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# Professional Geoscientists Ontario

# Randle Reef Contaminated Sediment Remediation Project Hamilton Harbour Ontario Overview and Application of Geoscience September 29, 2021

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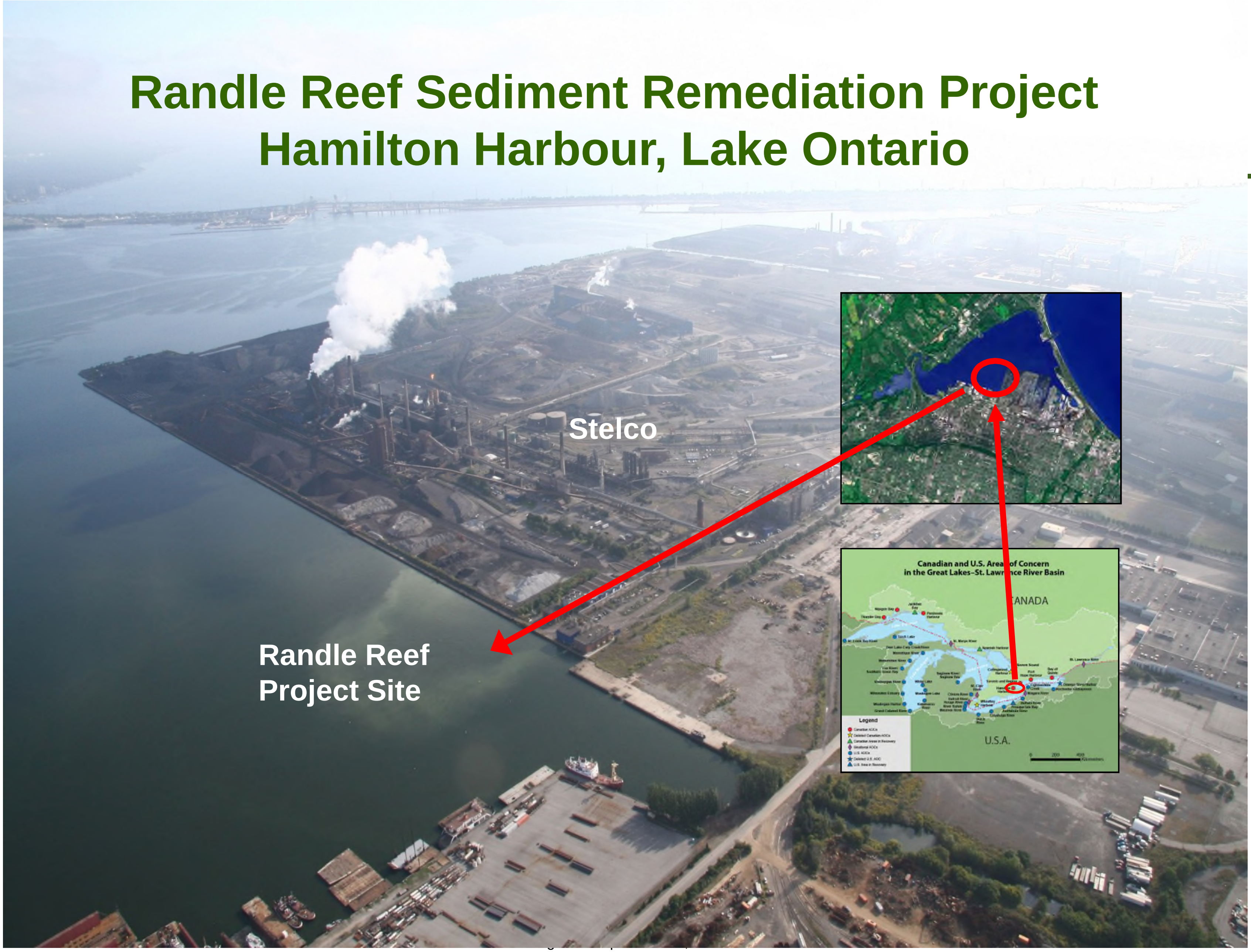
# Presentation Outline

1. Overview of the Project
2. Specific geoscience components
3. Questions

# Randle Reef Sediment Remediation Project
# Hamilton Harbour, Lake Ontario



# Randle Reef Sediment Remediation Project

- One of the **largest contaminated sediment sites** in the Great Lakes.
- Long history **precludes the 'Polluter Pay'** principle.
- Proponents adopted a **Shared Responsibility** model.
- One of the last major projects necessary for delisting the Hamilton Harbour Area of Concern

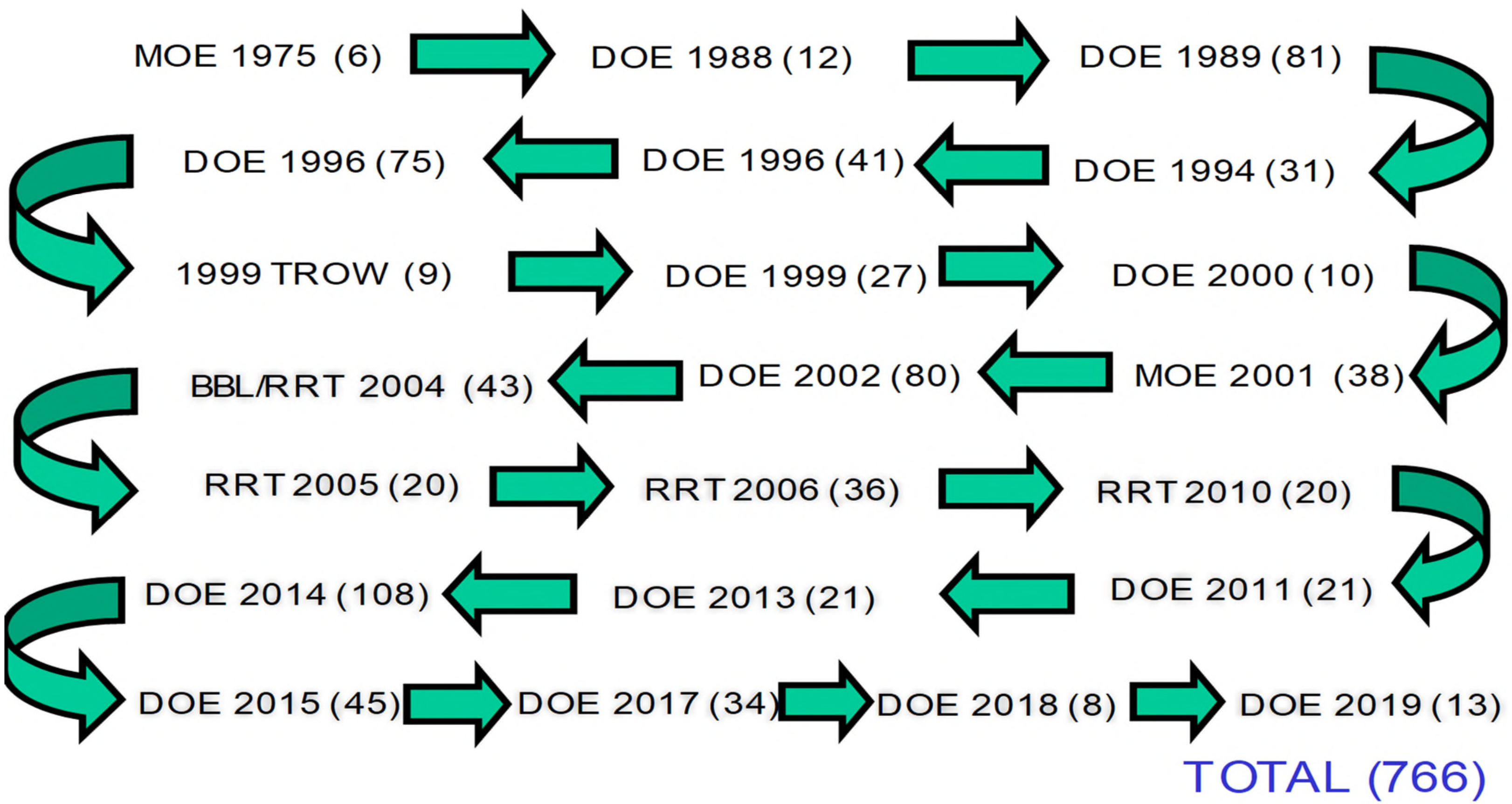
# Randle Reef Site Specifics

- Impacted by historic operation of coal gasification plants and steel operations;
- Approximately 695,000 $m^3$ of contaminated sediment
  - Polycyclic Aromatic Hydrocarbons (PAHs)
  - Heavy Metals
- PAHs are known to be toxic and carcinogenic

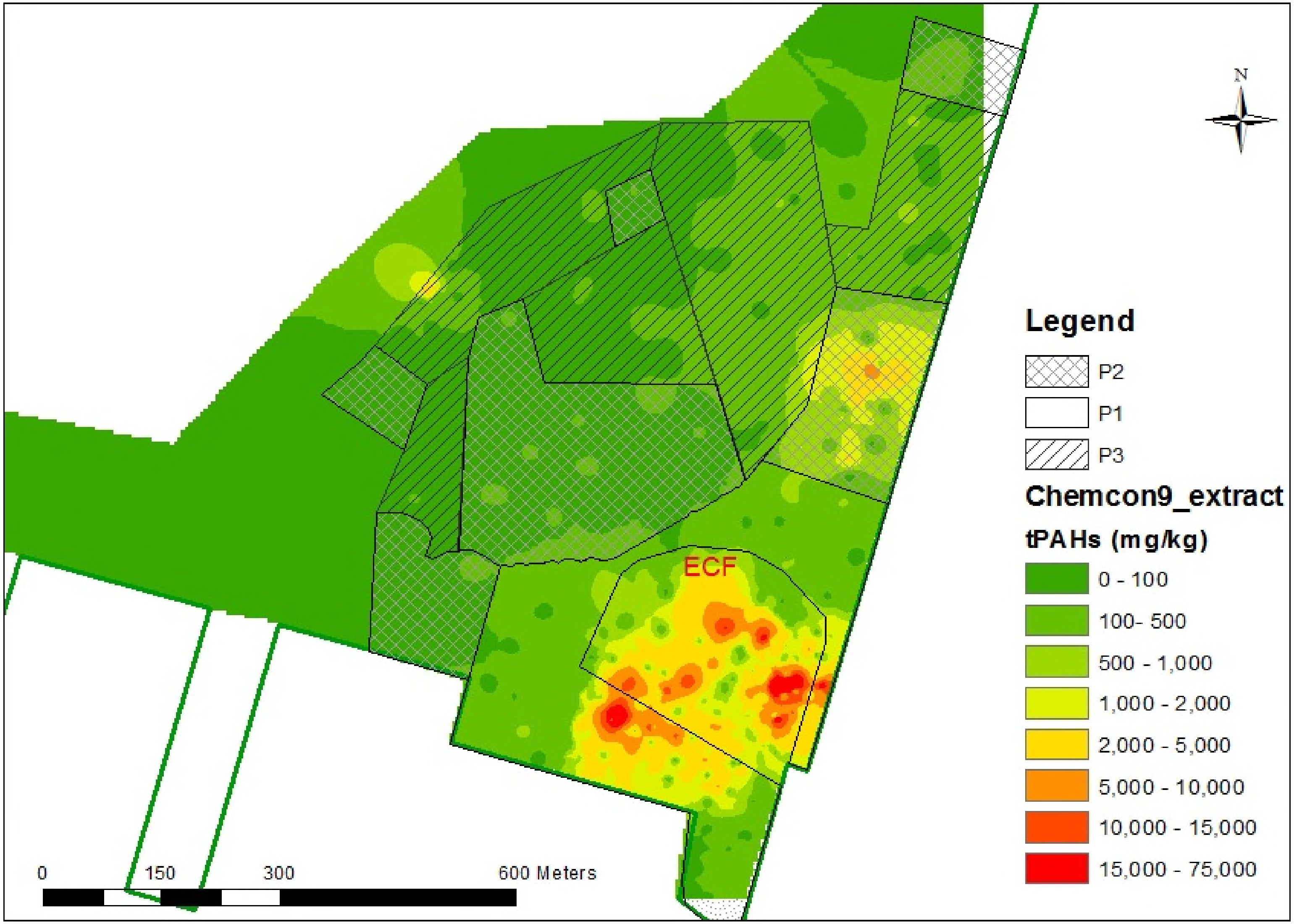
# Randle Reef Statistics

- Approximately 695,000 $m^3$ of contaminated sediment (PAHs & metals)
- Avg total PAH ~5,000 mg/kg
- Max ~73,000 mg/kg.
- Site Area: ~60 ha (148 acres)
- Depth of Water: ~4 m to 12 m
- Sediment Thickness: ~0.1 m to >3 m

# Randle Reef Chemistry



# Randle Reef PAH Contouring



# Site Specific Clean-up Criterion

- 100 mg/kg total PAHs
- Based mostly on toxicity of the sediment to benthos, but also considering:
    - Background levels in the harbour,
    - Other PAH site cleanup levels
    - Consideration of the location (industrial harbour, located near a major highway.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A Summary of the Site Specific Clean-up Criterion Developed for the Randle Reef Sediment Remediation Project, Hamilton Harbour

M. Graham[1], C. Vieira[2], E. Hartman[1] and R. Santiago[1]

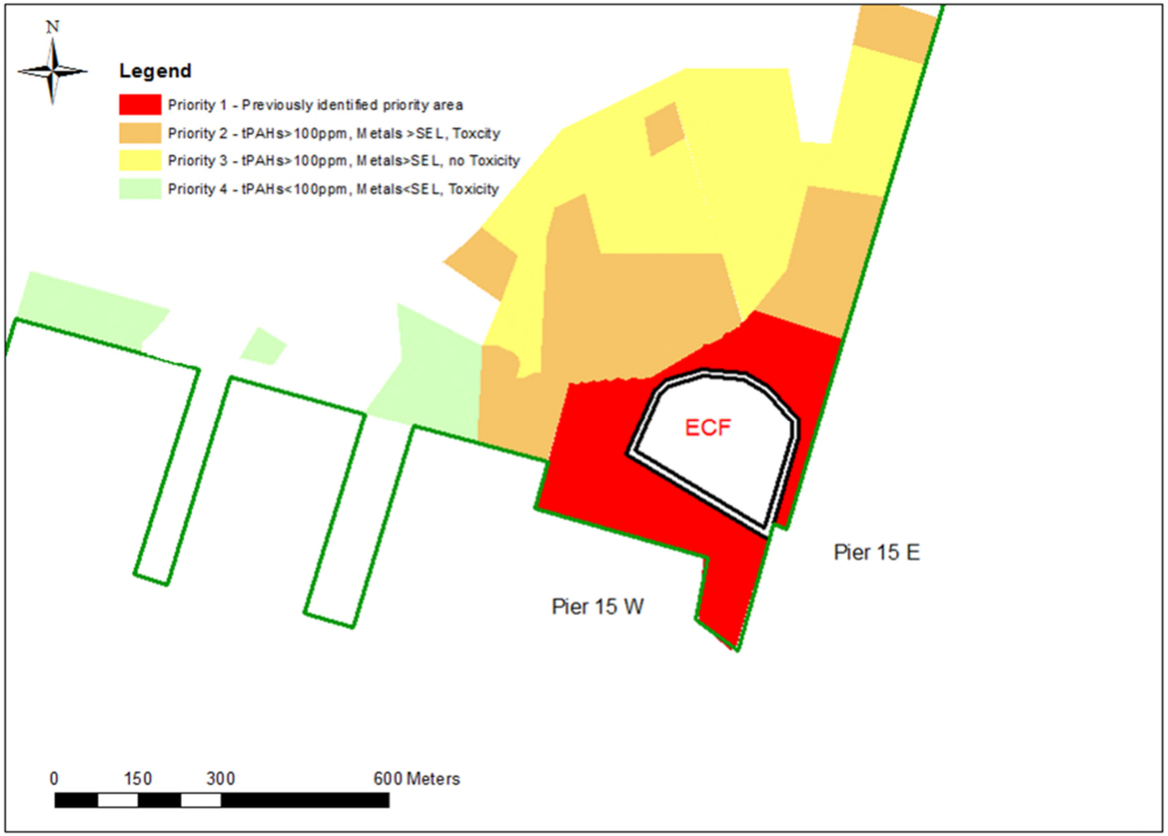
Ontario Region

September 9, 2013

[1]Environment Canada
Great Lakes Areas of Concern Section
Sediment Remediation Unit

[2]Ontario Ministry of the Environment
West Central Region

# Prioritization (Sediment Chemistry and Toxicity to benthos)



# Remedial Approach

8 years to complete:
2015-2022

2018
Dredging
(hydraulic &
mechanical)
Stage 2

2015
Containment
Stage 1

2022
ECF Capping
Stage 3

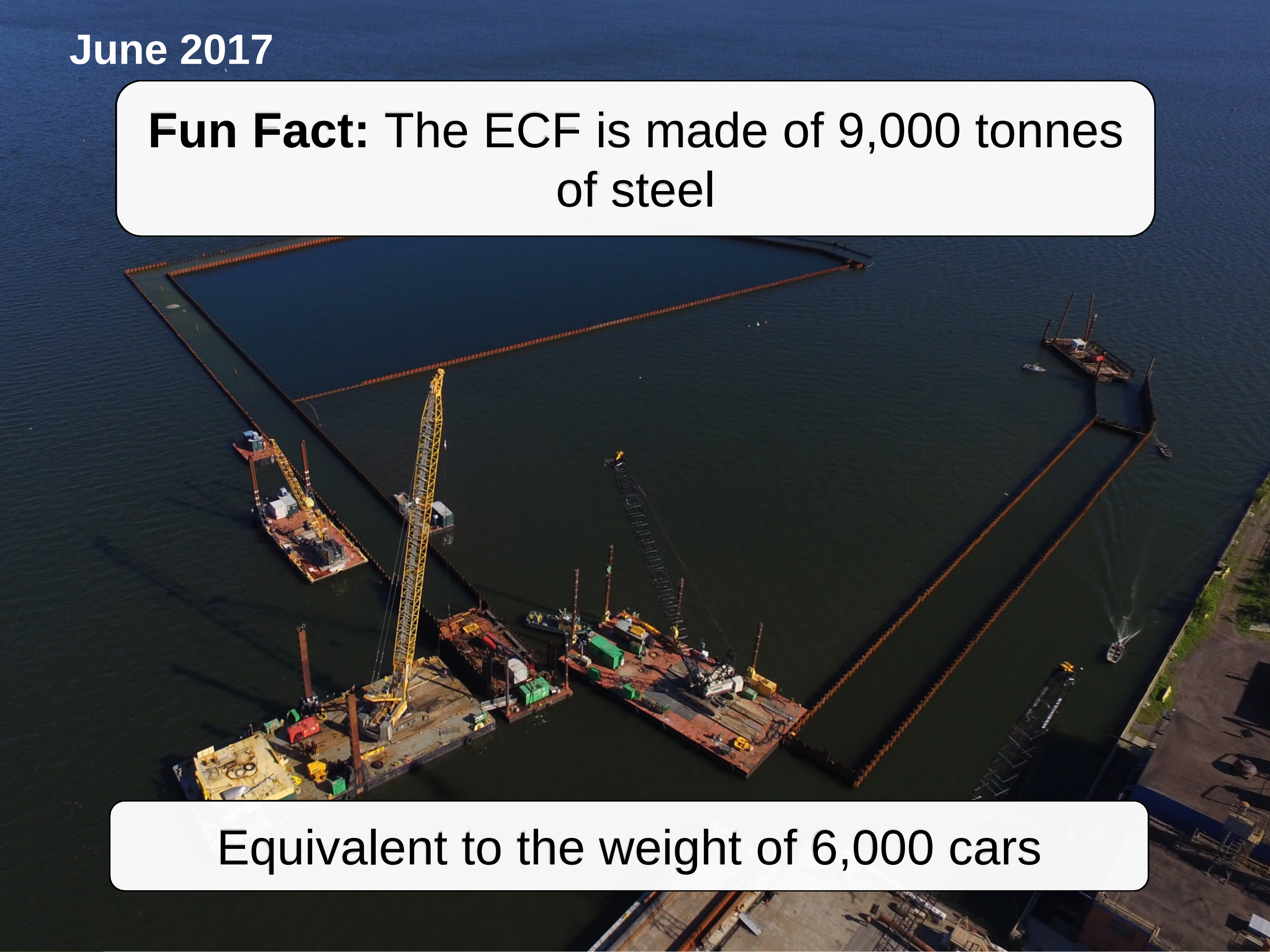
# Original Project Overview / Plan

Stelco
Channel

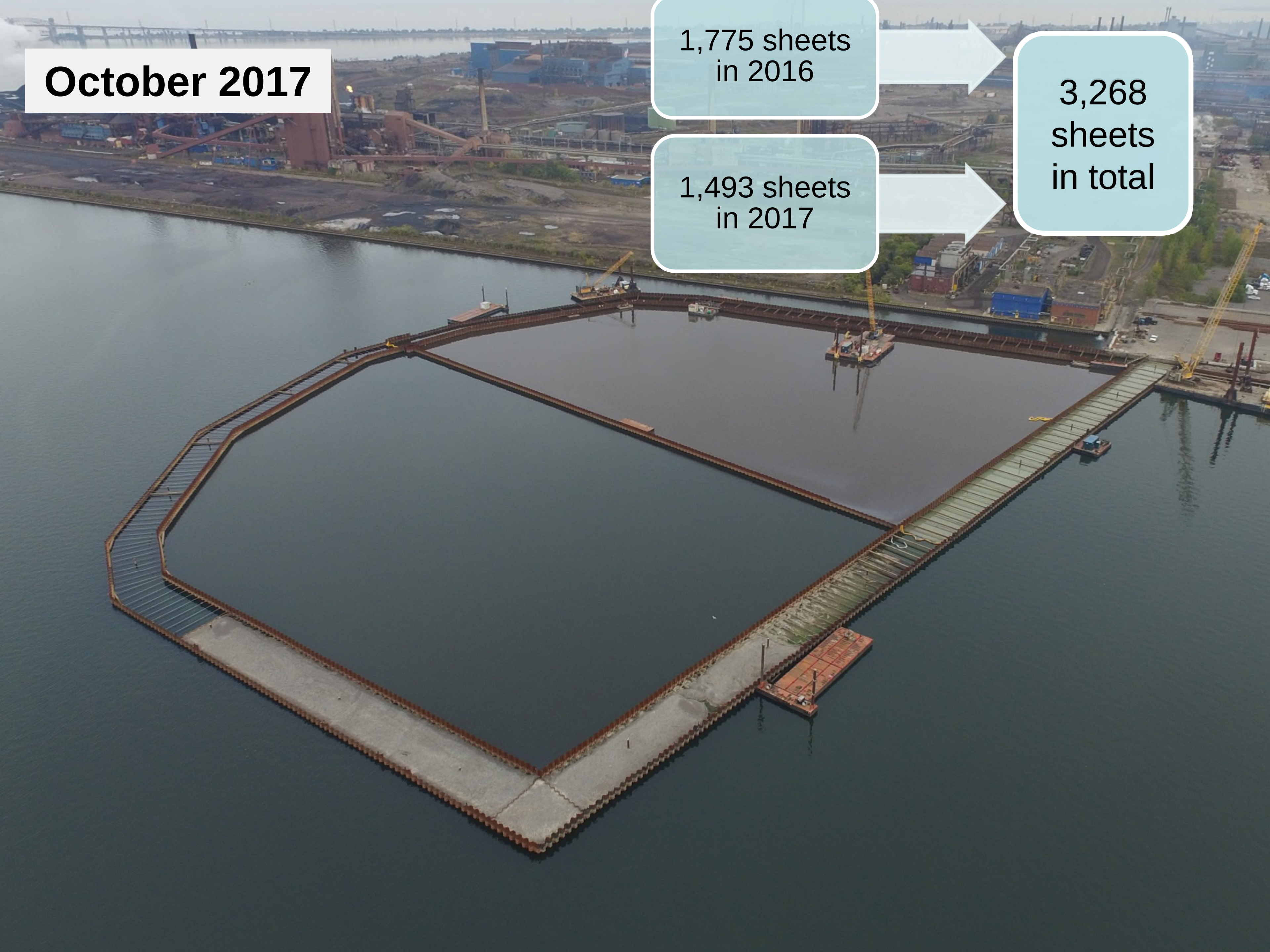
- Construct a 6.2 hectare Engineered Containment Facility (ECF) over the most highly contaminated sediment (140,000 $m^3$ *in-situ*);
- Using a combination of hydraulic and mechanical dredging, remove 445,000 $m^3$ and place within ECF;
- Thin Layer Capping of 105,000 $m^3$ of marginally contaminated sediment
- Cap Stelco Intake/Outfall Channel sediments 5,000 $m^3$
- Cap ECF and construct a port facility.
- Total sediment management of 695,000 $m^3$

June 2017

**Fun Fact:** The ECF is made of 9,000 tonnes of steel

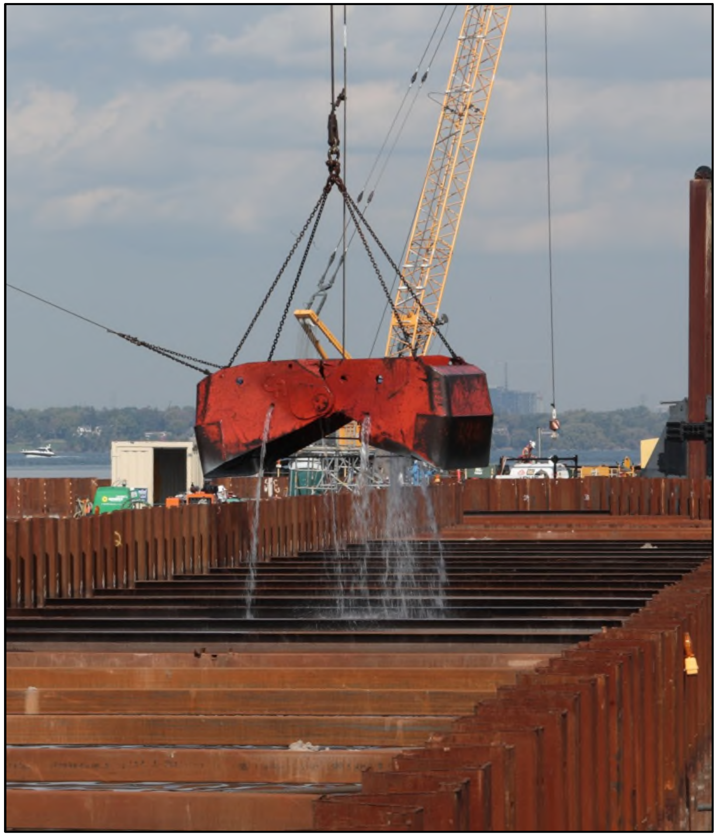


Equivalent to the weight of 6,000 cars


October 2017
1,775 sheets in 2016
1,493 sheets in 2017
3,268 sheets in total

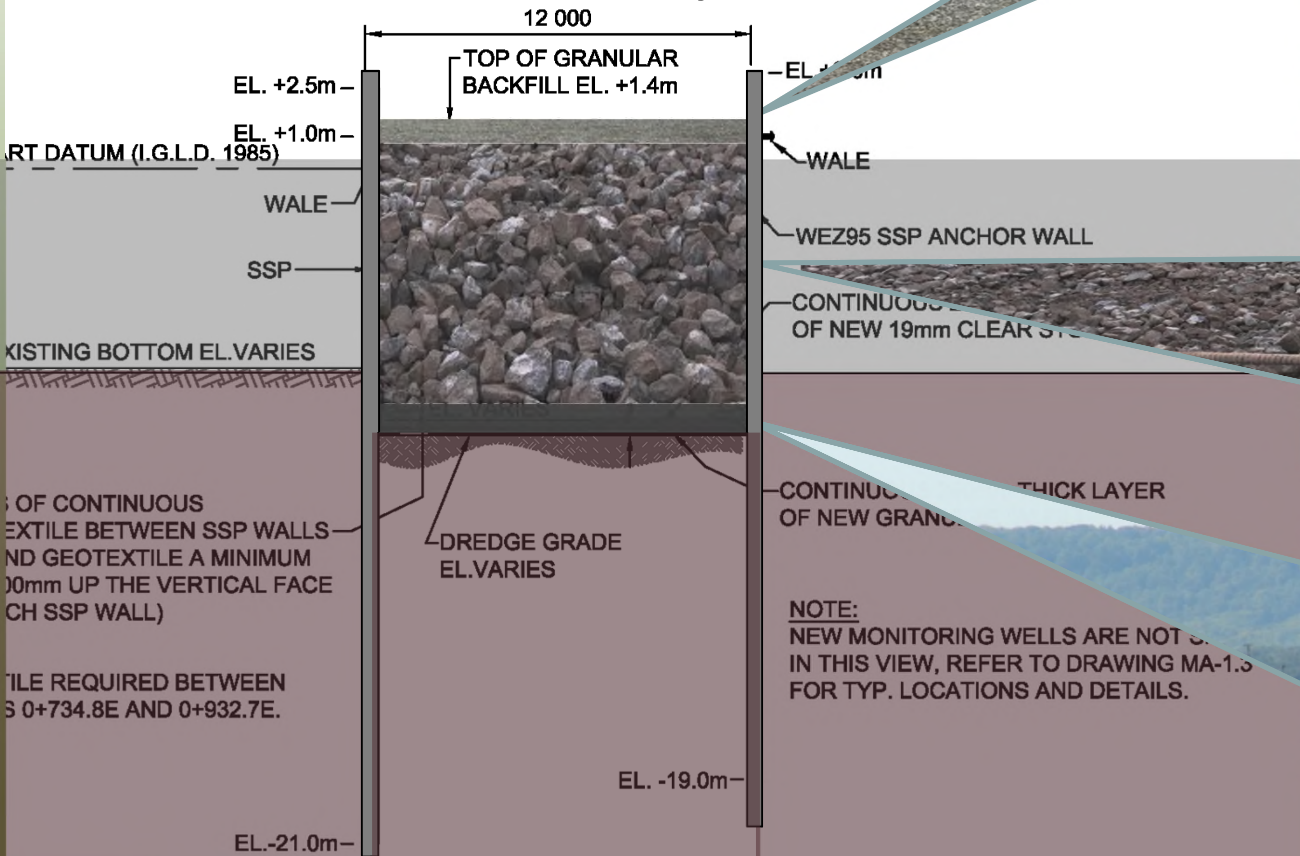
# Dredging Between the Walls

| | 2016 | 2017 | Total |
|---|---|---|---|
| Sediment ($m^3$) | 5,811 | 19,038 | 24,849 |
| Clay ($m^3$) | 4,544 | 3,849 | 8,393 |
| Total ($m^3$) | 10,355 | 22,887 | 33,242 |



# Backfill Materials Between Walls

- Initial Granular Layer
- Rock Fill
- Final Clear Stone Layer



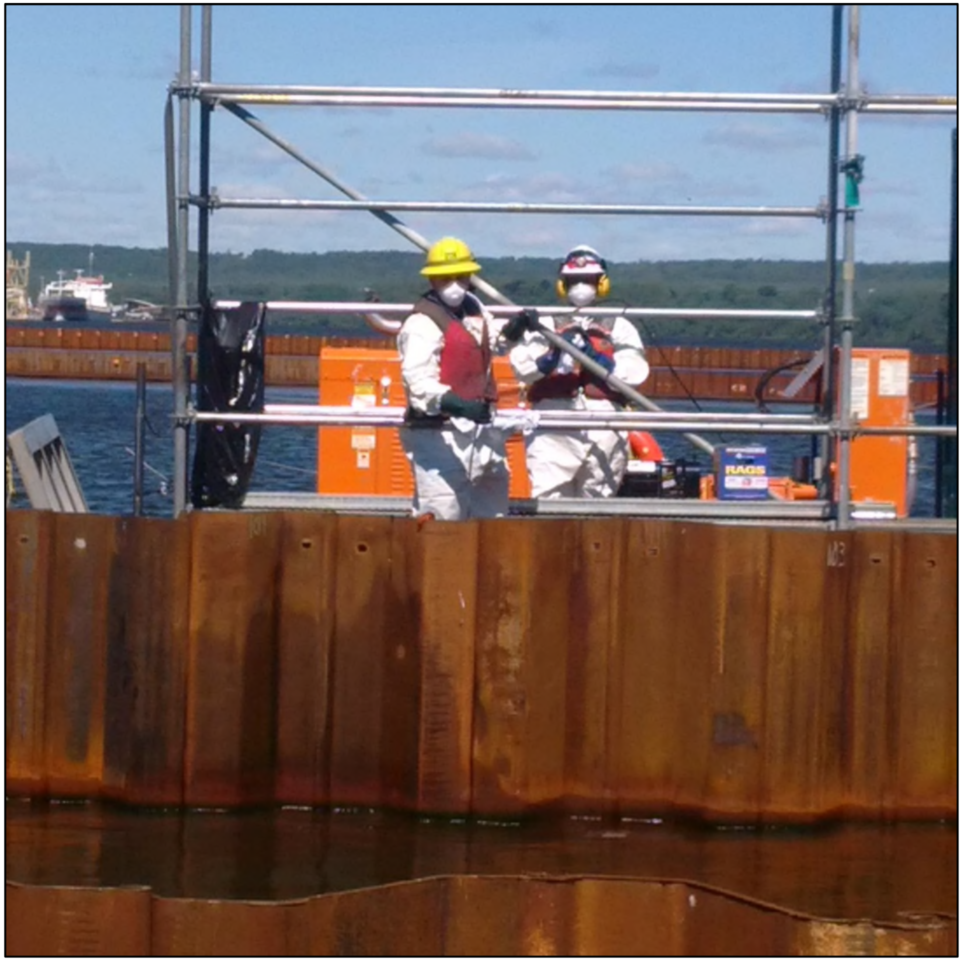



# Installation of Monitoring Well Casings

Before installation

After installation

# Interlock Flushing

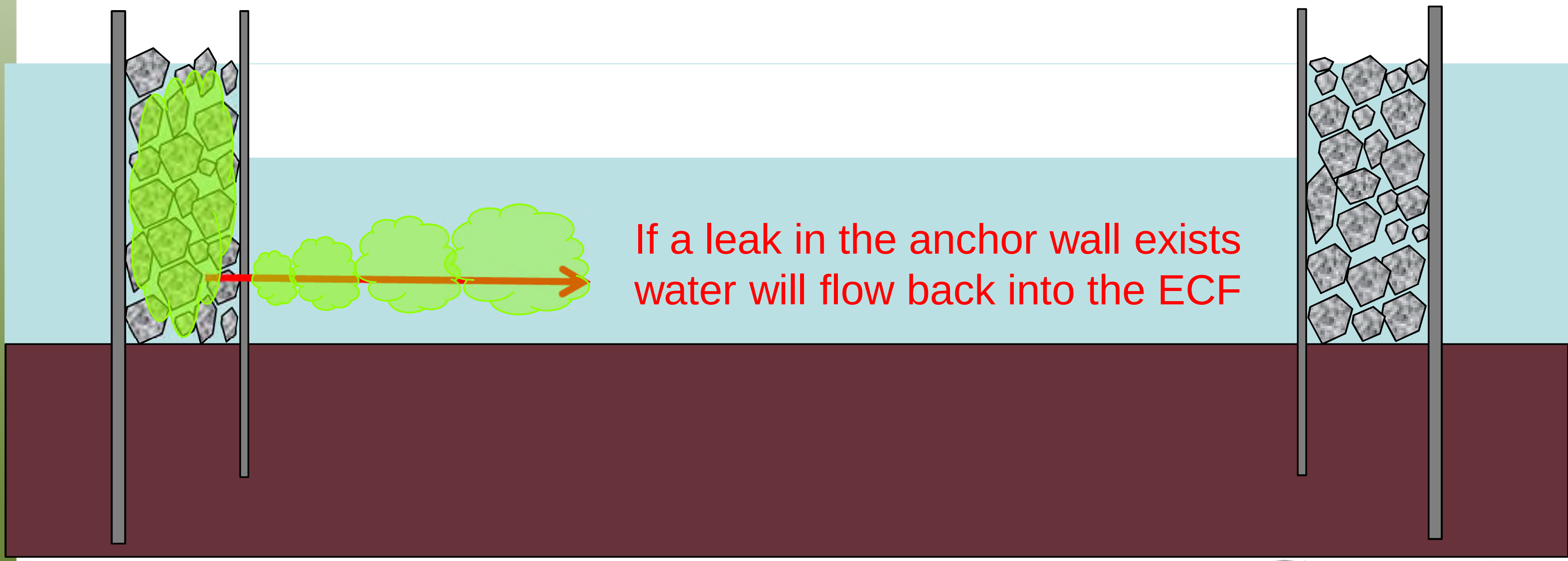



Standard Interlock

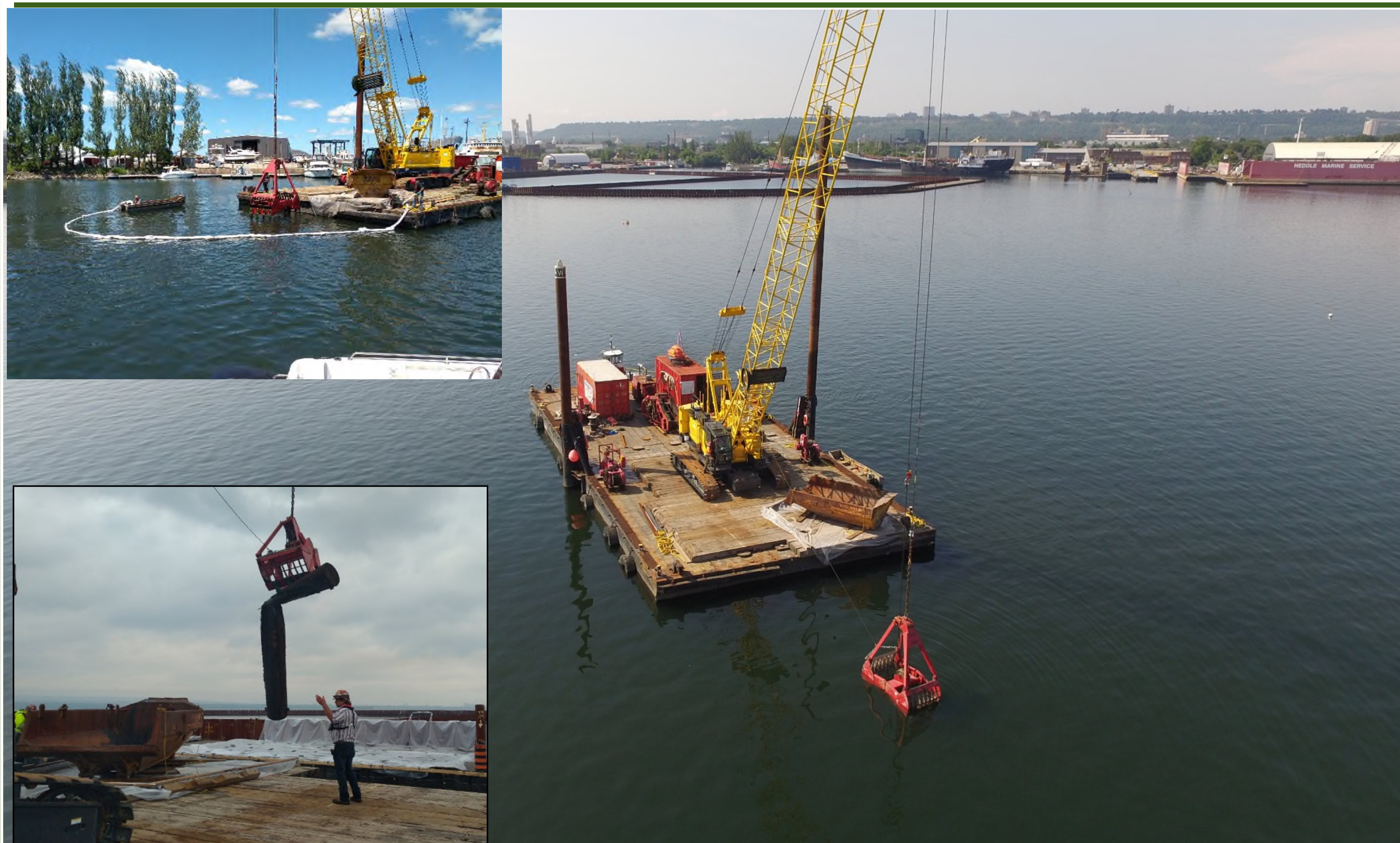
Waterloo Barrier Interlock

# Drawdown Test and Tracer Study

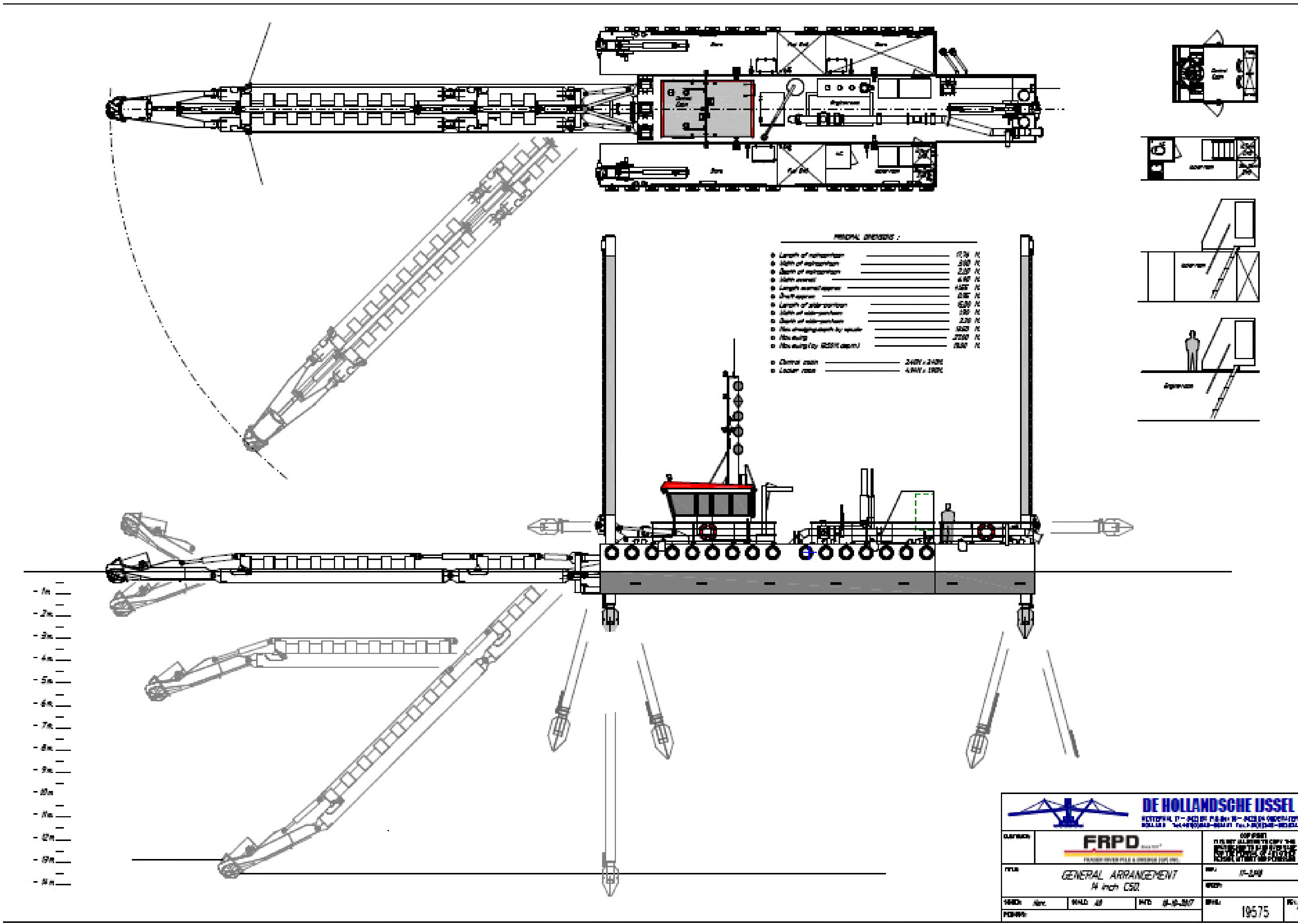
- Water was pumped down inside the ECF to check for leaks.
- Originally leaks were detected and tracers were used to locate **WHERE** the leak exists



# Stage 2 Debris Removal



# Stage 2 Equipment: Hydraulic Dredge



# Stage 2 Equipment: Hydraulic Dredge

# Randle Reef Sediment Remediation Stage 2

**Stelco:**
Nearby industrial property.

**Engineered Containment Facility (ECF):**
Isolates the most contaminated sediments from the environment via double sheet pile walls. Dredged materials are placed inside.

**Barge:**
Removes underwater debris prior to dredging.

**Pier 15:**
Owned by the Hamilton Oshawa Port Authority.

**Hydraulic Dredge:**
Dredges sediment with a cutter head and pumps it into the ECF via a floating pipeline.

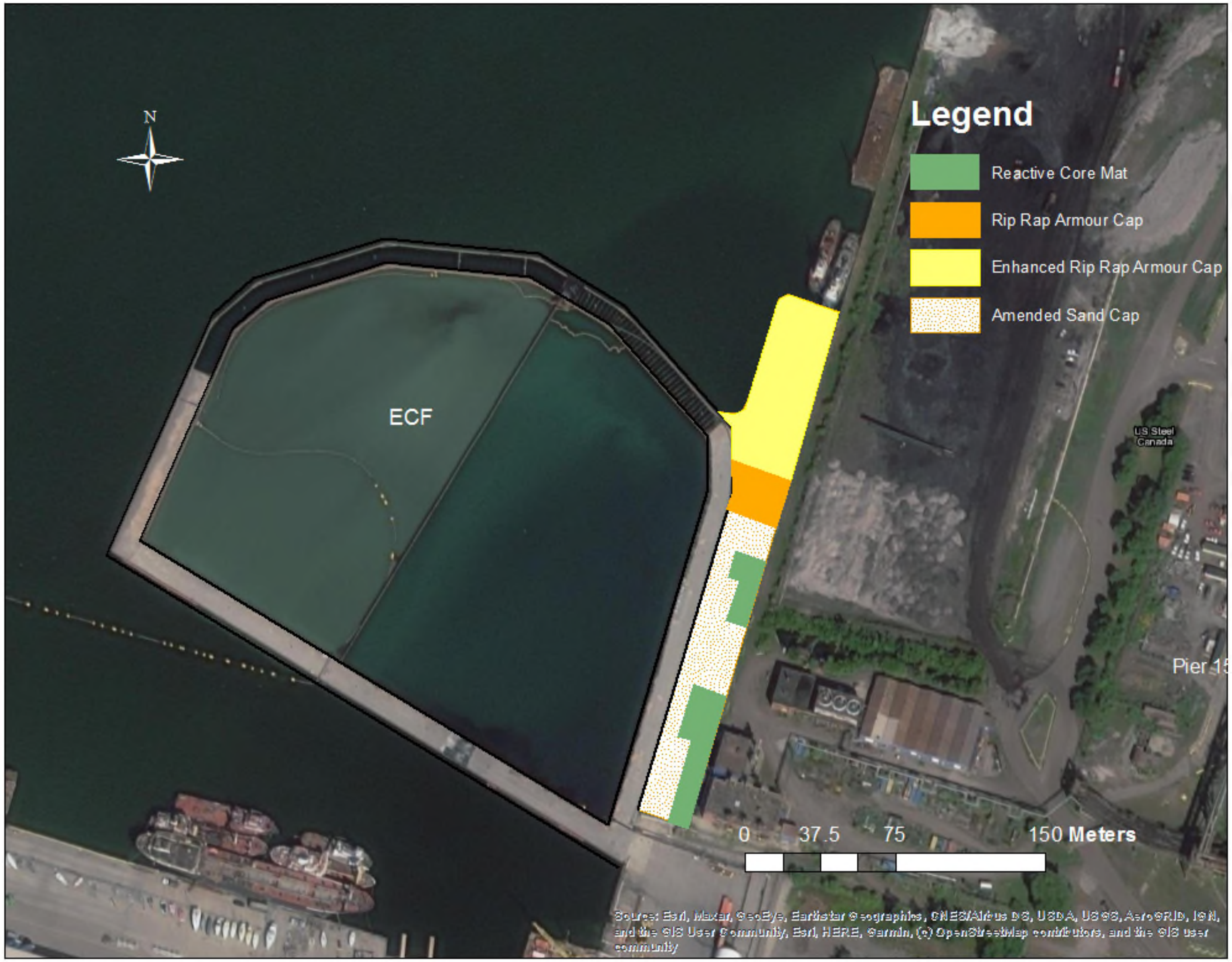
**Water Treatment Plant:**
Treats overlying water in the ECF and pumps clean water back into the Harbour.

# WTP Pipeline

# Isolation Capping

- During the Stage 1 construction additional areas of Non Aqueous Phase Liquids (NAPL) were found in the Stelco Channel. As a result the original design of the isolation cap was altered to include:
  - A larger chemical isolation layer (65 cm of amended sand having 3.3% total organic carbon.
  - Additional organoclay reactive core mats were added where NAPL is present.
  - Enhanced armouring (geotextile, rip-rap and a clearstone layers) at the north end and at the Stelco intakes.

# Isolation Cap – Final Design



# Environmental Monitoring

Water – measuring turbidity

Air – real time air monitoring along project boundary

Sediment – surface and core samples collected after dredging to certify removal of contaminated sediment

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# Confirmatory Sampling


- 20 m grid spacing
- SWAC of each Verification zone to be <100 mg/kg total PAH
- No individual sample over 500 mg/kg
- A small amount of 2nd pass dredging conducted
- A small amount of thin layer backfill used in select areas

# End of Stage 2 (July 2021 Aerial)

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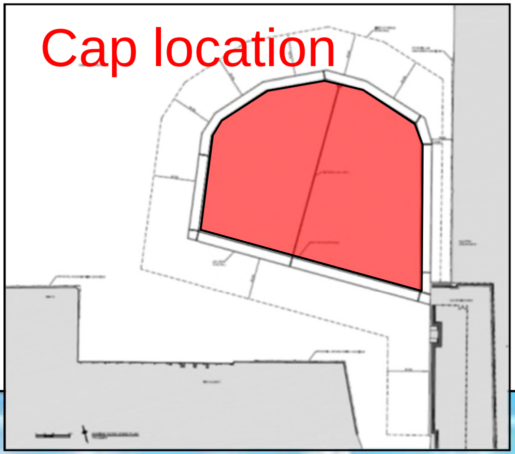
# Stage 3: Installation of ECF Cap

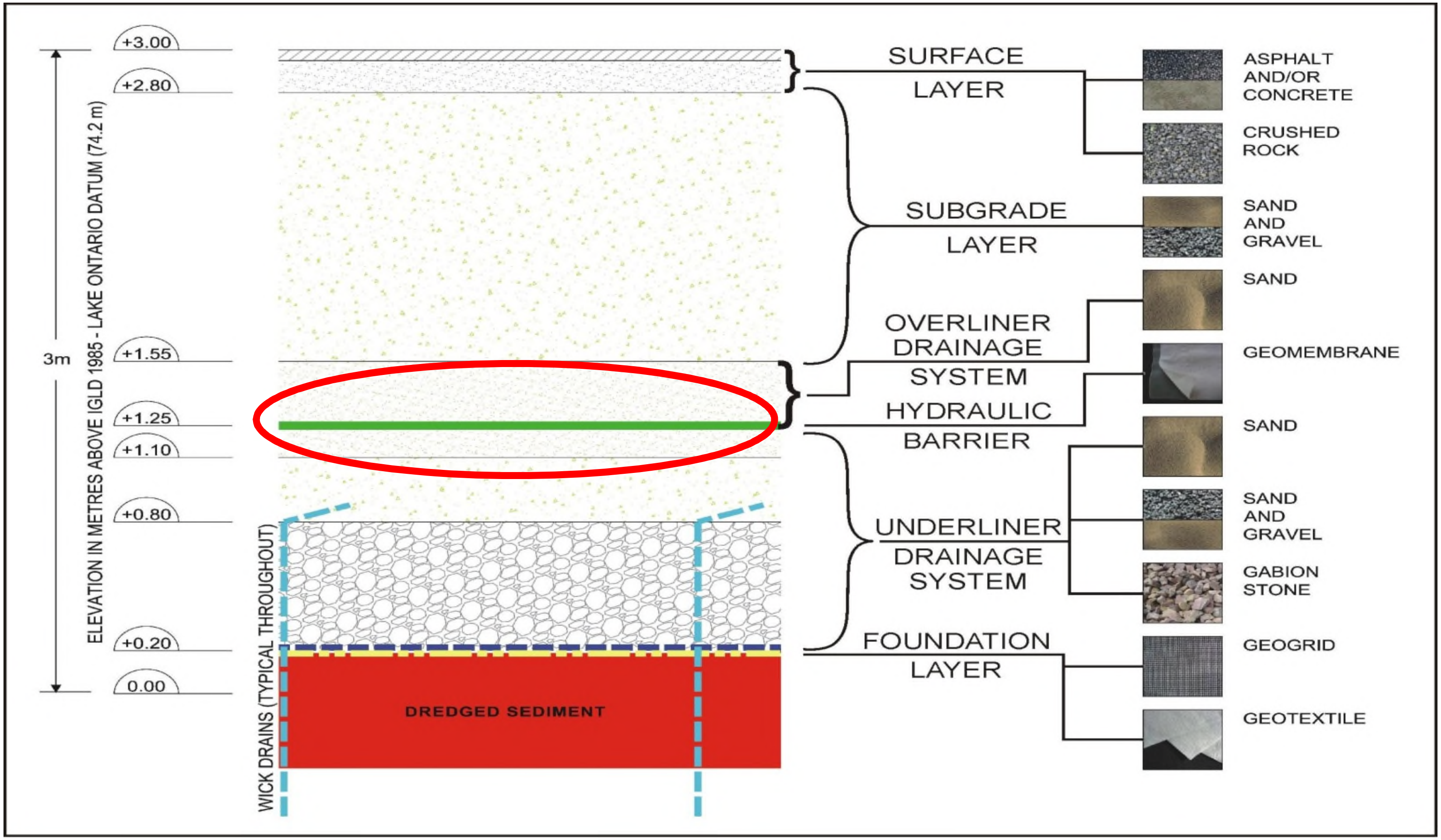
- The ECF capping system will consist of several layers:

  1. Foundation layer
  2. Underliner drainage system
  3. Hydraulic barrier layer
  4. Overliner drainage system
  5. Paved surface
  6. Stormwater management systems

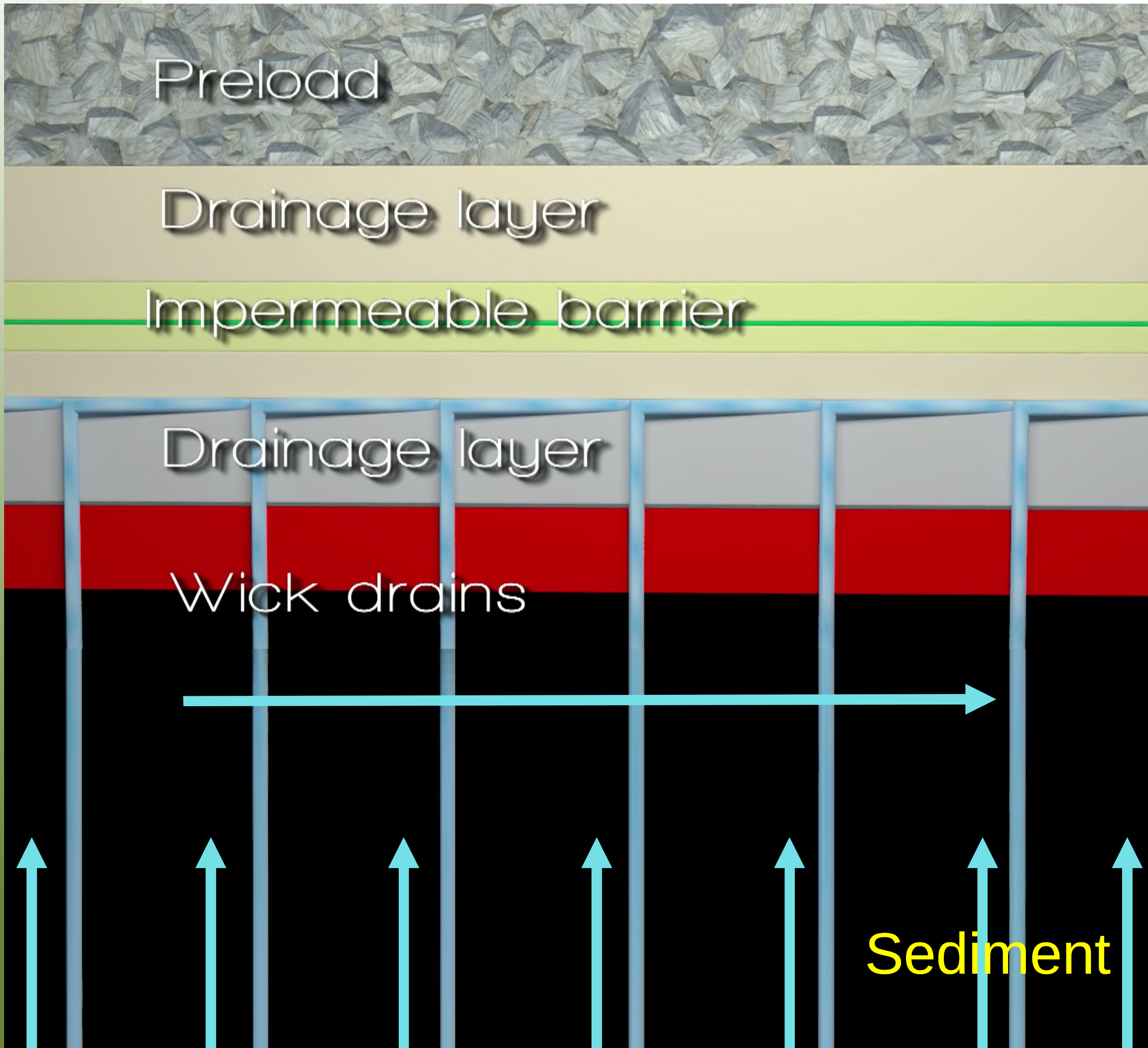
- Cap thickness ~3m




# Randle Reef ECF Cap – Multiple Layers



# Installation of ECF Cap cont'd




- A 'preload' of 150,000 tonnes will be placed on the cap;
- Wick drains will be used to increase the rate of consolidation and shorten the necessary 'preload' duration;
- Approximately 11,500 wick drains will be installed (4''x 1.5''x 33');
- It is anticipated that the "preload" will be in place for approx. 12 months and then removed.

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# Randle Reef - End Result

# Assessing the Effectiveness of the Randle Reef Clean Up

- PAH concentrations & profiles in suspended sediments and surface water
- Sediment toxicity & benthic invertebrate community structure.
- Larval & embryo deformities in fish exposed to PAHs.
- Wild fish health endpoints.
- Reproductive parameters (on site swallows) as well as blood, liver and tissue samples
- Tumours & external abnormalities in wild fish.

# Additional / Supplementary Studies (Geoscience focus)

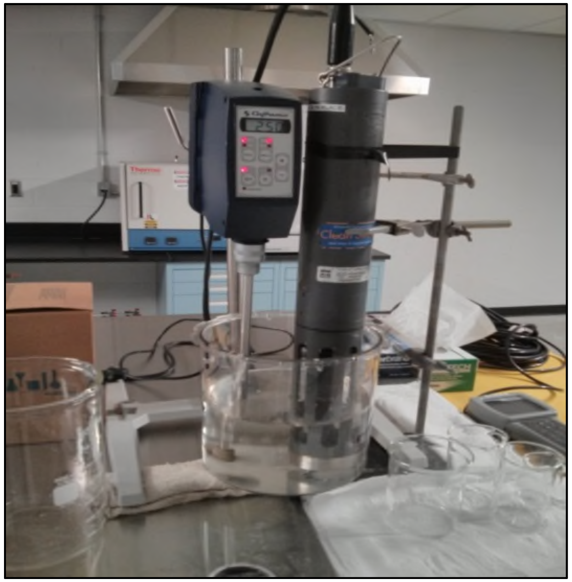
# Deriving Water Quality Criteria During Dredging

- Dredging introduces suspended sediment into the water.

- Traditionally, water quality impacts from dredging focused largely on the physical impacts of suspended solids on fish and fish habitat.  Randle Reef sediments are highly contaminated.

- ECCC used a modified DRET procedure to examine potential chemical and toxicological impacts with Randle Reef sediment at 3 TSS levels (25, 50 and 75 mg $L^{-1}$).

- The modified DRET procedure allowed ECCC to establish a site-specific TSS criteria protective of the environment.



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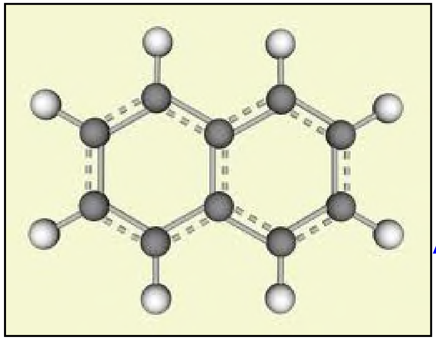
# Goal of Elutriate Study

Examine

chemical and toxicological effects resulting from a range of

**Total Suspended Solids (TSS)**

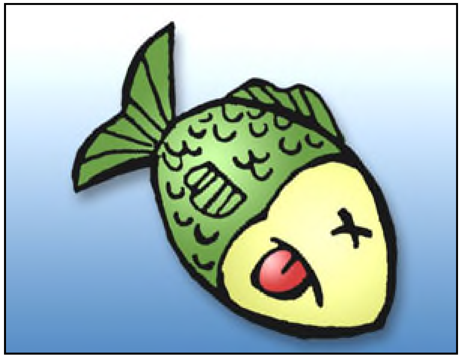
concentrations (25, 50 and 75 mg/L).



GOAL:

Determine

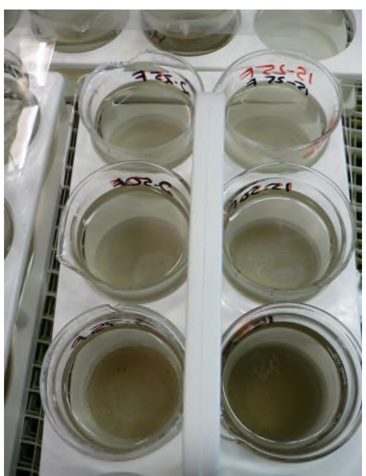
Acceptable TSS level for dredging at a compliance point acceptable to the regulatory authorities



# Elutriate Study

- Determine the total and dissolved contaminant loadings associated with 25, 50 and 75 mg/L TSS
- Relate these to literature toxicity values
- Conduct toxicity testing on elutriate containing 25, 50 and 75 mg/L TSS
- Establish a “safe” TSS limit
- Provide recommendations to modify the specifications in regards to water quality during dredging operations

# Methods (Elutriate Toxicity)



DRET solutions made with site water and selected site sediment, 15 min. mixing

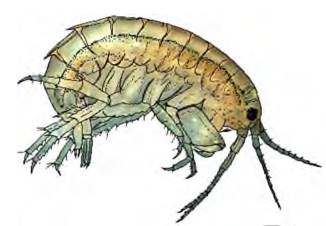
**Acute Toxicity Tests Conducted on:**

Water-column:

*Daphnia magna* and fathead minnow

Sediment-water interface:

*Hyalella azteca, Chironomus dilutus*



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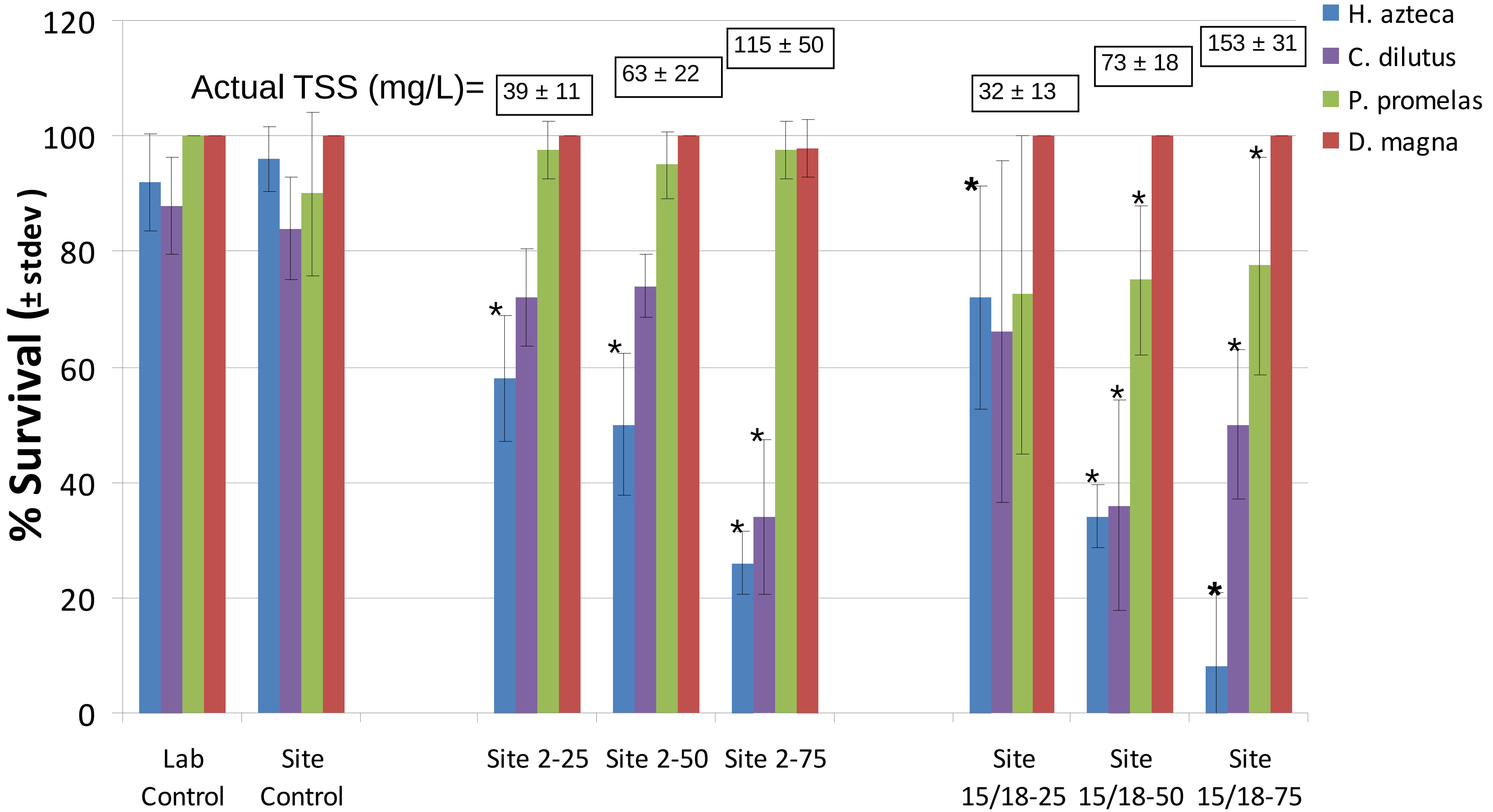
# Results (All Species Elutriate Toxicity)



# Conclusion

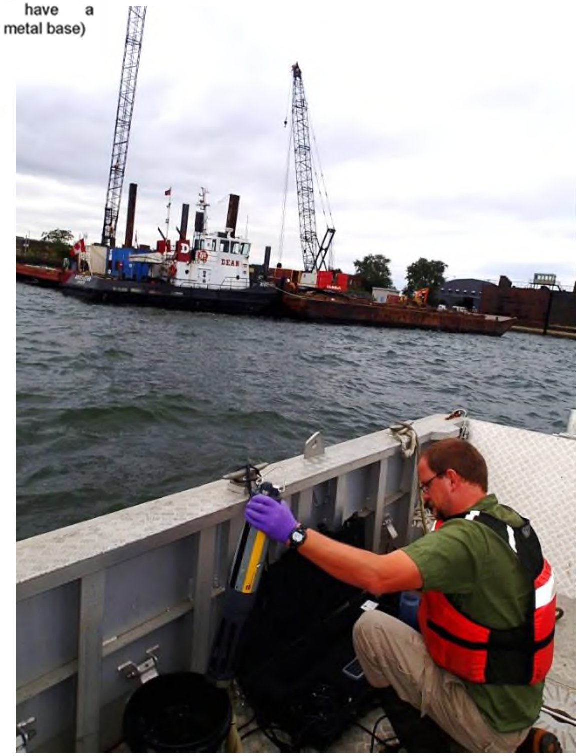
In order not to encourage "aggressive" dredging, EC recommended:

- ***25 mg/L above a floating background value, 100 m from the in-water work, when background levels are less than or equal to 75 mg/L. In any cases were background TSS exceeds 75 mg/L, the maximum allowable TSS will be 100 mg/L.***

# Correlation of TSS to Turbidity

**Turbidity**

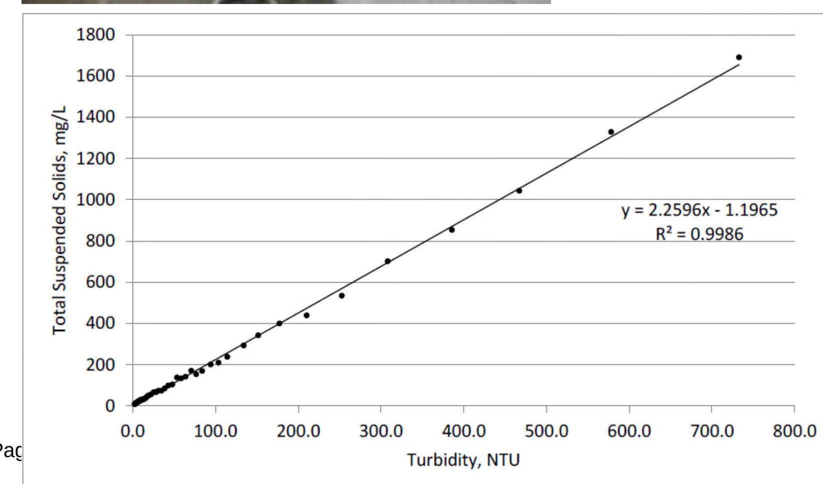
- Measures cloudiness caused by suspended solids
- Reported in Nephelometric Turbidity Units (NTUs)
- Field equipment provides instantaneous results
- Can be correlated to TSS

**Used as a surrogate to measure TSS at the site.**

# Correlation of TSS to Turbidity

- A site specific relationship between turbidity and TSS needs to be established.
- EC conducted a lab-based study using sediment and site water from 3 locations within the Randle Reef dredging area, covering the slightly differing grain size
- Results were similar between grain sizes
- Resulting (average) relationship TSS = 2.26*NTU - 1.2 (Essentially a 2:1 ratio of TSS to Turbidity)
- Work was repeated during Stage 1 and found to be 1:1 ratio but we stuck to the more conservative 2:1 as the contractor had no problems meeting.



# Modeling to assist the monitoring of Dredged Sediment Plume ( as Turbidity)

- In order to properly monitor any sediment plumes from the dredge, it is important to know the direction of the dominant current based on the prevailing wind direction.

- Randle Reef area is not a uni-directional river nor can we assume that generated current follows wind. The current patterns with the Engineered Containment Facility in place are likely complex.



Canadian Science Publishing

ARTICLE

## Modeling study of dredging induced sediment plume transport in Hamilton Harbour

Cheng He, Padala Chittibabu, and Matthew Graham

**Abstract:** To assess and predict the direction and range of a dredging induced contaminated sediment plume on the surrounding environment, a three-dimensional hydrodynamic and mud transport modeling system MIKE 3-FM was used in the Randle Reef area of Hamilton Harbour. Simulations were carried out with the typical local and maximum winds under which the dredging operation would proceed. The dredge plume travel pattern and range in both horizontal and vertical planes are examined under various wind conditions and model mesh resolutions. It was found that the simulated plume extents were very sensitive to transport model mesh resolution due to the additional numerical advection induced in the calculations. Detailed discussion of this particular issue has not been observed in other publications. The results of this simulation provide useful information for remediation project managers in planning and guiding the environmental monitoring of dredging operations. In addition, the methodology used in this study can be adapted to other dredging projects.

*Key words:* contaminated sediment plume, water quality monitoring, sediment remediation, Randle Reef, hydrodynamic and transport modeling.

**Résumé :** Afin d'évaluer et de prévoir la direction et l'étendue d'un panache de sédiments contaminés causé par le dragage dans le milieu environnant, un système de modélisation tridimensionnelle hydrodynamique et de transport de boue MIKE 3-FM a été utilisé dans la région du récif Randle du port de Hamilton. Des simulations ont été effectuées avec les vents locaux et maximaux typiques sous lesquels l'opération de dragage devait se dérouler. La trajectoire et l'étendue du panache de dragage dans les plans horizontal et vertical sont examinées dans diverses conditions de vent et dans diverses résolutions de maillage. Il a été constaté que les étendues simulées du panache étaient très sensibles à la résolution du maillage du modèle de transport en raison de l'advection numérique supplémentaire induite dans les calculs. On n'a pas observé de discussion détaillée sur cette question particulière dans d'autres publications. Les résultats de cette simulation donnent aux gestionnaires de projet de restauration des renseignements utiles quant à la planification et l'orientation de la surveillance environnementale des opérations de dragage. De plus, la méthodologie utilisée dans cette étude peut être adaptée à d'autres projets de dragage. [Traduit par la Rédaction]

*Mots-clés :* panache de sédiments contaminés, surveillance de la qualité de l'eau, assainissement des sédiments, récif Randle, modélisation hydrodynamique et de transport.

### Introduction

During dredging, suspended sediment plumes are generated and can potentially spread over a large area. Therefore, it is important to understand these ranges are under different operation conditions. In some water bodies, current patterns below the water surface can be much complicated and bottom flow can even occur in the opposite direction of the wind (He 2010). At such sites it is important to know the direction of the dominant currents and the estimated range of plume travel based on the prevailing wind direction. This allows for better and more targeted monitoring.

Hamilton Harbour is a closed basin except for an 820 m long, 107 m wide, and 9.5 m deep ship canal connecting with the west end of Lake Ontario. It is triangular in shape as shown in Fig. 1A, has a maximum depth of 23 m, a mean depth of 13 m, and a surface area of 21.5 $km^2$. The hydrodynamic behavior in the harbor is largely determined by its geometry, with the wind as the principal source of mechanical energy (Wu et al. 1996; Hamblin 1998). A weak harbour wide oscillation (seiche) can be induced with a period of approximately 2.6 h (Hamblin 1998), and the effect of astronomical tides is negligible. Exchange flow from Lake Ontario does not have a strong influence on flow conditions farther away from the canal such as in the Randle Reef (RR) region (Hamblin and He 2003). Flow circulation induced by a few small tributaries is only significant near the tributary mouth regions. Due to its shape, there is no dominant travel direction for harbour flow, resulting in complex flow patterns. A large-scale sediment remediation project known as the Randle Reef Sediment Remediation Project is currently underway in the harbour. Contaminated sediment is being dredged and placed into a constructed engineered containment facility (ECF). In the RR area, water depth is variable ranging from 4 m to 10 m and there are numerous vertical dock walls (approximately 10 m deep) along the local shoreline. The effects from breaking waves approaching a near shore shallow area are minimal in this area.

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Published at www.cdnsciencepub.com/cjce on 4 August 2020.

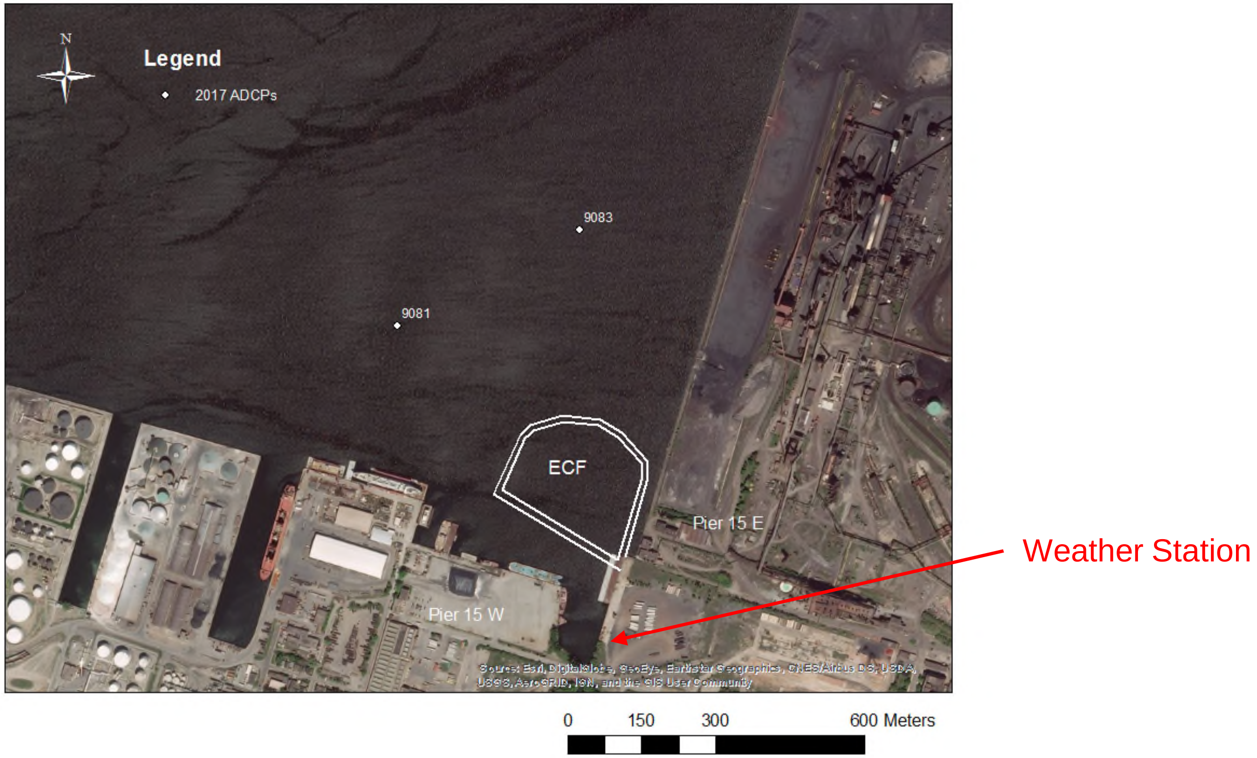
# Wind Data

- Davis Vantage Pro 2 Weather Station Mounted on the Site trailer.

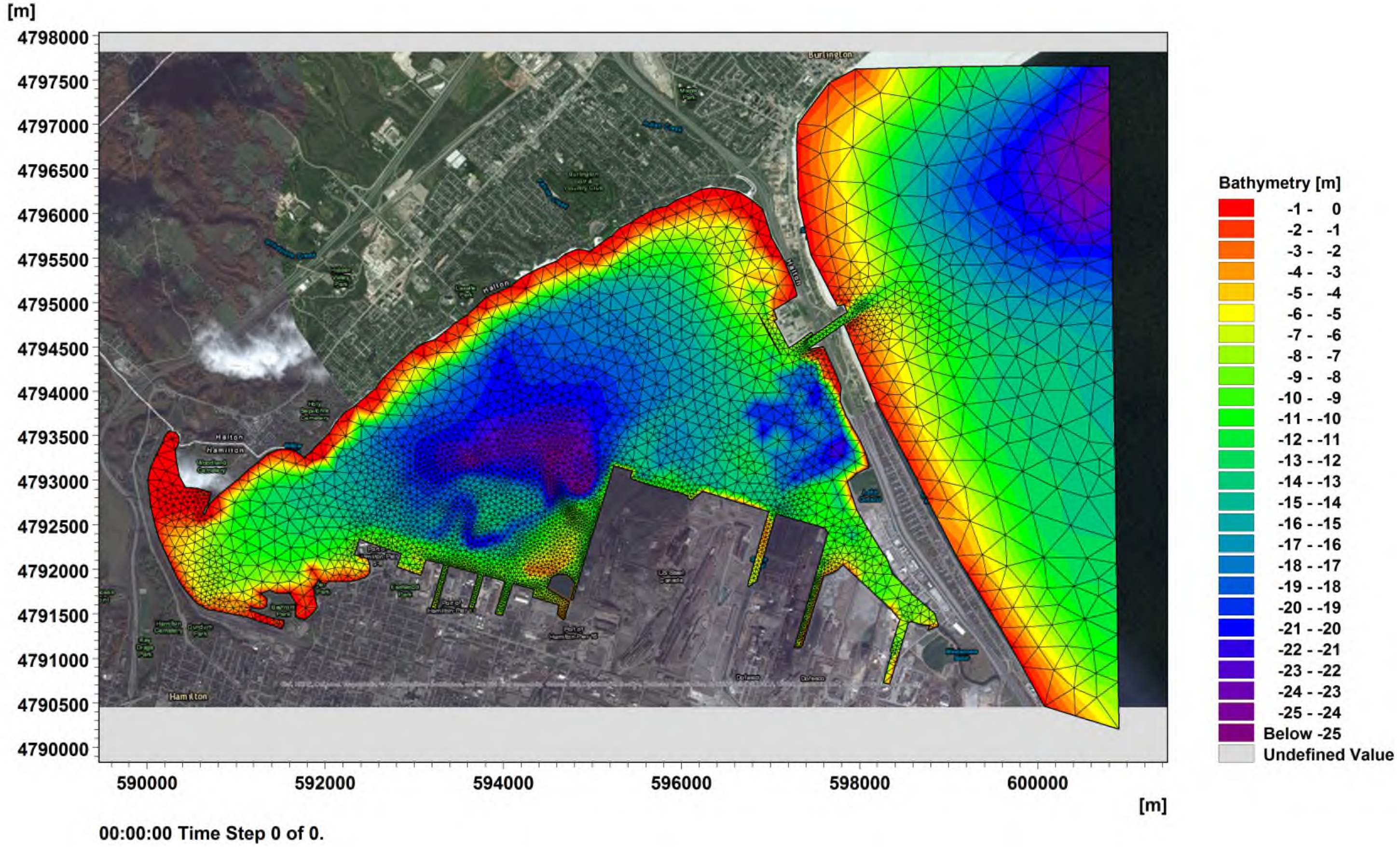
- CCIW weather station

# Water Curent Data

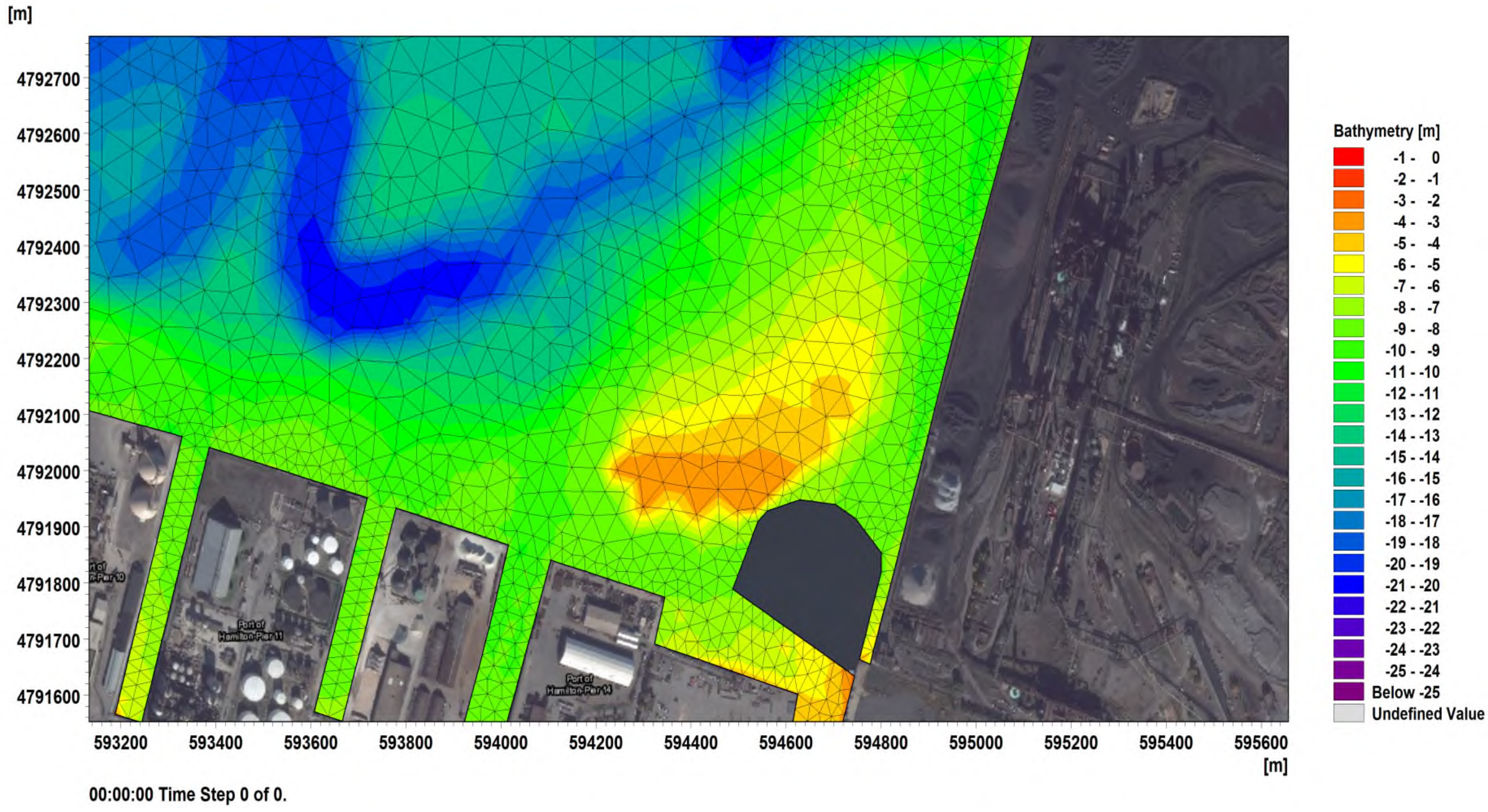
- 2 ADCPs deployed from July to October.



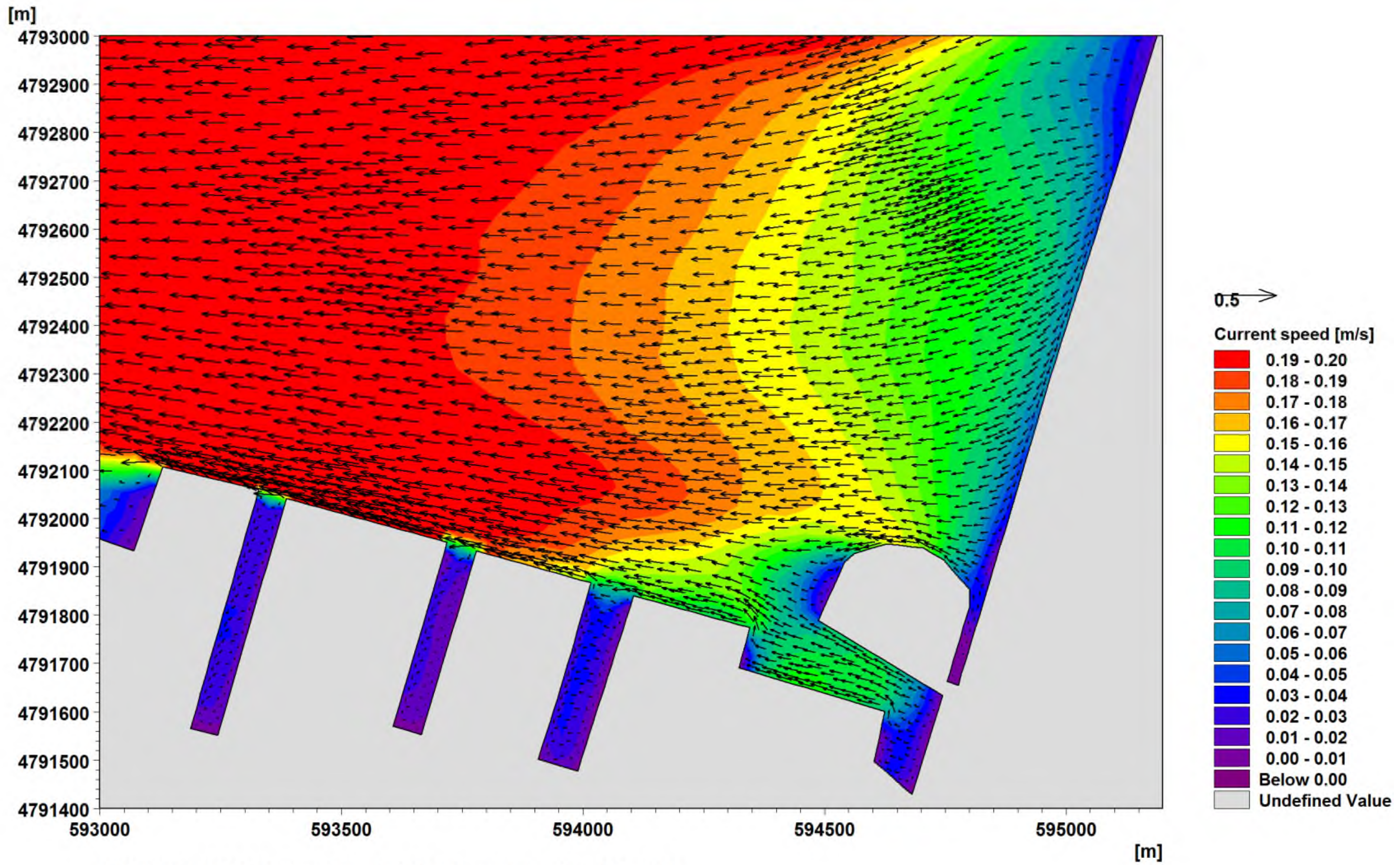
# Model Grid (MIKE 3)



# Model Grid Zoomed to Project Area

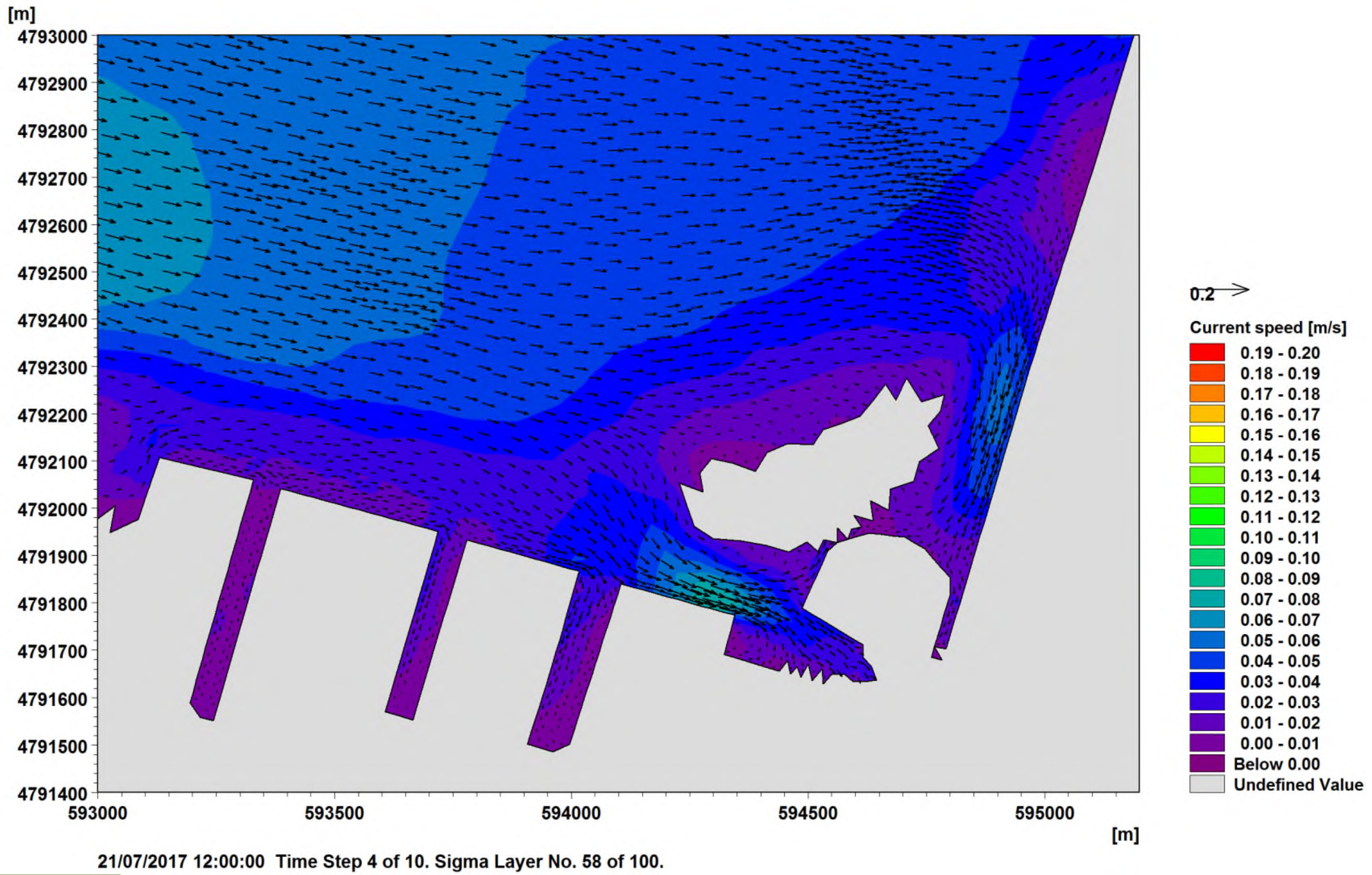


# Example Results (Surface flow – wind from east)




21/07/2017 12:00:00 Time Step 4 of 10. Sigma Layer No. 100 of 100.

# Example Results (Near bottom depth [8m]– wind from east)



# Additional Work to refine Depth to Clay or Clean lines for Dredging

- Contamination generally contained in a soft saturated dark brown layer of silt with varying amounts of sand.
- Underlying the contaminated sediment is usually a firmer substrate, often a silty clay but can also range from silts to sands in many areas.
- Silty clay layer is uncontaminated.
- In the early design phases of the remediation project the silty-clay layer was the target elevation for dredging for the majority of the site. This was conservatively selected.
- Measurements by divers in 2010 in selected locations confirmed that there were discrepancies between the interpolated dredge grade and the target silty clay layer. Hence the need to better define!

# Additional Work to refine Depth to Clay or Clean lines

**Addition deep coring**

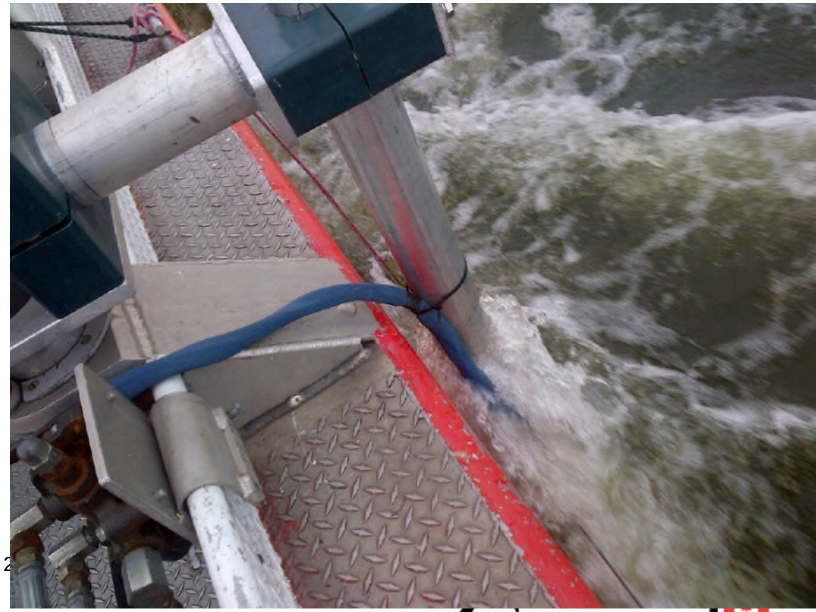
- Variety of methods used to define the silty clay layer that underlies most of the site.
- These were found to be inaccurate in a number of areas.
- Used long thin-walled aluminum core tubes for better penetration with vibracore
- Conducted a coring program along with sub-bottom profiling to better establish  the clay elevation
- Where clay was deeper that expected, also conducted additional sampling to identify clean lines based on the 100 ppm tPAH target level identified for the site

# Sub-bottom Profiling

- Sub-bottom profiler used was a Specialty Devices Inc, (SDI) BSS+.
- Complete hydrographic survey and sub-bottom profiling system contained in a single portable splash proof unit.
- includes an intelligent depth sounder, a true digital sub-bottom profiling capability, a differential GPS receiver (DGPS), a reference receiver, a navigation computer, a color display, survey software and rapid data playback and review software.

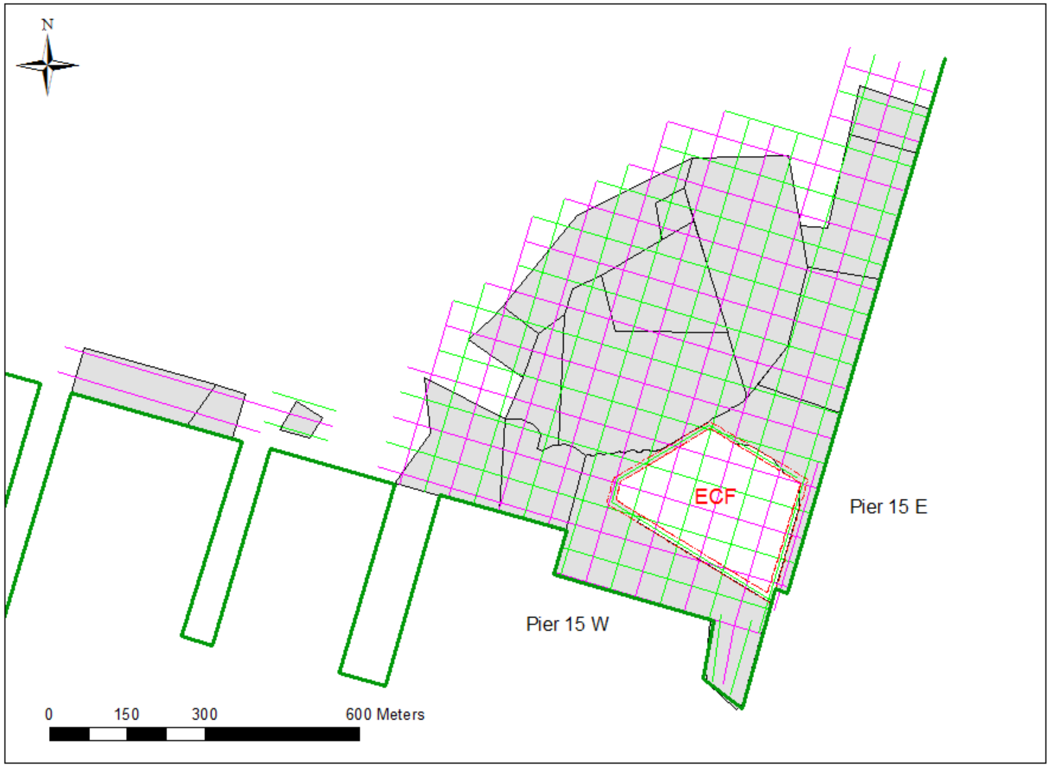
# Sub-bottom Profiling

- Unit was deployed from an 18 foot boat.
- Boat was advanced along the tracks at a speed of approximately 3 knots.
- Tow-fish was deployed off the survey vessel ~ 0.10 m below the water surface.
- Operated on 200, 12 and 3.5 kHz frequencies.

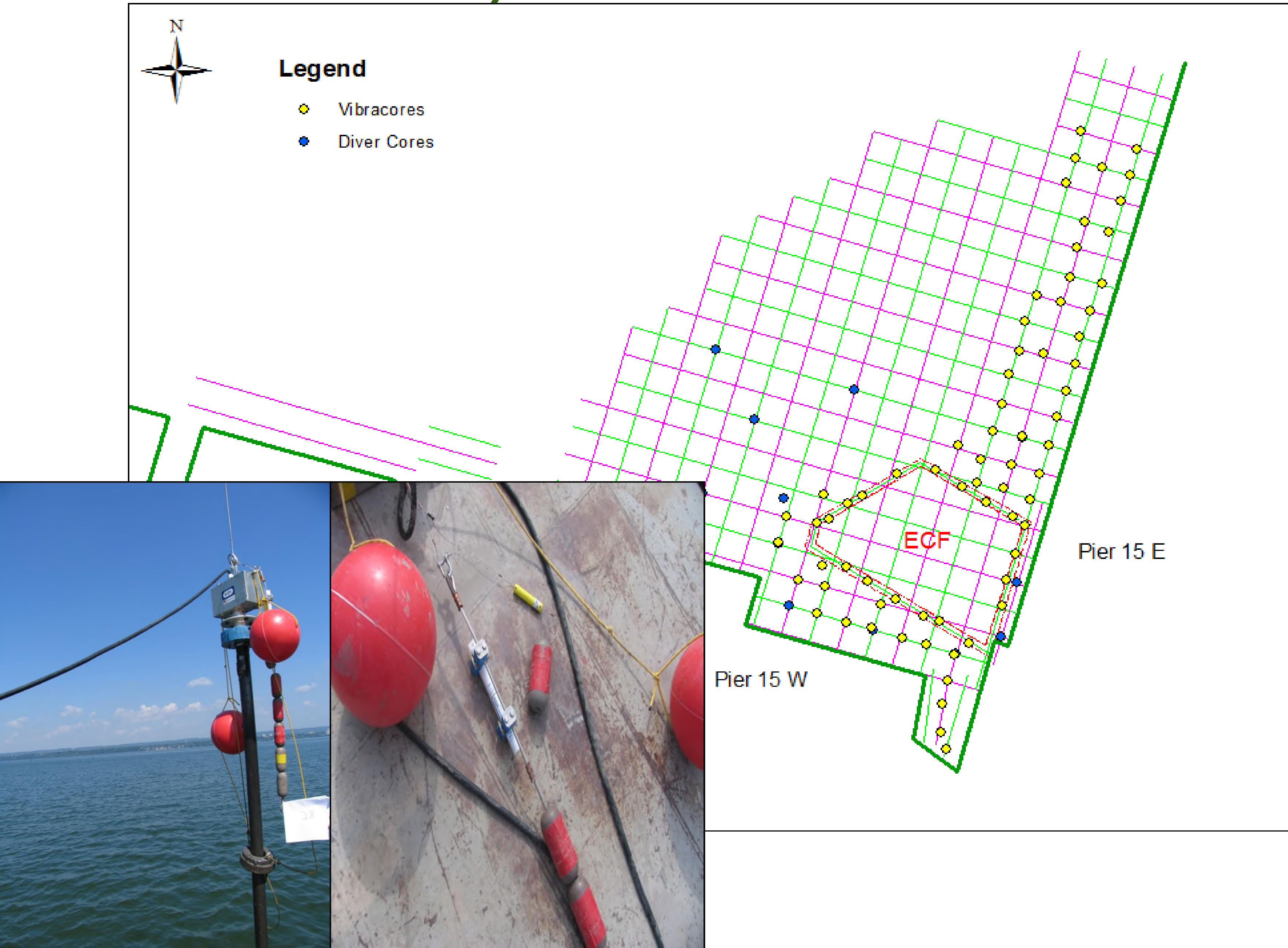



# Sub-bottom Profiling

- Track-lines (50m spacing).
- Covered the entire project area.



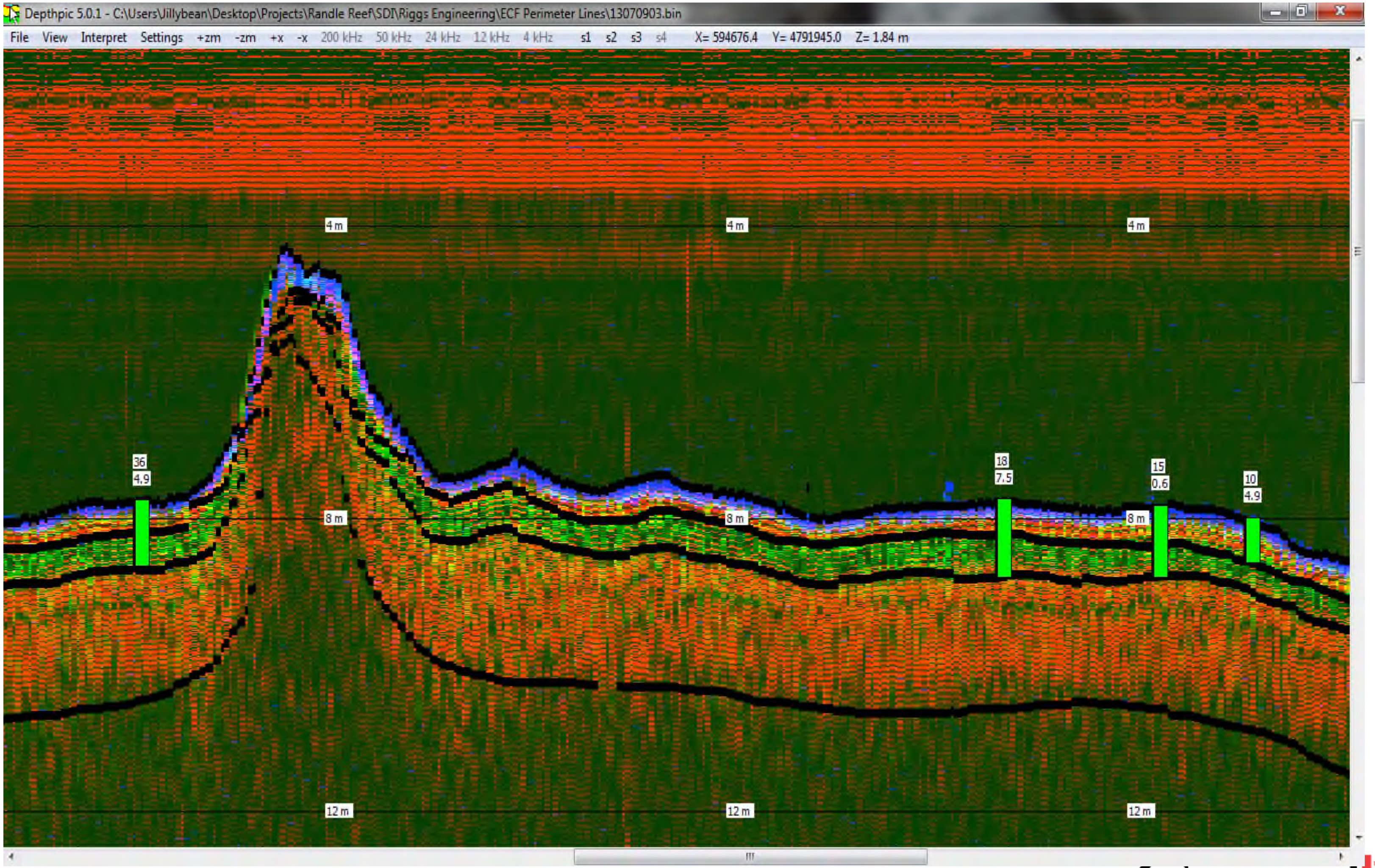
# Confirmatory Coring (Boat/Vibra core + Diver Collected cores)



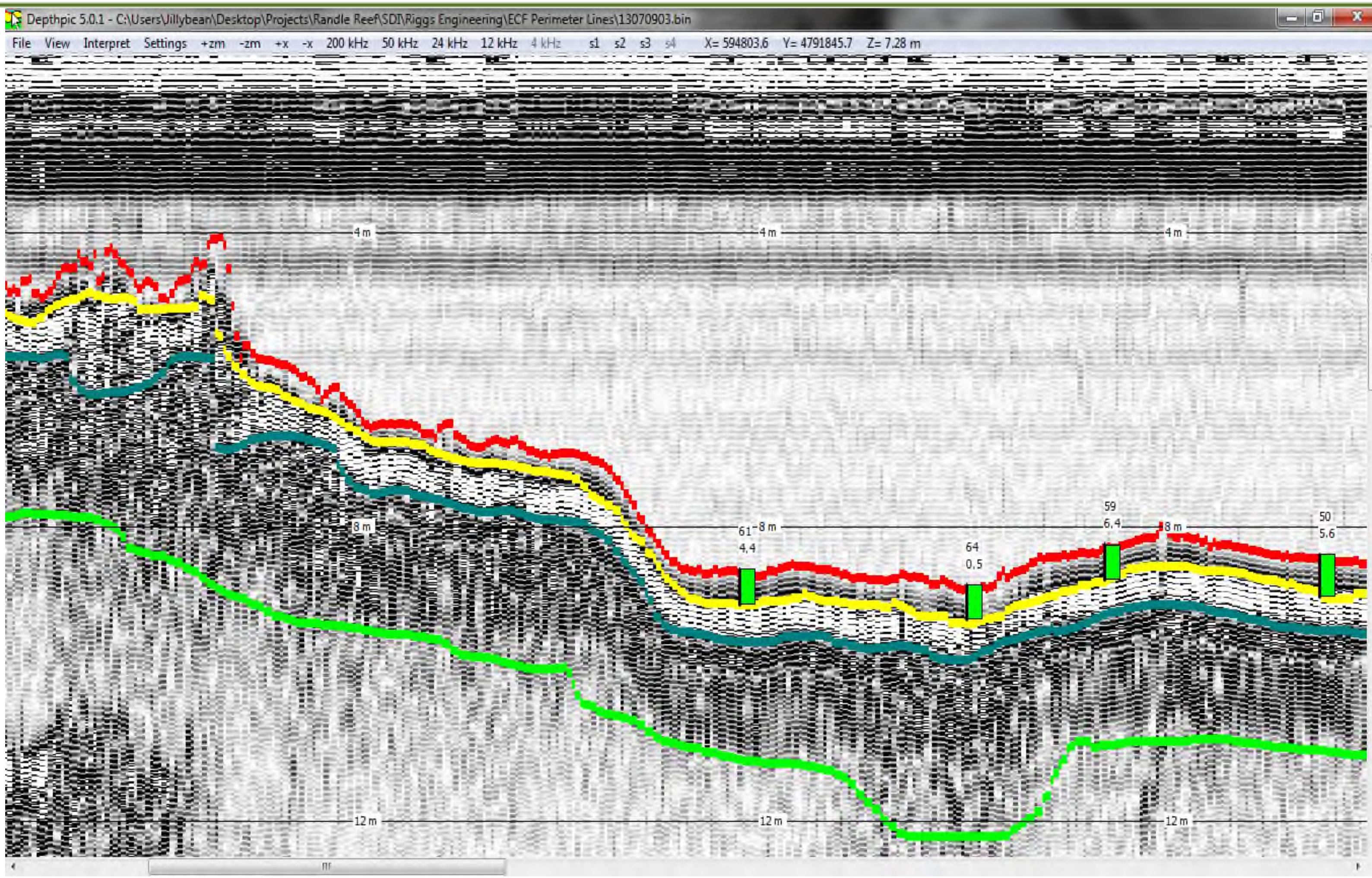
# Results

- Found that the best frequencies for the work being undertaken were the 200 kHz for identifying the sediment / water interface (bottom) and the 3.5 kHz for identifying the silty clay target dredge layer.
- The 50 kHz frequency was initially used to aid in the selection of the best frequencies.
- The 12 kHz frequency was essentially utilized to confirm the results of the 3.5 kHz.
- Interpolation and confirmation provided by the coring data

# Results


Depthpic 5.0.1 - C:\Users\Jillybean\Desktop\Projects\Randle Reef\SDI\Riggs Engineering\ECF Perimeter Lines\13070903.bin
File View Interpret Settings +zm -zm +x -x 200 kHz 50 kHz 24 kHz 12 kHz 4 kHz s1 s2 s3 s4 X= 594676.4 Y= 4791945.0 Z= 1.84 m
4 m
4 m
4 m
36
4.9
18
7.5
15
0.6
10
4.9
8 m
8 m
8 m
12 m
12 m
12 m

# Results



Depthpic 5.0.1 - C:\Users\Jillybean\Desktop\Projects\Randle Reef\SDI\Riggs Engineering\ECF Perimeter Lines\13070903.bin
File View Interpret Settings +zm -zm +x -x 200 kHz 50 kHz 24 kHz 12 kHz 4 kHz s1 s2 s3 s4 X= 594803.6 Y= 4791845.7 Z= 7.28 m
4 m
8 m
12 m
61
4.4
64
0.5
59
6.4
50
5.6

# Results

- The depth of penetration was limited to about 3m below the sediment water interface.
- Below this the signal quickly faded
- The penetration depth of approximately 3 m was adequate at the Randle Reef with the exception of one small area near the northeast corner of the ECF. Additional deep cores were taken in this area and used to fill in the data.
- The ground-truthed sub-bottom profiling data, once exported, corrected to chart datum and kreiged provided a more precise elevation and location of the silty clay across the site.

REMEDIATION Spring 2017

## The Use of Subbottom Profiling in Refining Dredge Cuts for a Large-Scale Sediment Remediation Project

Jill Coles
Matthew Graham
Brian Riggs

*A number of different techniques were employed to locate the target dredge grade on a large-scale Canadian sediment remediation project. These techniques included various coring events, Seabed Terminal Impact Newton Gradiometer (STING) testing, and geotechnical borings. Despite these techniques, the data set for interpolation of the dredge grade was widely spaced, and some of the investigations were not specifically intended to be used for defining the dredge grade. In order to reduce the risk of extra expenses from contractor claims resulting from differing sediment conditions, more precise planning was required. Due to the size of the area and the desired accuracy, subbottom profiling was identified as a potential tool to provide high-density coverage across the site. As with any geophysical tool, ground truth data were required to verify and aid in interpretation. This article describes how subbottom profiling was used to refine the dredge grade for the target layer, the associated challenges related to signal loss in some areas, and how they were overcome. ©2017 Wiley Periodicals, Inc.*

### INTRODUCTION

Hamilton Harbour, located at the western tip of Lake Ontario, Canada, is home to a highly contaminated sediment site known as Randle Reef. This site is considered one of the most contaminated sediment sites in Canada. It consists of approximately 60 hectare (Ha) of harbor bottom that is severely contaminated with polycyclic aromatic hydrocarbons (PAHs) and heavy metals. PAHs are present in very high concentrations, and it is well known that PAHs are carcinogens and also have the potential to adversely affect a wide variety of biota and humans (Kapuska, 2004; Marvin et al., 1995). The remediation plan for this site requires a double-walled sheet pile engineered containment facility (ECF) to be constructed surrounding the most highly contaminated sediments. After the ECF is built, the contaminated sediments outside the ECF will be dredged and placed inside the ECF to be isolated from the environment. The inner sheet pile wall will be a sealed environmental wall.

The contamination at Randle Reef is generally contained in a soft saturated dark brown layer of silt with trace amounts of sand. Underlying the contaminated sediment is usually a firmer substrate that is often silty clay but can also range from silts to sands in many areas. Where firmer substrates other than silty clay directly underlie the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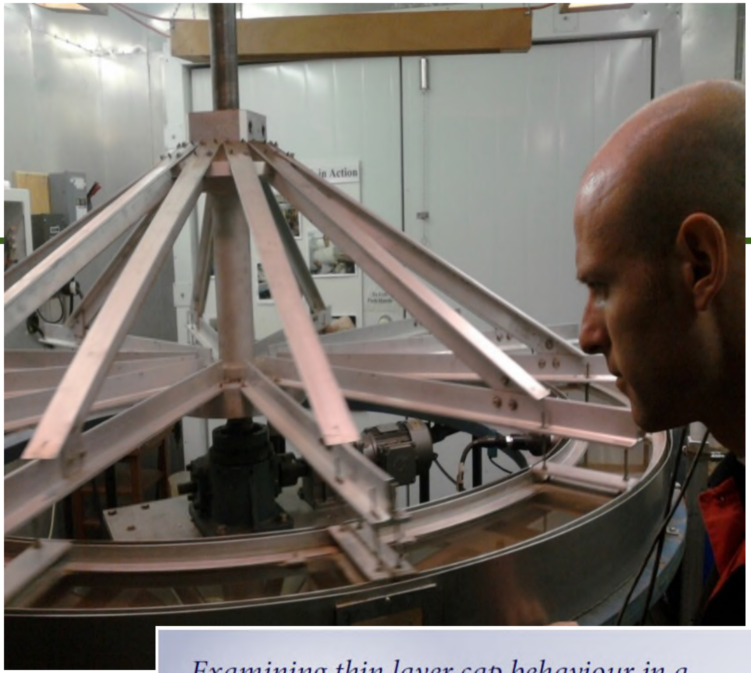
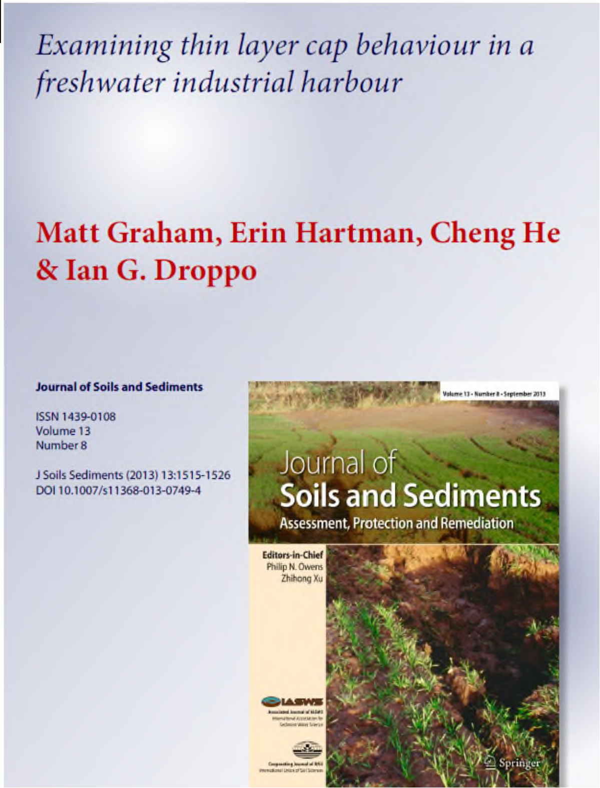
# Stability of Capping Sands

- Original design selected capping sand specs based on previous experience.
- No information or data provided on the stability of the selected sand .
- EC conducted testing on the proposed sand using a circular flume, as well as an approximate expression based on the well-known Shield diagram
- Modelled (Mike 3) the expected bottom shear stress in the Project area from wind and was verified by 2 ADCPs, moored at the site for an 8 month period.
- Estimated the shear stress from vessels that would be expected in the area.





# Stability of Capping Sands

- Mike 3 used for modeling along with Acoustic Doppler Current Profilers to verify the models predicted flows as well as determine the bottom shear stress use the "Law of the wall" method.

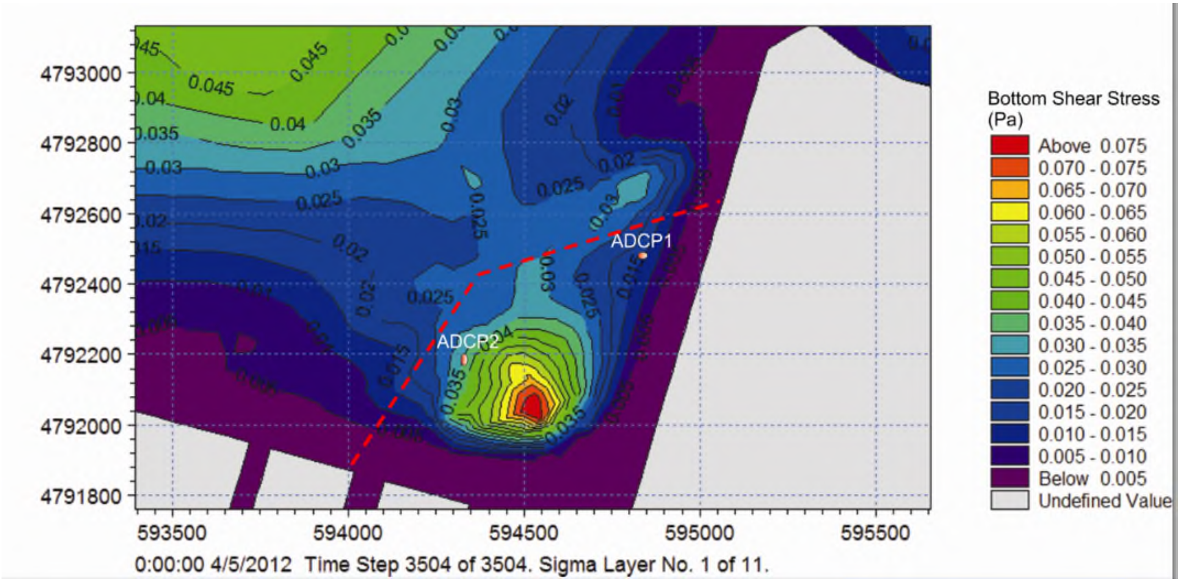
**"Law of the wall"**

$$u(z) = \frac{u_*}{\kappa} \ln \frac{z}{z_0}$$

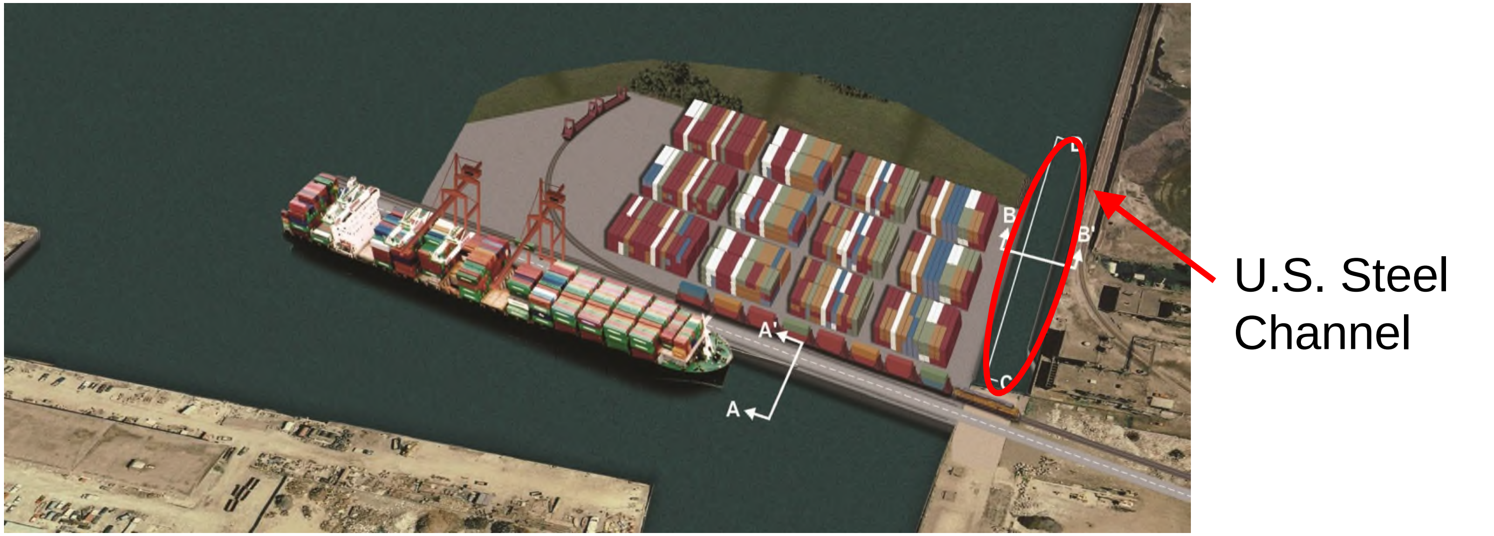
**Vessel induced bottom velocity**

$$V_b = \frac{C_1 \times D_p \times C_2}{Hp} \left[ \frac{P_d}{{D_p}^2} \right]^{1/3}$$

**Time averaged Bottom shear stress (Pa)**



# Stelco Channel Re-design and Modelling




- Channel required isolation capping due to intakes outfalls and presence of slag.
- Earlier version of Danny Reible's CapSim model used to design cap thickness and adsorbents. Groundwater upwelling is an important piece of data for this.
- Original Designer used a groundwater seepage rate from a paper that utilized shore-based piezometers, however, none of which were in the Stelco Channel itself.

# Stelco Channel Re-design and Modelling

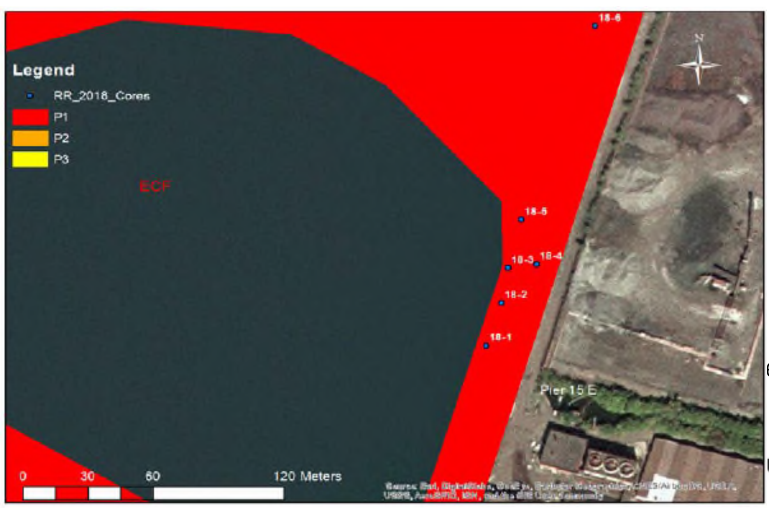
## Groundwater Seepage Study – Stelco Channel Cap

- In 2013 EC measured the flux rate by installing 4 seepage meters in the channel.
- Found that the original estimates were reasonable, but now had real data
- During Stage 1 evidence of NAPL was found near outer ECF walls adjacent to the Stelco Channel.
- As a result additional studies were undertaken by ECCC and a consultant to the Design Engineer


# Stelco Channel Re-design and Modelling

## Additional Field work

- There is a lot of slag in this area
- In 2018 EC Took box cores in the areas to try to better characterize the extent of the contaminated sediment above the slag and extent of NAPL
- In 2018 EC also took additional cores to further characterize the extent.
- Test pits were conducted by the contractor to penetrate the slag in selected locations.
- Selected Cores sections were provided to Anchor QEA for pore water analysis an NAPL mobility testing







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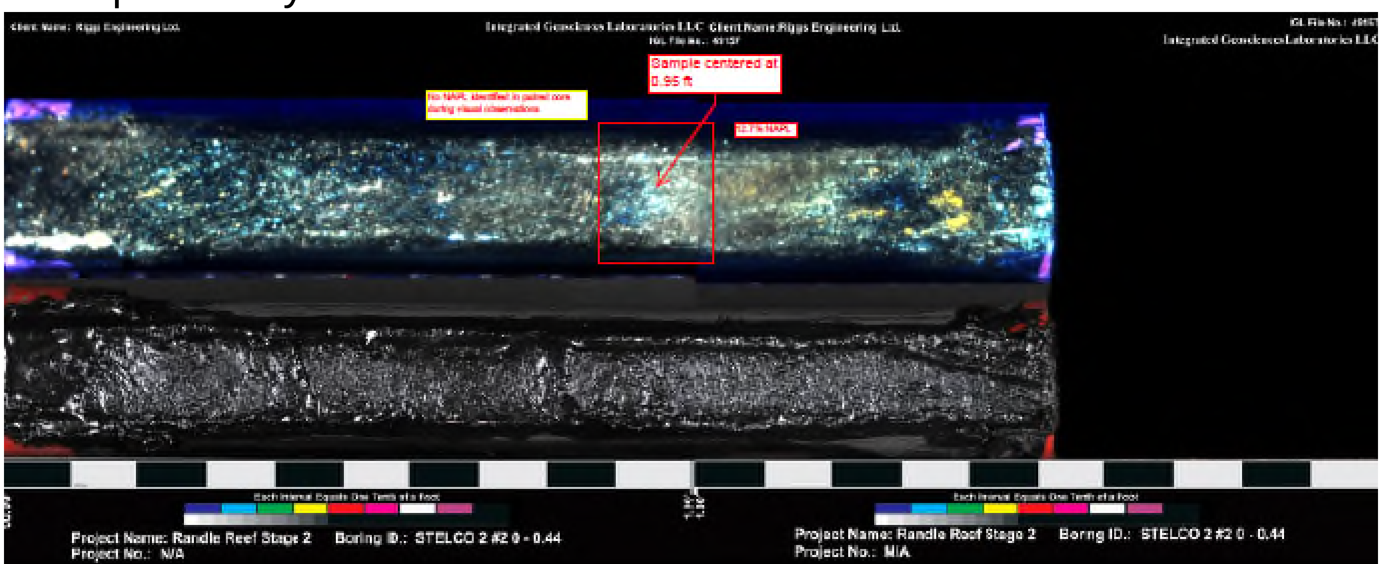
# Stelco Channel Re-design and Modelling

## Additional Field work

- In 2019 the design Engineer submitted select core sections for pore water analysis, specialized Ultra-violet and white light photography and then selected sections sent for NAPL mobility testing
- Generally for NAPL to migrate, it must be present in excess of residual saturation and there must sufficient force for it to move.
- Only one location showed NAPL saturation higher than residual saturation.  Therefore NAPL was potentially mobile at one location

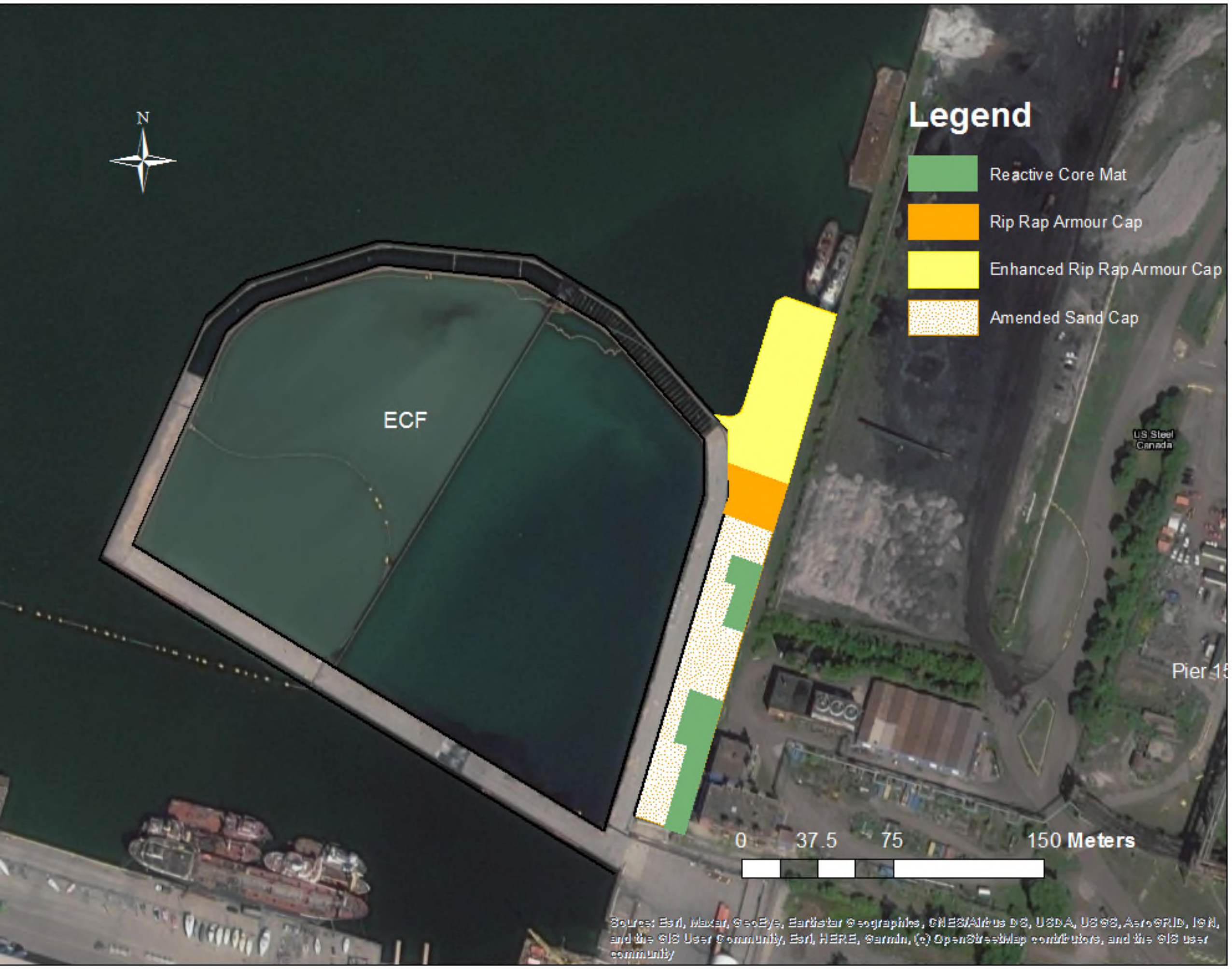


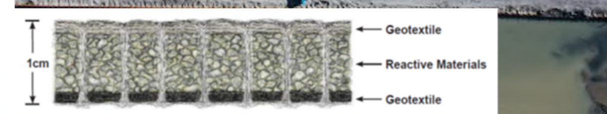
# Stelco Channel Re-design and Modelling

## Conclusions

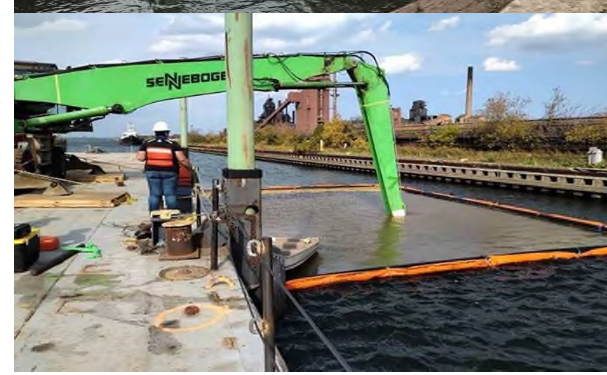
- Design Engineer re-ran the Reible CapSim model using the measured flux rates and more up-to-date sediment chemistry data and then adjusted the thickness of the amended sand layer
- Even though only one location showed the potential for mobile NAPL,  organoclay reactive core mats were added to the general areas where NAPL was confirmed

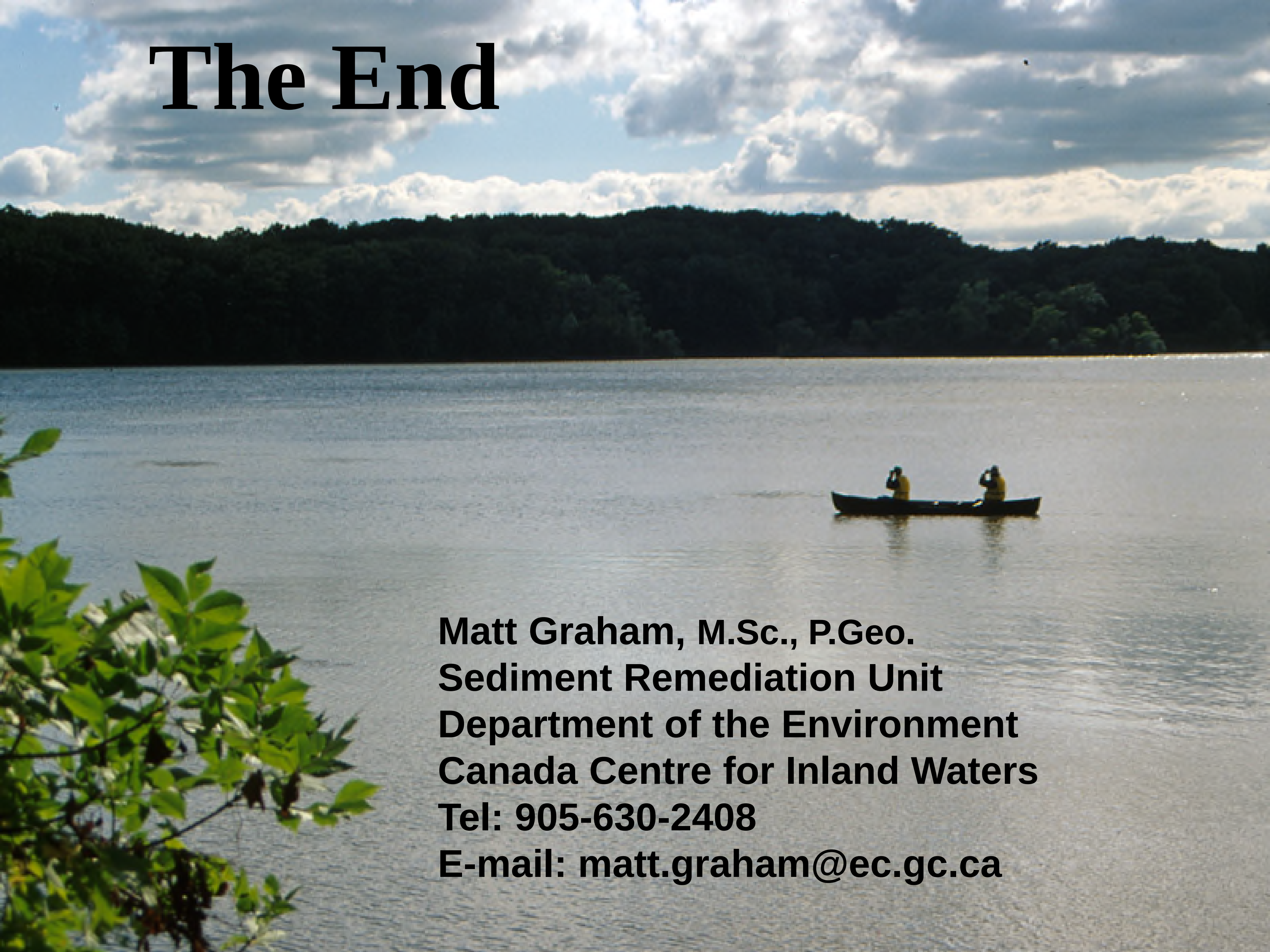
# Isolation Cap - Stelco Channel









# The End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