Attachment E

Engineering Contingencies Considerations

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Attachment E

Engineering Contingencies Considerations

1.0 Introduction

This attachment describes engineering contingencies that may be applied in the event that the action levels or the Resuspension Standard threshold are exceeded. The levels of the performance standard were developed using the statistical analysis of historical data, surface water quality modeling and applicable federal standards. The resuspension criteria will be used to govern the implementation of various engineering contingencies to minimize the release of PCBs during the remediation, to achieve the remediation goals as set forth in the Record of Decision (ROD) (USEPA, 2002), and to minimize the potential impact of dredging on ambient water quality. In the event that the resuspension criteria are exceeded, engineering contingencies will be implemented as necessary to minimize the potential impact of dredging on ambient water quality. A series of contingencies, ranging from increased monitoring frequency to cessation of dredging operation, have been proposed. These engineering contingencies will be implemented based on near-field and far-field water quality monitoring results.

The performance standard requires additional monitoring under certain conditions, the frequency and parameters for this additional monitoring of which are defined as a part of the performance standard. For other contingencies (*i.e.*, contingencies not specifically addressed in the performance standard), the specific technology cannot be selected, but must be a judgment that is specific to the problem encountered. Contingencies must be developed during the design stage for use in the event that water column concentrations exceed the performance standard. The performance standard does specify that if certain levels are exceeded, the cause of the exceedance will be examined and necessary changes must be made to the existing operations.

This attachment provides a brief overview of the performance standard (including a discussion of the monitoring locations needed to assess compliance with the standard), a summary of engineering contingencies used during similar projects, and a discussion of the engineering contingencies that may be applicable to the remediation.

Engineering contingencies for public and agricultural water intakes will be addressed in the Community Health and Safety Plan.

1.1 Performance Standard Monitoring Locations

Two types of monitoring locations are discussed throughout this attachment. Definitions are provided below:

Far-Field (Upper River and Lower River)

Far-field stations are fixed locations, typically located at dams and bridges. The primary contaminants to be monitored at these stations are PCBs and suspended solids. The results from monitoring at the far-field stations are the primary measure of PCB loss due to dredging, based on the assumption that only PCBs escaping each river section have the potential to cause significant downstream impacts.

Near-Field

Near-field monitoring locations are located within a short distance of the remedial operations, typically within a mile or so downstream. Depending upon the proximity of the various ongoing remedial operations to one another and the use of barriers, each remedial operation may have near-field monitoring locations associated with it. These near-field stations will be monitored continuously to determine the local impacts of dredging activities. The primary measurements in the near-field will be suspended solids concentrations and turbidity.

1.2 Resuspension Criteria

The resuspension criteria consist of three action levels and one standard providing limits on the PCB and suspended solids concentrations. Each of the resuspension criteria has associated monitoring requirements and engineering contingencies. The monitoring plan is summarized in Tables 1-2, 1-3 and 1-4 of the main document, showing the parameters required at each station and the frequency of sampling. Table 1-1 of the main document lists the concentration or load limits for each action level. Monitoring and resuspension criteria are fully described in the main body of the text and in Attachment F. An engineering evaluation of conditions in the river leading to elevated concentrations is recommended for Evaluation Level, but is mandatory for the Control Level and Resuspension Standard threshold. Similarly, implementation of engineering contingencies to reduce contaminant levels in the river is recommended at the Evaluation Level, but is mandatory for other the two other levels.

2.0 Monitoring and Contaminant Control Technologies Used At Other Sites

The monitoring and contaminant control technologies employed at three other PCB remediation sites are described below. The three sites are:

- St. Lawrence River Remediation Project at the Alcoa, Inc. Massena East Smelter Plant, New York, (Bechtal Environmental, 2000; 2002);
- New Bedford Harbor (Pre-Design Field Test), New Bedford, Massachusetts, (USACE, August, 2001); and
- Grand Calumet River, Gary, Indiana, (Earth Tech, Inc., 2002).

The technologies implemented at these three sites and reviewed in this attachment are containment (St. Lawrence River), dredging system design [hydraulic bucket design] (New Bedford Harbor), and monitoring (Grand Calumet River).

2.1 St. Lawrence River Remediation Project at the Alcoa, Inc. Massena East Smelter Plant, New York (Reynolds Metals)

In order to control the export of PCB-contaminated sediment at the St. Lawrence River Alcoa site, a containment system was installed as part of the remedial design. The containment system at this site included:

- A sheet pile wall that enclosed the entire remediation area;
- Silt curtains that provided secondary containment for the more highly contaminated Area C and also isolated uncontaminated portions of Area B from dredging areas; and
- Air gates (air curtain technology) that created an air-bubble curtain that acted as a circulation barrier while allowing for barge and tugboat access to areas enclosed by the silt curtain and pile wall.

Each of these components is discussed below.

Sheet Pile Wall

The wall consisted of interlocking steel sheeting embedded several feet or more into sediments and supported by H-beams (“king piles”) driven to greater depths. The sheeting and king piles were held together by a welded and bolted framework of steel braces and walers. The 3,800-foot finished wall consisted of about 200 king piles and 2,200 sheets. The maximum depth of water along the wall was about 32 feet.

The original design of the sheet pile wall specified that every fifth sheet would be driven to the water's surface to balance any differences in hydrostatic pressure between the inside of the wall and the outside environment. However, this was later changed and all sheets were raised to a height of about 2 ft above the river surface, minimizing the connection of turbid water inside the sheet pile wall with the river water outside the enclosure.

After the installation, a video survey was conducted to verify that there were no openings along the bottom of the wall or open seams in the sheeting. This survey identified a few small holes that were patched using sandbags. In addition, some of the sheeting was trimmed to reduce the height of all the sheets down to the 2 ft above water level (after installation) to reduce the surface area exposed to wind forces. Environmental monitoring data showed that the sheet pile wall functioned as designed and effectively contained the turbidity and suspended sediments generated during the dredging activities within the remediation area.

Silt Curtains

Silt curtains, consisting of 22-oz. PVC sheeting weighted on the bottom and suspended by polystyrene floatation buoys, were installed around Area C and a portion of Area B. The silt curtains were tied to H-beam anchor posts driven at a spacing of 100 feet, and anchored on the shoreline using a driven post or tree. The ballast for the curtains consisted of 3/8-in. galvanized anchor chain within a sealed pocket in the sheeting that could adapt to the bottom contours, thereby providing a complete vertical barrier. The curtain was suspended by cables attached to tensioners and anchor plates with reefing lines connected to the lower ballast chain to adjust the vertical height. A total of 1,222 feet and 996 feet silt curtains were used in Area B and Area C, respectively. The silt curtains effectively isolated the more contaminated Area C and prevented contamination of the clean portion of Area B.

The original design called for the installation of the silt curtain H-beam piles after the sheet pile wall was completed. However, due to the additional time required to install the sheet pile wall, this plan was changed for the clean part of Area B, and the silt curtain H-beam piles were driven while the sheet pile wall was being installed. A similar change for the contaminated part of Area B was not approved by the United States Environmental Protection Agency (USEPA).

Another change to the design of the silt curtain involved the addition of dual H-beams rather than a single H-beam to anchor the curtain. The original design specified that one H-beam would be placed at intervals along the inside of the curtain and timbers would be attached to the top of the beam to prevent barge traffic from hitting the curtain from the outside. The silt curtain manufacturer recommended placing dual H-beams at a spacing of 90 feet and then anchoring the curtain between the beams.

Air Gates

Air gates (air curtain technology) were used to create vertical circulation barriers that allowed boats to pass but restricted the movement of water between various parts of the remediation area. The air curtains consisted of 2-in. outside diameter (OD) steel pipe fitted with diffuser orifices on a helical, 9-inch spacing. The pipes had leg supports that raised them about a foot off the bottom. Geomembrane was laid beneath the pipes to minimize the disturbance of nearby sediment. Divers were used to place the liner, pipe and anchors, connect the supply lines and verify proper operation once the equipment was in place. A compressor station supplied air to the gates at a flow rate of about 1,000 cubic feet per minute (cfm) with flow pressures of 90 to 100 psig. The gates allowed for barge transit and limited the migration of turbid water across the barrier. A major objective of the gates was to contain the turbidity generated during the removal of Area C sediment. The gates accomplished this objective and otherwise functioned as designated for the duration of the project.

2.2 New Bedford Harbor (Pre-Design Field Test), New Bedford, Massachusetts

A pre-design field test was conducted at the New Bedford Harbor site to assess the effectiveness of hydraulic dredging as an engineering contingency to minimize the release of PCB contaminated material to the water column and to limit the transport of sediment away from the dredging area. The water quality monitoring data obtained during dredging activities indicated that the actual dredging process using a hydraulic excavator appeared to have a limited impact on the water column. The factors that minimized the release of material to the water column included the design of the bucket (tight closing with limited leakage), the configuration of the dredge (with a “moon-pool” work area enclosed behind a 36-inch silt curtain), and the controlled manner in which the operation was executed.

Factors that limited the transport of contaminated material away from the dredging area included the shallowness of the area (maximum depth of the dredged area was less than 10 feet (3 m)) at high tide and the limited currents (maximum currents generally measured less than 0.5 feet/sec.).

Activities performed in support of the dredging (e.g., the operation of support vessels such as tug boats) appeared to have a much greater impact on water quality than the dredging operations due to shallowness of the water, which measured about 4 to 5 feet in depth.

Normal fluctuations that occur in Upper Harbor due to changing environmental conditions appeared to be similar to, or greater in scale than, the overall impacts related to the actual dredging process.

2.3 Grand Calumet River, Gary, Indiana

Dredging activities are scheduled for completion in December 2003. The following was extracted from the Water Quality Certification Work Plan, dated July 2002.

Three water quality monitoring locations (Sites A, B, and C) are defined as the primary monitoring sites. A fourth monitoring location (Site D) is defined as the verification site.

- Site A is intended to monitor water quality upstream of dredging (located mid-channel of the Grand Calumet River at Transect 4 and will be re-located to Transect 2 as dredging progresses),

- Site B is located mid-channel, approximately 200 yards downstream of the open water dredge in Transect 12 to 36, and will be re-located as dredging progresses through cell D (or from Transect 12 to 36),

- The third station, Site C, is the downstream sample site and is located mid-channel downstream of Transect 36 (downstream of the limit of dredging), and

- A fourth sample location, Site D, also known as the verification sample site, will be situated 200 yards upstream of the open water dredge in transects 12 to 36, will be used to verify water quality exceedances, and used to determine if the exceedance is a result of the dredging operation or a different point source. This station was proposed in lieu of performing background sampling prior to initiating dredging. All water samples will be equal volume composites created from a total of three samples per location. The three samples per location will be taken from the water surface, at 50 percent of the water depth and at 80 percent of the water depth.

Three levels of monitoring will be utilized, including Level 3 Monitoring (*i.e.*, collection of composite water samples once per month from automatic samplers at Sites A and C and manually at Sites B and D for analysis of PCBs and other specified parameters). If results indicate no exceedances at Sites A, B and C, or if monitoring indicates exceedances at all three sites (A, B, and C), then it will be concluded that dredging is not the source and normal sampling will be conducted (once per month). If, however, results indicate exceedances at Sites B and C but not site A, then the water sample collected at Site D will be analyzed. If the sample from Site D indicates the parameters exceeded at Sites B and C are also exceeded at Site D, it will be assumed that the downstream exceedances at these sites are not a result of dredging and the normal frequency sample will be conducted. However, if no exceedances are found at Site D, it will be concluded that dredging is the source and enhanced monitoring consisting of additional sample collection at Sites A, B and C will be implemented at a rate of three times per week. When results indicate that the parameters of concern are less than the criterion for two months of consecutive samples, enhanced monitoring will be discontinued and the normal monitoring frequency will be resumed.

In addition to the increased sampling frequencies as a result of exceedances determined to be due to dredging, the Indiana Department of Environmental Management and the US Army Corps of Engineers will also implement a response action. If it is thought that an immediate threat to human health or aquatic life exists, the required response action will be issued within 72 hours, and this action will be implemented as quickly as possible, with a maximum time limit of one week to complete the implementation. If this schedule is not met, enhanced monitoring will be automatically implemented as described above, based on the parameters exceeded and the level of monitoring utilized when the exceedances occurred.

Possible response actions may consist of the following engineering contingencies:

- Decrease dredging operation,
- Install additional turbidity barriers or control mechanisms,
- Temporary cessation of dredging activities, and
- Conduct additional monitoring.

3.0 Engineering Contingencies for the Remediation

The required engineering contingencies for the Resuspension Performance Standard are described below. These include an increased monitoring frequency, engineering studies, containment technologies, operational modifications, equipment modifications and scheduling changes. With the exception of the monitoring frequency, specific implementations of the engineering contingencies must be planned during design.

The applicability of many of the containment technologies was evaluated in Appendix E.5 of the FS (USEPA, 2000). The advantage and limitation of each type of turbidity barrier were discussed. This information will be useful when choosing the appropriate containment system for a specific area to address the engineering contingency during the remediation.

3.1 Monitoring Contingencies

Monitoring frequency of the far-field stations will be increased at higher levels of exceedance to gain more information from which to evaluate conditions. The degree of increased frequency is detailed in Table 1-2, 1-3 and 1-4 of the main document for non-routine monitoring. The sampling method also changes for some stations—from grab samples to composites of hourly samples—to better capture the average water column concentration at the nearest representative far-field stations and to limit the number of analytical samples required.

3.2 Engineering Evaluations

In instances where water quality measurements exceed a resuspension criteria based on PCB concentration or load, an evaluation of the remedial operations should be conducted to determine the possible source and mechanism causing the exceedance, including:

- Examination of the barrier, if it is in use, for leaks and stability,
- Examination of the sediment transport pipeline if a hydraulic dredge is used,
- Examination of the turbidity associated with sediment transport barges and other support vehicles, and
- Sampling of PCB concentrations in the near-field.

The above-listed engineering studies will be mandatory in the event the Control Level and Resuspension Standard threshold are exceeded.

3.3 Barriers

Several types of barrier systems are described below:

- Fixed Structural Barriers,
- Non-Structural (Portable) Barriers,
- Other Portable Barrier Systems, and
- Control Zone Technology.

Fixed Structural Barriers

Fixed structural barriers, such as sheet piling, are particularly suitable for areas where there is a potential for high levels of resuspension. Sheet piling consists of a series of interlocking steel sections. The piles and panels are all driven into the riverbed to approximately the same depth. It is anticipated that turbidity barriers comprised of sheet piling will not be used areas where relatively shallow rock is present.

While fixed structural barriers provide considerable structural capacity, these systems are relatively expensive and usually require significant planning, equipment and manpower resources to install.

Non-Structural Barriers (Portable Barriers)

Non-structural barriers, such as silt curtains and silt screens (sediment curtains), can be considered for use to prevent the transport of sediments resuspended as a result of dredging activities Silt curtains are constructed of impervious materials that block or deflect the passage of water and sediments. Silt screens are similar to silt curtains; however, these barriers allow water to flow through while impeding the passage of a fraction of the suspended load. Typically, a silt curtain and silt screen are suspended by a flotation unit at the water’s surface and held in a vertical position by a ballast chain within the lower hem of the skirt. Anchors attached to the barrier also serve to hold it in place.

The advantage of using non-structural barriers is that they can easily be deployed and re-located to new work areas after dredging at a specific location has been completed. Silt curtains are not considered appropriate in situations where the river current is greater than approximately 1.5 feet per second and/or where the depth of the river exceeds 21 feet. However, it should be noted that if the silt curtain is set up in a configuration that is closely parallel to river flow, the curtain could function effectively in currents approaching 3 feet per second.

Other Portable Barrier Systems

Other commercial products such, as the Portadam^{TM} and Aqua-Barrier^{TM} systems, are also available for construction site containment, diversion of water flow, erosion control, and flood control. These systems are low-cost alternatives to building earthen dams or using sheet piles, and are relatively easy to set up. These systems are generally applicable to water depths of less than 10 feet.

The Portadam^{TM} system utilizes a free-standing steel support structure in conjunction with an impervious fabric membrane. The support members transfer fluid loading to an approximately vertical downward load, allowing for installation on a solid impenetrable foundation. This structure stands independently on the existing bed, eliminating the need for pile-driving equipment, cross bracing, or anchorage. The membrane is placed on the outer section of the support structure, and is rolled out all the way down to the level of the bed. Hydraulic loading on the membrane assists in the sealing and stability of the entire structure. Once installed, the work area enclosed by the structure can be de-watered.

The Aqua-Barrier^{TM} and GeoCHEM Water Structures^{TM} systems utilize water-filled, vinyl, polyester-reinforced tubes to provide mass for stability and they can be coupled together to form a barrier of any length. Punctures in the material can be easily patched with repair kits. They are lightweight, easy to transport, and re-usable. While these systems are not as sturdy as the Portadam^{TM} system, they can be used in cold weather conditions and are reasonably resistant to sunlight exposure.

Air gates are used to facilitate the passage of dredging-related traffic to and from an enclosed (i.e., sheet piled or silt curtained) area. The technology employs a continuous release of bubbles to reduce the flow of water to and from an enclosure. The air is supplied from a blower or compressed air source. The effort and cost associated with the deployment and operation of air gates are low and the performance of air gates appear to be superior when compared to silt curtain gates.

Control Zone Technology

A Control zone is a secure dredging area that is maintained and sealed off to prevent the release of contaminants generated inside the zone. Application of control zone technology (CZT) allows the excavation of contaminated sediments without the release of particulate and soluble contaminants into the surrounding water environment. It also establishes an area that can be easily monitored to confirm that remediation goals are met. This type of technology is more stringent than other barrier technology, since it requires additional water treatment. CZT has only been tested on a pilot scale and the cost is likely to be prohibitive. This type of technology could be considered for limited use in the most highly contaminated areas.

3.4 Operation and Equipment Modifications

Depending on the level of resuspension observed, operational control and equipment modification which include the following should be considered:

- Limiting boat speeds to reduce prop wash,
- Restricting the size of boats that can be used in certain areas,
- Loading barges to less than their capacity where it is necessary to reduce draft,
- Selecting an alternate dredge with a lower resuspension rate,
- Selecting alternate equipment or method for placing backfill or capping material, and
- Use of smaller, shallow draft boats for the transport of crewmembers and the inspection of dredges.

3.5 Scheduling Changes

The baseline PCB water column concentrations are high during the months of May and June relative to the remainder of the dredging season. As documented in the baseline water column level study (Attachment A), the 95 percent upper confidence limits (95% UCL) on the mean of PCB concentrations at the TI Dam and Schuylerville ranged from 110 ng/L to 200 ng/L in May and June. Remedial activities in high-concentration areas during high flow conditions may result in increased water column PCB concentrations that fall above resuspension criteria, resulting in the implementation of engineering contingencies, for example a containment system capable of containing enough of the resuspended material to maintain acceptable water column concentrations. Areas with higher sediment concentration may need to be scheduled for remediation in later months of each year (i.e., under low flow conditions, when the baseline level of PCB concentration is relatively low) if the engineering contingencies chosen are not effective. Baseline water column concentrations should also be considered when scheduling remediation in areas nearest water treatment plants in order to maintain a margin of safety for the public water supply.

4.0 Implementation Strategies

Flowcharts depicting the implementation of the Resuspension Performance Standard are provided in Figures 3-1, 3-2 and 3-3 of the main document for the near-field suspended solids, far-field total PCBs and far-field suspended solids, respectively. These flowcharts present the interaction between the three aspects of the Resuspension Performance Standard: resuspension criteria, monitoring requirements and engineering contingency requirements.

5.0 References

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Attachment F

Measurement Technologies

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LIST OF FIGURES

APPENDIX

Attachment F

Measurement Technologies

1.0 Introduction

This section provides detailed descriptions of specific measurement techniques for the general continuous monitoring prescribed in the performance standard. These include:

- In-situ Turbidity Measurement,
- In-situ Total Suspended Sediment Measurement,
- Semipermeable Membrane Devices (SPMDs),
- Trace Organic Platform Sampler (TOPS), and
- ISCO® Portable Water and Wastewater Sampler.

The above-listed instruments are presented as examples of technology that may be used during construction to satisfy the requirements of the standard, but the selection of appropriate technology will be a part of the design process.

Several other issues related to the monitoring are presented in this attachment. Correlations between turbidity and suspended solids measurements are discussed, and development of a correlation between these parameters will be required in order to obtain a real-time indication of dredge-related impacts on the water column. Attachment F-1 presents the results of a literature search on this topic. Attachment F-2 provides a synopsis of PCB analytical methods and associated detection limits. The detection limits for PCB congener analysis will be low in order to obtain detections at each station and to allow for identification in congener patterns.

2.0 Measurement Techniques

All types of dredging (navigational and environmental remedial action) create sediment plumes in the water column. Of particular interest for the Hudson River remedial action are plumes associated with the following activities:

- The mechanical and/or hydraulic dredging (sediment removal) operation,
- Material handling of dredged materials,
- Boat and barge movements, and
- Open-water placement of backfill materials.

The regulatory agencies and the public are concerned about potential adverse effects caused by these plumes on humans and biological resources, either through impact to water quality or increased siltation. To gain a better understanding of the temporal and spatial dynamics of sediment plumes, and in order to implement the performance standard for resuspension, it is necessary to monitor the plumes created to determine their composition, extent, and duration. Numerous techniques have been used to monitor sediment plumes, ranging from collection of water samples using simple water samplers to highly complex systems involving state-of-the-art instrumentation. Given the variety of techniques available to monitor dredging-related plumes, it is necessary to understand the advantages and limitations of the various techniques in order to determine which techniques provide the most cost-effective approach for each specific monitoring requirement.

The resuspension performance standard (as defined in Section 1) includes specifications for both PCBs and suspended sediment monitoring. The PCB standard requires measurement of the total PCB concentration, specifically, the measurement of the dissolved phase and suspended phase concentrations for all PCB congeners (monochlorbiphenyls through decachlorobiphenyl). Suspended solids (sediment) standards have been defined in order to serve as a surrogate for the amount of PCBs in the water column in order to provide a real-time indication of PCB concentration. Another parameter that could potentially serve as a surrogate for PCBs is turbidity. Although turbidity has been historically used during the monitoring of dredging activities to estimate suspended sediment using empirical correlations, it is well recognized that achieved correlations are site-specific and subject to significant error.

The objectives of measuring the water quality parameters discussed above (PCBs, suspended solids, and turbidity) are twofold:

- First, determine the water quality associated with the plume; and
- Second, track the plume both in space and time.

Knowledge of the spatial extent of a given plume is necessary to determine areas of potential plume impact. Similarly, knowledge of the time history of a plume provides information on how long a plume is present in a particular area and the time required for the plume to dissipate. It is clear that both near-field and far-field monitoring are necessary.

It may be important to measure various physical parameters not directly associated with water quality such as currents, waves, and water elevations. Currents carry plumes from the area in which they were generated into adjacent waters. Therefore, data on the current structure can be used to estimate the movement and spatial extent of the plume. Waves increase turbulence in the water column, which can potentially introduce additional sediment into suspension and prevent material in suspension from settling out.

Measurement techniques for monitoring of plumes involve one of the following:

- The collection of water samples from the water column for analysis either in the field or the laboratory (ex-situ methods), or

- The placement of instruments in the water column to directly measure water quality parameters or other physical parameters (in-situ methods).

Off-site laboratory analysis is time-consuming, expensive, and cannot provide data in the short term (i.e., within a few hours or less of sample collection). At present, there are no in-situ methods available for directly measuring PCB congeners in the water column, therefore, sample collection and laboratory analysis are required.

Concentrations of PCBs in the water column are often present at parts-per-billion (μg/L) or parts-per-trillion (ng/L) levels. Conventional sampling, extraction, and analysis methods like liquid-liquid extraction or solid-phase extraction can require the sampling and processing very large volumes of water (e.g., 50 liters) for an analysis of adequate sensitivity to detect low concentrations. (See Attachment F-2 for a synopsis of PCB analytical methods and associated detection limits.)

The limitations inherent in methods for the direct measurement of contaminant water concentrations have often prompted the use of biomonitoring to assess the exposure of organisms in the water column to trace or ultra-trace levels of hydrophobic chemicals like PCBs. Because certain organisms often bioconcentrate these trace or ultra-trace levels of PCBs to relatively higher concentrations (parts per million) in their lipids, determination of the bioavailable portion of environmental pollutants like PCBs is critical to assessing the potential for detrimental biological impacts.

This organism-based approach also has inherent problems, including biotransformation and depuration of contaminants, and inapplicability in many exposure situations due to the effects of stress on the biomonitoring organisms that often lead to a lack of proportionality between the biomonitoring organism tissue concentrations and ambient exposure concentrations (Petty et al., 2000). Therefore, innovative approaches for sampling and analyzing trace and ultra-trace levels of water-borne PCBs are needed.

The major mechanisms that result in relatively high concentrations of PCBs in organisms are passive processes and include the following:

- biomembrane diffusion, and
- partitioning of the chemical between an organism's lipid tissue and its environment.

Employing a mimetic chemistry approach (i.e., use of processes in simple or uniform media to mimic complex biological systems), scientists at the United States Geological Survey's (USGS) Columbia Environmental Research Center (CERC) have developed a passive, integrative sampler that simulates hydrophobic chemical bioconcentration. The uncertainty of estimating ambient exposure concentrations from tissue concentrations in biomonitoring organisms is thereby avoided. This sampler, the semipermeable membrane device (SPMD), measures the concentration of dissolved phase PCBs in the water column. A second type of integrating sampler, the Trace Organic Platform Sampler (TOPS), has been developed by New York State Department of Environmental Conservation (NYSDEC). The TOPS concentrates hydrophobic organic compounds from surface waters and is designed to collect suspended and dissolved-phase organics.

2.1 Correlations Between Turbidity and Suspended Solids

This section describes techniques traditionally used to measure turbidity and suspended solids in waters, how the two parameters relate to each other and to various environmental impacts, and why one cannot be routinely substituted for the other. An additional literature review is presented in Attachment F-1.

The term total suspended solids (TSS), sometimes referred to simply as suspended solids (SS), encompasses both inorganic solids such as clay, silt, and sand, and organic solids such as algae and detritus. It is a measure of the dry weight of suspended solids per unit volume of water, and is reported in milligrams of solids per liter (mg/L). The suspended solids concentration is determined by filtering a known volume of water through a filter of specific pore size (45 μm), and then drying and weighing the material retained on the filter. USEPA Method 160.2 is often used for this 'TSS' measurement.

Although popularly called suspended solids (the terminology used in this report), this method is more accurately termed non-filterable solids (or residue), because the size of separation (about 0.45 μm) is not the same as the boundary between suspended and dissolved solids. The suspended solids/dissolved solids boundary varies among molecules, but is generally around 0.1 μm. Another drawback of this method is that laboratories often perform this analysis using a 100 mL aliquot of the total sample provided, typically a 250-mL sample bottle. There is the potential that some of the solids adhered or adsorbed to the surfaces of the container, yielding a reported result with a low bias relative to the 'true' value. The method used by USGS to measure suspended sediment, ASTM Method D3977-97, may be preferable.

Turbidity is an optical property of water that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample. It is caused by water molecules, dissolved substances, and organic and inorganic suspended matter.

Turbidity measurements can be used as an operational aid in monitoring dredging and backfill placement operations as an adjunct to the more costly and time-consuming suspended solids measurements in a laboratory. The primary reason for wanting to use turbidity measurements instead of suspended solids is that turbidity measurements are immediate; nephelometric turbidity readings can be performed in a matter of minutes.

The collection and analysis of a suspended solids sample requires the following actions:

- Transport to the laboratory
- Analysis of the sample
    - filtering
    - drying
    - weighing
- Calculation of the suspended solids value

The transport and analysis process can take from 3 to 24 hours to complete. In the time it takes to get results of the laboratory analysis, the suspended solids of the discharge or water body of interest will have changed. Therefore, laboratory measurements for suspended solids cannot be easily used to detect and correct short-term problems or performance standard violations.

It is for this reason that turbidity measurements have historically been substituted for suspended solids. Turbidity is easy to measure quickly, but the following problems are associated with using turbidity as a surrogate for suspended solids:

- There is no universal relationship between it and suspended solids
- There is no universal relationship among turbidity measurements made on different water-sediment suspensions
- There is no universal relationship among turbidity measurements made on the same suspension with different instruments.
- Turbidity does not correlate well with many categories of environmental impact.

However, turbidity can be used to indicate suspended solids concentration on a site-specific basis, if certain specific techniques are used.

Two factors that prevent the development of a simple, universal relationship between suspended solids and turbidity are that the two parameters measure different things and their values are functions of different variables, . The suspended solids parameter depends on the total weight of particles in suspension, and is a direct function of the number, size, and specific gravity of the particles. In contrast, while turbidity is a direct function of the number, surface area, and refractive index of the particles, it is also an inverse function of their size (for constant suspended solids) (Thackston and Palermo, 2000).

The problems associated with the correlation of turbidity and suspended solids are based on two factors associated with calibration:

- The calibration changes with changes in grain size of the sediment.
- The calibration changes with sediment color.

A landmark paper co-authored by the inventor of one of the most widely used turbidity meters noted the following:

- The calibration changed by a factor of 10 based on color alone
- The change in calibration that is linear with sediment grain size (Sutherland et al., 2000).

For example, the calibration would change by a factor of 20 between white 5 micron sediment particles and gray 10 micron sediment particles. Such changes in sediment properties are not uncommon in nature. Since sediment color and grain size are not characteristics that are generally known during the course of a monitoring period, spot calibrations from samples are likely to contain unknown errors as sediment properties change in space and time (Agrawal and Pottsmith, 2000).These errors can reach several hundred percent and greater. Laser sensors described below in Section 2.3: In-situ Total Suspended Sediment Measurement overcome both these errors, making it easier to monitor suspended sediments.

2.2 In-situ Turbidity Measurement

Turbidity is the apparent “cloudiness” of water produced as light is scattered by particulate matter or dissolved material in the water. Presently established methods for measuring suspended sediments via optical turbidity are rooted in the research performed by Whipple and Jackson around the year 1900, which lead to a candle-based turbidity standard called the Jackson Turbidity Unit (JTU). Devices commonly used to measure turbidity include the Jackson candle turbidimeter, absorptimeters, transmissometers, and nephelometers (McCarthy, Pyle, and Griffin 1974). All but the nephelometer measure the effects of both the absorption and the scattering of light. The nephelometer measures scattered light only, and is the most commonly used device in colloidal chemistry, drinking water treatment, and water quality management. Turbidity measured by such an instrument is reported in nephelometric turbidity units (NTU).

A transmissometer projects a narrow beam of light through a volume of water and measures the intensity of the beam as it exits the volume of water. If particles are present in the water, they will attenuate the beam of light such that the light exiting the volume of water is less than the light entering the volume of water. The amount of attenuation can be measured, and with the appropriate calibration, these measurements can be used to estimate the suspended-particle concentration using an empirically-derived calibration curve. At low particle concentrations, transmissometers are very sensitive to small changes in particle concentration and/or size; however, at high-particle concentrations, transmissometers become saturated and lose their sensitivity to variations in concentration. Therefore, while transmissometers are very useful at measuring low-particle concentrations, they are inadequate for measurements at suspended solids levels above approximately 150 mg/L (Zaneveld, Spinrad, and Bartz 1979).

Nephelometers project a beam of light into a volume of water and measure the amount of light scattered out of the beam. The amount of light scattered is almost entirely dependent on the amount and size of particulate matter present in the volume of water. Ideally, a nephelometer would measure the amount of light scattered at all angles. Such a nephelometer is impractical, however, and standard nephelometers measure the scattered light at only one angle. Nephelometers use a device such as a photomultiplier tube or silicon photodiode to measure light that has been scattered at a specific angle, usually 90 degrees, from the main light path. The light source is usually a tungsten filament lamp or a light-emitting diode, and the light path is designed to minimize the amount of stray light that reaches the detector. Thus, a zero signal means that no light scattered at 90 degrees from the main light path and implies no turbidity.

Nephelometers used for in-situ measurements are, in general, referred to as optical backscatter sensors (OBSs). OBSs measure the amount of infrared light backscattered from a volume of water. While suspended sediment will reflect infrared light, organic matter will not (Tubman 1995). This characteristic of OBSs makes them well suited for the monitoring of sediment plumes because it does not bias the data by including organic matter. Because an OBS measures backscatter, its design is simple and compact relative to that of a transmissometer. More importantly, an OBS is capable of measuring significantly higher particle concentrations than a transmissometer, though it lacks the accuracy of the transmissometer at low-particle concentrations. Like the transmissometer, particle concentrations in the water can be estimated from OBS measurements using empirically determined calibration curves.

The ability of a particle to scatter light depends on the size, shape, and relative refractive index of the particle, as well as on the wavelength of the light (Lillycrop, Howell, and White 1996). The reading taken by the instrument depends on many design parameters, including the light source, detector, electrical circuit, sample container, and optical arrangement. As a result, two samples with equal suspended solids concentrations but different size distributions of particles will produce very different turbidity readings on the same nephelometer, and two different nephelometers may produce different turbidity readings on the same sample, even if they were calibrated on the same standard (Vanous 1978; Hach 1972). Although the original Jackson candle turbidimeter was standardized with a specific fine silica suspension in which one JTU equaled 1.0 mg/L of suspended solids, modern turbidimeters are no longer standardized against the Jackson candle, and the term JTU is no longer used. The Jackson candle turbidimeter is no longer an accepted standard method (*Standard Methods* 20th edition, APHA et al.).

Modern turbidimeters are standardized against a formazin suspension with a value of 40 NTU. The standards should be prepared according to *Standard Methods* 20th edition (APHA et al.) The 400-NTU stock suspension should be prepared monthly, and the 40-NTU standard turbidity suspension should be prepared daily. Experience shows that this turbidity can be repeatedly prepared within an accuracy of "1 percent (Hach 1972). The formazin turbidity standard is assigned a value of 40 NTU and can be diluted to any desired value.

One of the main benefits of measuring turbidity is that turbidity sensors are relatively simple, inexpensive, and robust. The objective of most turbidity measurements is to identify the presence of suspended solids and quantify the suspended solids based on a correlation between turbidity and suspended solids. Historically, the standard practice has been to use turbidity measurements to estimate suspended solids. Such estimates are accurate only under the following conditions:

- All measurements being compared are taken using the same turbidity sensor.
- The turbidity sensor is calibrated with a reference standard and suspended material from the area where the measurements are being taken.
- Particle size and composition of the suspended material do not change significantly during the measurement period.

Turbidity can also be measured in the field by collecting water samples and using portable instruments to analyze the samples. While these instruments are typically less expensive than in-situ sensors, the measurements take longer and may not represent true in-situ conditions, since particles may settle out of suspension prior to analysis. The cost of these instruments is approximately $1,500 to $2,000.

2.3 In-situ Total Suspended Sediment Measurement

Historically, suspended solids have been measured by collecting water samples and analyzing the samples in an off-site laboratory. Water samples can be collected using a bottle sampler or a submerged pump. Independent of the collection method, care must be taken to ensure that suspended particulate matter does not settle out of suspension or flocculate during collection or prior to analysis. Off-site laboratory analysis is time-consuming and cannot provide data in the short term. However, this approach is considered to be the most accurate and reliable method for measuring suspended solids. The alternative has been to estimate suspended solids based on other measurements such as turbidity or acoustic backscatter, both of which have limitations as discussed above.

New technology, Laser In-Situ Scattering and Transmissometry (LISST) has been recently developed that can measure suspended solids in-situ more accurately than can be achieved using correlations with turbidity. The instrument, the LISST-25, measures the scattering of a laser beam by particles in a volume of water. It should be noted, that laser diffraction measurements have been used to measure and characterize suspended sediments and floc-sizes in situ since 1985 (see, e.g. Bale and Morris, 1987; McCabe et al.,1993; Agrawal and Pottsmith, 1994; Gentien et al.,1995; Bale, 1996; van der Lee, 1998).

The LISST-25 is a small, self-contained unit that is suitable for field deployment and has real-time data return capabilities (Sequoia Scientific, Inc.). The instrument is capable of measuring particle total volume, particle total area, and the Sauter mean diameter within a particle range of 1.2 to 250 mm. These parameters are defined as follows:

- Particle total volume is the volume of material per volume of water.
- Particle total area is the projected cross-sectional area of the particles per volume of water.
- Sauter mean diameter is the ratio of the particle total volume to the particle total area.

If the density of the suspended particulate matter is assumed, it is possible to calculate the suspended solids concentration by multiplying the particle total volume by the assumed density.

Other models in the product line of the LISST instrument are capable of measuring the particle size distribution, in addition to the above-listed capabilities. The LISST-100 is the first in-situ laser that simultaneously measures the beam attenuation coefficient, the volumetric concentration (ml/L), and in-situ particle size spectra. It is designed to be submerged to a maximum depth of 300 m and is equipped with a built-in data logger.

The LISST-100 measures the particle size distribution in 32 logarithmically-spaced size classes in the range of 1.25 to 250 Fm (a LISST-100 type B). Other versions of the instrument can measure size ranges of 2.5 to 500 Fm and 7.5 to 1,500 Fm, spanning a 200:1 dynamic range in all cases. A detailed description of the design and the operational principles of the LISST-100 can be found in Agrawal and Pottsmith (1994), Agrawal et al.(1996) or Traykovski et al. (1999). However, the basic principles are explained very briefly below.

The LISST-100 measures the angular distribution of forward-scattered light energy over a path length of 5 cm, using a collimated laser beam with a wavelength of 670 nm. The energy of the scattered light is detected on 32 logarithmically-spaced ring detectors and stored in a built-in data logger. When data collection is complete, these raw data are off-loaded and mathematically inverted. The inversion yields the area distribution of the suspended particles in 32 size classes. By multiplying the area distribution by the diameter of each size class, the particle volume distribution is obtained. The absolute volume concentration (ml/L), is found by summing the volume distributions in all 32 size classes and dividing by an instrument-dependent calibration constant. The part of the light not scattered is detected by a photo-diode in the center of the ring detector, thus yielding the optical transmission, T, of the water. From the optical transmission, the beam attenuation coefficient at 670 nm, c(670), can be calculated using Eq. (1)

$$c(670)(m^{-1}) = -1/0.05\text{ m } \times \ln (T)\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

The processed data output from the LISST-100 thus consists of a particle volume distribution in 32 size classes, an absolute volume concentration (ml/L) and a beam attenuation coefficient at 670 nm. The LISST-100 also records the temperature and pressure. From the particle volume distribution, statistical parameters such as the mean and standard deviation can then be calculated. All software necessary for obtaining and analyzing raw data is supplied by the manufacturer of the LISST-100, Sequoia Scientific Inc., USA. (See Figure 1.)

Although the LISST instruments have not been used extensively in field studies of plumes when compared with turbidimeters, some documented information on their performance does exist (Melis, T., 2002, Mikkelsen, O., 2000). A recent study comparing the LISST to traditional methods of measuring suspended-sediment concentrations indicated that the LISST provided accurate measurements of the total volume concentration of suspended sediments (Traykovski et al, 1999). Once the accuracy and limitations of these systems are thoroughly documented by site-specific testing at the Hudson River PCBs Superfund Site, which could occur during the two-to three-year baseline/pre-dredge monitoring period if this device is selected for use, this instrument could prove very useful for the in-situ monitoring of sediment plumes in the Hudson River during Phase 1 and Phase 2 dredging activities. The cost of the monitoring equipment is approximately $15,000 to $30,000 for the LISST-25 and LISST-100. Because of the cost, some limited use of these instruments is warranted such at the far-field stations and for daily readings at the near-field stations.

2.4 Semipermeable Membrane Devices (SPMDs)

An SPMD is a passive sampling device that consists of a thin film of the neutral lipid, triolein, sealed inside a layflat, thin-walled tube of nonporous *(i.e*, no fixed pores; only transient thermally mediated cavities) low-density polyethylene (LDPE). The diameters of the transient cavities range up to approximately 10 Å, effectively precluding the sampling of any contaminant molecules associated with dissolved organic matter or particulates. This cavity size limitation has an important consequence: in general, only dissolved chemicals with molecular masses less than about 600 are sampled by SPMDs; this molecular mass limitation is very similar to that imposed by the pores of biomembranes.

At saturation, the capacity of an SPMD for a hydrophobic compound like PCBs is generally related to the compound's octanol-water partition coefficient (K_{ow}). The higher the K_{ow} is for a compound, the greater the capacity for that compound the SPMD has. Due to the very high concentration factors that are possible using an SPMD, even ultra-trace levels of the hydrophobic contaminants in the water column are readily analyzed.

Standard SPMDs are designed to sequester and concentrate hydrophobic compounds like PCBs and PAHs, but not ionic species such as ionic metals, salts of organic acids, or very polar organic chemicals. Neutral organic chemicals that are hydrophobic (i.e., with log K_{ow} values ≥ 3) will be concentrated significantly above ambient levels. In reality, any compound with a log $K_{ow} \geq 1$ will be concentrated by the SPMD, but for compounds with log K_{ow} values ≤ 3, there is no significant advantage in using SPMDs in lieu of other sampling techniques.

When placed in an aquatic environment, SPMDs passively accumulate hydrophobic organic compounds, such as PCBs. The LDPE tubing mimics a biological membrane by allowing the selective diffusion of organic compounds. Triolein is a major nonpolar lipid found in aquatic organisms. The passive sampling of the hydrophobic organic chemicals is driven by the mechanism of membrane- and lipid-water partitioning (See Figure 2).

SPMDs can be deployed for long periods of time (on the order of days to months) and can be used to estimate the time-weighted mean concentrations of the hydrophobic organic compounds in the water body. The SPMD is placed on a rack, which is then placed within a protective "shroud." Once the rack is added to the shroud, the device is ready for use in the water. An SPMD can be oriented vertically or horizontally as illustrated below:

An SPMD will effectively sample 0.5 to 10 L of water per day, depending on the chemical's hydrophobicity (as quantified by its water solubility or octanol-water partitioning coefficient, K_{ow}) and other factors. A compound with log K_{ow} of 6 would need 200 days at an effective sampling rate of 10 L per day to reach 90 percent of equilibrium. However, during the first 50 days, the uptake rate into the SPMD is linear.

The concentrations of these chemicals in rivers can change daily or even hourly. To get a true picture of the concentration of contaminants present in the water column, it would be necessary to collect and analyze and significant number of samples. The SPMD allows the calculation of a cumulative time-average of the concentration of each contaminant while the SPMD was in the water.

The ambient "truly dissolved" water concentration (C_w) can be estimated based on the concentration in the SPMD (C_{SPMD}), the volume of the SPMD (v_{SPMD}), the effective sampling rate (R_s), and the time of deployment (t):

$$C_w = C_{SPMD} V_{SPMD} / (R_s * t)$$

After a typical deployment period of approximately 15 to 30 days, the SPMDs are removed from the aquatic environment and recovered via dialysis using a nonpolar solvent such as hexane. This extract is then reduced, cleaned up, and enriched. The cleanup procedure typically includes gel permeation chromatography. This process removes any lipid and polyethylene waxes that might have carried over during the dialysis extraction. Further clean-up can be performed during enrichment on an activated alumina and silica gel column. The enriched extract is then analyzed for target compounds using chromatographic techniques.

A major portion of the sequestered residues can be recovered by opening the ends of the SPMD polyethylene tube and rinsing out the lipid with an organic solvent. However, analytes are generally recovered by dialyzing the intact SPMD (which requires removing periphytic growths, minerals, and debris from the exterior membrane surface) in an organic solvent such as hexane. Using this approach, contaminant residues present in the membrane (sometimes representing as much as 50 percent of the total) are also recovered for analysis and the dialysis process separates nearly all of the bulk lipid from the chemicals of interest.

A problem inherent with the deployment of SPMDs lies in the biofouling layer, the coating found on the membrane exterior. This biofouling layer can impede flux across the membrane, thus slowing the effective sampling rate (R_s). This impedance factor is specific to each SPMD at any given point in time. Impedance for a specific deployment can be quantified by measuring the loss of a surrogate compound (contained within the SPMD) during deployment.

The SPMD sampling rates are directly proportional to the SPMD membrane surface area. For example, a standard 1-g triolein SPMD (surface area about 450 cm^2) may extract 5 L of water per day for a PCB congener, whereas a standard triolein SPMD with half the surface area (225 cm^2) (0.5-g of lipid) can be expected to extract 2.5 L of water per day of the same congener, assuming similar conditions of exposure.

Due to the highly sensitive nature of the SPMDs, assembly and placement of the devices requires considerable care. According to Huckins *et al*. (1996), the following quality control (QC) procedures must be followed during the SPMD preparation phase:

- Use of synthetic triolein or lipid, with all new lots or batches analyzed for contaminants, ampulated, and stored in a freezer until use;

- Accurate delivery of small volumes of triolein requires the use of a micropipettor equipped with a total displacement plunger;

- Batch-extraction of SPMD tubing with nanograde hexane or cyclohexane just prior to use in SPMD construction;

- Enclosure of triolein in SPMD layflat tubing using a heat sealer, which results in a molecular weld;

- After assembly, SPMDs are sealed in clean, gas-tight paint cans (solvent rinsed to remove cutting oils) or gas phase sampling bags (Tedlar®) for transport to deployment sites.

Placement of the devices is important due to a variety of factors. According to Huckins *et al*. (1996), the following quality control (QC) procedures must be followed during the deployment phase:

- Use of plastic components should be minimized, with the exception of Teflon, due to the possible presence of leachable organic residues;

- The design of the structure to hold the SPMD should minimize abrasion of the membrane; and

- Since the SPMD membrane generally controls uptake, current velocity is usually only a concern in terms of abrasion and tethering.

Another important phase to consider is the recovery and storage of SPMDs. According to Huckins *et al*. (1996), the following QC procedures must be followed during this phase:

- As soon as SPMDs are recovered from the environment, they should be sealed in the original can or Tedlar bag and placed on ice. The devices should be shipped to the processing laboratory overnight; and

- SPMDs should be stored in the original container at –20^o C until they are analyzed.

During dredging activities in the Hudson River, SPMDs could be deployed at the far-field stations for periods of 15 days. The dissolved phase PCB concentration in the water column over the two- week period can then be determined. It should be noted that these measurements should be regarded as qualitative and used to measure relative changes in the water column concentration over successive two-week periods.

2.5 Trace Organic Platform Sampler (TOPS)

The detection of trace organic compounds in the water column is generally very problematic because many target compounds are typically present at concentrations that are below the detection limits of conventional analytical methods. In these instances, a non-detect result generally represents a failure in field sampling and/or laboratory analysis to measure these target compounds at environmentally relevant concentrations. Available analytical methods require large sample volumes to resolve concentrations in the picogram to femtogram per liter range. In environmental settings where concentrations are known to be exceedingly low, collection of large grab samples can be logistically difficult and cumbersome. Field processing of samples in these settings greatly simplifies the collection process while significantly lowering detection limits.

In order to overcome these difficulties, the NYSDEC developed the TOPS as a tool to obtain water column samples. The TOPS is composed of a set of plumbing, pumps, and sensors that concentrate hydrophobic organic compounds from surface waters. The device is designed to collect suspended solids using glass fiber cartridge filters (1 micron pore size), and to capture dissolved-phase organics (*e.g.,* dissolved phase hydrophobic organic compounds like PCBs) using the synthetic resin Amberlite XAD-2 (XAD). The 1 micron pore size filters were chosen for two reasons:

- They are readily available in desirable configurations, and
- They were assumed to be efficient at capturing most of the suspended solids in river settings.

XAD is a polymeric adsorbent of hydrophobic cross-linked polystyrene copolymer supplied as 20-60 mesh beads. The beads are an agglomeration of many microspheres, providing a continuous gel phase and a continuous pore phase. The XAD surface area is 300 m^2/g, and the open cell porous structure allows water to easily penetrate the pores of the resin. During the adsorption process, the hydrophobic portion of the adsorbate molecule is preferentially adsorbed on the hydrophobic polystyrene surface of the resin, while the hydrophilic section of the adsorbate remains oriented in the aqueous phase. Compounds adsorbed do not penetrate into the microsphere phase; they remain at the surface where they can be easily eluted. Unlike liquid/liquid extraction procedures, it is easy to scale up XAD sampling systems to treat exceptionally large volumes of water. These large water volumes have a greater likelihood of containing a detectable mass of the target organic analyte than smaller volumes.

The best use of the TOPS is to obtain whole-water concentrations of extremely dilute hydrophobic organic compounds. With adequate support, the TOPS is a very powerful field tool that can be deployed from ships or fixed locations where sample size is unlimited. In such cases, there is virtually no detection limit as more analyte can be obtained simply by pumping more water. The TOPS typically processes more than 5,000 liters in order to achieve adequate detection of target compounds. Where field setup is inconvenient and concentrations are expected to be relatively high, TOPS can be used in bench-top mode. Samples on the order of tens of liters can be brought in from the field and batch processed.

In its original configuration, the TOPS was run by an on-site operator for a fixed length of time (as short as one day) or at fixed intervals to sample wastewater effluent, coastal waters, and other environments with a low level of suspended sediments. The USGS, in cooperation with the NYSDEC, modified the TOPS for operation in river environments where suspended sediment concentrations are relatively high. Additional TOPS modifications allow for remote, automated, and flow-weighted operation (USGS, 2003 and NYSDEC, 2003).

The TOPS uses 110 VAC and processes water through cartridge filters (available in 4 or 10 inch lengths), and through XAD columns at a maximum rate of 620 mL/min. The TOPS can process water at a much greater rate through the filter (3,200 mL/min) than through the XAD, so significant amounts of suspended solids may be captured even in waters with low levels of suspended solids. Since the pump rates through the glass fiber filters and through the XAD are independent, sampling rates can be adjusted depending on the turbidity of the water.

Remote and automated operation was made possible by adding a Campbell CR10X data logger that performs the following tasks:

- Monitors stream stage,
- Triggers sample collection based on stream discharge, and
- Monitors flow through the XAD resin and filter and backpressure associated with the filter.

A modem connected to the data logger allows a user to dial into the site to initiate, monitor, or stop sampling. Hydrologic events rarely occur at convenient times, so data logger programming includes a set of conditions under which the TOPS will begin sampling automatically. These conditions usually take the form of a threshold change in river stage over time, but could include a variety of other programmable triggers, including river discharge. Ending the sampling activities performed by the TOPS can also be accomplished either manually or automatically. Automatic termination based on river stage is set for when the stage falls 80 percent of the difference between the event start stage and peak stage.

The collection of composite samples during periods of changing river discharge is best accomplished by flow-weighting the volume of water collected. Flow-weighting is a method by which the volume of sample water collected is proportional to the volume of water passing the sample station. Flow-weighting, as compared to fixed interval sampling, avoids the over-representation of conditions present during the beginning and end of the event and under-sampling of the the mass flux of contaminants passing during the hydrologic peak.

The contaminant flux can be determined by multiplying the contaminant concentration derived from the flow-weighted samples by the mean river discharge during the sampling period, and then converting to the appropriate units. In practice, flow-weighting is accomplished by collecting a fixed volume or sub-sample of river water every time a pre-set volume of river water passes the sampling station. This pre-set river water volume is an educated guess based on the anticipated river discharge maximum, expected duration of the event, and minimum sample volume required. Real time discharge data is required to collect a flow-weighted sample. The interval for collection of discharge data is dependent upon a variety of factors, but is principally dictated by the pre-set volume of river water used to trigger a sub-sample; in NYSDEC's application under the Contaminant Assessment and Reduction Project (CARP), discharge data were typically collected once per minute.

To allow sampling when suspended sediment concentrations are high, another pump was added to the sampling system that delivers a flow-weighted sample to a settling/compositing tank. In this configuration, the TOPS draws water from the tank instead of directly from the river. The tank sits on a scale which is monitored by the data logger. The mass of the water in the tank is used to control when the TOPS turns on and off and when the river water pump should turn off. The tank allows material that would otherwise prematurely clog the TOPS filter to settle. Settled material in the tank is collected and filtered at the end of the event, and composited for analysis with the TOPS filter. The advantages of using an additional pump in the sampling process include:

- The use of pumping rates that keep material in suspension without compromising the integrity of the TOPS filter;
- The ability to purge the sampling line before and after a sampling interval; and,
- The removal of the TOPS from the role of collecting a flow-weighted sample.

The addition of the settling tank to the TOPS system is primarily designed to extend the life of the TOPS cartridge filter; material settling to the bottom of the tank avoids TOPS filtration, thereby reducing the amount of material on the filter and prolonging filter life. Besides this obvious advantage, the tank has several additional benefits that improve the quality of sample collection. Without the tank, the main TOPS pump must collect and process the sample directly from the river, which requires the main pump to pull water from the river at a rate of at least 2 ft/sec to keep material in suspension. The filter may be able to process the volume of water required, but when the filtration is time constrained, the result is an increase in backpressure from the filter to the point where the TOPS shuts down. Additionally, as the filter accumulates sediment and backpressure builds, the effective pumping rate decreases with time, introducing bias into the sample collection in that the efficiency of the point intake to collect suspended material changes over time.

By removing the main TOPS pump from service as the direct collector of river water, the pump rate of the main TOPS pump can be significantly slowed. Slower filtration reduces backpressure from the cartridge filter and extends processing time. Slower pump rates also reduce the formation of air bubbles in the sampling line produced from the degassing of sample water under rapidly changing pressure conditions. Air bubbles can adversely impact the accuracy of the flow meters, which are critical in determining contaminant concentrations. The tank also gives the operator time to get to the site in the event that maintenance is needed. Sub-samples can be composited in the tank at the following times:

- At the beginning of the event before,
- During installation of the TOPS cartridge filter and XAD, and
- During the event to change a clogged filter.

By remotely monitoring river conditions and TOPS backpressure, sub-samples can be collected without interruption over the course of the hydrologic event.

A further advantage the tank- and sub-sample pump combination has over direct TOPS pumping is that the sub-sample pump can flush excess water remaining in the line following collection of a sub-sample without adversely affecting TOPS processing or pumping sample water back to the river. Without intake line flushing, the sub-sample water collected directly by the TOPS may be partially or entirely made up of water that remains in the sample line from the previous sub-sample. In addition, part or all of the sample water collected may not adequately represent the suspended sample fraction in that settling of suspended material occurs in the sample intake line between sub-samples – this is particularly a problem in locations requiring long sections of vertical or near vertical sample line.

Wound glass fiber cartridge filters are capable of filtering large volumes of water without clogging, but have the disadvantage of allowing more suspended material to pass through than conventional plate filters with the same nominal pore size. Experiments conducted to test the efficiency of the 10-inch cartridge filters (both 0.5 and 1 micron nominal pore size) indicate the efficiency changes with the volume of water processed, often times in unexpected ways, but generally in response to material loading of the filter. Over the course of these tests, both filter pore sizes trapped between 85 and 89 percent of the total mass of sediment sampled with pre-filter concentrations ranging from 3 to 82 mg/L. The TOPS can be equipped with a series of solenoid valves to periodically divert a sub-sample of water to a sample container. These valves and containers can be placed after the filter to assess the overall trapping efficiency of the filter.

A conventional automatic sampler is used with the TOPS to help interpret and support the organics data collected by the TOPS. This sampler collects discrete sample pairs for analysis of suspended sediment concentration and particulate and dissolved organic carbon concentrations. Sediment and organic carbon samples are collected at the beginning, end, and peak of the hydrologic event, in addition to measured changes in stage (e.g. every 0.5 feet of stage change).

2.6 ISCO® Portable Water and Wastewater Samplers

All of the portable samplers manufactured by ISCO can be divided into two groups: the full-size sampler and the compacted sampler. The compacted samplers are specially designed for locations with limited access, for example a manhole. The full-size sampler requires a larger space for installation. The open-channel flow conditions at the far-field monitoring stations in the Hudson River would be appropriate for a full-size sampler.

The Model 3710 sampler is a composite-only portable sampler that combines simple operation and high volume capacity for single-bottle sampling. The unit collects composites samples, based on time or flow interval, in a 2.5 gallon glass or polyethylene bottle or a 4 gallon polyethylene bottle. Up to 24 sampling stop and resume times can be preset for unattended, automatic sampling. The controller can be set up for uniform time interval, non-uniform time interval, and flow-paced sampling with or without time delay.

The Model 3700 sampler collects sequential or composite samples based on time, flow rate, or storm conditions. It is an ideal choice if the parameter monitoring and logging capabilities are not needed. The exclusive LD90 provides automatic compensation for changes in head height, plus automatic suction line rinsing to prevent cross contamination. Basic and extended programming modes are provided for uniform time intervals, non-uniform time intervals, stormwater runoff sampling, multiple bottle compositing, and split sampling. The bottle configurations for composite sampling are the same as for Model 3710. Sequential sampling bottle configurations include 24 x 1 liter polypropylene or 350 ml glass, 12 x 1 liter polyethylene or glass, and 4 x 1 gallon polyethylene or glass.

Both the Model 3710 and Model 3700 pumps maintain the USEPA-recommended 2 feet per second (fps) line velocity at head heights up to 16 ft, with ¼-inch suction line. For higher lifts, the 6700 series is recommended. The 6712 Portable Sampler is the most sophisticated full-size sampler that ISCO produces. Samples can be delivered at the USEPA-recommended velocity of 2 fps, even at a head height of 26 feet.

The plug-in 700 Series Modules and the new SDI-12 interface make it easy to add flow and parameter monitoring to the basic system. The 6712 Controller allows the user to select different programming modes to assure the most suitable routine for specific application. The included 4MB of memory gives the user great flexibility for logging environmental data. Choice of 11 different glass and plastic bottle configurations ranges from 24 x 1 liter to 1 x 5.5 gallon.

All the samplers require the power of 12 VDC. Ni-cad lead-acid batteries can be purchased from ISCO. But depending on the sampling frequency and the volume of one sample, the battery can last only 1 to 3 days. To meet the 2-week continuous sampling requirement set for the routine monitoring, the most convenient and economic way to provide the power for the sampler will be to provide the electricity to the sampling location.

The purchasing costs are as follows:

- $1,975 for Model 3710,
- $2,425 for Model 3700; and
- $2,700 for Model 6712.

To analyze PCB appropriately, the laboratory requires a 16-L sample. The 5-gallon container is needed to collect sufficient amount of water sample. Given the features of these samplers and the needs of this project, Model 3700 and Model 3712 would be the better choice. The details regarding how to deploy the samplers during remediation monitoring should be fully addressed in the design phase.

3.0 References

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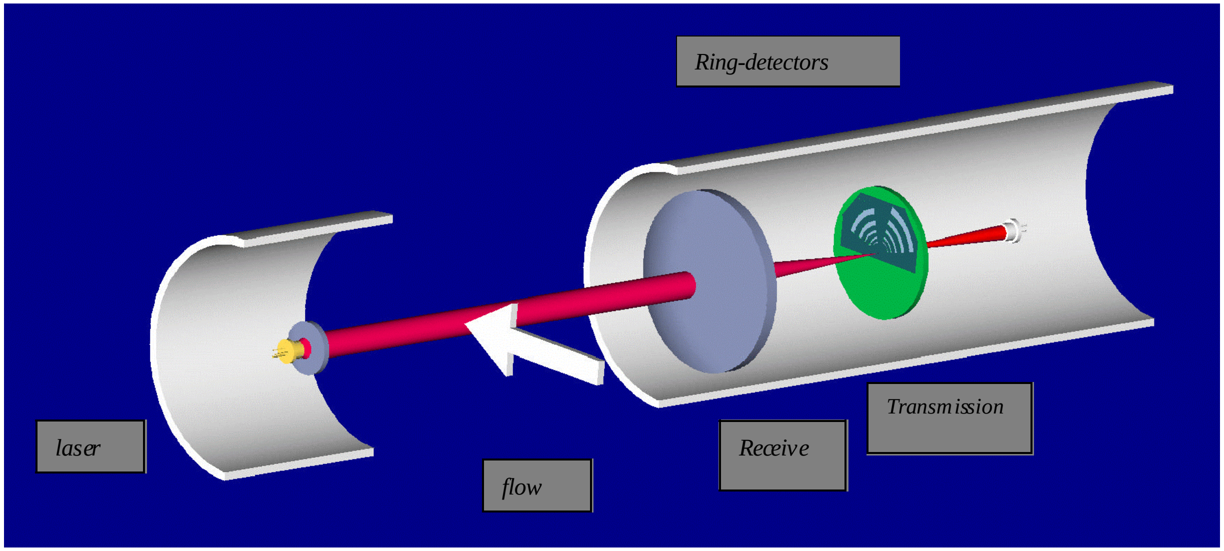


Figure 1 Laser diffraction principles – a cut away view of the basic LISST-100 instrument.

A collimated laser beam illuminates particles (left to right). Multi-angle scattering is sensed by a specially constructed photo-diode array placed in the focal plane of the receiving lens. The array detector has 32 concentric rings, placed in alternate quadrants. An aperture in the center passes the attenuated beam for measurement of optical transmission.

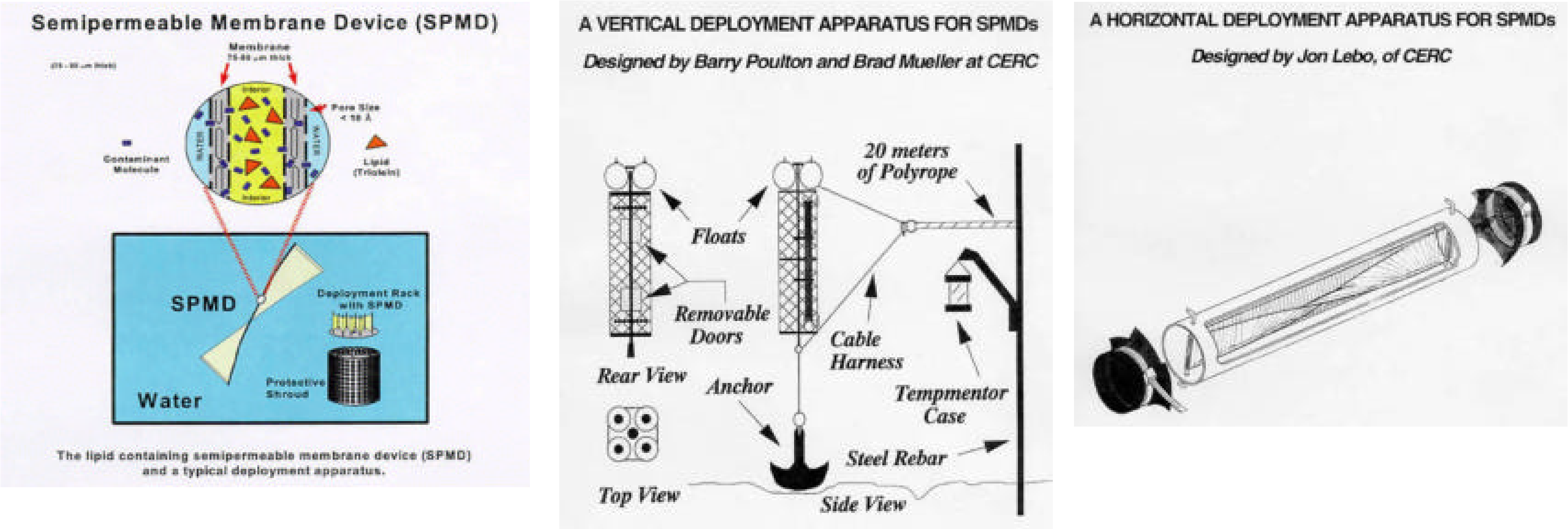


Figure 2. SPMD Apparatus

Attachment F-1

Literature Review

Attachment F-1
Literature Review

1.0 Introduction

PCB concentrations cannot be measured quickly or easily in the field, requiring time-consuming laboratory analyses. Turbidity and total suspended solids (TSS) can be measured relatively quickly and easily using real-time monitoring devices. To develop an estimate of the real-time PCB concentration in the vicinity of the dredging operations, the development of relationships between turbidity and TSS and TSS and PCB concentrations will be investigated.

Analysis of TSS and PCB data from a set of GE water column monitoring samples did not yield a correlation between the two parameters. Based on this observation, the PCB concentrations in the near-field will be projected using modeled solids concentrations (obtained using the DREDGE and/or SED20 models), consideration of the travel time, average concentrations in each river section, and an estimate of the time to reach equilibrium between the dissolved and suspended phases. It is not anticipated that PCB concentrations will be measured in the near-field during remediation.

PCB concentrations will be measured at the far-field stations, via sampling and analysis, and the levels will be compared with the TSS levels from the near-field stations to determine if a correlation exists. Phase 1 of the remediation will provide information that can be used to further refine any observed relationship between near-field solids and far-field PCB concentrations; refinements could be incorporated in the Final Phase 2 Engineering Performance Standards. The papers below were reviewed to investigate the feasibility and applicability of such a correlation.

2.0 Paper List

1. Chattooga River Watershed Ecological/Sedimentation Project (Pruitt at al., 2001)
2. Improved Methods for Correlating Turbidity and Suspended Solids for Monitoring (Thackston et al., 2000)
3. St. Lawrence River Sediment Removal Project Environmental Monitoring Plan: Section 2: Pre-Sediment Removal Data Collection (BBL Environmental Services, Inc., 1995)
4. Use of Acoustic Instruments for Estimating Total Suspended Solids Concentrations in Streams—The South Florida Experience (Patino et al., USGS, 2003)
5. Appendix K: Water Quality Monitoring Pre-Design Field Test Dredge Technology Evaluation Report, New Bedford Harbor Superfund Site, Section K.6.2 (USACE, 2001)
6. Suspended Solids Flux Between Salt Marsh and Adjacent Bay: A Long-term Continuous Measurement (Suk et al., 1999)

3.0 Chattooga River Watershed Ecological/Sedimentation Project (Pruitt at al., 2001)

The purpose of this study was to conduct a sediment-yield evaluation and analyses to determine if sediment was a primary cause of physical and biological impairment to streams within the Chattooga River watershed, located in northeast Georgia, northwest South Carolina, and southwest North Carolina. This goal was achieved by sampling sediments and aquatic ecology from different areas of the watershed and correlating the data by site.

For the aquatic ecological analysis, a total of three reference sites and 56 other sites from six subwatersheds (Headwaters, Lower Chattooga, Middle Chattooga, Stekoa Creek, West Fork, and Warwoman Creek) were sampled. Biological sampling methods were focused on benthic macroinvertebrates and used modified rapid bioassessment protocols. Reference sites were chosen prior to sampling based on habitat condition, *in-situ* water chemistry, and surrounding land use. Two of the reference sites were located on the Chattooga River, and one on the upper Chattahoochee River located outside of the Chattooga watershed. Data from all stations were analyzed using a multimetric approach: 17 metrics were calculated from the raw data, and ultimately the five of those that had the greatest ability to detect impairment were selected.

For sediment sampling, 17 stream reaches were selected for storm flow investigations based on the following criteria: relative degree of biological impairment as measured using modified rapid bioassessment protocols, position within the watershed, relative geomorphic condition, and access logistics. Storm flow investigations were performed during three storm events in March 1998, June 1999, and March 2000. A total of 58 observations were made across the 17 stations.

Total suspended sediment (TSS) was analyzed through the filtration of whole water samples and in accordance with USEPA Method 160.2. Bedload samples were collected using a 6-inch cable-suspended bedload sampler or a 6-inch wading type bedload sampler. The samples were transported to the laboratory in 1-liter containers, and processed for particle size determination in the laboratory using the EPA-SESD wet sieve method. Laboratory results of dry-weight bedload samples ($M_{b,\ grams}$) were converted to bedload transport rate (Q_b, tons/day) by the following equation:

$$Q_B = K(W_T/T)M_T$$

where:

Q_B = bedload discharge (tons/day)
K = converts grams/second/foot to tons/day/foot
W_T = wetted surface (ft)
T = total time sampler on bottom (seconds)
M_T = total mass of samples (grams)

The amount of bedload sediment measured over the course of the three storm events averaged 13.32 tons/day, with mean particle sizes ranging from fine sand to very coarse sand. On average, the bedload sediments only accounted for 14% of the total sediment load. The TSS averaged 85.3 tons/day over the course of the three storm events, making up 86% of the total sediment load on average. Total sediment load (bedload sediment + TSS) was compared to discharge and road density (road length/corresponding drainage area). Road density is a factor that represents the net impacts of road construction and maintenance, interception of subsurface interflow, routing of other non-point sources to the stream, and entrainment, mobilization, and transport of sediment to the stream.

Study results indicated that the biological conditions in most of the streams sampled showed little or no impairment due to sedimentation effects. 78% rated “very good” or “good,” 19% rated “fair,” and 3% rated “poor.” None rated as very poor. Although some sedimentation or habitat effects of sedimentation were evident at many sites, a negative biological response was not always presented. The most degraded biological community was observed in the Stekoa Creek subwatershed. Data indicated that impaired streams contained a higher concentration of bedload and suspended load sediments when compared to the reference streams. Study results also indicated that the road density and sediment sources associated with the road density were the source of 51% of the total sediment loading.

Good correlation was observed between the biological index and the normalized TSS data. Data suggest that a TSS concentration normalized to discharge/mean discharge greater than 284 mg/l adversely affected the biological community structure. However, based on regional concentrations, a normalized TSS concentration of 58 mg/l or less during storm flow provides an adequate margin of safety and is protective of aquatic macroinvertebrates in the area. Corresponding turbidity limits of 22 and 69 NTU represent the margin of safety and threshold of biological impairment.

Reference

Pruitt, B. A.; Melgaard, D. L; Howard, H.; Flexner, M. C.; Able, A. “Chattooga River Watershed Ecological/Sedimentation Project,” *FISC Proceedings*, Federal Interagency Sedimentation Conference, Reno, Nevada, March 26-30, 2001.

4.0 Improved Methods for Correlating Turbidity and Suspended Solids for Monitoring (Thackston et al., 2000)

This article describes techniques that are traditionally used to measure turbidity and suspended solids in water, how the two parameters relate to one another and to various environmental impacts, and why one cannot be routinely substituted for the other. This paper also outlines techniques describing the use of quick turbidity measurements as aid to monitoring dredging and dredged material disposal operations.

Turbidity and suspended solids are common parameters of concern for regulatory agencies, and thus are often included in the environmental monitoring plans for dredging operations. Because suspended solids measurements cannot be made quickly and easily in the field, turbidity measurements are often taken instead. While turbidity can be measured quickly, there is no universal correlation between the two parameters, or between turbidity measurements taken from different suspensions or the same suspension with a different instrument. However, turbidity can be used as an indicator on a site-specific basis.

Total suspended solids (TSS) include both inorganic solids and organic solids. TSS is a measure of the dry weight of suspended solids per unit volume of water, and is reported in milligrams of solids per liter of water (mg/l).

Turbidity is an optical property of water that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample, and is reported in Nephelomatic Turbidity Units (NTUs). The source of turbidity in a sample includes suspended inorganic and organic matter, water molecules, and dissolved substances. The ability of a particle to scatter light depends on the size, shape, relative refractive index of the particle, and the wavelength of the light.

There is no universal correlation of TSS and turbidity, but sediment-specific correlations are useful as a real-time indicator of suspended solids. Such correlations have been developed in the laboratory using whole sediment samples. Generally, any samples used to produce a correlation between TSS and turbidity must be suspension-specific, not just site-specific. The sample must approximate the suspension to be representative of the size, number, shape, and type of particles present.

Most discharge or monitoring permits that are associated with dredging operations are based on TSS rather than turbidity because TSS correlates well with environmental impact and is at least roughly comparable from site to site and sediment to sediment.

It has been suggested that there are three general situations where a TSS-turbidity correlation curve may serve as an aid in the routine monitoring of a dredging operation:

- Solids resuspension in the immediate vicinity of the dredge (20-50m) where most solids will be continuously replenished by dredging actions.

- Containment area effluent, where only the finer particles will be present due to the settling of larger, heavier particles near the point of inflow for the contaminant disposal facility. For this case, a laboratory settling column and test procedure would be required to obtain a representative sample.

- Open-water dredged material placement where the larger, heavier solids will begin to settle to the bottom immediately upon leaving the dredge discharge pipe, hopper, or barge usually in a well-defined plume. This case requires the use of a laboratory column-settling test to obtain a representative sample.

Reference

Thackston, E. L.; Palermo, M. R. "Improved Methods for Correlating Turbidity and Suspended Solids for Monitoring," *DOER Technical Notes Collection* (ERDC TN-DOER-E8), U.S. Army Engineer Research and Development Center, Vicksburg, MS, 2000.

5.0 St. Lawrence River Sediment Removal Project Environmental Monitoring Plan: Section 2: Pre-Sediment Removal Data Collection (BBL Environmental Services, Inc., 1995)

The goal of the pre-sediment removal data collection program was to verify bottom conditions, obtain background water quality information, and obtain a location survey of the sediment control system in the St. Lawrence River at the GM Massena site. One of the tasks planned to accomplish these objectives was pre-dredging turbidity monitoring.

To perform real-time monitoring that allowed for a rapid response to changing river conditions, a water quality parameter that is easily measured and correlates with sediment resuspension during removal activities must be chosen. Turbidity was the parameter selected in this case.

A downstream total suspended solids (TSS) maximum limit of 25 mg/l above background was defined as the conservative action limit based on two variables: previous environmental dredging projects and a 1994 site-specific bench-scale laboratory correlation between TSS and turbidity.

The 1994 bench scale experiment established a site-specific correlation between TSS and turbidity for the GM Massena site, resulting in the use of real-time turbidity measurements as a surrogate for TSS measurements. The laboratory-produced correlation, which is based on a combination of all data points from the treatability test (including some elevated TSS results (> 300 mg/l) from the beginning of the settling test), is described by the equation 1 below:

$$\text{Turbidity (NTU)} = 7.3745 + (0.61058 \text{ X TSS}) + (0.00094375 \text{ X TSS}^2) \qquad (1)$$

with a correlation coefficient of $r^2 = 0.941$

Turbidity monitoring data collected in 1994 indicated that the St. Lawrence River can be characterized as having a relatively low suspended solids content (based on the evaluation of background river water samples, which contain < 10 mg/l TSS) and low turbidity readings. A regression analysis was rerun by BB&L only including data that fell within the expected working range, defined as: TSS < 60 mg/l and turbidity > 60 NTU. The regression equation 2 calculated is defined below:

$$\text{TSS (mg/l)} = [0.63\text{x x (turbidity in NTU)}] + 6.8 \qquad (2)$$

with a correlation coefficient of $r^2 = 0.43$

Based on the revised regression (2), a turbidity of 28 NTU would correlate to a value less than 25 mg/l TSS concentration. Dredging activities would not take place when the measured TSS background was above 60 mg/l. So, due to the nearly linear relationship that exists between turbidity and TSS for the St. Lawrence River in the subject area, a turbidity increase of 28 NTUs from upstream to downstream was defined as the action level for the St. Lawrence Sediment Removal Project during waterborne activities.

Real-time turbidity measurements were obtained from three monitoring locations, one 50 feet upstream of the western extent of the control system and two between 200 and 400 feet downstream of the eastern-most active installations, during the mobilization and installation of the Phase I sediment control system to evaluate any potential short-term effects of the operations. Measurements were collected near 50% water depth. Turbidity was also monitored if visible sediment releases were observed during sheet pile installations.

Reference

"St. Lawrence River Sediment Removal Project Environmental Monitoring Plan." Prepared for General Motors Powertrain by BBL Environmental Services, Inc. May 1995.

6.0 Use of Acoustic Instruments for Estimating Total Suspended Solids Concentrations in Streams—The South Florida Experience (Patino et al., USGS, 2003)

An acoustic velocity meter (AVM) and an acoustic Doppler velocity meter (ADVM) were used in a study to estimate the total suspended solids (TSS) concentration in two southern Florida streams. The AVM system provides information on automatic gain control (AGC), which is an index of the strength of the acoustic signal recorded by the instrument as the acoustic pulse travels across a stream. The ADVM system provides information on acoustic backscatter strength (ABS), which is an index of the strength of return acoustic signals recorded by the instrument. Both the AGC and the ABS values increase as the concentration of suspended material increases.

The AVM system was installed in 1993 in the L-4 Canal, a man-made channel in northwestern Broward. The canal is approximately 40 feet wide and averages between 7 and 8 feet in depth. The water velocities in this canal range from –0.5 to 2.5 feet per second. The ADVM system was installed in 1997 in the North Fork Stream (a tidal channel), located in Veterans Park in southeastern Florida. The stream is about 280 feet wide and averages 8 feet in depth, with water velocities that range from about –1.5 to 1.5 feet per second and a salinity that varies from fresh to brackish (0.2 to 15 mg/l).

Depth integrated samples for TSS were collected at the L-4 Canal site using a DH-59 sampler and equal discharge increment (EDI) methodology, and samples at the North Fork site were collected using a point sampler at the same depth as the ADVM system and located 9 feet away from the transducer faces (near the start of the sampling volume). TSS concentrations ranged from 22 to 1,058 mg/l at the L-4 Canal site, and from 3 to 25 mg/l at the North Fork site.

Regression analysis techniques were used to develop empirical and site-specific relationships between the AGC and ABS results and the TSS and the two sites. The equation below describes those relationships:

$$\mathrm{TSS} = 10^{\{A*[a + b*\log(\text{salinity}) + C*\log(\text{temperature})] + d*\log(\text{velocity}) + e\}}$$

The relationships obtained using the site-specific equations produced good correlations, with coefficients of 0.91 and 0.87 at the L-4 Canal and North Fork sites, respectively. The results suggest that this technique is feasible for estimating TSS concentrations in streams using information from acoustic instruments.

Reference

Patino, E.; Byrne, M. J. “Use of Acoustic Instruments for Estimating Total Suspended Solids Concentrations in Streams—The South Florida Experience,” U.S. Geological Survey, Ft. Myers, FL. Available at **http://water.usgs.gov/osw/techniques/TSS/Patino.pdf**, downloaded in Feburary 2003.

7.0 Section K.6.2 – Correlation Analysis found in Appendix K: Water Quality Monitoring Pre-Design Field Test Dredge Technology Evaluation Report, New Bedford Harbor Superfund Site (USACE, 2001)

A Pre-Design Field Test was undertaken in order to evaluate the performance of a dredge system under consideration for use at the New Bedford Harbor Superfund Site. The objectives of the test focused on the performance of the dredge system. This report section evaluates the impacts on water quality associated with the test; the following tasks were performed for the evaluation:

- Predictive modeling was used to aid in the design of the water quality monitoring field program and to assess the utility of modeling for the full-scale remediation effort.

- Field monitoring was performed to assess sediment resuspension during the dredging operation, to collect water samples for laboratory analysis, and to ground-truth the predictive modeling.

- Laboratory analysis of water samples for TSS and PCBs was performed to assess water quality impacts.

- A correlation assessment between the field and laboratory data was performed.

Three correlation studies were performed on the data obtained from the monitoring samples:

- TSS vs. total particulate PCBs – Analysis of the data revealed an excellent correlation between the two parameters. The study yielded a coefficient of fit for the linear relationship of 0.84, suggesting that TSS could serve as a good indicator of the particulate PCB concentrations associated with operations similar in scope to the pre-design work.

- Total particulate PCBs vs. total dissolved PCBs – Analysis of the data yielded a poor correlation between these parameters. An exponential function provided a better fit to the data.

- TSS vs. total dissolved PCBS – Analysis of the data provided a poor correlation between these parameters. An exponential function provided a better fit to the data.

A review of the individual dissolved/particulate data pairs indicated the following:

- For the reference samples, the dissolved phase and particulate PCB concentrations were generally similar on a per liter basis, with the dissolved-phase concentration sometimes exceeding the particulate concentration.

- For the samples impacted by the dredging operations, the total particulate PCB concentration was generally increased to a much greater degree than the dissolved-phase PCB concentration.

Analysis of the monitoring data also suggested the following:

- A moderate correlation between the total suspended solids measured in the lab and the turbidity measured in the field. The linear coefficient of fit for these data was 0.56. Measurement of both parameters from the same water parcel would be expected to increase the strength of the correlation.

- Given the different correlations indicated by the data, turbidity to TSS and TSS to PCB, the results suggest that field measurement of turbidity could be used as an indicator of the mobilization and transport of particulate-bound PCBs during the full-scale remediation activity.

Reference

USACE. 2001. “Appendix K: Water Quality Monitoring Pre-Design Field Test Dredge Technology Evaluation Report, New Bedford Harbor Superfund Site,” *Pre-Design Field Test – Dredge Technology Evaluation Report*, New Bedford Harbor Superfund Site, New Bedford, Massachusetts. Prepared by Foster Wheeler Environmental Corporation, Boston, Massachusetts. August 2001.

8.0 Suspended Solids Flux Between Salt Marsh and Adjacent Bay: A Long-Term Continuous Measurement (Suk et al., 1999)

The goal of this study was to establish an improved methodology to determine the suspended solids flux between Schooner Creek, NJ, a tidal salt marsh, and Great Bay, adjacent to it. The most significant difference in methods used in this study was related to data collection. Field data were collected continuously from March to October 1996.

A suite of instruments, including a current velocity sensor, a turbidity sensor, an automatic water sampler, a pressure transducer, and a data logger were placed in (and around) a location 300 m from the mouth of Schooner Creek, to measure the velocity, water surface elevations, and suspended solids concentrations of the creek. Water velocity was measured at a depth corresponding to the mid-depth of the creek at high tide. The instruments were placed in the water on the deeper side of the creek so that they would remain submerged.

Total suspended solids (TSS) in the stream were quantified using turbidity as an indicator. A feasibility study performed prior to the experiment's initiation that examined 593 water samples over 25 different time periods found that that the measured suspended solids concentrations were statistically related to the measured turbidity. The average correlation coefficient for flood and ebb time periods averaged 0.827, indicating that turbidity measurements would provide surrogate measurements of the suspended solids concentration.

The water flux rate was derived from measurements taken by the submerged instruments and calculated as a product of the current velocity and the area of the wetted cross section, and cumulative flow volumes were calculated using the average flow rate for successive time intervals.

The TSS flux was calculated as the product of the water flux and the TSS concentration. Two TSS fluxes were calculated:

- TSS fluxes for the entire recording period (periods of balance and imbalance) using TSS concentrations derived from the overall regression relationship.
- TSS fluxes for periods of time where the calculated water fluxes were more balanced, yielding net flux values that were not strongly impacted by a water imbalance.

Analysis indicated that the flow data are not continuous, and there are several different natural and artificial factors that may attribute to a water imbalance, though the researchers decided that net water import or export during a particular time was most likely due to the measurement of an incomplete cycle of water exchange across marsh boundaries other than the creek mouth.

The study also calculated a minimum number of water sample sets needed to produce a reasonably good TSS-turbidity regression relationship. To do so, varying combinations of water sample sets were used to develop a number of different regression relationships. The regression relationships were then used in the flux calculations, and the relative error was calculated.

The following observations were produced from the study:

- Data analysis indicated that the cumulative and cycle fluxes calculated for the entire recording period are considerably uncertain due to an imbalance in the calculated water fluxes.

- Data analysis indicated that the coefficient of correlation between the cumulative TSS fluxes per tidal cycle and the average TSS concentration differences was 0.71. The flow-weighted average TSS concentration resulting from all of the water balance periods during the flood tide was higher than that during the ebb tide, contributing to a net import of TSS.

- Data suggested that, for this study, a reasonably good overall TSS-turbidity regression was established when five data sets with correlation coefficients greater than or equal to 0.80 were used.

Reference

Suk, N. S.; Guo, Q.; Psuty, N. P. "Suspended Solids Flux Between Salt Marsh and Adjacent Bay: A Long-term Continuous Measurement," *Estuarine, Coastal, and Shelf Science,* Vol. 49, pp. 61-81, 1999.

Attachment F-2

PCB Analytical Methods
Detection (Reporting) Limits in Water

Attachment F-2
PCB Analytical Methods
Detection (Reporting) Limits in Water

1. **CLP Method OLM04.1** (September 1998)
   Contract-required quantitation limit is 1 Fg/L for all Aroclors
   (CRQL for Aroclor 1221 is 2 Fg/L)
   Laboratories can report lower detections (e.g., 0.5 J [Fg/L])

2. **SW-846 Method 8082** (Rev 0, December 1996)
   MDLs (method detection limits) for Aroclors range from 0.054 to 0.90 Fg/L
   (Method provides no data as to Aroclor-specific MDLs)

3. **PCB Congeners - Dual Column GC/ECD** (Laboratory-specific)
   STL/Colchester Vt (formerly Aquatec)
   Detects inidividual PCB congeners at a detection limit of 0.001 Fg/L
   (Monochlorobiphenyls at 0.005 Fg/L)
   (Other labs have other methods with varying detection limits)

4. **NYSDEC Analytical Services Protocol Low-Concentration Method (91-6)**
   CRQL is 0.2 Fg/L for Aroclors except for 1221 (0.4 Fg/L)

5. **USEPA Method 505**, Revision 2.1 - 1995 (Organohalide Pesticides and PCBs by microextraction/GC)
   - MDL for Aroclors 1016, 1248, 1254 - about 0.1 Fg/L
   - MDL for Aroclor 1260 - about 0.2 Fg/L
   - MDL for Aroclor 1242 - about 0.3 Fg/L
   - MDL for Aroclor 1232 - about 0.5 Fg/L
   - MDL for Aroclor 1221 - about 15.0 Fg/L

   (from Method 505 Revision 2.0, USEPA EMSL, 1989)

6. **USEPA Method 508**, Revision 3.1 (1995). Determination of Chlorinated Pesticides in Water by GC/ECD.

   - Note to method summary states that the extraction is similar to Method 608 (q.v.), and the extract can be analyzed by 508, 525, or 608; however, no performance data for Aroclors were collected as part of method development for 508.

   - EDLs (reporting limits) for most single-component pesticides are in the 0.01 Fg/L to 0.05 Fg/L range (a few are higher and a few are lower).

- This method is supposedly being used by Waterford for monitoring its drinking water supply. The detection and reporting limits would have to be developed on a laboratory-specific basis. Multi-component analytes (such as Aroclors, and also toxaphene and chlordane) typically have higher reporting limits than single-component pesticides.

7. **USEPA Method 680** (PCBs by GC/MS)
Arocolor detection limits are about 100 Fg/L

8. **USEPA Method 608** (Pesticides/PCBs by dual column GC)
Aroclor Detection limits 0.5 Fg/L (1.0 Fg/L for Aroclor 1221)

9. **USEPA Method 525.2** (1995 revision)
Method uses solid/liquid extraction by either disk or cartridge and analysis using quadropole MS or ion trap. MDLs are presented for method analytes for each of the four possible combinations; except Aroclor MDLs only by disk and ion trap. Sensitivity is better for more chlorinated arolcors. MDLs range from 0.018 Fg/L for 1260 to 0.054 Fg/L for Aroclor 1221.

10. **USEPA Method 1668A** (December 1999) - Chlorinated Biphenyl Congeners in Water, Soil, Sediment, and Tissue by HRGC/HRMS.

    - Detection limits (EMDLs) and reporting limits (EMLs) are provided for more than 150 congeners in both water and non-aqueous matrices.

    - Method is more sensitive for less-chlorinated congeners.

    - Reporting limits for individual congeners range from 50 to 1000 pg/L (10 pg/L for BZ#2) in water (detection limits [EMDLs] are typically 1/3 to ½ the reporting limit [EML]).

    - Reporting limits range from 5 to 100 ng/kg (except 1 ng/kg for BZ#2) in non-aqueous samples (detection limits [EMDLs] are typically 1/5 to ½ the reporting limit [EML]).

11. **Green Bay Method.** Original method not reviewed (or obtained). *Not included in the GE August Design Support Sediment Sampling and Analysis Plan (Revision 1, August 2002).* Reportedly a single-column PCB congener GC/ECD method.

General notes on units of measure:

- g/L = parts per thousand (10^{-3});
- mg/L = parts per million (10^{-6});
- Fg/L = parts per billion (10^{-9});
- ng/L = parts per trillion (10^{-12});
- pg/L = parts per quadrillion.(10^{-15}).

Attachment F-3

Memo Regarding PCB Analyses; Whole Water Extracts vs. Separated Particle and Filtrate Extracts

February 25, 2003

To: Kelly Robinson, Earthtech (TAMS)
From: Richard Bopp, RPI
Re: PCB Analyses; Whole Water Extracts vs Separated Particle and Filtrate Extracts

Background

Since I first analyzed Hudson River water samples for PCBs in the late 1970s, I have been interested in particle/water partitioning. Consequently, I have always filtered the samples and extracted and analyzed the particles and filtrate separately. In addition, based on considerations of analytical sensitivity, I have always analyzed large volume (typically 18 liter) water samples. These procedures were adopted by the USEPA for the water column PCB samples that we collected and processed as part of the Hudson River PCBs Reassessment.

Several other important datasets rely on an EPA-approved whole water extraction and analysis of much smaller volume (typically 1 liter) samples. These include

- The USGS monitoring in the upper Hudson. This program provides the longest historical record of water column PCB levels.

- The GE monitoring between Rogers Island and Schuylerville conducted under consent order with the NYSDEC as part of the remnant deposits monitoring program. This set of samples, collected approximately weekly since 1997 provides, by far, the most detailed picture of PCB transport ever developed (J. Tatten, Master's Project, RPI, 2000; Task 3 Final Report to NYSDEC, Contract C003844, 2000).

In 1993 I was at RPI and supervising the collection and processing of the water column samples for the Hudson River PCBs Reassessment. As I recall, I suggested that on one of the transects we collect duplicate samples for PCB analysis through NYDSEC at the NYSDOH labs. In addition, since their standard procedure was whole water extraction, it was arranged that at least some of the samples also be analyzed as separate particle and filtrate fractions. This would allow a more direct comparison with the EPA sample analysis and provide a test of my general impression that whole water extraction would not be particularly efficient at recovering particle-associated PCBs. The suggestion was welcomed at NYSDEC and collaboration was facilitated by the fact that I had been employed there in 1990-91.

Analysis and interpretation of the data from this exercise was to form the basis of the Master's project of Christine Juliano. After an initial data gathering and analysis effort, Christine decided to work on a different project and completed her Master's. My preliminary look at the data indicated that whole water extraction missed a significant fraction of the particle-associated PCBs. Although based on very limited data, I have used this observation often to support my geochemical bias toward separate particle and filtrate extraction and analysis.

Over the past month, I have had two requests for a more quantitative assessment of this data. Both were related to water column monitoring associated with the proposed dredging. The first was from Kelly Robinson at Earth Tech (TAMS), the primary EPA contractor on the Upper Hudson River PCB project. A few days later, Roger Sokol of the NYSDOH requested similar information specifically for monitoring the Waterford, NY drinking water supply and raw water intake on the Hudson. I was able to locate files prepared by Christine Juliano that contained water column PCB data from the upper Hudson consistent with events described above.

More Detailed Information

The sample ID format and numbering used in the files indicates that the samples were collected during EPA transect 4 (April 12 to April 14, 1993) at Stillwater (0007), Waterford (0008), the Hoosic River (0012), Mohawk River (0013), and Green Island Bridge (site 0014). Two of the samples, Waterford and Green Island, have data for whole water and separate particle and filtered water analyses. Further confirmation of the identification of these samples comes from the fact that the TSS levels in the files prepared by Christine Juliano are identical to those reported for samples TW-0004-0008 (34.0 mg/l) and TW-0004-0014 (39.8 mg/l) in the EPA Database. More specific collection information can most likely be retrieved from the detailed field notes kept by Rensselaer personnel and submitted to TAMS a part of the official record of our work with EPA on the reassessment. The rest of this report will refer to the Waterford (004-0008, 04/13/93) and Green Island (004-0014, 04/13/93) samples.

As I recall, I was informed that the separation of particulate and dissolved phases for the NYSDOH analysis was accomplished by pouring the water sample through a soxhlet extraction thimble. This simple procedure should be comparable to separation by more standard filtration techniques that typically employ pre-fired glass fiber filters. The corresponding EPA samples that we collected were filtered by Kevin Reed of RPI through pre-fired Whatman GF/F filters. Soxhlet extraction thimbles used in PCB analyses are also treated to minimize blanks. Paper thimbles are typically pre-extracted and glass fiber thimbles are pre-fired.

Results

- In terms of total PCBs, the DOH values reported for the whole water extracts were about half of the (particulate + dissolved) PCBs in the replicate samples (Table 1).
- At the congener level, whole water extraction yielded results lower than (P + D) in every case with only one exception (BZ 24, 27). Figures 1 (Waterford) and 2

(Green Island) present data for a range of more abundant congeners that together comprise over half the total PCBs.

- The figures also show that the differences between whole water and (P + D) results tend to be less for the lower chlorinated congeners. This is consistent with a simple model of the whole water extraction process – complete recovery of dissolved PCBs and less efficient recovery of particulate phase PCBs.
- Based on this first order model applied at the congener level, the whole water extraction missed 61 ± 20% of the particle-associated PCBs in the Waterford sample (Table 2) and 72 ± 13% in the Green Island sample (Table 3).

Implications

- The above analysis provides support for the logical assumption that whole water extraction will result in an underestimate of total PCBs. It is also logical to assume that the degree of under-recovery would depend significantly on the details of the procedure (the number of extraction cycles, the solvent used, the percentage of solvent removed between extraction cycles, the degree of sample agitation etc.).
- If the simple model presented above is applied, the degree of under-recovery will also depend on the TSS in the sample. Using an average particle extraction efficiency of 33% (based on the DOH analyses) and an average upper Hudson PCB particle/water distribution coefficient of 10^5 (Bopp et al., Final Report to NYSDEC, Contract C00708, 1985), first-order error estimates can be made.

TSS (mg/l)	% of PCB on Particles	% under-recovery of total PCBs
2	17	11
10	50	33
40	80	53
100	91	61

- This analysis raises the possibility that historical (USGS) estimates of PCB transport in the upper Hudson that focused on high flow, high TSS, high transport events may be low by on the order of 50% and suggests a low bias to any transport estimates that utilize the weekly GE water column monitoring data.
- The potential for significant under-recovery of PCBs when using whole water extractions should be considered in the design of any future monitoring program.

Cc: Roger Sokol, NYSDOH

Tables

Table 1. 'Total PCBs in samples collected April 12 -14, 1993 (all PCB concentrations in ng/l)

	Waterford DOH	(0008) EPA	Green I DOH	(0014) EPA
Particulate	225.4	159.8	227.7	144.5
Dissolved	74.4	75.0	50.9	53.5
P + D	299.8	234.8	278.6	198.0
Whole Water	159.9		110.6	
TSS (mg/l)	34.0		39.8	

Table 2. 'Waterford

	004-0008 Whole Water	004-0008 Particulate	004-0008 Filtered Water	sum P+F		%P missed		%T missed
CONGENER								
BZ-10,BZ-4	17	9.5	13	22.5		58		24
BZ-19	4.8	2.3	3.6	5.9		48		19
BZ-18	12	5.1	6.9	12		0		0
BZ-15,BZ-17	11	8.5	5.8	14.3		39		23
BZ-16,BZ-32	4.3	3.5	2.8	6.3		57		32
BZ-31	7.5	12	4.2	16.2		73		54
BZ-28	8.3	14	4.6	18.6		74		55
BZ-20,BZ-33,BZ-53	3.6	5.6	2.1	7.7		73		53
BZ-52	6.4	9.5	3	12.5		64		49
BZ-49	5.6	8.8	2.2	11		61		49
BZ-47	4.4	7.6	1	8.6		55		49
BZ-44	3.7	6.2	1.5	7.7		65		52
BZ-37,BZ-42,BZ-59	1.2	3.2	1	4.2		94		71
BZ-41	3.1	5.3	1.2	6.5		64		52
BZ-70	4.8	11	1.6	12.6		71		62
BZ-66,BZ-95	7.8	18	2.1	20.1		68		61
BZ-110,BZ-77,BZ-136	2.3	6.4	***0.5***	6.9		72		67
Totals	107.8	136.5	57.1	193.6		61		45
					Std. Dev.	20	Std. Dev.	19
BZ-24,BZ-27	7.7	2.7	4	6.7		-37		-15

Table 3. Green Island

CONGENER	004-0014 Whole Water ng/L	004-0014 Particulate ng/L	004-0014 Filtered Water ng/L	sum P + F		%P missed		%T missed
BZ-10,BZ-4	13	8.5	9.9	18.4		64		29
BZ-19	3.8	1.7	3	4.7		53		19
BZ-18	7.9	5.1	5.2	10.3		47		23
BZ-15,BZ-17	7.4	8.9	4.1	13		63		43
BZ-16,BZ-32	3.3	3.5	2.2	5.7		69		42
BZ-31	5.3	13	2.5	15.5		78		66
BZ-28	5.9	15	2.7	17.7		79		67
BZ-20,BZ-33,BZ-53	3	5.7	1.7	7.4		77		59
BZ-52	4.6	8.6	2.1	10.7		71		57
BZ-49	4.1	8.6	1.5	10.1		70		59
BZ-47	3.2	6.7	***0.5***	7.2		60		56
BZ-44	3.7	6.2	1.5	7.7		65		52
BZ-37,BZ-42,BZ-59	1	3.1	1	4.1		100		76
BZ-41	2.2	9.4	1	10.4		87		79
BZ-70	3.3	10	1	11		77		70
BZ-66,BZ-95	5.3	15	1.1	16.1		72		67
BZ-110,BZ-77,BZ-136	1.7	6.4	1	7.4		89		77
TOTALS	78.7	135.4	42	177.4		72		55
					Std. Dev.	13	Std. Dev.	18
BZ-24,BZ-27	5.2	2.3	2.8	5.1		-4		-2

Figures

Figure 1
WATERFORD

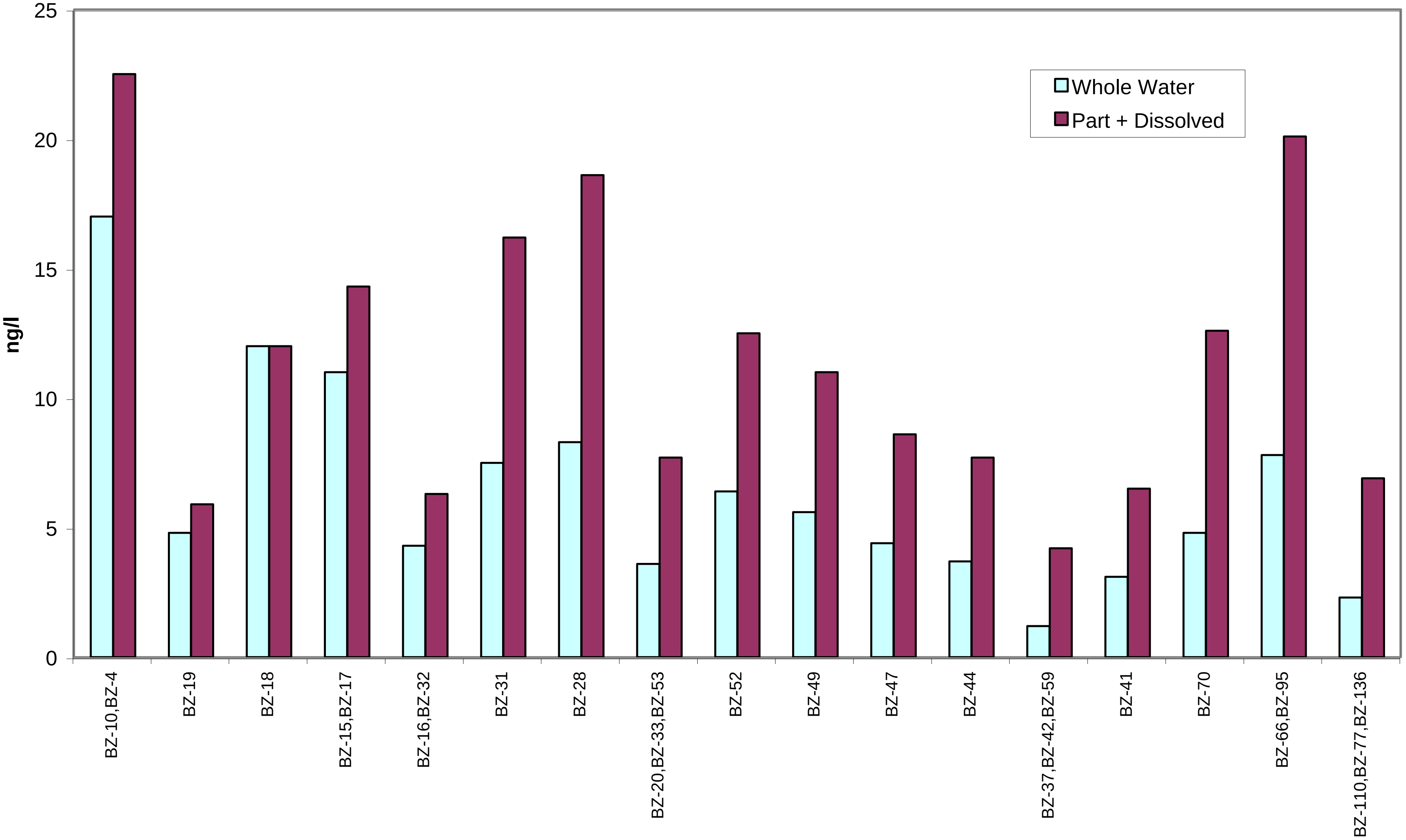
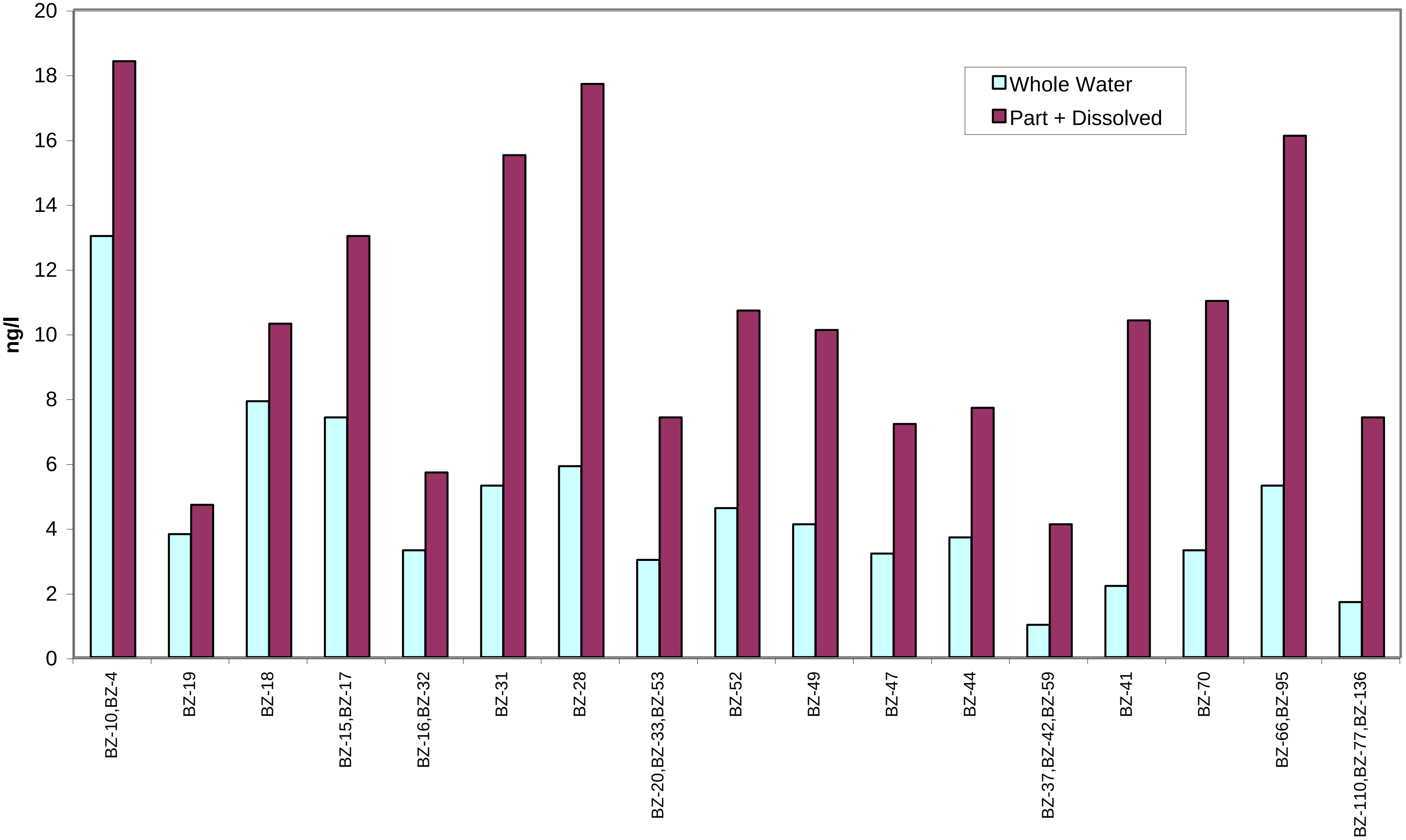


Figure 2
GREEN ISLAND



Attachment G

Statistical Justification of the Sampling Frequency for Phase 1 Monitoring Program

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Statistical Justification of the Sampling Frequency for Phase 1 Monitoring Program

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Attachment G

Statistical Justification of the Sampling Frequency for Phase 1 Monitoring Program

1.0 Introduction

The monitoring plan for the Resuspension Performance Standard is summarized in Tables 1-2, 1-3 and 1-4 of the main document. This attachment describes the adequacy of the sampling frequencies required as part of the routine monitoring programs, which are derived using United States Environmental Protection Agency (USEPA)-defined methods for assessing statistical uncertainty (USEPA, 2000). The analyses cover only routine monitoring and the minimum levels of contingency monitoring as defined in the Resuspension Standard. Additional monitoring related to the required engineering studies at the Control Levels (as well as exceedance of the standard threshold) may be required, depending on the anticipated cause of the exceedance. The design of these additional monitoring programs may be developed during the remedial design period. Alternatively, *ad hoc* monitoring plans may be developed by the design team during the actual dredging operation in response to observations made at the time.

A particular limitation to the analysis presented in this attachment is that little information on the variance of river conditions in response to dredging-related releases. Little data exist on which to develop the estimate of variance. As a result, the variation of baseline conditions was used as a means to estimate the variance for dredging operations. These estimates for sampling requirements and the associated error rates will require review once additional data become available during Phase 1.

2.0 Estimates of the Tolerable Error for the Monitoring Sampling Frequency Using Decision Error Feasibility Trials (DEFT) Software

The USEPA's guidance on data quality objectives (USEPA, 2000) was used in the development of the monitoring program for the Phase 1 dredging operation. This guidance describes a seven-step process for identification of the decision points and data needs associated with the environmental problem to be addressed. With regard to PCB releases via resuspension during the Phase 1 operation, there is a major concern to be resolved: How can the USEPA verify that PCB concentrations in the Upper Hudson River are in compliance with the resuspension criteria?

The focus of this analysis will be to design the appropriate sampling program, particularly the optimal sampling frequency that must be implemented to address the above-mentioned concern.

In the following discussion, the data quality objectives (DQO) process (USEPA QA-G4; USEPA, 2000) is applied as outlined below:

1. State the Problem
2. Identify the Decision
3. Identify the Inputs to the Decision
4. Define the Boundaries of the Study
5. Develop a Decision Rule
6. Specify Tolerable Limits on Decision Errors
7. Optimize the Design for Obtaining Data

A separate discussion is provided for each question. A summary of the sampling requirements is provided in Section 1 of the Resuspension Performance Standard.

3.0 Development of Data Quality Objectives

3.1 Statement of the Problem

The USEPA needs to verify that water column concentrations of PCBs in the Upper Hudson are below the Resuspension Standard criteria, thereby permitting unfettered dredging operations. If PCB concentrations are not within acceptable levels, then additional monitoring and possible modifications to the engineering operations may be required.

The USEPA staff represents the decision makers who will consult with General Electric Company (GE), the New York State Department of Environmental Conservation (NYSDEC), water supply operators, local government representatives, and non-government organizations.

The conceptual model is defined as follows:

- PCB loads and concentrations within the Upper Hudson are currently derived from sediment-based sources that contribute about 50 to 200 ng/L to the water column under typical flow conditions. These concentrations constitute baseline conditions. Dredging of contaminated sediments will add to this water column burden to some degree. Anticipated load additions due to dredging are expected to be less than 300 g/day (Evaluation Level threshold) under normal routine dredging for a 6-year remediation program. This is especially true for Phase 1, since the operation is planned at only half of the annual production rate anticipated for Phase 2.

- Although the mean daily Total PCB load increase due to dredging is expected to be well below 300 g/day, instantaneous conditions may result in momentary fluxes that are much higher. Consistent Total PCB loads higher than 300 g/day are considered indicative of problems in the dredging operation and warrant further study. Exceedance of the 300 g/day threshold does not constitute an immediate risk to human or ecological health but rather will delay the recovery of the river if allowed to continue for long periods of time. Similarly, exceedance of the 600 g/day action level does not represent an immediate risk to human or ecological health, but, as is the case a 300 g/day load, an extended amount of time above this action level will delay the river's recovery.

- Total PCB concentrations in excess of 350 ng/L alone do not represent a risk to downstream users so long as levels remain below the drinking water maximum contaminant level (MCL) of 500 ng/L (total) PCBs. However, the proximity of this level (350 ng/L) to the MCL warrants more careful scrutiny and closer observation if 350 ng/L is exceeded due to the short transit time from the dredging area to the nearest public water supply intakes (two to seven days).

- Suspended solids data will provide an indication of increased PCB contamination in the water column. Net far-field suspended solids concentrations must be below 12 mg/L to be at routine levels and below 24 mg/L to be at or below the Evaluation Level. Net near-field suspended solids concentrations (as defined in the Resuspension Standard) must be below 60 mg/L, 100 mg/L, or 700 mg/L, depending on the location of the station relative to the dredge and the river section in which dredging is occurring. The duration of the exceedances provides an indication of the severity of the exceedance and the required response.

3.2 Identify the Decision

Depending on the magnitude of the dredging-related PCB load increase, the USEPA may decide to do one or more of the following as described in Section 1 of this document:

- Increase monitoring frequency;
- Modify monitoring techniques;
- Modify dredging operations;
- Add additional engineering controls to the dredging operation; or
- Suspend the dredging operation until the PCB release problem has been resolved

The primary question governing this decision is: Are water column concentrations in compliance with the resuspension criteria? If water column concentrations are not in compliance, required actions involve collection of additional samples to further define the PCB loads if the requirements of the first decision statement are met, with further increases in monitoring and the possibility or requirement of engineered modifications to the operation, as described in the standard.

3.3 Identify the Inputs to the Decision

To determine net PCB loads due to dredging (i.e., the total load less the baseline), the following data are needed:

- Instantaneous and mean daily river flow at all monitoring locations
- PCB concentrations at multiple monitoring locations, including the first far-field station downstream of the dredging operation and extending to Waterford.
- PCB concentration at a location upstream of the dredging operation (specifically Rogers Island)
- Suspended solids concentrations
- Total organic carbon (TOC) on suspended solids
- Dissolved organic carbon content (DOC; *i.e.*, TOC on filtered water samples)

- Historical concentrations of PCBs, suspended solids, TOC on suspended solids at each of the main monitoring locations

The first six items listed above are used to characterize the actual conditions during dredging. The seventh item is used to provide a basis for comparison to establish the net load relative to the historical baseline conditions. The difference between baseline conditions and conditions measured during dredging is the net increase in PCB concentration due to dredging activities at each monitoring location. The product of the mean daily flow and this concentration difference yields an estimate of the net load increase for comparison against the load-based criteria. Suspended solids and PCB concentration data will be used together to examine the usefulness of a suspended solids-PCB correlation to estimate PCB levels based on suspended solids monitoring alone.

The methods for sample analysis include:

- PCB congeners with a detection limit of 0.5 ng/L total PCBs. The effective congener detection limit is roughly 0.05 ng/L Currently this can only be achieved by one of the following: EPA's dual column GC/ECD method, Standard Method 1668A or GE's modified Green Bay Method.

- Total Suspended Sediment with a detection limit of 0.1 mg/L, by Analytical Method ASTM D3977-97, Standard Test Method for Determining Sediment Concentration in Water Samples, or equivalent. No subsampling of a sampling container is permitted.

- Organic carbon on the suspended solids can be done via a Total Organic Carbon method or by a combustion technique but must be sensitive down to 0.1% (1000 mg/kg) on the suspended solids.

- Dissolved organic carbon method should have a detection limit of 0.5 mg/L, such as ASTM Method D4839-03 [0.1 mg/L] or EPA 415.2 [.05 mg/L].

3.4 Define the Boundaries of the Study

The boundaries of the site are defined as the shorelines of the Hudson River, excluding its tributaries, between the Fennimore Bridge at Hudson Falls and the Federal Dam at Troy. The Fennimore Bridge is included as the upper boundary, rather than the northern end of Rogers Island, because of the potential for PCB releases associated with the remediation of the GE Hudson Falls facility that will be taking place at the same time or just prior to the sediment remediation.

In recognition of the need to simplify monitoring, both project data needs and ease of access will be considered when choosing monitoring locations. The following stations, all of which are accessible by bridge, were selected based on access considerations:

- Fennimore Bridge
- Rogers Island
- Schuylerville
- Stillwater
- Waterford

These locations also roughly divide the river into 10 to 15 mile segments, providing sufficient resolution to identify potential PCB sources by location. The separation of these locations also allows natural hydrodynamic processes to homogenize PCB concentrations in the river, simplifying the sampling process.

Given that most of the dredging is scheduled for the Thompson Island (TI) Pool, an additional monitoring location is identified at the TI Dam so as to better identify loads originating in this reach.

Because dredging-related releases will depend on many factors related to dredge operation, sediment type and location with in the river, the PCB load is expected to vary significantly over time. Daily monitoring is considered a minimum basis for determining compliance with the lowest (most stringent) secondary criterion of 300 g/day. When this threshold is exceeded, a higher frequency of monitoring will used to document and understand the sources of PCBs to the water column.

The loads released by dredging are expected to vary rapidly over time and thus will need to be reviewed daily. Sampling when routine conditions are expected will measure the daily variability. The weekly variability, as defined by a 7-day running mean calculated daily, will be used to test compliance with the load-based criteria. This technique will allow confirmation of compliance with the long-term load criterion while also collecting data to demonstrate that more significant exceedances of PCB concentration criteria (*e.g.*, exceeding 350 or 500 ng/L) have not occurred.

The transit time of water from the TI Pool to Waterford is expected to vary from two to seven days, depending inversely on flow. As a result of the normal dispersion and settling processes, the intensity of any short-term PCB release is expected to be diminished as the river travels from TI Pool to Waterford. Thus, for a dredging operation in the TI Pool, the discrete sample collected at TI Dam has not undergone the same level of integration as a sample obtained at Waterford. Thus collecting samples along the Upper Hudson serves to examine both short-term (one hour duration) and longer-term (one- to two-day duration) PCB loads and PCB concentrations. Both measures are needed to assess the success of the resuspension controls.

The sampling program must reflect the need to assess gradual increases in long-term impacts, such as PCB mass transported downstream and the consideration of acute PCB concentrations at downstream public water supplies. The long-term averages (7-day period) and daily results are required to assess such long term impacts. To address the protection of downstream water supplies, 24-hour turn-around times are needed for the two monitoring stations downstream of, but closest to, the dredge operation. For Phase 1, these are expected to be the TI Dam and Schuylerville stations. Based on the above considerations, and those of the standard, the decision units are the loads as measured weekly and the concentrations measured daily.

The results from the two far-field stations closest to the dredging operations provide some indication of what the downstream PCB levels. However, due to the highly variable nature of the PCB release process, samples must still be collected from locations farther downstream and the concentrations confirmed to be in compliance with the standard. These samples can have a longer turn around time, on the order of 7 days from collection to result, since their role is primarily confirmational. These samples are necessary during Phase 1 but may be dropped in Phase 2, depending on the success of the suspended solids monitoring and the actual PCB loss rates.

3.5 Develop a Decision Rule

The decision rules are derived from the performance standard criteria described in Volume 1 of the document and justified in Sections 2 and 3 of Volume 2 of the document. The decision rule is designed to test compliance with the standard criteria.

The arithmetic mean is selected as the primary measure since it reflects an integration of several measures and representative of the integrated PCB load over the averaging period. Compliance with each of the resuspension criteria is the primary focus of this DQO discussion.

3.6 Specify Tolerable Limits on Decision Errors

Current estimates of PCB release due to dredging, as developed in other attachments to this document, indicate that PCB loads and concentrations are likely to fall below the action level criteria during most of the operation. More specifically, the estimates of PCB release indicate that when the PCB loads and concentrations are viewed on a daily or weekly basis, momentary flux variations will average out so as to fall below the action level criteria. Additionally, the threshold criteria developed for the decision rules do not represent conditions immediately dangerous to human health or the environment. Based on this, the null hypothesis for the decision rule is taken as the condition that the river is in compliance (*i.e.*, the river flux or concentration of total PCBs is below the criteria value). This approach also takes into consideration that daily monitoring will continue, and that confirmation of any day's decision about dredging releases and water column concentration will be obtained in the next sample taken.

USEPA's Decision Error Feasibility Trials Software (DEFT (USEPA, 2001)) was used to develop the sampling requirements for this program. The results of this analysis are presented in Table 1.As defined in USEPA (2001):

- A *false acceptance* decision error occurs when the sample data lead you to decide that the baseline condition is probably true when it is really false.

- A *false rejection* decision error occurs when the limited amount of sample data lead you to decide that the baseline condition is probably false when it is really true.

- The *gray region* is a range of true parameter values within the alternative condition near the Action Level where it is "too close to call."

False acceptances were minimized because it is the more serious error. In general, decisions that were more critical, such as confirmation of exceedance of the Resuspension Standard which requires the shut down of operations, or exceedance of the Control Level which requires intense monitoring and implementation of engineering evaluations and solutions, required a large number of samples and had greater certainty than the less critical decisions. For the suspended solids measurements, it was clear that the implementation of a continuous monitor capable of estimating suspended solids concentrations would be needed to provide a reasonable amount of certainty in these decisions. The low level of certainty is tolerable only because any decisions made as a result of an exceedance of the suspended solids will be confirmed by measurements of PCB concentrations in the impacted water column.

For PCB measurement-based decisions, a false acceptance rate of 5 percent or less was sought, with lower rates sought when an incorrect decision would yield an unnecessary halting of the operation or an engineering improvement. The rate of 5 percent was selected as an acceptable error for the lower action level criteria, since exceedance of the action level criteria only initially induces additional monitoring which will quickly confirm the exceedance. This error rate reflects a balance between setting the monitoring requirements as low as possible while still providing protection.

3.7 Optimize the Design for Obtaining Data: Results of the Analysis

The final sampling requirements for the standard were developed using DEFT (USEPA, 2001), a program to estimate sampling requirements based on a project-specific error rate. Table 1 summarizes the analysis of the various criteria, acceptable *gray region* around each criterion, the sampling frequency required by the resuspension standard, and the false acceptance and false rejection levels. The table is organized by measurement type (*i.e.*, PCB and suspended solids). For all criteria except the confirmation of the 500 ng/L exceedance, the null hypothesis assumed that river conditions were in compliance.

Two important assumptions were made to develop the error rate values in the table. There is no site-specific data on the expected variance of water column conditions related to dredging. As a result, the extensive analysis of variance compiled in Attachment A was used. A nominal coefficient of variance was assumed for PCBs and suspended solids based on the variance observed under baseline conditions. For PCB measurements (both

Total PCBs and Tri+), the coefficient of variance is assumed to be 25 percent. For suspended solids, the coefficient of variance was assumed to be 75 percent.

This section also includes a set of figures illustrating the statistical calculations used to estimate the error rates. Figures 1 to 25 represent the calculations for each line in Table 1.

Table 1 shows that the higher level of sampling associated with the higher action levels and the and Resuspension Standard yield low false error rates, reflecting the need to be accurate before taking costly actions or improvements. In some instances, the false rejection rate is fairly high, indicating that additional sampling may be unnecessarily triggered. However, this represents a protective approach from the perspective of ensuring the safety of public water supplies. Additionally, the higher monitoring rates will quickly confirm the need to remain at the action level thought to be exceeded.

Higher error rates were estimated in the transition from routine conditions to the Evaluation and Control Levels, reflecting the relative low sampling rate required for routine sampling. Also shown in the table is the one week confirmation result (*i.e.,* the error rate for the combination of one week of routine monitoring and one week at the action level). In each instance, the false acceptance error was brought below 5 percent, thereby confirming the need to sample at the higher rate or indicating that sampling at the routine rate may be resumed.

The results for the monitoring requirements implemented after exceedance of the standard demonstrate the need for the intensive sampling specified. In this instance the river is assumed be in exceedance of the standard. Four additional discrete samples (Figure 7) do not provide sufficient certainty given that the next day's decision will involve the temporary halting of the dredging operations. However, by collecting hourly composites, the power of the same four analyses is greatly improved and the 5 percent false acceptance rate is attained.

Table 1 also presents the results for the long-term integrative samples. These samples will serve to confirm the results of the daily routine monitoring, or indicate that more frequent sampling is warranted. The results assume the automated collection of eight samples per day over a one- to two-week period.

The results for suspended solids illustrate the need to use a continuous sampling system such as a turbidity probe. In the lower portion of the table, results for the discrete sampling program are compared with those that can be achieved with a continuous probe taking a reading once every 15 minutes. In almost all cases, the continuous reading probe provided more than an order of magnitude improvement in the expected error rate. Better rates can be achieved using the continuous probes by simply taking data more frequently.

Note that this analysis does not consider any uncertainty introduced by use of a probe over discrete samples. Nonetheless, given a semi-quantitative relationship between the probe and the actual suspended solids levels, it is highly likely that the probes will provide a substantial reduction in the expected error rates for suspended solids monitoring, reducing unnecessary additional PCB sampling prompted by a false indication.

Figures 26 through 28 show the Total PCB sampling requirements for the evaluation and control levels to achieve 5 percent false acceptance and false rejection rates if automatic samplers were used. Using the automated sampler, one composite sample with 24 aliquots (i.e., 1 aliquot per hour) is collected each day. At the evaluation level, to achieve the false acceptance and false rejection rate of 5 percent, 2 composite samples with 24 aliquots of each sample are needed (Figure 26). This means that data from at least two days are needed to be certain that the evaluation level is exceeded. Three composite samples with 24 aliquots each sample are needed to be certain that that 600 g/day Total PCB load action level is exceeded at the control level (Figure 27). For a concentration exceedance at the control level, four composite samples with 24 aliquots each sample are needed to achieve false acceptance and false rejection rates of 5 percent (Figure 28).

Table 2 summarizes the various criteria, the associated gray region, the sampling frequency required by the resuspension standard, and the false acceptance and false rejection levels when the automatic sampler is used. Figures 29 through 34 illustrate the statistical calculations used to estimate the error rates for each line of Table 2. Using the automatic sampler, the error rates for most of the sampling requirements are less than 1 percent. The highest error rate was about 2 percent for the false rejection of the sampling requirement from evaluation to control level. However, this value is still below 5 percent error rate. This analysis shows that the power of the sampling program for Total PCB using automatic sampler is greatly improved.

4.0 References

USEPA, 2000. Guidance for the Data Quality Objectives Process EPA/600/R-96/055. August 2000.

USEPA, 2001. Data Quality Objectives Decision Error Feasibility Trials Software (DEFT) - USER'S GUIDE. EPA/240/B-01/007. September 2001.

Tables

Table 1
Summary of Sampling Frequency Requirements and Expected Error Rates

Analysis	Transition	Detail	Sampling Time Period	Action Level	Number of Samples[1]	Grey Region Limit	False Rejection Error Limit - a (%)	False Acceptance Error Limit - b (%)	Figure Number
Total PCB Sampling Requirements (25% CV)									
Far Field									
	Routine to Evaluation Level	Routine to > 300 g/day	1 week	300 g/day	7 (1 sample/day for 1 week)	400 g/day	7.5	5	1
	Routine to Control Level	Routine to > 600 g/day	1 week	600 g/day	7 (1 sample/day for 1 week)	700 g/day	25	15	2
	Confirmation of the Control Level	Confirmation of > 600 g/day	1 week routine + 1 week	600 g/day	28 (7 samples routine + 21 samples control level)	700 g/day	5	4	3
	Routine to Control Level	Routine to > 350 ng/L	1 week	350 ng/L	7 (1 sample/day for 1 week)	400 ng/L	27.5	20	4
	Confirmation of the Control Level	Confirmation of > 350 ng/L	1 week routine + 1 week	350 ng/L	28 (7 samples routine + 21 samples control level)	400 ng/L	10	5	5
	Evaluation to Control Level	300 g/day to > 600 g/day	1 week evaluation + 1 week	600 g/day	35 (14 samples evaluation level + 21 samples control level)	700 g/day	4	2	6
	Resuspension Standard Threshold	Confirmation of > 500 ng/L[2]	1 day routine + 1 day	500 ng/L	5 (1 sample routine + 4 samples confirmation)	400 ng/L	15	30	7
		Confirmation of > 500 ng/L (24 hours)[2]	1 day	500 ng/L	4 composites of 6 aliquots each	400 ng/L	5	7	8
	Routine to Control Level	Continuous Total PCB 1-week or 2-week deployment	1 week or 2 weeks	350 ng/L	2 composites of 56 aliquots each	400 ng/L	6.5	5	9
Suspended Solids Sampling Requirements (75% CV)									
Far Field									
	Routine to Evaluation Level	Far-field - Baseline to > 12 mg/L	1 day (3 hrs for 24 hrs)	14 mg/L	8 (discrete)	21 mg/L	27.5	12.5	10
			1 day (15 min for 24 hrs)	14 mg/L	96 (continuous)	21 mg/L	0.1	0.1	11
	Routine to Control Level	Far-field - Baseline to > 24 mg/L	1 day (3 hrs for 24 hrs)	26 mg/L	8 (discrete)	39 mg/L	27.5	12.5	12
			1 day (15 min for 24 hrs)	26 mg/L	96 (continuous)	39 mg/L	0.1	0.1	13
	Evaluation to Control Level	Far-field - 12 mg/L to > 24 mg/L	1 day evaluation + 1 day	26 mg/L	16 (discrete)	39 mg/L	15	5	14
			1 day evaluation + 1 day	26 mg/L	192 (continuous)	39 mg/L	0.5	< 0.5	15
Near Field									
	Routine to Control Level	Near Field - River Sections 1 and 3	6 hours (1 sample per 3 hours)	100 mg/L	3 (discrete)	150 mg/L	35	25	16
		Baseline to > 100 mg/L	6 hours (1 sample per 15 min)	100 mg/L	24 (continuous)	150 mg/L	6.6	5	17
	Routine to Control Level	Near Field - River Section 2	6 hours (1 sample per 3 hours)	60 mg/L	3 (discrete)	90 mg/L	35	25	18
		Baseline to > 60 mg/L	6 hours (1 sample per 15 min)	60 mg/L	24 (continuous)	90 mg/L	6.6	5	19
	Evaluation to Control Level	Near Field - River Sections 1 and 3	1 day (3 hrs for 15 hrs)	100 mg/L	5 (discrete)	150 mg/L	27.5	20	20
		Baseline to > 100 mg/L	1 day (15 min for 15 hrs)	100 mg/L	60 (continuous)	150 mg/L	0.7	0.5	21
	Evaluation to Control Level	Near Field - River Section 2	1 day (3 hrs for 15 hrs)	60 mg/L	5 (discrete)	90 mg/L	27.5	20	22
		Baseline to > 60 mg/L	1 day (15 min for 15 hrs)	60 mg/L	60 (continuous)	90 mg/L	0.7	0.5	23
	Routine to Evaluation Level	Near Field	3 hours (1 sample per 3 hours)	700 mg/L	2 (discrete)	1000 mg/L	40	30	24
		Baseline to > 700 mg/L	3 hours (1 sample per 5 min)	700 mg/L	36 (continuous)	1000 mg/L	16.5	5	25

Note

[1] Sampling frequency at the different action level can be found in Table 1-2 of Volume 1 of the document

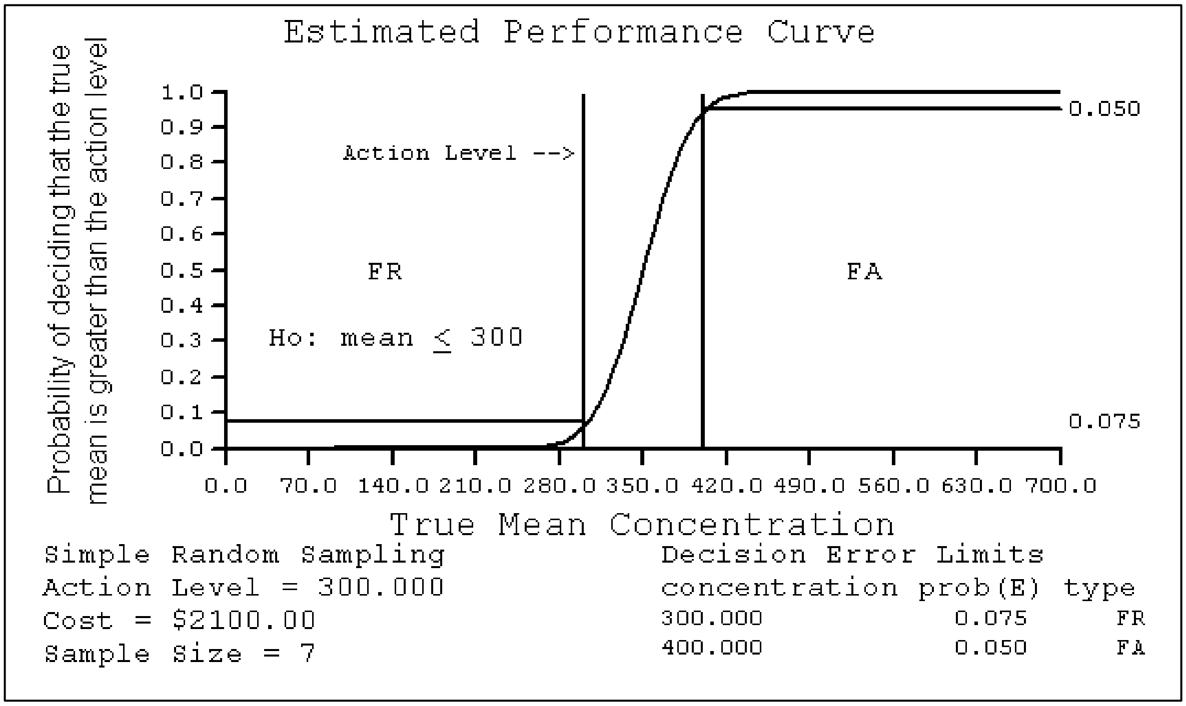
[2] Null hypothesis for the 500 ng/L assumed that river conditions were not in compliance, for all other action levels, the null hypohesis assumed that river conditions were in compliance. See text for discussions.

Table 2
Summary of Sampling Frequency Requirements and Expected Error Rates for Automatic Sampler

Analysis	Transition	Detail	Sampling Time Period	Action Level	Number of Samples	Grey Region Limit	False Rejection Error Limit - a (%)	False Acceptance Error Limit - b (%)	Figure Number
Total PCB Sampling Requirements (25% CV) **Far Field**									
	Routine to Evaluation Level	Routine to > 300 g/day	1 week	300 g/day	7 composites of 24 aliquots each (1 sample/day for 1 week)	400 g/day	0.1	<0.1	29
	Routine to Control Level	Routine to > 600 g/day	1 week	600 g/day	7 composites of 24 aliquots each (1 sample/day for 1 week)	700 g/day	0.5	0.1	30
	Confirmation of the Control Level	Confirmation of > 600 g/day	1 week routine + 3 day	600 g/day	10 (7 samples routine + 3 samples control level)	700 g/day	0.5	<0.5	31
	Routine to Control Level	Routine to > 350 ng/L	1 week	350 ng/L	7 composites of 24 aliquots each (1 sample/day for 1 week)	400 ng/L	1	1	32
	Confirmation of the Control Level	Confirmation of > 350 ng/L	1 week routine + 3 day	350 ng/L	10 (7 samples routine + 3 samples control level)	400 ng/L	0.5	<0.5	33
	Evaluation to Control Level	300 g/day to > 600 g/day	2 day evaluation + 3 day	600 g/day	5 (composite sampling every 1 hour, 1 sample/day)	700 g/day	2	1	34

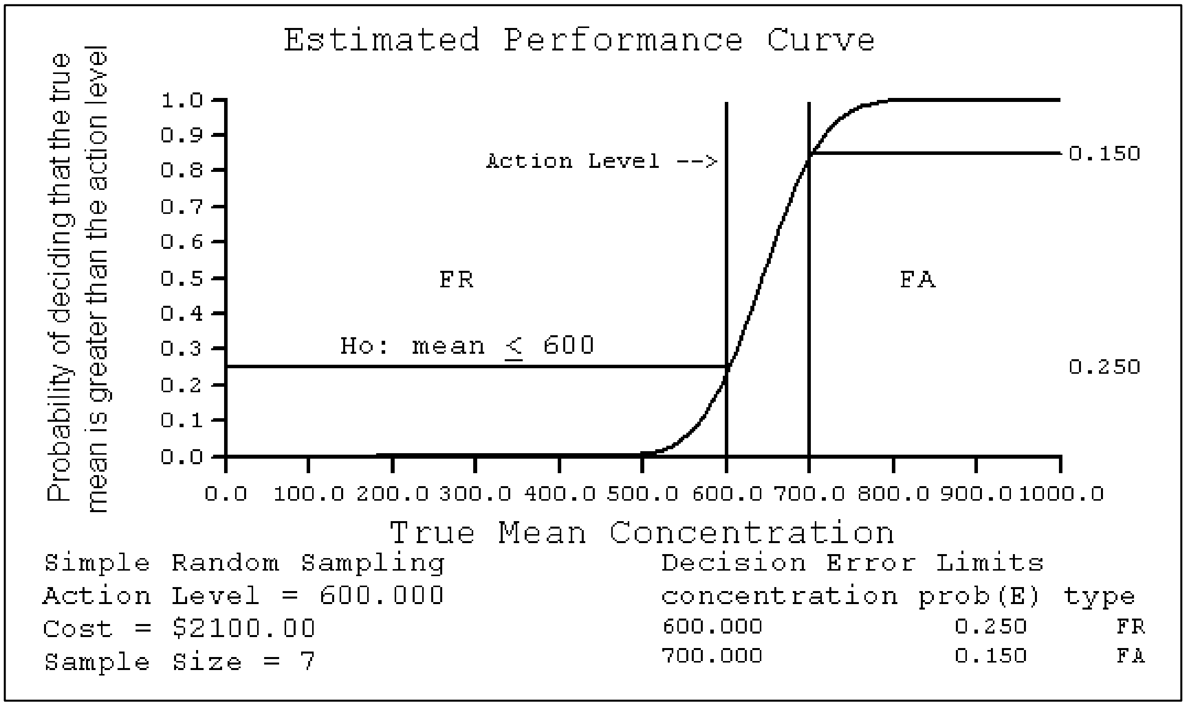
Figures

Figure 1
Routine to Evaluation Level
Action level of 300 g/day



```
Simple Random Sampling                Decision Error Limits
Action Level = 300.000                concentration prob(E) type
Cost = $2100.00                       300.000          0.075   FR
Sample Size = 7                       400.000          0.050   FA
```

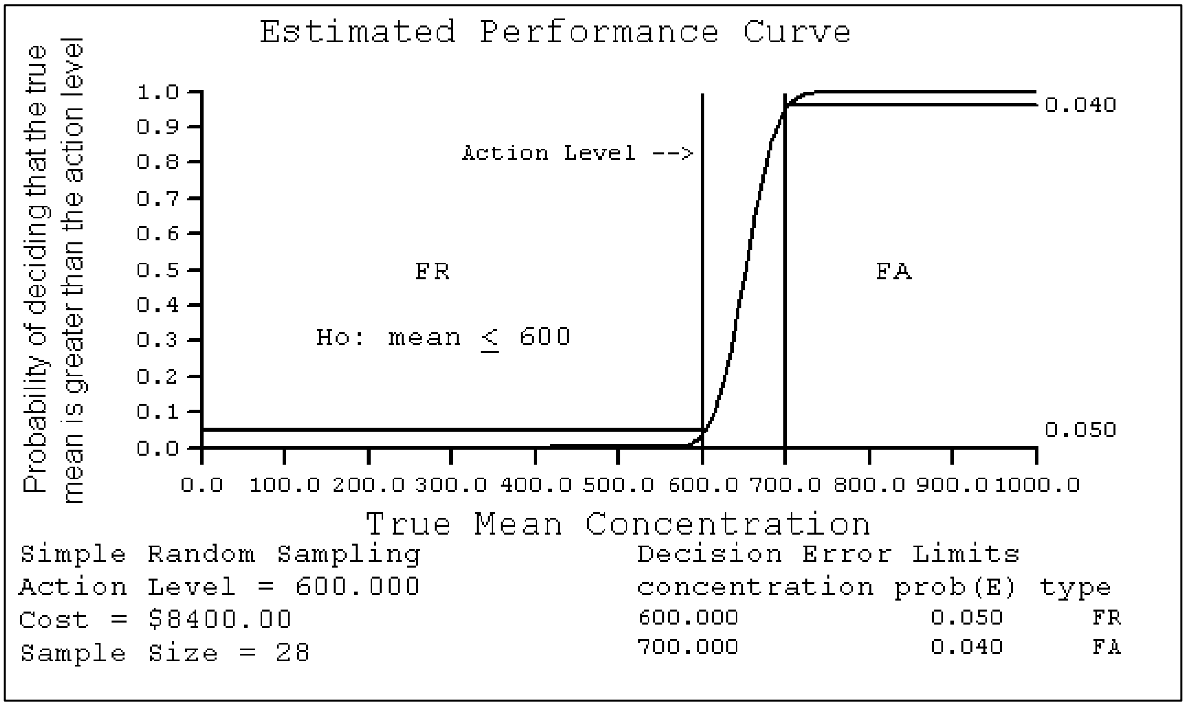
Figure 2
Routine to Control Level
Action Level of 600 g/day



```
Simple Random Sampling                Decision Error Limits
Action Level = 600.000                concentration prob(E) type
Cost = $2100.00                       600.000          0.250   FR
Sample Size = 7                       700.000          0.150   FA
```

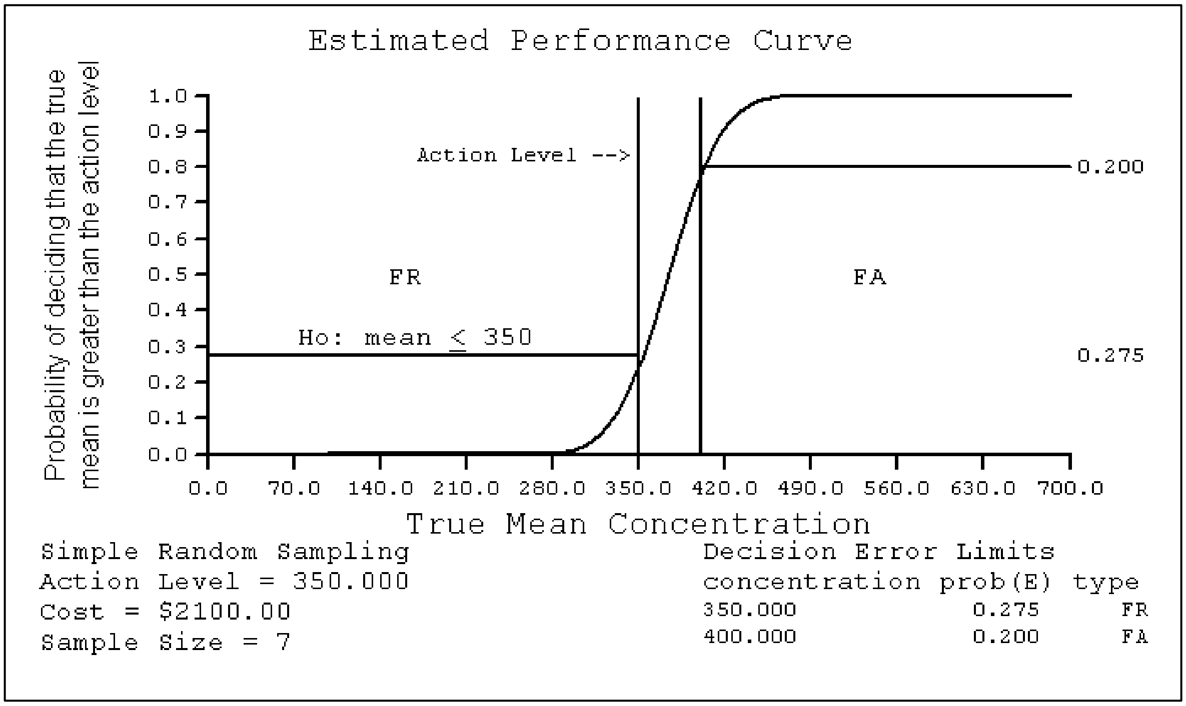
Note: Figures generated from DQO – DEFT using a coefficient of variation for all total PCB cases of 25 percent.

Figure 3
Confirmation of the 600 g/day
Action Level of 600 g/day



```
Simple Random Sampling          Decision Error Limits
Action Level = 600.000          concentration prob(E) type
Cost = $8400.00                 600.000        0.050    FR
Sample Size = 28                700.000        0.040    FA
```

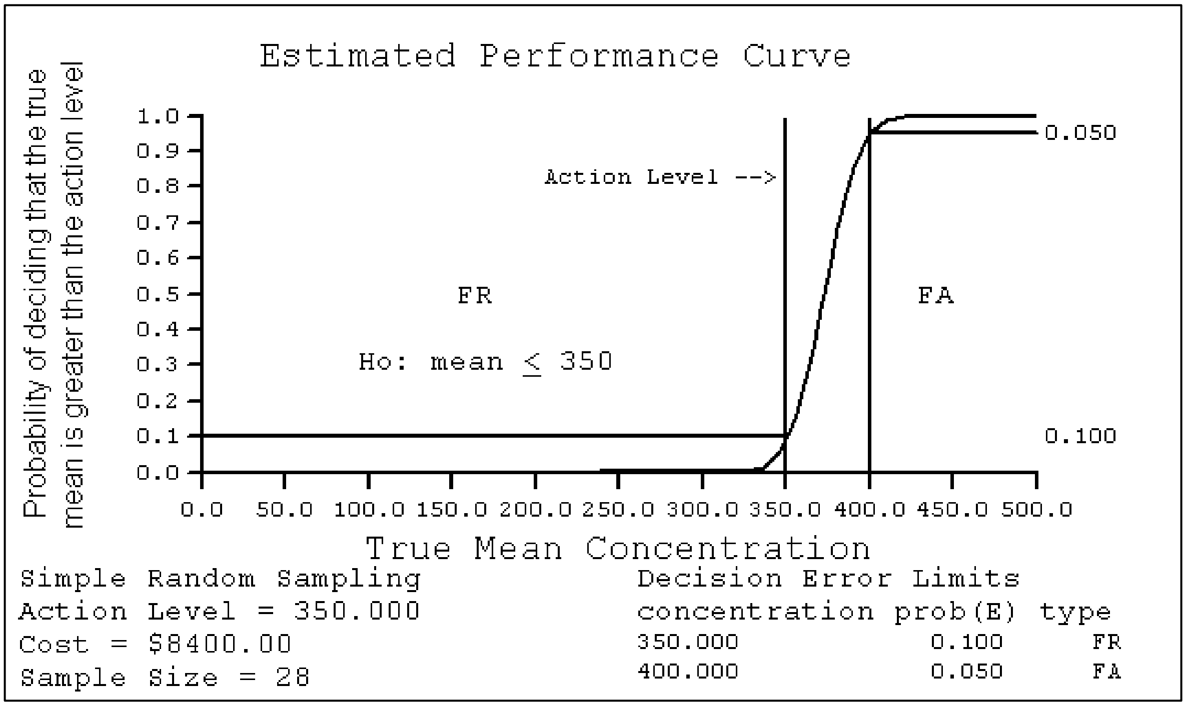
Figure 4
Routine to Control Level
Action Level of 350 ng/L



```
Simple Random Sampling          Decision Error Limits
Action Level = 350.000          concentration prob(E) type
Cost = $2100.00                 350.000        0.275    FR
Sample Size = 7                 400.000        0.200    FA
```

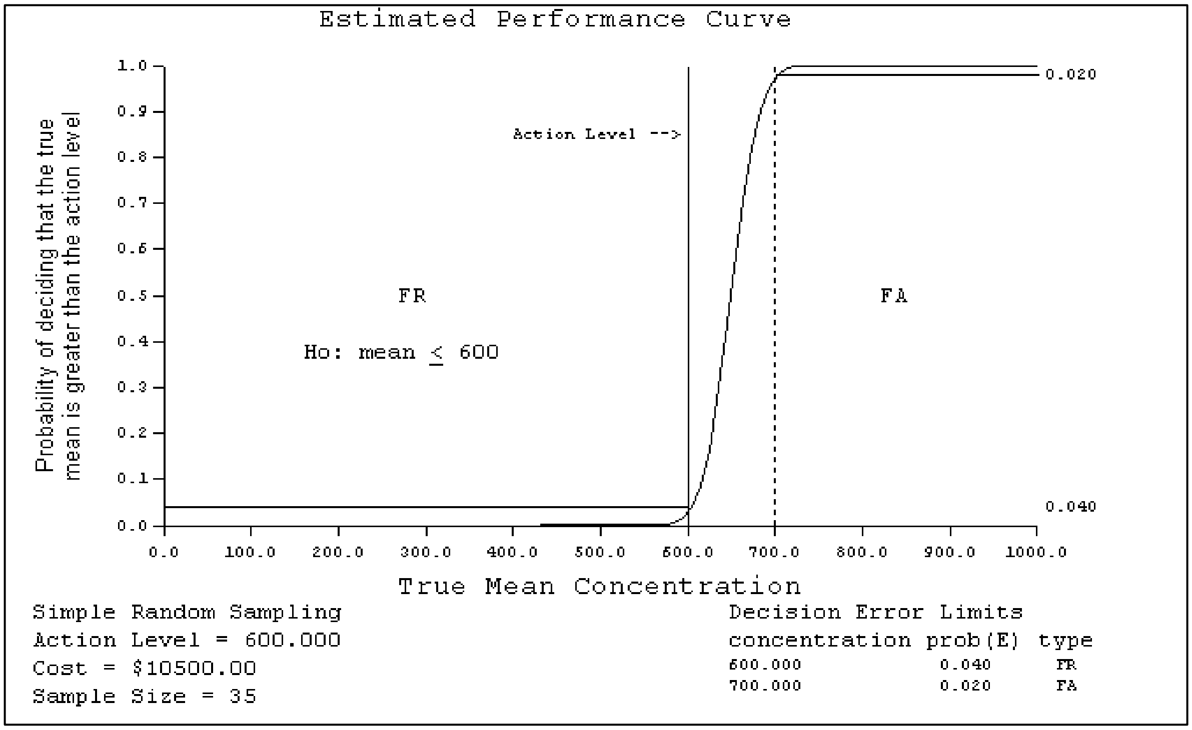
Note: Figures generated from DQO – DEFT using a coefficient of variation for all total PCB cases of 25 percent.

Figure 5
Confirmation of the 350 ng/L
Action Level of 350 ng/L



```
Simple Random Sampling          Decision Error Limits
Action Level = 350.000          concentration prob(E) type
Cost = $8400.00                 350.000          0.100    FR
Sample Size = 28                400.000          0.050    FA
```

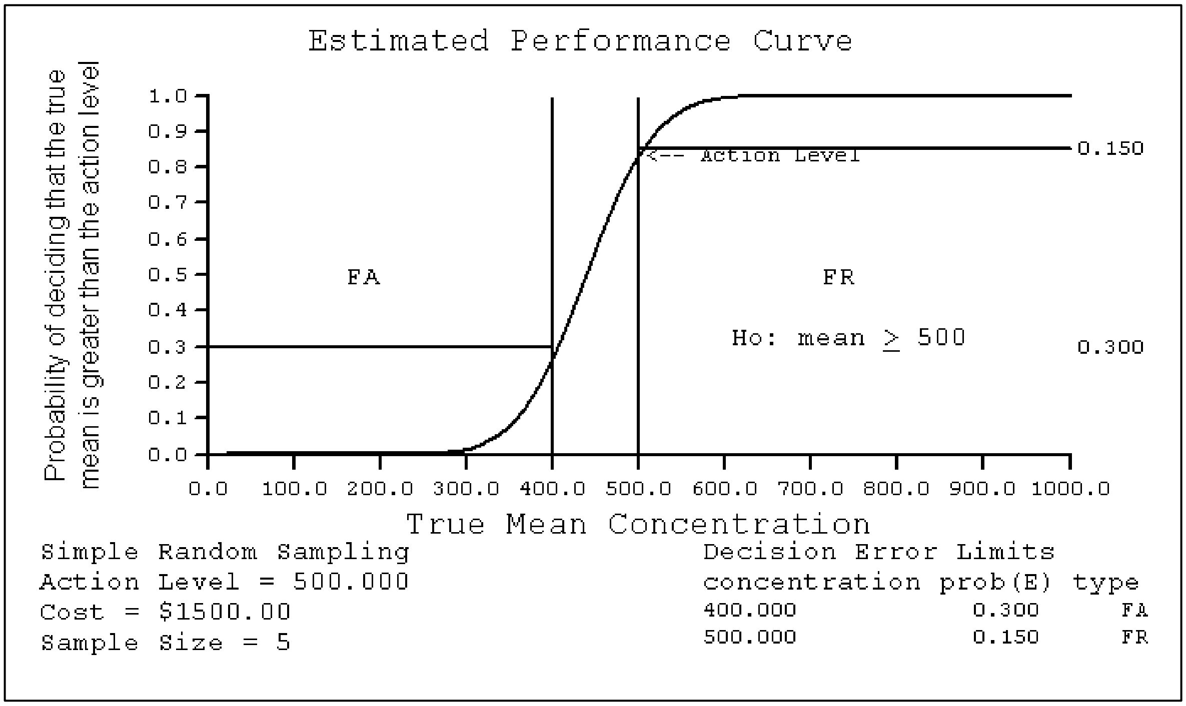
Figure 6
Evaluation Level to Control Level
300 g/day to 600 g/day



```
Simple Random Sampling          Decision Error Limits
Action Level = 600.000          concentration prob(E) type
Cost = $10500.00                600.000          0.040    FR
Sample Size = 35                700.000          0.020    FA
```

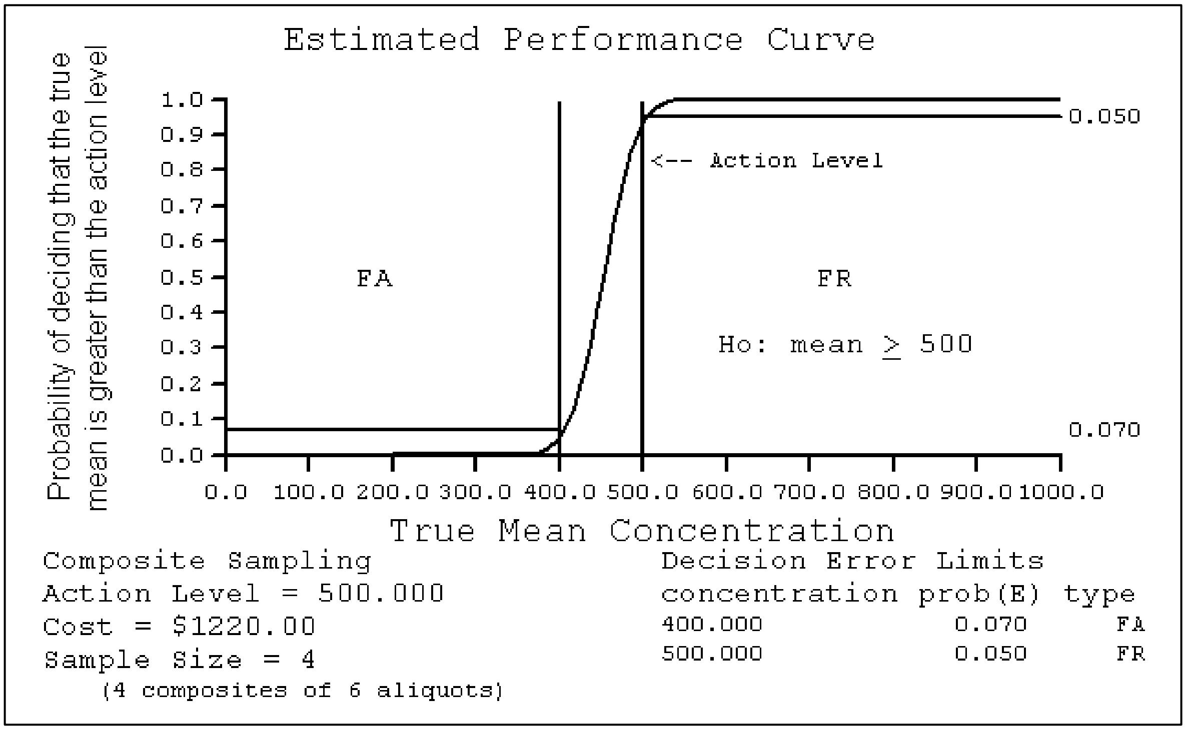
Note: Figures generated from DQO – DEFT using a coefficient of variation for all total PCB cases of 25 percent.

Figure 7
Resuspension Threshold
Confirmation of 500 ng/L



```
Simple Random Sampling                      Decision Error Limits
Action Level = 500.000                      concentration prob(E) type
Cost = $1500.00                             400.000           0.300    FA
Sample Size = 5                             500.000           0.150    FR
```

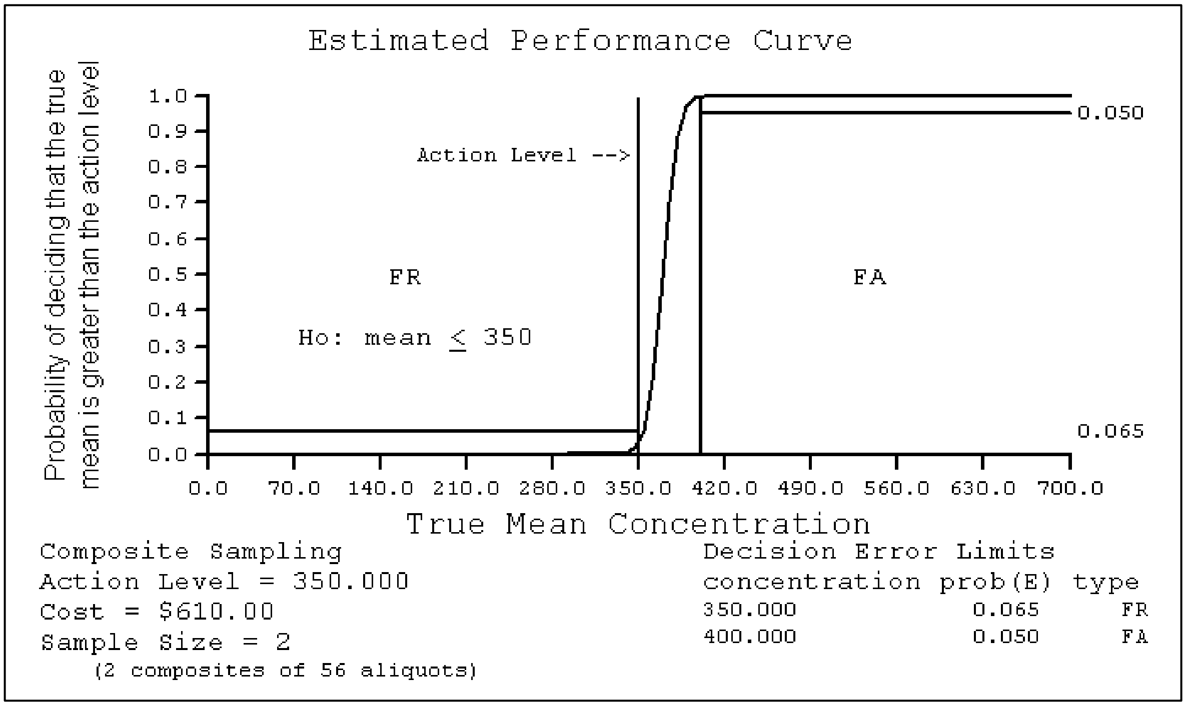
Figure 8
Resuspension Threshold
Confirmation of 500 ng/L (24 hours; 4 samples of 6 aliquots)



```
Composite Sampling                       Decision Error Limits
Action Level = 500.000                   concentration prob(E) type
Cost = $1220.00                          400.000          0.070    FA
Sample Size = 4                          500.000          0.050    FR
    (4 composites of 6 aliquots)
```

Note: Figures generated from DQO – DEFT using a coefficient of variation for all total PCB cases of 25 percent.

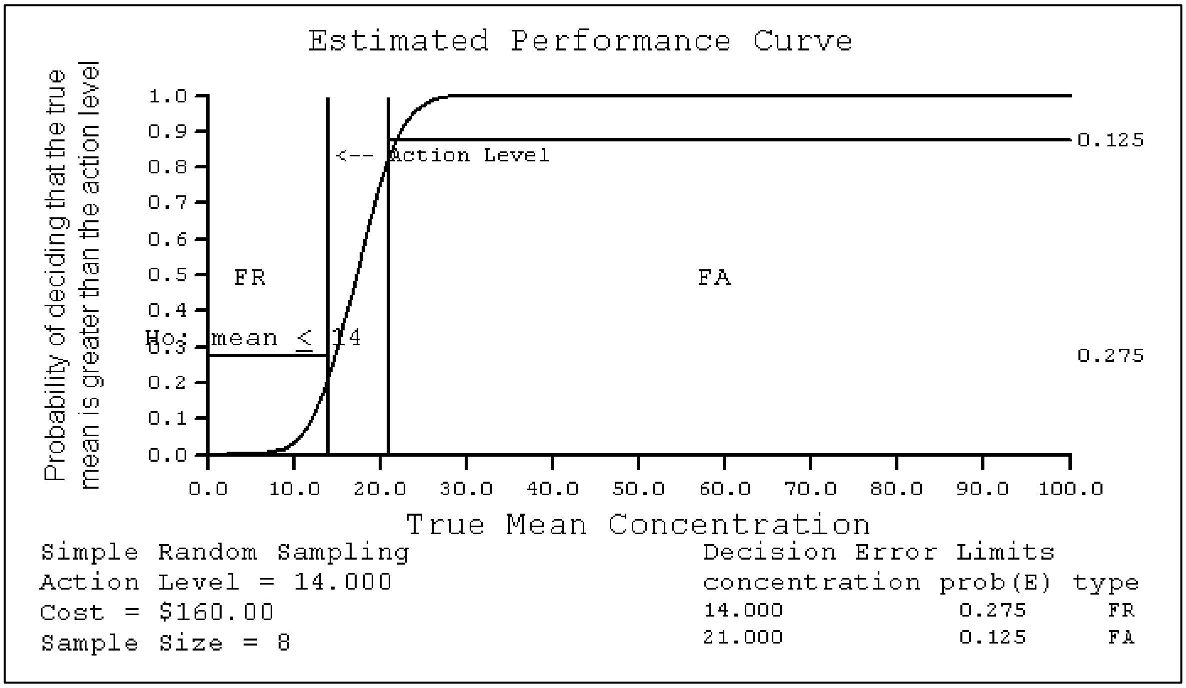
Figure 9
Routine to Control Level (350 ng/L, 2-week deployment) or Evaluation Level to Control Level (350 ng/L, 1-week deployment) Continuous total PCB sampling requirements



```
Composite Sampling                  Decision Error Limits
Action Level = 350.000              concentration prob(E) type
Cost = $610.00                      350.000         0.065   FR
Sample Size = 2                     400.000         0.050   FA
   (2 composites of 56 aliquots)
```

Note: Figures generated from DQO – DEFT using a coefficient of variation for all total PCB cases of 25 percent.

Figure 10
Routine to Evaluation Level
(Far-field Baseline to >12 mg/L with discrete samples every 3 hrs for 24 hrs)

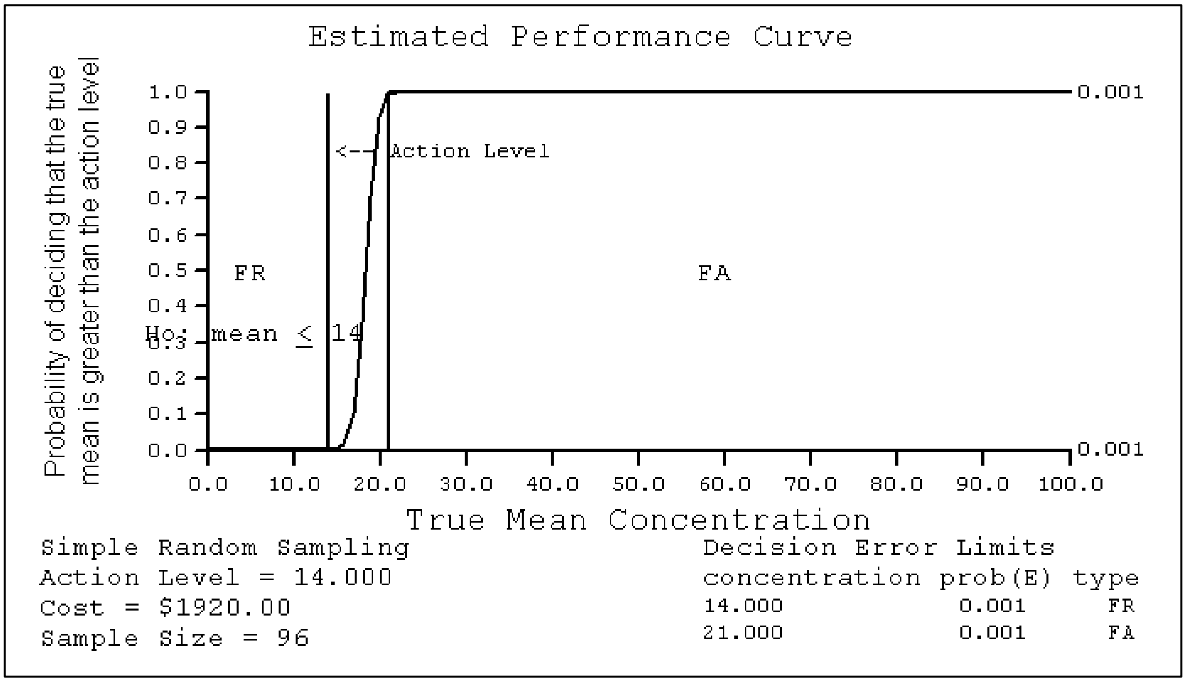


Simple Random Sampling
Action Level = 14.000
Cost = $160.00
Sample Size = 8

Decision Error Limits

concentration	prob(E)	type
14.000	0.275	FR
21.000	0.125	FA

Figure 11
Routine to Evaluation Level
(Far-field baseline to >12 mg/L with continuous sampling every 15 min for 24 hrs)



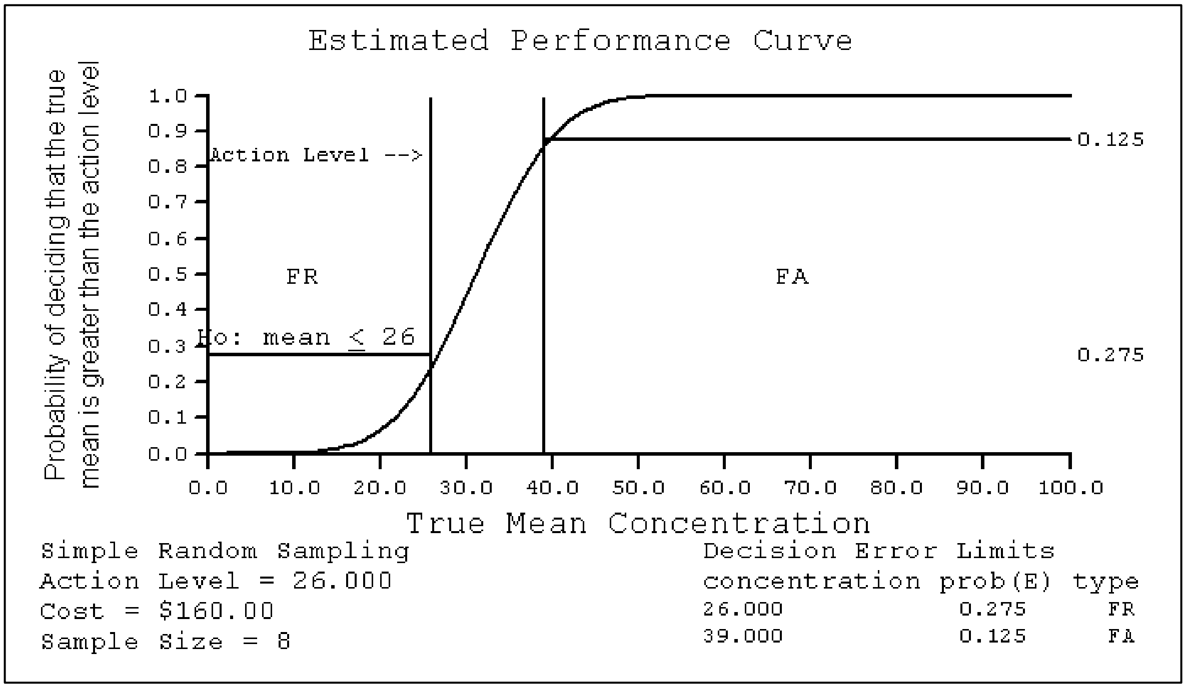
Simple Random Sampling
Action Level = 14.000
Cost = $1920.00
Sample Size = 96

Decision Error Limits

concentration	prob(E)	type
14.000	0.001	FR
21.000	0.001	FA

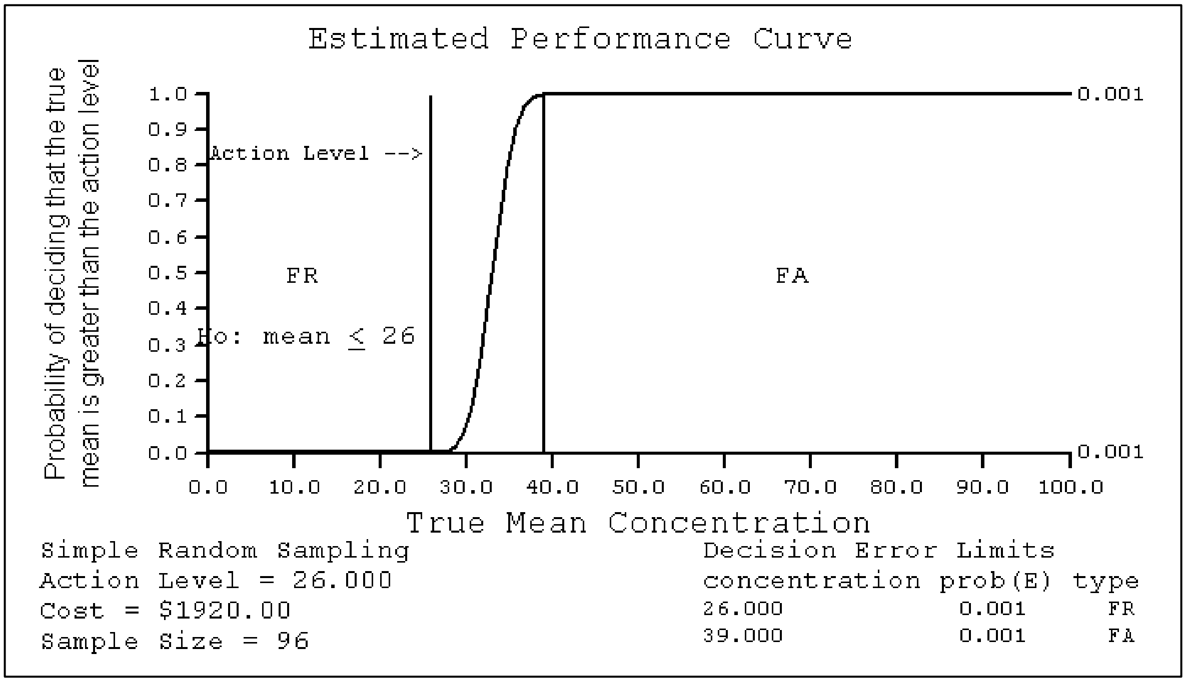
Note: The analysis is based on a baseline of Schuylerville conditions (Average TSS concentration from May-Nov of 2.4 mg/L with an average standard deviation from May-Nov of 1.87 mg/L) and coefficient of variation equal to 75 percent.

Figure 12
Routine to Control Level
(Far-field Baseline to >24 mg/L with discrete samples every 3 hrs for 24 hrs)



```
Simple Random Sampling                 Decision Error Limits
Action Level = 26.000                  concentration prob(E) type
Cost = $160.00                         26.000          0.275   FR
Sample Size = 8                        39.000          0.125   FA
```

Figure 13
Routine to Control Level
(Far-field baseline to >24 mg/L with continuous sampling every 15 min for 24 hrs)



```
Simple Random Sampling                 Decision Error Limits
Action Level = 26.000                  concentration prob(E) type
Cost = $1920.00                        26.000          0.001   FR
Sample Size = 96                       39.000          0.001   FA
```

Note: The analysis is based on a baseline of Schuylerville conditions (Average TSS concentration from May-Nov of 2.4 mg/L with an average standard deviation from May-Nov of 1.87 mg/L) and coefficient of variation equal to 75 percent.

Figure 14
Evaluation to Control Level
(Far-field Evaluation to Control Level with discrete samples every 3 hours for 24 hours)

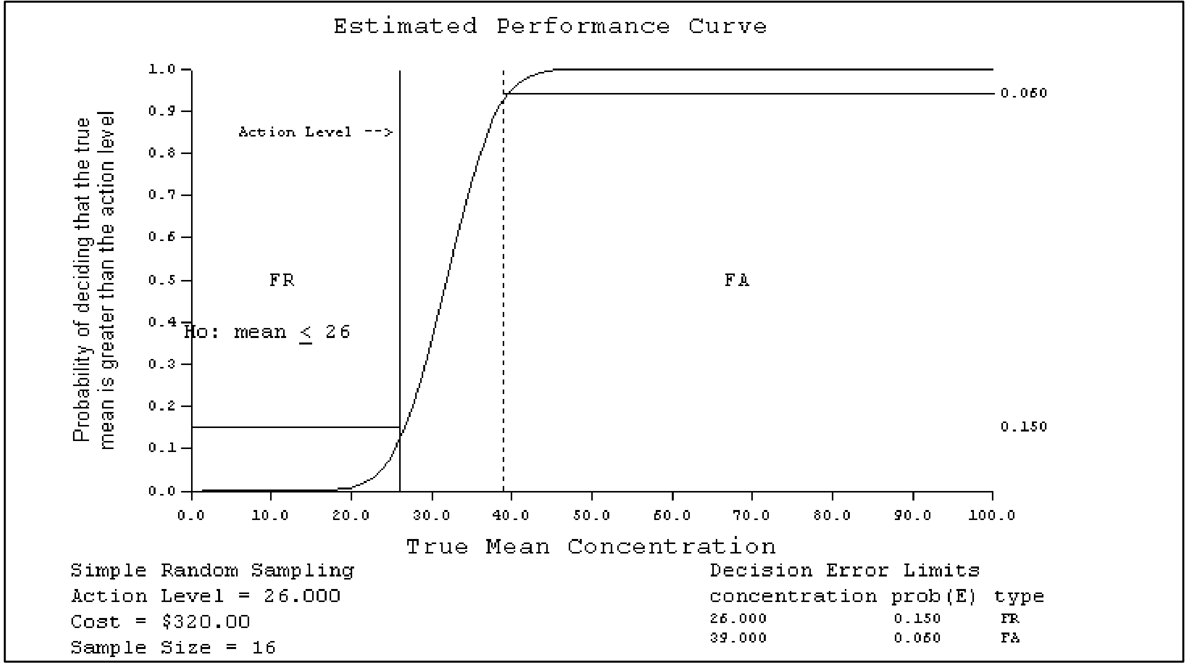
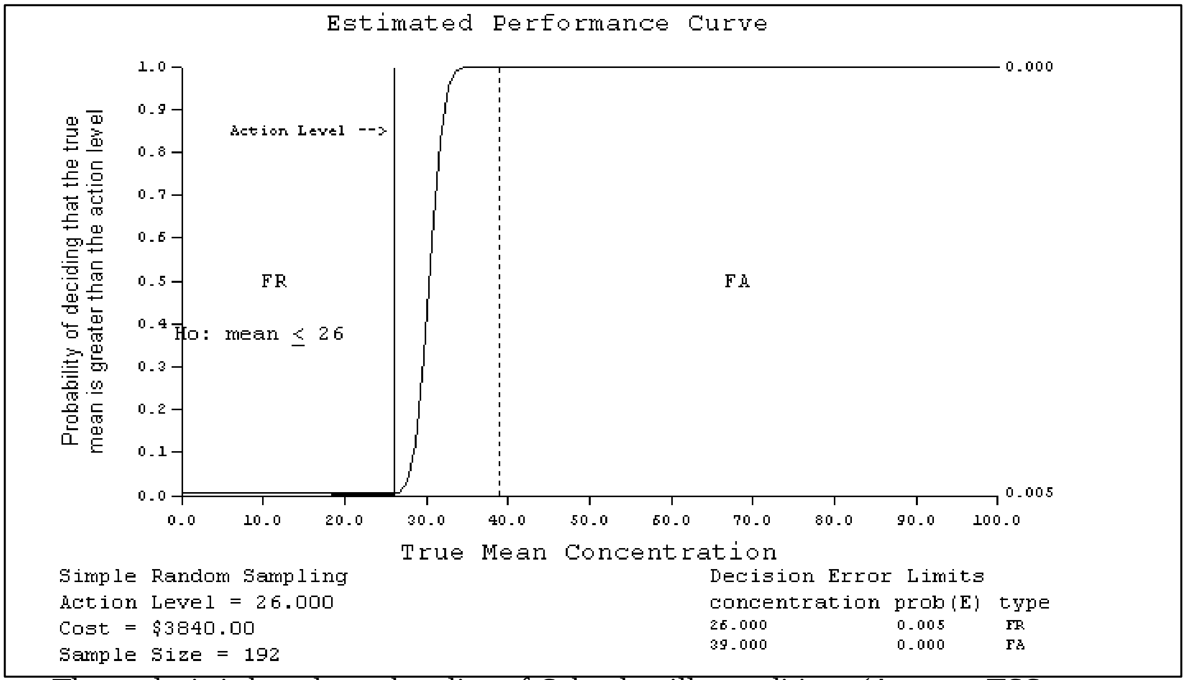
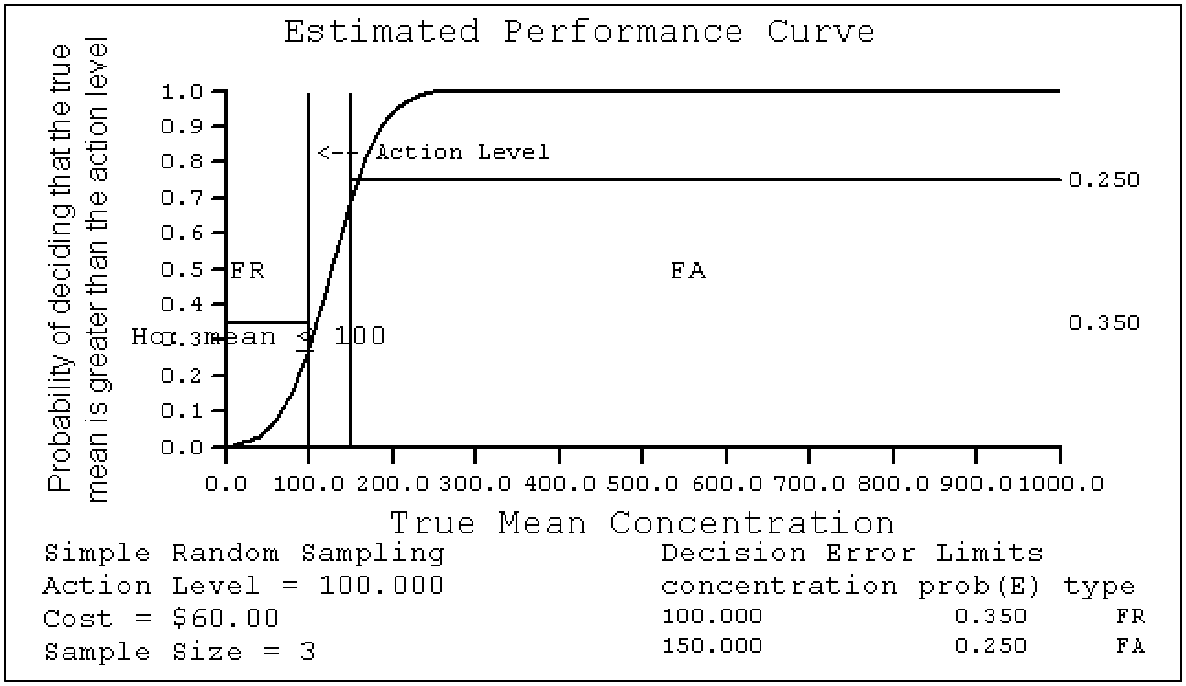


Figure 15
Evaluation to Control Level
(Far-field Evaluation to Control Level with continuous sampling every 15 min for 24 hours)



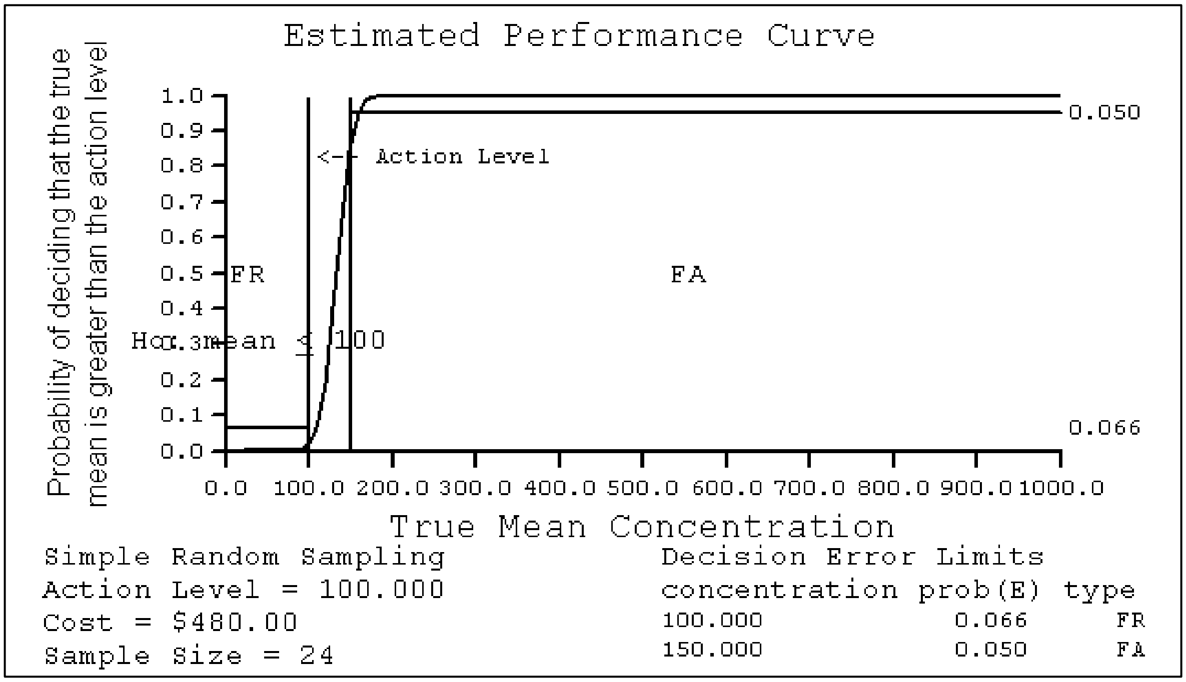
Note: The analysis is based on a baseline of Schuylerville conditions (Average TSS concentration from May-Nov of 2.4 mg/L with an average standard deviation from May-Nov of 1.87 mg/L) and coefficient of variation equal to 75 percent.

Figure 16
Routine to Control Level Near-field River Sections 1 and 3
(baseline to >100 mg/L with discrete samples every 3 hours for 6 hours)



```
Simple Random Sampling              Decision Error Limits
Action Level = 100.000              concentration prob(E) type
Cost = $60.00                       100.000           0.350   FR
Sample Size = 3                     150.000           0.250   FA
```

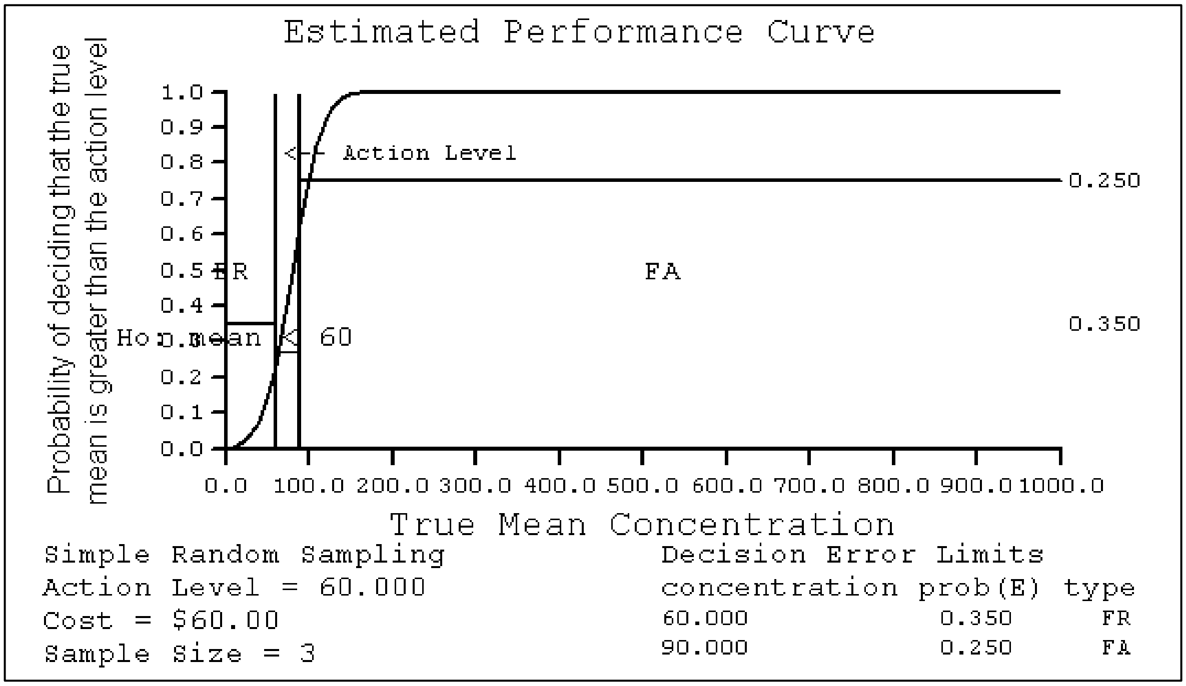
Figure 17
Routine to Control Level Near-field River Sections 1 and 3
(baseline to >100 mg/L with continuous sampling every 15 min for 6 hrs)



```
Simple Random Sampling              Decision Error Limits
Action Level = 100.000              concentration prob(E) type
Cost = $480.00                      100.000           0.066   FR
Sample Size = 24                    150.000           0.050   FA
```

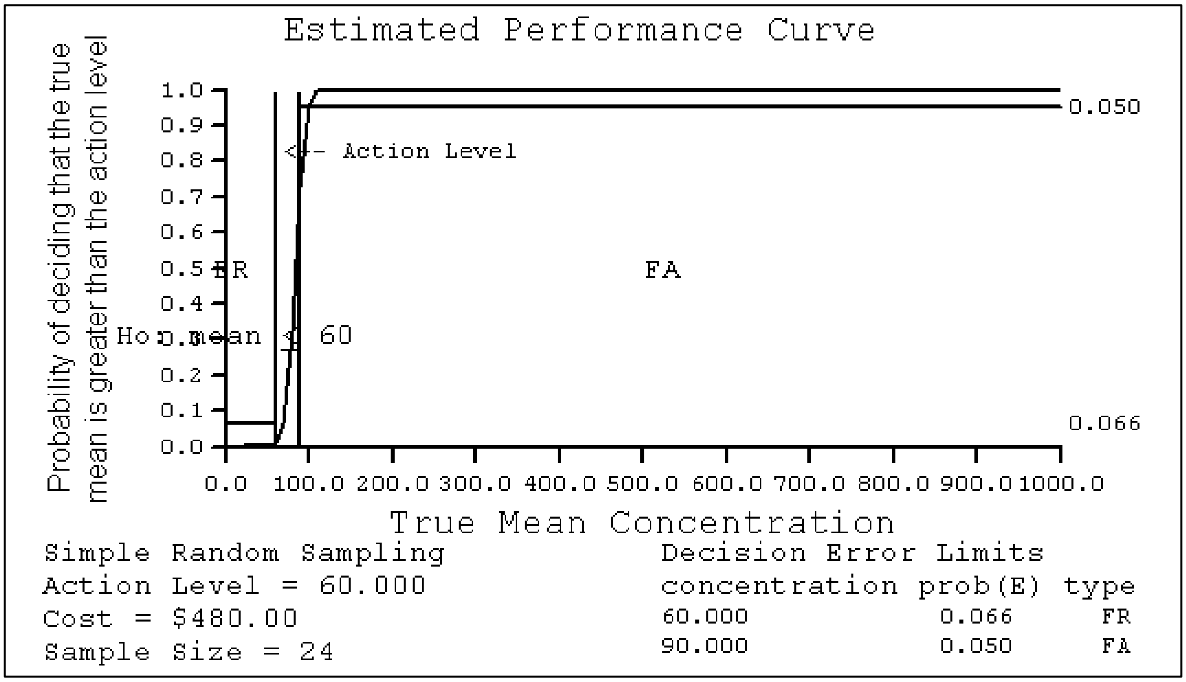
Note: The analysis is based on a coefficient of variation equal to 75 percent.

Figure 18
Routine to Control Level Near-field River Section 2
(baseline to >60 mg/L with discrete samples every 3 hours for 6 hours)



```
Simple Random Sampling              Decision Error Limits
Action Level = 60.000               concentration prob(E) type
Cost = $60.00                       60.000         0.350   FR
Sample Size = 3                     90.000         0.250   FA
```

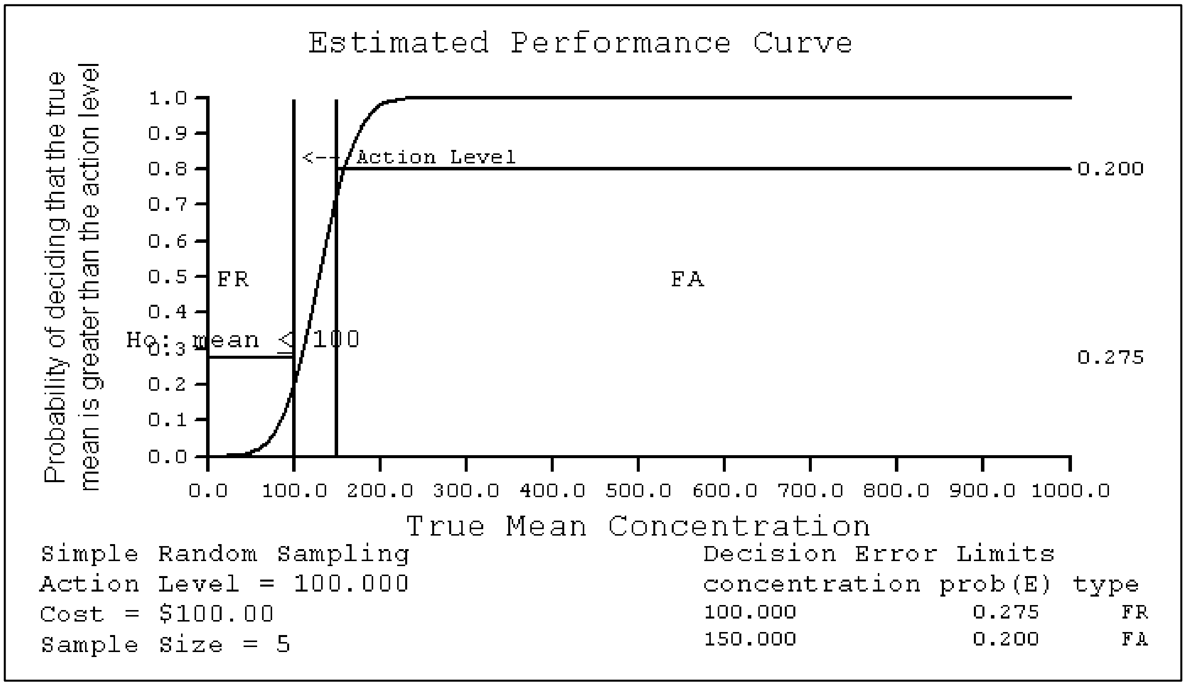
Figure 19
Routine to Control Level Near-field River Section 2
(baseline to >60 mg/L with continuous sampling every 15 min for 6 hrs)



```
Simple Random Sampling              Decision Error Limits
Action Level = 60.000               concentration prob(E) type
Cost = $480.00                      60.000         0.066   FR
Sample Size = 24                    90.000         0.050   FA
```

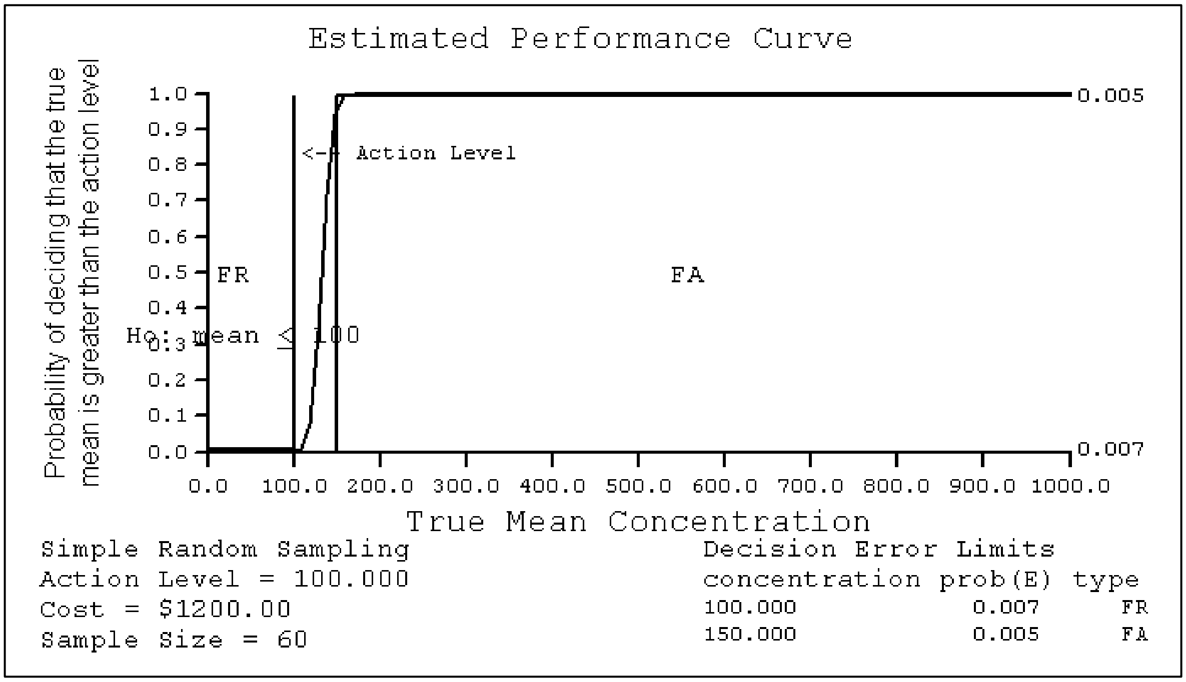
Note: The analysis is based on a coefficient of variation equal to 75 percent.

Figure 20
Evaluation to Control Level Near-field River Sections 1 and 3
(baseline to >100 mg/L with discrete samples every 3 hours for 15 hours)



```
Simple Random Sampling                         Decision Error Limits
Action Level = 100.000                         concentration prob(E) type
Cost = $100.00                                 100.000         0.275    FR
Sample Size = 5                                150.000         0.200    FA
```

Figure 21
Evaluation to Control Level Near-field River Sections 1 and 3
(baseline to >100 mg/L with continuous sampling every 15 min for 15 hrs)



```
Simple Random Sampling                         Decision Error Limits
Action Level = 100.000                         concentration prob(E) type
Cost = $1200.00                                100.000         0.007    FR
Sample Size = 60                               150.000         0.005    FA
```

Note: The analysis is based on a coefficient of variation equal to 75 percent.

Figure 22
Evaluation to Control Level Near-field River Section 2
(baseline to >60 mg/L with discrete samples every 3 hours for 15 hours)

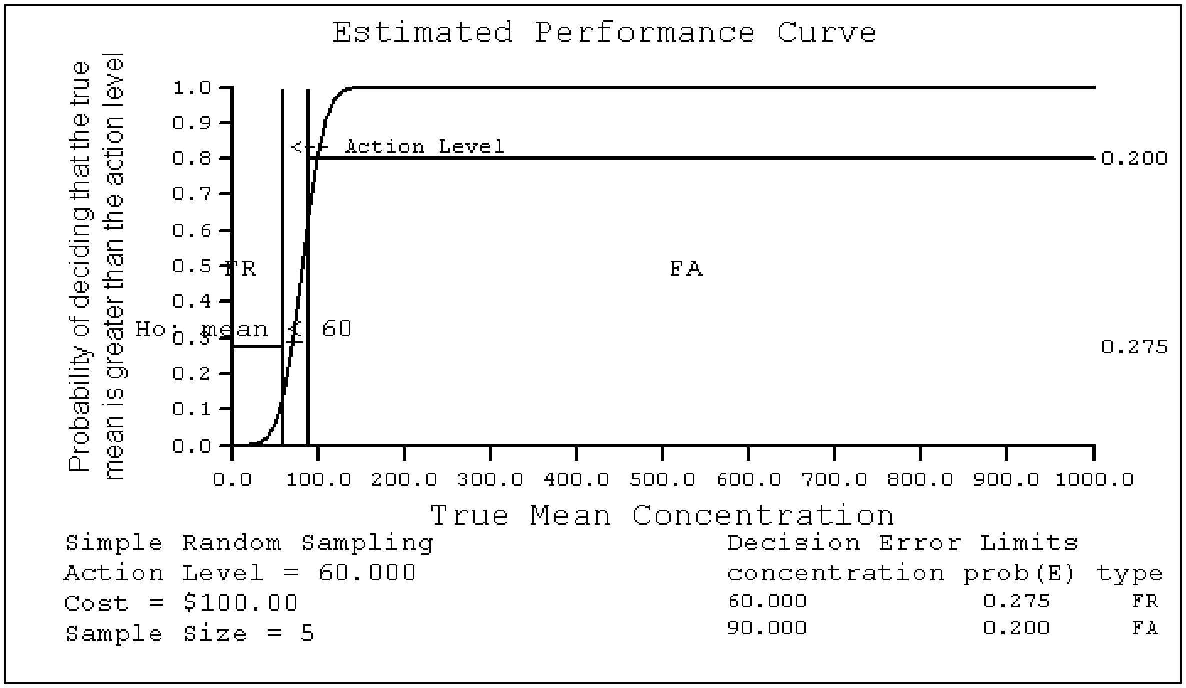
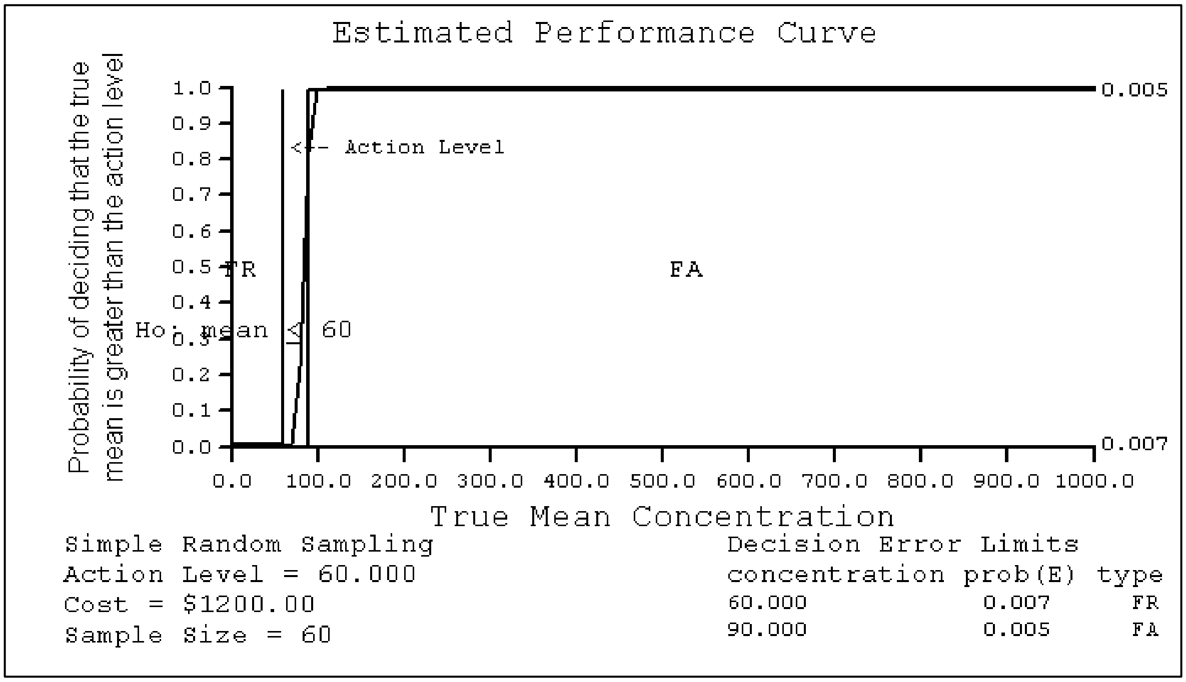


Figure 23
Evaluation to Control Level Near-field River Section 2
(baseline to >60 mg/L with continuous sampling every 15 min for 15 hrs)



Note: The analysis is based on a coefficient of variation equal to 75 percent.

Figure 24
Routine to Evaluation Level
(Near-field baseline to >700 mg/L with discrete samples every 3 hrs for 3 hrs)

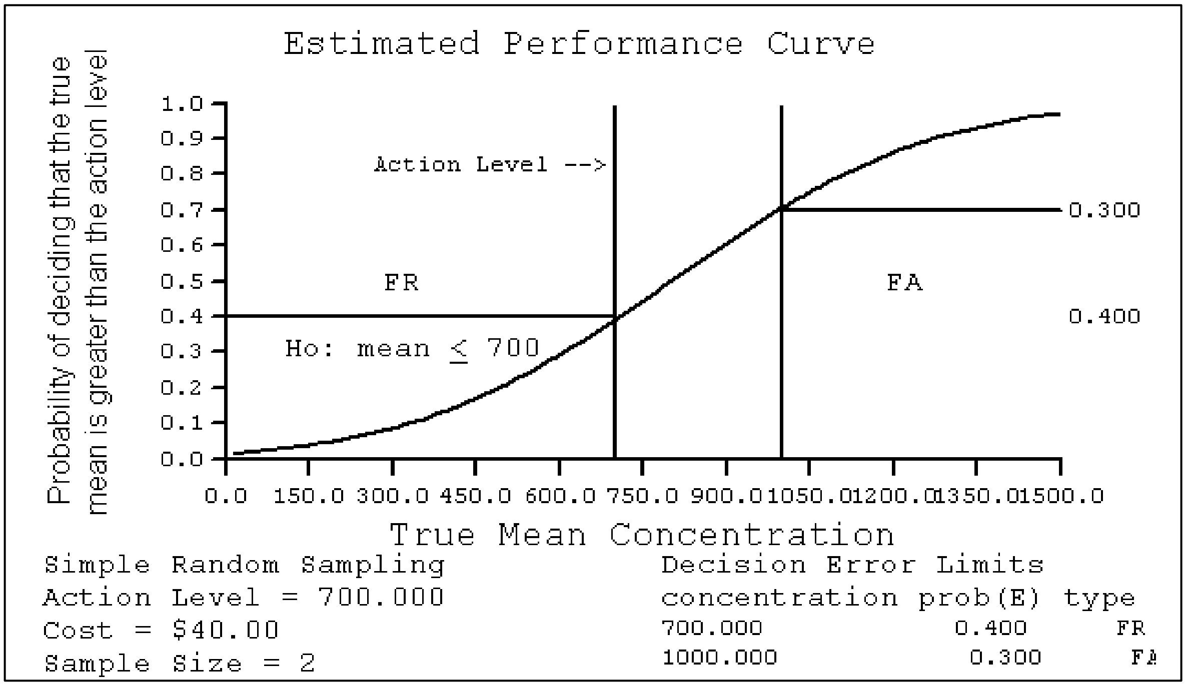
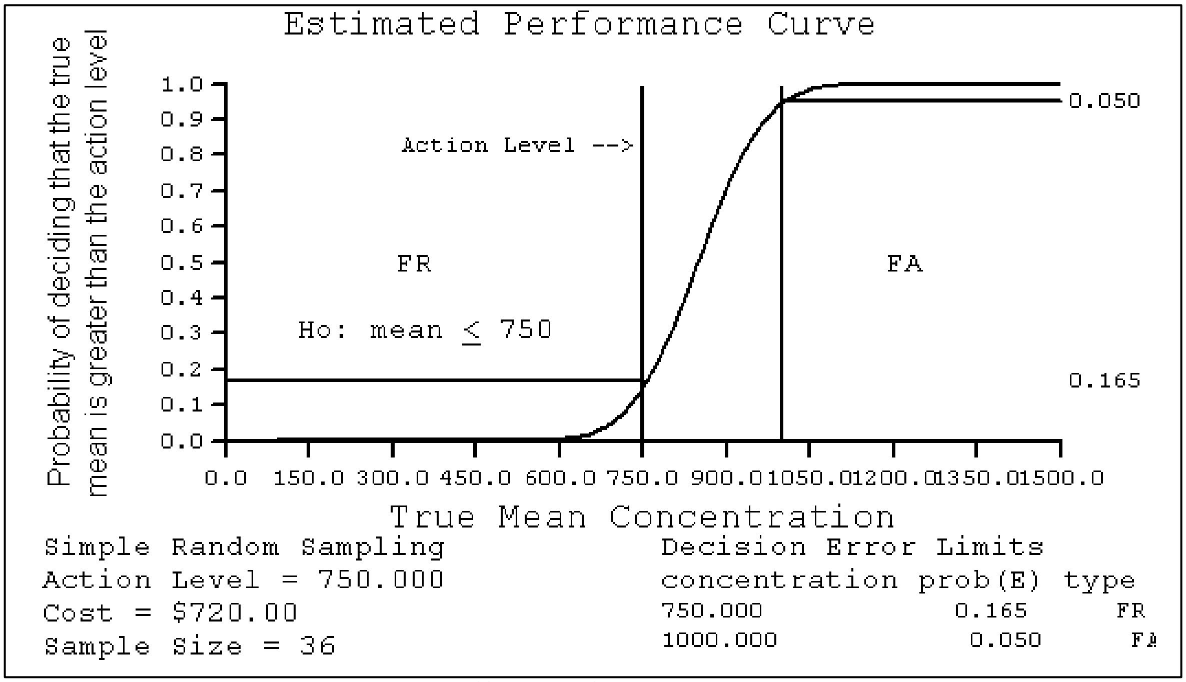


Figure 25
Routine to Evaluation Level
(Near-field baseline to >700 mg/L with continuous sampling every 15 min for 3 hrs)



Note: The analysis is based on a coefficient of variation equal to 75 percent.

Figure 26
Automatic Sampler at the Evaluation Level (300 g/day)
(1 sample per hour for 24 hours)

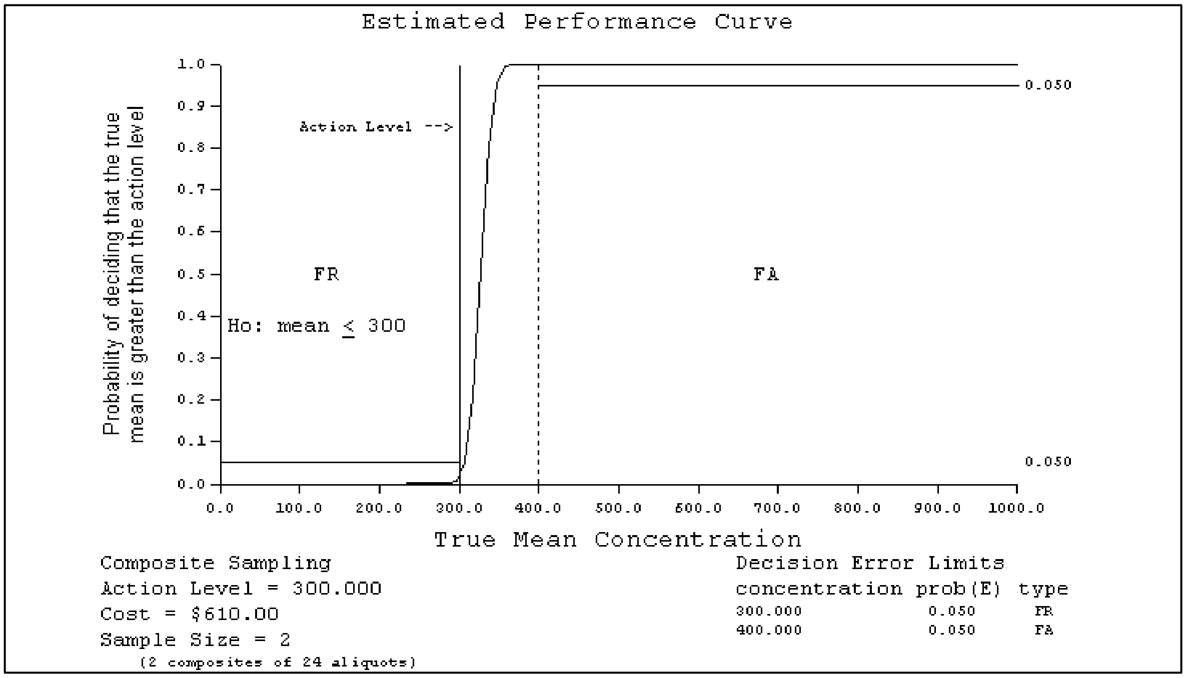
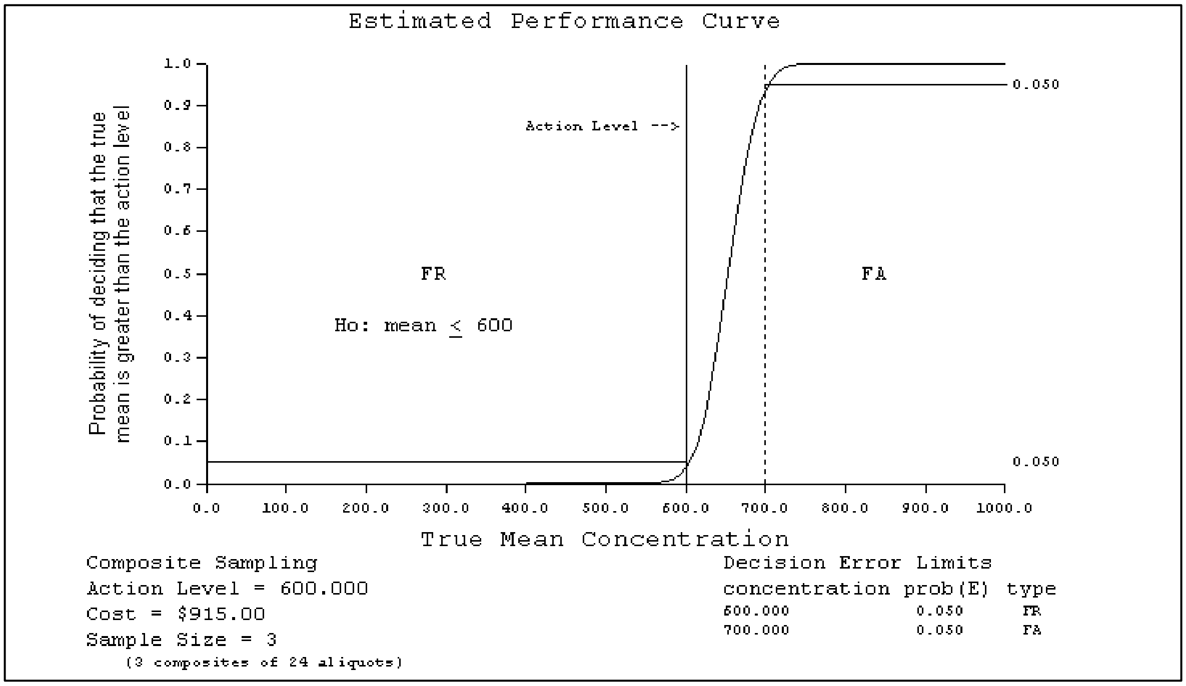


Figure 27
Automatic Sampler at the Control Level (600 g/day)
(1 sample per hour for 24 hours)



Note: Figures generated from DQO – DEFT using a coefficient of variation for all total PCB cases of 25 percent.

Figure 28
Automatic Sampler at the Control Level (350 ng/L)
(1 sample per hour for 24 hours)

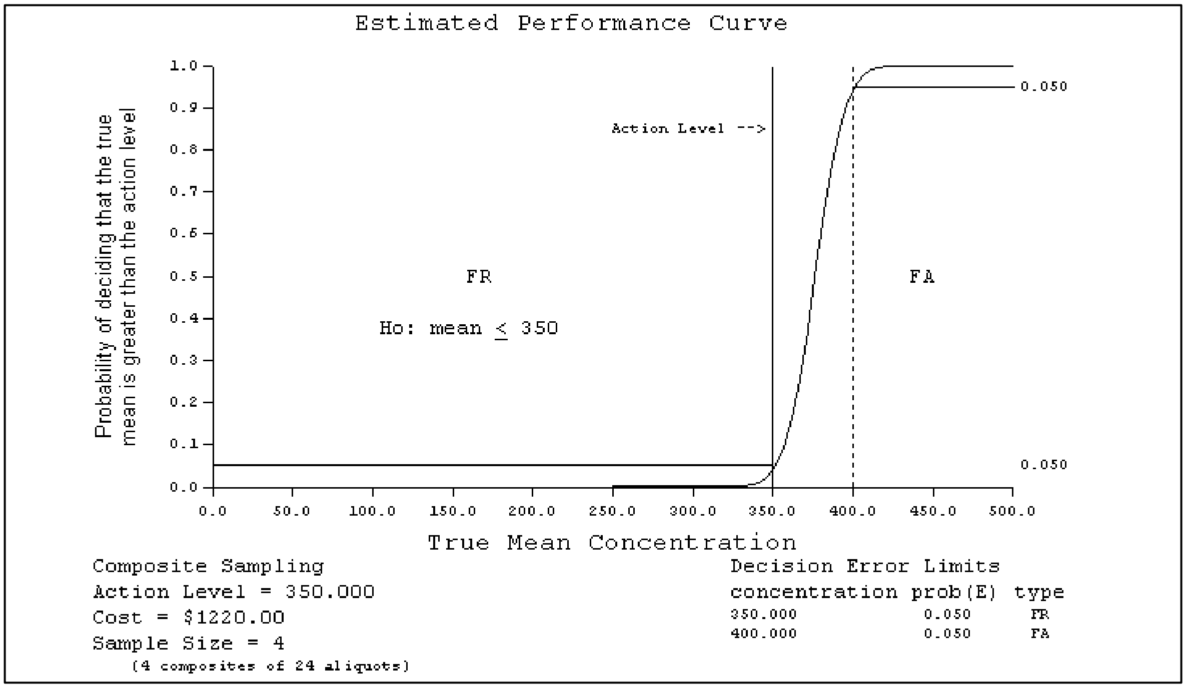
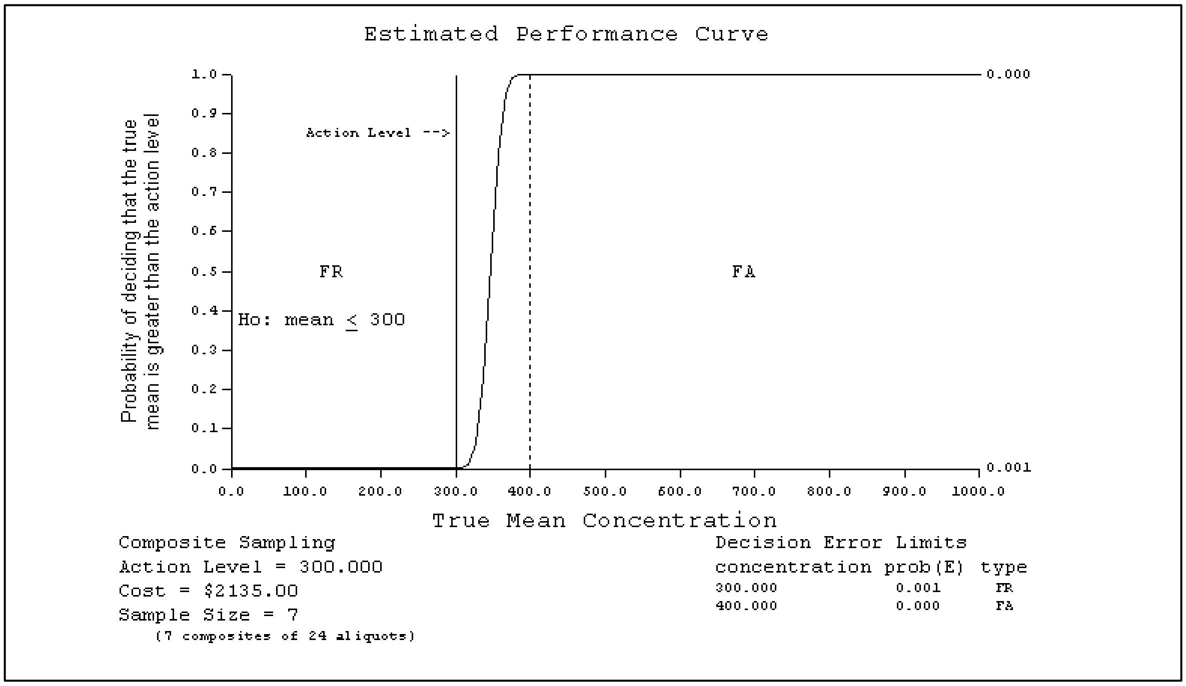


Figure 29
Routine to Evaluation Level with Automatic Sampler
Action level of 300 g/day



Note: Figures generated from DQO – DEFT using a coefficient of variation for all total PCB cases of 25 percent.

Figure 30
Routine to Control Level with Automatic Sampler
Action level of 600 g/day

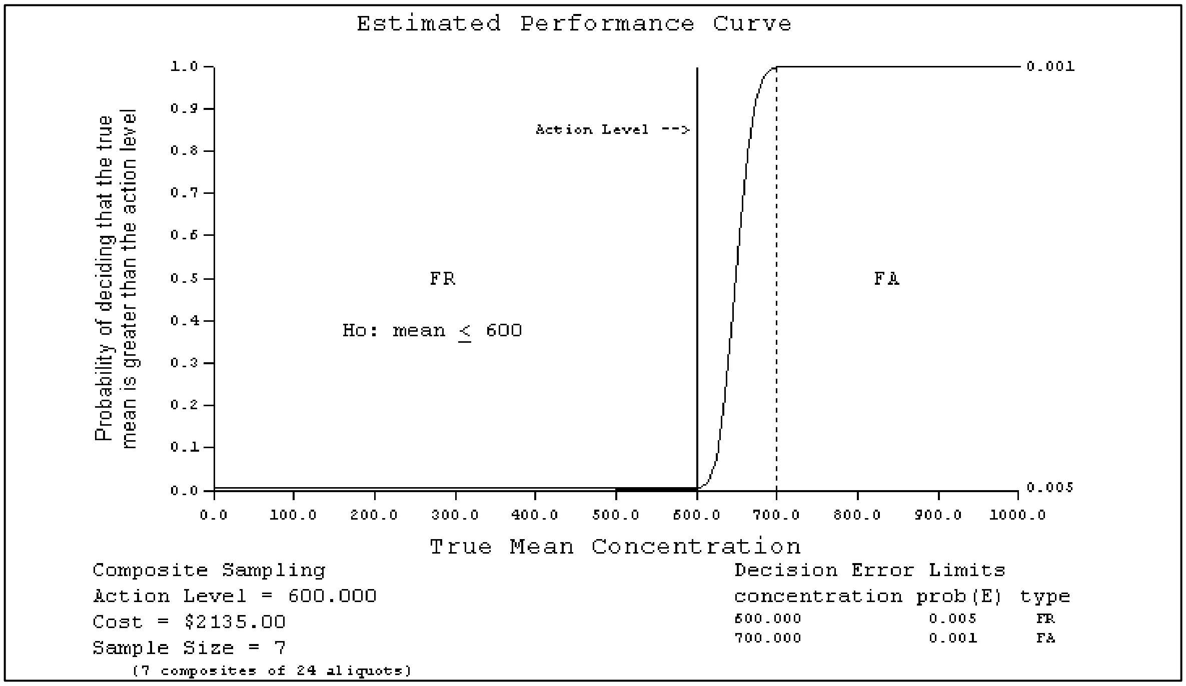
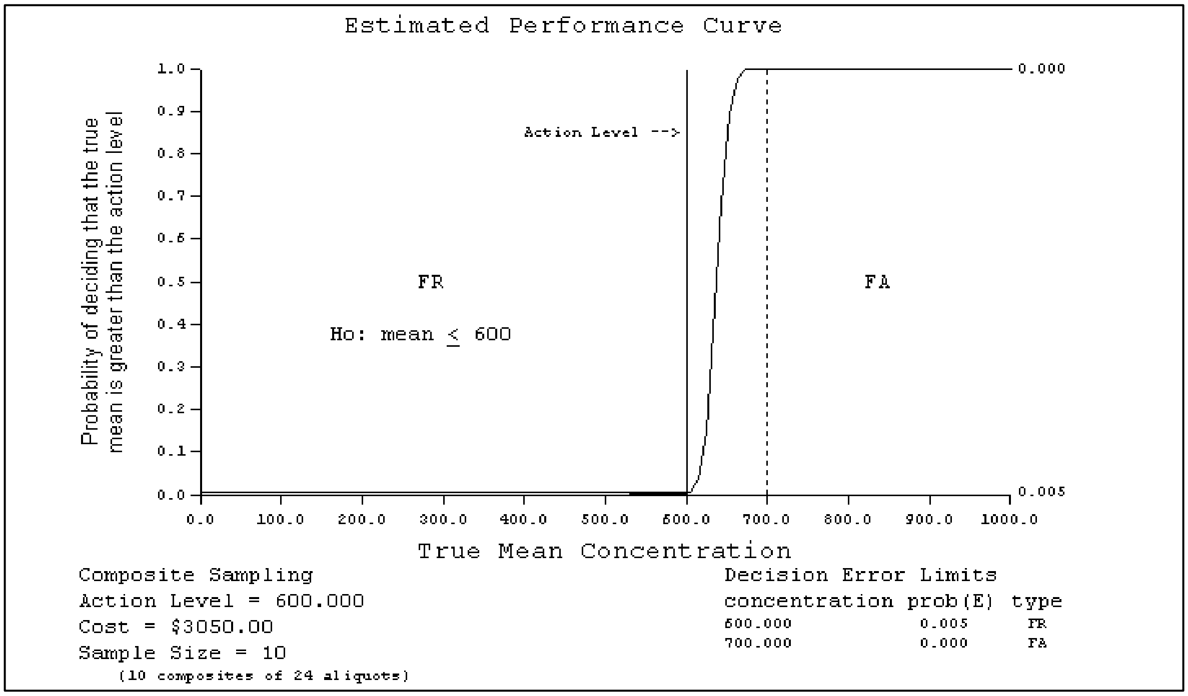
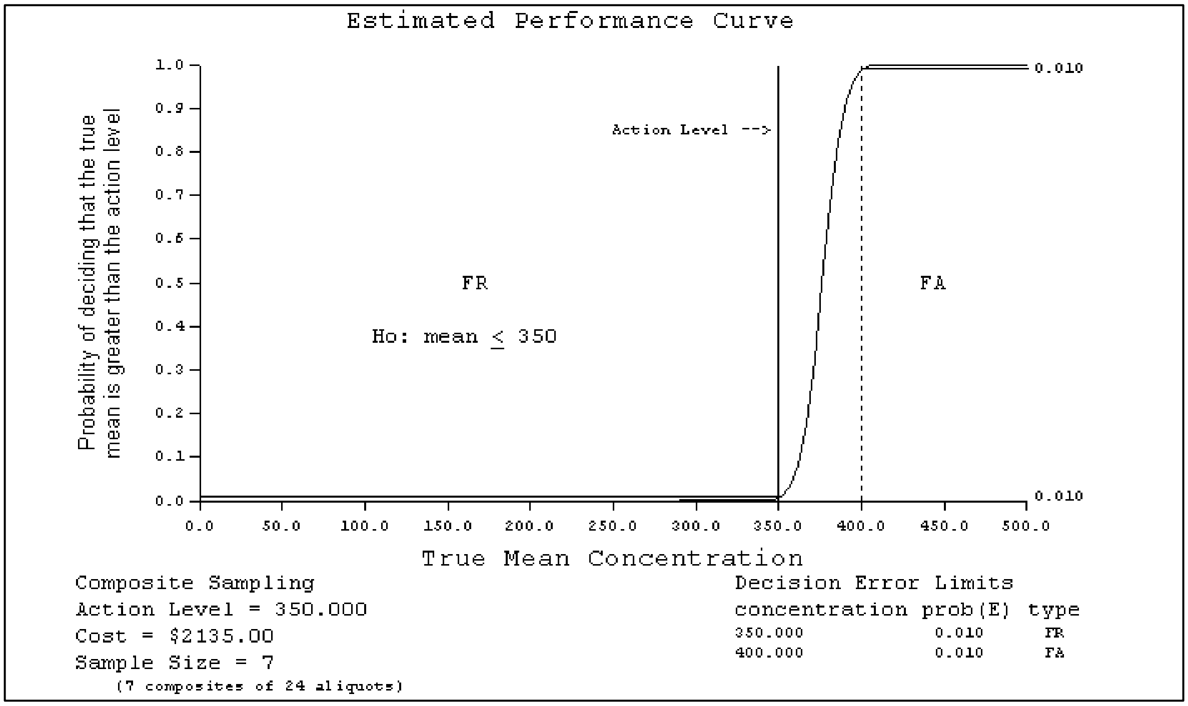


Figure 31
Confirmation of the 600 g/day with Automatic Sampler
Action level of 600 g/day



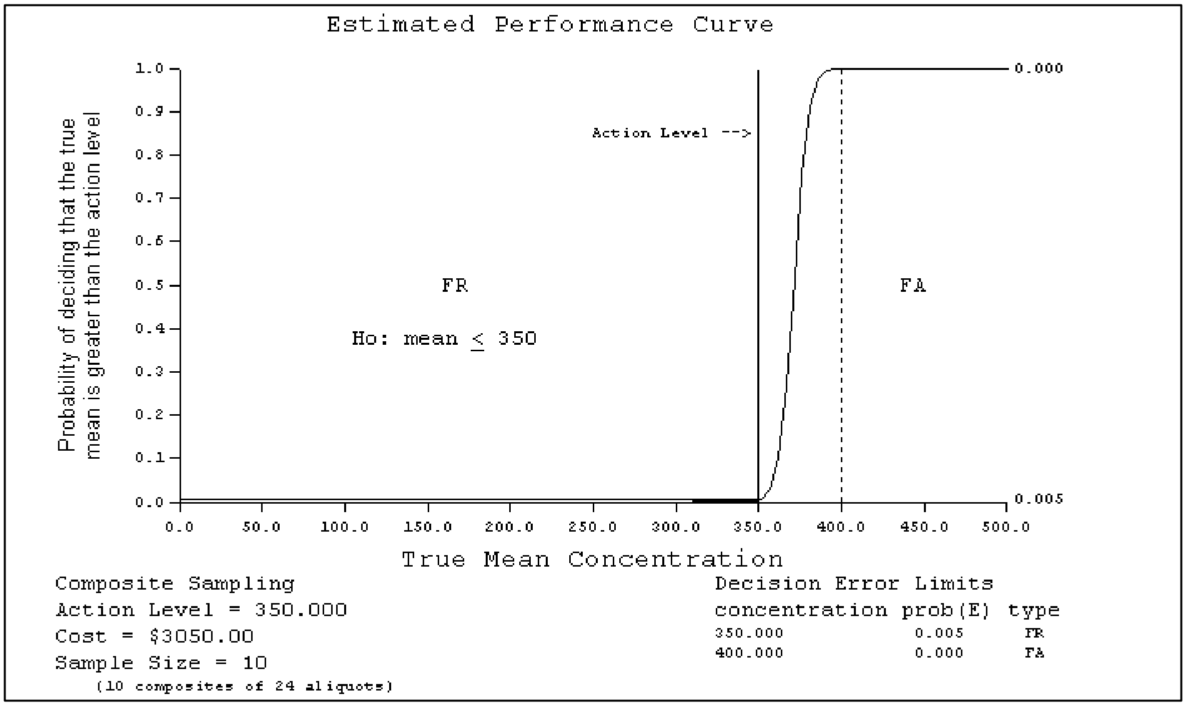
Note: Figures generated from DQO – DEFT using a coefficient of variation for all total PCB cases of 25 percent.

Figure 32
Routine to Control Level with Automatic Sampler
Action level of 350 ng/L



```
Composite Sampling                        Decision Error Limits
Action Level = 350.000                    concentration prob(E)  type
Cost = $2135.00                           350.000          0.010    FR
Sample Size = 7                           400.000          0.010    FA
    (7 composites of 24 aliquots)
```

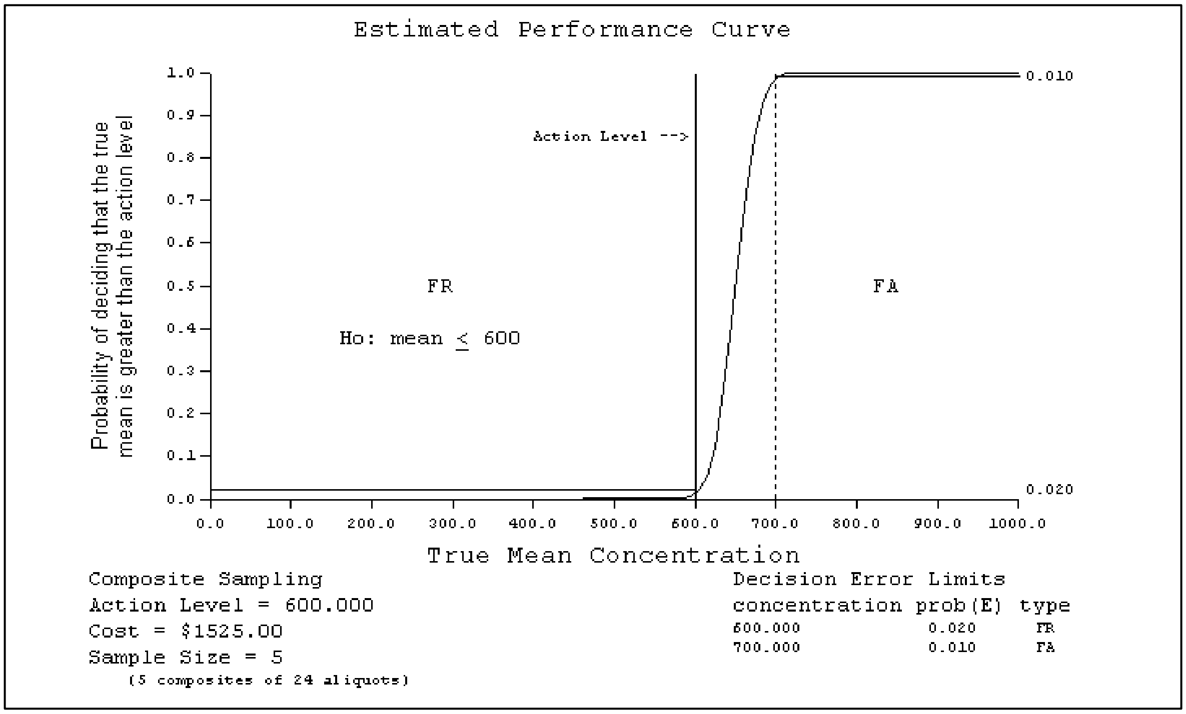
Figure 33
Confirmation of the 350 ng/L with Automatic Sampler
Action level of 350 ng/L



```
Composite Sampling                        Decision Error Limits
Action Level = 350.000                    concentration prob(E)  type
Cost = $3050.00                           350.000          0.005    FR
Sample Size = 10                          400.000          0.000    FA
    (10 composites of 24 aliquots)
```

Note: Figures generated from DQO – DEFT using a coefficient of variation for all total PCB cases of 25 percent.

Figure 34
Evaluation to Control Level with Automatic Sampler
Action Level 600 g/day



Note: Figures generated from DQO – DEFT using a coefficient of variation for all total PCB cases of 25 percent.

Attachment H

Estimated Cost and Feasibility of the Phase 1 Monitoring Program

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Attachment H

Estimated Cost and Feasibility of the Phase 1 Monitoring Program

1.0 Abstract

Cost estimates for the Phase 1 monitoring program were calculated assuming that the major costs for the monitoring program are the labor costs to collect the samples and the analytical costs. On this basis, the estimated cost of the Phase 1 monitoring program is approximately $3,000,000. The estimated cost of the Phase 1 monitoring program cannot be used as a basis for estimating the monitoring costs for the remainder of the remediation. The Phase 1 monitoring program is designed to measure compliance with the standard and to evaluate and refine the implementation of the standard. The sampling efforts for the second objective are designated as "special studies." The results of the monitoring in Phase 1 will determine the extent to which the Phase 1 monitoring program requirements can be reduced (after the completion of Phase 1) and still measure compliance with the resuspension criteria with an acceptable degree of certainty.

2.0 Introduction

A number of different sampling and data collection events of which the Phase 1 monitoring program is included, will occur as part of the remediation of the Hudson River PCBs Site. Components of the Phase 1 monitoring program include various water column sampling and analyses to assess different techniques and measurement types for monitoring and verifying compliance with the Resuspension Performance Standard; and also to generate additional data to improve understanding of the sediment and contaminant transport processes which may occur during the dredging program. Ongoing monitoring during dredging operations subsequent to Phase 1 (Phase 2 monitoring) will include monitoring conducted from the second year of the dredging program through its completion. It is anticipated that the Phase 2 monitoring program will not be as intensive as the Phase 1 program, as it is expected that data obtained during Phase 1 will enable either the number of samples, or the analytical parameters, to be reduced while still ensuring compliance with the resuspension criteria.

In addition to compliance monitoring, the Phase 1 monitoring program includes five special studies for the resuspension standard. These are as follows:

- Near-field PCB Release Mechanism (Dissolved vs. Particulate)
- Development of a Semi-Quantitative Relationship between TSS and a Surrogate Real-Time Measurement for the Near-field and Far-field Stations (Bench Scale)
- Development of a Semi-Quantitative Relationship between TSS and a Surrogate Real-Time Measurement for the Near-field and Far-field Stations (Full Scale)
- Non-Target, Downstream Area Contamination
- Phase 2 Monitoring Plan

These studies are intended to:

- Determine the Total PCB water column concentrations and the nature of contaminant release from the remedial operations (dissolved or suspended phase release).
- Determine and maintain a semi-quantitative relationship between TSS and a real-time surrogate measurement.
- Determine the extent of downstream contamination in the non-target areas.
- Establish alternate strategies to more efficiently handle the requirements of the monitoring program.

Costs for these special studies are also provided where sufficient scope for the study is available.

The estimated costs of the Phase 1 program cannot be used to project the monitoring costs for the rest of the remedial program, since it is likely that the Phase 1 program is be more sample- and analytical-intensive than the Phase 2 monitoring program will be.

The cost estimate provided in this analysis focuses on the two main elements of the program: labor and laboratory analytical cost. The cost estimate for the Phase 1 monitoring program is based on specific scenarios for implementing the monitoring program, which are described in detail below. Standard laboratory rates are used to estimate the analytical costs; however, it is likely that lower rates can be negotiated for this program (due to the large quantity of analyses being performed). The final cost of the Phase 1 monitoring program will also be dependent on the degree to which the operations are in compliance with the resuspension criteria.

Alternate strategies may be developed to more efficiently handle the requirements of the monitoring program. Other modifications to the monitoring program, which reduce the costs of the program, will be acceptable, as long as all data quality objectives are met and the modification is not so substantial as to cause the resuspension criteria to be reevaluated. The standard requires that a special study establishing any proposed alternate strategies for sampling be demonstrated concurrently with the Phase 1 program.

3.0 Phase 1 Compliance Monitoring Cost Estimate

It is assumed that the primary costs for the Phase 1 monitoring program will be labor costs associated with the sample collection and laboratory analytical costs. It is also assumed that the quality assurance/quality control requirements will be limited due to the quick turnaround requirements. Estimated costs for these elements for the monitoring program described in the Resuspension Performance Standard were developed and are described below. The labor costs are a function of two variables: the level of effort (i.e., the personnel-hours required to collect the samples), and the labor rates (dollars per hour). Similarly, the analytical costs are a function of the number of analyses of each type performed (e.g., PCB analysis, TSS, total organic carbon), and the unit cost for each of these analyses.

The calculated cost estimates for the Phase 1 monitoring presented assumes that two field laboratories will be established to perform the total suspended solids (TSS) analyses. As the facilities (a mobile office trailer) and equipment (scale, oven, filters, and glassware) are relatively simple and inexpensive, costs for the field laboratories (which will likely be less than $10,000 for each) are not included in this estimate. Costs for the technicians to perform the analyses are not included in this estimate; however, the costs for the TSS analysis are addressed as a laboratory analytical cost (based on the cost of an off-site laboratory performing the TSS analyses). The estimated samples required and the laboratory analytical costs for routine and non-routine monitoring are provided in Tables 1 through 3.

In the discussion below, a number of the sampling activities are discussed relative to the 'operations' which are occurring at the time. In this context, 'operations' means any remedial activities that involve sediment disturbance. These activities will be primarily the dredging activites, but may also include other activities such as debris removal and installation or removal of containment other than silt curtains.

3.1 Labor Costs - Level of Effort (LOE)

The level of effort for both the routine monitoring and non-routine monitoring efforts are presented below. Each (routine and non-routine) is further subdivided into the LOE estimate for near-field and far-field sample collection.

3.2 Routine Monitoring with Automated Suspended Solids Collection

3.2.1 Far-Field (Including Baker's Falls)

If the 1 suspended sample per every 3 hours is collected by mechanical means (i.e., by an ISCO sampler), there is a significant reduction in LOE requirements of the Ft Edward, TI Dam, Schuylerville, Stillwater and Waterford stations, for all action levels. Using automated samplers will not change the LOE requirements of the remaining stations. Under these conditions, the field crews would manually collect the whole-water PCB, DOC and grab suspended solids samples. The field crew would also be responsible for picking up the automated suspended solids samples, replenishing sample vials in the ISCO devices and delivering the samples to the field laboratories. One field crew could sample multiple stations during each shift, with a reasonable breakdown of stations being Ft Edward/TI Dam and Schuylerville/Stillwater/ Waterford.

The LOE breakdown for routine monitoring is shown in Table 4.

It may be possible for 1 crew to collect the samples at all 5 stations, but when considering possible problems related to collection at the TI Dam, a more conservative estimate is more appropriate.

3.2.2 Near-Field

One crew should be able to handle up to five operations of near field sampling. Above that, a second crew will be required. Each crew will consist of two samplers and one boat operator. The crew will collect the samples, fill out required paperwork and transport the samples to the field labs described above.

The LOE breakdown (for five operations) for routine monitoring is shown in Table 5.

The major assumption of this estimate is that the dredging operations are within close proximity to one another (i.e., all are within the same pool). Additional personnel will be required if operations are being conducted in two or more pools.

3.2.3 Routine Monitoring LOE Summary

Based on the near-field and far-field estimates and the assumptions listed above, the LOE for routine monitoring is between 10 and 16 people per day (the variability is contingent on specifics of operations) to collect samples, fill out paperwork and transport the samples to one of two field labs for the duration of the program.

3.3 Non-Routine Monitoring with Automated Suspended Solids Collection

3.3.1 Far-Field (Including Baker's Falls)

For non-routine sampling with automated suspended solids collection, the station assignments of the field crews must change as a result of the additional sampling requirements and consideration of river mile. The realignment would be Ft Edward/TI Dam/Schuylerville and Stillwater/Waterford. The Sampling Level dictates the number of additional crews required. Under most instances, 1 additional crew is added for each sampling event. For example, a second crew is added during Evaluation Level monitoring and a third crew is added for Concern Level evaluation. For Threshold Level monitoring, a fourth crew is added to collect the 4 required samples.

The LOE breakdown is for non-routine monitoring is shown in Table 4.

Additional reductions in LOE requirements for both routine and non-routine monitoring may be possible if technicians at the field laboratories are made responsible for picking up automated suspended solids samples from the ISCO samplers.

3.3.2 Near-Field

The hourly suspended solids sample collection requirement of the non-routine monitoring would require one crew per two operations, with an additional person added to each crew to shuttle samples to the field laboratories.

The LOE breakdown (assuming six operations) is for non-routine monitoring is shown in Table 5.

With two or fewer operations, only one additional person (relative to routine monitoring) per shift would be required; five additional people per shift would be required for three or four operations; nine people per shift for five or six operations, and so on. The maximum number of additional people would be 17 people per shift at a maximum of 10 operations.

The major assumption of this estimate is that dock space can be accessed nearby the operations so that the time required to get the samples to shore for transport to the labs is not a significant factor. As with Routine Monitoring, the estimate assumes that operations are being conducted in the same pool, and the LOE is estimated only for sample collection, documentation and transport to the field labs.

A concern of the non-routine sampling is the immediate need for the additional personnel if the surrogate relationship is not in compliance. The range of people required for non-routine sampling (personnel in addition to the full-time staff doing routine monitoring) is significant, starting at 9 people (Evaluation Level, one or two operations) up to a maximum of 33 additional personnel (Control Level, 10 operations). At the maximum level, the size of the field crew essentially doubles. From a resource management standpoint, maintaining a pool of 30 qualified and trained individuals to be ready to sample with less than 12 hours notice would be difficult, at best.

3.3.3 Non-Routine Monitoring LOE Summary

Based on the near-field and far-field estimates and the assumptions listed above, the LOE for non-routine monitoring is between 14 and 56 people per day (the variability is contingent on specifics of operations) to collect samples, fill out paperwork and transport the samples to one of two field labs for the duration of the program.

4.0 Cost Parameters

Labor Rates

It is assumed that the average cost for sampling technicians during an 8-hour shift will be $416 ($52/hour loaded rate, based on a $20/hour direct rate and an overhead factor of 1.6).

Laboratory Analysis – Estimated Quantities

The estimated laboratory analysis quantities for far-field (Upper Hudson River and Lower Hudson River) and near-field laboratory analyses are provided in Tables 1 through 3.

Laboratory Analysis - Unit Costs

The estimated unit costs for laboratory analyses are listed below.

PCB Congeners (standard turnaround time)	$	300
24-hour Turnaround Time	$	600
72-hour Turnaround Time	$	525
Suspended Solids 3-hour Turnaround Time	$	20
Dissolved Organic Carbon	$	35
Suspended Organic Carbon	$	60

The PCB congener rates above assume a 100 percent surcharge for 24-hour turnaround time, and a 75 percent surcharge for 72-hour turnaround.

5.0 Special Studies

The monitoring programs for the resuspension and residual standards are organized to separate sampling necessary to measure compliance with the standard from sampling efforts needed to evaluate and refine the implementation of the standard. This has been accomplished by designating the second category of sampling efforts as “special studies.” The special studies will be conducted for limited periods of time to gather information for specific conditions that may be encountered during the remediation or to develop an alternate strategy for monitoring. Specific conditions may include different dredge types, contaminant concentration ranges, and varying sediment textures. Each of these studies is integral to the Phase 1 evaluation, the development of Phase 2, and is also tied to compliance issues.

There are a total of five special studies for the resuspension standard. These are as follows:

- Near-field PCB Release Mechanism (Dissolved vs. Particulate)
- Development of a Semi-Quantitative Relationship between TSS and a Surrogate Real-Time Measurement for the Near-field and Far-field Stations (Bench Scale)
- Development of a Semi-Quantitative Relationship between TSS and a Surrogate Real-Time Measurement for the Near-field and Far-field Stations (Full Scale)
- Non-Target, Downstream Area Contamination
- Phase 2 Monitoring Plan

Costs for the near-field PCB, semi-quantitative relationship (bench scale) and non-target downstream area contaminant special studies are provided. The full scale semi-quantitative relationship is included in the cost of compliance monitoring. No cost estimates can be calculated for the Phase 2 monitoring plan special studies because the s scope of the study has not been defined.

5.1 Near-field PCB Release Mechanism (Dissolved vs. Particulate)

The special study to characterize near field PCBs will consist of collecting samples in the vicinity of a remedial operation once a day for approximately seven days. This would be one event. It is estimated that approximately five events would be needed to characterize the different conditions during remediation. The samples would be collected from upstream, in two transects across the plume downstream from the dredge and within the containment, if present. The samples will be depth integrated. There will be five sample locations along each transect. Most of the samples will be collected for whole water analysis, but a subset will be filtered and both the suspended and dissolved phase sent for analysis. An acoustic sensor will be used to define the extent of the plume

It is assumed that two boats with a crew of three technicians will be required each day of sampling at a single location for a full day. One boat will be responsible for defining the extent of the plume and identifying the sampling locations while the other boat collects the samples.

Thus the LOE breakdown (for the 7-day operations) is:

2 crew x 3 people x 1 shifts per day = 6 people per day for the duration of the program.

The estimated costs are provided in Table 6.

5.2 Development of a Semi-Quantitative Relationship between TSS and a Surrogate Real-Time Measurement for the Near-field and Far-field Stations (Bench Scale)

To determine an initial relationship between TSS and a surrogate (turbidity or laser particle analysis) it is proposed that three types of sediment (silty, fine sand and medium sand) be collected for detailed analysis. For each sediment type one bucket full of sediment will be required.

For labor costs, assume that one field crew of 2 people can collect and handle the 3 buckets of sediment in an 8-hour day. Thus:

1 crew x 2 people x 1 day = 2 man days, to collect the material.

Therefore the labor costs are approximately $832.

To conduct the bench study from this material, the following cost estimate is based on the USACE Long Tube Settling Test (LTST) and the batch test as described in a paper by Earhart (Earhart, 1984).

As per the USACE methodology, the LTST takes a full 15 days to determine compression settling results, however, the test could be run for just a few days to determine the turbidity-TSS correlations only.

Assuming three sediment samples are tested, the costs are as follows:

$4000	Column construction (one LTST column as per EM 111-2-5027)
$3000	Labor and supplies to do a column settling test for one sediment sample assuming a column run of 3 days (note: the cost for multiple columns in use simultaneously would be less) x 3 samples
$3000	Earhart method correlations (for each sediment sample) x 3 samples

$10000 report preparation and QC reviews for all testing.

Summarizing, for 3 samples:

$4000 + $9000 + $9000 + $10000 = $32,000.

The total estimated cost for this study is approximately $33,000.

5.3 Non-Target, Downstream Area Contamination

For a study involving 40 sediment trap locations that are distributed over a 5 acre area, and with each of the 40 locations has co-located sediment traps, the following is an estimate of costs including the cost of the sampling equipment, labor, and sample handling.

There are very few easily identifiable vendors for sediment traps. However, based on a quote from Aquatic Research Instruments from Hope ID, the price for one sediment trap would be about $175. It was indicated that purchasing by volume could affect this price, but using that quote for estimation purposes:

$175 per sediment trap x 80 traps = $14,000. Add another $500 for necessary sundry equipment (stakes & rope which are necessary for trap deployment), and the total cost for equipment is $19,000.

For labor costs, assume that it will take one 2-man crew 3 days to deploy the 80 traps, 1 day per week to collect and manage the samples for the 3-week program, and one day for demobilization, the labor estimate would be:

1 crew x 2 people x 7 days = 14 man days.

This estimate assumes 10 or 12-hour days. Therefore, the labor costs can be estimated as approximately $12,000 (14 man days, 12 hours with over time).

Assuming the study duration is three weeks approximately 160 samples, the lab analytical costs will be approximately $48,000.

The total estimated cost per study is approximately $79,000. For five studies (assuming the traps can be reused), the total cost for this special study is approximately $319,000.

6.0 Reasonable Estimate of Monitoring Program Cost

The weekly costs for far-field (Upper Hudson River and Lower Hudson River) and near-field laboratory analyses are provided in Tables 1 through 3. The daily cost for far-field and near-field labor are provided in Tables 4 and 5. The costs per day are summarized in Table 7.

The cost of the monitoring program will depend on the amount of time that is spent at each monitoring level. It is assumed that Phase 1 will last for 30 weeks and have 210 days of operation. Far-field monitoring will be conducted every day during Phase 1. Near-field monitoring will be conducted only on the days of operation.. During Phase 1, on average four operations will be ongoing throughout to meet the production goal of half the annual production rate. If the monitoring level is routine through Phase 1, the cost of the monitoring program will be approximately $4,000,000.

Cost if Routine Throughout Phase 1	
Upper River Far-Field	$987,425
Lower River Far-Field	$ 14,400
Near-Field	$527,072
Total	$1,528,897

It is likely that some amount of non-routine monitoring will be required during Phase 1, although extended periods of higher level monitoring (Control Level or Threshold) are not foreseen because the amount of resuspension export can be controlled by changes to the remediation like maintaining strict adherence to operating procedures. It is unlikely that the concentrations at Waterford will exceed 350 ng/L Total PCB if Phase 1 is conducted in River Section 1 and the baseline concentrations stay relatively low. Therefore, it is likely that the Lower River Far-Field monitoring will be at the Routine Level throughout Phase 1. For a reasonable estimate of Upper River Far-Field monitoring, it is assumed that Routine Level monitoring will be needed for 26 of the 30 weeks and Control Level monitoring will be needed for the remaining four weeks. Similarly for Near-Field monitoring, it is assumed that all stations will be in compliance for 26 weeks and non-routine monitoring will be required for four weeks. This near-field non-compliant monitoring is somewhat high assuming four stations will be out of compliance at each of the 4 operations, but this additional cost may address the limited far-field monitoring that will accompany exceedances of the near-field suspended solids resuspension criteria and engineering evaluations. The estimated costs the special studies (for near-field PCBs, bench scale for a semi-quantitative relationship and non-target contaminant) are presented in Table 8. A reasonable estimate of the monitoring program cost for Phase 1 is also provided in Table 8.

The present worth cost estimated for the selected remedy in the feasibility study (FS, [USEPA, 2000]) is $470,000,000. During Phase 1, approximately 10 percent of the total volume to be removed will be dredged. Assuming that the cost of Phase 1 will be in proportion to the amount of sediment dredged, the cost for the Phase 1 operations will be approximately $47,000,000. For both the minimum monitoring requirements and the reasonable estimate, the monitoring program represents less than 10 percent of the total cost of the Phase 1 program.

The Phase 1 monitoring encompasses more than merely demonstrating compliance with the resuspension criteria and has been developed to provide answers to questions such as the nature of the PCB releases. This data generated during the Phase 1 monitoring program can be used throughout the remediation and justifies the cost of the program. The water column monitoring cost estimated in the FS for the selected remedy was substantially lower than the estimated cost of the Phase 1 program presented herein; however, the performance standard requirements were added during development of the ROD in response to public comments and the additional costs associated with meeting fixed standards and answering the questions raised by the public are accounted for in this estimate. One important goal of the monitoring program during Phase 1 is to gather data to demonstrate that the water column concentrations and loads can be assessed with confidence using fewer or less costly measurements (suspended solids or turbidity, as opposed to PCB analysis). If a semi-quantitative relationship is demonstrated during Phase 1, the monitoring program can be reduced accordingly for Phase 2.

The costs used in this estimate are conservative. The analytical costs used in these estimates are higher than what may be negotiated given the large amount of samples. The amount of labor needed for the monitoring program could differ from what is estimated here. For instance, if the laboratory were to filter the whole water samples for the levels other than routine, there would not be a need to add additional people for far-field sampling (with perhaps an addition of two people to shuttle samples to the lab). In addition, the monitoring program has been developed to conform to a series of data quality objectives. This allows for alteration of the monitoring plan as long as all of the data quality objectives are met. As a result, less costly means of achieving these objectives may be developed. Similarly, the costs for operating two field laboratories for seven months (assuming staffing by one technician each for 24 hours per day, seven days per week) may be on the order of about $550,000 (total for two field labs – based on the same labor rates as above; and trailer rental and equipment costs of about $10,000 for each field lab); this may be less costly than the estimate herein, which is based on off-site laboratory costs for the TSS analyses.

7.0 Feasibility and Other Considerations

The benefit of using ISCO samplers lies in labor cost savings, as the collection of the 8 daily TDS samples at the far-field stations will be automated. Under this proposed sampling plan, whole-water PCB and the associated TDS sample will still be collected manually, with depth-integrated samplers. Field personnel will also be required to gather the ISCO-generated samples and to replenish sample bottles in the ISCO. The schedule for this must be determined so as to accommodate overall QC requirements. This task could effectively be shared between the crews collecting the PCB samples and the field laboratory personnel.

The ISCO samplers must be positioned in locations that are within product specifications (e.g., distance from and height above the river) and, to prevent tampering, the ISCOs must be properly secured. Electric power will have to be provided to the locations, unless models employing low-voltage DC-current are employed.

Another benefit of the automated samplers is the elimination of variation between samples, caused by differences in sampling technique of the individual sampler or by differences in sampling location. They also eliminate the need for people to be out on bridges or near dams in the dark or inclement weather.

However, the primary advantage of this program is the elimination of managing large pools of samplers, many being “on-call” for extended periods. Coordinating personnel required to collect samples at increasingly higher action levels becomes much easier than the previous program. Under the current plan, a small pool of individual collect the whole-water PCB samples, reducing the potential for variability in sample technique and thereby providing the best opportunity to meet data quality objectives.

The use of ISCOs will require the inlet lines be permanently mounted within the river and safe from recreational traffic. At the 4 bridge stations, inlet tubing could be attached to bridge abutments or to buoys near the bridge. At the TID station, recreational traffic is not necessarily an issue; so weighted tubing could be strung from the sampler to buoys positioned at a safe distance upriver of the dam. This will allow for precise positioning of intakes to address concerns about flow at that station.

Routine maintenance will likely be required on the ISCO intake ports, as well as after storm events, to clear accumulated debris carried by the current. This may also involve repositioning the intake ports due to drift or to high flows. This task can be best accomplished through the use of a johnboat transported by vehicle between stations and launched nearby the station.

This proposed program makes efficient use of sampling crews by pairing up locations for each PCB sampling event. For example, under Routine monitoring conditions, 1 crew of 2 individuals will sample the Ft. Edward and TID stations (upriver crew), while another crew of 2 people (downriver crew) will sample the Schuylerville, Stillwater and Waterford stations. The travel time between the Ft Edward and TID stations is approximately 10 minutes, meaning that this crew should have a relatively easy time collecting the samples from both stations. The upriver crew only samples 2 stations due to unique problems presented at the TID station. The downriver crew will sample 3 stations, however the short travel time (approximately 10 minutes between each station) and the relative ease of collection at these stations warrant the additional station. Each of these stations require sampling from bridges that have wide sidewalks and guard rails for safety.

Another factor to consider is the placement of the mobile labs. If the labs are situated near the TID station and near the Waterford station, the crew could deliver the upstream sample to the lab for processing then move downriver to collect samples at the next station.

With respect to meeting the required turn around times for sample analysis, the proposed extraction method for PCB analysis is solid-phase extraction (SPE). Although the extraction time varies somewhat based on the physical characteristics of the sample (e.g., suspended matter which may tend to slow down the process), it appears that the actual process can be completed in an hour or so. Add to that the analysis itself, which may take a minimum of an hour (based on the time from injection of the sample through the completion of the analysis). However, it needs to be considered that extraction for 1-L samples is fairly automated; the 8-L extraction requires manual intervention during the extraction.

It thus appears that 24-hour TAT for PCBs for the proposed 1-L method is at least theoretically achievable. Whether or not this would require the lab to run additional shifts (add a second and/or third shift) or weekend shifts is a separate issue that would be contingent upon the scheduling of sample delivery to the laboratory, as well as how many samples had to be processed at once.

A hidden advantage in the decrease in sampling staff is a net decrease in the potential for safety incidents. The smaller pool of samplers in this program will become acquainted with specific safety issues at each site, which will help in minimizing accidents. For additional safety measures, a communication system should be employed, such as hand-held radios or a higher gain system that could be tied into the field laboratories, as well. All field personnel should be required to carry cellular telephones (with service that covers the area in question) to contact local authorities. The Hudson valley presents unique problems to cellular customers, so care should be paid as to which cellular carrier is chosen. The Minimal safety equipment for the crewmembers will be steel-toed boots, hard hats, safety glasses, nitrile gloves and PFDs.

8.0 Conclusions

The Phase 1 monitoring plan developed for the performance standard measures compliance with the resuspension criteria and provides important information on the nature and impact of the remediation on the river. The estimate cost of the water column monitoring is approximately $3,000,000. The costs developed for Phase 1 cannot be applied to the entire remediation, because modifications to the monitoring program may be made for Phase 2; it is likely that these modifications will result in cost reductions after the Phase 1 program data are reviewed and the Phase 2 monitoring program is optimized.

9.0 References

Earhart, H.G. 1984. “Monitoring total suspended solids by using nephelometry,” Environmental Management 8(1), pp. 81-86.

USEPA, 2000. Phase 3 Report: Feasibility Study, Hudson River PCBs Reassessment RI/FS. Prepared for USEPA Region 2 and the US Army Corps of Engineers (USACE), Kansas City District by TAMS Consultants, Inc. December 2000.

Tables

Table 1
Sampling Cost on a Weekly Basis - Upper River Far-Field Stations

Routine Monitoring Number of Samples per Day Only	Lab Turn-Around Time (hr.)	Laboratory Analyses				Integrating Sampler for PCBs	Laboratory Analyses				Integrating Sampler for PCBs
		Congener-Spec. PCBs Whole Water	DOC & Susp. OC	SS	SS (1/3-hours)^3		Congener-Spec. PCBs Whole Water	DOC & Susp. OC	SS	SS (1/3-hours)^3	
RM 197.0 - Bakers Falls Br.	72	1	1	1			525	95	20		
RM 194.2 - Ft Edward	72	7	7.5	7.5	56	0.5	3,675	713	150	20	150
RM 188.5 - TI Dam	24	7	7.5	7.5	56	0.5	4,200	713	150	150	150
RM 181.4 - Schuylerville	24	7	7.5	7.5	56	0.5	4,200	713	150	150	150
RM 163.5 - Stillwater	72	7	7.5	7.5	56	0.5	3,675	713	150	150	150
RM 156.5 – Waterford	72	7	7.5	7.5	56	0.5	3,675	713	150	150	150
Analytical Cost/Week		36	38.5	38.5	280	2.5	19,950	3,658	770	620	750
Total Analytical Cost/Week		**38.5 or 5.5 /day**					**25,748 or 3,678 /day**				

Evaluation Level Number of Samples per Day Only	Lab Turn-Around Time (hr.)	Laboratory Analyses				Integrating Sampler for PCBs	Laboratory Analyses				Integrating Sampler for PCBs
		Congener-Spec. PCBs Whole Water	DOC & Susp. OC	SS	SS (1/3-hours)^3		Congener-Spec. PCBs Whole Water	DOC & Susp. OC	SS	SS (1/3-hours)^3	
RM 197.0 - Bakers Falls Br.	72	1	1	1			525	95	20		
RM 194.2 - Ft Edward	72	7	7.5	7.5	56	0.5	3,675	713	150	20	150
RM 188.5 - TI Dam	24	14	0.5	0.5	56	0.5	8,400	48	10	150	150
RM 181.4 - Schuylerville	24	14	0.5	0.5	56	0.5	8,400	48	10	10	150
RM 163.5 - Stillwater	72	7	7.5	7.5	56	0.5	3,675	713	150	10	150
RM 156.5 – Waterford	72	7	7.5	7.5	56	0.5	3,675	713	150	150	150
Analytical Cost/Week		50	24.5	24.5	280	2.5	28,350	2,328	490	340	750
Total Analytical Cost/Week		**52.5 or 7.5 /day**					**32,258 or 4,608 /day**				

Control Level Number of Samples per Day Only	Lab Turn-Around Time (hr.)	Laboratory Analyses				Integrating Sampler for PCBs	Laboratory Analyses				Integrating Sampler for PCBs
		Congener-Spec. PCBs Whole Water	DOC & Susp. OC	SS	SS (1/3-hours)^3		Congener-Spec. PCBs Whole Water	DOC & Susp. OC	SS	SS (1/3-hours)^3	
RM 197.0 - Bakers Falls Br.	72	1	1	1			525	95	20		
RM 194.2 - Ft Edward	72	7	7.5	7.5	56	0.5	3,675	713	150	20	150
RM 188.5 - TI Dam	24	21	1	1	56	1	12,600	95	20	150	300
RM 181.4 - Schuylerville	24	21	1	1	56	1	12,600	95	20	20	300
RM 163.5 - Stillwater	72		7	7	56	7		665	140	20	3,675
RM 156.5 – Waterford	72		7	7	56	7		665	140	140	3,675
Analytical Cost/Week		50	24.5	24.5	280	16.5	29,400	2,328	490	350	8,100
Total Analytical Cost/Week		**66.5 or 9.5 /day**					**40,668 or 5,810 /day**				

Threshold Number of Samples per Day Only	Lab Turn-Around Time (hr.)	Laboratory Analyses				Integrating Sampler for PCBs	Laboratory Analyses				Integrating Sampler for PCBs
		Congener-Spec. PCBs Whole Water	DOC & Susp. OC	SS	SS (1/3-hours)^3		Congener-Spec. PCBs Whole Water	DOC & Susp. OC	SS	SS (1/3-hours)^3	
RM 197.0 - Bakers Falls Br.	72	1	1	1			525	95	20		
RM 194.2 - Ft Edward	72	1	1	1	8	1/2-weeks	525	95	20	20	21
RM 188.5 - TI Dam	24	4	1	1	8	1	2,400	95	20	20	600
RM 181.4 - Schuylerville	24	4	1	1	8	1	2,400	95	20	20	600
RM 163.5 - Stillwater	24	4	5	5	8	1	2,400	475	100	20	600
RM 156.5 – Waterford	24	4	5	5	8	1	2,400	475	100	100	600
Analytical Cost/Day		18	14	14	40	4	10,650	1,330	280	180	2,421
Total Analytical Cost/Day		**22 /day**					**14,861 /day**				

Table 2
Sampling Cost on a Weekly Basis - Lower River Far-Field Stations

Lower River Sampling Requirements on a Weekly Basis

Routine Monitoring	Lab Turn-Around Time (hr.)	No. of Analyses/Week			Cost of Analyses/Week		
		Congener-specific PCBs Whole	DOC & Susp. OC	SS	Congener-specific PCBs Whole Water	DOC & Susp. OC	SS
Mohawk R. at Cohoes	72	0.25	0.25	0.25	131	24	5
RM 140 - Albany	72	0.25	0.25	0.25	131	24	5
RM 77 - Highland	72	0.25	0.25	0.25	131	24	5
Analytical Cost/Week		0.75	0.75	0.75	394	71	15
Total Analytical Cost/Week					480		

Non-Routine Monitoring	Lab Turn-Around Time (hr.)	No. of Analyses/Week			Cost of Analyses/Week		
		Congener-specific PCBs Whole	DOC & Susp. OC	SS	Congener-specific PCBs Whole Water	DOC & Susp. OC	SS
Mohawk R. at Cohoes	24	1	1	1	600	95	20
RM 140 - Albany	24	1	1	1	600	95	20
RM 77 - Highland	24	1	1	1	600	95	20
Analytical Cost/Week		3	3	3	1800	285	60
Total Analytical Cost/Week					2145		

Note:

(1) Non-routine monitoring will be triggered only when Waterford or Troy have total PCB concentration greater than 350 ng/L.

Table 3
Sampling Cost on a Weekly Basis - Upper River Near-Field Stations

Near-Field Sampling Requirements on a Weekly Basis
Routine Monitoring (with use of continuous reading probe to indicate suspended solids concentrations)

No. of Operations	No. of SS Laboratory Analyses	Cost of SS Laboratory Analyses
1	35	700
2	70	1400
3	105	2100
4	140	2800
5	175	3500
6	210	4200
7	245	4900
8	280	5600
9	315	6300
10	350	7000

Non-Routine Monitoring

	Number of SS Laboratory Samples with 4-Hour Turn-Around per Week				
	Number of Stations with Exceedences of the Standard				All Stations
No. of Operations	1	2	3	4	5
1	49	98	147	196	245
2	98	196	294	392	490
3	147	294	441	588	735
4	196	392	588	784	980
5	245	490	735	980	1,225
6	294	588	882	1,176	1,470
7	343	686	1,029	1,372	1,715
8	392	784	1,176	1,568	1,960
9	441	882	1,323	1,764	2,205
10	490	980	1,470	1,960	2,450

	Cost of SS Laboratory Samples with 4-Hour Turn-Around per Week				
	Number of Stations with Exceedences of the Standard				All Stations
No. of Operations	1	2	3	4	5
1	980	1,960	2,940	3,920	4,900
2	1,960	3,920	5,880	7,840	9,800
3	2,940	5,880	8,820	11,760	14,700
4	3,920	7,840	11,760	15,680	19,600
5	4,900	9,800	14,700	19,600	24,500
6	5,880	11,760	17,640	23,520	29,400
7	6,860	13,720	20,580	27,440	34,300
8	7,840	15,680	23,520	31,360	39,200
9	8,820	17,640	26,460	35,280	44,100
10	9,800	19,600	29,400	39,200	49,000

Table 4
Labor Cost on a Daily Basis - Far-Field Stations

Routine Monitoring Station	No.of people	No. of shift/day	No. of people/day	Labor /day
Baker's Falls (1)	2	0.1	0.2	
Ft Edward/TID	2	1	2	
Schuyl/Still/Wat	2	1	2	
Total			4.2	$ 1,747

Evaluation Level Station	No.of people	No. of shift/day	No. of people/day	Labor /day
Baker's Falls (1)	2	0.1	0.2	
Ft Edward/TID/Schuyl	2	2	4	
Still/Wat	2	1	2	
Total			6.2	$ 2,579

Contol Level Station	No.of people	No. of shift/day	No. of people/day	Labor /day
Baker's Falls (1)	2	0.1	0.2	
Ft Edward/TID/Schuyl	2	3	6	
Still/Wat	2	1	2	
Total			8.2	$ 3,411

Threshold Station	No.of people	No. of shift/day	No. of people/day	Labor /day
Baker's Falls (1)	2	0.1	0.2	
Ft Edward/TID/Schuyl	2	3	6	
Ft Edward/TID/Schuyl	2	1	2	
Still/Wat	2	3	6	
Still/Wat	2	1	2	
Total			16.2	$ 6,739

Notes:
(1) Other stations includes Bakers Falls Bridge and Lower Hudson.

Table 5
Labor Cost on a Daily Basis - Near-Field Stations

Near-Field Sampling Requirements on a Weekly Basis
Routine Monitoring

No. of Operations	No.of people	No. of shift/day	No. of people/day	Labor /day
1-5	3	2	6	$ 2,496
5-10	6	2	12	$ 4,992

Non-Routine Monitoring

No. of Operations	No.of people	No. of shift/day	No. of people/day	Labor /day
1-2	4	2	8	$ 3,328
3-4	8	2	16	$ 6,656
5-6	12	2	24	$ 9,984
7-8	16	2	32	$ 13,312
9-10	20	2	40	$ 16,640

Table 6
Near-Field Total PCB Concentration Special Studies

Assumptions:
Assume 4 different types of dredges.
One sampling event will be conducted for each dredge type and one debris removal
Sampling will be conducted once per day for one full work week.
There are 7 days per work week.
5 locations are occupied in the transect.
There are 2 transects:one outside the containment and one 100 m downstream of containment
One subsample is located in water depth greater than 10 ft., others less than 10 ft.
At the one deeper location one sample is collected 0-10 ft, one deeper than 10 ft.
At least three samples will be taken within containment and composited
Samples will be vertically integrated.
All work is done in containment.

		Congener-Specific PCBs					
		Whole Water	Dissolved Phase	Suspended Phase	DOC & Susp. OC	SS	Probe Turbidity
Number of upstream samples		1			1	1	1
Number of samples per transect		4	2	2	6	6	6
Number of transects	2						
Number of samples with containment			1	1	1	1	1
Number of Analyses per Day		10	5	5	15	15	15
Number of Days per Event	7						
Total Number of Analyses per Event		70	35	35	105	105	
Analytical Cost Per Event		$ 21,000	$ 10,500	$ 10,500	$ 9,975	$ 2,100	
Total Analytical Cost per Event	$ 54,075						
Number of Technicians per Day	6	(2 boat crews of 3)					
Total Labor Costs per Event	$17,472						
Total Cost per Event (Labor+Analytical):	$ 71,547						
Number of Events	5						
Total for Study	$ 357,735						

Table 7
Summary of Labor and Lab Analytical Costs by Action Level

Phase 1 Costs/Day

Upper River Far-Field			
Level	Analytical	Labor	Total
Routine	3,678	1,747	5,425
Evaluation	4,608	2,579	7,187
Control	5,810	3,411	9,221
Threshold	14,861	6,739	21,601

Lower River Far-Field	
Level	Analytical
Routine	69
Non-Routine	306

Near Field	Routine		Non-Routine				
Non-Compliant	Analytical		Analytical				
Stations		Labor	1	2	3	4	Labor
1	100	2,496	140	280	420	560	3,328
2	200	2,496	280	560	840	1,120	3,328
3	300	2,496	420	840	1,260	1,680	6,656
4	400	2,496	560	1,120	1,680	2,240	6,656
5	500	2,496	700	1,400	2,100	2,800	9,984
6	600	4,992	840	1,680	2,520	3,360	9,984
7	700	4,992	980	1,960	2,940	3,920	13,312
8	800	4,992	1,120	2,240	3,360	4,480	13,312
9	900	4,992	1,260	2,520	3,780	5,040	16,640
10	1,000	4,992	1,400	2,800	4,200	5,600	16,640

Table 8
Reasonable Estimate of Phase 1 Season Monitoring Plan Costs

Assume:
Half Production (4-operations on average)
Far-Field Sampling on all days; Near-Field on days of operation

210	days of operation	
30	weeks/Phase 1	
7	days/week far-field sampling	
26	weeks of Routine Monitoring Upper River Far-Field	987,425
4	weeks of Control Monitoring Upper River Far-Field	258,184
30	weeks of Routine Monitoring Lower River Far-Field	14,400
26	weeks of Routine Near-Field Monitoring	527,072
4	weeks of Non-Routine Near-Field Monitoring at 4 Stations	249,088
	Monitoring Cost:	2,036,169
	Special Study for Total PCBs	357,735
	Special Study for Total PCBs	33,000
	Special Study for Total PCBs	319,000
	Monitoring Cost & Special Study:	2,745,904