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Chapter 24

TECHNICAL CHALLENGES ON THE MARINE HYDRAULIC DREDGING PROJECT, NEW BEDFORD HARBOR SUPERFUND SITE

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Abstract: Jacobs Engineering Group, Inc. (Jacobs) and Sevenson Environmental Services, Inc. (Sevenson) are conducting remedial activities at the New Bedford Harbor Superfund Site (Site) under contract with the US Army Corps of Engineers (USACE). Funding and oversight for this project is provided by the US Environmental Protection Agency (EPA) through the national Superfund Program. The Site is located in Bristol County, Massachusetts, approximately 55 miles south of Boston. Contamination at the Site consists of marine sediments impacted by polychlorinated biphenyls (PCBs) and heavy metals from industrial activities adjacent to the shoreline.

The selected remedial alternative for the Site involves hydraulic dredging for removal of the PCB-impacted sediment. Following removal, the remedy includes sand separation, sediment dewatering, wastewater treatment, and sediment transportation to an off-site disposal facility.

In 2004 and 2005, the Team (Jacobs, Sevenson, USACE and EPA) solved a number of technical challenges related to dredging in this unique marine setting. Upon initiation of dredging in 2004, hydrogen sulfide (H2S) gas at concentrations exceeding OSHA’s current permissible exposure levels, was immediately released from the marine sediments into an enclosed treatment facility. The elevated H2S concentrations were mitigated through engineering controls consisting of chemical treatment and local exhaust ventilation to carbon treatment. Ferric sulfate (Fe2(SO4)3) was injected into the dredge slurry to reduce or eliminate H2S by precipitating ferric sulfide (FeS). A high volume air extraction system was installed to capture any un-reacted H2S. A second challenge involved maintaining the required dredge production despite the presence of debris embedded in the sediment. To overcome this challenge, unique equipment was designed to remove the debris while maintaining the low water column turbidity thresholds established for environmental protection. A third challenge presented to the Team was the accurate monitoring of the vertical and horizontal progress of the dredging in the shallow tidal marine setting. This was accomplished by using a combination of tools, including a Global Positioning System (GPS), laser level soundings, and acoustic bathymetric surveys.

Resolving these technical challenges allowed the Team to reduce the risk of personal injury and increase overall productivity. The lessons learned on the New Bedford dredging program can be applied to other freshwater and marine dredging environments where success is measured not only in sediment removal rates per day, but in worker safety metrics and process quality control.

Key words: marine; marine hydraulic dredging; PCB; hydrogen sulfide; H2S, safety; debris removal; bathymetry.

1. INTRODUCTION

From the 1940s into the 1970s, electrical capacitor manufacturing plants in the New Bedford area discharged PCB waste either directly into the Harbor or indirectly through discharges to the City of New Bedford’s sewer system. In the mid-1970s, as a result of EPA investigative sampling,
polychlorinated biphenyl (PCB) contaminants were identified in the sediments and the seafood in the New Bedford Harbor area. In 1979, the Massachusetts Department of Public Health issued regulations prohibiting fishing and lobstering throughout the Site due to high levels of PCB contamination, ranging to higher than 100,000 parts per million (ppm) in various parts of the Harbor. The Site was included on the Superfund National Priorities List (NPL) in September 1983. EPA’s site-specific investigations were initiated in 1983-1984, and included engineering feasibility studies of alternative dredging methods and disposal of contaminated sediments, pilot dredging and disposal studies to field test different dredging and disposal technologies for the contaminated sediments, and extensive physical and chemical computer modeling of the Site. These studies are summarized in more detail in EPA’s Administrative Record of Decision (ROD) for the Site.

In September 1998, after years of study, public debate, and consensus building, EPA selected a cleanup remedy for the entire Upper and Lower Harbor areas as a solution to the widespread PCB contamination in and around New Bedford Harbor. The remedy involved the dredging of about 170 acres and containment of approximately 450,000 cubic yards (cy) of PCB-contaminated sediment in confined disposal facilities (CDFs).

The ROD, issued by EPA in September 1998, described the following three principal goals for the project:

1. The reduction of health risks due to consumption of PCB-contaminated local seafood;
2. The reduction of health risks due to contact with PCB-contaminated shoreline sediments;
3. The improvement of water quality in the highly distressed marine ecosystem in the Harbor.

Based upon additional sampling events since the original ROD was signed, the estimate of quantities of material requiring dredging and disposal has increased 95 percent to approximately 880,000 cy. In addition to concerns from neighboring businesses and residences regarding the practical implementation of CDFs, these factors led the EPA to reconsider off-site disposal for the remaining contaminated material, rather than further construction of CDFs. The EPA documented the decision to use off-site disposal rather than construct CDFs in an Explanation of Significant Difference (ESD) document dated February 2002.

To satisfy the goal of the ROD, sediment removal is required if the concentration of total PCBs exceeds the limits specified for designated areas within the New Bedford Harbor. The total PCB value is defined as the sum of PCB homologue groups. Harbor sediments that exceed the PCB levels specified in the EPA ROD (between 1 to 50 ppm, depending on exposure risk established by the EPA) will be removed from the Harbor and processed through desanding, dewatering, and wastewater treatment equipment. Contaminated oversize material, sand, and filter cake (silt) will be transported off-site for landfilling.

2. HARBOR DREDGING EQUIPMENT AND MATERIALS

The processing equipment in use on the project was designed and installed by the Jacobs Engineering and Sevenson Environmental project team. Much of the equipment in use was already owned by Sevenson, and therefore was readily available for use on the New Bedford project. In many instances, long lead times for equipment design and manufacture were avoided, allowing the Jacobs/Sevenson team to mobilize and set up the treatment process train quickly and efficiently. The major equipment systems in use on the project are briefly described in this section.

2.1 Dredges

The Jacobs/Sevenson team recommended hydraulic dredging with a rotary auger as the method to remove sediment from the New Bedford Harbor. This method was subsequently accepted by the EPA and USACE. Hydraulic dredging was selected for the following reasons:
Hydraulic dredging at this Site is believed to be more cost-efficient than mechanical methods;
An Ellicott Mud Cat™ hydraulic dredge draws 18 to 30 inches of water, which facilitates dredging within shallower intertidal areas;
Hydraulic dredging is an efficient and relatively clean method of pumping sediment material onshore;
Hydraulic dredging provides a uniform removal of material at predetermined cut depth elevations.

The dredge equipment selected for use at the Site was the Mud Cat™ Model MC 2000 type, manufactured by Ellicott, a division of Baltimore Dredges, LLC. To make effective use of tidal conditions, two dredges are used, one within the intertidal zone and the second within the subtidal zone. The pump on each dredge can deliver 1,500 to 3,000 gallons per minute (gpm) of slurry with a solids content of up to 20 percent. One dredge operates at a time, providing a constant flow of dredge material for the solids separation systems downstream (desanding and dewatering) to operate uninterrupted.

2.2 Pipeline and Booster Pump Stations

The two dredges operate in different dredge management units (DMU) in the harbor, but are in close proximity to each other. In general, the dredges are positioned so that at least one dredge can operate during low tide conditions. A 10-inch high-density polyethylene (HDPE) pipeline connected from each dredge carries the slurried sediment to a diesel booster pump. The booster pump maintains the proper flows in the pipeline to convey the sediment 5,500 feet to the desanding operation. Each pipeline is sized to maintain sufficient velocity (7-10 feet/second) within the pipe to avoid settling of the dredged material in the pipeline.

The pipes convey the sediment load to the desanding operations set up at the EPA/USACE property adjacent to the harbor (known as Area C). After desanding, the sediment slurry is pumped through a 12-inch diameter, double walled HDPE pipeline to the dewatering process and wastewater treatment system at another EPA/USACE facility along the shore of the harbor (Area D). The Area D dewatering facility is approximately 7,000 feet south of the Area C desanding facility (see Figure 1).
2.3 Desanding Equipment

The desanding equipment consists of:
- Dual, high G-force, linear-motion, vibrating shaker screens to remove oversized materials;
- Hydrocyclones suspended over high G-force, fine screen shakers to remove the sand fraction;
- A V-bottom desanding tank; and
- Diesel transfer pumps to transport the desanded slurry to the dewatering system.

The dredging operation generates slurry at a rate of 1,500 to 3,000 gpm. On average, the slurry contains approximately 8-15 percent solids by weight. The dredged slurry is first pumped through a coarse vibrating shaker screen with 2-inch mesh screens to remove the over-sized material. The screens remove debris, stones, shellfish, large wood chips, and some gravel from the slurry. Screened material is discharged onto a contained pad and stored within the desanding building at Area C pending analysis and off-site disposal. The screened slurry is gravity-fed into V-bottom tanks where it is then pumped through desander units.

Each desander unit consists of three, 10-inch diameter hydrocyclones mounted over fine shaker screens. The desanding operation removes approximately 15 to 50 percent of the total solids in the dredge slurry, depending upon the feed material from the dredge. In general, the resulting slurry solids content to the filter press operation is 8 to 12 percent (by weight).

The underflow from the hydrocyclones is directed over dual, vibrating linear motion shakers with 200-mesh (74 microns) screens for sand removal. As with the coarser screened material, this sand fraction is temporarily stored within the desanding building, pending analysis for PCBs and off-site disposal. The overflow from the desanders is collected in a 20,000-gallon, agitated pump tank, and is pumped to the dewatering system at Area D. The dredge, booster pumps, and desanding equipment design layout is shown in the Area C process flow diagram (see Figure 2). A mass balance for the dredging, desanding, and dewatering processes 2006 remediation season is shown in Figure 3.
Figure 2. Dredging & Desanding Process Flow Diagram
Figure 3. Sediment Processing Using De-sanders Followed By Filter Presses
2.4 Dewatering Equipment

The primary objective of the sediment dewatering process is the removal of sediments, and associated oils that contain PCBs, from the dredge fluid. The dewatering equipment consists of agitated mix tanks (feed tanks), a polymer injection system, fast feed pumps, and recessed chamber JWI filter presses. The dewatering process is designed to minimize the volume and therefore the weight of material that must be disposed, saving significant costs. The volume reduction is accomplished by squeezing the desanded slurry though polypropylene cloths at 225 pounds per square inch (psi), yielding a high solids cake and a filtrate stream for further treatment. The filter presses generally produce filter cake greater than 60 percent solids, with a clean filtrate stream (<50 mg/l total suspended solids (TSS)).

A total of six, 219 cubic-foot filter presses are in use on the project, providing a total volume of 1,314 cubic feet of filter cake material per drop (a drop refers to one cycle of filter press operation). The filter cake material is conveyed away from the press area to a central loadout bay, where the cake is loaded by front-end loaders into rail cars for transport to off-site disposal. The building was designed and constructed by the EPA/USACE to house all of the dewatering, wastewater treatment and rail car load-out facilities. A rail spur into the Site connects directly to the City of New Bedford rail yard, and to the main CSX railroad tracks.

2.5 Wastewater Treatment Equipment

The wastewater treatment system is designed to treat contaminants in the filtrate from the filter presses, namely oil and grease, PCBs, cadmium, chromium, copper, and lead. To meet the regulatory standards for direct discharge to a surface water body, the treatment process was designed with significant process redundancy. The design of the wastewater treatment plant was completed after extensive treatability studies. The average design capacity of the wastewater treatment system is 1,626 gpm, with a peak flow capacity of 2,000 gpm. The wastewater treatment equipment design is shown in the Process Flow Diagram (see Figure 4).
Figure 4. Process Flow diagram for Waste Water Treatment

Table 1 presents the expected filter press filtrate influent flow and load data used in the design selection and sizing of the wastewater treatment equipment.
Table 1. Wastewater Influent Characteristics (24-Hour Day)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Limit</th>
<th>Basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Influent Flow Rate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Day</td>
<td>1,626 gpm</td>
<td></td>
</tr>
<tr>
<td>Peak Hour</td>
<td>2,000  gpm</td>
<td></td>
</tr>
<tr>
<td>Total Suspended Solids</td>
<td></td>
<td></td>
</tr>
<tr>
<td>mg/L</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>lbs/Day @ Average Flow</td>
<td>415</td>
<td></td>
</tr>
<tr>
<td>Total Organics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>mg/L</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>lbs/Day @ Average Flow</td>
<td>16.6</td>
<td></td>
</tr>
<tr>
<td>Total PCBs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>mg/L</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>lbs/Day @ Average Flow</td>
<td>4.15</td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td></td>
<td></td>
</tr>
<tr>
<td>mg/L</td>
<td>0.015</td>
<td></td>
</tr>
<tr>
<td>lbs/Day @ Average Flow</td>
<td>0.12</td>
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</tr>
<tr>
<td>Copper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>mg/L</td>
<td>0.037</td>
<td></td>
</tr>
<tr>
<td>lbs/Day @ Average Flow</td>
<td>0.3071</td>
<td></td>
</tr>
<tr>
<td>Cadmium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>mg/L</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>lbs/Day @ Average Flow</td>
<td>0.0415</td>
<td></td>
</tr>
<tr>
<td>Chromium</td>
<td></td>
<td></td>
</tr>
<tr>
<td>mg/L</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>lbs/Day @ Average Flow</td>
<td>0.0415</td>
<td></td>
</tr>
</tbody>
</table>

2.6 Basis for Wastewater Treatment System Design

Table 2 contains effluent water quality target concentrations that serve as the basis of design for the wastewater treatment system. These target effluent concentrations were included in the EPA ROD.

Table 2. Effluent Target Concentrations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Limit</th>
<th>Basis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Suspended Solids</td>
<td>0.1</td>
<td>Requirement for meeting PCB and metal standards</td>
</tr>
<tr>
<td>Oil &amp; Grease mg/L</td>
<td>0.3</td>
<td>Requirement for meeting oil and grease standards</td>
</tr>
<tr>
<td>Total Organics</td>
<td>0.10</td>
<td>Requirement for meeting TOC standards</td>
</tr>
<tr>
<td>PCBs mg/L per aroclor</td>
<td>0.000065</td>
<td>Discharge criteria in ROD</td>
</tr>
<tr>
<td>Lead mg/L</td>
<td>0.0085</td>
<td>Discharge criteria in ROD</td>
</tr>
<tr>
<td>Copper mg/L</td>
<td>0.0056</td>
<td>Discharge criteria in ROD</td>
</tr>
<tr>
<td>Cadmium mg/L</td>
<td>0.0093</td>
<td>Discharge criteria in ROD</td>
</tr>
<tr>
<td>Chromium mg/L</td>
<td>0.05</td>
<td>Discharge criteria in ROD</td>
</tr>
</tbody>
</table>

The constituents listed in Table 2 are the basis for selecting the treatment process flow train. A constituent of special concern is removal of suspended solids and oil and grease. Treatability studies completed on characteristic New Bedford sediments have shown that PCBs and heavy metals are generally bound up in the solids or in the oil and grease trapped in the sediment. Therefore, a key element of the design was to contain these contaminants in the wastewater treatment process.

Filtrate flow from the filter presses is first equalized in three tanks, in order to reduce flow and pollutant surges to the treatment processes. Following equalization, ferric sulfate is added in-line to precipitate heavy metals present in the filtrate. This process is known as iron coprecipitation. Sodium hydroxide is added to maintain a slightly alkaline pH necessary for optimum precipitation. Polymer is added to improve solids settling. After chemical treatment, the water flows to high-rate dissolved-air flotation (DAF) units to remove oil and ferric-metal solids generated by the iron coprecipitation process. Following the DAF units, the wastewater is pumped to bag filters and sand filters to remove remaining solids and coprecipitated metals.
Granular activated carbon (GAC) reactors are in place downstream of the bag filter/sand filter processes to remove remaining PCBs and metals. The GAC filters vessels are arranged in a series of two reactors per train to maximize carbon usage, and avoid breakthrough of PCBs. Additional bag filters are installed downstream of the GAC units to capture any carbon fines with adsorbed contaminants, prior to sampling and discharge of treated effluent into New Bedford Harbor.

3. **ENGINEERING/SAFETY CHALLENGES DISCUSSION**

Upon start up of the dredging and sediment processing systems in the fall of 2004, the project team was immediately confronted with a number of unanticipated operational conditions. These conditions posed unique engineering challenges that were unique to the specific conditions of the Site. To mitigate safety and operational concerns associated with these conditions, additional engineering controls were required. The most immediate and significant concern was the presence of elevated H$_2$S gas released at the coarse screen shaker operation after the dredged slurry arrived in the desanding building. Other operational challenges included removal of sunken debris prior to dredging and the accuracy of dredge progress tracking.

3.1 **H$_2$S Control Problem**

During the planning and mobilization stages of the project in 2004, engineering controls for off-gassing of the sediment were put into place at the desanding facility. A sprung structure type building was erected over the desanding process at Area C with negative pressure air venting to carbon treatment vessels. The building was intended to contain odors from decaying shellfish and other organic matter removed from the top few feet of sediment. H$_2$S gas, while not detected in appreciable quantities in EPA/NAE sediment sampling programs, was also expected to be safely contained within the sprung structure. A 10,000 cubic feet per minute (cfm) air ventilation system with GAC filtration units was installed to purify the air prior to venting.

Upon initiation of dredging and processing sediment, H$_2$S gas from the entering sediment was immediately detected in the desanding building at concentrations exceeding current permissible exposure levels. To protect the workers from exposure to elevated H$_2$S, the dredging operation was temporarily suspended in order to evaluate the cause of the elevated gas levels and to develop an engineering solution so that dredging could safely resume.

Often characterized with a rotten egg odor, H$_2$S is relatively harmless at low concentrations (<5 ppm). However, at higher concentrations the human nose is desensitized to the H$_2$S odor, and therefore a person can not detect its presence by smell alone. At 100 ppm by volume in air H$_2$S gas can be lethal to humans, and is therefore considered a very significant safety concern.

H$_2$S is often present in marine sediment due to normal anaerobic (no oxygen present) degradation of organic material. Combined sewer outfalls in the dredging area, connected to the City of New Bedford’s sanitary system, were considered to be the primary cause for the elevated H$_2$S.

The hydrogen sulfide equilibrium reaction is shown below:

\[
\text{HS}^- + \text{H}^+ \leftrightarrow \text{H}_2\text{S}
\]

This equilibrium is highly pH dependent. At a neutral pH value of 7, 50 percent of the HS$^-$ will remain as HS$^-$ and 50 percent will be in the gaseous H$_2$S form.

If the pH is shifted to 5.0, 99 percent of sulfides will exist as H$_2$S (both gaseous and aqueous). If the pH is shifted to the alkaline range, for example, 8.5, 99 percent of the sulfides will exist as aqueous HS$. Therefore, it is desirable when sulfides are present to maintain alkaline conditions, or to take steps to remove soluble sulfides from solution.

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**Gaynor et al.: Technical Challenges On The New Bedford Harbor Superfund Site**

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3.1.1 H₂S Control Alternatives

The following conventional hydrogen sulfide control alternatives were identified and technically evaluated to resolve the problem:

1. Oxidate sulfide to sulfate using chemical oxidants;
2. Shift slurry pH from 7 to 8.5 or higher, which shifts sulfide equilibrium away from hydrogen sulfide gas to 99 percent HS;
3. Add ferric sulfate, Fe₂(SO₄)₃, to eliminate H₂S by precipitating ferric sulfide (FeS) in conjunction with the production of sulfuric acid (H₂SO₄) according to the following equation: Fe₂(SO₄)₃ + 3H₂S → 2FeS↓ + S²⁻ + 3H₂SO₄;
4. An air-release system at the entrance to the Desanding Building prior to the shaker screens to vent gaseous H₂S to an enclosed air treatment system; and
5. A targeted air handling system over the shaker screens, hydrocyclones, and v-bottom tank to provide additional removal of gases liberated in that area.

Alternatives #3 and #5 listed above were selected as the most practical solutions for application at the Site. Adjustment of slurry pH, while shown to be effective in bench-scale tests, was deemed impractical in the slurry pipeline. The abrasive nature of the dredged slurry precluded any in-pipe instrument, meaning that pH could not be effectively controlled by an in-line pH control loop.

Bench tests were immediately conducted to determine the dosage of ferric sulfate required to control H₂S. The tests indicated that 300 mg/L was the most appropriate dosage considering the nature of the changing solids concentration in the dredge pipeline.

3.1.2 H₂S Control System Implementation Results

Within 14 days of encountering elevated H₂S in the sediment, an engineering control solution was implemented, using a 50 percent (Fe₂(SO₄)₃ solution injection combined with an air monitoring process. Ferric sulfate was injected into the dredge slurry approximately 2,500 feet upstream of the desanding plant, allowing 5-7 minutes of contact time to reduce or eliminate H₂S by precipitating FeS. This contact time was determined to be sufficient in the bench tests. Prior to implementation of the control system, hydrogen sulfide was released at concentrations in excess of 100 ppm by volume as the slurry flow transitioned from pressure flow in the pipeline to atmospheric pressure at the desander. After the addition of ferric sulfate, H₂S gas concentrations at the desander were reduced to generally 0.1-0.2 ppm by volume.

As a redundant safety precaution, workers potentially exposed to H₂S within the desanding building were required to operate with OSHA Level B supplied air.

With the ferric sulfate system and redundant air supply systems in place, dredging operations continued uninterrupted for the remainder of the 2004 season. Although the ferric injection system was effective in reducing the levels of H₂S in the Desanding Building, there were still intermittent spikes of H₂S. Workers in that building continued to wear OSHA Level B Personal Protective Equipment (PPE) as a back-up safety precaution for the remainder of the 2004 processing season.

3.1.3 H₂S Control System Enhancements

During the 2004 dredging season, it also was determined that the greatest release of H₂S gas was caused by the desanding unit shaker screen. To alleviate this condition, an enhanced air ventilation system, including air-capture hoods over the desanding units and more robust air flow and filtration systems were engineered and installed for the 2005 field season. The enhanced air system allowed the team to reduce the level of personal protection in the Desanding building from OSHA level B to modified level D.

A second engineering improvement, implemented to increase safety and increase production, was the automation of the ferric sulfate injection system. It was noted in 2004 that spikes of hydrogen
sulfide correlated to deeper cuts by the dredges. The automated system uses flow meters and nuclear density meters to continuously calculate the mass flow of the dredge slurry. Nuclear density meters were used in place of other density devices to avoid inserting any kind of obstruction in the slurry pipeline.

The rate of ferric sulfate injection was paced based on the mass flow of the slurry, using a direct correlation between density of dredged material and slurry flow rate. The flow signal and density signal from the respective meters are fed to an integrating controller which converts those signals to a mass flow (flow times density), and generates a 4-20 mA signal that is used to pace the output of the ferric sulfate feed pumps.

The automated system successfully reduced the safety risks associated with manual operation and significantly reduced the amount of ferric sulfate used because the amount of ferric sulfate added varied proportionately with the density and flow rate of the slurry.

3.2 Debris Removal

The New Bedford Harbor region has historically been an area of significant urban land use, including light industry, textile mills, housing complexes, and fisheries related businesses. As such, the presence of sunken and buried debris in the harbor sediment is common. The hydraulic dredge being used on the project, with its submerged auger and pump suction, is particularly vulnerable to fouling by sunken debris, causing production delays, potential equipment damage, and extended down time. In anticipation of these delays, an aggressive debris removal operation is performed prior to dredging, using a barge-mounted excavator to pull material from the top 1-2 feet of sediment.

3.2.1 Debris Removal System Problem

The initial attempts at debris removal operation used a conventional excavator and a perforated, 2 cy bucket to pull debris from the mud. However, it quickly became apparent that, because the operator did not have a means to monitor vertical control with the excavator, the amount of sediment disruption and volume of contaminated sediment removed with the bucket was unacceptable. In addition, the disturbed sediment created high turbidity levels in the water column near the operation. The high levels threatened to exceed the EPA established water column turbidity thresholds [300 nephelometric turbidity units (ntu)] for the perimeter of the dredge zone. Consequently, this method of debris removal was terminated within the first week during the 2004 dredge season. Ceasing the debris removal operations created a situation where dredging proceeded at the risk of encountering sunken debris.

3.2.2 Engineered Refinements to the Debris Removal System Results

During the 2005 winter off-season, engineering efforts were made to develop a debris-removal system that would satisfy the requirements to remove debris, while reducing disturbances to the sediment, and minimizing water column turbidity levels. To satisfy these criteria, a custom-made hydraulic debris removal tool was developed.

During the next dredging season in the fall of 2005, debris removal operations resumed using an excavator-mounted, hydraulic rake system with a separate rake “thumb” attachment that allowed the operator to remove debris from the sediment without suspending excessive material in the water column. The excavator was also retrofitted with an additional extension boom to provide greater reach into the sediment. In addition, a computer-operated, depth-monitoring station was installed within the cab of the excavator, allowing the operator to view a digital display of the debris removal rake depth on a computer screen mounted in the cab.
3.3 Dredge Tracking Process

The pre-established target dredge depth throughout the harbor was the theoretical depth below mudline to remove sediment above the clean-up action levels. This depth, referred to as z-star ($z^*$), was derived by other consultants to the EPA/USACE, using a comprehensive data set, geostatistical analyses, and modeling methods that predicted compliance depths between analytical sampling locations.

3.3.1 Dredge Tracking System Problem

The dredge area is divided into 25-foot by 25-foot blocks (z-blocks) that represent the target sediment removal depths across the harbor. The amount of sediment to remove within each z-block corresponds with an associated target “clean” elevation predicted by the model. The clean elevation is the elevation to dredge to in order to reach $z^*$. Accurate dredge monitoring is crucial to ensure that the target cleanup elevations are being attained and that costly overdredging is avoided.

At the beginning of the project in 2004, dredging elevations were solely determined based upon a stationary laser set up on shore and a surveyor’s rod with laser receiver used to measure elevation for vertical control on the dredge. Horizontal control was measured by visual observation of the position of the dredge relative to known sheet pile locations installed in the dredge area. Although this was the accepted method for dredge tracking during the early stages of the project, the degree of accuracy required to assure that the $z^*$ depths were attained demanded that the survey and tracking system be enhanced for subsequent dredge seasons.

3.3.2 Dredge Tracking Process Enhancements Results

Prior to dredging activities in 2005, a bathymetric survey of each dredge area was conducted to assess the change in the harbor bottom elevation in the proposed dredge compared to the most current comprehensive USACE bathymetric survey conducted in 1999. The 1999 bathymetric survey provided the base data for the creation of $z^*$. All bathymetric surveys are conducted relative to National Geodetic Vertical Datum 1929 (NGVD 29) and relative to North American Datum 1983 (NAD 83), for vertical control and for horizontal control, respectively. This harbor bottom assessment allowed the project team to modify the cut depths in the z-blocks depending on whether erosion or deposition had occurred in areas since the 1999 bathymetric survey and the genesis of $z^*$.

The progress of dredge cut monitoring was enhanced using several different methods. First, as previously done in 2004, the vertical progress is monitored by the dredge operator using a surveyor’s rod with an attached bottom plate, a rotating laser datum, and a receiver to gauge the cut depths relative to the reference datum. The horizontal progress is tracked by the dredge operator using a visual relationship of the dredge relative to the sheet piles and temporary survey stakes placed in the dredge area on 25-foot intervals corresponding with the north-south and east-west intersections of the 25-foot $z^*$ blocks. The horizontal progress of the dredge is also tracked electronically, using GPS equipment that is programmed to continuously collect horizontal position data as the dredge progresses. The GPS information is reviewed at the end of each day to document the area covered and to identify areas that may have been missed by the dredge. This information is then used to plan the following day’s dredging activities. Figure 5 is an example of the daily GPS data and the area tracked by the GPS while dredging.

Dredging progress is also physically measured each week following the completion of dredging activities. A bathymetric survey of the areas dredged during the previous week is conducted on Saturday, typically a non-dredging day. Quality control (QC) surveys are also periodically performed within the dredge area during dredging for verification of cut depths. The QC survey utilizes the GPS and adjustable rod and plate equipment to verify vertical measurements (relative to NGVD 29) and horizontal measurements (relative to NAD 83) made by the weekly bathymetric survey. Figure 6 shows data gathered from a bathymetry survey with GPS elevation check data overlaid for QC purposes.
Figure 5. 10/20/05 Dredging with GPS Locations
At the conclusion of dredging activities each season, a final bathymetric survey is completed. The final survey provides an accurate depiction of the bottom conditions and a post-dredge surface to compare to the pre-dredge bathymetric survey. By comparing the two, the volume of sediment...
removed can be calculated. Figure 7 shows the net change in bottom elevation and corresponding volume of sediment removed calculated from the bathymetric survey data.

4. CONCLUSION/ACCOMPLISHMENTS

Despite the technical challenges that the project team has faced during the first two seasons of dredging at New Bedford Harbor, the amount of contaminated sediment removed per day of dredging has been impressive. The table below briefly describes the accomplishments over the first two dredging seasons.

<table>
<thead>
<tr>
<th>Table 3. 2004 and 2005 Field Season Accomplishments Summary</th>
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<tbody>
<tr>
<td>Harbor Dredging</td>
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<tr>
<td>Area of Harbor Dredged</td>
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<tr>
<td>Volume of Sediment Dredged</td>
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<tr>
<td>Average Volume Dredged Per Day</td>
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<tr>
<td>Amount of material disposed or stockpiled</td>
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<td>Amount of filtrate successfully treated</td>
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Figure 7. Change in Sediment Thickness from Pre-Dredge Survey