OPERATIONAL AND ENGINEERING CONTROLS FOR THE 3 RS: RESUSPENSION, RELEASE AND RESIDUAL

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ABSTRACT

This paper is part of the session on the USACE Technical Guidelines for Environmental Dredging (hereinafter referred to as the *Guidelines*). The evaluation of sediment resuspension, contaminant release, and dredging residuals (3Rs) will help determine the need for any control measures for environmental dredging projects. The potential need for controls will be determined based on predictions of these processes and any regulatory control requirements. For purposes of the G*uidelines*, operational controls include actions that can be undertaken by the dredge operator to reduce the impacts of the dredging operations, whereas, engineering controls require a physical construction technology or modification of the physical dredge plant to cause the desired change in conditions. Examples of engineering controls might include installation of silt curtains, sheet-pile enclosures, removable (portable) dams, and pneumatic (bubble curtains). Usually, an attempt will be made to implement an operational change prior to using the engineering method because of the costs of engineering controls. Implementation of operational and/or engineering controls should be based on a clear understanding of how the dredge is actually being operated, not just knowledge of what is in the project plans.

This paper presents an overview of the types of various control measures for environmental dredging projects as they relate to the 3Rs – resuspension, release, and residual.

Keywords: Sediment Remediation, Dredging Operations, Resuspension, Release, Residuals

INTRODUCTION

The topic of this session, U.S. Army Corps of Engineers (USACE) Environmental Technical Guidelines, was published in 2008. This paper supports the *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites,* released by the U.S. Environmental Protection Agency (USEPA) in 2005. In another paper in this session, Dr. Paul Schroeder describes how to predict the magnitude of the 3Rs – resuspension, release and residuals during environmental dredging of contaminated sediments. This paper provides an overview of the *Guidelines* environmental dredging operational and engineering controls for reducing the impacts of the 3Rs during environmental dredging.

The evaluation of sediment resuspension, contaminant release, and dredging residuals will help determine the need for any control measures. The potential need for controls will be determined based on predictions of these processes and any regulatory control requirements and will be made during the feasibility study and remedial design phases of the project. For purposes of the USACE Environmental Dredging Technical Guidelines (USACE 2008), operational controls include actions that can be undertaken by the dredge operator to reduce the impacts of the dredging operations, whereas, engineering controls require a physical construction technology or modification of the physical dredge plant to cause the desired change in conditions. Application of operational and engineering controls is potentially expensive and can significantly reduce overall production rates and efficiency. Further, the improper use of controls can have direct negative impacts on a project and the environment (e.g., through increased sediment resuspension or increasing the time needed to complete the project). The degree of controls needed is a site-specific or area-specific decision. Therefore, controls should be applied only when conditions clearly indicate their need and should not be set as a requirement solely because they can be applied (USEPA 2005).

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CONTROLS FOR RESUSPENSION

A primary factor in selecting a type of dredge for an environmental project is its ability to minimize or reduce sediment resuspension. All dredges re-suspend some sediment, however, depending on a site-specific analysis; controls for resuspension might or might not be required.

Experience normally dictates a tiered approach to controlling impacts from resuspension. Initially, there would be more intensive monitoring to better define the magnitude and duration of the resuspension, followed by the use of operational and/or engineering controls, and ultimately, halting of the dredging operations, which is the most extreme situation. The various tiers for control measures would be triggered based on exceedance of any sediment resuspension and/or contaminant release thresholds that were established for the site.

Operational Controls for Resuspension

Operational controls are actions taken by the dredge operator in an attempt to reduce the amount of sediment loss from the dredging operation. Such controls can directly influence dredging productivity and their effectiveness at controlling sediment resuspension is uncertain (Bridges *et al*. 2008). The *Guidelines* presents several examples of operational controls that have been used (evaluated) on a limited basis and are shown in Table 1.

Table 1. Examples of operational controls for resuspension.

• Reducing the dredging rate to slow down the dredging operation (this is especially important with respect to bucket speed approaching the sediment surface and bucket removal from the surface after closing), to minimize the amount of resuspension of bottom sediments.
• Reducing bucket over-penetration, or digging too deep, which can cause sediment to be expelled from the vents in the bucket or cause sediment to become piled on top of the bucket, then eroded during bucket retrieval.
• Eliminating overflow from barges during dredging or transport.
• Changing the method of operating the dredge, based on changing site conditions such as tides, waves, currents, and wind, to allow dredging during more favorable conditions to reducing resuspension.
• Modifying the depth of the cutterhead, rate of swing of the ladder and of the rotating cutterhead, and reducing the speed of advance of the dredge.
• Modifying the descent or hoist speed of a wire-supported bucket and using a rinse tank to clean the bucket each cycle.
• Eliminating bottom stockpiling of dredged material or sweeping with the dredge bucket/head.
• Sequencing the dredging by moving upstream to downstream allowing for resuspended material to settle away from the area being dredged.
• Varying the number of dredging passes (vertical cuts) to increase sediment capture.
• Using properly sized tugs and support equipment, reducing the impacts of propeller wash.
• Using top down dredging to minimize cut wall failure/sloughing reducing resuspension of sediment.

Dredge operators are often challenged to find an optimal rate and method of operation for a given set of conditions. For hydraulic dredging, resuspension is generally minimized at the same point that production is optimized. If the rate of operation is slowed or accelerated, the resuspension and release may be increased (Francingues and Thompson 2006).

In addition to controls placed on operation of the basic dredging equipment, other operational control measures may be considered for mechanical dredging. These include the use of submerged trays or plates to catch or contain spillage from buckets as they are raised and slewed to the barge, and the use of wash tanks to remove adhering sediments from a bucket prior to start of the next cycle (Palermo et al. 2008). Still others may include use of filtration cloth, hay bales, curbing, or other physical baffles (similar to storm water BMPs) to control runoff from barges or re-handling areas and daily construction oversight and progress surveys. Such measures could slow the overall dredging process, and the advantages with respect to reduction of resuspension should be considered in light of the disadvantages with respect to production (Palermo et al. 2008).

Engineering Controls for Resuspension

Engineering controls use equipment or modifications of dredging equipment to reduce or control the amount of sediment loss from the dredging operation. Examples include the use of environmental buckets, sealed or seamless barges, large buckets for debris removal, specialty dredgeheads designed to minimize resuspension (shrouds) and residuals (Vic Vac®), and turbidity curtains, commonly used to retain suspended sediments in the immediate vicinity of the dredging operation (Francingues and Palermo 2005). Other examples may include installation of shields around dredgeheads, and sheet-pile enclosures. Usually, an attempt will be made to implement an operational control prior to using the engineering method because of the costs of engineering controls (Francingues and Thompson 2006). Selecting physical barriers as engineering controls for a remediation should include a) considerations of compliance (e.g., predicted water quality criteria exceedances), and b) considerations of the risks posed by the anticipated releases of contaminants from the dredging operation.

CONTROL MEASURES FOR CONTAMINANT RELEASE

Control of contaminant release to the water column is directly linked to control of sediment resuspension. However, control of contaminant releases from the dredging site is also a function of transport and removal of contaminants from the water column. Increasing sedimentation rates will also decrease the release of dissolved contaminant, the spread of contaminants, bioavailability, and short-term risks. Nevertheless, the first consideration for control of dissolved and volatile releases is control of resuspension. However, in some extreme cases, the control of sediment resuspension may not be adequate in controlling contaminant release and the resulting risks.

The *Guidelines* address measures to control the following four types of contaminant releases:

- NAPL releases and floatables,
- Particulate contaminant releases,
- Dissolved contaminant releases, and
- Volatile emissions.

CONTROLS FOR RESIDUALS

The uncertainty associated with estimating the nature and extent of residual contamination following removal of the contaminated sediment is one of the more significant limitations currently associated with predicting the effectiveness of environmental dredging. Complete removal of all contaminated sediment is not possible with existing technology, and limited field results for completed environmental dredging pilots and full-scale projects suggest that post-dredging residual contamination levels have often not met desired cleanup levels (Bridges et al. 2008). Experience shows that a residuals layer will often be present following production dredging. We also know that some management of these production dredging residuals might be needed, especially where there is a very low action level for contaminant concentrations. There are both operational and engineering controls for residuals.

Which to choose will be determined by the unique situation associated with the site and the cleanup goals. In many cases, both will be required to achieve the site-specific objectives.

Operational Controls for Residuals

The *Guidelines* presents a number of operational controls for residuals, which are listed in Table 2.

Table 2. Examples of operational controls for residuals.

• Considering the need for separate debris-removal operations prior to sediment dredging, during the production dredging if multiple passes are performed, and possibly prior to a cleanup pass if debris is a major cause for residuals generation.
• Sequencing the dredging from upslope to downslope and up current to down current.
• Setting and sequencing production cuts to reduce concentrations in residuals.
• Providing for an appropriate overdredging allowance for production cuts.
• Overdredging with a cleanup pass to reduce the thickness of the contaminated residuals layer and to mix residuals from clean underlying sediment with the contaminated residuals, decreasing the contaminant concentration in the residuals.
• Placing bucket accurately so as not to allow missed sediments between bucket placements.
• Eliminating bucket over penetration and overfilling.
• Rapid sampling after dredging to provide feedback to the dredge operator showing effects of operations.

The effectiveness of the operational controls listed in Table 2 has not been documented across a range of site conditions. In addition, implementing operational controls may result in increased dredging costs and increased time to complete dredging operations. These potential impacts should be compared with the potential benefits of reduced residuals prior to implementing operational controls.

Post Dredging Controls for Residuals

Depending on the results of monitoring following production dredging, one of several options for managing the residuals may be required. There are several possible post-dredging management actions for residuals based on the residuals' characteristics and site conditions.

The *Guidelines* addresses the following types of post-dredging residual controls.

- Monitored Natural Recovery
- Cleanup Dredging Passes
- Additional Production Passes
- Residuals Cover, and
- Engineered Isolation Cap

CASE EXAMPLES

Examples of most, if not all, of the control measures mentioned in the *Guidelines* can be found in the environmental dredging projects listed in the MCSS database (General Electric et al. 2004). Excerpts from the project summaries in the database are reported. For these projects, silt curtains were the most commonly reported measure used for control of resuspended sediments. A number of projects used sheet piles for containment, to permit excavation in the dry, and to stabilize banks during or following dredging, and as settling basins for water management and for control of suspended solids and contaminant releases, including NAPL associated with contaminated groundwater. Although the latter instance falls more within the purview of source control, dredging was impacted for at least two projects (Housatonic Project 2, Velsicol Project 1 (Pine River)) by the discovery of contaminant seeps that had to be addressed before dredging could continue.

Examples of Structural Controls

The types of structures that were used to control releases or to isolate excavation areas for the projects listed in Table 3 were quite varied and were used for both hydraulic and mechanical dredging. The size and the configuration of the installations also varied.

Table 3. Several Examples of structural controls .

Location	Type of Structural Control	Comments
1. Bayou Bonfouca, Slidell LA	Silt Curtains with absorbent booms	Placed along the bayou and around the excavation site
2. St. Lawrence River project -1 (Reynolds metals site) near Massena, NY	3800 ft of sheetpile and silt and air curtains	Dredged mechanically, with the air curtains allowing the movement of equipment into and out of the work area.
3. St. Lawrence River project -2 4. GM Central Foundry Site	2500-ft sheetpile along nearshore site	Dredged hydraulically
5. Grand Calumet River, IL	3 – Cofferdam areas & sheetpiles with some cofferdams	Cofferdams were ½-mile long in the upper 1-½ miles of the Grand Calumet River. Sheetpiles for bank stabilization
6. Tyler Pond (Willow Run Creek project)	Sheetpile	For dewatering and excavation in the dry in 1/3 of the pond
7. Fields Brook	Dam and by-pass;	For dewatering and excavation in the dry
8. Gill Creek (DuPont)	Cofferdam and the creek was rerouted	Vacuum dredging, mechanical excavation, and spray washing
9. Housatonic River (Project 3)	Sheet pile diversion & bypass pumping	Diverion over 0.8 miles and by-pass pumping over 0.7 miles of river and dry excavation
10. Tennessee Products – Project 1 Hot Spot removal	Rock Dam	Port-A-Dams and flume tubes initially proposed but replaced by rock dam and long stick excavator
11. Ottowa River Project 2	Earthen Berms with	Dry excavation

	sheet piles	
12. Velsicol Project 1 (Pine River)	Sheetpile cofferdam and divided into four cells	Water produced in dewatering the impoundment was pumped to a sheetpile settling basin prior to treatment and discharge back to the river
13. Velsicol Chemical Project 2 Pine River Hot Spot)	Sheetpile around the 3-acre hot spot	Located within the 11-acre removal zone and sediment were stabilized before dry excavation.
14. Mallinckrodt Baker (formerly J.T. Baker)	Bladder structure and stone dam	Infiltration to the excavation area was managed by pumping, and sediment was removed with excavators.
15. Starkweather Creek	Double silt curtain	Reduce suspended sediment transport and construction debris downstream
16. Arthur Kill Station, Station Island NY	Combination – Silt curtain with wave attenuation system & oil boom	Mechanical excavation with environmental bucket, standard bucket and extended reach excavator under tidal conditions.
17. Junction Creek, Sudbury, Northern Ontario, Canada	Earthen dams & by-pass pumping for dry excavation	Geosynthetic clay liner to immobilize residual impacts. Flooding overtopped dams. Onsite dewatering pads. Habitat restoration.

Examples of Operational Controls

Two projects are presented in the *Guidelines* that demonstrate the use of upstream to downstream sequencing of the dredging operations. These are a) Starkweather Creek using a conventional backhoe for excavation through the water column, on 100-yd sections of the creek with stabilization of each section before proceeding to the next section and b) upstream to downstream excavation at the Velsicol Project 1.

Examples of the use of cleanup passes are the St. Lawrence River project initial sediment removal, which was conducted with a derrick barge and 5½-yd3 bucket. Cleanup passes were made with 2½-yd3 buckets, to allow more precise control of removal thickness. Also, a highly innovative dredge head (Vic Vac®) designed for cleanup passes was applied at the Fox River site and the Ashtabula site. Operational controls for the Ashtabula River project also included limiting bucket cycle time, prohibiting nighttime dredging, and partial filling of watertight barges.

Finally, the dredging of Lavaca Bay used a shield over the cutterhead and demonstrated slow advance rate for the dredge, slow cutterhead speed (5 RPM), and slow lateral movement of the cutterhead.

Example of Adaptive Management

Major sediment remediation projects can take place over a large area, over an extended period of time, and involve a wide range of variable site conditions. Successful completion of such complex projects can be enhanced by a flexible management framework that encourages ongoing adaptation of the operational and engineering controls through continuous gathering and review of performance data, followed up by real time method adjustments to improve the effectiveness of the remedial action.

One project is presented in the *Guidelines* that demonstrates the use of dredge monitoring programs to facilitate adaptive management for environmental dredging. The Head of Hylebos Waterway sediment remediation project applied adaptive management through full-time observation of the dredging and subsequent sampling with concurrent adjustment of the operational controls and dredging methods to improve the capture of impacted sediment and reduce the post-dredging residual layer. Full time observation of dredging from the cab of the dredge, sitting side-by-side with the operator (Type 1 Monitoring), facilitated real-time adjustment to the dredging plan. It provided a means to adapt to the unknown site conditions that existed in between pre-dredging data points and achieved full removal of the target material (no undredged residual). The information from post-dredging sediment samples collected each day immediately behind the dredge (Type 2 Monitoring) provided visual classification of the nature and thickness of the residual layer and provided the dredge operator immediate feedback on effectiveness of the current operational controls in limiting residual layer formation. This resulted in ongoing adjustments to the operational controls to further reduce the residual layer. The chemical concentrations measured in the top 10 cm of sediment each day following the planned two-pass dredging program (Type 3 Monitoring) provided an indication of the effectiveness of the operational controls in meeting the project chemical cleanup criteria. The adjustments in operation controls led to the substantial reduction of the residual layer to less than 1 cm for most of the dredged areas, and resulted in dredging alone being sufficient to meet the site cleanup goals (Fuglevand, Webb, 2007).

Examples of Dredging Management Practices

In addition to the examples cited above and discussed in the *Guidelines*, six cases of dredging management practices were reviewed to determine the various operational and engineering controls for dredging of contaminated sediments. The six cases reviewed are summarized and presented in Table 4, three of which involve navigational dredging and three of which involve remedial (or environmental) dredging. The controls most commonly used among the projects were an environmental bucket and operational controls on dredging. It is important to note that turbidity curtains were purposely not used in the Passaic River demonstration so as not to interfere with the monitoring of the transport and fate of resuspended sediment (Hayes, personnel communication 2008). In most cases, the types of controls used were normally referred to as best management practices (BMPs) and were usually included as conditions in the dredging specifications and the State's water quality certification (WQC).

CONCLUSIONS

All dredges re-suspend some sediment, but removal can be achieved at an efficient rate with minimal resuspension rates. Operational and engineering control measures can be applied to further reduce the impacts of sediment resuspension. Sediment resuspension can also result in release of dissolved contaminants to the water column and release to the air through volatilization. Such releases are subject to far field transport and the resulting exposures and risks should be appropriately evaluated. All dredges will leave behind some residual directly affecting cost and effectiveness of environmental dredging. Case examples exist, where operational and engineering controls have been demonstrated successfully and many unsuccessfully for a variety of reasons. Environmental dredging projects require a recognition of the unique project features that necessitates a site-specific application and adaptation of control measures. It has been demonstrated that some controls slow down the progress of the dredging and can add to the overall cost of the project. There is no prescribed or standard set of controls for environmental dredging but the *Guidelines* discussed in this paper will help in making an informed decision on how to control the 3Rs. Selecting the right controls for an environmental dredging project depends on site-specific, equipment-specific and sediment-specific conditions, and, in many cases, it also relies on the skill of the dredge operator.

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Table 4. Six case examples of dredging management practices

Case Example	Project Type	Equipment Used	Management Practice Used	Issues
(1) Passaic River Pilot Study - 2005 Newark Bay, New Jersey	Environmental Contaminants: Metals, PAHs, PCBs, Chlorinated Pesticides	• Mechanical (crane) • Cable Arm clamshell bucket (8-cubic yards) • ClamVision positioning system • Guide barge • Hopper barges (2) • Rinse tank barge (secured to dredging barge) • Assorted tugs and crew boats	• Environmental bucket • Guide barge (minimize use of spuds) • Use of rinse tank for bucket • Optimize bucket cycle time • Optimize bucket hang time over water • Minimize use of tug boats to minimize prop wash	• Overfilling of bucket required adjustments to operational techniques • Prop wash from tugs caused resuspension of sediments • Optimization of cycle time to minimize sediment resuspension • Frequent movement of spuds caused sediment resuspension
(2) Newark Bay Study Area FEIS (Future Project) New York/New Jersey Harbor	Navigation Deepening Contaminants: Ambient levels	• Closed clamshell environmental bucket. • Hopper barges • Assorted tugs and crew boats	• Control the rate of descent • Sensors on the dredging equipment • Retrieval rate of 2 fps • No barge overflow • Solid hull or sealed barges • No washing of gunwales • All decant water holding scows shall be water tight and of solid hull construction • Discharge of decant water to Newark Bay only • Decant water to be held 24 hours before addition to decant holding scow • TSS measurement of decant	Not Applicable

			water can be substituted for holding time • Avoid resuspending or pumping sediment that has settled in the decant-holding scow. • Complete dewatering form and certified by QA/QC person. • NYD inspection at least twice per week. • Final project reporting within six months of project completion	
(3) Newark Bay Channels – Invitation No. W912dr-08-B-0011, October 16, 2008 New York/New Jersey Harbor	Maintenance Dredging Contaminants: Ambient levels	• Closed clamshell environmental bucket. • Hopper barges • Assorted tugs and crew boats	• Same conditions as contained in the WQC • Same as Case Study 2. Newark Bay Deepening	Not Applicable
(4) GASCO Early Removal Action – 2005 Portland Harbor Portland, OR	Environmental Contaminants: Tar (PAHs)	• Mechanical (crane) • Cable Arm clamshell bucket and standard clamshell bucket • Hopper barges • Assorted tugs and crew boats	• Silt curtain • No multiple dredge bucket bites • No bottom stockpiling • No dragging of dredge bucket • No lateral movement of submerged dredge bucket • Pausing before opening silt	• Overfilling of bucket required adjustments to operational techniques • Dragging of dredge bucket along top of sediment • Dunking of bucket in water to clean

			curtain access gate • Reduce or stop dredging during peak currents • Dredging only during daylight hours • Modified bucket cycle time • Speed up movement of dredge bucket from water to barge • Limit over-filling of dredge bucket	• Optimization of cycle time to minimize sediment resuspension
(5) Todd & Lockheed Shipyards Remediation Seattle, WA	Environmental Dredging Contaminants: Creosote piles NAPL	• Clamshell Bucket	• Absorbent boom • 4- to 6-ft silt curtains around dredging operations • Minimize entrainment of water during dredging by taking complete "bites" with the dredge bucket whenever possible. • Full bucket held just at the water's surface to allow water to drain before the bucket was swung to the barge. • Passively dewatering of DM on flat-deck barge through straw bales and filter fabric • Spill-Collection platform under path of the clamshell bucket during swing over water. • Asphalt curbing surrounded the transloading area to	• None reported

			prevent sediment, sediment drainage water, and contact stormwater from migrating offsite. • Water collected treated on site by a process of settling, multimedia filtration, and carbon filtration and discharged to the sanitary sewer.	
(6) Boston Dredge Bucket Comparison Boston Harbor MA	Navigation Dredging Contaminants: Ambient levels	• Conventional (open) clamshell bucket • Cable-Arm navigational bucket (not the environmental bucket) • Great Lakes Dredge and Docks closed bucket	• Turbidity and TSS monitoring	• Insignificant difference in three types of buckets based on efficiency • No advantage of Cable-Arm navigation bucket over conventional bucket