ENVIRONMENTAL DREDGING

From Zone 3A, two sub-sections were defined for sediment removal. Area A was located on the footprint of the RCB where sediment removal was required prior to removal prior to berm construction. Area B was located inside the bermed area and was the most impacted section.

Although the specification documents did not request the use of a specific dredging technology other than an environmental clamshell, the Cable Arm Environmental Clamshell was the technology selected to deal with site specific conditions. These conditions included the unconsolidated nature of the sediment, liquid contaminants, variety of debris mixed in with the sediments, and the lack of space for dewatering.

A computerized differential global positioning system was also used in conjunction with the dredging technology. This system provided bucket position accuracy in relation to the barge of 10 cm on the x-y & z planes.

The cable arm environmental bucket, which is operated from a barge mounted crane, operates similarly to conventional clam dredges, with several refinements to minimize environmental impacts. The design of the bucket allows for the reduction of resuspended sediment and maximizes the percent solids generated.

Prior to dredging, a survey using Ground Penetrating Radar identified considerable oversize material present in the area proposed for dredging. Over 500 tonnes of debris was removed with a grapple then pressure washed and removed to a local landfill for disposal.

Dredging started on October 20, 1997 with removal of sediment located at the footprint of the berm (Area A) and was completed on November 1, 1997 (1,200 m^3 sediment were removed). Operations were then transferred to Area B on November 2, 1997 and was suspended on November 22, 1997 (2,000 m^3 was removed) when it was shut down due to ice accumulation.

Dredged sediment was placed in a scow moored along side the barge. From the scow, the sediment was pumped to a modified grain ship, where it was stored until dewatering facilities were constructed in the summer of 1998. During the dredging operations, a silt curtain was used in conjunction with RCB to confine resuspended material to the work area.

There were numerous and lengthy periods of downtime mainly associated with the handling a large quantity of sub-surface debris (sawdust, logs, poles, wires and a few railing carts) located close to the pier wall. Setbacks were due to handling and transport of this debris as well as time spent to re-positioning the barge.

During dredging the calculated average production rate was 18.5 m^3/hr, when considering re-positioning of the equipment as an integral part of the removal operations and 31.8 m^3/hr when re-positioning is not considered.

In August of 1998 the remaining 9,800 m^3 of contaminated sediment was removed from Zones 1 & 2 (Area B). The sediment was placed in a dredge scow , double handled with a conventional clamshell and placed in one of the three dewatering cells (approximate capacity 500 m^3) .

The completed berm was used as the containment structure to confine resuspended sediment generated from the dredging operation.

Comparable results were compiled during the removal of the sediment located in Area B. The average production slightly increased to 40 m^3/hr with solids content reaching 35% during dredging. The total volume of sediment removed from Area B was measured at 9,800 m^3 .

To confirm the dredging depths and quantities, detailed bathymetric surveys were conducted before and after the dredging activities. Surveying was also carried out during the dredging.

6. SEDIMENT TREATMENT

Bioremediation was chosen as the initial sediment treatment method. A treatment facility was constructed and included dewatering ponds, a mixing plant, an engineered bioremediation cell (EBC), a retention pond, and a water treatment plant. These facilities were constructed inside the north side of the RCB, on fill placed there for this purpose.

The sediment for treatment was offloaded from scows, and initially place into dewatering cells, which were required to make the material more manageable.

The sediment was then transported to an enclosed mixing shed for pretreatment where it was screened down to 6 inches in diameter, and mixed with a patented nutrient source DARAMEND® using a tractor. The mixing shed provided an enclosed area to control the volatiles generated during mixing.

In order to maximize the biological degradation of the organic contaminants, moisture, oxygen and nutrient levels were controlled.

Following pre-treatment the sediment was transferred to the EBC. The EBC was lined with a geomembrane to prevent contaminants from leaching from the treatment area.

The EBC also included an underdrain system to collect any water seepage from the deposited sediments during treatment. The underdrain system discharged to a retention pond, and to a water treatment plant.

Due to the higher than anticipated sediment contaminant concentrations, the site-specific remediation criteria were not met. Enhanced bioremediation bench scale test in the laboratory confirmed that bioremediation would not meet the cleanup criteria within a reasonable time frame. After a second treatment tender process, off-site high temperature thermal desorption treatment was selected.

In the summer of 2001, approximately 17,000 tonnes of contaminated sediment from the EBC was loaded into environmental rail cars and transported to Princeton, British Columbia for treatment. During thermal treatment, sediment is exposed to high temperatures where contaminants are extracted into a vapour gas phase separating them from the cleaned soil. There are 9 primary components of the treatment process :

1 **Soil processing unit** screens the sediment down to six inches
2. **Rotary kiln**. Converts contaminants into a vapor phase leaving behind clean soil (550F to 1000F)
3. **Soil reconstitution unit** the treated soils are stacked, and water is added to control dust
4. **Rotary Tacking Conveyor** cleaned soils are fed through a rotary conveyor and stored temporarily.
5. **Primary baghouse** removes dust and particulate from the vapour in the rotary kiln
6. **Secondary baghouse** removes particulate and dust from vapour in the soil reconstitution unit.
7. **Contaminated air stream** is fed to a propane add fuel static mixing station
8. **Dual recuperative reactors** The contaminated air stream is completely oxidized (1800F to 2200F)
9. **Stack emission** from recuperative reactors are monitored to ensure environmental compliance

All sediment has been successfully treated to the 1991 (CCME) industrial/ commercial soil criteria for total PAHs, CP and PCDD/F. Below are the initial concentrations prior to treatment.

Table 1 : EBC Sediment concentrations

Cont.	CCME Criteria	Min [ ]	Max [ ]	Ave [ ]
T. PAHs (ppm)	260	2000	25000	9000
CP (ppm)	5	10	160	
PCDD/F TEQ(ppb)	.5	1	4	

7. ISOLATION OF ON SITE CONTAMINANTS

The NOWPARC plan included three components to isolate on-site contaminants and prevent further damage to the marine environment. Contingency measures were also identified to address deficiencies, if necessary.

The RCB provides secondary containment for contaminants, as well as protection from wave action from shipping activities within Thunder Bay Harbour for the new fill area.

Infilling of the confined area effectively caps residual contaminated sediments. Approximately 800,000 tonnes of clean fill was placed between the RCB and the pier to create a buffer zone.

The industrial site remains in operation and is situated on highly contaminated fill. To prevent off-site movement of creosote, approximately 114,000 tonnes of clay were placed along a 600 m section around the pier face. Specifications required that the barrier be constructed with a permeability factor of less than 1×10^{-5} cm/sec. Tests indicated that the clay isolation barrier provided good containment but did not consistently meet the permeability requirements due to lenses of coarser material and difficulty in sealing with native clay layer at the lake bottom.

Consequently, a Waterloo Sheet Pile wall was installed in October 2001 as a contingency measure to ensure containment of the on site contaminants. Approximately 6000 m^2 of sheet piling was placed along a 660 m section around the pier. The steel sheet sections were driven into the native clay layer and that the joints between sections were sealed with concrete-like grout material.

8. GROUNDWATER TREATMENT PLANT

The key to success of the source control measures is to have the hydraulic gradient towards the pier. To maintain that gradient, the groundwater level beneath the pier and within the area confined between the Waterloo Barrier and the Clay Isolation Barrier must be kept below the measured lake level. To treat the groundwater collected, both biological reactor and filter type treatment works were considered. The granular activated carbon (GAC) filtration process was chosen based on cost, availability and flexibility.

The treatment works constructed in 2001 consists of

- Weeping tile collection systems
- Oil/water separator / oil recovery tank
- Iron catalyst filter
- Self-indexing particulate filter
- Particulate bag filters
- Modified organo clay filter
- Activated carbon filters
- Metals removal filter

Effluent quality is monitored prior to being discharged to Lake Superior. There are monitoring requirements for total suspended solids, chemical oxygen demand, phenol, pentachlorophenol, PCDD/F, PAHs, and Aquatic Lethality (Rainbow Trout and Daphnia Magna).

Changes were also made at the industrial site to improve the management of stormwater and divert stormwater runoff from the pier area. A collection system was installed along the groundwater collection trench.

9. FISH HABITAT COMPENSATION

A Fish Habitat Compensation study was undertaken to provide the information required to obtain authorization from the Department of Fisheries and Oceans (DFO) for probable Harmful Alteration, Disruption or Destruction (HADD) of fish habitat as per section 35(2) of the Fisheries Act.

The fish habitat compensation goals were:

- Removal and containment of creosote contaminated sediments;
- Containment of the NWP industrial site through the creation of a vegetated shoreline buffer zone;
- Re-routing of stormwater run-off from the northern log laydown area away from the shoreline habitat area;
- Creation of a diversity of sustainable fish habitat types through the creation of an intercoastal type wetland area, reclamation of a portion of the old NWP marsh and through the application of a variety of site treatment applications along the containment berm;
- Addressing the DFO policy of no-net-loss of fish habitat;
- Improved benthic production in the post-development study area;
- Creation of waterfowl wetland and upland habitat for nesting, rearing, feeding and staging;
- Improved reptilian and amphibian habitat;
- Improved aesthetics through creation of a visual barrier to the NWP industrial site.

The resulting conceptual plan involved four components.

1. Excavation and sculpturing of approximately 11,000 m^2 of reclaimed land adjacent to the existing NWP marsh.
2. Development of a chain of small islands to extend offshore from the NWP site and the NOWPARC berm.
3. Site treatments along the containment berm to create different types for fish habitat.
4. Sculpturing and planting of a 15 -30 metre wide buffer zone between the industrial site and the lake.

Approximately 150,000 m^2 of Lake Area was lost and approximately 48,000 m^2 of new habitat was created.

All structural changes are now in place along the shoreline and containment berm. Waterfowl have been quick to move into the expanded marsh and the initial study shows fish are utilizing the area.

10. LONG TERM MONITORING

Post construction monitoring of the sediments in zone 3B indicated results indicated the following:

- No significant accumulation of PAH compounds in mussel tissues.
- No effects on benthic community structure.
- No lethality to any of the three test species in bioassays and there was no evidence of PAH uptake by fathead minnows.

The survey confirmed that biological effects were significantly reduced or absent in the area immediately outside the berm. A long term monitoring plan has been developed and will be implemented in 2003.

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