



**INNOVATIVE TECHNOLOGY DEMONSTRATION
PILOT STUDY
ELECTRO-KINETICS
DEWATERING AND CONSOLIDATION
OF
ERIE PIER FINE SILTS**

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Reported By

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Executive Summary

During the first week of August, 2006, a study was conducted by Electro-Petroleum, Inc (EPI), electrochemical processes, llc (ecp), the University of Minnesota Duluth's Natural Resources Research Institute (NRRI); with major assistance of Harrison Marine; and with oversight by the U.S. Army Corps of Engineer's (USACE), Detroit District and its Waterways Experiment Station (WES), Engineer Research and Development Center (ERDC), Vicksburg, on the use of Direct Current for the dewatering and consolidation of fine silt from the Erie Pier Confined Disposal Facility (CDF), Duluth MN. Previous work by EPI and Harrison Marine had demonstrated that fine silt could be settled rapidly from a water column using Direct Current. EPI had also previously used Direct Current to remove water from mud pits generated in the oil patch, aiding in the solidification of the mud for final disposal.

This demonstration was conducted on fine silt taken from the settling basin at the CDF in an area "downstream" from the sluicing and desanding operation conducted at the site. Two tests were conducted: an initial rapid half day test, and a second 5 day test run in parallel to a controlled settling test. The goal of the test was to measure the amount of water which could be removed from the material and measure the shrinkage in the volume of the silt. By compacting the silt it was anticipated that additional storage capacity volume could be created in a CDF to allow additional dredged material to be disposed in the facility. A second benefit would be to aid in the recycling of the silt currently stored in the CDF by making it more physically easy to handle with heavy excavating equipment. The test demonstrated the removal of 17% of the initial volume as water and a shrinkage of 30% in total soil volume.

Background

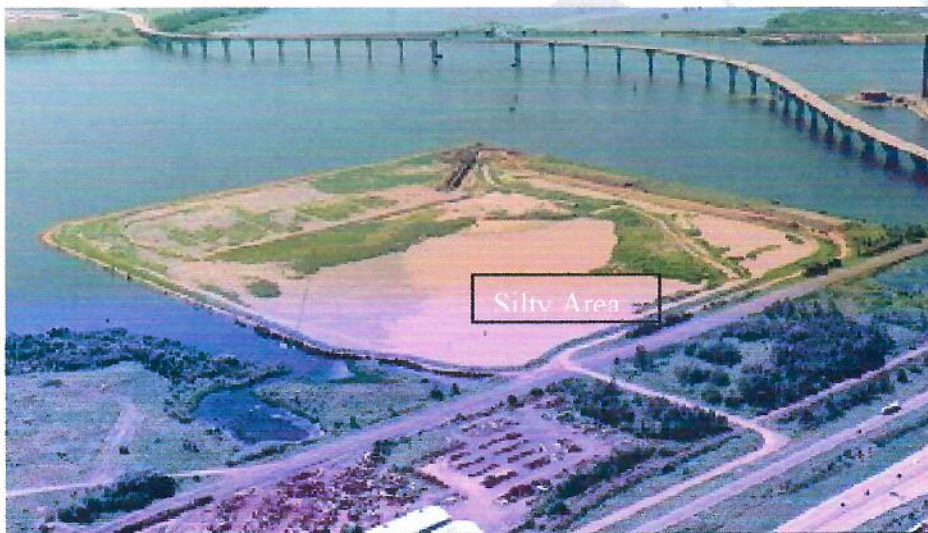
The Erie Pier Confined Disposal Facility (CDF) is located in the Port of Duluth-Superior and is the repository for sediments dredged from the harbor. As stated in the Draft Environmental Impact Statement for the facility:

"Maintenance dredging for the Federal project averages about 150,000 yards per year. Much of the dredged material is placed in the Erie Pier CDF, which is located on approximately 82 acres along the northwest shore of Duluth-Superior Harbor. The CDF was constructed in 1979 to hold up to one million cubic yards of material dredged from the Federal navigation project over a 10 year period. Clean sand dredged from the outer parts of the harbor is generally used for beach nourishment to mitigate the affects of beach erosion along the lake.

Since 1988, a washing operation has been conducted at the Erie Pier CDF to separate out the cleaner, coarse grained fraction of the dredged materials for beneficial use. Through this operation, over a half million cubic yards of coarse grained material have been removed for various beneficial uses, primarily construction projects. This has helped extend the

life of the Erie Pier CDF by several years. Nonetheless, remaining capacity at the Erie Pier CDF is insufficient for future dredged material placement needs.”¹

Along with other possible uses of the material in the CDF, such as a soil amendment for mineland reclamation, decreasing its overall volume would be desirable. An aerial view of the CDF is shown in Figure 1; the view is looking from the northeast to the southwest. The area in the northeastern (near) side of the CDF has been filled with a fine grained material reported to be up to 30 feet deep and soupy enough so that walking across the site is impossible. We propose that through the use of electrokinetics the sediment can be dewatered and solidified, thereby increasing the support of the soil and reducing the overall volume of the CDF.



**Figure 1. Erie Pier CDF Showing Silty Sediment in
Lower Center Of the Picture**

Electro-Petroleum, Inc., with the assistance of James Harrison, demonstrated that the settling rate for silt from the CDF could be enhanced under a DC Field. EPI had also previously used Direct Current to remove water from mud pits generated in the oil patch adding in the solidification of the mud for final disposal. This work is covered under a US Patent No. 4,382,341.

The use of electrokinetics as a dewatering method is reported many times in the literature and a review will not be covered in this Report.

Test and Test Methodology

The tests outlined in this report are very simple and straightforward. A sample of silt is collected, placed in a container, the volume of silt is measured, electrodes are inserted into the silt and a DC voltage is applied across the sediment. As the water collects at the cathode (negative electrode) the water is allowed to drain off through holes in the container. Over the test period, the current to the system is recorded, the water removed is collected and quantified, and the final volume of the soil is measured.

Two tests were conducted with material removed from the same location at the CDF. A picture of Larry Zanko removing the material from the site with a shovel is shown in Figure 2. Larry referred to the material as "Gaviidae excrement", which describes the characteristics of the material. In the photograph you can see that a pallet was required to distribute Larry's weight to prevent sinking into the sediment. The site where the material was removed was reviewed by Dave Bowman from the US Army Corps of Engineers as being visually the fine silty type of material which is found on the site. All of the tests were conducted at the CDF in an area where EPI and NRRI have been conducting DC remediation testing.



Figure 2. Larry Zanko Removing Samples of Fine Silt for Test from the CDF

Both tests were conducted by placing the silty material in clear plastic cells measuring 50 cm long and 40 cm high with a ridge running along the side 26 cm from the bottom. The width below the ridge was 38 wide and above the ridge was 40 cm wide. The cells were filled to near the side ridge (26 cm depth), with a measurement being taken prior to the test in all cases. The cells prior to filling are shown in Figure 3.



Figure 3 Clear Plastic Test Cells

TEST 1

In the first test, a single cells was filled with fine silt to a depth of 26 cm and two steel electrodes inserted into the cell to be treated. DC Power was applied at a relatively high current density of approximately 62 amps per square meter for the first 16 minutes. The current was then reduced to 20 amps per square meter for the next 210 minutes. The current was again raised to approximately 75 amps per square meter for two hours. Note that this voltage is well beyond the voltage which would be used in a field operation where the current density of less than one amp per square meter would be used over a longer period of time. The higher power levels were used to rapidly demonstrate the concept.

Results Test 1

During the six hour test a total of 2400 ml of water was removed from the test cell. The initial volume in the test cell was calculated to contain 45.60 liters of silt. The 2400 ml of material removed from the silt was approximately 5.3% of the volume. On a mole to mole basis we calculated that 133 moles of water were removed for each mole of electrons used in the demonstration. At the end of the test the now-stabilized, dewatered silt was dumped from the cell and was visibly denser than at the start. Figure 4 shows the material after initial removal and in Figure 5 the material is shown after three days of rain during which 5 inches of rain fell on the location.



Figure 4 Material after Initial Removal



Figure 5 Material after 5 inches of Rain

TEST 2

Test 2 was conducted with material taken from the same location as that used in Test 1. This test was run at a lower current density and for a longer period of time than Test 1. A control test was run in parallel with the test and, in addition to measuring the fluid removed in the test, the shrinkage volume was measured.

In order to fill the cells equally a bucket of the silt was placed in bins on an alternate basis in an attempt to have a homogenized mix in each cell. Figure 6 shows Dave Bowman placing a bucket of silt in one of the cells. After the cells were filled the dimensions of the fill in the cells were measured in length, width and height. These measurements were taken of a relatively flat soil surface at the Test site on the CDF.



Figure 6. Dave Bowman Assisting in the Loading the Cells with Silt

The cells were then set up in the lids in such a way that any free water could be removed at one end of the cell. This is shown in Figure 7.

In Figure 7 one can also clearly see that electrodes (steel plates) had been inserted into the active test cell. Also shown in the picture is Larry Zanko drilling weep holes into the cell to allow any free or produced water to flow out of the cell. Water that accumulated in the tray under the cell was measured and recorded. The green wire shown in the picture was attached to the cathode while the black wire was attached to the anode. Within minutes of turning on the system water could be seen accumulating around the anode. The water which collected at the anode flowed through the weep holes in the cells to the tray under the cell. Due to gravity drainage a small amount of water was collected in the control cell.

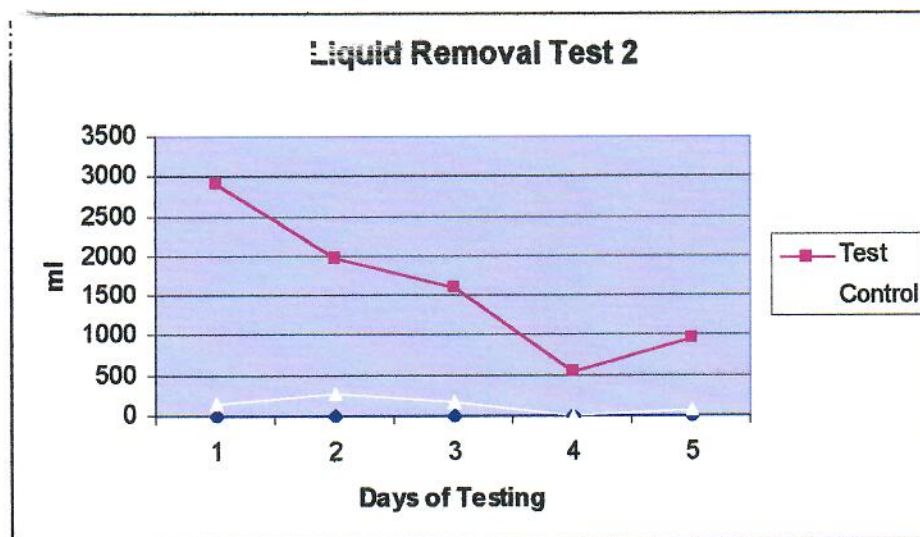


Figure 7. Test Set Up Showing Electrodes in Test Cell with Control in Back

Test 2 Results

The test was run for three days and demonstrated a steady removal of water from the energized cell. On the evening of the third day a storm, producing more than 2" of rain which filled the trays with water. This rain was assumed to fill both trays equally and was subtracted from the data during final analysis. Over the three days of testing using Direct Current a total of 7910 ml of liquid drained from the test cell compared to 695 which drained from the control cell. The initial volume of silt in the Test cell was 45.60

liters and the control cell contained 48.45 liters of silt. The volume of liquid removed was calculated to be 17.3% of the test cell volume and 1.4% of the control cell volume. It must be noted that the volume removed from the control cell was by gravity drainage only. The volume of water removed is shown in Graph 1.



Graph 1 Liquid Removal from Test and Control Cell

At the end of the test the volume of material remaining in the cells was again measured. The volume in the test cell was calculated to be 31.84 liters and the volume in the control cell was measured to be 44.43 liters. This translates to a 30.2% volume reduction in the test cell and 8.3% reduction in the control cell. This is summarized in Table 1.

Table 1

	Test Cell	Control Cell
Initial Volume	45.60 liters	48.45 Liter
Final Volume	31.84 liters	44.43 liters
% Reduction in Volume	30.1%	8.2%
Liquid Removed	7910 ml	695 ml

The efficiency of the second test as measured in moles of water removed per mole of electrons (amp – sec) used was calculated for the second test as 135 moles/mole.

At the conclusion of the test the silt had consolidated to a point that it could support a man's weight as attested to by Dave Bowman standing on the compacted material shown in Figure 8. Dave Bowman could not be persuaded to stand in the control cell since the material had not been consolidated.



Figure 8. Testing the Stability of the Consolidated Silt.

Figure 9 shows the test cell on the left and the control cell on the right at the conclusion of the dewatering and consolidation test of Erie Pier fine silt. Note the markings embedded in the test cell surface remained over time while those in the unconsolidated control disappeared – a further indication of the stabilization of the silt.

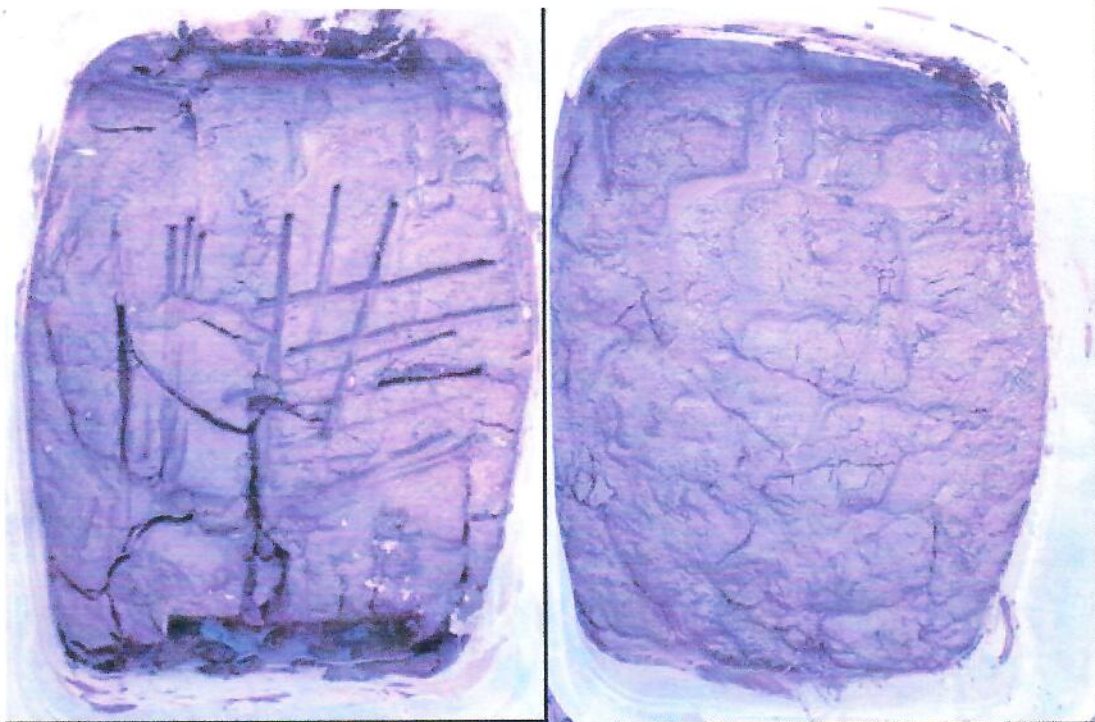


Figure 9. Test and Control Cell at the Conclusion of the Test

Conclusion

At the end of the test we concluded that the fine silt from Erie Pier Confined Disposal facility can indeed be dewatered using Direct Current. The process, in this test, removed 17.3 % of the volume as liquid. The process, in this test, was able to reduce the volume of the silt by 30%. Based on these results we propose to carry out a larger test in the larger silted area of the CDF. If the results of this test are extrapolated to the CDF up to 9 feet of additional capacity could be realized in this DCF by treatment with electrokinetics.

¹ Intent To Prepare a Draft Environmental Impact Statement (DEIS) for Dredged Material Placement at Duluth-Superior Harbor, Minnesota and Wisconsin <http://www.epa.gov/fedrgstr/EPA-IMPACT/1995/February/Day-13/pr-494.html>