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US Army Corps of Engineers
New England District

WATER QUALITY MONITORING SUMMARY REPORT
2009 REMEDIAL DREDGING
NEW BEDFORD HARBOR SUPERFUND SITE, OU #1

Contract No. W912WJ-09-D-0001-0010

Prepared For:
United States Army Corps of Engineers
New England District
696 Virginia Road
Concord, MA 01742

Prepared By:
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81 Technology Park Drive
East Falmouth, MA 02536

July 2010

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EXECUTIVE SUMMARY

In 2009, remediation activities at the New Bedford Harbor Superfund Site included hydraulic dredging of contaminated sediments from four separate areas within the upper harbor. Water quality monitoring was performed during remediation activities to help optimize the field program, minimize potential ecological impacts, and provide field reconnaissance information to document the activities. Data and observations resulting from the water quality monitoring was used to document background conditions and gauge the extent of water quality impacts potentially resulting from remediation operations. The water quality monitoring program helped to ensure that dredging activities were conducted in a manner that did not produce extensive turbidity plumes and associated potential impacts, such as toxicity to marine organisms, contaminant transport or hindrance of the seasonal migrations of anadromous fish within the Acushnet River. This report presents the scope and key findings from the water quality monitoring performed during the 2009 dredge season.

Remediation activities, including dredging and debris removal were performed from June 1 through December 1, 2009, resulting in the removal of some 49,809 cubic yards of contaminated sediments. Water quality monitoring was performed during the first week of dredging to reaffirm the ecological protectiveness of the project-based compliance criteria, and to establish baseline water quality conditions of the harbor. The monitoring program included: 1) boat-based monitoring to survey *in-situ* turbidity and observe the dredge area for sediment plumes as well as fish and wildlife passage, 2) moored water quality sensors to collect *in-situ* data to supplement the boat-based monitoring; and 3) collection of discrete water samples for physical, chemical, and biological testing to assess the protectiveness of the project-based compliance criteria.

Boat-based *in-situ* measurements were evaluated against the project-specific turbidity compliance criteria, which was reevaluated and redefined during the 2009 dredge season. Phase I of the 2009 season adopted the monitoring compliance criteria of previous years. Phase I monitoring was based on a warning level defined as 50 Nephelometric Turbidity Units (NTU) above background 300 feet down-current of dredging and associated activities. Consistent with previous years, the compliance threshold for Phase I was defined as 50 NTU above background 600 feet down-current of dredging and dredge-related activities. The 2009 dredging season was unique, though, because there was active dredging of multiple dredge areas simultaneously. This dredging improved the efficiency with which contaminated sediments were removed from the harbor, but added complexity to the definition of a plume from the dredging activity with respect to the Phase I monitoring approach. The traditional monitoring protocol used in previous years and for Phase 1 of 2009 proved inadequate. For instance, applying the Phase I methods as the dredging advanced produced a warning level exceedance event that subsequently demonstrated no adverse acute toxic effects observed in discrete water samples from the plume. To optimize the water quality monitoring program, an investigation and reevaluation of the project-specific compliance criteria was conducted. A toxicity evaluation dilution study was developed to reassess the protectiveness of the 50 NTU criteria and to modify the overall monitoring approach. Based on the results of the toxicity evaluation dilution study, modifications to the water quality monitoring program

and to the project-based compliance criteria were employed, and a Phase II revised approach of the 2009 monitoring season began August 3, 2009.

During Phase II of the 2009 water quality monitoring program, the entire active dredge zone, including all four dredge areas and the region between them, not actively dredged in 2009, was considered the containment or active dredge zone. Rather than attempt to monitor individual activities within the zone that proved not to have any toxicological impacts by the traditional methods, the Phase II approach was designed to monitor water quality impacts resulting from the collective remediation activities. Monitoring occurred outside of the boundaries of the containment zone, at 300 foot transects south of the zone during the ebb tide and north of the active dredge zone during the flood tide. The results of the toxicity evaluation dilution study indicated that turbidity plumes 100 NTU above background exhibited no adverse acute toxic effects. Based on these results, the turbidity compliance criterion was raised from 50 NTU to 100 NTU above background, or ambient turbidity levels in the harbor. The 100 NTU criteria threshold at the 300 foot down-current transect from the active dredge (containment zone) was redefined as the compliance threshold. Phase II greatly improved the efficiency of the monitoring approach, satisfied monitoring objectives, and was less restrictive on the remedial operations, while remaining ecological protective as demonstrated by the toxicity evaluation. During the Phase II approach, no exceedances of the water quality compliance criteria were observed.

Boat-based monitoring and the continuous *in-situ* turbidity data from the water quality moorings revealed that dredge operations did, at times, have an effect on the water quality in the immediate vicinity of the dredging activity. The continuous water quality data also revealed, however, that weather events, tidal activity, and natural influences greatly affected water quality throughout the harbor. When turbidity plumes were observed, they were generally immediately adjacent to active debris removal operations or near the dredge on windy days when push-boats were utilized to keep the dredge positioned in a straight line. These plumes tended to be ephemeral, and were confined to within ~100 feet of the active operation.

Throughout the 2009 dredge season, large numbers of fish and wildlife were observed. Lower trophic level fish were consistently observed moving throughout the river, between the Sawyer Street facility and north of the Wood Street Bridge. Birds, such as great blue herons, green herons, gulls, swans, cormorants, egrets, osprey, terns and other wading birds, were observed feeding along the shoreline and in the river. A coyote was observed on the eastern shoreline on one occasion. During the middle of the summer, hypoxic conditions were observed in the northernmost dredge areas and north of Wood Street. Water temperatures reached 30°C and dissolved oxygen concentrations dropped to below 1 mg/L. Such hypoxic conditions are naturally occurring in estuarine systems like the Acushnet River. Small fish were observed struggling, and a few were found dead during this warm low-oxygen time period; however, no large scale fish kills occurred. During the active dredge season, when fish were most abundant, there appeared to be no restriction of movement past the dredge area.

The combination of boat-based monitoring, continuous *in-situ* water quality monitoring data, and discrete water samples demonstrated that the remediation operations have measureable impacts to water quality. These impacts, however, were limited to near-field areas, contained within the active dredge zone, and generally decreased with increasing distance from the active operations. Overall, the PCB and toxicity data, along with the *in-situ* water quality measurements, confirmed the project compliance criteria are ecologically protective, while allowing remediation efforts to progress. The reader is referred to Section 5 of this report for a more detailed summary of the 2009 water quality monitoring program results.

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1.0 INTRODUCTION

1.1 SITE LOCATION AND DESCRIPTION

The New Bedford Harbor Superfund Site, located in Bristol County, Massachusetts, extends from the shallow northern reaches of the Acushnet River estuary south through the commercial harbors of New Bedford and Fairhaven and into 17,000 adjacent acres of Buzzards Bay (Figure 1). The City of New Bedford, located along the western shore of the Site, is approximately 55 miles south of Boston. New Bedford is currently home port to a large offshore fishing fleet and is a densely populated manufacturing and commercial center. By comparison, the eastern shore of New Bedford Harbor is predominantly residential, light commercial or salt marsh.

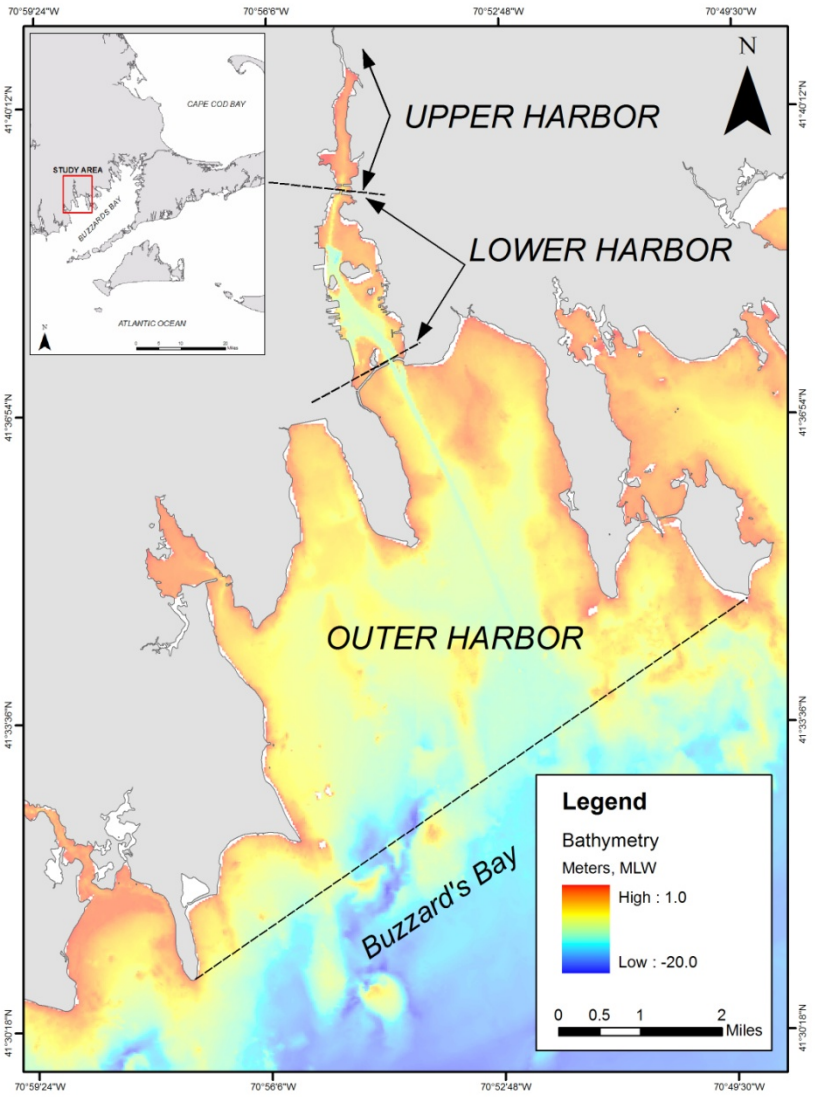


Figure 1. Basemap of New Bedford Harbor Superfund Site in Southeastern, MA

The Acushnet River's 16.5 square mile drainage basin discharges to New Bedford Harbor in the northern reaches of the Site, contributing relatively minor volumes of fresh water to the tidally influenced harbor. Numerous storm drains, combined sewer overflows (CSOs), industrial discharges, as well as smaller brooks and creeks also discharge directly to the Site. The upper and lower harbors are believed to be areas of net groundwater discharge. The estuary can be characterized as a shallow, well-mixed system.

Industrial and urban development surrounding the harbor has resulted in sediments becoming contaminated with high concentrations of many pollutants, notably polychlorinated biphenyls (PCBs) and heavy metals. Contaminant gradients within harbor sediments decrease from north to south. The source of the contamination has been attributed to two electrical capacitor manufacturing facilities that operated between the 1940s and the 1970s. One facility, Aerovox Corporation, is located near the northern boundary of the Site, and the other, Cornell-Dubilier Electronics, Inc. is located just south of the New Bedford Harbor hurricane barrier. The two facilities are known to have discharged PCB-laden wastes either directly into the harbor or indirectly via discharges to the City's sewerage system.

Based on human health concerns and ecological risk assessments, the United States Environmental Protection Agency (USEPA) added New Bedford Harbor to the National Priorities List in 1983 as a designated Superfund Site. Through an Interagency Agreement between the USEPA and the United States Army Corps of Engineers, New England District (USACE NAE), the USACE is responsible for carrying out the design and implementation of remedial measures at the Site.

The Site has been divided into three geographic areas: the upper, lower and outer harbors, consistent with geographic features, basin morphology and gradients of contamination (Figure 1). The Site is also defined by three state-sanctioned fishing closure areas extending approximately 6.8 miles north to south and encompassing approximately 18,000 acres in total. The upper harbor comprises approximately 187 acres, with current sediment PCB levels ranging from below detection to approximately 4,000 parts per million (ppm). Prior to the removal of the most contaminated hot spot sediments in 1994 and 1995 as part of EPA's first cleanup phase, sediment PCB levels were reported higher than 100,000 ppm in the upper harbor. The boundary between the upper and lower harbor is the Coggeshall Street Bridge; at this point the harbor is constricted to a width of approximately 100 feet. The lower harbor comprises approximately 750 acres, with current sediment PCB levels ranging from below detection to over 100 ppm. The boundary between the lower and outer harbor is the 150 foot wide opening of the New Bedford hurricane barrier. The hurricane barrier was constructed in the mid-1960s. Sediment PCB levels in the outer harbor are generally low, with only localized areas of PCBs in the 50 – 100 ppm range near the Cornell-Dubilier plant and the New Bedford sewage treatment plant's outfall pipes. The southern extent of the outer harbor is a line mapped from Rock Point (the southern tip of West Island in Fairhaven), southwesterly to Negro Ledge, and then southwesterly to Mishaum Point in Dartmouth (Figure 1).

1.2 PROJECT OBJECTIVES

Remediation of the Site involves the excavation and dredging of approximately 900,000 cubic yards of PCB-contaminated sediment. The majority of the contaminated material is being removed by a hydraulic dredge that pumps a spoils-slurry to the project's Sawyer Street facility where it is mechanically processed to remove all sand, gravel, and debris. The remaining silt and clay slurry is then pumped to the Area D Dewatering Facility located on Herman Melville Boulevard where it is mechanically dewatered and transported off-site for disposal.

The Site is divided into a series of Dredge Management Units (DMU) based primarily on contamination levels, contamination sources, and topography. In 2009, remediation activities at the Site included hydraulic dredging in four areas, M, G, J and L (Figure 2). Three of the four areas (Areas M, G and J) dredged during the 2009 season were in the vicinity of the Aerovox facility. These three areas comprised the majority of the estuary between the Wood Street Bridge and the Aerovox facility. The fourth area, Area L, is located south of the submerged cable crossing.

During dredging and dredging related activities, such as debris removal, the resuspension of sediments can transport contaminated sediments away from the dredge area. Additionally, contaminated sediments suspended in the water column present a concern for toxicity to aquatic organisms in the area. The water quality monitoring program was developed to assess the near-field water column impacts as well as the extent of sediment resuspension and transport away from the dredging operation.

1.3 WATER QUALITY MONITORING PROGRAM

The primary objective of the 2009 water quality monitoring program was to conduct boat-based and fixed-station field monitoring during remediation activity to gauge and limit the impacts to water quality from dredge-related activities. An additional objective was to ensure that the remediation dredging activities were conducted in a manner which did not hinder the seasonal migration of anadromous fish in the Acushnet River. The field reconnaissance information, collected as part of this effort, was made available to the USACE, USEPA, and dredge operators to fulfill these objectives.

To meet these objectives, a tiered monitoring approach was employed consistent with previous years' monitoring which incorporated field measurements of turbidity and water quality parameters along with discrete water samples for physical, chemical, and biological testing, as needed. The 2009 water quality monitoring program was marked by a change in the project compliance criteria, dividing the season into Phases I and II, before and after the modifications, respectively.

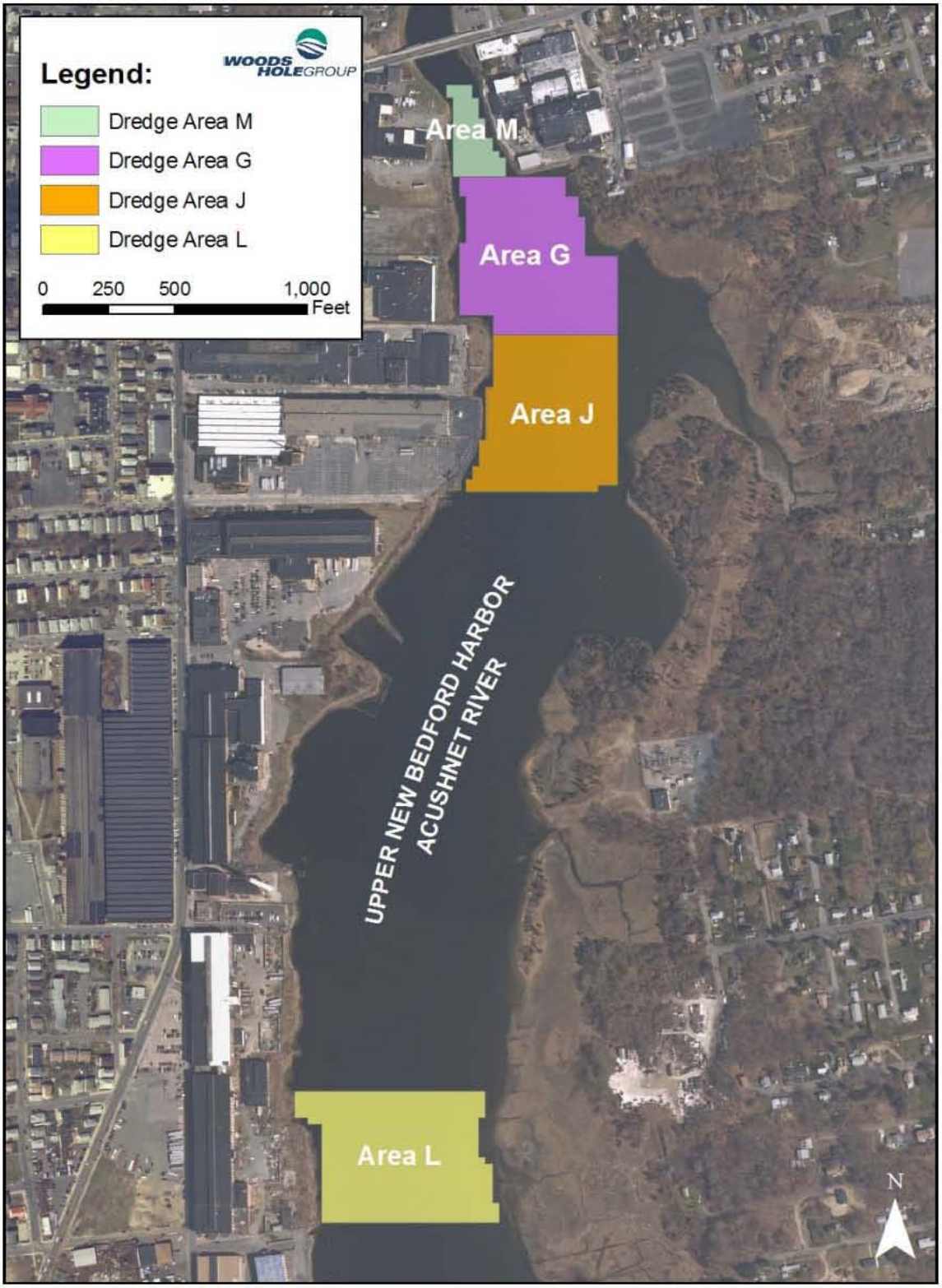


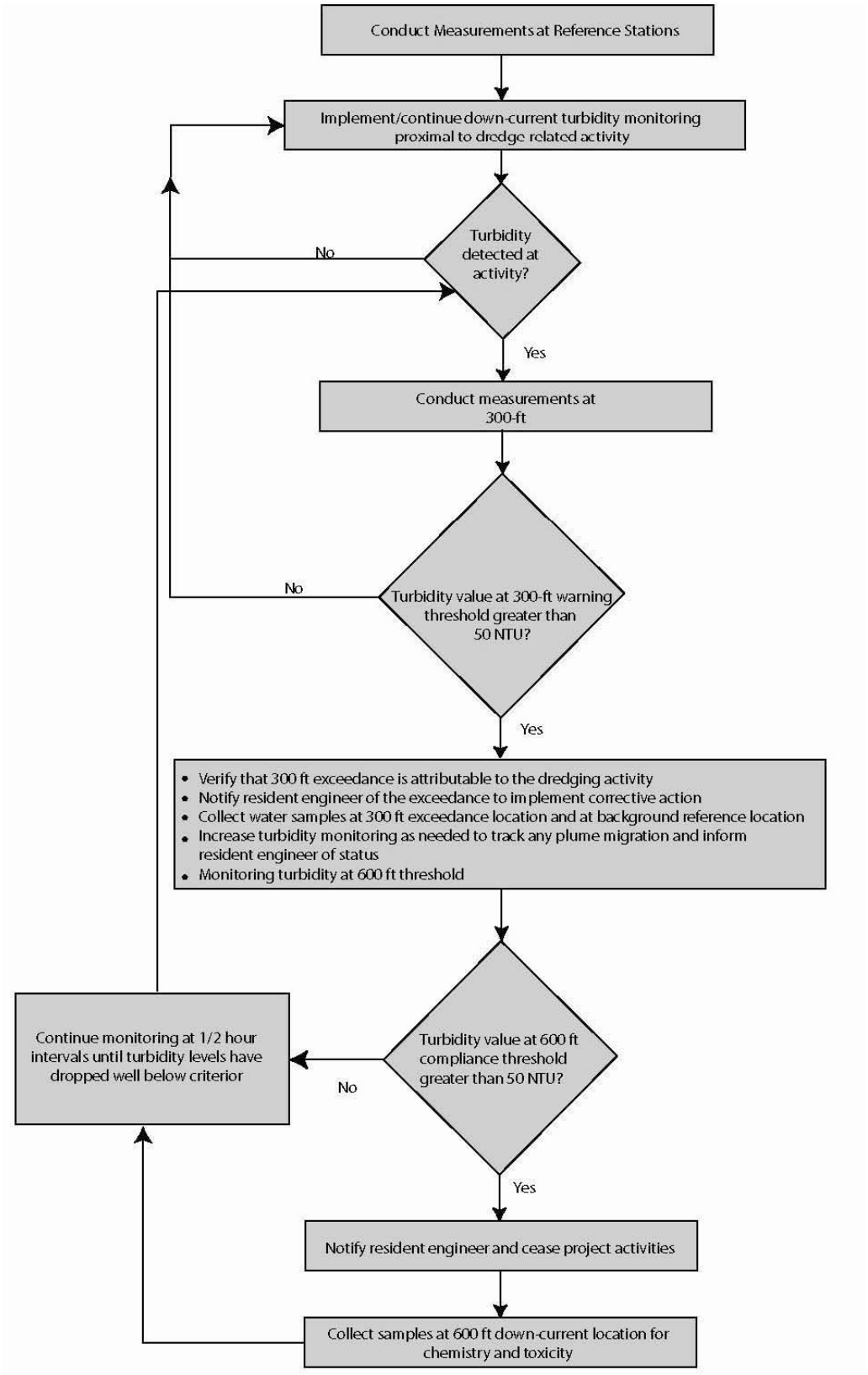
Figure 2. Basemap of 2009 Remediation Dredging Areas

1.3.1 Phase I

The compliance criterion for the 2009 season was initially defined as 50 Nephelometric Turbidity Units (NTU) above background turbidity levels measured 600 feet down-current of dredging activity. A warning was issued if turbidities exceeded the 50 NTU criteria at a distance 300 feet down-current of the dredging activity. The criterion was based on historical observations in other operational areas of New Bedford Harbor which demonstrated that this turbidity level rarely, if ever, had adverse biological effects.

Background turbidity was quantified from observations 1000 feet up-current of all dredging activity. For example, if background turbidity of the ambient harbor water was quantified as 10 NTU, then the exceedance criterion for that particular time would be 60 NTU. If values of 50 NTU or greater above background were observed 300 feet from the dredging activity and it was verified that the exceedance could be attributed to the activity, the resident USACE engineer (Mr. Paul L'Heureux) was notified to implement corrective actions and WHG proceeded to collect water samples. Following water sample collection at the 300-foot location, WHG monitored 600 feet down-current. If turbidity levels reached 50 NTU above background at the 600 foot transect, the exceedance qualified as a compliance violation and all remediation activities were terminated. Water samples were collected at the 600-foot location, as well as at the background station located 1000 feet up-current of all activity. Figure 3 depicts the decision sequence for Phase I of the 2009 Water Quality Monitoring Program.

After the full suite of water samples were collected, an initial toxicity analysis was performed using the *Arbacia punctulata* (sea urchin) 1-hour sperm immobilization/fertilization bioassay. Results of this initial toxicity screening and information regarding the intensity and duration of the plume were delivered to appropriate USACE personnel to determine whether subsequent analytical chemistry testing should be performed. Figure 4 illustrates the tiered decision sequence for water sample analyses.



Notes: 1:50 NTU value was defined as 50 NTU above background turbidity level

Figure 3. Decision sequence for 2009 water quality monitoring – Phase I

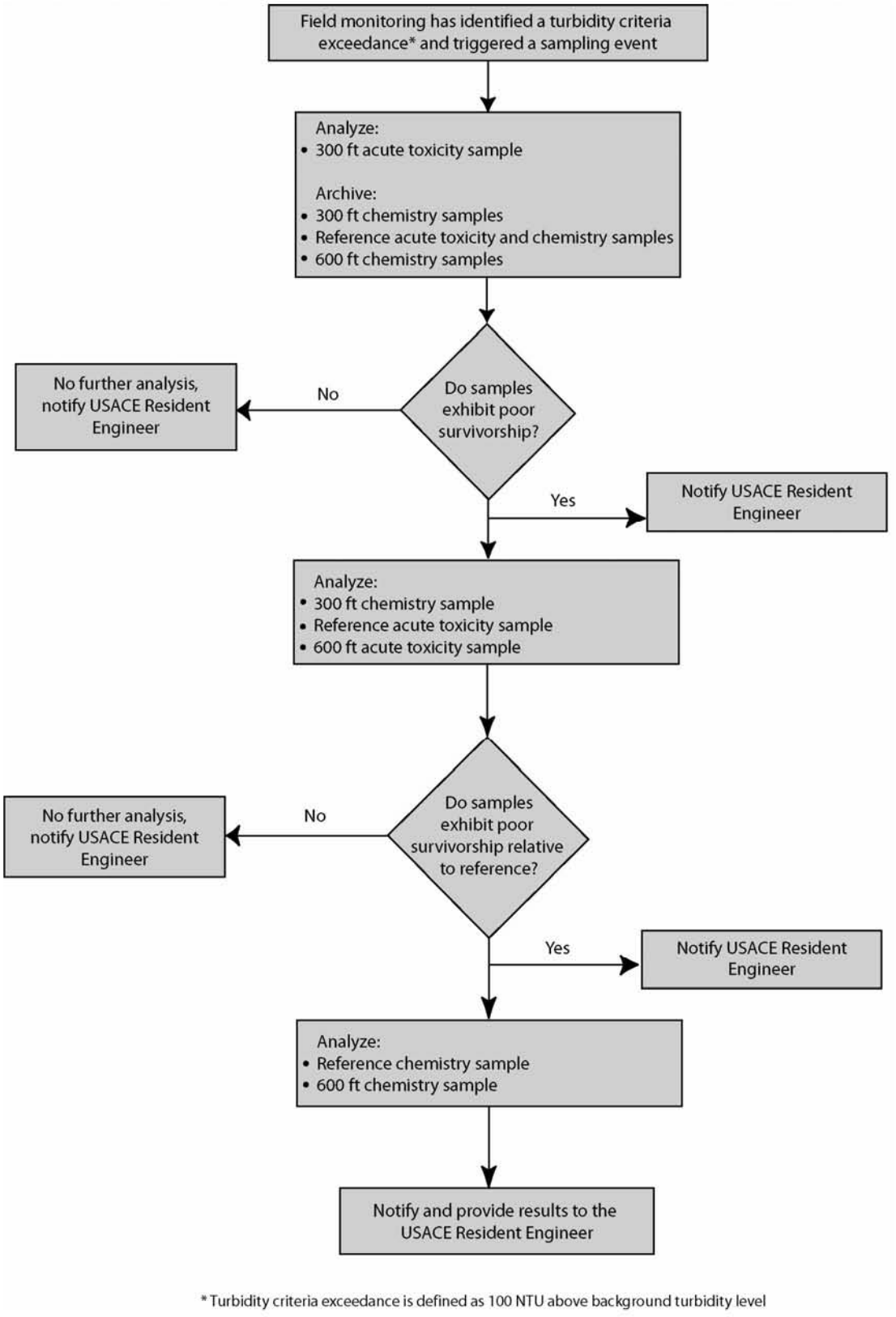


Figure 4. Decision sequence for Level III water quality sample analysis

1.3.2 Compliance Criteria Modifications Leading to Phase II

The compliance criterion for the 2009 dredge season was reevaluated in July, 2009 for several reasons. First, the criterion of 50 NTU's 300' from the dredge was based on historical observations in other operations which demonstrated that this turbidity level rarely if ever caused adverse biological effects; therefore, it was adopted as a "protective" concentration. A new dose-response test with freshly collected resuspended upper harbor sediment (7/22/09) showed that concentrations as high as 110 NTU's had no significant toxic effect in the *Arbacia* test or the Mysid test. Further, there was still 88% fertilization in the *Arbacia* test at 190 NTUs, indicating that while this result may be statistically different, it probably isn't biologically relevant. Based on these data, it was reasonable to reassess the old NTU criterion level and increase it from 50 to 100. This would be less restrictive on the operation and still be "protective" as defined by the toxicity tests.

The second rationale for the modification concerned the logistics associated with the operational turbidity monitoring. Because of simultaneous and separate dredging and debris removal operations in the upper harbor in 2009, monitoring became at best complicated and at times, unwieldy. The overall monitoring objective has always been to restrict toxic impacts and resuspended contamination to the immediate area of the dredge, while preventing redistribution of contaminants to cleaner areas north of Wood St. and south of the Coggeshall St. Bridge. While this was easier in past remedial operations due to limited dredging in one area at a time, the 2009 season included multiple dredge areas in the upper harbor, multiple removal operations in each (i.e., sediment and debris), time restrictions due to water depth, etc. Therefore, the "operational" boundaries were redefined as the northern-most dredging/debris removal area and the southern-most working area. This was consistent with limiting effects north of Wood St. and south of Coggeshall St., as has been done in the past. Adopting this approach simplified the operational monitoring, maintained adequate environmental protection, and ultimately speeded up the contaminant removal.

Based on this new NTU criterion and monitoring boundaries, the 100 NTU threshold was not to be exceeded 300 feet down-current of the active work zone. The active work zone was defined as the area between the northern boundary of Area M and the southern boundary of Area L. In the event that no work was being done in Area L on an ebb tide, the boundary was instead 300 feet down-current of the southern boundary of Area J. If the criterion was exceeded, the on-site resident USACE engineer Mr. Paul L'Heureux was notified of the event and water samples were collected. These "exceedance" water samples were submitted for analysis according to the priority outlined by the USACE (Figure 3). The sample analysis prioritization began with acute toxicity assays to determine if subsequent chemical analysis was necessary.

An exceedance of the 100 NTU turbidity criterion was considered a "compliance threshold violation," when observed 300 feet down-current of the active work zone. This is in contrast to a "high turbidity event," which occurred when turbidity levels reached 100 NTU above background, but still within the active work zone before reaching the compliance boundary. While a high turbidity event is cause for concern and certain adjustments should be made to active dredging operations in the area, it does not

constitute a project-specific compliance threshold violation and therefore does not require collection of water quality samples.

1.3.3 Phase II

A technical memorandum issued by the EPA on August 3rd, 2009 marked the formal installment of the modifications to the water quality monitoring compliance criteria and approach (USEPA, 2009). For the remainder of the 2009 dredge season, the 100 NTU compliance threshold was not to be exceeded 300 feet down-current of the active work zone, as defined above. If the criterion was exceeded, the on-site resident USACE engineer Mr. Paul L'Heureux was to be notified and water sample collections were initiated. The Phase II water quality monitoring decision sequence is outlined in Figure 5.

In the event of an exceedance of the threshold criteria, water samples were to be submitted for analysis according to the priority outlined by the USACE, which began with acute toxicity assays to determine if subsequent chemical analysis was necessary. The prioritization sequence for sample analysis was performed in the same manner as done under Phase I during the 2009 season with the exception of the 600 ft water samples, which were not collected under Phase II (Figure 4).

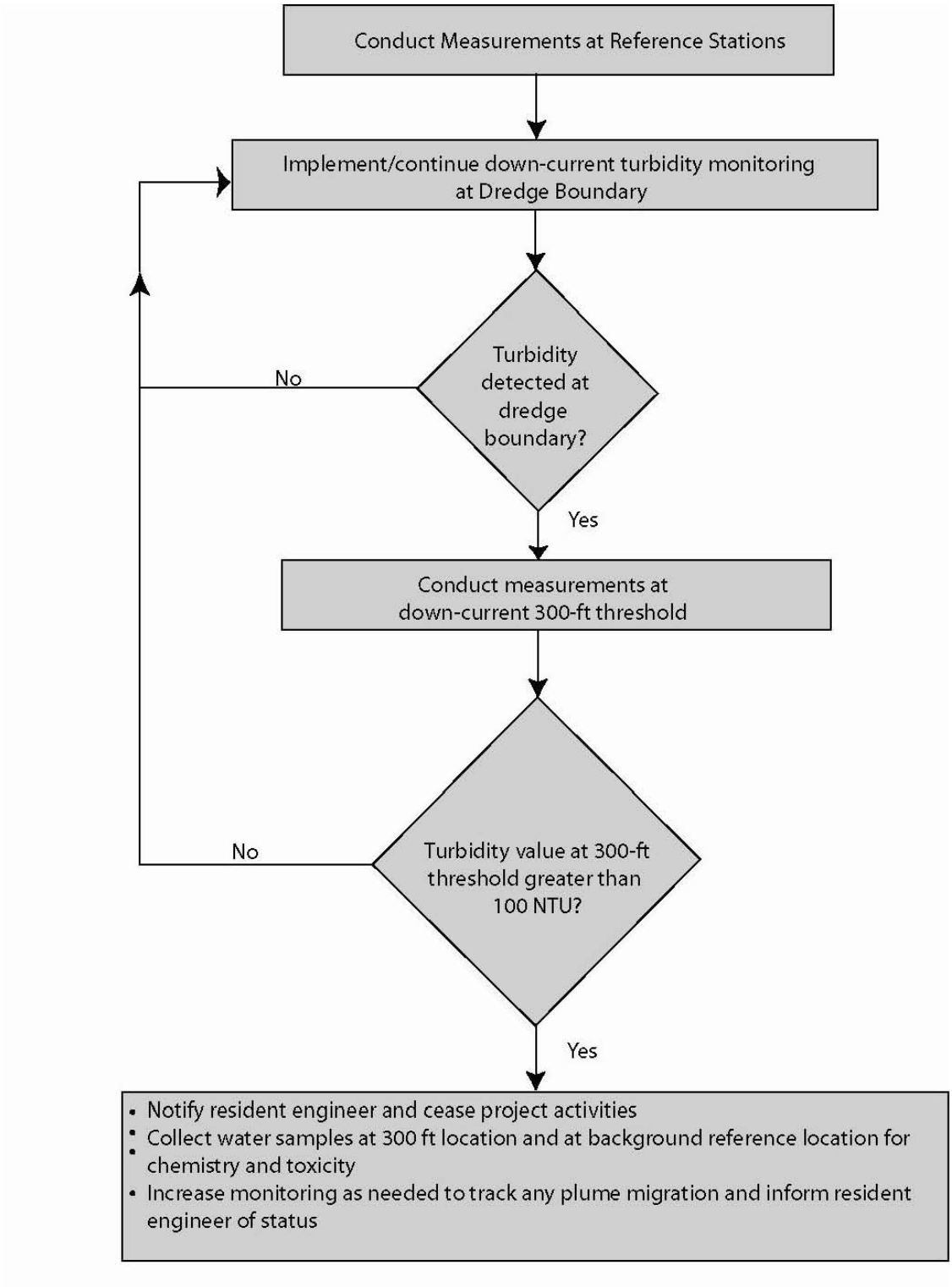


Figure 5. Decision sequence for 2009 water quality monitoring – Phase II

2.0 METHODS

Methods employed to monitor water quality and collect water quality samples are summarized below and described in detail in the project Field Sampling Plan (Woods Hole Group 2009A) and Quality Assurance Project Plan (Woods Hole Group 2009B).

2.1 MONITORING APPROACH

The established sampling approach for this program employed a variety of methods to characterize sediment resuspension, sediment transport, and its potential impact on water quality. The overall approach utilizes an adaptive, criteria-based, sampling scheme to monitor project-related water quality impacts. *In-situ* boat-based water quality monitoring was performed along transects immediately adjacent to defined distances down-current of dredging operations and at up-current reference stations as described in Section 1.4.2. The daily boat-based monitoring data was supplemented with fixed station instruments that recorded a continuous time series of the pertinent parameters, to provide near continuous observation of the system's water quality during dredging operations.

As with previous years' efforts, a tiered monitoring approach was employed using varying levels of monitoring intensity to assess dredging related water quality impacts, as described in Section 2.2. More intensive monitoring occurred during the initial week of dredging to verify the effectiveness of the project-specific turbidity compliance threshold and to track sediment plume dispersion and potential for contaminant transport downfield of the dredge. Following the intensive monitoring at the start of the season, boat-based monitoring was performed twice weekly by WHG. Flexibility in the monitoring program was necessary throughout the dredging process in order to respond to changing field conditions.

The three general levels of monitoring are defined as follows:

- Level I represents the highest level of monitoring and includes the collection of discrete water samples. Level I sampling was conducted for activities considered to have the greatest potential to impact water quality or when new conditions were encountered. Level I sampling included collection of discrete water samples at designated stations: Reference, Dredge Boundary, 300 feet down-current, and 600 fee down current. Water samples were collected for all test parameters from the depth of highest turbidity, based on *in-situ* readings. For the last five years, Level I sampling has been implemented to collect discrete samples at locations representing a full range of turbidities to evaluate relationships, if any, among the turbidity, PCB and toxicity data and to confirm that the current criteria were adequately protective of the aquatic environment.

  Level II represents a lower level of monitoring intensity compared to Level I, and performed to identify any project related water quality impacts adjacent to any dredging or operational activity related activity as warranted.
- Level III represents routine, boat-based monitoring performed during dredging activities to evaluate *in-situ* turbidity readings against the project-specific water

quality compliance criteria. Collection of discrete water samples for laboratory testing was conditional based on results of *in-situ* turbidity monitoring and/or visual observations of any oil sheens.

Complete details of these sampling methods are provided in the Field Sampling Plan (WHG 2009A) and Quality Assurance Project Plan (WHG 2009B).

2.1.1 Boat-Based Water Quality Monitoring

Except for Level 1 monitoring events, boat-based water quality monitoring was conducted twice weekly during the course of the 2009 dredge season. Beginning in June, 2009 and ending in December, 2009, monitoring was typically scheduled on Mondays and Thursdays, throughout the active dredge season and supplanted with the fixed mooring data. A YSI 6920-V2 datasonde was used to collect *in-situ* measurements of depth, temperature, salinity, turbidity, and dissolved oxygen along monitoring transects. This datasonde was equipped with optical turbidity and dissolved oxygen sensors. A handheld YSI 650 was used to acquire real-time water quality data during observation transects. Data was recorded on field log sheets and summarized in a daily report, which was delivered to the USACE at the end of each boat-based monitoring day (Appendix A). The sondes were calibrated for all parameters once per week according to manufacturers specifications to ensure data quality.

At the start of each monitoring day, the vessel transited to the appropriate reference location, 1000 feet up-current of the active dredge areas. During a flood tide, this location was 1000 feet south of the Area L southern boundary. Conversely, during an ebb tide, the reference readings were measured 1000 feet north of the northern boundary of Area M. These "background" reference values were used to characterize the ambient conditions in the estuary and serve as the basis for comparison with the active monitoring data on a given day and tide. Reference values were re-established as necessary given changes in weather and tidal conditions.

Once reference values were established, the team would initiate boat-based monitoring per required protocols. During Phase I of the 2009 season, water quality parameters were monitored at distances 300 feet down-current from any active dredge related operations. This required transiting between active dredge areas and examining the potential for impacts to water quality at each operational area. If a turbidity plume was detected 300 feet from the activity with sustained turbidity readings of 50 NTU above background or greater, the on-site USACE resident engineer was notified and work crews were advised to adjust operational activity to allow for the plume to disperse. If turbidity readings remained 50 NTU above background or greater at the 300 ft down-current transect water quality samples were collected and USACE project personnel were notified of the exceedance of the warning level criteria. Turbidity levels were then monitored at the location 600 feet down-current transect for potential compliance criteria violations. If the plume was detected at the 600 foot transect and turbidity exceeded 50 NTU, WHG would notify USACE Resident Engineer, who would in turn direct the dredging contractor to terminate all dredging related activities. Figure 6 depicts the monitoring thresholds for Phase I of the 2009 water quality monitoring program.

During Phase II of the 2009 dredge season, water quality parameters were monitored at the specified transects 300 feet down-current from the active dredge zone. As previously defined, the active dredge zone comprised the area between the northern boundary of Area M and the southern boundary of Area L (See Figure 7). Under the Phase II water quality monitoring approach, an exceedance of the 100 NTU criteria at either of the 300 foot transects would indicate a compliance violation. If such a plume was identified and turbidity readings remained elevated 100 NTU above background for a sustained period, the resident engineer Mr. Paul L'Heureux was to be notified and all dredge related operations were to be shut down until the condition abated. Figure 7 depicts the monitoring compliance transects for Phase II of the 2009 water quality monitoring efforts.

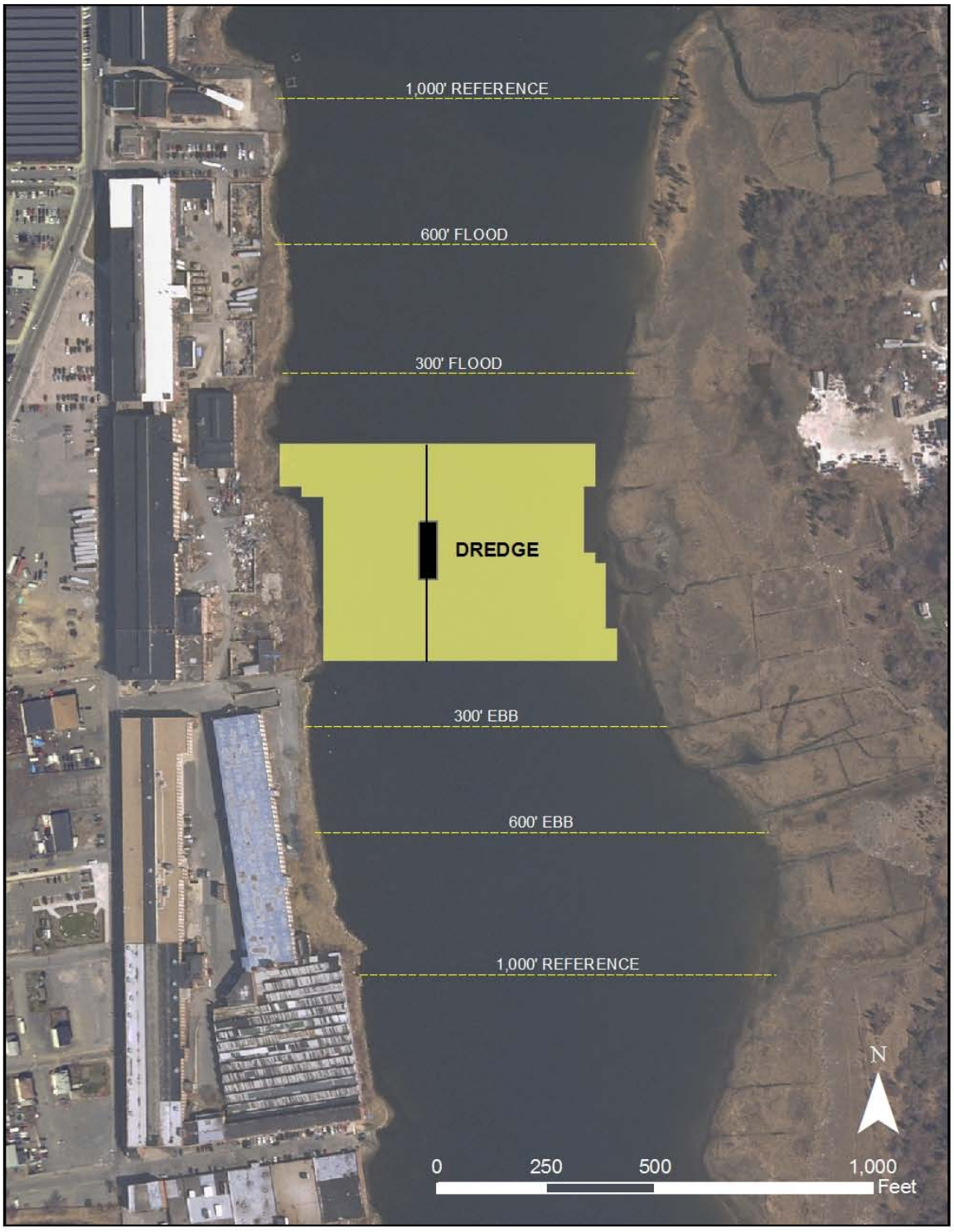


Figure 6. Basemap of compliance thresholds for turbidity criteria – Phase I

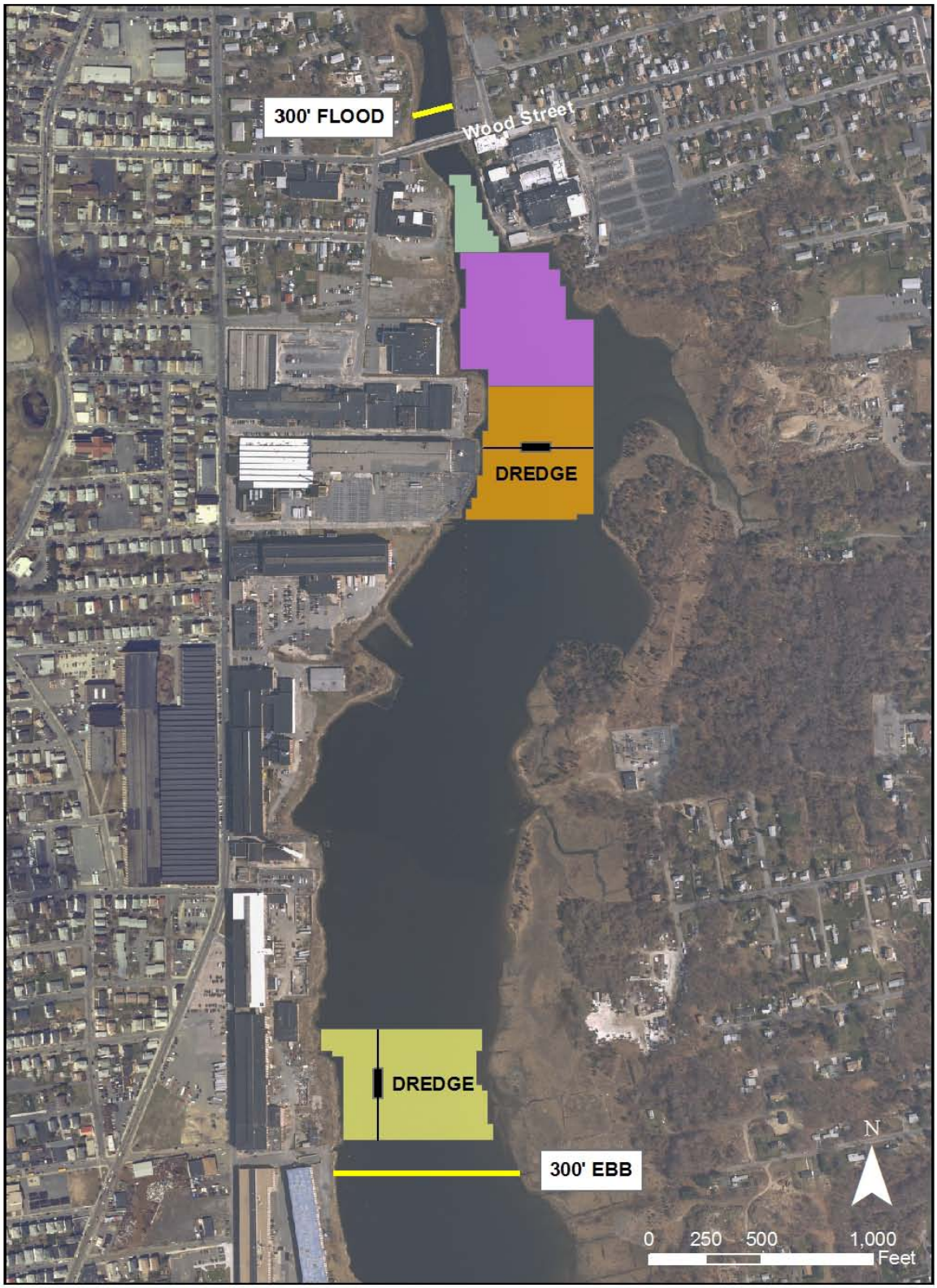


Figure 7. Compliance monitoring transects for turbidity exceedance criteria – Phase II

2.1.2 Fixed Station Water Quality Monitoring

In addition to the active boat-based monitoring, fixed station water quality moorings were deployed at five locations throughout the upper portion of the estuary (Figure 8). Monitoring instrumentation included YSI 6920 data sondes that provided depth, temperature, salinity, turbidity and, dissolved oxygen measurements, recorded in 15-minute intervals. The locations were strategically selected in order to best supplement the boat-based water quality monitoring data (Figure 5). Mooring locations included: 1) North of the Wood Street Bridge, 2) North of Area G, 3) South of Area J, 4) North of Area L, and 5) South of Area L. Moorings were designed to either float approximately 1.0 – 1.5 feet below the water surface, or to be fixed on the bottom (Figure 8).

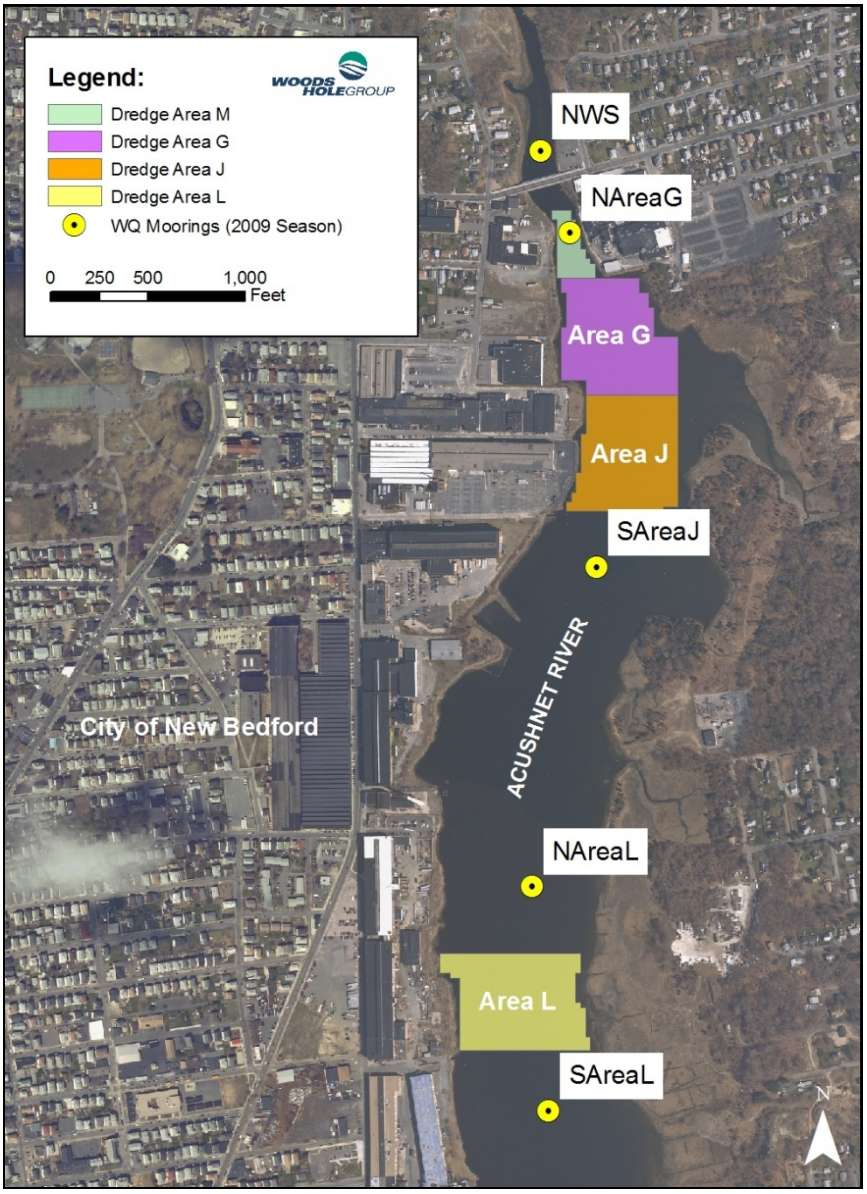


Figure 8. 2009 Fixed Station Water Quality Mooring Locations

A fixed mooring was located north of the Wood Street Bridge 1 foot off the bottom due to the shallow water conditions. It was attached to a milk crate facing upward and weighted by a heavy chain, with a marker buoy attached so as not to be disturbed by any boating or fishing activity (Figure 9). At this location, readings collected were at least 600 feet away from any operational activity. The four remaining moorings were floating design. The floating moorings were fastened to a line and a chain connected to the mushroom anchor and suspended by a lobster buoy. Each mooring also had a larger indicator buoy so that the mooring location was easily discernable and minimize disturbance (Figure 9). The instruments were positioned to float vertically, with the sensors facing upward. The moorings south of Area J, north of Area L and south of Area L were positioned 300 feet from their respective dredge area boundaries (Figure 8). A fourth floating mooring was positioned south of the Wood Street Bridge. This mooring was added during the 2009 dredge season to provide better spatial coverage and to monitor increased activity in Areas M and G and identify plume migration into the previously remediated area north of Wood Street.

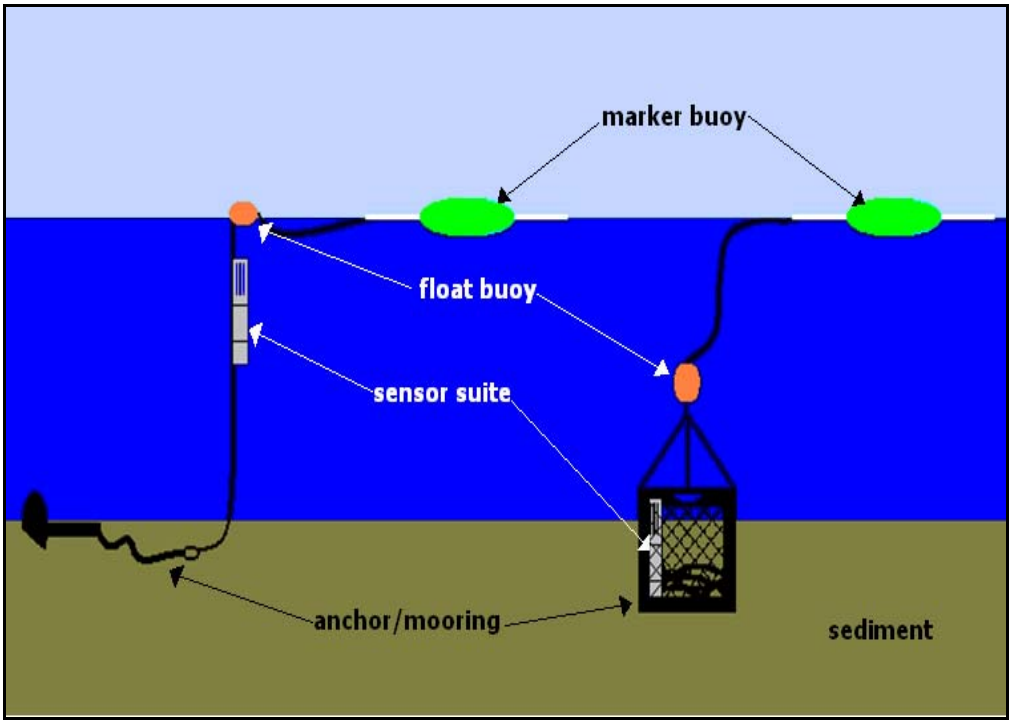


Figure 9. Diagram of fixed station water quality moorings

Data from the water quality moorings was downloaded twice per week and reported to the USACE. The data was provided as figures of the turbidity and dissolved oxygen time series at each station over a three to four day period. An example of a bi-weekly report figure is included as Figure 10. The tidal cycle was also displayed on the figures, collected from the bottom-fixed mooring north of Wood Street. Information regarding dredge related activities were provided by the dredge contractor and included on these figures. Times of active dredging and debris removal in the areas immediately adjacent to each mooring were shaded on the figures to determine whether elevated turbidity levels could be attributed to dredging activities. For the moorings located north and

south of the Wood Street Bridge, any dredge related activities in Areas M or G was shaded. Activity in Area J was shaded for the mooring south of Area J, and any activity within Area L was shaded for the moorings north and south of Area L. The complete time series of turbidity data for each mooring are provided in Appendix B to this report.

The moorings were maintained approximately every other week (14 days). Maintenance required that the instruments be recovered and brought back to the lab trailer for cleaning, recalibration, and to have batteries changed, as needed. Once routine maintenance was performed and the data had been downloaded, the mooring instruments were returned to their original locations.

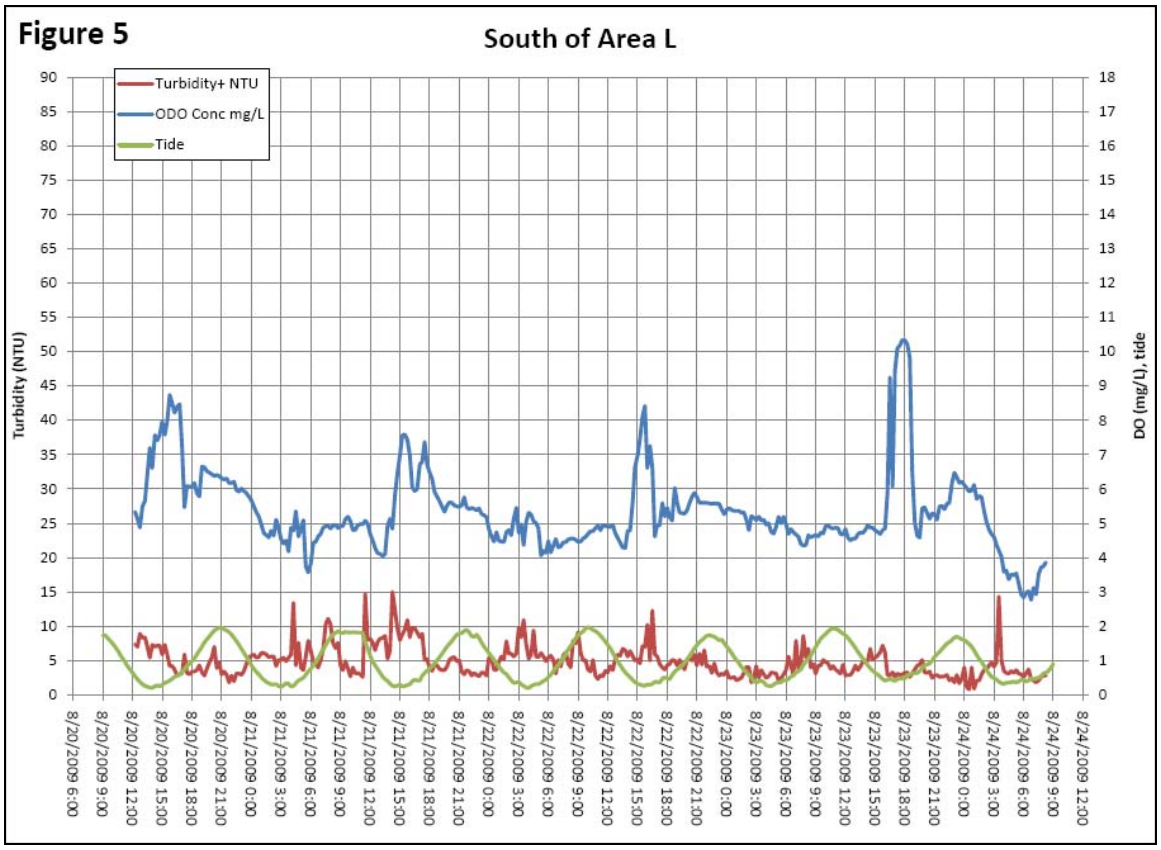


Figure 10. Example of bi-weekly report figure plotting fixed station water quality mooring data

2.1.3 Discrete Water Samples

Discrete water samples were collected during boat-based monitoring using a diaphragm pump connected to 10 feet of tygon tubing. Prior to collecting samples at a given location, water was pumped continuously through the system for approximately two minutes to flush the equipment. This process purged the pumping system in order to reduce the potential for site-to-site cross-contamination. The YSI *in-situ* sensor was placed in the water adjacent to the tubing inlet during collection to ensure that the sensor measurements and the analytical results were representative of the parcel of water being tracked.

Following the purging procedure, water sampled from the pump outlet was collected into the appropriate sample containers for laboratory testing (Table 1). The GPS coordinates of the sample collection were recorded in the WHG field logbook and later entered into electronic files (EDDs) for inclusion in the project database. Following collection, samples were stored on ice in coolers until delivery to the participating laboratories for analysis (Table 1). For each sample event, a routine set of field-based quality control (QC) samples were collected to monitor data quality. Samples included one equipment blank and one field duplicate sample for each set of 20 or fewer field samples. Field QC samples were collected for all test parameters except toxicity assays.

Table 1. Sample collection requirements and participating laboratories

Parameter	Sample Volume	Sample Container	Preservation	Storage Condition	Holding Time	Analytical Lab
TSS	1 L	HDPE Bottle	Ice	4 ± 2 °C	7 Days	**Alpha Analytical** 320 Forbes Blvd Mansfield, MA 02767 Ph:508-822-9300
Turbidity	1 L	HDPE Bottle	Ice	4 ± 2 °C	48 Hours	
PCB (unfiltered)	1 L	Wide-mouth Amber Glass Bottle	Ice	4 ± 2 °C	7 Days	
PCB (dissolved)	1 L	Wide-mouth Amber Glass Bottle	Ice	4 ± 2 °C	7 Days	
Total Metals	500 ml	HDPE Bottle	$HN0_3$	4 ± 2 °C	6 Months	
Toxicity	5 gallons	Cubitainer	Ice	4 ± 2 °C	24 Hours	**EnviroSystems, Inc** One Lafayette Road P.O. Box 778 Hampton, NH 03843 Ph: 603-926-3345

2.2 LABORATORY ANALYSIS

Laboratory testing was performed on contingency based and/or preplanned discrete water samples. Contingency based samples (Level III), collected in the event of an exceedance of the project's warning or compliance criteria were analyzed according to the program's decision sequence for sample analysis. In short, Level III samples were analyzed for toxicity and results were used to determine if subsequent chemical and physical analyses would be required. Figure 4 depicts the decision sequence for sample analysis for a Level III sampling event. At the direction of USACE, planned samples (Levels I and II) were submitted for total suspended solids (TSS), turbidity, PCB (total and dissolved phases), and toxicity testing. An additional sample was collected and archived in the event that heavy metals analysis was later requested. Laboratory methods are summarized below and described in detail in the project QAPP (WHG 2009B).

In addition to the discrete water samples, a routine set of laboratory-based QC samples were prepared from those bottles submitted to the laboratory to monitor data quality in terms of accuracy and precision. Depending on the analysis, QC samples included a procedural blank, laboratory control sample (LCS), laboratory control sample duplicate (LCSD), matrix spike (MS), and matrix spike duplicate (MSD). Specific QC samples and the associated measurement quality objectives are discussed in the QAAP (WHG 2009B).

2.2.1 Total Suspended Solids and Turbidity

In addition to real-time *in-situ* turbidity monitoring, discrete water samples were submitted for total suspended solids (TSS) and turbidity analyses at Alpha Analytical Laboratories (AAL). Water samples were analyzed for TSS following AAL Standard Operating Procedure (SOP) "Total Suspended Solids (TSS) Non-Filterable Residue, Rev. 6.1" (WHG 2009B), which is based on a modified USEPA Method 160.2. In brief, a well-mixed sample was filtered through a 0.45 µ membrane filter and the residual retained on the filter was dried and weighed. Results were reported on a milligram dry-weight basis per volume of water filtered (mg/L). Water samples were analyzed for turbidity following AAL SOP "Turbidity 180.1 Rev. 2.2" (WHG 2009B), which is based on USEPA Method 180.1. Sample results were reported as NTU.

2.2.2 Polychlorinated Biphenyl Congeners (NOAA-18)

Polychlorinated biphenyl (PCB) analyses for the National Oceanic and Atmospheric Administration (NOAA) eighteen congeners were conducted by AAL, using both unfiltered (total) and filtered (dissolved) water samples. Dissolved phase samples required filtering using Gelman AE glass fiber filters (0.45 µm pore size) and the filtrate captured for analysis.

Polychlorinated biphenyl samples (total and dissolved) were extracted following modified EPA Method 3510C, AAL SOP "Extraction of Water Samples by Separatory Funnel" (WHG 2009B). An aliquot of a well mixed, homogeneous aqueous sample is accurately measured for sample preparation. Generally, 1L of a water sample is extracted. The sample is spiked with surrogate compounds and then extracted using methylene chloride. The extract is dried using anhydrous sodium sulfate and solvent exchanged to hexane during sample concentration. After extraction and concentration, the SW-846 3600-series methods for extract clean-up techniques are applied as necessary. The extract may be treated with Florisil (3620B) or GPC (3640A) for hydrocarbon and lipid removal, and copper (3660B) for sulfur removal. The extract is solvent exchanged into hexane and concentrated to the appropriate volume, generally 10mL, and transferred for analysis. Prior to analysis, the extract is cleaned with sulfuric acid (3665A). Alternatively, this method can be employed for lower detection limits by decreasing the final volume to 1-5mL.

After clean-up and re-concentration, the extracts are analyzed on a gas chromatograph (GC) which is fitted with two capillary columns of differing polarities each employing separate ECD detectors. This process follows a modified USEPA Method 8082 (WHG 2009B). The extracts of PCB Congeners are spiked with internal standards (IS) prior to

analysis. The target analytes are resolved on each column and detected using an electron capture detector (ECD). Analytes are introduced into the GC/ECD by injecting a known volume of the calibration standards, quality control samples, and sample extracts into the GC which is temperature and flow programmed to separate the analytes. Identification of the target analytes is accomplished by confirming a target hit on two dissimilar columns using Retention Time (RT) and Pattern Recognition (PR). Concentrations are calculated from the ECD response using internal standard techniques. Sample results were reported in micrograms per liter (µg/L) for the individual eighteen congeners.

For each batch of 20 or fewer samples, a laboratory method blank, LCS/LCSD, MS and MSD was processed and analyzed with the field samples.

2.2.3 Toxicity

Acute and chronic (sub-lethal) exposure screening assays were performed to evaluate the potential toxicity of surface water samples. All assays were conducted by EnviroSystems, Inc. (ESI) located in Hampton, New Hampshire. The information regarding the toxicity analyses that is contained in this section has been obtained from the ESI report text (Appendix D). Assay design included a laboratory control treatment and one or more surface water samples, generally including a site reference sample. Samples were evaluated "As Received" without dilutions. Testing was based on programs and protocols developed by the USEPA primarily designed to provide standard approaches for the evaluation of toxicological effects of discharges on aquatic organisms, and for the analysis of water samples. Testing included the following assays: modified 2 day acute and 7 day chronic assays conducted with the mysid shrimp, *Americamysis bahia*, and the red macro alga, *Champia parvula*, and 60 minute chronic fertilization assays conducted with the purple sea urchin, *Arbacia punctulata*.

2.2.3.1 Test Species

Americamysis bahia, ≤5 days old, were obtained from cultures maintained by Aquatic Research Organisms (ARO), Hampton, New Hampshire. Juvenile shrimp were collected daily, isolated, and placed in a rearing tank for up to 6 days. Holding tanks were maintained in a flow-through culture mode at a temperature of 25±2°C. At the start of the assays the mysids were 7 days old. Juveniles were fed <24 hour old brine shrimp on a daily basis. Water temperature, salinity, and pH were monitored on a daily basis. Prior to testing organisms were siphoned from the rearing tanks to a holding vessel, and then transferred to test chambers using a large bore pipet, minimizing the amount of water added to test solutions.

Arbacia punctulata adults were from cultures maintained by ESI. Original stock was obtained from commercial supply. Male and female urchins were maintained in separate chambers. Adult urchins were induced to spawn by the injection of a potassium chloride solution. The viability of gametes obtained was determined prior to their addition to the test solutions. Eggs and/or sperm that would not result in a fertilized egg were rejected from the pool of gametes used in the assay.

Champia parvula biomass was obtained from stock cultures maintained by the Saskatchewan Research Council. Original stocks were obtained from the University of Texas algal collection. The male and female plants were maintained in separate culture vessels under sterile conditions. Algal cultures were maintained on an orbital shaker (100 rpm) at 23±2°C under a ratio of 16 hours light: 8 hours dark at a light intensity of 40 to 75 foot candles light intensity. Cultures are "cropped" and transferred to fresh nutrient solutions on a weekly basis.

2.2.3.2 Site Water Samples and Laboratory Control Water

Prior to testing, samples were evaluated to document salinity, conductivity, and total residual chlorine. Total residual chlorine was measured by amperometric titration (MDL 0.02 mg/L). Prior to use in the assays, the salinity of the samples was adjusted, as necessary, to predetermined levels using artificial sea salts for *A. bahia* and *A. punctulata* assays, and GP-2 salts for the *C. parvula* assays. When necessary, the salinity of samples for the *A. bahia* acute and chronic exposure assays were adjusted to 25±2‰ while samples used for the *A. punctulata* and *C. parvula* assays were adjusted to 30±2‰. Samples with "as received" salinity above these levels were not adjusted.

Laboratory control water used for the mysid and sea urchin assays was collected from the Hampton/Seabrook Estuary. This water is classified as SA-1 and has been used to culture marine test organisms since 1981. The laboratory control water used in the algal assay (48 hour acute portion), collected from Hampton Harbor, New Hampshire, is the same water used in culture maintenance. Prior to use, seawater used in the algal assays was filtered through glass fiber filters and sterilized. Control water used in the algal assays conducted by AquaTox (acute and chronic portions) was natural seawater collected from the West Coast of Canada. Salinity of the surface water samples was adjusted, as required, using commercial sea salts.

2.2.3.3 Bioassay Tests

Americamysis bahia Acute Exposure Assays

The endpoint for the *A. bahia* bioassay was survival (acute). The 48 hour static acute toxicity tests were conducted at 25±1°C with a photoperiod of 16:8 hours light: dark. Test chambers for the acute assays were 250 mL glass beakers containing 200 mL test solution in each of 4 replicates with 10 organisms per replicate. Survival and dissolved oxygen were measured daily in each replicate prior to test solution renewal. Salinity, temperature and pH were recorded in a composite sample of the "old" test solution and in the "new" test solution prior to being added to the test chamber. Specific conductivity was measured in one replicate of each sample at the start of the assay. Mysids were not fed during the assay.

Americamysis bahia Chronic Exposure Assays

The 7 day assays were conducted at a temperature of 26±1°C with a photoperiod of 16:8 hours light:dark. Mysids were maintained in 250 mL beakers containing 150 mL of test solution. Approximately 100 mL of the test solution were replaced each day. The assay incorporated 8 replicates with 5 organisms per replicate. Survival and dissolved oxygen were measured daily in each replicate prior to test solution renewal. Salinity, temperature

and pH were recorded in a composite sample of the "old" test solution and in the "new" test solution prior to being added to the test chamber. Incubator temperatures were also recorded on a daily basis. During the test, mysids were fed #24 hour old *Artemia* nauplii. On Day 7 of the assay, surviving mysids were removed from test solutions, rinsed to remove any surface detritus and salts, and transferred to tared foils and dried for 24 hours at 103°C. Foils were weighed to the nearest 0.01 mg. Mean dry weights per individual were obtained by dividing the net dry weight of all surviving organisms by the number of organisms added at the start of the assay.

***Arbacia punctulata* Chronic Exposure Fertilization Assays**

The endpoint for the *A. punctulata* bioassay was fertilization. Gametes were obtained by potassium chloride injection to induce spawning. Sperm were collected dry, diluted to achieve a concentration of approximately 5.0 x 107 sperm/mL in the surface water treatments. Actual sperm concentrations are provided on laboratory bench sheets within ESI's report in Appendix D. Sperm solutions were added to 5 mL aliquots of each sample being evaluated and allowed to remain in the test solutions for 60 minutes before the addition of unfertilized eggs. Each treatment incorporated a total of four (4) replicates. After 20 minutes exposure, the assay was terminated by the addition of 0.2 mL of preservative. Aliquots of preserved solution were counted to determine numbers of fertilized and unfertilized eggs. Fertilization was accepted based on the presence or absence of a fertilization membrane around the egg.

***Champia parvula* Acute Exposure Assays**

The target endpoints for the acute *C. parvula* bioassay were coloration and necrosis. The red algae assay was conducted with a 2 day exposure period to the surface waters and laboratory control treatments. Each treatment used four replicates with five female branches and one male branch per replicate. Temperature was maintained at 23±1°C. The light source was cool white and fluorescent bulbs set on a 16:8 hours light:dark cycle, with a light intensity of 40 to 75 foot candles. Light intensity was checked at the start of each assay. Temperatures were monitored on a daily basis. Test chambers were 200 mL borosilicate glass fleakers. Upon test termination, plants were examined to determine the physical condition and coloration of the individual branches. Branches showing signs of degeneration were noted and used to establish an acute endpoint.

2.2.3.4 Data Analysis

Statistical analysis of acute and chronic exposure data was completed using Comprehensive Environmental Toxicity Testing System (CETTS) software. The program computes acute and chronic exposure endpoints based on EPA decision tree guidelines specified in individual test methods. For chronic exposure endpoints statistical significance was accepted at $\alpha < 0.05$.

2.2.3.5 Quality Control

As part of the toxicity testing laboratory quality control program, standard reference toxicant assays are conducted on a regular basis for each test species to provide relative health and response data while allowing for comparison with historic data sets.

3.0 CHRONOLOGY OF MONITORING OBSERVATIONS

Water quality monitoring was performed from the onset of the dredging season, starting in June 2009 and continuing through the extended dredging season until late December 2009. Remedial dredging began on June 1, 2009 and was completed on December 1, 2009. In the following summary, all turbidity values referenced are the actual values as read from the sensor and therefore, not corrected for background levels. Field logs and daily summary reports, as well as figures depicting the complete time series from *in-situ* fixed-station water quality monitoring station instruments are included in Appendices A and B, respectively. Complete tide data corresponding to the 2009 dredge season is included on the field logs (Appendix A). The following section provides a weekly summary of water quality monitoring observations and activities. The text was summarized from the daily field logs and weekly summary reports submitted to the USACE throughout the 2009 dredge season.

Week of June 1 – June 5, 2009 (Spin-Up)

- **Days monitored**: Wednesday 6/3, Thursday 6/4 and Friday 6/5.
- **Areas of activity**: Dredging and debris removal in Area L, pipe work in Areas M, G and J.
- **Exceedances**: None.
- **Turbidity summary**: Wed: ref = 1-3 NTU, 300-ft transect L = 17-40 NTU, 600-ft transect L = 7-12 NTU; Thurs: ref = 3-5 NTU, 300-ft transect L = 10-28 NTU; Fri: ref = 3-5 NTU, 50-ft transect L = 60-80 NTU, 100-ft transect L = 30-40 NTU, 200-ft transect L = 20-30 NTU, 300-ft transect L = 10-30 NTU
- **Wildlife**: Many fish observed jumping. Jellies were abundant throughout the harbor.
- **Notes**: Monitoring on Wednesday 6/3 showed elevated turbidity readings of <40 NTU above background 300-ft north of Area L during debris removal on the flood tide. While monitoring the pipe installation work being done in Areas M, G and J, slightly elevated turbidity values ranging from 6 – 12 NTU were observed. Also, a moderate to heavy sheen appeared and collected on the northern most oil boom in the M/G/J areas.

  On Thursday 6/4, two fixed YSI moorings were deployed 150-ft south and north of the Area L boundaries. Turbidities ranging 25 – 50 NTU were observed directly adjacent to operations in Area L, but were 10 – 30 NTU outside of the area boundaries. During debris removal operations, a short plume with maximum turbidity value of 185 NTU was observed but quickly dissipated once the operator noticed and ceased working. Surrounding the dredge in Area L and outside of the boundaries of L on Friday 6/5, readings were 10 – 30 NTU. A narrow (50 feet wide) plume of higher turbidity, ranging from 30 – 80 NTU trailed the debris removal barge but dissipated quickly with distance to only 30 – 40 NTU at 100-ft down-current.

Week of June 8 – June 12, 2009 (Week 1)

- **Days monitored**: Monday 6/8, Wednesday 6/10 and Friday 6/12.

- **Areas of activity**: Dredging and debris removal in Areas J and L. Debris removal in Area G.
- **Exceedances**: None.
- **Turbidity summary**: Mon: ref = 2-5 NTU, 200-ft transect L = 10-30 NTU, 300-ft transect = 5-12 NTU; Weds: ref = 6-12 NTU, 300-ft transect J = 10-12 NTU (flood) and 10-20 NTU (ebb); Fri: ref = 11-15 NTU, 100-ft transect G = 20-30 NTU (slack high) and 30-80 NTU (max 130, ebb), 300-ft transect L = 6-10 NTU
- **Wildlife**: Many shorebirds and jellies observed. A dead seagull was found floating in Area J on Friday 6/12.
- **Notes**: On Monday 6/8, during times of inactivity, turbidity readings surrounding the debris removal barges in Area L were as high as 40 NTU. It is thought that during low tides, the barge may be touching the bottom sediments, causing a disturbance of sediments into the water column. High readings were also observed very close (<100 feet) to the debris removal barges in Area L during activity, but these plumes dissipated rapidly with increasing distance. Monitoring surrounding dredging and debris removal in Area J on Wednesday 6/10 showed a narrow plume of turbidity traveling south of the activity, limited to <30 NTU at a distance of 300-ft down-current.

  On Friday 6/12, the two YSI moorings were recovered, cleaned, and recalibrated, and then redeployed in their new long-term locations 300-ft south of Areas J and L. A plume of turbidity was observed in Area J in association with debris removal in Areas G and J and dredging in Area J. The plume reached a maximum reading of 130 NTU 100-ft down-current from the activity, but was short-lived. Turbidity generally ranged from 30 – 80 NTU in this region, and was 30 – 40 NTU 200-ft down-current from the activity.

Week of June 15 – June 19, 2009 (Week 2)

- **Days monitored**: Tuesday 6/16 and Wednesday 6/17.
- **Areas of activity**: Dredging in Area L and debris removal in J and L.
- **Exceedances**: None.
- **Turbidity summary**: Tues: flood ref = 1-4 NTU, ebb ref = 4 NTU, 50-ft transect L = 60-80 NTU, 100-ft transect L = 30-50 NTU, 300-ft transect L = 5-10 NTU; Wed: ref = 2-5 NTU, 300-ft transect L = 10-40 NTU, 300-ft transect J = 4-7 NTU
- **Wildlife**: Many shorebirds observed, many jellies, a few fish jumping.
- **Notes**: On Tuesday 6/16, WHG deployed a third fixed station YSI mooring in a long-term location north of Wood Street. The mooring is approximately 100-ft north of the bridge and 300-ft north of Area M. Monitoring showed elevated turbidity immediately surrounding debris removal in Area L, as high as 76 NTU at a distance of 50-ft down-current. At a distance of 100-ft, readings diminished to <50 NTU, and under 10 NTU 300-ft down-current. Activity was also monitored in Area J, where no readings of over 10 NTU were observed. Wednesday 6/17 experienced similar turbidity readings, elevated to <50 NTU within 300-ft of debris removal and dredging in Area L, and under 15 NTU 100-ft from debris removal in Area J.

Week of June 22 – June 26, 2009 (Week 3)

- **Days monitored**: Tuesday 6/23and Wednesday 6/24.
- **Areas of activity**: Dredging in Area L and debris removal in Areas J and L.
- **Exceedances**: None.
- **Turbidity summary**: Tues: ref = 10-15 NTU, 600-ft transect = 10-15 NTU, 300-ft transect = 15-20 NTU; Wed: ref = 2-6 NTU, 600-ft transect = 10-15 NTU, 300-ft transect = 10-40 NTU
- **Wildlife**: Many shorebirds observed and fewer jellies than past weeks.
- **Notes**: Monitoring this week exhibited higher ambient turbidity levels than recent weeks, as high as 10 – 15 NTU, likely due to the significant wind and rainfall during the previous week. Water samples were collected on Wednesday 6/24 for turbidity, total suspended solids, metals (archived), dissolved PCBs and total PCBs analysis by AAL and toxicity assays by ESI. The sampling was performed in conjunction with water quality monitoring at five sites: 1) a reference location upstream of all activity collected during a flooding tide 1000-ft south of Area L, 2) a reference location upstream of all activity collected during an ebbing tide 1000-ft north of Area M and north of Wood Street, 3) the site of active debris removal in J, 4) 300-ft downstream of active debris removal, south of J during ebb, and 5) 600-ft downstream of active debris removal, south of J during ebb. Turbidity levels ranged from 80 – 160 NTU. A strong H_2S odor was noted during sampling at the site of active debris removal.

Week of June 29 – July 3, 2009 (Week 4)

- **Days monitored**: Monday 6/29 and Tuesday 6/30.
- **Areas of activity**: Dredging and debris removal in Areas J and L.
- **Exceedances**: None.
- **Turbidity summary**: Mon: ref = 1-10 NTU, 600-ft transect = 10-30 NTU, 300-ft transect = 10-40 NTU; Tues: ref = 2-10 NTU, 600-ft transect = 1-5 NTU, 300-ft transect = 5-15 NTU.
- **Wildlife**: Terns and ospreys seen fishing, and nesting swans were abundant.
- **Notes**: On Monday 6/29, the field team observed a moderate sheen in Area J associated with debris removal and high turbidity within 100-ft of activity. The turbidity plume and sheen was carried north of the debris removal. No exceedances were observed, however readings of >40 NTU at 300-ft downstream were cause for some concern, so operations were slowed to reduce the turbidity plume. WHG continued to monitor for half an hour after debris removal ceased. Turbidity levels dropped off quickly to between 30 – 50 NTU at the source, and 10 – 20 at 300-ft down-current.

  On Tuesday 6/30, a heavy sheen was observed in Area L associated with the debris removal in the northwest corner. The sheen was not contained by the oil boom and was noticeable 300-ft south of Area L. Jacobs Engineering (JE) was notified (Mr. Josh Cummings) and debris removal was stopped for 2 – 3 hours. WHG monitored the sheen, which was contained within the oil boom in Area L when debris removal started again.

Week of July 6 – July 10, 2009 (Week 5)

- **Days monitored**: Tuesday 7/7 and Thursday 7/9.
- **Areas of activity**: Dredging and debris removal in Areas J and L.
- **Exceedances**: High turbidity event on 7/9/09 in Area L associated with debris removal. WHG was unable to collect water samples due to plume dissipation. This event is qualified as a warning criteria exceedance.
- **Turbidity summary**: Tues: ebb ref = 2-5 NTU, flood ref = 4-10 NTU, 300-ft transect J = 5-15 NTU, 300-ft transect L = 5-20 NTU; Thurs: ref = 5-7 NTU, 300-ft transect J = 5-20 NTU, 300-ft transect L = 20-80 NTU
- **Wildlife**: Fish observed jumping around Area J. Many swans near the Sawyer St dock and by Area J. No jellies were noted.
- **Notes**: Monitoring on Tuesday 7/7 observed a moderate to heavy sheen in Area L associated with the debris removal. The sheen was mostly contained within the oil boom. Turbidity levels were not elevated in this area. The fixed station YSI units were recovered, cleaned and recalibrated for redeployment.

  On Thursday 7/9, a small turbidity plume, narrow and focused, with readings as high as 60 NTU appeared <100-ft downstream of a push boat working to keep a dredge straight in Area J. That same day, WHG observed a slight sheen and very turbid water (50 – 120 NTU) surrounding the recently active, but currently inactive debris barge located in the northwest corner of Area L. At the southern boundary of Area L and 300-ft from the debris removal barge, readings as high as 80 NTU were observed, generally averaging 30 – 60 NTU. The plume was narrow and localized, and as WHG prepared to collect water samples, the plume dissipated. No samples were collected.

Week of July 13 – July 17, 2009 (Week 6)

- **Days monitored**: Tuesday 7/14, Wednesday 7/15, Thursday 7/16 and Friday 7/17.
- **Areas of activity**: Dredging and debris removal in Area G, dredging in Area J and debris removal in Area L.
- **Exceedances**: Wednesday 7/15: warning criteria exceedance occurred in Area G associated with various activities including debris removal, dredging and boat traffic. WHG was able to collect water quality samples at the 300-ft downstream location.
- **Turbidity summary**: Tues: ebb ref = 5-17 NTU, flood ref = 5-15 NTU, 300-ft transect J = 20-30 NTU, 300-ft transect G = 10-35 NTU; Weds: ref = 5-16 NTU, 300-ft transect G = 40-105 NTU, 700-ft transect G = 20-45 NTU; Thurs: ref = 5-18 NTU, 300-ft transect G = 5-20 NTU, 300-ft transect J = 6-15 NTU, 300-ft transect L = 5-20 NTU; Fri: ref = 4-10 NTU, 300-ft transect L = 30-90 NTU, 300-ft transect G = 20-30 NTU, 100-ft transect J = 12-40 NTU;
- **Wildlife**: Fish jumping south of Area L, Many swans, blue and green herons, a kingfisher as well as the usual gulls and cormorants were observed. No jellies observed.
- **Notes**: Monitoring on Tuesday 7/14 observed a slight sheen in Area G associated with the debris removal and activity surrounding the preparation of the dredge.

The debris removal barge was positioned close to the shoreline in the southwest corner of Area G, and a plume of very high turbidity (120 – 265 NTU) was confined between the barge and the shore. The turbidity levels slowly dropped as WHG continued to monitor this plume. The plume was contained to an area approximately 100-ft from the debris removal barge.

Water quality monitoring on Wednesday 7/15 resulted in an exceedance of the project's warning criteria at the 300 foot threshold. Elevated turbidity levels were observed within Area G directly adjacent to the activity, so WHG transited into Area M, to a distance 350-ft from the debris removal and 300-ft from the dredge. WHG monitored water quality for over half an hour, observing a constant turbidity of 30 – 50 NTU with an increase to sustained 60 – 90 NTU and spikes to 105 NTU. USACE Engineer Paul L'Heureux was notified and WHG was able to sample the exceedance at the 300-ft distance. WHG continued to monitor for another half an hour. Turbidity remained elevated despite the halted debris removal and decreased boat traffic. Elevated levels (20 – 45 NTU) were seen past the 600-ft boundary as well.

On Thursday 7/16, WHG returned to monitor Area G where the warning criteria exceedance had occurred on the previous day. Turbidity levels were limited to a range of 40 – 60 NTU during both debris removal and dredging. WHG monitored this area for greater than two hours, to ensure that no exceedances reoccurred. Turbidity levels were near background (<20 NTU) in both Areas J and L.

Monitoring on Friday 7/17 observed a heavy sheen in Area L associated with the debris removal. The sheen was mostly contained within the oil boom, in the northwest corner of the dredge area. Turbidity levels were elevated in this area, ranging from 30 – 90 NTU (20 – 80 NTU above background). JE personnel and Paul L'Heureux were notified, and WHG continued to monitor the area. These elevated turbidity readings quickly decreased to <20 NTU above background once debris removal stopped.

Week of July 20 – July 24, 2009 (Week 7)

- **Days monitored**: Wednesday 7/22 and Friday 7/24.
- **Areas of activity**: Dredging and debris removal in Areas J and L.
- **Exceedances**: None.
- **Turbidity summary**: Weds: flood ref = 9-10 NTU, ebb ref = 3-45 NTU, 300-ft transect J = 10-15 NTU, 300-ft transect L (down-current) = 10-40 NTU, 300-ft transect L (up-current) = 6-22 NTU; Fri: flood ref = 3-13 NTU, ebb ref = 4-17 NTU, 200-ft transect G = 7-25 NTU, 600-ft transect G= 7-11 NTU
- **Wildlife**: Fish jumping south of Area L. A green heron, egrets, swallows, swans and shorebirds observed.
- **Notes**: On Wednesday 7/22, samples were collected for a toxicity study from a location in Area G where a warning level criteria exceedance occurred on 7/15. WHG also performed water quality monitoring on Wednesday, and cleaned and recalibrated the YSI moorings. A fourth mooring was added 300-ft north of Area

L. Water quality monitoring on Friday 7/24 observed no areas of concern associated with dredging activity. Turbidity levels were elevated <20 NTU above background near all activity in the northern area of the river.

Week of July 27 – July 31, 2009 (Week 8)

- **Days monitored**: Wednesday 7/29 and Friday 7/31.
- **Areas of activity**: Dredging and debris removal in Areas J and G. Dredging in Area L.
- **Exceedances**: None.
- **Turbidity summary**: Weds: flood ref = 2-8 NTU, 100-ft transect J = 5-70 NTU, 200-ft transect J = 5-30 NTU, 150-ft transect G = 2-10 NTU (brief spike to 110 NTU), 300-ft transect G = 2-25 NTU; Fri: flood ref = 3-11 NTU, 150-ft transect L = 5-1 NTU, 150-ft transect J = 8-20 NTU
- **Wildlife**: Fish observed north of Wood St near shoreline, as well as egrets, herons, swans, shorebirds. Very small fish (baitfish) near Sawyer St docks with other small fish jumping and feeding (Friday morning).
- **Notes**: Monitoring on Wednesday 7/29 observed low background turbidity levels as well as very low dissolved oxygen concentrations in the northern dredge areas (M and G) and north of the Wood Street Bridge. Dissolved oxygen levels in the very thin salt water layer during the daytime flood tide were as low as 0.12 mg/L or about 6%. The dissolved oxygen was much higher (between 3 – 8 mg/L) in the fresh water layer that lay on top of the salt water in the top 4 feet of water, in an area about 5 feet deep.

  Water quality monitoring on Friday 7/31 observed a heavy sheen north of dredging activity in Area L. The sheen was escaping the oil boom due to heavy winds out of the south and a flood tide. There was no turbidity plume associated with the activity. Turbidity levels resembled background readings. The sheen was only spotty and light during periods of no activity, but when the dredge was active, the sheen was heavy. Thunderstorms ended activity in the afternoon on Friday.

Week of August 3 – August 7, 2009 (Week 9)

- **Days monitored**: Monday 8/3 and Thursday 8/6.
- **Areas of activity**: Debris removal in Area G. Dredging and debris removal in Area J. Dredging in Area L.
- **Exceedances**: None.
- **Turbidity summary**: Mon: ebb ref = 2-8 NTU, 100-ft transect J (up-current) = 4-6 NTU, 100-ft transect J (down-current) = 3-17 NTU, 250-ft transect J = 3-8 NTU, 100-ft transect L = 8-16 NTU; 125’ L = 5-9 NTU; Thurs: ebb ref = 2-12 NTU, 300-ft transect G = 6-9 NTU
- **Wildlife**: Small fish observed north of Wood Street clearly stressed and struggling. Approximately a dozen fish were dead or dying. WHG collected three of these fish for identification by USACE. Fish observed jumping in all monitored areas. A coyote was seen in the afternoon on Thursday 8/6 on the Acushnet/Fairhaven shoreline between Areas J and L.

- **Notes**: Monitoring on Monday 8/3 provided no turbidity readings above 20 NTU. A light sheen was observed north of Area L, heading north on the flood tide. A very light sheen was observed near debris removal in Area L, moving south on the ebb tide. Water quality monitoring on Thursday 8/6 exhibited very low dissolved oxygen concentrations north of Wood Street and throughout the harbor. Turbidity levels were very low in all areas, below 15 NTU.

Week of August 10 – August 14, 2009 (Week 10)

- **Days monitored**: Monday 8/10 and Thursday 8/13.
- **Areas of activity**: Debris removal and dredging in Areas G and J. Dredging in Area L.
- **Exceedances**: None.
- **Turbidity summary**: Mon: flood ref = 2-6 NTU, north of Wood Street = 5-9 NTU, 300-ft transect up-current G = 4-9; Thurs: flood ref = 1-7 NTU, 300-ft transect L = 3-13 NTU, 300-ft transect J = 5-9 NTU (flood) and 6-15 NTU (ebb), 300-ft transect J = 9-30 NTU, 300-ft transect G = 11-45 NTU
- **Wildlife**: An abundance of birds, including great blue heron, many egrets and other herons, cormorants, seagulls and turns feeding on large numbers of small fish. A few dead and struggling fish also observed.
- **Notes**: Monitoring on Monday 8/10 observed turbidity levels <20 NTU surrounding all activity throughout the day. At the fixed-station mooring north of Wood Street, an abundance of aviary wildlife was feeding on large schools of small (1"-2") fish. A few of the fish were dead or appeared to be dying. Salinity levels in this area ranged from about 3 – 26 ppt. Lower levels (3 – 15 ppt) were within the first foot of water (surface to one foot depth) and between one and two feet deep was about 15 – 25 ppt. The salinity of the lower depths (below two feet to the bottom) was >25 ppt. Fish appeared to be swimming in healthy schools within the first 2 feet of water, while the unhealthy, struggling fish tended to lie around the one foot depth. In this water layer, dissolved oxygen concentrations were higher than in the lower depths (1 – 3 mg/L as compared to <1 mg/L).

  On Thursday, no stressed or dead fish were observed. Work during the ebbing tide in the afternoon exhibited slightly elevated turbidity (about 20 – 30 NTU above background) at a distance 300-ft downstream (south) from the debris removal and dredging in Area G. Also, a light sheen was noticed moving south from the debris removal in Area J, but was contained within the oil boom.

Week of August 17 – August 21, 2009 (Week 11)

- **Days monitored**: Monday 8/17 and Thursday 8/20.
- **Areas of activity**: Debris removal in Areas G and L. Dredging in Areas J and L.
- **Exceedances**: None.
- **Turbidity summary**: Mon: ebb ref = 3-17 NTU, flood ref = 2-11 NTU, 200-ft transect L (up-current) = 2-11 NTU, 350-ft transect L (down-current) = 6-13 NTU, 100-ft transect J = 6-60 NTU; Thurs: ebb ref = 3-6 NTU, 300-ft transect L

= 3-13 NTU, 100-ft transect G = 11-20 NTU, 300-ft transect J = 3-9 NTU, 300-ft transect L = 3-30 NTU

- **Wildlife**: Avian wildlife observed throughout the harbor feeding on small bait fish. Two young boys seen fishing on the banks north of Wood St reported catching small bluefish. Fish observed jumping throughout the harbor. Approximately one dozen dead fish located north of Wood St. Many birds, including blue and green herons, egrets, cormorants, seagulls and terns observed fishing in the river north of Wood St.
- **Notes**: On Monday 8/17 high background turbidity levels were observed, ranging from 2 – 17 NTU. Dissolved oxygen concentrations were 7 – 12 mg/L as compared to 0 – 6 mg/L the previous week. Data from the YSI moorings revealed that dissolved oxygen concentrations were sometimes >18 mg/L, usually peaking during mid-afternoon or evening hours. These DO levels are much higher than past weeks and higher than any levels WHG has observed in New Bedford Harbor during 2009. Water temperatures are as high as 30° C in shallow areas, such as Areas M, G, and north of Wood St. Turbidity levels were elevated to >40 NTU above background 100-ft north of Area J. A strong southerly wind required the use of a push-boat to keep the dredge in line while operating. Due to the low tide, the propeller stirred up sediments, likely causing the elevated turbidity levels WHG observed. On Thursday 8/20, turbidity levels were low throughout the harbor. Dissolved oxygen levels ranged from 1.5-7 mg/L. Water temperatures remained between 26-30° C.

Week of August 24 – August 28, 2009 (Week 12)

- **Days monitored**: Monday 8/24 and Thursday 8/27.
- **Areas of activity**: Debris removal and dredging in Area G. Dredging in Area J. Debris removal in Area L.
- **Exceedances**: None.
- **Turbidity summary**: Mon: flood ref = 2-4 NTU, ebb ref = 1-2 NTU, 300-ft transect G = 6-31 NTU, 300-ft transect J = 3-7 NTU, 100-ft transect J and 300-ft transect G = 14.5 NTU; Thurs: flood ref = 2-6 NTU, 150-ft transect J = 18-27 NTU, 300-ft transect G = 6-33 NTU
- **Wildlife**: An abundance of aviary wildlife observed, including great blue herons, green herons, egrets, cormorants, seagulls and terns. Bluefish seen feeding on large numbers of menhaden north and south of Wood St. Ospreys observed diving for fish between Area J and Area L. Before dredging operations started, birds were observed resting on the equipment in Area G. Included were gulls, cormorants, egrets and swans.
- **Notes**: Monitoring on Monday 8/24 observed low turbidity levels surrounding all activity throughout the day (<31 NTU). A spotty sheen appeared near debris removal and dredging in Area G but did not travel away from the area where it originated. Dissolved oxygen concentrations were lower than previous weeks, ranging from 2 – 7 mg/L compared to 7 – 12 mg/L. Water temperatures range from 23 – 27°C throughout the harbor. On Thursday, turbidity levels <33 NTU were observed surrounding all activities.

Week of August 31 – September 4, 2009 (Week 13)

- **Days monitored**: Monday 8/31 and Thursday 9/3
- **Areas of activity**: Dredging in Area G and Area J. Debris removal in Area L.
- **Exceedances**: None
- **Turbidity summary**: Mon: flood ref = 1.5-6 NTU, 150-ft transect J = 1-40 NTU: ebb ref = 1-4.5 NTU, 300-ft transect G = 2-7 NTU, 300-ft transect J = 2-56 NTU (ebb) and 6-80 NTU (flood), 150-ft transect L = 10-41.5 NTU, 300-ft transect L = 7.5-36.5 (ebb) and 2.5-7.5 NTU (flood)
- **Wildlife**: No birds observed north of Wood Street, where they had been abundant in previous weeks. Large numbers of small fish, possibly "snapper" bluefish was seen jumping in the area between dredge Areas J and L. The fish action attracted multiple ospreys as well as some seagulls and other birds to the area.
- **Notes**: On Monday 8/31, WHG collected the five YSIs deployed in the harbor and brought them back to the trailers for routine maintenance; cleaning and calibration. Upon redeployment of the units, water quality profiles were taken at each of the five sites. A slight, spotty sheen was observed south of debris removal in Area L. The addition of secondary oil booms surround Area L appeared to limit the amount of sheen that appeared outside the boundary. Salinity readings showed the top 1 foot to be freshwater, (salinities less than 10 ppt), likely from the large amount of rainfall over the weekend.

  On Thursday, turbidity levels appeared elevated surrounding the dredging activities in Area J during low tide. Push boats were being used to keep the dredge straight on its course and readings of up to 75 NTU above background were seen 300-ft north of the dredge. This was not an exceedance due to the compliance criteria being elevated to 100 NTU on August 4, 2009. WHG was unable to back away any farther due to the low tide and insufficient water in Area G. Turbidity levels were also slightly elevated near the debris removal in Area L, <30 NTU above background at a distance of 250-ft downstream. A light to moderate, spotty sheen was observed south of the debris removal in Area L. Dissolved oxygen concentrations were relatively low, between 0.5 – 5.5 mg/L and generally higher at the surface and in the top two feet of water.

Week of September 7 – September 11, 2009 (Week 14)

- **Days monitored**: Tuesday 9/8 and Thursday 9/10.
- **Areas of activity**: Dredging in Area G and Area J. Debris removal in Area L.
- **Exceedances**: None.
- **Turbidity summary**: Tues: flood ref = 0.3-2.3 NTU, 500-ft transect L = 1-2 NTU, 400-ft transect G (flood) = 5-40 NTU, 100-ft transect G (slack high) = 70 NTU, 300-ft transect G = 2-7 NTU, 300-ft transect J = 3.5-7 NTU, 200-ft transect L = 2.5-3 NTU ; Thurs: flood ref = 0.7-1.5 NTU, 300-ft transect J = 9-26 NTU, 300-ft transect G = 11-15 NTU (flood) and 2-7 NTU (ebb), 300-ft transect in L = 2-20 NTU
- **Wildlife**: Fish observed jumping in the northeastern corner of Area J. A dead cormorant located in the oil boom at the northern boundary of Area G on Tuesday

9/8. Abundant aviary wildlife appeared throughout, especially north of Wood Street.

- **Notes**: On Tuesday 9/8, WHG monitored activity in Areas L, J and G. Elevated turbidity levels (68 NTU above background) were observed very close to the dredge in Area G, <100-ft downstream. These values decreased to approximately 38 NTU above background at a distance of 400-ft downstream from the dredge. Turbidity levels near all other activity on the harbor were <5 NTU above background values. The dissolved oxygen concentration throughout the harbor was between 4.5 – 9 mg/L. Slightly lower values (~4 mg/L) were observed at depth. A moderate sheen was observed surrounding the dredge in Area G, which was working in the northern most region of Area G.

  On Thursday, turbidity levels appeared slightly elevated surrounding the dredging activities in Area J, approximately 24 NTU above background. Turbidity was approximately 18 NTU above background 300-ft downstream from debris removal in Area L. Dissolved oxygen concentrations ranged from 5.5 – 10 mg/L, the lower concentrations occurring at depth. There were no noticeable sheens or odors surrounding activity in the harbor on Thursday.

Week of September 14 – September 18, 2009 (Week 15)

- **Days monitored**: Monday 9/14 and Thursday 9/17.
- **Areas of activity**: Dredging in Area G and Area J. Debris removal and dredging in Area L.
- **Exceedances**: None.
- **Turbidity summary**: Mon: flood ref = 0-3 NTU, 300-ft transect L (up-current) = 2-7 NTU, 300-ft transect L (down-current) = 0.5-23 NTU (morning) and 10-52 NTU (afternoon). 400-ft transect L = 2.5-13; Thurs: ebb ref = 3-7 NTU, 800-ft transect G = 10-14 NTU, 300-ft transect G = 25 NTU
- **Wildlife**: Fewer birds observed throughout the harbor. Fish observed jumping in all areas, particularly the region between Areas J and L.
- **Notes**: Monitoring on Monday 9/14 observed background turbidity levels ranging from 0.1 – 2.6 NTU at the flood reference site, 1000-ft south of Area L. Turbidity levels were consistently low throughout the harbor in the morning. Slightly elevated turbidity readings (<50 NTU above background) were noted near dredging in Area L, about 300-ft north (down-current). The WHG vessel backed away to a distance of 400-ft downstream of the dredge where turbidity levels decreased to <10 NTU above background. Dissolved oxygen concentrations in the harbor remain in a range between about 3.5 – 6.5 mg/L during monitoring hours.

  On Thursday 9/17, work was halted in the late morning due to a large, heavy sheen emanating from the debris removal activity in Area L. This sheen was noted between the northern boundary of Area L and the Sawyer Street dock, a distance of >2000-ft. Turbidity levels were low, however, under 20 NTU above background. Background turbidity readings from the northern ebb reference site ranged between 3 – 7 NTU. Turbidity was slightly elevated (approximately 20

NTU above background) within Area M, north of dredging in Area G. Dissolved oxygen concentrations ranged between 3.0 – 7.5 mg/L.

Week of September 21 – September 25, 2009 (Week 16)

- **Days monitored**: Monday 9/21 and Thursday 9/24.
- **Areas of activity**: Dredging in Area G and Area J. Debris removal in Area G and Area L. Pipe maintenance in Area G.
- **Exceedances**: None.
- **Turbidity summary**: Mon: ebb ref = 2-3 NTU, 300-ft transect J = 6-13 NTU, 600-ft transect J = 3-7 NTU, 300-ft transect L = 4-5 NTU; Thurs: ebb ref = 3-5 NTU, north of Wood Street (flood) = 6-11 NTU, 100-ft transect J = 7-11 NTU, 300-ft transect J = 1.5-10 NTU, 300-ft transect L = 1.5-4 NTU
- **Wildlife**: A large school of fish observed in the excavated channel on the shoreline at the Aerovox facility and continuing south into the region between Areas J and L. The fish were schooling and jumping in this area throughout the day and appeared healthy. Approximately 100+ fish were observed.
- **Notes**: Water quality monitoring on Monday 9/21 observed low background turbidity levels at the reference site north of the Wood Street Bridge. Turbidity levels were consistently low throughout the harbor around activities in all areas. Dissolved oxygen concentrations were slightly higher than usual, between 8 – 11 mg/L. On Thursday 9/24 background turbidity levels were 3-5 NTU and no readings above 25 NTU were noted. Turbidity levels were <10 NTU above background at 100-ft downstream from the dredge in Area J. Dissolved oxygen readings were lower than Monday, between 3.5 – 9 mg/L. No sheens were observed during monitoring on either day.

Week of September 28 – October 2, 2009 (Week 17)

- **Days monitored**: Monday 9/28 and Thursday 10/1.
- **Areas of activity**: Dredging in Area J. Debris removal and dredging in Area G and Area L.
- **Exceedances**: None.
- **Turbidity summary**: Mon: flood ref = 1-4 NTU, 75’ G = 14-120 NTU, 75’ G = 16-60 NTU; Thurs: ebb ref = 6-9 NTU, 600-ft transect G = 6-40, NTU, 300-ft transect J = 5-25 NTU, 300-ft transect L = 4-10 NTU, 300-ft transect L = 2-5 NTU
- **Wildlife**: Many fish observed jumping throughout harbor. Blue crabs observed swimming and mating. Water fowl feeding on small fish south of Wood Street.
- **Notes**: Water quality monitoring on Monday 9/28 observed low background turbidity levels ranging from 1.3 – 3.8 mg/L at the reference site 1000-ft south of Area L. Turbidity levels were elevated surrounding activity in Area G, with both the dredge and debris removal in operation. A short burst of high turbidity (<120 NTU) was observed, but quickly dissipated. Turbidity readings at a distance of 75’ down-current of the activity generally ranged from 20 – 80 NTU with a reported average reading of approximately ~50 NTU. Dissolved oxygen concentrations in monitored areas ranged between 3 – 8 mg/L, the higher

concentrations appearing in the southern areas of the harbor. No sheen or odor was observed near any activity.

On Thursday, 10/1, turbidity readings at the northern reference site were 6.1 – 8.1 NTU. Monitoring around activity in Area G exhibited slightly elevated turbidity levels with a maximum value of approximately ~30 NTU above background 600-ft down-current. Based on the ebbing tide, WHG moved farther down-current into Area J and continued to monitor water quality. Turbidity readings decreased to 17 NTU above background, maximum. Dissolved oxygen levels ranged from 1.8 – 5.4 mg/L in northern regions to 5.0 – 9.1 mg/L in the southern areas that were monitored.

Week of October 5 – October 9, 2009 (Week 18)

- **Days monitored**: Monday 10/5 and Thursday 10/8.
- **Areas of activity**: Dredging in Area J. Debris removal and dredging in Area G and Area L.
- **Exceedances**: Short-lived high turbidity event resulting in a warning criteria exceedance on Monday 10/5 associated with debris removal in Area G.
- **Turbidity summary**: Mon: flood ref = 1-3 NTU, ebb ref = 2-3.5 NTU, 300-ft transect G = 10-180 NTU (average range: 50-90 NTU), 600-ft transect G = 10-50 NTU; Thurs: ebb ref = 4-6.5 NTU, 300-ft transect J and 1000-ft transect G = 5-25 NTU
- **Wildlife**: Fish observed jumping in Area J near dredge. A dead bird (possibly a duck) was seen in the oil boom south of Area J.
- **Notes**: Water quality monitoring on Monday 10/5 observed low background turbidity levels at both reference sites. Turbidity levels were elevated surrounding activity in Area G, with both the dredge and debris removal in operation. A short-lived plume of high turbidity (<180 NTU) was observed where turbidity generally ranged from 50 – 90 NTU 300-ft down-current within the active work zone. Due to this elevated reading, the debris removal operator was notified and asked to stop work for a short time while WHG continued to monitor the turbidity in the plume. Turbidity decreased after the initial spike, although infrequent ephemeral plumes would appear, ranging from 80 – 120 NTU. Turbidity readings 600-ft down-current ranged from 5 – 50 NTU. The highest turbidity readings appeared between 1.0 – 1.5 feet below the surface, between the fresh water layer and the salt water layer below. Once work had been halted for almost an hour and readings had decreased consistently below 60 NTU, debris removal operation resumed and WHG continued to monitor the work. Turbidity levels continued to decrease and remained below 30 NTU for the duration of debris removal work in Area G. It was noted that a much thicker layer (greater than one foot) of fresh water lay on the surface throughout the harbor, likely due to the significant amount of rainfall the previous weekend.

  On Thursday 10/8, all five moored YSI sondes were cleaned and recalibrated. WHG monitored activity in Areas G and J, observing near background turbidity levels surrounding all activity. Dissolved oxygen concentrations appeared

normal, ranging from 4.6 – 9.8 mg/L. Water temperatures have been decreasing, with a maximum temperature of 20.3° C last week, 18.2° C on Monday, and a maximum reading of 17.2° C on Thursday.

Week of October 12 – October 16, 2009 (Week 19)

- **Days monitored**: Tuesday 10/13.
- **Areas of activity**: Dredging in Area J. Debris removal and dredging in Area G and Area L.
- **Exceedances**: None.
- **Turbidity summary**: Tues: flood ref = 1-3 NTU, 300-ft transect J = 4-33 NTU, 300-ft transect L = 4-56 NTU, 300-ft transect G = 8-12 NTU.
- **Wildlife**: A dead striped bass was observed in Area J on Tuesday 10/13. Many birds (gulls and terns) were observed feeding on small fish.
- **Notes**: Monitoring on Tuesday 10/13 took place primarily on a flood tide. Turbidity readings 300-ft down-current (north) of dredging in Area J exhibited a maximum reading of 30 NTU above background. Turbidity readings were higher 300-ft down-current of the debris removal in Area L, approximately 50 NTU above background. Water quality monitoring exhibited increasingly colder water throughout the harbor. Average water temperature was approximately 15° C, down from 17° – 18° C the previous week. Dissolved oxygen concentrations were normal, between 7.3 – 11 mg/L.

Week of October 19 – October 23, 2009 (Week 20)

- **Days monitored**: Monday 10/19 and Friday 10/23.
- **Areas of activity**: Dredging and debris removal in Area G, Area J, Area L and Area M.
- **Exceedances**: None.
- **Turbidity summary**: Mon: flood ref = 0-1 NTU, ebb ref = 2.5-3.5 NTU, 300-ft transect J = 5-35 NTU (max: 50 NTU), 300-ft transect L = 10-60 NTU, 600-ft transect L = 10-30 NTU; Fri: flood ref = 2-6 NTU, 300-ft transect L = 3-4 NTU (flood) and 0-3 NTU (ebb), 300-ft transect J = 5-9 NTU (flood) and 3-12 NTU (ebb).
- **Wildlife**: Fish observed jumping in between Areas L and J. Water fowl observed on Friday 10/23.
- **Notes**: Dredging and debris removal work progressed north into Area M this week. The fixed-station mooring previously located in Area M was removed and repositioned just south of the Wood Street Bridge. The mooring location was moved to keep the equipment from interfering with the work in Area M. The mooring north of the Wood Street Bridge remains in its location, as an approximate 300-ft marker for the compliance zone, given a flooding tide.

  On Monday 10/19, turbidity levels down-current (south) of dredging in Area J were generally between 5 – 35 NTU, with brief plumes of higher turbidity (<50 NTU). South of debris removal operations in Area L, a narrow (~20 feet wide) plume of high turbidity was observed. The plume was visible (<60 NTU), as was the transition to the surrounding less turbid waters (5 – 20 NTU). Farther down-

current, at a distance of 600-ft, turbidity within the visible plume decreased to 10 – 30 NTU. The plume was contained in the top 0.5 foot of water. Dissolved oxygen concentrations ranged from 6 – 11 mg/L. Water temperatures ranged between 11° – 14° C.

On Friday 10/23, water quality monitoring observed no significant elevated turbidity surrounding any activity. Background turbidity was approximately 6 NTU. The highest reading observed was 12 NTU 300-ft down-current (south on an ebb tide) from both dredging and debris removal in Area J.

Week of October 26 – October 30, 2009 (Week 21)

- **Days monitored**: Monday 10/26 and Thursday 10/29.
- **Areas of Activity**: Dredging and debris removal in Area G, Area J, Area L and Area M.
- **Exceedances**: None.
- **Turbidity summary**: Mon: flood ref = 0.5-2 NTU, 300-ft transect J = 15-20 NTU, 300-ft transect J = 9-36 NTU, 300-ft transect M = 2-6 NTU; Thurs: flood ref = 1.5-1.7 NTU, 300-ft transect M = 4-87 NTU (ebb) and 0.3-24 (flood), 300-ft transect J = 1-18 NTU, 300-ft transect L = 1-3 NTU
- **Wildlife**: Fish observed jumping and water fowl present throughout harbor.
- **Notes**: On Monday 10/26, turbidity readings were elevated to ~34 NTU above background at 300-ft down-current of dredging and debris removal in Area J. Turbidity readings were near background levels surrounding work in Area M, during both active dredging and debris removal. Monitoring of work done in Area M on Thursday 10/29 observed a plume of turbidity 300-ft south of the dredge, at a spud location inside of dredge Area G. Brief but frequent spikes up to a maximum of 85 NTU above background were observed, with general turbidity ranging between 20 – 40 NTU. On the flood tide, WHG returned to Area M to monitor dredging activity 300-ft north of the dredge. At this time turbidity levels had decreased to ~20 NTU above background. Water quality monitoring surrounding dredging in Area L, and debris removal in Area J, observed no significant elevated turbidity readings.

Week of November 2 – November 6, 2009 (Week 22)

- **Days monitored**: Monday 11/2 and Thursday 11/5.
- **Areas of activity**: Dredging and debris removal in Area G, Area J, Area L and Area M.
- **Exceedances**: None.
- **Turbidity summary**: Mon: ebb ref = 0-0.5 NTU, 300-ft transect M = 3-87 NTU, 300-ft transect L = 0.5-1 NTU, 300-ft transect J = 10-32 NTU; Thurs: ebb ref = 2-10 NTU, 300-ft transect M = 9-66, 300-ft transect J = 2-67 NTU, 300-ft transect M = 18-77 NTU, 300-ft transect J = 5-31 NTU.
- **Wildlife**: Fish observed jumping throughout the harbor.
- **Notes**: Work continued in Area M, including both dredging and debris removal. Background turbidity on Monday 11/2 was very low (<2 NTU). Background readings on Thursday 11/5 were slightly elevated, ranging between 2.7 – 9.8

NTU. Water quality monitoring of the debris removal and dredging in Area M on Monday 11/2 observed elevated turbidity values as high as 87 NTU. Similar readings were observed on Thursday 11/5, although debris removal and dredging were not currently active. During dredging, turbidity readings ≤66 NTU were observed while readings ≤77 NTU were observed during debris removal. The highest turbidity readings were at a depth of about 1.5 feet. In general, turbidity values averaged between 20 – 30 NTU during activity. A slight to moderate sheen was observed both days surrounding work in Areas M and J. Monitoring of debris removal and dredging in Area J also observed elevated turbidity readings both days. Readings <67 NTU were observed 300-ft south of debris removal during an ebb tide, and 31 NTU at 300-ft south of dredging during an ebb tide.

Week of November 9 – November 13, 2009 (Week 23)

- **Days monitored**: Monday 11/9 and Thursday 11/12.
- **Areas of activity**: Dredging and debris removal in Area G, Area J, and Area M. Dredging in Area L.
- **Exceedances**: None.
- **Turbidity summary**: Mon: flood ref = 0-0.5 NTU, 200-ft transect J = 30-160 NTU (average ~100 NTU), 250-ft transect L = 0.3-3 NTU, 100-ft transect M = 20-80 NTU (average ~30 NTU); Thurs: flood ref = 0.4-3 NTU, 250-ft transect M = 4-12 NTU, 300-ft transect J = 5-17 NTU.
- **Wildlife**: Fish observed jumping throughout the harbor. Abundant water fowl, especially swans.
- **Notes**: Background turbidity on Monday 11/9 was very low, around 0 NTU throughout the water column (depths of 1 – 9 feet at the reference location). Elevated turbidity readings were observed adjacent to and down-current of the debris removal in Area J during a flood tide, ranging from 30 – 160 NTU, but averaged between 75 – 125 NTU. A sheen was also observed in this area during debris removal activity. During dredging in Area M, turbidity elevated, ranging from 20 – 80 NTU, but averaged approximately 30 NTU at a distance of 100-ft down-current.

  On Thursday 11/12, WHG monitored 250-ft down-current of dredging in Area M where turbidity ranged between 4 – 12 NTU. Likewise, 250-ft down-current of dredging in Area J, turbidity ranged between 5 – 17 NTU. No sheens were observed. Dissolved oxygen concentrations ranged approximately 6.5 – 9.5 mg/L, with water temperatures generally between 10° – 11° C.

Week of November 16 – November 20, 2009 (Week 24)

- **Days monitored**: Monday 11/16 and Thursday 11/20.
- **Areas of activity**: Dredging and debris removal in Area M. Dredging in Areas J and L. Debris removal in Area G.
- **Exceedances**: None.
- **Turbidity summary**: Mon: ebb ref = 0.4-1.3 NTU, 250-ft transect G/M = 2-95 NTU, 200-ft transect J = 8-40 NTU, 200-ft transect L = 2 NTU; Thurs: flood ref =

0.5-1 NTU, 300-ft transect M = 4.9-6.2 NTU (flood) and 11.8-20.2 NTU (ebb), 300-ft transect J = 1.9-30.5 NTU.

- **Wildlife**: Fish observed jumping in Areas G and J on Monday, and south of J on Thursday. Many swans, herons, a kingfisher and other water fowl observed.
- **Notes**: Monitoring on Monday 11/16 exhibited significantly elevated turbidity down-current of active debris removal and dredging in Areas G and M during the ebb tide. Turbidity ranged from 2 – 95 NTU, and averaged approximately 30 – 40 NTU. Plumes of high turbidity (>70 NTU) were not sustained, but a maximum reading of 95 NTU was observed. The pulses of higher turbidity were thought to be attributed to the debris removal barge becoming grounded on the bottom sediment due to the low tide conditions at the time of monitoring. A heavy sheen was observed in the vicinity of active debris removal in Area G. Dissolved oxygen concentrations were between 6.5 – 8.5 mg/L and water temperatures were between 10° – 12° C.

  On Thursday 11/19, turbidity readings of ~30 NTU above background were noted 300-ft downstream of the dredge in Area M during the ebb tide. Turbidity readings were also slightly elevated (~30 NTU above background) south of debris removal in Area M on the ebb tide. During the flood tide, however, turbidity decreased to near background levels north of the debris removal in Area M.

Week of November 30 – December 4, 2009 (Week 25)

- **Days monitored**: Monday 11/30.
- **Areas of activity**: Dredging in Areas G and L.
- **Exceedances**: None.
- **Turbidity summary**: Mon: ebb ref = 0.8-1.0 NTU, 300-ft transect G = 1-60 NTU, 300-ft transect L = 0.6-1.2 NTU (ebb) and 1.2-5.3 NTU (flood).
- **Wildlife**: Abundant swans, seagulls, water fowl. No fish observed.
- **Notes**: During monitoring on Monday 11/30, background turbidity readings were relatively low for New Bedford Harbor, around 1 NTU. Elevated turbidity was observed during a low ebbing tide, at a distance of 300-ft down-current of the dredge in Area G. The highest turbidity readings were observed in the bottom foot of water. Turbidity values ranged between 30 – 50 NTU, with a maximum of just under 60 NTU. The surface water in this location was near background (~2 NTU). WHG monitored activity in Area L during the ebb, low water slack, and flood tides at a distance of 300-ft downstream. Turbidity readings were at background levels during the ebb and low tides, and elevated only slightly, to ~5 NTU during the flood tide. This was the final day of boat-based monitoring for the 2009 dredge season.

4.0 RESULTS

Results of the WHG water quality monitoring of 2009 remedial dredging operations at the New Bedford Harbor Superfund Site are presented in this section. Complete results, fixed-station time series, and laboratory reports are provided as Appendices to this report.

4.1 DREDGING SUMMARY

Remedial dredging was initiated on June 1, 2009 and completed on December 1, 2009. The remediation efforts during the 2009 dredge season focused on four areas, identified as Areas M, G, J and L, described north to south (Figure 2). The entire Site is divided into a series of Dredge Management Units (DMU) based primarily on contamination levels, contamination sources, and topography. Portions of the following DMUs fell within the boundaries of the four Areas and were thus dredged in the 2009 season: DMU-1, DMU-2, DMU-3, DMU-4, DMU-10, DMU-12, DMU-13, DMU-14, DMU-102(MF) and DMU-103(MF).

Once the dredge areas were determined, sheet piling was placed around the perimeter of each section, at approximately 50-foot spacing, to anchor the perimeter and dredge winching cables. The perimeter cable was run around the sheet piles at approximately the high tide mark. Also along the perimeter, floating, absorbent oil booms were placed to contain any surface oil slicks. A 'gate' in the south end of the dredge area was used for all vessels entering or leaving the operation.

Dredging was performed by Sevenson Environmental Services Inc. (SES) under the direction of Jacobs Engineering (JE). Sevenson utilized a Mud Cat™ hydraulic dredge equipped with a horizontal auger (Figure 11). The dredge was propelled by winching itself along a transverse cable which spans the dredge area to opposite sides of the perimeter cable. As a pass is completed, support crews relocated the cable to position for the next pass. Dredged material was pumped through a flexible pipeline to a booster pump, then to the de-sanding facility at Sawyer Street. Following de-sanding, the remaining fine material was pumped via a separate pipeline to the dewatering, treatment, and handling facility in the Lower Harbor. In total, JE has estimated that the dredging team removed 49,809 cubic yards of material in 2009.

Figure 11. Mud Cat™ hydraulic dredge

Hydraulic dredges cannot process large debris contained in the native sediment because the oversized material fouls the auger and suction of the slurry pipeline. Therefore, the operation requires a separate debris removal operation prior to the dredging of a particular area. Debris removal was accomplished by 'raking' the bottom with a barge-mounted excavator (Figure 12). The end of the excavator has two forked jaws that are hydraulically opened and closed. The jaws are deployed to the bottom and methodically "grab" or scrape the bottom for debris. Each "grab" of the bottom is brought to the surface, rinsed of sediment and inspected. If debris such as cobbles, old tires, timbers or scrap metal is contained within the excavator jaws, the debris is stored in scows secured to the debris removal platform or barge. Support boats were used throughout the operation to transport crews, maintain dredges, handle the pipeline, and move barges.

Figure 12. Debris removal excavator and debris storage scow

The northern most portions of Areas M and G contain intertidal areas and therefore dredging operations could not always be conducted, especially during low tides. When low water prevented work in these areas, the dredge crew moved operations to deeper waters in Areas J and L. Due to the narrowing of the estuary in the northern regions of the harbor and the shallow waters in these locations, the use of heavy equipment in Areas M and G caused some concern that the equipment and dredge activity might impact the seasonal migration of anadromous fish species. For this reason, the dredging of Area M was only performed after November 1, 2009 to alleviate the potential for impacts on migratory fish species.

4.2 FIELD MONITORING SUMMARY

Water quality monitoring was conducted in an adaptive manner in response to changing operational and weather related conditions. The monitoring approach was modified 1) as tides and winds changed, 2) as dredge activities moved between areas, 3) as debris removal activities changed, and 4) as warranted based on support activities. All of these activities (dredging, debris removal, and support activities) had the potential to impact water quality. The monitoring program incorporated assessment of the entire operation.

The monitoring activities were also largely influenced by tidal conditions and safety. The dredge areas and the associated perimeter cable and oil boom spanned most of the width of the river limiting access to northern portions of the river, including the northern reference location. At lower tides, the northern portion of the river was nearly impassable, making it difficult to monitor work performed in Areas M and G during these periods. Due to the narrow river channel and shallow water depths at this location, however, there was increased potential for water quality impacts. This is supported by the increased turbidities observed during the month of July in Areas M and G. The turbidity exceedance water quality samples collected from Area G in July, however, resulted in no acute toxic effects and spurred the re-evaluation of the exceedance criteria.

The toxicity results from the two discrete sampling events exhibited no adverse effects on the subject species; therefore, it was thought that the project's turbidity compliance threshold was perhaps overly conservative, causing unnecessary stoppages to the remediation work, and over-complicating the monitoring tasks of the field team. The results of the water toxicity evaluation study led to the modification of compliance criterion and the definition of a new compliance threshold for turbidity. After the modifications to the compliance criteria, no turbidity threshold violations occurred for the remainder of the 2009 dredge season.

4.2.1 Boat-Based Monitoring

Boat-based water quality monitoring was performed three days a week at the start of dredging during the first two weeks of June, and typically twice a week until dredging was completed on December 1, 2009. Site conditions and *in-situ* water quality measurements collected during boat-based monitoring are summarized in Section 3.0 and documented per monitoring protocols in the field logs and daily reports, located in Appendices A and B, respectively. Water quality monitoring was performed primarily north of activities during a flood tide and south of activities during an ebb tide. Access to the northern areas was somewhat limited during low tidal periods and data at times reflects this limitation.

4.2.1.1 Turbidity Summary

Each water quality monitoring day began with a transit to one of two reference locations, 1000-ft down-current of the active work zone. The water quality readings collected at the reference location provided data regarding the background conditions and established the baseline turbidity for use in determining the compliance threshold on a given day. Turbidity values were generally higher and dissolved oxygen concentrations lower at the northern reference site as compared to the southern reference site. Background turbidity readings were typically around 5 NTU, but ranged over the season between zero and 15 NTU, depending on environmental conditions.

During dredging and debris removal, *in-situ* turbidity readings in the active dredge area increased compared to background conditions, with readings ranging from 0-160 NTU, depending upon the proximity to dredging activities and environmental conditions. The maximum reading of 160 NTU was observed on November 9, 2009 in Area J. It occurred during a flood tide, in a plume that migrated 200-ft north of the debris removal

barge. Readings within the plume ranged from 30-160 NTU, averaging approximately 100 NTU, and dissipated with increasing distance from the active operation.

Turbidity plumes observed during boat-based monitoring were generally weak (<30 NTU) and turbidity levels decreased as the plume migrated down-current, away from its origin. Plumes were observed on multiple occasions throughout the dredge season on both flood and ebb tides and were typically short-lived or ephemeral. Often, the plumes occurred south of debris removal in Area L on an ebb tide and north of debris removal in Areas M, G and J on the flood tide. At times, such as on October 19, 2009, a plume of turbidity was highly visible, but water quality readings indicated the turbidity ranged only 5-20 NTU. On other occasions, plumes of elevated turbidity of >100 NTU were not as readily visible. One such instance occurred on June 16, 2009 when debris removal operations created a plume of turbidity as high as 75.8 NTU, but the plume was not noticeable from view of the vessel.

Oily sheens were observed near dredging and debris removal operations, particularly during operations on the western shoreline of Area L. The addition of a second line of oil booms surrounding Area L helped to reduce the dispersion of sheen outside of the Area's boundaries. After closely monitoring water quality surrounding these oily sheens, it appeared there was no significant correlation between an oily sheen and high turbidity readings.

Relatively high turbidity readings were frequently observed immediately adjacent to dredging support activities. This is especially the case for, but not limited to, debris removal activities and the use of boats to push barges or boats for re-location and wind stabilization. During high winds, boats were used to maintain the hydraulic dredge's direction, and when used during low water levels, the motor's propeller wash often disturbed bottom sediments, forming narrow plumes of high turbidity. This was observed on numerous occasions throughout the dredge season. The single turbidity compliance threshold violation or "exceedance" event sampled during the 2009 dredge season occurred during a time of heavy boat traffic and active debris removal and dredging. Occasionally, localized plumes of elevated turbidity were observed around or emanating from inactive debris removal barges. When water levels were particularly low, the barge appeared to disturb sediments beneath it and create a plume of turbidity in the immediate vicinity of the barge. Such events were observed and documented on June 8 and November 16, 2009. Close monitoring of these activities and conditions ensured that elevated turbidity plumes did not migrate outside of the active work zone. On average, dredging itself did not produce high turbidities in surrounding areas.

4.2.1.2 Dissolved Oxygen Summary

Particular attention was also given to the concentration of dissolved oxygen (DO) during the 2009 dredge season. At the request of the USACE, WHG closely monitored this water quality parameter due to the concern for potential impacts to anadromous fish, other fish species and migration. During August, water temperatures peaked at approximately 30° C and dissolved oxygen concentrations decreased to hypoxic conditions throughout the system. This is a naturally occurring phenomenon during summer months in estuarine systems. Dissolved oxygen readings of <1 mg/L were

frequently observed north of Wood Street and in the vicinity of Areas M and G. These water quality conditions occur naturally in shallow stratified estuaries, but provided a warning for the dredging operators to be cautious as to not exacerbate the situation. Because of the project's activity in the northern regions of the estuary during the fall migratory season, characterization of dissolved oxygen conditions were important to distinguish between naturally occurring conditions and dredge related impacts to water quality.

During the first few weeks in August, schools of small bait fish were observed in the river north of Wood Street. On occasion, these fish appeared to be stressed, possibly suffering hypoxic effects due to the low dissolved oxygen levels in the estuary. While a few dead fish were observed, no large scale fish-kills occurred. Efforts to limit activity and keep equipment from interfering with fish passage or water flow exchange during hypoxic conditions in the northern areas were successful, as directed by the 2009 USACE Fish Protection Plan. The dredging operations had little or no effect on the fish migration or the overall health of the local fish and wildlife population.

4.2.2 Fixed-Station Continuous Monitoring

Two water quality sensors (YSI 6920 sondes) were deployed on June 4, 2009, during the first week of active dredging operations. Their initial positions were approximately 150-ft north and 150-ft south of the Area L dredge boundaries. These sensors remained in their initial short-term locations until they were recovered on June 12, 2009 for cleaning and re-calibration. Upon redeployment, the two YSI units were moved to their long-term locations, NBH – SAreaL (300-ft south of Area L) and NBH – SAreaJ (300-ft south of Area J). On June 16, 2009, a third mooring was deployed approximately 100-ft north of the Wood Street Bridge, and named NBH – NWS. A fourth mooring was added 300-ft north of Area L (NBH – NAreaL) on July 22, 2009, and a fifth mooring was placed approximately 300-ft north of Area G, inside Area M (NBH – NAreaG) on August 6, 2009. The fifth mooring was repositioned approximately 50-ft north of Area M on October 23, 2009 when dredge operations started in that area. Figure 8 depicts the locations of the water quality moorings.

The deployment of the continuously recording water quality sensors provided additional information that complemented the adaptive boat-based monitoring approach discussed above. The location of the sensors north and south of the dredge areas provided valuable information regarding tidal influences on sediment suspension and transport. Continuous readings provided water quality data for periods when active monitoring of dredge activities was not performed, as well as during nights and weekends, offering background conditions for comparison.

Dredging operations frequently stopped and started due to mechanical or physical issues and the location of active operations was highly variable. Moreover, the 2009 active dredge zone was divided into four separate dredge areas, each actively dredged at various dates and times depending on tides, fish migration, and other factors. As a result, it was difficult to positively determine whether active work in a given area would cause changes in water quality recorded in the five moorings' data sets. However, examining the record of dredge activity for each area and comparing it with the continuous water quality record

for the moorings in closest proximity allows for a cause-effect relationship to be determined.

The figures in Appendix B present the fixed station time series data along with times of active dredge operations. The figures were included in the weekly reports during the 2009 dredge season. Turbidity signals related to dredge activity were clearly observed in the time series. These signals manifest as peaks in turbidity above background. The background turbidity signal in the estuary is influenced by tidal conditions, river flow, weather and wind, output from CSOs, and other factors. As a result, the background signal can fluctuate on scales from minutes to days. The background turbidity level, on a given day in one area of the estuary, can be different than the background turbidity level in another area. The minor fluctuations and differences based on location are apparent in the figures in Appendix B. In some cases, it is difficult to discern whether a fluctuation in turbidity is merely background, or related to dredge activities. However, most often the turbidity level did not exceed the project-specific compliance criteria (50 or 100 NTU); when this did occur, it was on a time scale of 1-2 hours, maximum.

At times, the cause-effect relationship is apparent. This was the case for data recorded at the mooring north of Area G during a deployment from November 9 – 12, 2009. Figure 13 depicts data for this time period at the mooring 50 feet north of Area G and provides information regarding active operations in Areas G and M. Periods of sustained elevated turbidity are apparent during dredge-related activity in Areas G and M. Due to the proximity of the mooring to the dredge activities, the turbidity measurements are relatively high (176 NTU maximum), as the activity was likely less than 100' away from the mooring. This is the only occasion when turbidity readings were sustained and elevated to such levels. Noticeable spikes in turbidity readings also occurred during weekends and inoperable hours. Such spikes mirror those observed during operation periods and may be attributed to natural conditions in the estuary or malfunctions of the water quality sensors.

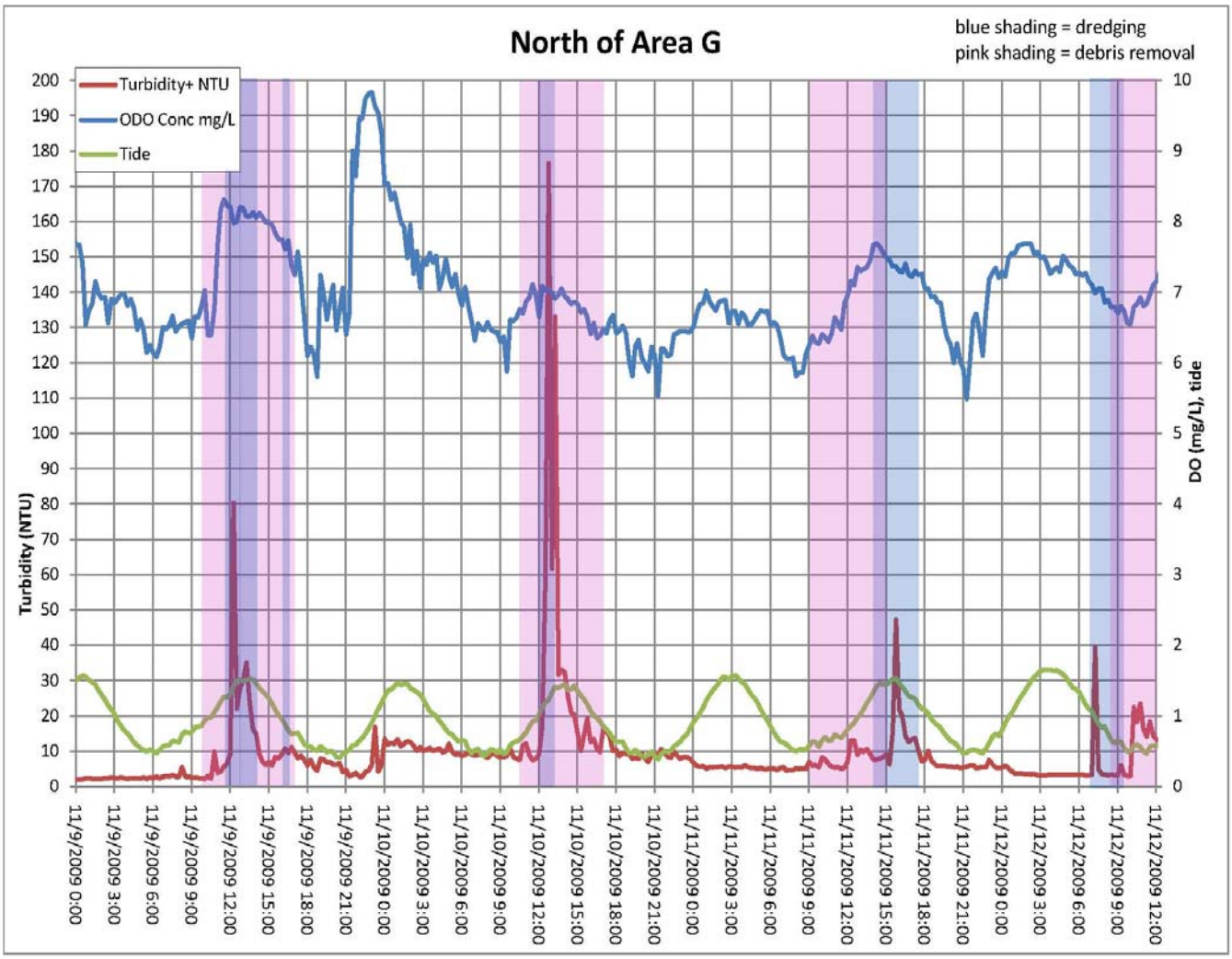


Figure 13. Example of turbidity levels related to dredging and debris removal in the northern part of the estuary, November 9-12, 2009

Weather events also appeared to have an impact on water quality. Significant amounts of rainfall occurring throughout the summer months caused frequent but minor spikes in turbidity. Storm events can also cause naturally elevated turbidity levels that can approach the project-specific turbidity compliance threshold. A large storm on December 20 deposited 20.0 inches of snow in the harbor and caused sheets of ice to form on the river. The storm period is apparent in the turbidity record of three of the fixed-station sondes (Figure 14). During this particular storm, all dredge related equipment had been demobilized and there was no dredge activity anywhere on the harbor.

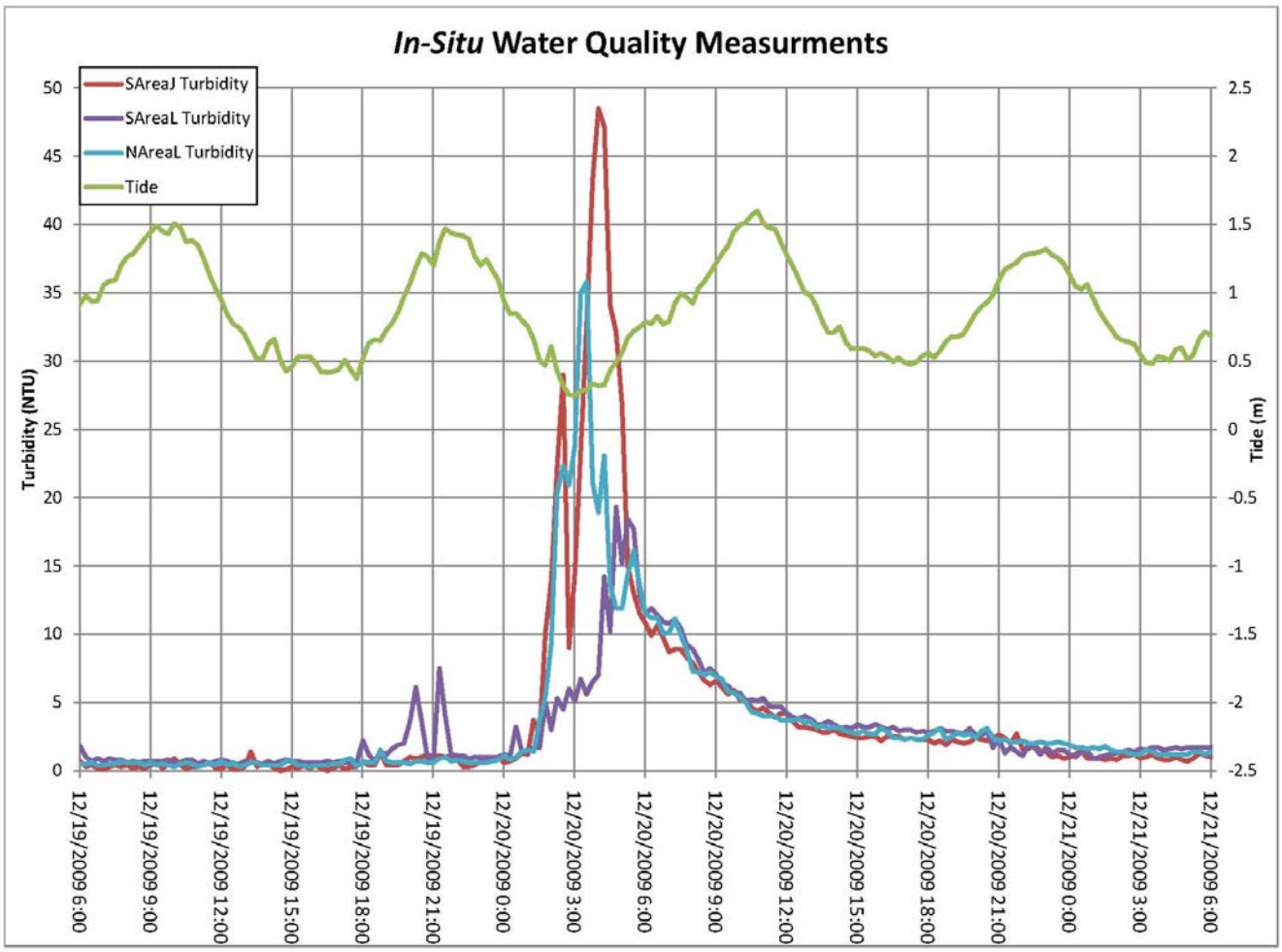


Figure 14. Example of turbidity levels coinciding with a weather event (snow storm) occurring December 19-21, 2009

Continuous *in-situ* dissolved oxygen (DO) data was also collected at each of the water quality moorings. The dissolved oxygen concentrations varied significantly over the seven month deployment. During August, periods of near-hypoxic conditions in the northern areas of the estuary were followed by DO concentrations as high as 16.93 mg/L (recorded at NBH – NWS on 8/16/09 17:31). The rapid, drastic change in DO was also observed at the mooring north of Area G, just south of the Wood Street Bridge. Because the mooring north of Wood Street is fixed on the bottom, it is sometimes difficult to make accurate comparisons with the other moorings, which are floating at a constant depth, independent of tide and water level. However, in the case of the data from August 12-16, 2009, the readings were very similar. Figure 15 depicts the data collected at the mooring north of Area G over this five-day period. Hypoxic conditions during the first two days are followed by readings of super-saturated (high DO) water on August 14-16, 2009. During the first two days, DO concentrations were <1 mg/L at night, and about 3 mg/L during peak hours of the day. On August 14th and 15th, DO spiked during the late afternoon to 10.18 mg/L on August 14th and16.14 mg/L on the 15th. This dramatic

fluctuation in DO could have been caused by an algal bloom in the upper harbor and is likely not an effect of dredge related activities. The production rates of phytoplankton are known to have an effect on dissolved oxygen concentration. The fluctuations in DO during the summer were noticeable in all areas of the harbor. Fluctuations were particularly dramatic in the most northern areas where fresh and salt water actively mix, the bathymetry is very shallow, and water is warm. Water temperature during the five days highlighted in Figure 15 reached a maximum of 29.29°C at 15:00 on August 16, 2009.

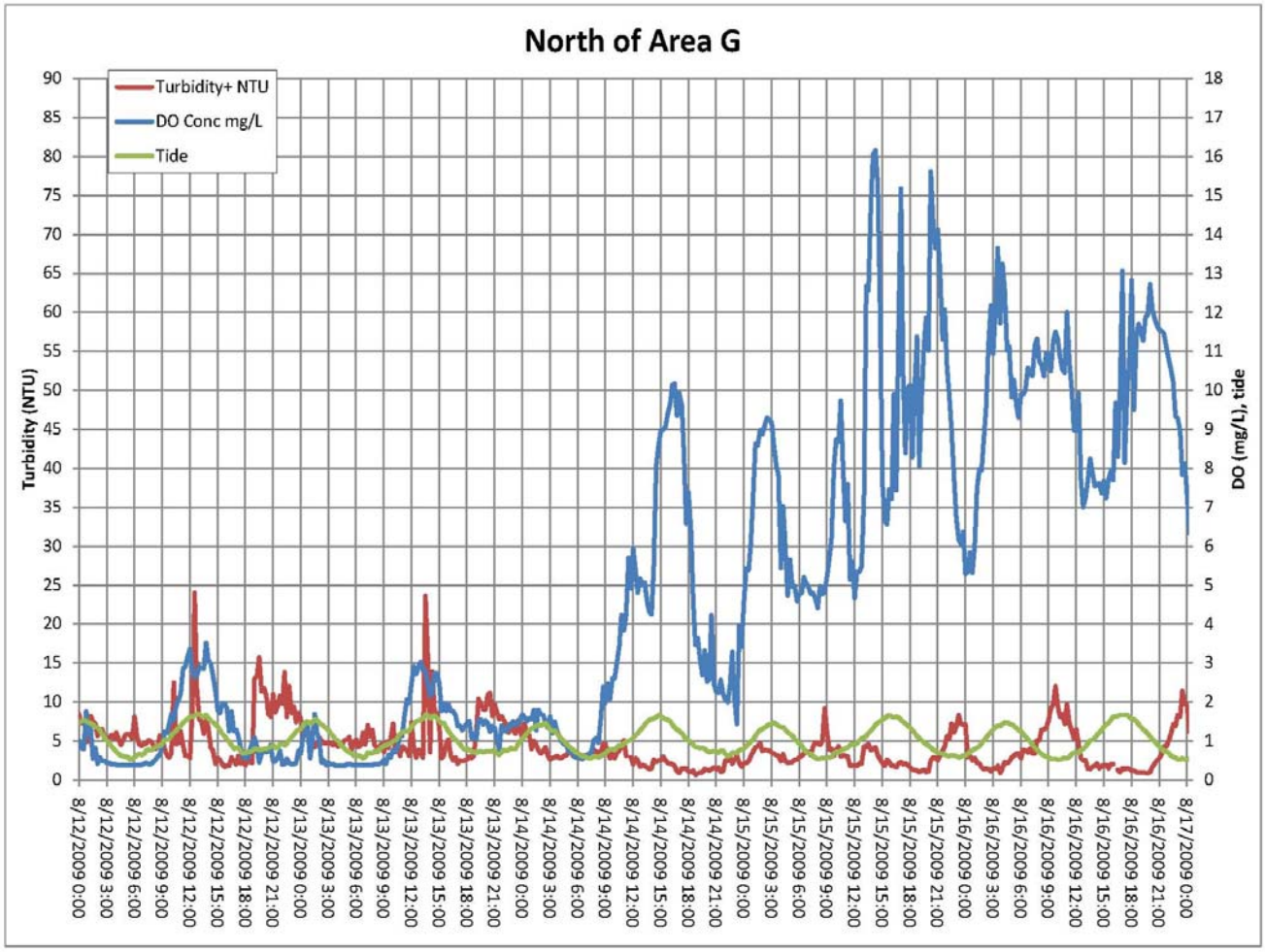


Figure 15. Example of rapid changes in dissolved oxygen, August 12-16, 2009

Water temperature in the active areas over the 2009 dredge season ranged from 32.37°C (recorded north of Area G on August 18, 2009 at 15:45) to -2.15°C (recorded @ NBH – NWS on December 11, 2009 at 21:45). Temperatures below freezing were occasionally recorded north of Wood Street, likely due to the mixing of saline bottom water with the abundant fresh water in this area, decreasing the freezing point of water at this location. In general, water temperatures were only just above freezing during December. Temperature readings of 1.24°C, 0.76°C, 0.28°C, and 0.47°C were recorded at moorings

NBH – NAreaG, NBH – SAreaJ, NBH – NAreaL, and NBH – SAreaL, respectively during the month of December.

4.2.3 Collection of Discrete Water Samples

Discrete water samples were collected three times throughout the 2009 season during boat-based monitoring operations (Table 2). Under the protocols outlined in Section 2.1, the sampling team functioned in an adaptive sampling mode, utilizing real-time *in-situ* data to guide monitoring and sample collection. Non-exceedance data from samples gathered from an artificially created suspended sediment plume provided valuable information regarding the potential effects of dredging and related activities on water quality. These Level I water samples were collected to establish near-baseline conditions and/or re-establish relationships between field measurements (i.e. turbidity) and toxicity results to verify the protectiveness of the project turbidity compliance threshold. The turbidity warning criteria exceedance on July 15, 2009 provided additional data that initiated the reevaluation of the project compliance criterion. The subsequent toxicity evaluation study supported the adjustment of the turbidity compliance threshold from 50 to 100 NTU above background. This new turbidity criterion was accompanied by a protocol adjustment where a violation would only occur when turbidity exceeded 100 NTU above background at locations 300 feet from the northern-most boundary of Area M and the southern-most boundary of Area L. The results of chemical and biological testing of all discrete water samples are presented and discussed further in Section 4.3.

Table 2. Summary of discrete water sampling events

Sampling Event	Date	Sample ID (WQ-TOX-)	Sample Description
Level I Water Quality Samples	6/24/2009	001-062409	1000-ft south, flood reference
		002-062409	1000-ft north, ebb reference
		003-062409	plume source
		004-062409	300-ft south of source, ebb
		005-062409	600-ft south of source, ebb
Project Criteria Exceedance Samples	7/15/2009	001-071509	at site of exceedance, 300' down-current from debris removal in Area G
Toxicity Evaluation Dilution Study Samples	7/22/2009	001-072209	100% plume water
		002-072209	75% plume, 25% reference
		003-072209	50% plume, 50% reference
		004-072209	25% plume, 75% reference
		005-072209	100% reference site water

4.2.3.1 Level I Water Quality Samples

The first sampling event was conducted on June 24, 2009. Water quality samples were collected as part of the Level I monitoring and sampling performed at the start of the 2009 dredge season. These samples were analyzed in order to reaffirm the turbidity exceedance criteria of 50 NTUs and to assess the protectiveness of the project's warning and compliance thresholds, 300 feet and 600 feet down-current, respectively. Samples were analyzed for turbidity, TSS, PCBs (total and dissolved), toxicity, and metals (archived) during dredging and debris removal activities in Area J. Due to the normally low turbidity levels during work, the debris removal operator was instructed to create an artificial suspended sediment plume which was monitored via *in-situ* readings from the YSI6920 data sonde. Water quality samples were collected at five locations during this event: 1) at the source of this plume (77 NTU), 2) 300-ft down-current (12 NTU), 3) 600-ft down-current (15 NTU), 4) at the northern, ebb tide reference location (6.6 NTU), and 5) at the southern, flood tide reference site (5.4 NTU). These planned samples were analyzed to verify the validity of the project compliance criteria during dredging activities and to examine the background conditions at the reference stations.

4.2.3.2 Project Criteria Exceedance Samples

On July 15, 2009, a plume of sustained turbidity (generally 60–90 NTU, maximum 105 NTU over a 30 minute period) was observed 300-ft down-current of debris removal and dredging in Area G. Water quality samples of this plume were collected. Despite the corresponding high turbidity readings, the acute bioassay results indicated that the plume did not have adverse toxic effects on the test species. The complete data report from ESI is provided in Appendix D and these results are further discussed in Section 4.3. No analytical chemistry was performed on the July 15 water samples because the acute bioassay results were non-toxic.

4.2.3.3 Toxicity Evaluation Dilution Study Samples

The goal of the water toxicity evaluation dilution study was to reevaluate both the turbidity exceedance criteria and the compliance threshold with the intent to simplify the monitoring approach and reduce interference with remedial progress, while remaining ecologically protective. The methodology used was to create an artificially suspended sediment plume and collect enough water from the plume and from a background location to complete five dilutions of varying turbidities for analysis. Given a plume of 200 NTU, analyses could be performed on water samples of approximately 200 NTU, 150 NTU, 100 NTU, 50 NTU and background. Boat based *in-situ* monitoring of the plume provided real-time turbidity readings and samples were collected when the plume was sustained at approximately 200 NTU. Four of the five toxicity sample cubitainers were filled to 100%, 75%, 50% and 25% full. The fifth cubitainer was filled with natural, low-turbidity water from the reference location up-current. The three cubitainers that had been partially filled with water from the artificial plume were topped off with the low-turbidity reference site water as well. The five samples were sent to ESI for toxicity analyses. A small sample of well-mixed water was collected from each cubitainer and sent to AAL for turbidity analysis. The actual turbidity values for the five water samples were: 190, 140, 110, 92, and 7.2 NTU (reference).

ESI evaluated the results of acute and chronic toxicity assays performed using the mysid shrimp, *Americamysis bahia*, the sea urchin, *Arbacia punctulata*, and red macro algae, *Champia parvula*. The evaluation identified potential acute toxic affects in the sea urchin, *Arbacia punctulata*, and red macro algae, *Champia parvula*, that were exposed to the 140 and 190 NTU water samples. The 110, 92 and 7.2 NTU samples showed no adverse toxic effects in either the sea urchin or red macro algae assays. Based on these analyses, the USACE determined that the results supported a change in the project's turbidity compliance criteria from 50 NTU to 100 NTU above background. It was also indicated that the violation threshold should be adjusted to 300-ft from the northern and southern boundaries of the 2009 active dredge-zone, as opposed to 600-ft from the plume-related activity, with a warning threshold at 300 feet. Sustained high-turbidity plumes within the "active work zone" were to be monitored and sampled on a case-by-case basis. This study maintained the ecological protectiveness of the project's turbidity compliance criteria, and the production of the remediation dredging operation in the harbor.

4.3 LABORATORY TESTING SUMMARY

A summary of the results from the three water sampling events are provided in this section. The first event on June 24, 2009, which established near-baseline levels for activity on the harbor included a complete suite of analyses: toxicity, TSS, turbidity, dissolved and total PCBs, and a sample was archived for potential future metals analysis. The second sample collection took place during an exceedance of the turbidity warning criteria on July 15, 2009. These samples were analyzed for toxicity only. The samples collected for chemical analysis were archived and ultimately disposed of due to the results of the toxicity assays. The third set of discrete water samples were collected on July 22, 2009 as part of the toxicity evaluation dilution study. These samples were analyzed for toxicity and turbidity.

4.3.1 Total Suspended Solids and Turbidity

Total suspended solids concentrations from the June 24, 2009 Level I sampling event ranged from 11.7 mg/L, at the ebb reference site, to 154 mg/L, at the source of the artificially created turbidity plume (Table 3). Turbidity ranges from the *in-situ* water quality monitoring sonde are comparable with the lab-based results. At the artificially created plume collection site, turbidity ranged from 16.7-158.9, as observed from the YSI 6920 sonde. The laboratory value of 77 NTU is consistent with the *in-situ* measurement range. Turbidity values and total suspended solids concentrations in site water were generally lower at reference locations, and decreased with increasing distance from the active site.

Turbidity observations from the *in-situ* monitoring during the water collection for the toxicity evaluation study performed on July 22, 2009 are also comparable to the laboratory results (Table 3).

Table 3. Summary of total suspended solids (TSS) and turbidity results

Sampling Event	Date	Sample ID (WQ-TSS/TUR-)	Sample Description	Lab Results		*In-situ* Measurements
				TSS (mg/L)	Turbidity (NTU)	Turbidity (NTU)
Level I Water Quality Samples	6/24/2009	001-062409	1000-ft south, flood reference	14.2	5.4	2.6-5.9
		002-062409	1000-ft north, ebb reference	11.7	6.6	1.8-4.5
		003-062409	plume source	154.0	77.0	16.7-158.9
		004-062409	300-ft south of source, ebb	20.0	12.0	10.9-17.3
		005-062409	600-ft south of source, ebb	24.0	15.0	8.3-36.7
Toxicity Evaluation Dilution Study Samples	7/22/2009	001-072209	100% plume water	NA	190	170-220
		002-072209	75% plume, 25% reference	NA	140	plume/reference mixture
		003-072209	50% plume, 50% reference	NA	110	plume/reference mixture
		004-072209	25% plume, 75% reference	NA	92	plume/reference mixture
		005-072209	100% reference site water	NA	7.2	4.9-9.0

4.3.2 Polychlorinated Biphenyl Congeners (NOAA-18)

Polychlorinated biphenyl testing for the NOAA-18 congeners was performed for one sampling event during the 2009 dredge season: the Level I samples collected June 24, 2009. Results are presented in Table 4 as total concentrations of the NOAA-18 congeners. For all congener analyses resulting in a non-detect, a value of zero is used in determining the sum of the NOAA-18 congeners. Results for individual congeners are reported with all complete analytical data in Appendix C. Concentrations of the NOAA-18 PCB congeners ranged from 0.422 µg/L to 14.106 µg/L in the total (unfiltered) water samples, and from 0.147 µg/L to 3.342 µg/L in the dissolved phase (filtered) samples (Table 4). The dissolved phase samples contained lower concentrations than the total, unfiltered samples. Concentrations of dissolved PCBs were lowest at the reference sample sites, and as expected, the concentrations were highest in the plume and decreased with distance down-current. Total PCB concentrations of NOAA-18 congeners were also lowest at the background reference locations, and higher within the turbidity plume.

Table 4. Summary of Total and Dissolved PCB (NOAA-18 Congeners) results

Sampling Event	Date	Sample ID (WQ-TPC/DPC)	Sample Location Description	Lab Results		
				Turbidity (NTU)	Dissolved PCBs (µg/L)	Total PCBs (µg/L)
Level I Water Quality Samples	6/24/2009	001-062409	1000-ft south, flood reference	5.4	0.147	0.422
		002-062409	1000-ft north, ebb reference	6.6	0.824	1.349
		003-062409	plume origin	77.0	3.342	14.106
		004-062409	300-ft south of origin, ebb	12.0	1.837	5.323
		005-062409	600-ft south of origin, ebb	15.0	1.789	4.019

4.3.3 Toxicity

Toxicity results from the acute and chronic (sub-lethal) exposure assays performed on site water samples collected on three separate occasions are summarized in Table 5. Results are presented for the test endpoints: survival, growth, development, and reproduction. Results for test endpoints for each sample were statistically compared to those from both the event-specific site reference water and the laboratory control sample.

Table 5. Summary of toxicity results

Sampling Event	Date	Sample ID (WQ-TOX-)	Sample Description	Lab Results						
				Turbidity (NTU)	Sea Urchin *(A. punctulata)*	Mysid *(A. bahia)*			Red Algae *(C. parvula)*	
					mean fertilization (%)	48-hr mean survival (%)	7-day mean survival (%)	7-day mean biomass (mg/mysid)	48-hr mean survival (%)	7-day mean reproduction (cystocarp/tip)
Level I Water Quality Samples	6/24/2009	001-062409	1000-ft south, flood reference	5.4	93.4	95.0	92.5	0.314	100.0	44.9
		002-062409	1000-ft north, ebb reference	6.6	86.3	97.5	97.5	0.287	100.0	38.3
		003-062409	plume origin	77.0	94.1	100.0	100.0	0.436	100.0	0.5
		004-062409	300-ft south of origin, ebb	12.0	85.2	100.0	97.5	0.297	100.0	24.9
		005-062409	600-ft south of origin, ebb	15.0	N/A	N/A	N/A	N/A	N/A	N/A
		N/A	laboratory control sample	N/A	96.4	100.0	100.0	0.298	100.0	45.9
Turbidity Criterion Exceedance Samples	7/15/2009	001-071509	exceedance	*in-situ* range: 30-105 (average: 60-90)	97.8	95.0	90.0	0.307	100.0	29.3
		N/A	laboratory control sample	N/A	98.8	100.0	87.5	0.337	100.0	9.5

Sampling Event	Date	Sample ID (WQ-TOX-)	Sample Description	Lab Results			
				Turbidity (NTU)	Sea Urchin *(A. punctulata)*	Mysid *(A. bahia)*	Red Algae *(C. parvula)*
					mean fertilization (%)	48-hr mean survival (%)	48-hr coloration/ necrosis (qualitative scale)
Toxicity Dilution Study Samples	7/22/2009	001-072209	100% plume water	190.0	93.7	97.5	0.0
		002-072209	75% plume, 25% reference	140.0	90.3	100.0	0.8
		003-072209	50% plume, 50% reference	110.0	98.1	97.5	2.0
		004-072209	25% plume, 75% reference	92.0	98.0	97.5	2.9
		005-072209	100% reference site water	7.2	99.1	100.0	3.2
		N/A	laboratory control sample	N/A	98.8	100.0	4.0

Level I water quality samples collected on June 24, 2009 suggest a trend of reproductive failures by the red macro algae (*C. parvula*) under chronic exposure to high turbidity water. This assay, however, is often considered to produce false positive results, due to over sensitivity of the test species to a number of environmental factors. These results therefore should not be heavily considered, except when in conjunction with adverse effects on other species. Fertilization percentages in the sea urchin *A. punctulata* varied among samples with no apparent correlation between turbid water and fertilization rate. Likewise, the mysid shrimp *A. bahia* showed no acute or chronic toxic effects via the 48-hour or 7-day assays based on exposure to the site water samples.

Toxicity assays performed on the samples collected on July 15, 2009 did not exhibit any significant adverse effects when compared to the laboratory control. The site water samples did result in lower *A. punctulata* fertilization rates and lower 48-hr survival rates when compared to the lab control, however these differences were not statistically significant. Furthermore, 7-day survival (*A bahia*) and 7-day reproduction (*C. parvula*) were high in the site water sample when compared to the lab control. These results coupled with rigorous statistical analyses have supported that the exceedance water samples did not have any significant acute or chronic toxic effects on the test species.

The sample collection on July 22, 2009 was performed to evaluate the toxicity of water with varying turbidity concentrations in the 2009 dredge zones. The objective of the study was to compare the results of toxicity assays on water at 200 NTU, 150 NTU, 100 NTU, 50 NTU and background. Actual turbidity values for the five water samples were: 190, 140, 110, 92, and 7.2 (reference). The ESI analytical report (Appendix D) evaluates the results of acute and chronic toxicity assays. All red macro algae *C. parvula* analyses resulted in significant adverse (toxic) differences when qualitatively compared with both the lab control and the site reference water samples. The mysid shrimp (*A. bahia*) assays exhibited no significant adverse effects. The sea urchin (*A. punctulata*) analyses resulted in adverse effects in the water samples at the highest turbidity levels (140 and 190 NTU), however all samples exhibited fertilization rates over 88%, which generally indicates a non-toxic affect on the organism. The significant differences in fertilization of the *Arbacia punctulata* assays in the 140 and 190 NTU samples were interpreted by ESI as false positives caused by a statistical difference in numbers that did not correspond to a dangerous decrease in the organism's fertilization rates. Although an adverse toxic effect was exhibited for the red macro algae (*C. parvula*) assays, ESI scientists believe that these plants are overly sensitive. The qualitative results of this assay are not robust, especially in comparison to the other assays performed for this project.

4.3.4 Quality Control

Complete laboratory QC data from AAL and ESI is included in the laboratory reports and provided in Appendix C and D of this report. In general, the quality of the data was acceptable and the analytical methods were in control. For example, target parameters were undetected in the method/procedural blanks, indicating that the methods were free of contamination. Results for the laboratory-based QC samples, such as LCS and MS/MSD samples were acceptable for all test parameters, indicating that the laboratory

procedures were in control. Field-based QC samples (i.e. field duplicate samples) were also acceptable, indicating sampling methods were also in control.

5.0 DISCUSSION

The water quality monitoring program was developed to monitor and limit the potential impacts of dredging on water quality for the purpose of minimizing ecological harm and limiting redistribution of contaminated sediments. Achieving this goal required utilizing a variety of monitoring techniques:

- Adaptive boat-based *in-situ* monitoring used to track sediment plumes in real-time
- Collection of water samples for analytical testing, used to establish baseline water quality conditions and assess project compliance criteria
- Continuous *in-situ* data collection using fixed-station instrument moorings strategically selected locations. Data was collected autonomously to provide water quality data when boat-based monitoring was not possible
- Observational monitoring of water quality conditions with respect to fishery and wildlife impacts, used to minimize ecological risk factors

5.1 FISHERY AND WILDLIFE OBSERVATIONS

Field staff consistently recorded visual observations regarding fish migration and wildlife behavior throughout the 2009 dredge season. Large numbers of fish were observed in the upper harbor, between the Sawyer Street facility and the northern reaches of the estuary, north of the Wood Street Bridge. Lower trophic level fish and juveniles were consistently observed schooling throughout the estuary, particularly north of Wood Street. Larger predatory fish such as striped bass and bluefish were often seen feeding on these smaller fish. On occasion, in late summer, highly stressed and dead or dying fish were observed during hypoxic conditions and water temperatures near 30°C (Figure 16). The stressed fish were most often observed in the top layer of water where dissolved oxygen concentrations were slightly higher (~3 mg/L compared to <1 mg/L) than deeper water. Although a dozen or more dead fish were observed on a given day, no large-scale fish kill events occurred during the 2009 dredge season. The fish mortality that did occur is likely attributable to the poor water quality conditions (low DO concentrations, high temperature) that naturally occur during the late summer months. There appeared to be no restriction of movement or migration of fish past the dredge areas.

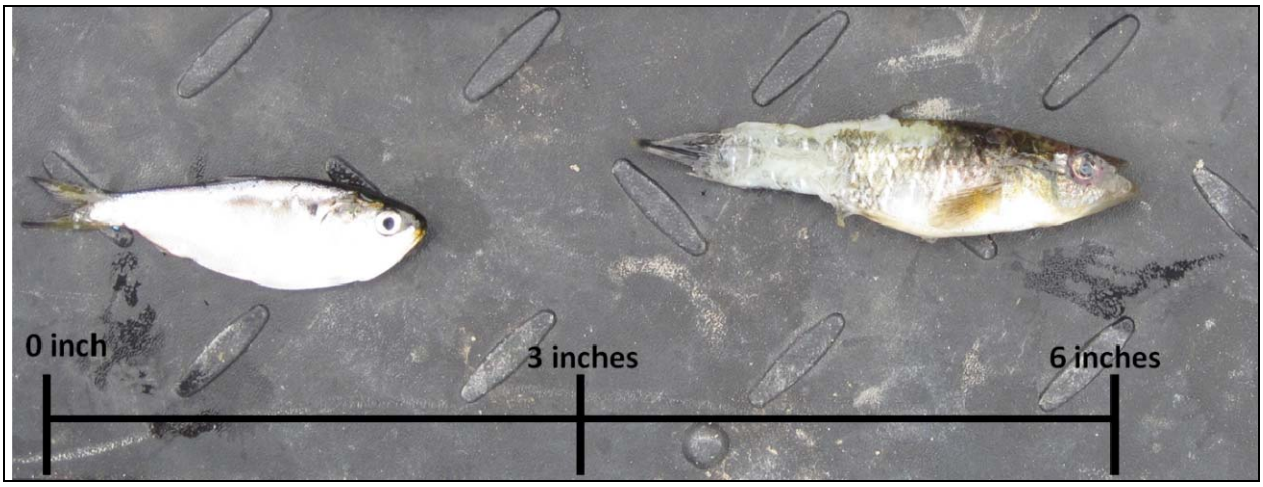


Figure 16. Dead fish collected from north of Wood Street Bridge on August 6, 2009

Birds such as great blue herons, green herons, gulls, swans, cormorants, egrets, terns and osprey, as well as other water fowl were observed living and feeding in the estuary surrounding all active dredge areas (Figure 17).

Figure 17. Cormorants and gulls observed perched on pipeline during active dredge operations

Other wildlife observed during the 2009 dredge season included a coyote, seen on August 6, 2009. The coyote was spotted on the Fairhaven (eastern) shoreline between areas J and L in the late afternoon. Undisturbed by boat traffic and active dredge operations, it remained resting on the shore for a short period during a low tide before retreating back into the marsh in the direction from which it had emerged.

5.2 SUSPENDED SEDIMENT AND TRANSPORT FROM DREDGING ACTIVITIES

In 2009, the project-specific turbidity compliance criteria of 50 NTUs above background was reevaluated and determined to be an overly conservative threshold. In order to be less restrictive on remedial operations and simplify the monitoring approach but remain ecologically protective, the turbidity criteria and compliance threshold were modified. The toxicity evaluation dilution study demonstrated that plumes of 100 NTU turbidity had no adverse toxic effect on the test species. The compliance threshold was adjusted to 300 feet down-current of the active work zone, encompassing all active dredge areas.

This allowed for more simplified sampling and monitoring, but continued to prevent far-field toxic impacts and suspended contaminated sediments being redistributed to cleaner areas.

Given the narrow and shallow characteristics of the estuary in the active 2009 dredge zones, distribution of turbidity plumes was often restrained by bathymetry and work-related vessels. The containment of turbidity plumes resulted in elevated turbidity levels immediately adjacent to dredging activities that rapidly decreased with distance from the source.

In general, there were three activities with potential to generate suspended sediment plumes; 1) dredging, 2) debris removal, and 3) support activities. Direct field reconnaissance information collected in close proximity to dredge operations allowed field personnel to determine which activities had the greatest potential to contribute to turbidity plumes. These findings were generally consistent with previous monitoring years.

The hydraulic dredging operation created virtually no measurable or sustained sediment plumes above 30 NTU, as evidenced by both boat-based and continuous *in-situ* turbidity monitoring data. In the event that an object became fouled in the auger-head of the dredge and required manual removal, the auger would be lifted to the water surface. If high winds or strong tidal flow drew surface water across the sediment-covered auger, a localized plume of turbidity and often a light to moderate sheen was observed down-wind or down-current of the dredge. Such plumes were spatially limited and temporally short-lived. Also during period of high winds, the use of support vessels was necessary to keep the dredge moving in line with the dredge cables. In areas of low water level, the supporting push-boats' propeller disturbed sediments to create narrow plumes of elevated turbidities.

Suspended sediment plumes related to debris removal activities were more common. These plumes tended to occur in pulses. Rapid increases and decreases in turbidity readings, or "spikes" were observed in conjunction with the debris removal rake being lifted through the water column and releasing sediments. Constant communication with excavator operators performing debris removal showed that when this work was done carefully and slowly, plumes were less frequent and of lower turbidity. Frequent breaks would allow suspended sediments to settle to the bottom before the operator disturbed the water again with a subsequent pass of the excavator's rake.

Debris removal barges had the potential to create plumes of suspended sediment when not in use, as well. If the barge was located in a particularly shallow area or during a very low tide, the wave or wind induced motion of the barge could disturb sediments below it and create a plume surrounding the barge. These plumes tended to be localized to within 100-ft of the barge. This effect was observed on multiple occasions.

The short-term, pulsed nature of the suspended sediment plumes was also observed in the continuous fixed station *in-situ* data record. Turbidity spikes occurred frequently during operational activity and usually represented only one or two readings at a time (lasting

15-30 minutes). Short-lived spikes in turbidity during non-working hours and occasional single spurious readings were also recorded which were not attributed to dredging operations, rather to naturally occurring weather events and other sources, such as CSOs or a momentary blockage of the turbidity sensor. These types of spikes were observed on both incoming and outgoing tides.

Sustained plumes of elevated turbidity lasting more than 30 minutes were also observed in the *in-situ* data from the continuously monitoring fixed stations. Often, these plumes could be correlated with activities in dredge areas adjacent to the fixed station moorings. However, the sustained peaks occasionally occurred during night hours and over weekends, when no dredge related activities were taking place. As discussed previously in Section 4.2.3, weather can be a significant factor affecting turbidity readings throughout the harbor, especially in the shallow waters of the 2009 active dredge areas.

Large variations in dissolved oxygen concentrations (DO), beyond normal diurnal cycling, were observed in the fixed station data. Over the course of the season, concentrations varied from near 0 mg/L to just under 20 mg/L, depending on location. These changes were gradual at times, such as when DO increased slowly during daylight hours, and did not decrease overnight before climbing again the next day. Other times, a change in DO concentrations was observed to be very rapid. Such events were likely caused by a bloom of algae or other photosynthesizing organisms, releasing oxygen into the water causing super-saturation. Generally, large fluctuations in DO concentrations were observed at the northern moorings. These fluctuations were apparent to a lesser magnitude in the data from moorings surrounding Area L.

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APPENDIX A. WATER QUALITY MONITORING FIELD LOGS AND DAILY REPORTS

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APPENDIX B. CONTINUOUS *IN-SITU* FIXED STATION WATER QUALITY TIME SERIES DATA

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APPENDIX C. ALPHA ANALYTICAL LABORATORIES REPORTS AND ANALYTICAL DATA

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APPENDIX D. ENVIROSYSTEMS, INC. REPORTS AND ANALYTICAL DATA