

CONTROL OF RESUSPENDED SEDIMENTS IN DREDGING PROJECTS

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ABSTRACT

Over the past 20 – 25 years there have been increased concerns regarding potential impacts of dredging contaminated sediments and the associated resuspended sediments on nearby environmental resources. In response to the need to protect the environment, a number of best management practices (BMP) have been specified by the U.S Army Corps of Engineers (USACE), other Federal Agencies and by State Regulators. Many agencies have designated silt or turbidity curtains as a BMP. Consequently, silt curtains are considered an integral and necessary regulatory strategy in many dredging projects in addition to environmental windows. Unfortunately, how effective and under what circumstances silt or turbidity curtains function properly has generally been overlooked or misunderstood by far too many of us (e.g., USACE, U.S. EPA, States, Contractors, Public, etc.). Many of the dredging contractors will attest to the fact that silt curtains just don't work under many of the site conditions they encounter. The published literature contains few comprehensive studies that demonstrate how effective silt or turbidity curtains have been in meeting the intended project objectives (Johanson 1976, 1977; JBF Scientific Corporation 1978; Lawler, Matusky and Skelly Engineers 1983)

This paper reviews the basic types of control measures used in navigation and environmental dredging projects. It provides technical guidance on the selection and specification of controls for resuspended sediments and turbidity.

Keywords: Resuspended sediments, silt curtains, turbidity curtains, and dredging control measures.

INTRODUCTION

Dredging is a process that removes sediments from a waterway by various types of dredging equipment. Removal is the dislodging of sediments by mechanical, hydraulic or pneumatic equipment. All dredging equipment will cause sediment disturbances, which have been characterized by the 5 R's – removal, release, resuspension, residual and risk (Francingues 2005). The first four concerns of the dredging process are illustrated in Figure 1.

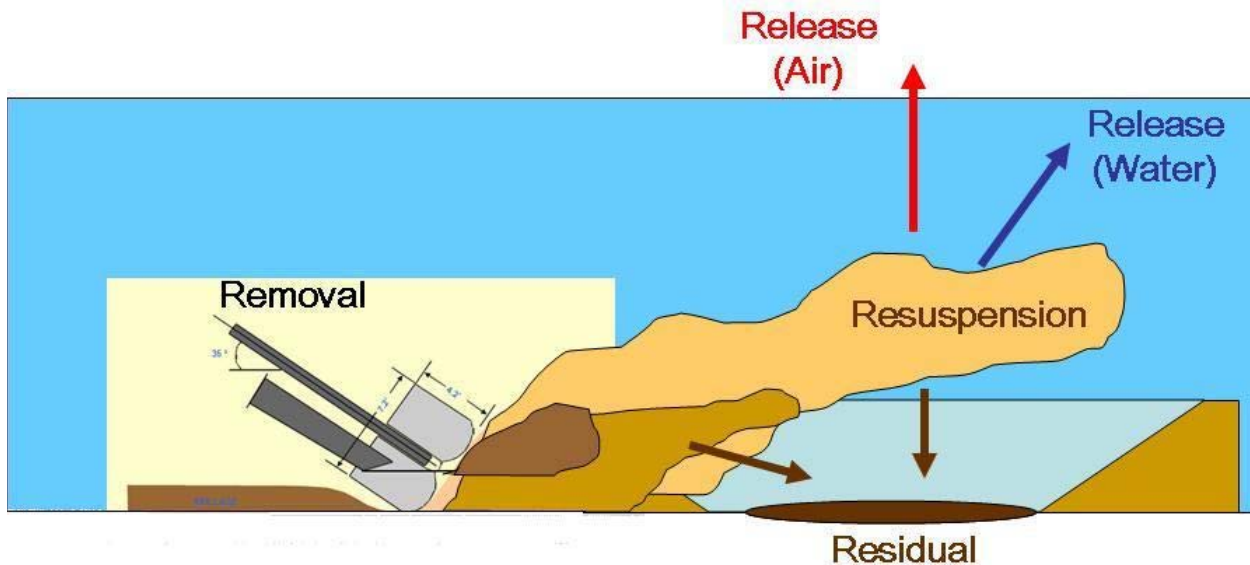


Figure 1. Removal, resuspension, release and residual in dredging.

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A concern with dredging resuspension is not only the potential increase of suspended solids in the water column but the potential to release dissolved contaminants from the porewater and by desorption from the resuspended sediment particles. In addition to the dredging equipment, resuspension can be caused by the propwash of tender boats, through filling and overflowing of barges, and by leaks in pipelines, etc. The potential for volatile organic compound (VOC) releases to the air, though rarely a problem for navigation projects, may also be a concern for highly contaminated sites (U.S. EPA 2005).

Recent guidance for sediment remediation by the U.S. EPA (2005) states that,

“When evaluating resuspension due to dredging, it generally is important to compare the degree of resuspension to the natural sediment resuspension that would continue to occur if the contaminated sediment was not dredged, and the length of time over which increased dredging-related suspension would occur. Some contaminant release and transport during dredging is inevitable and should be factored into the alternatives evaluation and planned for in the remedy design. Generally, the project manager should assess all causes of resuspension and realistically predict likely contaminant releases during a dredging operation. “

Resuspension concerns for navigation dredging are primarily physical effects of turbidity and burial and result in seasonal restrictions (dredging windows). However, environmental dredging concerns are more related to the potential releases of chemicals and residual contamination left behind from the dredging operation. Residual sediment is defined as the materials remaining in the dredging footprint following a dredging operation and might include “generated residuals” and/or “undredged inventory” (Palermo 2006). Causes of residual may include incomplete characterization, inaccuracies of dredging, “fallback” – dislodged sediment not picked up, and resettlement of resuspended sediments (Palermo 2006).

The type and amount of sediment resuspension, releases, and residuals during a dredging operation depend upon many site-specific project factors such as:

- Sediment physical and chemical properties
 - Grain size distribution (e.g., percentages of silt, clay, sand)
 - Organic carbon content
 - Amount of sulfides,
 - Spatial and vertical distributions of contaminants in the sediment (e.g., layering)
- Site conditions
 - Water velocity and degree of mixing
 - Water salinity, hardness, alkalinity
 - Type and extent of debris in the sediment
 - Weather such as storm events resulting in wind and waves
 - Wakes from passing ships in nearby navigation channels
- Equipment
 - Type of dredge (e.g., cutterhead pipeline, open or close bucket, specialty dredgehead)
 - Methods of dredge operation
 - Skill of operators
 - Extent of tender boat activity

In general, the actual dredging process may result in a limited impact on the water column, support activities around the project may have a greater impact on the water quality, and, ambient and local disturbances may have a similar

or greater impact than the dredging operation. Also, it is generally assumed that the degree of contaminant release is directly related to the degree of sediment resuspension, and, therefore, control of resuspension may be considered a high priority at many dredging project sites especially where there is known sediment contamination.

CONTROL MEASURES

Operational Controls

A distinction should be made between operational controls and engineered controls. Operational controls include actions that can be undertaken by the dredge operator to reduce the impacts of the dredging operations. Whereas, engineered controls require a physical construction technology or modification of the physical dredge plant such as shrouding the cutterhead to cause the desired change in conditions. Usually, an attempt will be made first to implement an operational fix prior to using the engineered method because of the costs of engineered controls.

Operational Controls for Resuspension

Operational controls for resuspension include changes in dredging methods and in operation of the equipment. Examples of operational controls might include;

- Reducing the dredging rate (e.g., slowing the operation),
- Changing dredging operations based on site conditions such as tides, waves, currents, and wind,
- Modifying dredge operations such as depth of the cutterhead, ladder swing speed, cutter rotation speed, or speed of advance of the dredge),
- Using a sequence of dredging such as moving upstream to downstream, and,
- Changing the number of vertical cuts (passes) to increase sediment capture.

Operational Controls for Residuals

Dredges always leave behind some residual sediment that might also be contaminated, usually within the dredged area, that can be transported to adjacent areas. The composition of the residual is typically a fluid mud (high water content) layer that may exist, at least temporarily, as a turbid nephloid layer. The U.S. EPA (2005) lists the primary sources of the dredging residuals as: 1) contaminated sediment below the dredge line that was not removed, 2) sediment loosened by the dredge head or bucket, but not captured and removed, 3) sediment on steep slopes that falls into the dredged area, and 4) resettling of sediment from the dredging operation. The Guidance also states that “the extent of the residual contamination is dependent on a number of factors including:

- Skill of operator and type and size of dredging equipment;
- Steepness of dredge cut slopes;
- Amount of contaminated sediment resuspended by the dredging operation;
- Extent of controls on dispersion of resuspended sediment (e.g., silt curtains, sheet piling);
- Vertical profile of contaminant concentrations in sediment relative to the thickness of sediment to be removed;
- Contaminant concentrations in surrounding undredged areas;
- Characteristics of underlying sediment or bedrock (e.g., whether over-dredging is feasible); and
- Extent of debris, obstructions, or confined operating area (e.g., which may limit effectiveness of dredge operation).

Operating controls for residuals are extremely limited to a number of additional cleanup passes.

Operational controls for VOCs

These types of controls are also limited but may include;

- Reducing dredging production rates to minimize resuspension and releases,
- Overlapping dredge passes to minimize resuspension at edge of cut where sloughing may occur,
- Decreasing the sweep speed of the cutterhead, and,
- Modifying the dredging sequence so most of contaminated sediments are dredged in winter.

Operational controls for Noise and Light

Operational controls for noise and light aesthetics at dredging projects are similarly limited as for residuals and VOCs. Examples might include;

- Noise
 - Establish operating levels for equipment,
 - Modify work schedule, cease night operations,
- Light
 - Re-aim and shield lighting to reduce light spillage,
 - Inform the public on operations with monitoring data (real time is possible with websites).

Engineered Controls

Engineered controls for dredging may be defined as designed controls or containments deployed around or in conjunction with the dredge plant. Engineered controls include containment barriers, such as;

- Cofferdams,
- Removable Dams (e.g., Geotubes),
- Sheet piles,
- Silt Curtains,
- Silt Screens,
- Oil booms, and,
- Pneumatic (Bubble) Curtains.

Two examples of engineered controls are the coffer dam and sheet pile, which are shown in Figure 2. The remainder of this paper will focus on the use of silt curtains and screens as engineered controls for resuspension.

Silt Curtains and Silt Screens

Perhaps, the most recognized engineered control used for resuspended sediment at dredging projects is the “silt or turbidity” curtain. The USACE recently published ERDC Technical Note TN-DOER-21 on silt curtains as a dredging management practice for navigation dredging projects (Francingues and Palermo 2005). This technical note reviews the basic types of silt and turbidity curtains used in navigation and environmental dredging projects. Silt or turbidity curtains, turbidity screens, silt/turbidity barriers, gunnerbooms, etc., are not to be confused with silt fences used in control of soil erosion. So, what’s in a name? Plenty, if the task is to control suspended solids and turbidity generated in the water column as a result of navigation and environmental dredging operations. Silt or turbidity control devices have many names that are used interchangeably by the USACE, U.S. EPA, State Regulatory Agencies, dredging contractors, A&E firms, and manufacturers and suppliers. However, in this paper, the terms “silt curtain and silt screen” will be used to describe devices deployed in water to control suspended solids or turbidity resulting from dredging operations.



Figure 2. Examples of engineered controls – coffer dam & sheet pile (Francingues 2005).

In order to properly select silt curtains or silt screens, several key questions should be asked by the project designer of the dredging project.

- What type of silt curtain or screen is needed?
- What components will be needed for the silt curtain or screen?
- What will be the functions of the silt curtain or screen?
- What project site-specific processes will affect the silt curtain or screen selection, deployment, operation?
- How will the silt curtain or screen be deployed?
- What types of products are commercially available for use at this project?
- What is known about the effectiveness of silt curtains or screens on similar projects?
- What information is available on selection, design, specification and deployment of silt curtains or screens on similar projects?
- What should be done to properly select and use a silt curtain or screen at this site?

A number of lessons learned are available regarding selection, design, and deployments of silt curtains or screens (Francingues and Palermo 2005). These are:

- The device should be selected, designed, and installed to meet all permit and water quality certification requirements where applicable.
- Very few applications are alike. Each one has a unique feature that requires a site-specific application and adaptation.
- In general, the device should be used on slow to moderate currents, stable water levels, and relatively shallow water depths.
- The device should be designed to pass water either under or through it. They are designed to confine suspended sediment and to allow it to settle or be filtered, not to impede the movement of water.
- In applications where the device will be extended to the bottom of the waterway, in tidal or moving water conditions, a heavy woven pervious filter fabric or tide flaps should be designed into the device to create a permeable design and to relieve pressure on the device wall.

- Currents greater than 1 to 1-1/2 knots are problematic, lead to difficult and often expensive designs. Silt curtains should not be used in higher current velocities (> 3-5 knots) unless there are unusual circumstances and special designs are developed.
- Device deployments for high, fast water and winds require highly customized designs. However, for all practical purposes the 1 to 1-1/2 knot value appears to be an industry standard.
- In low currents, resuspension and turbidity are localized so there is a question whether a silt curtain is even necessary.
- In high currents where sediment plumes spread, silt curtains and screens are very difficult to maintain properly, and can result in a dysfunctional device.
- At all but the lowest current flows, the device will “billow out” to the downstream allowing water to pass beneath the device and to reduce the effective skirt depth.
- Extra length (up to 10-20 %) and depth (slack) of curtains should be included in designs to allow for tidal fluctuations and exchanges of water within the device.
- Special designs may be required for applications of curtains and screens at depths greater than 3 – 4.6 meters (10-15 feet) or with currents exceeding 1-1/2 knots, particularly in tidal waters. At greater depths, loads or pressures on curtains and mooring systems become excessive and could result in failure of standard construction materials.
- High winds can lift large curtains out of the water like a sail.
- Curtains and screens can sink due to excessive marine, biological growth on the fabric.
- An attempt should be made to avoid an excessive amount of joints in the curtain or screen; a minimum continuous span of 15 meters (50 feet) between joints is a “good rule of thumb.”
- Devices should be a bright color (yellow or “international” orange are recommended) that will attract the attention of nearby boaters.
- In tidal situations, where currents move in both directions, it is important to attach anchors on both sides of the device to hold the curtain in place and to not allow it to overrun the anchors and pull them out when the tide reverses.
- Anchor lines should be attached to the flotation device, not to the bottom of the device.
- Removal of silt curtains and screens should be in a manner to avoid or minimize resuspension of settled solids.
- Removal of settled solids trapped by the device is optional and should only be considered if the resulting bottom contour elevation is significantly altered.
- When dredging contaminated sediment, the installation of silt curtains and screens within continuous or intermittent sheetpile walls to provide anchoring points has shown to be more effective than the device alone.
- Silt curtains or screens can be effective in containing floating debris but not always in containing contamination. Soluble contaminants, particularly heavy metals, can flow through, around or under the curtain.
- Protection of aquatic habitat can be successfully achieved with deflection curtains provided they are properly designed and deployed taking into consideration the site-specific conditions.
- Designs should conform to relevant contract specifications and manufacturer recommendations and guidelines for installation and safety measures.

- Silt curtains and screens should not be considered a “one solution fits all” type of best management practice. They are highly specialized, temporary-use devices that should be selected only after careful evaluation of the intended function and designed based upon a detailed knowledge of the site where they will be used.

A checklist is provided by Francingues and Palermo (2005) to aid the designer or reviewer of silt curtains to select, design, specify, deploy, and maintain silt curtains at dredging projects. The checklist addresses the following topics;

- Pre-dredging Site Survey,
- Deployment,
- Silt Curtain Specifications,
- Transportation,
- Mooring,
- Deployment Model,
- Maintenance,
- Recovery,
- Monitoring.

Unfortunately, few projects initially reviewed in preparation of the USACE Technical Note contained the information needed to make a good assessment of silt curtain performance (Francingues and Palermo 2005). Therefore, to develop a more comprehensive understanding of the performance of silt curtains under a variety of applications, a one-page survey form was prepared (Table 1) and sent to selective individuals to solicit a critique of the survey form and to encourage their participation in the development of case studies. The following case study details a dredging project reviewed for the Technical Note where silt curtains were used to control TSS/turbidity from a weir effluent.

Case Study Example of a Silt Curtain

Project: Lake Palourde Fill Site, Atchafalaya River, Berwick Bay - Cutterhead Dredge St. Mary Parish, Louisiana.
Phase I: 7August 2001 – 2 November 2001 and Phase II: 17 July 2002 – 13 August 7, 2002

A 610 mm (24-inch) pipeline dredge was mobilized to create a lake fill at Lake Palourde, using material from Morgan City Harbor with the assistance of a booster pump and an additional 5,793 meter (19,000 feet) of pipeline. Two earthen-rock dikes were constructed at Lake Palourde Fill Site with approximately 12,542 square meters (15,000 square yards) of geo-textile fabric to cover the rock dike. The lake fill was divided into three cells labeled A, B, & C. The purpose of dredging was to create a shoreline protection fill structure. During Phase I of the project, approximately 424,353 cubic meters (555,000 cubic yards) of material (from medium sands to fine sand with mud) were placed before the filling was stopped because mud was flowing over the rock dike weir at the end of Cell C into Lake Palourde. During Phase I, the Prime Contractor installed 83.8 meter (275 feet) of silt curtain (permeable) around the weir on the low end of the Cell “C” leading into Lake Palourde. An additional 45.7 meter (150 feet) of silt curtain was placed along the tree line near Brownell Park, located just north of the weir. At the end of Phase I, the silt curtain was left in-place. A secondary silt curtain was installed before Phase II dredging began. The contractor elected to use this dual curtain arrangement to provide additional turbidity controls. Figure 3 is a photograph showing the double curtain deployment. August 2002, approximately 367,000 cubic meters (480,000 cubic yards) of dredged material were placed with a 686 millimeter (27-inch) pipeline dredge without a booster pump. Silt curtains were used as a BMP. The objective was to control TSS/turbidity from the weir effluent discharge into the Lake to meet Section 401 Water Quality Certification. Also, it was felt that the placement of the 45.7 meter (150 feet) of curtain along the shoreline would serve to protect the shoreline grasses from any impacts as a result of the effluent discharge over the weir. There was no indication of any sensitive habitat or endangered species problems.

Table 1. Dual curtain installation at Lake Palourde fill site.


The information contained herein should be used for informational, educational and research purposes. Please indicate whether your response should be treated as confidential by circling Yes or No below.	
ORGANIZATION:	
Project Name:	
Project Date:	
Project Description:	
Name of Preparer:	
Keep confidential: Yes or No	
Insert the number of your responses in the column at the right: 	
1 = Strongly Disagree; 2 = Disagree; 3 = Agree; 4 = Strongly Agree; 5 = Unknown/NA	
• Sediment controls were used	
• Water Quality impact was an issue (physical, chemical, biological)	
• Protection of natural resources was an issue	
• Regulators required control measures (Best Management Practice)	
• The application warranted the measures implemented	
• The silt/turbidity curtains used performed as predicted by the designer/vendor	
• The depth of the curtain was less than that of the water	
• The project goal and objectives were achieved	
• No work stoppages occurred due to permit violations as a result of monitoring	
• Curtains were used to keep sediment out of an area	
• Curtains were used to keep aquatic life out of an area	
• Project reports were kept throughout the project and are available for review	
• Linear length of curtain was sufficient to allow efficient work area	
• Anchoring the curtains was simple	
• Velocities were lower than 1.5 ft/sec	
• Suspended solids samples were taken both sides of the barriers	
• Records were kept of these tests	
• The project stayed within budget	
• The curtains were purchased for this project	
• Costs for curtains, including deployment and retrieval are available	
• The curtains were custom made	
• Technical guidance on using the silt curtains was insufficient	
• Contact specifications were accurate regarding sediment control requirements	
• Installation was difficult	
• Removal was easy	
• The silt curtains will be used again on another project	
• Photo records were kept of the installation and project and are available	
• I recommend the use of these devices in a similar dredging application but in a different physical environment	



Figure 3. Dual curtain installation at Lake Palourde fill site.

Silt curtains used in New Orleans District projects are designed as permeable curtains that are buoyed at the top and anchored at the bottom. The overall height of the curtain is designed to be 1.33 times the water depth in which the curtain is deployed. That is, $2/3$ of the skirt is equal to the water depth and an additional $1/3$ of the water depth is added to the skirt. The curtain performed as anticipated and met the project requirements; however, water quality monitoring was not required nor conducted. Details on the materials and installation including the cost of the silt curtains were not available from New Orleans District Personnel.

The following additional information was requested from the dredging contractor but not received in time for preparation of the case study.

- Contract specifications and performance standards
- Commercial product selected including manufacturer and point of contact (i.e., name, telephone, fax, email)
- Curtain depth, length of sections, and overall length of curtain deployed
- Flotation system used and section connectors
- Mooring/Anchoring systems deployed
- Method(s) of installation (unfurled or furled)
- Equipment needed to install and recover curtain (shore crane, derrick barge, boats, etc.)
- Incremental costs of the curtain installation including mobilization and demobilization

The Lake Palourde case study example illustrates the typical information needed to address the performance and costs of site curtain installations at a navigation dredging project. More case study examples are needed to properly address the design and performance characteristics of these devices. Anyone wishing to offer a project as a case

study example is encouraged to complete and send the form (Table 1) to the author at the following email address: frasang@canufly.net.

Silt curtains have been used at many locations with varying degrees of success. For example, silt curtains were found to be effective in limiting suspended solids transport during in-water dike construction of the CDF for the New Bedford Harbor pilot project. However, the same silt curtains were ineffective in limiting contaminant migration during dredging operations at the same site primarily as a result of tidal fluctuation and wind (Averett et al. 1990). Problems were experienced during installation of silt curtains at the General Motors site (Massena, New York) due to high current velocities and back eddy. Dye tests conducted after installation revealed significant leakage, and the silt curtains were removed. Sheet piling was then installed around the area to be dredged with silt curtains used as supplemental containment for hot spot areas. A silt curtain and silt screen containment system was effectively applied during dredging of the Sheboygan River in 1990 and 1991, where water depths were 2 m or less. A silt curtain was found to reduce suspended solids from approximately 400 mg/L (inside) to 5 mg/L (outside) during rock fill and dredging activities in Halifax Harbor, Canada (U.S. EPA 1994). At some sites, changes in dredging operating procedures may offer more effective control of resuspension than containment barriers.

CONCLUSIONS

In this paper, the present a variety of control measures for resuspension of sediment particles and other sediment-related issues associated with navigation and environmental dredging. However, they have chosen to concentrate primarily on two engineered controls, silt curtains and silt screens, and have presented a case study as an example of the type of information that is needed to properly select and design a proper installation of these devices.

The terms “*silt curtain*” and “*silt screen*” are used to describe devices deployed in water to control suspended solids or turbidity resulting from dredging operations. Very few deployments are alike. Each one has unique features that require a site-specific application and adaptation. For all practical purposes the cost-effective, limiting deployment value of 1 to 1-1/2 knot current velocity appears to be an industry standard with exceptions on a case-by-case basis. Unfortunately, few comprehensive studies are published on the actual performance of silt curtains under varying project conditions. Additional case studies are needed to properly document the functional characteristics and incremental costs of silt curtains under demanding projects conditions of moderate to high currents, winds and waves. The authors have solicited examples of case study projects in this paper to expand the knowledge of silt curtain performance.

The USACE has developed and provided guidance in the form of a technical note that contains information for the design and review of silt curtains. The purpose of the checklist in the technical note is to prompt the designer or reviewer to consider various critical aspects of selection, designation, and installation of silt curtains for typical dredging projects (Francingues and Palermo 2005).

Silt curtains are highly specialized, temporary-use devices that should be selected only after careful evaluation of the intended function and designed based on a detailed knowledge of the site where they will be used. They should not be considered the “one solution fits all” type of best management practice for control of resuspension at dredging projects.

Finally, all dredging project managers should be concerned with the 5 R’s of dredging – removal, release, resuspension, residual, and risk, especially when dredging contaminated sediments. However, the types of control measures that may be needed become very equipment specific, sediment specific, site specific and dredge operator (leverman) specific.

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