Hudson River

PCBs SUPERFUND SITE

Engineering Performance Standards

Technical Basis and Implementation of the Productivity Standard

April 2004

Volume 4 of 5

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Prepared by:
Malcolm Pirnie, Inc.
104 Corporate Park Drive
White Plains, New York 10602

and

TAMS Consultants, Inc.
an Earth Tech Company
300 Broadacres Drive
Bloomfield, New Jersey 07003

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ATTACHMENTS

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List Of Acronyms

AMN	Water treatment facility (*formerly known as* SRMT)
ARARs	Applicable or Relevant and Appropriate Requirements
ATL	Atlantic Testing Labs
CAB	Cellulose Acetate Butyrate
CAMU	Corrective Action Management Unit
Cat 350	Caterpillar Model 350
CDF	Confined Disposal Facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF	cubic feet
cfs	cubic feet per second
CLP	Contract Laboratory Program
cm	centimeter
CPR	Canadian Pacific Railroad
CSO	Combined Sewer Overflow
CU	certification unit
CWA	Clean Water Act
cy	cubic yard(s)
DDT	Dichlorodiphenyltricholorethane
DEFT	Decision Error Feasibility Trials
DGPS	Differential Global Positioning System
DMC	Dredging Management Cells
DNAPL	Dense Non-Aqueous Phase Liquid
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DQOs	Data Quality Objectives
DSI	Downstream of the dredge area inside the silt curtain
DSO	Downstream of the dredge area outside the silt curtain
EDI	Equal Discharge Interval
EMP	Environmental Monitoring Plan
EPS	Engineering Performance Standards
EQUIL	Software model used to determine chemical equilibrium between the particle-bound solid and the water column or aqueous phase
ESG	ESG Manufacturing, LLC
EWI	Equal Width Interval
FIELDS	Field Environmental Decision Support
FISHRAND	USEPA's peer-reviewed bioaccumulation model

FJI	Fort James Water Intake
fps	feet per second
FRRAT	Fox River Remediation Advisory Team
FS	Feasibility Study
ft	foot
ft^2	square feet
GE	General Electric Company
GEHR	General Electric Hudson River
GCL	Geosynthetic Clay Liner
g/cc	grams per cubic centimeter
g/day	grams per day
GIS	Geographic Information Systems
GM	General Motors
gpm	gallons per minute
GPS	Global Positioning System
HDPE	High Density Polyethylene
HUDTOX	USEPA's peer-reviewed fate and transport model
IDEM	Indiana Department of Environmental Management
JMP	a commercial software package for statistical analysis
kg/day	kilograms per day
lbs	pounds
LWA	length-weighted average
MCL	Maximum Contaminant Level
MCT	Maximum Cumulative Transport
MDEQ	Michigan Department of Environmental Quality
MDS	ESG Manufacturing model #. For example, MDS-177-10
MFE	Mark for Further Evaluation
MGD	million gallons per day
ug/L	micrograms per liter
mg/kg	milligrams per kilogram (equivalent to ppm)
mg/L	milligrams per liter
MPA	Mass per Unit Area
MVUE	minimum unbiased estimator of the mean
ng/L	nanograms per liter
NBH	New Bedford Harbor
NJDEP	New Jersey Department of Environmental Protection
NPDES	National Pollution Discharge Elimination System
NPL	National Priorities List

NTCRA	Non-Time-Critical Removal Action
NTU(s)	Nephelometric Turbidity Units
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
OBS	Optical Backscatter Sensor
O&M	Operations and Maintenance
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
PCDFs	Polychlorinated Dibenzofurans
pcf	pounds per cubic foot
PL	Prediction Limit
ppm	part per million (equivalent to mg/kg)
PVC	Polyvinyl Chloride
Q-Q	Quantile-Quantile
QA/QC	Quality Assurance / Quality Control
QAPP	Quality Assurance Project Plan
QRT	Quality Review Team
RCRA	Resource Conservation and Recovery Act
RDP	Radial Dig Pattern
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RM	River Mile
RMC	Reynolds Metals Company
ROD	Record of Decision
RS	Responsiveness Summary
Site	Hudson River PCBs Superfund Site
SLRP	St. Lawrence Reduction Plant
SMU	Sediment Management Unit
SOP	Standard Operating Procedure
SPI	Sediment Profile Imaging
SQV	Sediment Quality Value
SRMT	St. Regis Mohawk Tribe Water treatment facility (*former name for* AMN)
SSAP	Sediment Sampling and Analysis Program
SSO	Side-stream of the dredge area outside of the silt curtain
SVOCs	Semi-Volatile Organic Compounds
TAT	Turn-around Time
TDBF	Total Dibenzofurans
TG	turbidity generating unit
TI	Thompson Island
TIP	Thompson Island Pool

TM	turbidity monitoring
TOC	Total Organic Carbon
Tri+	PCBs containing three or more chlorines
TSCA	Toxic Substances Control Act
TSS	Total Suspended Solids
UCL	Upper Confidence Limit
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
USI	Upstream of the dredge area outside the silt curtain
USO	Upstream of dredge area outside the silt curtain
USS	US Steel
VOC	Volatile Organic Compound
WDNR	Wisconsin Department of Natural Resources
WINOPS	Dredge-positioning software system used to guide the removal of contaminated sediment
WPDES	Wisconsin Pollutant Discharge Elimination System
WSU	Wright State University

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Hudson River PCBs Superfund Site
Volume 4: Technical Basis and Implementation of the Productivity Standard

1.0 Technical Background and Approach

1.1 ROD Requirements Related to Performance Standard for Dredging Productivity

The United States Environmental Protection Agency's (USEPA's) Record of Decision (ROD) for the Hudson River PCBs Superfund Site (USEPA, February 2002) specifies a number of conditions that influence the development of the Productivity Standard. For the purposes of developing the Productivity Standard, the ROD's mandates were placed into two categories:

- Requirements that relate directly to productivity and schedule
- Factors that influence or constrain productivity

The principal elements of the remedy that directly influence the Productivity Standard are as follows (ROD at pp. ii to iii and 94 to 95):

- An estimated 2.65 million cubic yards (cy) of sediment are to be removed from the Upper Hudson River. This estimate was initially developed in the Feasibility Study (FS) (USEPA, 2000).
- Of the 2.65 million cy, an estimated 341,000 cy will be removed for purposes of improving project-related navigation.
- Dredging will occur in two phases: Phase 1 and Phase 2.
- Phase 1 dredging will be conducted initially at a reduced rate, and the results of monitoring during Phase 1 will be used to make any necessary adjustments to operations in Phase 2.
- Phase 2 dredging will be conducted at full scale.
- The design for the project will plan for a construction period of six years.
- The first year will be at less than full scale and the next five years will be at full scale.

In summary, USEPA's objective is to remove sufficient polychlorinated biphenyl (PCB) contaminated sediment from the Upper Hudson River, estimated at 2.65 million cy, in a period of six years in order to meet the objectives stated in the ROD. The initial year of work will entail considerable monitoring of dredging operations to allow evaluation of and adjustments to the dredging program. Full-scale removal operations will then be conducted for five years, during which the remaining targeted contaminated sediment will be removed.

1.2 Direct Implications of ROD Requirements for Productivity

To develop the Productivity Standard for Phase 1 and Phase 2, and to confirm the feasibility of accomplishing the remedy in accordance with the Productivity Standard, it is necessary to view the ROD requirements from the perspective of developing and implementing a construction and materials handling operation. The requirement to remove an estimated 2.65 million cy of sediment establishes the overall scale of the effort but does not, in and of itself, set measurable targets for the remedial work as the project progresses. In addition, although the 2.65 million cy figure is the current best approximation of the volume of sediment to be dredged, this estimate is expected to be revised during the remedial design.

The volume of contaminated sediment referred to in this Productivity Standard is the volume as measured *in situ* in the riverbed. It is estimated to be approximately 2.65 million cy based on sediment sampling data available through the end of 2001. New data from the ongoing sediment sampling program and other analyses begun by GE in 2002 may result in a revision of this volume estimate. A change of 10 percent or less in the overall volume will be addressed by revising the required volume for the final year of Phase 2. However, if the volume of sediment to be dredged changes by more than 10 percent as a result of the current sampling program and final design considerations, the Phase 2 required and target volumes will be adjusted based on the guiding principles and approach that were used to develop the Productivity Standard (refer to Volume 1 Section 4.3). To develop a quantitative and measurable Productivity Standard, the following assumptions were made and applied throughout this chapter:

- The estimated volume of sediment that will be removed is 2.65 million cy, as stated in the ROD.
- Dredging during Phase 1 will require the removal of about 200,000 cy of sediment, with a target for removal of 265,000 cy.
- An average of approximately 490,000 cy of sediment will have to be removed during each of five full-scale dredging years (Phase 2). A target removal objective is set at 530,000 cy per year for the first four seasons of Phase 2 and 265,000 cy for the final season of dredging.
- In the ideal case, there will be a minimum of 30 weeks available each year to conduct dredging operations, and dredging operations will occur seven days per week, as per the FS and the Responsiveness Summary (RS). However, the project schedule will include provisions for some downtime that might result from high river flows and other uncontrollable events.
- Transfer, processing, and transportation (for disposal) facilities will be available to manage dredged sediments at the rate implied by the Productivity Standard.
- The sequence in which the various sediment deposits are dredged will not be influenced by whether the sediment is considered a waste as defined under the Toxic Substance Control Act (TSCA) (*i.e.* contains ≥ 50 mg/kg Total PCBs) or non-TSCA waste (contains <50 mg/kg Total PCBs). A determination of the regulatory status of the sediment will be made by sampling processed sediment prior to loading rail cars or barges for shipment to the disposal site.

Given the above assumptions, it is possible to consider general productivity parameters for the project's full-scale production years. Table 1-1 presents a gross calculation of generalized production rates required to meet the six-year schedule specified by the ROD. These generalized rates are obtained by dividing the total estimated volume to be dredged in a season by the total estimated available calendar time in a season.

Dividing total estimated volume to be dredged per season by the total estimated available calendar time in a season = generalized production rates needed to meet the 6-yr ROD-mandated schedule.

While these generalized rates are presented for illustrative purposes as a starting point for evaluating the equipment and facilities necessary to achieve the Productivity Standard, the actual average weekly and average daily production rates will have to be increased to account for a lack of production on holidays and downtime due to high flow events in the river, breakdowns of equipment, the need to remove unanticipated submerged obstacles, and similar disruptions in the project schedule.

From the perspective of meeting the project's overall goals, the seasonal production rate is most critical. The average monthly rate may be used as a basis for monitoring whether the project is on track toward achieving the seasonal target. The average daily production rate will have the greatest impact on setting requirements for the capacity of transfer, processing, and transportation facilities. Knowing the project's average daily effective time (percent of time the dredge is actually dredging and delivering sediment to the processing/shipping site), it is also possible to estimate the hourly throughput that will have to be handled by various conveyance and processing subsystems. The capacities and redundancies to be designed and built into these subsystems should be based on an assessment of the peak daily and hourly loads that are likely to be generated by the dredging equipment.

Seasonal production rate is critical to meeting the project's overall goals.

1.3 Indirect Implications of ROD Requirements for Productivity

In addition to those elements of the ROD that have a direct bearing on productivity, there are several facets of the ROD that may have an indirect impact on project output. Among the most significant of these are the following:

- Backfilling dredged areas with approximately one foot of clean fill, to isolate PCB residuals and to expedite habitat recovery, where appropriate
- Removal of all PCB-contaminated sediments in areas targeted for remediation with an anticipated residual of approximately 1 mg/kg Tri+ PCBs (prior to backfilling)
- Limiting allowable dredging related resuspension rates

The additional equipment and time needed to backfill dredged areas is factored directly into the Productivity Standard. Backfilling is planned for and is treated as one component of the construction activities that comprise the overall program; it will impact project output much the way the other activities do.

The requirements identified in the second and third bullets above are reflected in the Resuspension Standard (see Volumes 1 and 2) and the Residuals Standard (see Volumes 1 and 3). The Resuspension Standard and Residuals Standard will influence productivity and, ultimately, the Productivity Standard. For instance, conforming to the Resuspension Standard may result in the following actions being taken, as appropriate:

- Selecting different dredging equipment
- Implementing contingency measures such as modifying dredge operating procedures or collecting samples more frequently
- Postponing or reducing operations until more favorable river conditions are present
- Delaying operations while monitoring data are evaluated
- Installing turbidity containment barriers around the dredging site, if such barriers are not already in use

Similarly, the Residuals Standard may result one of the following actions being taken:

- Selecting different dredging equipment
- Conducting additional dredging passes within targeted areas or redredging of areas that fail to meet the Residuals Standard
- Constructing an engineered cap over residual sediments in extreme cases where the Residuals Standard is not met despite best efforts to remove the sediments

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1.4 Other Factors Influencing Productivity

A number of other factors, beyond those considered above, may impact project productivity. Among the more significant of these are the following:

- The distribution of targeted sediments within the Upper Hudson River
- Limitations on in-river work imposed by river conditions and the need to maintain traffic on the canal system
- Limitations on in-river work as a result of standards set on equipment noise and air emissions
- The interrelationship of dredging productivity to the location and capacities of transfer, processing and transportation facilities

The first two of these additional factors are addressed in the analysis presented below. The remaining two factors are not evaluated in this document but will be addressed in the project design. With regard to noise, it is assumed that the noise standards set by USEPA will not constrain the productivity of the dredging operations (*i.e.*, noise abatement will either not be necessary or noise abatement technology installed on dredging equipment will not significantly affect the productivity of the equipment). Furthermore, consistent with the ROD, it is assumed that in-river activities and sediment processing and transportation operations are not restricted to certain days or hours.

Since the location(s) and characteristics of sediment processing/transfer facility(ies) are not known at this time, it is not possible to factor into the productivity analysis any constraints on the ability of those facilities to handle dredged sediments. Rather, it is assumed that once the location(s) of the processing/transfer facility(ies) is(are) identified, the facilities will be designed to ensure adequate processing capability to handle incoming sediments at rates commensurate with USEPA's project goal of completing the project in six years. However, processing and shipping considerations have not been ignored in developing the Productivity Standard. Instead, the Productivity Standard has been developed with consideration of the design team's need for flexibility to avoid the problems associated with radical, short-term fluctuations in the volume of sediment sent to the processing/transfer facilities, so that on-site sediment staging requirements can be reduced and off-site transportation needs can be anticipated and coordinated.

1.5 Approach to Development of Standard

The approach taken to develop the Productivity Standard is to:

- Establish minimum productivity requirements for Phases 1 and 2 of the project that meet the requirements of the ROD.
- Identify and evaluate the anticipated field conditions that will impact productivity.
- Obtain, where possible, reports or other information on projects that are similar to the Upper Hudson River environmental dredging project and can provide support to the Productivity Standard.
- Identify typical production rates for available dredging equipment that has been demonstrated to function successfully under the field conditions anticipated in the Upper Hudson River.
- Prepare an example production schedule based upon use of the identified plant and equipment that supports the assumption that the proposed Productivity Standard can be met and the project completed within the time frame established by the ROD.

While the development of the Productivity Standard includes an example production schedule, the design team will develop the actual project schedule as a separate activity. The purpose of the example production schedule is to demonstrate that the performance standards are feasible and can be met using conservative assumptions and at least one selection of equipment from the wide array of such equipment currently available and in use on environmental dredging projects.

2.0 Supporting Analyses

2.1 Recent Projects and Developments in Dredging Technology

To take into account the most current technologies and information available from other dredging sites, a search was conducted on the USEPA web site, and parties associated with other sediment remediation/dredging projects were contacted to update the database developed during preparation of the FS and RS. In addition, follow-up conversations were held with site managers contacted during completion of the FS and RS where it was thought that additional information with regard to dredging, equipment, schedules, constraints, and the like could be obtained. The information obtained from these sources is presented in Volume 5: *Appendix: Case Studies of Environmental Dredging Projects*.

The review of recent projects and developments in dredging technology revealed a number of points that are of interest in developing the productivity standard. Some of the more significant findings are as follows:

- A large number of sediment remediation projects have been completed or are being designed using mechanical dredges equipped with special buckets designed to minimize resuspension and to produce a flat bottomed cut. Positioning of the dredge and bucket to ensure that sediment is not "missed" is accomplished with global positioning system (GPS) equipment linked to computers on board the dredging vessel. This equipment has been demonstrated to achieve cut tolerances of less than 6 inches when properly operated.

Numerous sediment remediation projects employ mechanical dredges with buckets designed to minimize resuspension, and GPS to optimize positioning.

- Many, if not most, projects reviewed made use of some type of containment structure around the dredges to minimize the loss of resuspended sediments to downstream areas. Containment systems ranged from interlocking steel sheet piling to traditional silt curtains.

- Resuspension has not been a major problem in most instances where containment systems have been used. Where such systems have not been employed, resuspension has been addressed through careful control of the dredging operation and limiting dredging operations during adverse weather or high flow periods. A decision as to whether it is more cost-effective to spend part of a dredging season installing an engineered containment system around an area to be dredged, or to depend on careful operation of the dredges and ancillary equipment to control resuspension, must be made on a site-specific basis and should be addressed in final design.

Resuspension has been addressed through containment systems or careful control of the dredging operation.

- Achieving low cleanup levels (*e.g.*, <1.0 mg/kg) has proven difficult under certain circumstances, for example where boulders or other obstacles are present in or underlying the sediment to be removed. In many of the projects reviewed, it was necessary to redredge at least some areas to achieve the target cleanup level, and on some projects the target cleanup level was not reached in limited, extremely difficult areas despite multiple passes of the dredging equipment.

Achieving low cleanup levels has proven difficult in some cases, resulting in the need for re-dredging.

2.2 Analysis of Factors Affecting Productivity

A number of factors may affect the length of time required to complete the Upper Hudson River environmental dredging project, including:

- The actual volume of sediments to be dredged.
- The capacity and production rates of dredging equipment selected.
- The sediment processing/transfer facility(ies) (including the water treatment system).
- The distance from the dredging areas to the sediment processing/transfer facility(ies).
- Any physical limitations on reaching areas targeted for dredging.
- The potential need to conduct a number of passes with the dredge to achieve target clean up goals.
- The rate at which backfill can be placed over dredged areas.
- Engineering constraints imposed on the construction manager regarding resuspension.
- Potential bottlenecks in the transportation networks required for shipping sediments to off-site disposal facilities.
- Poor weather.
- High river flows.

These factors must be taken into account in developing the Productivity Standard to demonstrate that the standard can be met. Some of the more critical factors are discussed below.

2.2.1 Dredging Equipment

Four general types of dredging systems are considered here:

- Mechanical dredges with scow transport
- Hydraulic dredges with hydraulic transport
- Mechanical dredges with hydraulic transport
- Hydraulic dredges with scow transport

Alternative equipment may also be required in some areas, such as around docks, locks, retaining walls, submerged utility lines, and bridge piers, and in shallow water along the shoreline where access by large equipment is limited. This equipment may include small, diver-assisted dredges, amphibious excavators and trucks capable of working in shallow water and on beaches and conveying sediment to scows located in deeper water, and similar equipment not usually associated with major dredging projects.

2.2.2 In-River Factors

Factors affecting the productivity of the various types of dredges and auxiliary operations that are likely to be considered and used in the Upper Hudson are described below.

2.2.2.1 Need to Minimize Resuspension and Residuals

Refer to Volume 1: *Statement of the Engineering Performance Standards for Dredging*, Volume 2: *Technical Basis and Implementation of the Resuspension Standard*, and Volume 3: *Technical Basis and Implementation of the Residuals Standard.*

> *Properly operated hydraulic dredges can function with limited resuspension of particulate matter into the water column.*
>
> *Improvements in bucket design and electronic controls, and properly designed silt barriers also minimize the problem of resuspension.*

Environmental dredging to remove contaminated sediments is inherently slower than navigational dredging because of the care that must be taken to avoid excessive resuspension and ensure that sediment is not “missed” by the dredge. Numerous projects conducted over the past decade show that properly operated hydraulic dredges can function with limited resuspension of particulate matter into the water column. Recent improvements in bucket design and electronic controls have significantly reduced the problem of resuspension when using mechanical dredges (See Volume 5: *Appendix: Case Studies of Environmental Dredging Projects*). The use of properly designed silt barriers to isolate areas being dredged has been demonstrated to prevent the loss of resuspended sediment downstream. Although not required by the Productivity Standard, it is assumed that silt barriers will be considered for control by the design team.

> *GPS and on-board computer positioning software increase accuracy in overlapping cuts, thus reducing risk of missed sediment.*

The use of GPS, coupled to an on-board computer running WINOPS or a similar software package, has been shown to be effective in assisting dredge operators to position a dredge head or bucket to ensure overlapping cuts and reduce the probability of missing contaminated sediment.

However, recent experience has shown that, even where these devices have been used, the problem of residual contamination has not been completely eliminated. In some instances, most notably the 1999-2000 dredging of PCB-contaminated sediments and paper mill sludges in Cumberland Bay in Lake Champlain, inspection of the lake bottom following initial dredging showed that windrows (long heaped rows) and pockets of undredged material remained, despite the fact that GPS equipment was used to control and map dredge passes. Further investigations revealed that the GPS equipment suffered from numerous failures and that wind gusts, which blew the dredge off station, were a problem on a number of days (Earth Tech, 2002).

In the St. Lawrence River, opposite the former Reynolds Metals Primary Aluminum Extraction Plant where PCB-contaminated sediments were dredged from a 35-acre area using derrick dredges equipped with cable arm environmental buckets during the summer of 2001, sampling following initial dredging showed that the dredging had successfully removed the contaminated sediment to the target cleanup level set for the project in 134 of 268 "cells" established at the start of the project for control purposes. The WINOPS system was used to control the derrick dredges and the placement of the buckets, and the initial dredging included some over-cut in an attempt to avoid leaving contaminated material behind.

In this case, fully 50 percent of the cells had to be redredged to remove residual contamination a slightly different situation was thought to be responsible for the need to redredge. This problem of residual contamination apparently resulted from the inability of the bucket used to remove the final layer of PCB-contaminated sediment above a compacted glacial till. Redredging successfully remediated 78 additional cells in one additional pass of the dredge. A second attempt at redredging succeeded in remediating 22 more cells, and 34 cells were redredged three or more times. One cell was dredged a total of ten times and still did not achieve the target cleanup level. A report on the project (Bechtel, 2002) concluded that, in addition to the problem encountered in removing all of the sediment overlying a compacted till, large rock fragments and other obstructions in the dredging area hindered the clean up work. Whatever the reason, the records for this project show that redredging was very time consuming and resulted in very low overall dredge production rates.

2.2.2.2 Shallow Water Depth

The draft of a small hydraulic dredge is usually in the 30-inch range, while larger hydraulic dredges and mechanical dredges have drafts of 3 feet or more. Although a dredge can work from deep water toward the shore or shallow areas of the Upper Hudson River, it will not be able to operate where the post-dredging water depth is less than about 3 feet. The use of a hydraulic excavator or crane with a relatively long boom can extend the range of the mechanical dredge into shallow water to a limited extent but, even under these conditions, some areas of the river cannot be accessed by either a mechanical or hydraulic dredge unless some over-cutting of the riverbed is done.

Material removed by a mechanical dredge typically is deposited in a scow for transport to the treatment and shipping location. Typical scows designed for use on the Champlain Canal have a maximum draft, when loaded, of up to 12 feet and can accommodate a load of about 3,000 tons. An empty scow has a draft of about 1 foot. While a mechanical dredge can operate in post-dredging water depths of around 3 feet, a scow moored in 3 feet of water could not be loaded with more than about 500 tons of sediment and water. A scow located in 6 feet of water could be loaded with a little over 1,000 tons of sediment and water, and this is probably the practical minimum load that could economically be transported from a dredge site to an on-shore treatment and shipping location. Because the scow must be positioned within the reach of the dredge's derrick, excavator arm, or crane boom for loading, the area where a mechanical dredge can function effectively is constrained by the water depth required for the loaded scow.

To overcome this difficulty, some dredging companies, notably Bean Environmental and Dry-Dredge Systems, Inc., have constructed dredges that receive mechanically dredged sediment in a hopper, where it is slurried and pumped through a dredge pipeline to the disposal or materials dewatering site. Such mechanical dredges with hydraulic transport may be useful in remediating portions of the Upper Hudson where the water is too shallow to provide access for loaded scows.

Where contaminated sediments extend to the shoreline or are found along the narrow beaches that line portions of the Upper Hudson, their removal may require the use of land-based equipment or amphibious equipment capable of operating either on land or in water, such as that manufactured by Marsh Buggy, Inc. In some instances where access to the shoreline is relatively easy, the excavated material could be loaded onto trucks for delivery to the sediment processing site. Where access cannot be obtained along the shore, the sediment may have to be loaded onto amphibious carriers and transferred to shallow draft scows located as close to the shoreline as possible.

Small hydraulic cutterhead dredges typically have a draft of from 24 to 30 inches. These dredges can also work from deeper water to shallow areas to create the water depth required to prevent grounding and, because the slurry is pumped through a pipeline, the area in which they operate is not constrained by a need for sufficient water depth to float a scow.

2.2.2.3 Distance to Treatment and Shipping Site

In the FS, it was assumed that two on-shore sediment processing/transfer facilities would be constructed for the project. One facility was assumed to be located near the northern reach of the project and the second facility would be located in the Albany area. While the availability of two separate on-shore sediment processing/transfer facilities might provide more flexibility in the design of the dredging program and facilitate a higher productivity rate, the Productivity Standard was developed with consideration that only one sediment processing/transfer facility (located in River Section 1) might be available. The assumption of one facility was made to be conservative with respect to the schedule, in that it would factor in sufficient time for sediments removed from any location within the Upper Hudson to be transported to one location. Note, however, that the assumption does not reflect a worse case based on available information, which would be one facility at or below the southern extreme of the project area.

There is a practical limit to the distance any given hydraulic dredge can pump sediments through a pipeline without the need for booster pumping stations. This limit is a function of:

- The dredge pump and horsepower.
- The density of the slurry being pumped.
- The diameter of the dredge pipe.
- Any change in elevation between the dredge and the pipeline discharge point.

As the distance pumped increases, the pump discharge rate decreases. Furthermore, to avoid plugging the dredge pipeline, it must be flushed of slurry before shutting down the dredge pump for maintenance, for moving the dredge to a new location, or for adding slurry pipe. The time required to flush the pipeline increases with pipeline length and must be factored into any production schedule that anticipates shutting down the dredge for a period of time each day. Finally, the use of multiple booster pumping stations to extend the distance from the on-shore treatment and shipping location that a hydraulic dredge can work has some additional limiting factors. Multiple booster pumping stations:

- Require additional time in a dredge production schedule for starting, stopping, and refueling.
- Add to the potential for operating problems that may stop production entirely until corrections can be made.
- Increase the time needed for mobilization and demobilization at the beginning and end of each dredging season.

Experience has shown that each in-line booster pump can reduce the effective dredging time by from 5 to 10 percent.

Where the distance from the dredging location is too great for a hydraulic dredge and booster pumps to operate effectively, the dredge can pump to a scow located in deep water at the end of the dredge pipeline. However, the slurry contains a high percentage of water (usually from 85 to 90 percent of the flow), so the scows will only carry a small percentage of their normal load in terms of solids. Thus, hydraulic dredging with scow transport of the sediment will likely be restricted to small areas that are difficult to access, if the method is used at all.

The production rate of mechanical dredges using scows to transport the sediment to the on-shore treatment and shipping locations and hydraulic dredges pumping to scows, which in turn are towed to the treatment and shipping sites, is only affected if an insufficient number of scows is available to ensure that the dredge is able to work continuously while scows are in transit. Provided that the movement of scows through the locks is not unduly restricted by the canal operating schedule or by other navigation on the canal, the distance from the dredge to a sediment processing/transfer facility should not have a major impact on production rates for a mechanical dredge or a hydraulic dredge with scow transport. However, as is noted above, the use of a hydraulic dredge with scows to transport the slurry will require a significantly greater number of scows, as each load will have a low solids content.

2.2.2.4 Sediment Characteristics

The physical characteristics of the sediment are an important factor in selecting the type of dredges to be employed and the method of transporting and dewatering the dredged sediments. A summary of the most recent geotechnical data on sediment characteristics, collected in 2002 and 2003 by General Electric (GE) (GE, 2003; 2004), is shown in Table 2-1. The data cover all the recent sampling results, including the analyses of samples in areas that may not be dredged, and show the range of particle size distribution, plasticity index, bulk density and true specific gravity to be encountered during the project.

2.2.2.5 Thickness of Sediment Layer to be Dredged

Both mechanical and hydraulic dredges are designed with an optimal depth of cut in mind. If a hydraulic dredge is designed to achieve optimal production at a cut of 2 feet per pass of the dredge head, it will not be as efficient at deeper or shallower cut depths. At deeper cut depths, the operator may find that the cutterhead is overloaded or may clog the dredge discharge pipe by trying to pump too dense a slurry at too low a velocity. At a shallower cut, the dredge head will not be completely immersed in the sediment and the slurry will contain a much higher ratio of water to solids than when in a production cut.

Similarly, the bucket on a mechanical dredge is designed for a depth of cut that just fills the bucket when the jaws are moved from a fully open to a closed position. Allowing the bucket to penetrate further into the sediment before closing the jaws will cause the bucket to overflow, increasing the potential for resuspension or, if a completely enclosed bucket type is employed, possibly preventing the bucket from closing tightly. If a thinner layer of sediment is to be removed, the bucket will not be completely filled when it is closed, which would also reduce efficiency and productivity.

The depth of contamination in the Upper Hudson River sediments varies from less than 1 foot to over 6 feet. If a hydraulic, cutterhead dredge designed for an optimal cut of 2 feet per pass is working in an area where 3 feet of sediment is targeted for removal, it may achieve a high production rate when removing the first two feet but a substantially lower production rate when it removes the remaining 1-foot layer. The same will be true for a mechanical dredge using an environmental bucket: it will be most efficient when operating at its optimal cut depth and less efficient when operating at shallower cut depths, as the bucket will not be completely filled when it closes.

2.2.2.6 Boulders, Cobbles, and Debris

Most of the dredging required to remediate the Upper Hudson River will occur in areas outside the navigation channel. The areas outside the channel have not been dredged in the past and are likely to contain a significant amount of debris.

Boulders, cobbles, and debris in the sediments significantly impact dredge production rates.

The presence of boulders, cobbles, and debris in the sediments has a significant impact on dredge production rates, especially for hydraulic dredges. Boulders, large numbers of cobbles, sunken logs, abandoned vehicles, and other debris that cannot be pumped interfere with the progress of a hydraulic dredge. Other debris, such as tree roots and limbs, heavy growths of underwater weeds, old fence wire, cables and similar material can clog the cutterhead, intake pipe, or main pump on a hydraulic dredge and force the operator to shut the dredge down until the material can be cleared.

Boulders and debris can also interfere with mechanical dredge operations by preventing the bucket from closing tightly. If the bucket is not closed when retrieved, the sediment will fall back into the water and cause resuspension. If an environmental bucket is used, with controls and alarms to warn the operator when the bucket is not closed, the operator must reopen the bucket, shift its location, and attempt to close it again until he is sure that it is sealed before lifting it from the river bottom.

For the most part, loose cobbles in the one-foot diameter and smaller range do not interfere with mechanical dredges. Occasional cobbles in this size range will be tossed aside by the cutter on a cutterhead dredge, but numerous stones of this size will make it very difficult for the dredge to retrieve the sediment that generally surrounds the cobbles.

To minimize delays in dredging related to the presence of boulders and debris, visual surveys conducted by divers, ground penetrating radar, and side scan sonar surveys are frequently used to determine where these adverse dredging conditions exist and to plan in advance for coping with them. Hydraulic excavators mounted on workboats and equipped with grapples or other material handling devices are generally used to remove sunken logs, appliances, and other debris, while heavy growths of weeds can be removed with weed harvesters. Boulders and cobbles can be moved to areas outside of the navigation channel that have already been dredged by a workboat operating in close coordination with the dredge, but a loss of production inevitably occurs under these conditions. Environmental buckets mounted on hydraulic excavator booms and equipped with hydraulic pistons to close the bucket can minimize the problem of debris for mechanical dredges but may have secondary problems of maintenance and repair that can impact overall production.

2.2.2.7 Presence of Bedrock and Highly Compacted Sediments

Undulating and scalloped bedrock surfaces and compacted glacial till, which usually contains boulders and cobbles in the Hudson River valley, can impede dredge production rates if found at the base of a layer of contaminated sediment. It is very difficult to remove sediment from the uneven surface of water-eroded bedrock outcrops in the riverbed without leaving some material behind, regardless of the type of dredge employed. Following an uneven, hard surface with the dredgehead on a hydraulic dredge is very difficult and slow. The bucket on a mechanical dredge cannot remove sediment from small pockets and crevices in a bedrock surface and is not designed to sweep a hard, uneven surface clean of sediment. The problem of dealing with residual contamination located in a thin layer over a hard base material is a difficult one and multiple passes of a low production dredge or the need for small, diver-assisted dredges should be expected in such areas if the target cleanup level is to be met.

Highly compacted glacial till located immediately below the contaminated sediment can also decrease dredge production rates. The environmental buckets currently in use for removing contaminated sediments by mechanical dredges are not efficient at cutting into highly compacted material. They are particularly inefficient when employed on a derrick dredge or crane, as these machines depend upon the weight of the bucket to penetrate the sediment. These buckets are more effective if they are mounted on the boom of a hydraulic excavator that can apply downward pressure on the bucket to force it into the compacted material.

2.2.2.8 Interference with Navigation

The Champlain Canal is a popular route for travelers to and from Canada, Lake Champlain, and Albany. Freight traffic has all but ceased on the canal in the last decade due, in part, to the fact that dredging by the New York State Canal Corporation to maintain a 12-foot minimum navigation depth has not been performed because of PCB contamination. Inasmuch as a number of communities and marinas along this route are dependent upon the dollars spent by tourists using the canal system, the dredging operations associated with PCB remediation will have to be conducted in a manner that minimizes interference with boat traffic. This includes:

- Sinking hydraulic dredge pipelines beneath the navigation channel.
- Allowing tourists' boats to pass through locks if they reach them ahead of scows carrying contaminated sediments.
- Avoiding blocking the channel with work boats.
- Maintaining buoys, navigation lights, and markers to identify work zones and protect against accidents.

The extent to which interference with navigation will impede dredging progress and productivity is very difficult to gauge, as it is not known whether the fact that a major sediment remediation project is underway along the canal will discourage tourists from using this route during the project or attract curiosity seekers who want to observe the work. Nevertheless, some delays must be expected due to navigation issues and should be considered when estimating probable dredge production rates for development of a project schedule. An evaluation of the impact on navigation of scows carrying dredged sediment and backfill material through the locks is provided in Attachment A.

2.2.2.9 Length of Dredging Season and Daily Operating Hours

The annual production rate during dredging is dependent upon the length of the dredging season. At present, the New York State Canal Corporation opens the Champlain Canal during the first week of May each year, provided the high flows characteristic of spring runoff from the Adirondack Mountains have subsided, and closes the canal to traffic in early November. Ice does not normally form until mid to late December, and it may be possible to extend the dredging season into early December if the Canal Corporation will agree to keep the locks staffed or by organizing the work such that all of the dredging takes place in a single pool between locks following closure of the canal to normal traffic.

The daily production rate during dredging is affected by the number of hours the dredges can work in a day. Dredging projects frequently continue around the clock, seven days per week, although maintaining, refueling, and moving the dredges to new areas usually require that they be shut down for some time period on a periodic basis. The Canal Corporation establishes the lock operating schedule each year and currently staffs the locks on the Champlain Canal from 7:00 A.M. until 5:00 P.M each day between opening day and about the middle of May, from 7:00 A.M. until 10:00 P.M. from the middle of May to about the middle of September, and from 7:00 A.M. to 5:00 P.M. from that date until the canal closes for the winter. Arrangements would have to be made to staff these locks during the night if transit through the locks is needed beyond the usual schedules (see Attachment A, Evaluation of In-River Transportation).

The daily production rate during dredging is affected by the number of hours the dredges can work in a day.

2.2.3 Implications of Post-Dredging Sampling and Redredging

Sampling of the river bottom will be conducted when contaminated sediment has been removed from an area to the elevation established during design. If this sampling shows that residual contamination above the Residuals Standard criterion of 1 mg/kg PCB still exists, the contaminated areas can be redredged as discussed in the Residuals Standard. It is expected that, in order to avoid delays in the overall program, sampling will be conducted as soon as the design elevation has been achieved and dredging will continue while the samples are being analyzed.

Sampling of the river bottom will be conducted when contaminated sediment has been removed from an area to the elevation established during design.

If extensive redredging is found to be necessary in an area, and if the remaining sediments are amenable to removal by the equipment employed for the initial, production dredging work, that equipment may be used for the redredging process and the project will experience some delay. If the sampling indicates that the residual contamination exists as a thin layer of sediment or small pockets of sediment surrounding obstacles such as large boulders, a different dredge may be employed to remove it while the primary dredging equipment proceeds to other areas of the river targeted for dredging. If the river is to be remediated within the time frame established in the ROD, the project schedule must account for delays resulting from the need to redredge an area. The schedule should reflect the fact that silt barriers and other structures erected to prevent the loss of resuspended sediments downstream, if used, will remain in place until an area has been completely remediated.

2.2.4 Backfilling of Dredged Areas and Stabilizing Disturbed Shorelines

If backfill material is fine-grained soil, backfilling should occur while silt barriers are in place.

The ROD requires that dredged areas be backfilled, where appropriate, with one foot of clean soil. In addition, where dredging has resulted in undercutting banks along the shore, stone fill, gravel, or other stabilizing material will have to be placed to prevent erosion and cave-ins. If the backfill material is fine-grained soil, placing this material is expected to create turbid conditions, and should be done while any silt barriers that may have been erected to isolate an area for dredging are still in place. The rate at which backfill or shoreline stabilizing material can be installed may be affected by:

- The method of placing the material.
- Whether the water depth is sufficient to allow barges loaded with soil to be moored within easy reach of the equipment used to place it.

All disturbed shorelines and all dredged areas should be backfilled before the work is shut down for the winter.

In order to minimize delays in dredging, it will be necessary for placement of the backfill and shoreline stabilization work to begin as soon as an area is deemed clean. This work is likely to have an impact on the rate that dredging can proceed, particularly toward the end of the dredging season, as all disturbed shorelines and all dredged areas should be backfilled before the work is shut down for the winter. Otherwise, banks areas may be eroded and residual contamination in sediments loosened by the dredges may be scoured and transported to downstream areas when high flows occur during the following spring runoff period.

2.2.5 Sediment Dewatering, Water Treatment, and Shipping

Production bottlenecks often occur in dewatering dredged sediments and treating the resulting water.

Experience on other projects has shown that production bottlenecks often occur in the dewatering of dredged sediments and treatment of the resulting water. In fact, many dredging projects involving small volumes of contaminated sediments have been designed such that the rate at which dredging can proceed is limited to the rate that the sediment can be dewatered. For these projects, it has been judged to be more economical to erect small, low-capacity dewatering and water treatment facilities that operate 24 hours per day and limit dredging to less than 8 hours per day rather than to invest in large capacity dewatering and water treatment facilities capable of keeping up with the dredge over a 24 hour dredging period.

Given the scale of the Upper Hudson River project, it is consistent with the ROD and should be economical to erect large, temporary dewatering and water treatment facilities with a capacity that is closely aligned to that of the dredge production rate so that the dredges can operate on a nearly continuous basis. A conceptual design of a dewatering system capable of handling mechanically dredged sediments and of achieving the high production rates required for the project is presented in Attachment B.

2.2.5.1 Mechanical Dewatering of Hydraulically Dredged Sediments

It is expected that the sediment will be mechanically dewatered or otherwise treated for immediate shipment from the area. A number of mechanical systems have been proven effective for dewatering hydraulically dredged sediments. One system, used in a number of recent sediment remediation projects including Cumberland Bay, Deposit N and Sediment Management Unit (SMU) 56/57 on the Fox River, and the General Motors Powertrain facility on the St. Lawrence River (Earth Tech, 2002; Foth and Van Dyke, 2001, and BB&L, 1996), employed shaker screens and hydrocyclones to separate sand and gravel from the dredge slurry and either belt filter presses or recessed cavity filter presses to dewater the silt and clay sized fraction. In this type of system, the dredge slurry is discharged onto a series of shaker screens consisting of a coarse bar screen to remove stones and debris, followed by finer screens that remove gravel and coarse sand.

The effluent from the screens is discharged into a large hopper. From the hopper, the slurry is pumped through a series of hydrocyclones sized to remove the sand fraction, which is discharged onto another shaker screen equipped with a fine screen. The overflow from the hydrocyclones contains the silt and clay sized particles and is usually discharged into tanks where chemicals are added to promote dewatering. From these tanks, the conditioned slurry is pumped into filter presses to separate the solids from the water. These presses can usually produce a filter cake containing over 50 percent solids, by weight. The filtrate water is discharged to a water treatment system for additional treatment prior to discharge back to the river.

Dewatering non-cohesive sediments is relatively easy, as the sediments drain rapidly and are readily removed from the flow.

A condition typically imposed on the dewatering system by designers and by operators of disposal facilities is that the solids must be dewatered to the point where they pass a paint filter test, *i.e.* the solids must be dry enough so that no free water will drip from them when placed in a paint filter (USEPA Method 9095). This is relatively easy and inexpensive to achieve when dewatering non-cohesive sediments consisting of sand and gravel, because these materials drain rapidly and are readily removed from the flow using hydrocyclones and shaker screens. Slurry can be pumped onto a shaker screen and through high capacity hydrocyclone at rates of 2,500 gallons per minute and higher, so only a limited number would be required to handle the flow from a hydraulic dredge pumping 8,000 to 9,000 gallons per minute of slurry. However, nearly all sediments contain some amount of silt and clay sized particles, which must be dewatered using some type of filter press, a centrifuge, or other device designed specifically to handle fine-grained material.

Dewatering hydraulically dredged sediments containing a high percentage of silts and clays is slower, more labor intensive, and more costly.

Hydraulically dredged sediments containing a high percentage silts and clays are much more difficult and expensive to dewater than non-cohesive sediments because most of the dewatering must be accomplished in the filter presses. Capturing and dewatering the fine-grained sediments in recessed cavity filter presses or belt filter presses require careful attention to the chemical conditioning of the slurry and the operation of the equipment. It is slow and labor intensive when compared to using screens and hydrocyclones. Furthermore, the capacity of individual presses is low and cycle times can be long, so a large number of presses are usually needed to keep up with the volume of slurry produced by the dredge.

Data indicate that Upper Hudson River dredged material will be about 60 percent sand and gravel and 40 percent silts and clay.

As might be expected, the sediments targeted for remediation in the Upper Hudson River include some deposits consisting of a high percentage of silts and clays and others that are primarily sand and gravel. Available data on the grain size distribution of the targeted sediments indicate that, on average, approximately 60 percent of the dredged material will be sand and gravel that can be dewatered using screens and hydrocyclones while 40 percent will be silts and clays that will have to be dewatered using filter presses or a similar technology (see Section 2.2.2). However, each deposit is different, and when the dredge is operating in an area where the sediment consists primarily of silt and clay, most of the material processed will have to be dewatered in the filter presses. Thus, if hydraulic dredging is used, the filter presses or other equipment selected to dewater the fine grained sediments should be sized to handle the maximum amount of fine material expected to be dredged on any given day.

Because the slurry produced by a hydraulic dredge usually contains from 85 to 90 percent water, by weight, a great deal of water must be treated prior to returning it to the Upper Hudson River. Water treatment systems typically used in conjunction with mechanical dewatering systems for the remediation of PCB-contaminated sediments employ chemical mixing tanks for coagulants, settling tanks with skimmers to remove settleable solids and any floating oils or foam, mixed media pressure filters to remove particulates, and granular activated carbon pressure filters to remove dissolved PCBs. These treatment systems generally produce an effluent with turbidity of less than one Nephelometric Turbidity Unit (NTU) and PCB concentrations less than 0.064 parts per billion, the normal limit for discharge to a surface water in New York State.

The area requirements for dewatering and water treatment systems associated with a hydraulic dredging project are governed more by space needed for temporary staging of TSCA and non-TSCA sediments, and for rail or truck loading areas, than for the actual dewatering and water treatment equipment. Typically, a mechanical dewatering system capable of handling 4,000 to 5,000 cy of sediment per day requires about 3 acres of usable space, and a water treatment system with a capacity of around 9,000 gallons per minute can be constructed on 1.5 to 2 acres. Buffer space surrounding the facility, construction trailers, decontamination areas, equipment wash down areas, temporary staging areas, rail sidings and loading areas, etc, may require up to 10 additional acres, depending upon topography and layout. Overall, a location with about 15 to 20 acres of useable space will be needed if hydraulic dredging and mechanical dewatering is employed for those portions of the work within pumping distance of the material to be dredged.

2.2.5.2 Dewatering of Mechanically Dredged Sediments

Mechanical dredges are capable of removing sediment at close to its *in situ* solids content. As a result, the amount of water collected with the sediment is significantly less than with hydraulic dredges. Nevertheless, the dredged sediment delivered to the material processing site will be too wet to load directly into rail cars for shipment, and some dewatering and water treatment will be required.

Mechanically dredged sediment will be delivered to the processing facility location by scow. If the trip from the dredging area to the site is long enough for the solids to settle in the scow, some of the supernatant water can be pumped off to a water treatment plant similar to that described for treating water from a hydraulic dredging operation. If the supernatant contains too high a concentration of suspended solids, the liquid can be passed through a filter press prior to delivery to the water treatment system. However, decanting supernatant from the scows will not eliminate enough water to allow the sediment to pass the paint filter test, and additional dewatering steps will be necessary.

The FS described a method of physically stabilizing mechanically dredged sediments by adding Portland cement to bind up the water and change the material into a low grade concrete. It was estimated that the amount of Portland cement needed would be approximately 8 percent of the weight of the sediment. A significant advantage of this method comes from the fact that storage silos for the cement and pug mills or other mixing equipment can be erected on a relatively small facility. The major disadvantage of this method of dewatering is that the weight of the material to be shipped to the disposal site is increased by the amount of cement added and the amount of water that is bound up in the mixture by the cement. Nevertheless, the addition of cement or another binder material to make the sediment pass a paint filter test can be a cost-effective method of reducing the free water if transportation and tipping costs at the receiving facility are low.

Other methods of removing water from mechanically dredged sediments include:

- Processing the sediment in the same manner as used for hydraulically dredged sediments.
- Spreading the sediment on sand beds constructed over a grid of perforated pipe and allowing it to drain by gravity prior to shipping.
- Modifying the transport scows by installing false bottoms and underdrains to promote better drainage during the trip from the dredging location to the unloading site.

The area required for dewatering mechanically dredged sediments is normally less than that required for hydraulically dredged sediments. As in the case of hydraulically dredged sediments, much of the area needed is for staging, loading, and shipping facilities, and support facilities. Where mechanical dredging is employed and the scows are to be unloaded with clamshells, the sediment processing/transfer facility should be immediately adjacent to the Hudson River to avoid the necessity of double handling the sediment. While mechanically dredged sediments can be unloaded from scows using a solids handling pump and piped to a dewatering site some distance from the river, it may be necessary to add water to the sediment to create a pumpable slurry. However, pumping adds to the cost of the project and the added water, if any, must be removed from the sediment or bound up using chemical additives prior to shipping. Where hydraulic dredging is used, the facility can be located away from the Hudson River and the sediment pumped inland through the slurry pipeline.

2.2.5.3 Rail Shipping of Processed Sediment

The ROD calls for the transportation of processed sediments by rail or barge to licensed off-site landfills. Rail facilities in the Upper Hudson River corridor were considered adequate to handle the additional traffic associated with the dredged sediments although there is limited room in existing local rail yards to make up a full train of loaded gondolas or shipping container cars.

An evaluation of the ability to process, load rail cars, and transport processed sediment from a candidate sediment transfer/processing facility at the northern end of the Thompson Island Pool, the Old Moreau Landfill, was presented in the FS and RS. The evaluation concluded that transporting 1,600 tons per day from this location should be possible. This evaluation has been revised to reflect the possibility of transporting all sediments - up to 4,500 tons per day - from this one location. The revised evaluation is presented in Attachment C[1]. This revised assessment indicates that there is sufficient land area available at this location to construct rail sidings capable of holding 45 rail cars simultaneously, together with the necessary sediment processing and water treatment facilities, but cautions that the ability of the Canadian Pacific Railroad to transfer the loaded cars[1] to a local rail yard for assembly into a train needs to be confirmed.

The ability to construct rail loading facilities of an adequate size and capacity to handle the expected volume of sediments will be dependent upon the location(s) ultimately selected for the sediment processing/transfer facility(ies), but it is expected that potential transportation problems can be satisfactorily addressed during facility selection and design. If necessary, processed sediment could be loaded into barges carrying 2,000 tons or more each and transported to another facility with adequate rail sidings and transfer equipment to meet the schedule. Even at a production rate of 6,000 tons of dewatered sediment per day, only three barges would be required, and this should not interfere significantly with the current low level of traffic on the canal.

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[1] This revised evaluation was performed to illustrate the feasibility of achieving the Performance Standard for Dredging Productivity under conservative assumption of one location, rather than a less conservative assumption of two or more locations. The location was selected near majority of dredging (in River Section 1). This evaluation does not suggest that USEPA has selected this location or that the location is considered preferable. Facility siting will be conducted in accordance with the procedures set for in Facility Siting, Concept Document (USEPA, December 2002).

2.2.6 Quality of Life Factors

Quality of life issues that may affect the time needed to complete the project include noise and lights from the dredges and ancillary equipment working on the Hudson River and from the sediment processing/transfer facility(ies), traffic delivering chemicals and fuel to the facility(ies), and similar factors. These factors are the subject of a separate study and report being performed by the USEPA. Quality of Life performance standards will be established (under separate cover) to limit disturbance to the lifestyle of people and businesses along the river and in the immediate surroundings as much as practical. The effect of these "quality of life" standards on the dredging, treatment, and shipping of contaminated sediments is not currently known, but will be taken into account in the schedule for the project as they are developed. The dredging sequence and operations may require adjustment in areas adjacent to population centers and operating marinas.

2.3 Example Production Schedule

> *The actual project schedule will be developed during the design of the project.*

An example production schedule has been prepared to illustrate the feasibility of achieving the Productivity Standard using relatively conservative assumptions and at least one selection of equipment from the wide array of such equipment currently available and in use on environmental dredging projects. It should be clearly understood that the actual project schedule will be developed during the design of the project and may be very different from this example. The actual volumes and locations of sediment to be dredged, the location(s) of the processing and transfer site(s), the need for containment of the dredging areas, the type and capacity of dredging equipment, among other major factors for which assumptions have been made in developing the example schedule, will all be determined during final design. The example schedule is discussed in some detail and presented in Attachment D. Backup for the example schedule is presented in Attachment E. A summary of the major assumptions that were made in developing this schedule and the results of this work is presented below while a more detailed list of the assumptions used is presented in the attachments.

2.3.1 Major Assumptions used in Development of Example Production Schedule

- The volume and location of the sediments to be dredged are as presented in the FS and are based on the analytical results for samples collected during a number of sampling events conducted over the last 25 years. The example schedule assumes that the volume will be 2.65 million cy. However, a new sampling program is nearing completion and it is expected that the locations and volumes used for the example schedule will change when this work is complete.

- A single, sediment processing and transfer facility has been assumed to be located at the northern end of the Thompson Island Pool. Although the FS assumed that two such facilities would be constructed, one at the northern end of the project area and one at the southern end, a single site has been assumed for development of the example schedule based on a belief that this would be a more conservative assumption.

- The sediment processing and shipping facilities will be designed with sufficient capacity keep up with the rate at which sediment is delivered to the sediment processing and transfer facility.

- Dredging and similar work on the river will be conducted 24 hours per day, six days per week. Conducting routine weekly maintenance tasks on dredges and ancillary equipment is anticipated to occur on the seventh day of the week. This is considered to be a conservative assumption since it does not rely on a seventh day of dredging activity. If dredging were to occur seven days per week, a higher rate of production would be achievable.

- Overall, it has been assumed that the effective time available for dredging will average 13 hours per day. No dredging will take place at all on many working days during a construction season, as a significant amount of time is needed to relocate the equipment from one dredging site to another, install and remove sediment barriers, etc.

- The New York State Canal Corporation normally opens the Champlain Canal to traffic during the first week of May and closes the system in the first week of November. It has been assumed that the arrangements can be made with the Canal Corporation to extend the operating season until the end of November, and possibly longer during mild years, and that 24–hour per day access through the locks will be arranged to allow floating equipment to navigate the system. It has also been assumed that, following closure of the locks in the fall, work will still be permitted within a pool between locks for as long as weather and river conditions permit.

- For development of the example production schedule, it has been assumed that silt barriers would be used for all dredging work outside of the navigation channel and would not be removed until the dredging of that area was complete and backfill and shoreline stabilization work was finished.

  This assumption was made so that a conservative scenario could be developed to estimate productivity. The installation and use of silt barriers delays the start of dredging each spring, causes delays in production due to the need to enter the enclosed area through gates in the barrier, and requires the dredging contractor to cease dredging and place backfill over a dredged area early enough in each dredging season to be able to remove the silt barriers before ice forms on the river. Although the use of silt barriers should make it possible to remove debris from the river and dredge at a relatively high rate without as much concern about meeting the Resuspension Standard, the time required to install and remove the barriers detracts from the number of days available for dredging each season. A detailed evaluation of the cost effectiveness of installing silt barriers and a decision on their use will be made as part of the final design process.

- Mechanical dredging has been assumed for the development of the example production schedule under the belief that mechanical dredging will be slower than hydraulic dredging in most instances where hydraulic dredging might be possible (see Attachment F for an evaluation of applicable dredging equipment). Two different size mechanical dredges have been assumed to be available:

  - A dredge consisting of a hydraulic excavator with an extended boom fitted with a 4 cy, hydraulically activated environmental bucket has been assumed to be the primary production dredge used where the depth of water is at least 3 feet following dredging and the thickness of the contaminated sediment layer and volume of sediment to be removed are great enough to warrant such a dredge. A production rate of 82 cy per hour of actual dredging work has been assumed for mechanical dredges of this size and type.

  - A dredge similar to that described above but with a 2 cy, hydraulically activated environmental bucket has been assumed to be used in areas where the sediment layer to be dredged is less than about 2 feet, the water depth is less than that needed for the larger dredge, or the area and volume of sediment to be dredged is small. This dredge would also be used for redredging, if post-dredging sampling indicates that additional sediment must be removed from an area.

    A production rate of 27 cy per hour has been assumed for this smaller dredge when dredging to achieve the original design cut lines. No production rate has been assumed for redredging an area using this dredge, as any production rate would be dependent upon the thickness of the sediment layer to be removed, the total area to be covered by the dredge, and the characteristics of the material to be removed. Rather than assuming a product rate for redredging in terms of cy per hour and making additional assumptions regarding the amount of redredging that might be needed, the example production schedule assumes that redredging will require about one half as much time as needed to achieve the original design cuts established for the project, *i.e.,* if 30 days are required to dredge an area to the design cut lines, 15 additional days have been allowed for redredging work in the same area following sampling and analysis of the initial results.

- The dredged sediment would be placed in scows located where a post-dredging water depth of 6 feet or more is available to provide the necessary draft. The extended booms on the dredges will make it possible for these machines to excavate sediments located at a distance of up to 30 feet from the dredge in shallow water. Where the post-dredging water depth is too shallow to permit scows to be placed in reach of the dredge, it is assumed that other dredging equipment, such as described in Section 2.2.1, and small, shallow draft scows will be used. The assumed production rate for this equipment is 27 cy per hour of actual dredging work.

- Post-dredging soundings to confirm that the sediment has been removed to the design depth and sampling to determine the level of residual contamination remaining, if any, will be carried out as soon as a sufficient area has been dredged to the design grade to permit this work to be done without interfering with the dredging effort. The example production schedule assumes that post-dredging sampling will be completed within a few days of completion of dredging in a particular area and prior to the removal of any silt barriers or other containment structures.

- If all the original inventory of contaminated sediment has been removed in accordance with the final design, and sampling and analysis of the remaining sediment indicates that redredging is required to achieve compliance with the Residuals Standard, the redredging effort will be limited to two attempts at achieving compliance. As has been noted above, for the purposes of preparing an example production schedule it has been assumed that the time required to redredge an area is equal to 50 percent of the time required for removal of the original inventory.

- Although the ROD states that dredged areas will be backfilled, as appropriate, the example production schedule assumes that all dredged areas will be backfilled. It is not possible to know, in advance, how much of the areas targeted for dredging will have to be backfilled, so a very conservative assumption has been made for the extent of this work.

- The shipping of dewatered or otherwise processed sediments from the processing and transfer site to a final disposal site is assumed to be done continuously to meet the requirement that no processed sediments be stockpiled on the site at the end of a construction season for disposal the following year.

2.3.2 Results of Example Production Schedule

The example production schedule, presented in Attachment D, indicates that four primary (4-cy bucket) and six alternative (2-cy bucket) dredges will be needed for a significant portion of the time if the project is to be completed in the six-year period stated in the ROD. However, the number of dredges in operation simultaneously may vary from zero to as many as ten, exclusive of any redredging equipment, for short periods of time. While this upper number could be reduced by using larger dredges in some areas, it indicates that very careful control and scheduling of the dredging effort will be required to minimize delays at locks, a backup of scows at the unloading location, and similar problems.

The example also illustrates that if redredging is required in a given area, it should take place while the production dredges continue to work downstream. If the dredging is stopped to await post-dredging sampling, analysis, and evaluation, and a decision as to whether redredging will be necessary in a given area, the project will not be completed on time.

Cessation of dredging to await post-dredging sampling, analysis, and evaluation would prevent on-time completion of the overall project.

Phase 1 work is anticipated to begin on or around the first of May and be completed by the early December. However, the example production schedule indicates that actual dredging would not begin until mid-June and would be completed by November 7. Mobilization and site preparation would be accomplished during the first six weeks of the Phase 1 construction season and shoreline stabilization, completion of backfilling, winterizing equipment to be left on site, and demobilization would occur during the last four weeks or so.

The example schedule indicates that, during the second year of the project when full scale dredging is underway, actual dredging should begin in early May and be completed by mid October. In the third year of the project, the dredging would begin by May 2 and end by November 12. In the next two years, dredging would begin in the first week of May and end by November 6 and September 29, respectively. In the last year of the project, dredging would be completed by the end of August. The fact that dredging continues late into the fall in some years, and ends sooner in others, results from the selection of areas to be dredged in a given year. A different sequence of dredging would result in different beginning and ending dates than those shown in the example, and any changes in the volume of material to be dredged in a given target area would extend or shorten the time needed to complete that area.

A summary of the volumes assumed to be dredged, the area remediated, and completion date for work each calendar year, taken from the example schedule is presented in Table 2-2.

The example schedule was developed to meet or exceed the Productivity Standard. Table 2-3 compares the volumes dredged in the example production schedule with the Productivity Standard and illustrates that the schedule meets these standards in all years.

While the example production schedule presented herein is based on a large number of assumptions, all of which will have to be confirmed during design of the project, it supports the belief that the project can be completed in the six-year time frame set forth in the ROD. It is anticipated that a final schedule for the project that meets these goals will be developed once sampling of the sediments has been completed, final designs have been prepared, and the work under Phase 1 has been completed and evaluated.

3.0 Rationale for the Development of the Performance Standard

The Productivity Standard - Phase 1 is based on achieving 200,000 cy of production, as measured in the river. The Productivity Standard - Phase 1 is based on a dredging goal that will facilitate the collection of sufficient data to validate the Residuals Standard and the Resuspension Standard. This dredging goal is within the range noted in the ROD of 150,000 to 300,000 cy, and is approximately 40 percent of the average annual production rate for Phase 2. Furthermore, the Productivity Standard - Phase 1 is based on the fact that, as identified in the ROD, Phase 1 will span one construction season and Phase 2 activities will span five construction seasons. Utilizing 2.65 million cy as the total estimated project volume, the total production rate for Phase 2 activities was calculated as follows:

- Phase 1 Required Production Volume = 200,000 cy
- Phase 2 Required Production Volume = 2,650,000 – 200,000 = 2,450,000 cy over 5 years, or 490,000 cy annually

A target dredging rate has also been developed and included in the standard. The project must be designed and scheduled to meet the cumulative annual target volumes, with approximately one-half a typical season's worth of work being completed in the final season. The annual target productivity rate was calculated as follows:

The Phase 2 target annual production volume (seasons 1 through 4 of Phase 2) is (2,650,000 cy – 265,000 cy)/4.5 = 530,000 cy. Therefore, the cumulative target volumes are structured so that 265,000 cy will be designed and scheduled to be removed in the final season of Phase 2

4.0 Implementation of the Performance Standard for Dredging Productivity

4.1 Productivity Threshold Criteria

4.1.1 Productivity Standard – Phase 1

The Productivity Standard – Phase 1, reduced scale dredging, is as follows:

1. The minimum volume of sediment to be removed, processed, and shipped off site during Phase 1 shall be 200,000 cy. Phase 1 must be designed and scheduled to meet the targeted removal volume of 265,000 cy.

2. For a period of at least one month during Phase 1, the minimum production rate shall be the rate required to meet the Phase 2 Performance Standard in order to demonstrate the capabilities of the dredging equipment and the sediment processing and transportation systems.

3. Stabilization of shorelines and backfilling of areas dredged during Phase 1, as appropriate, shall be completed by the end of the calendar year and prior to the spring high flow period on the river. Processed sediment shall not be stockpiled and carried over to Phase 2 for disposal.

4.1.2 Productivity Standard – Phase 2

The Productivity Standard – Phase 2, full scale dredging, is as follows:

1. Based on an estimate of 2.65 million cy of sediment, the minimum volume of sediment to be removed, processed and shipped off site during each of the five years of Phase 2 (full scale dredging) shall be as shown in the middle column of Table 4-1. Furthermore, Phase 2 must be designed and scheduled to meet the targeted removal volumes shown in the right-hand column of Table 4-1. The project must be designed to be completed with a reduced annual volume for the final season of the project (Phase 2, Year 6).

2. Stabilization of shorelines and backfilling, as appropriate, of areas dredged during a dredging season in Phase 2 shall be completed by the end of the work season and prior to the spring high flow period in the river.

3. All dredged material should be processed and shipped for disposal by the end of each calendar year. Processed sediment shall not be stockpiled for disposal the following dredging season.

Phase 1 activities will not only accomplish a portion of the work required to remediate the River, but will also provide data that will be useful for planning the work in subsequent years. USEPA will select the areas to be dredged during Phase 1. It is expected that Phase 1 dredging will be performed in areas exhibiting a range of dredging conditions that might be expected during the full scale project, including dredging in both deep and shallow areas of the river and in areas with differing bottom characteristics. It is further expected that the monitoring program conducted during this phase will provide sufficient productivity and other performance data to refine the project design or the performance standard, as necessary, for the full scale dredging work to be done in Phase 2 (years 2 through 6).

If the total volume of sediment to be removed varies by more than 10 percent from the current estimate of 2.65 million cy, it is expected that the Productivity Standard for Phase 2 and the targeted productivity volumes will be recalculated. The formulas used to develop the Productivity Standard for Phase 2 and the target productivity volumes are described in Section 3 of this document and should be used for recalculating these volumes.

4.2 Monitoring and Reporting Requirements

Implementation of the Productivity Standard will require certain monitoring, record keeping, and reporting activities. At a minimum, the following requirements should be met:

- Dredging productivity shall be monitored and detailed records shall be maintained to document production throughout the duration of the project. Specific monitoring and record keeping requirements will depend upon the dredging methodology employed and will be determined during final design. At a minimum, daily reports of dredging operations shall be maintained on U. S. Army Corps of Engineers (USACE) daily dredging report forms appropriate to the type of dredges in use and summarized at the end of each week and each month.

  At a minimum, the weekly and monthly summaries shall provide information on:

  - locations dredged.
  - number of hours of actual dredging time and gross volume dredged each day and each reporting period.
  - cumulative amount dredged for the season.
  - time required for off-loading scows, if used.
  - weight and moisture content of the dredged sediments.

  Similar information shall be maintained on redredging efforts. In addition, records shall be kept of:

  - locations of backfill and sediment caps placed.
  - volumes of backfill or capping material placed and the hours spent in placing backfill and sediment caps.

- locations and details of shoreline work including shoreline dredging and restoration rates.

The weekly and monthly dredging production summaries shall also provide details on any delays encountered in the work, the reasons for the delays (*i.e.* weather, high river flows, equipment problems, canal traffic problems, quality of life standards, etc.) and the hours lost to production as a result of these delays.

- Overall project productivity shall be recorded daily and summarized weekly and monthly. Weekly and monthly summaries shall provide information on:

  - total tonnage of material processed, shipped from the processing site and stored on the site; concentration and mass of PCBs in the processed sediments.
  - volume of water treated and returned to the river.
  - delays encountered in the overall project including information on the reasons for the delays.

- By March 1 of each year, the construction manager shall provide USEPA with a production schedule showing anticipated monthly sediment production for the upcoming dredging season. The schedule must meet or exceed the cumulative productivity target volume defined by the standard.

- Monthly and annual productivity progress reports shall be submitted to the USEPA for determining compliance with the Productivity Standard. Monthly productivity progress reports will be compared to the production schedule submitted by the construction manager and will be the primary tool for demonstrating whether the project is on schedule. Annual production progress reports will determine compliance with the Productivity Standard and will be used to plan subsequent seasons' dredging work.

- At the end of each month, a monthly progress report shall be prepared and submitted to USEPA for review and comparison to expected production rates as described by the construction manager in his anticipated schedule and required to meet the Productivity Standard. Monthly reports shall be submitted by the 15^{th} day of the following month and shall present weekly, monthly, dredging season, and project totals information.

- Annual reports shall be submitted within 30 days of the end of work each season. The reports shall include, but need not be limited to:

  - a summary of the estimated total volume of sediment dredged, as measured *in situ* in the river.
  - a map showing the locations where dredging, confirmatory sampling and backfilling have been completed and where work is ongoing. The map shall display the general type of ongoing work in each area under

remediation, confirmatory sampling, redredging, backfilling, shoreline excavation and stabilization, containment installation or removal work, etc.

- total weight and average moisture content of sediments shipped off site or added to the temporary stockpiles on the site.
- a graph showing the anticipated cumulative dredging production as necessary to meet the productivity performance standard and the actual cumulative production achieved to date.
- a table, graph or other means of showing the cumulative total mass of PCB released to the lower river from the beginning of the project through the date of the monthly report, and a projection as to whether the cumulative PCB loss to the lower river will be below the of 650 kg restriction for the six-year scheduled duration of the project.
- identification of any problems encountered in meeting the Productivity Standard and steps taken to overcome these problems.

For annual reports only, a copy of each daily dredge production report form and each weekly report in an appendix or appendices to the report document.

4.3 Action Levels

As described in Volume 1 of this document, two action levels for Productivity have been identified: a concern level and a control level. Implementation of the Productivity Standard requires the following actions if these action levels are exceeded.

4.3.1 Concern Level

In any given dredging season, whenever the monthly dredging productivity falls below the scheduled productivity for that month by 10 percent or more, the construction manager shall identify the cause of the shortfall and take immediate steps to correct the situation by adding additional equipment and crews, working extended hours, modifying his plant and equipment or approach to the work, or other steps needed to achieve the necessary production rate and erase the deficit in productivity over the following two months or by the end of the dredging season, whichever occurs sooner.

4.3.2 Control Level

If the monthly productivity falls below the scheduled productivity by 10 percent or more for two or more consecutive months, the construction manager shall provide a written report to USEPA's site manager detailing steps underway or to be taken to erase the shortfall in production that season. If the construction manager fails to erase the shortfall at the end of the dredging season, the construction manager will be subject to action taken by USEPA.

5.0 References

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Tables

Table 1-1
Phase 2 Productivity Parameters

Timeframe	Required Production Rate	Target Production Rate
Dredging Season	490,000 cy/season	530,000 cy for first four seasons of Phase 2, 270,000 cy for final season of Phase 2
Average Weekly (1)	16,300 cy/week	17,700 cy/week (3)
Average Daily (2)	2,300 cy/day	2,500 cy/day (3)

(1) Based on a 30-week schedule.

(2) Based on a 7-day work week.

(3) These are the rates for the 530,000-cy/year seasons.

Table 2-1

Geotechnical Characteristics of Upper Hudson River Sediments

Geotechnical Characteristics of Upper Hudson River Sediments											
Parameter	Units	Number	Mean	Std Dev	Minimum	10%	25%	Median	75%	90%	Maximum
Bulk Density	g/cc	27985	1.1	0.46	0.03	0.5	0.69	1.09	1.49	1.7	2.27
Clay	%	1803	11.8	11.8	0	1.2	2.5	8.3	18	26.4	80
Silt	%	1803	25.7	20.7	0	2.1	5.6	21.8	42.8	55.8	84.9
Fine Sand	%	1803	36.7	21.8	0	9.8	19	34	52.7	68.4	96.7
Coarse Sand	%	1803	3.9	6.4	0	0	0	0.3	5.7	13.7	46.5
Medium Sand	%	1803	14.5	17.3	0	0.8	1.9	6	23	41.2	81
Gravel	%	3161	6.5	13.4	0	0	0	0	5.9	24.5	99.2
Liquid Limit	%	1358	16.9	26.3	0	0	0	0	38	58	166
Plastic Limit	%	1358	2.6	9.8	0	0	0	0	0	0	87
Plasticity Index		115	18.6	12.7	3	7.6	11	16	21	31	92
Specific Gravity	g/cc	1358	2.5	0.2	1.4	2.309	2.42	2.56	2.68	2.7	3.0

Table 2-2
Mechanical Dredging Schedule by Phase and Year

Season	Volume Remediated (cubic yards)	Area Remediated (acres)	Dredging Completion Date	Work Completion Date
Phase 1 (Year 1)	268,977	50	11/07/06	12/14/06
Phase 2 (Year 2)	529,440	78	10/15/07	12/20/07
Phase 2 (Year 3)	601,810	86	11/12/08	12/22/09
Phase 2 (Year 4)	564,533	62	11/06/09	12/22/09
Phase 2 (Year 5)	447,387	53	9/29/10	11/12/10
Phase 2 (Year 6)	237,860	63	8/30/11	11/12/11

Table 2-3
Cumulative Dredge Volumes

Season	Cumulative Volume From Example Production Schedule (cubic yards)	Required Cumulative Volume (cubic yards)	Target Cumulative Volume (cubic yards)
Phase 1 (Year 1)	268,977	200,000	265,000
Phase 2 (Year 2)	798,417	690,000	795,000
Phase 2 (Year 3)	1,400,227	1,180,000	1,805,000
Phase 2 (Year 4)	1,964,760	1,670,000	1,855,000
Phase 2 (Year 5)	2,412,147	2,160,000	2,385,000
Phase 2 (Year 6)	2,650,000	2,650,000	2,650,000

Table 4-1
Productivity Requirements and Targets

Project Phase and Year [1]	Required Cumulative Volume (cubic yards)	Target Cumulative Volume (cubic yards)
Phase 1 (Year 1)	approximately 200,000	265,000
Phase 2 (Year 2)	690,000	795,000
Phase 2 (Year 3)	1,180,000	1,325,000
Phase 2 (Year 4)	1,670,000	1,855,000
Phase 2 (Year 5)	2,160,000	2,385,000
Phase 2 (Year 6)	2,650,000 [2]	2,650,000 [2]

[1] The overall completion schedule, if appropriate, will be adjusted in accordance with the USEPA-approved remedial design schedule.

[2] All productivity requirements and target volumes discussed herein are based on the volume estimate presented in the ROD (USEPA, 2001, 2002). The volume estimate of 2.65 million cubic yards is expected to be refined, as described in Volume 1 Section 4.3, as new sampling data are obtained and analyzed during remedial design.