The “4Rs” In Sediment Management: A Synopsis And Overview

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“4Rs” Workshop – April 2006

- Sponsored by the US Army Corps of Engineers and the US Environmental Protection Agency
- 50 experts from government, academia, and the private sector
- Focused on 4 issues relevant to environmental dredging
  - Sediment resuspension resulting from dredging operations
  - Release of contaminants from bedded and suspended sediment in connection with dredging
  - Residual contaminated sediment produced by and/or remaining after dredging
  - Environmental risks that are the target of and associated with dredging

“4Rs” Workshop – April 2006

- Goals of workshop
  - Promote consistency in the terms used to define the challenges represented by the 4Rs
  - Develop consensus for a conceptual model that relates the relevant processes
  - Identify current resources and needs regarding data and methods/models to better describe and understand processes
  - Identify key uncertainties and make recommendations regarding future research to resolve those uncertainties

Technical Report Synthesizing the Workshop

- “The 4Rs of Environmental Dredging: Resupsension, Release, Residual, and Risk”
- Published February 2008 by the US Army Corps of Engineers, Engineer Research and Development Center, Environmental Laboratory
- ERDC/EL TR-08-4
- Available at: http://libweb.erdc.usace.army.mil

Environmental Dredging

- Dredging performed specifically for the removal of contaminated sediments for the purpose of remediating environmental risks

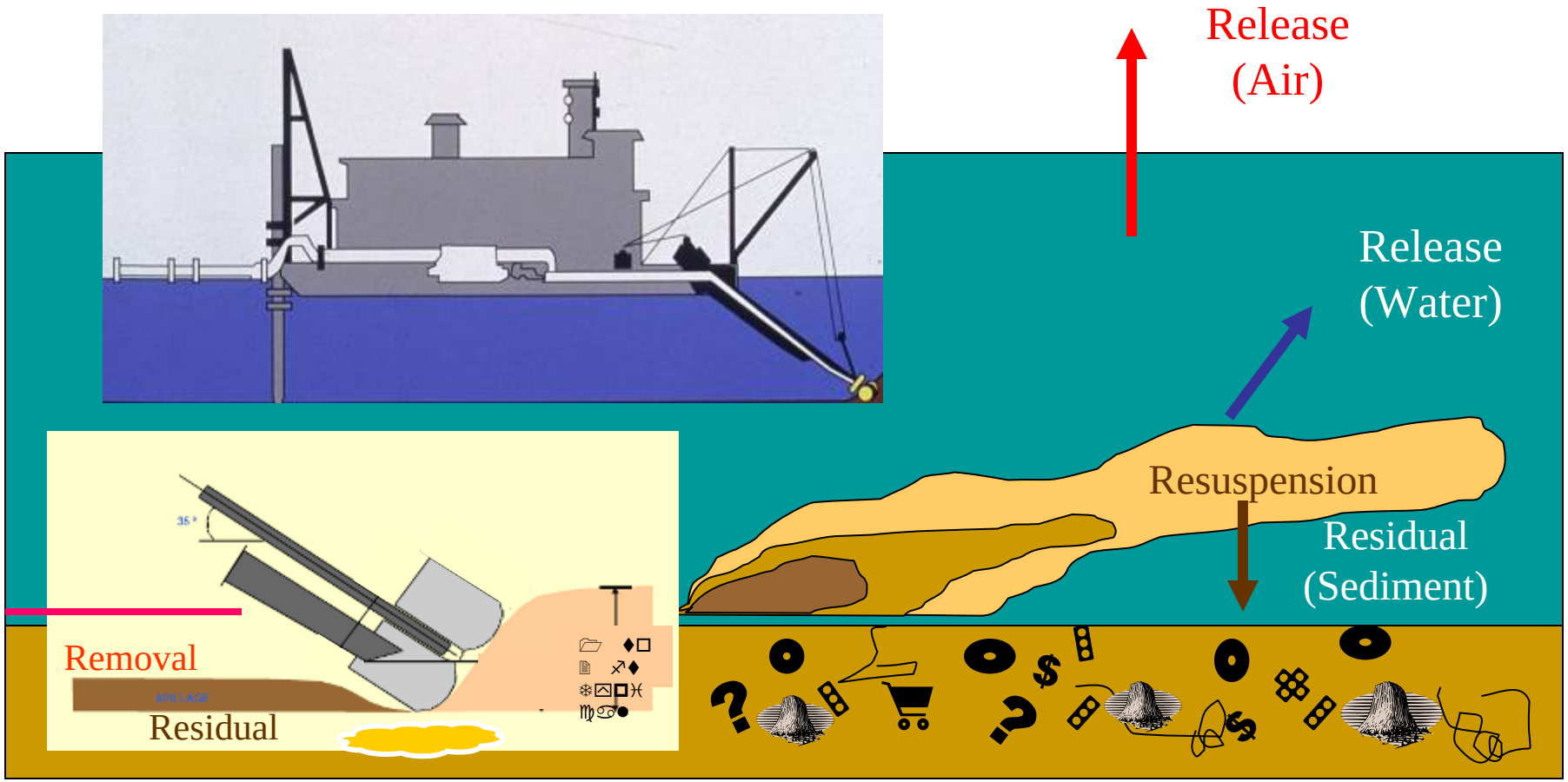
Key Considerations

- All dredging results in the resuspension of sediment
- Resuspended particulate material may be redeposited at the dredging site or transported to other locations in the water body
- Resuspended contaminants may dissolve into the water column and be available for uptake by biota
- Contaminants may also be released from residuals

Key Considerations

- No dredging operation can remove every particle of contaminated sediment
- Resuspension, release and post-dredging residual will result in some level of short-term and continuing risk at the site
- These risks need to be understood and accounted for when predicting the likely performance of environmental dredging in the remedy evaluation and selection process

Conceptual Illustration Of Environmental Dredging And Processes



From D. Reible, 2007

Resuspension

- Defined as the “processes by which a dredge and attendant operations dislodge bedded sediment particles and disperse them into the water column”. *p. 4.*

Resuspension Rates

- Rates are dredge-specific
- Rates ranging from 0.1% to over 5% have been reported (Hayes and Wu 2001; Anchor Environmental 2003)

Activities Affecting Resuspension

- Activities include:
  - Dredge-head movements
  - Spillage
  - Prop wash
  - Dredge movement
  - Anchoring systems
  - Debris removal
  - Management of silt curtains

Factors Affecting Extent of Resuspension

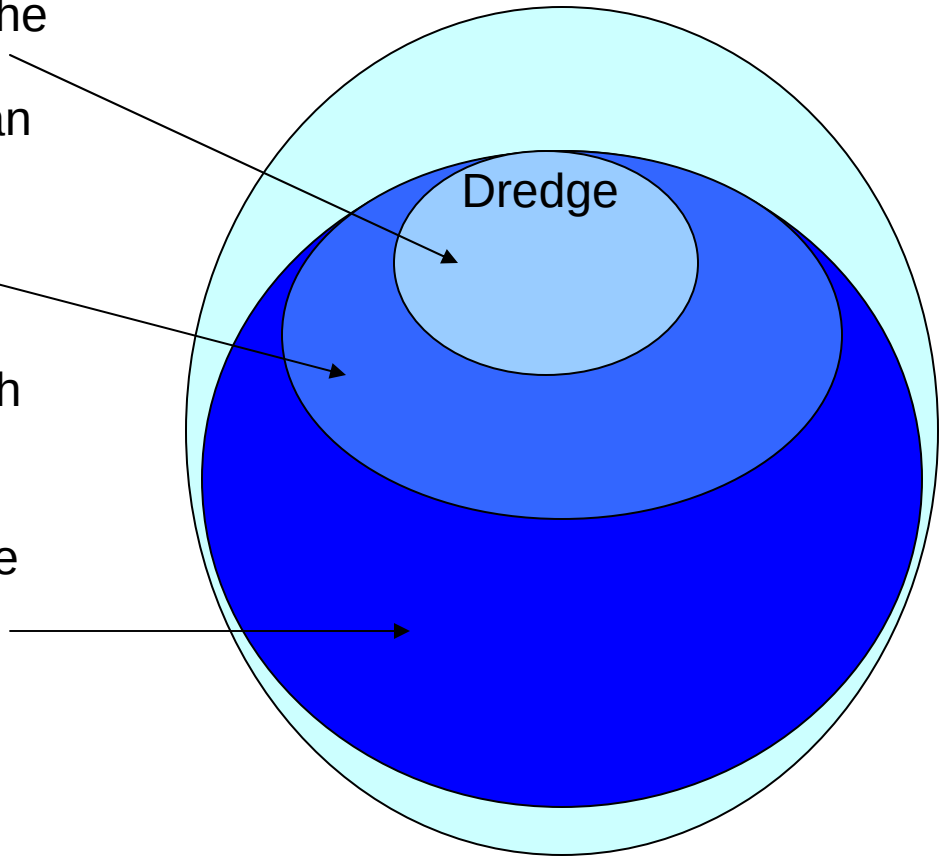
- Sediment properties
  - Bulk density
  - Particle size distribution
  - Mineralogy
- Site conditions
  - Water depth
  - Currents
  - Wave
  - Presence of hardpan, bedrock, loose cobbles or boulders

Factors Affecting Extent of Resuspension

- Nature and extent of debris and obstructions
- Operational considerations
  - Production rate
  - Thickness of dredge cuts
  - Dredging equipment type
  - Method of operation
  - Operator skill

Scales of Resuspended Sediment Transport

- Initial Mixing Zone – area where dredging operation dominates the process and where induced currents are more important than ambient currents
- Near Field Zone – plume area dominated by rapid settling velocities, changes in sediment total concentration and load with distance from the dredging operation
- Far Field Zone – area where the total load in the plume is slowly varying and where advective diffusion and settling are of the same order of magnitude



Mixed Results with Resuspension Control Methods

- Silt curtains
  - Complicated to install and maintain in moderate or high energy areas
  - Flows typically pass below or around curtains not securely fastened to the bottom
  - Effectiveness not fully understood
- Operational control measures
  - Limiting swing speed for cutterhead dredge
  - Limiting cycle times for bucket dredges
  - Affect productivity, but effectiveness at controlling resuspension is uncertain

Resuspension and Remedy Selection

- Resuspension poses water quality and ecological concerns
- Potential effects of resuspension should be considered when evaluating and selecting a remedy

Release

- Defined as “the process by which the dredging operation results in the transfer of contaminants from sediment pore water and sediment particles into the water column or air.” *p. 14.*

Empirical Estimate of Release

- Fox River SMU 56/57 hydraulic dredging pilot project - approximately 2.2% of the PCBs dredged were released and transported downstream
- Similar results reported for the 2005 dredging pilot project on the Grasse River

Processes Affecting Release

- Contaminants adsorbed on and absorbed to resuspended particles may partition to the water column
- Contaminants in residuals may be released to the water column by:
  - Densification
  - Diffusion
  - Bioturbation
- Release from residuals may significantly affect long-term flux of sediment-associated contaminants into the water column

Processes Affecting Release

- Resuspension and dispersion of bedded sediment particles and pore water by dredging operations
- Erosion/resuspension of dredging residuals and other high solids concentration layers on the bottom, including “fluff” and fluid mud

Short – Term Release

- Short-term refers to the during dredging operations time period
- Short-term release directly to the water column may be 1 to 3 orders of magnitude greater than pre-dredging releases
- Not really “short-term” because many environmental dredging projects operate 24/7 for 4-10 months and span multiple dredging seasons

Long – Term Release

- Long-term refers to the post-dredging time period
- Strongly dependent on the impacts of the releases from the residual layer and surface weighted area concentration following dredging

Release and Remedy Selection

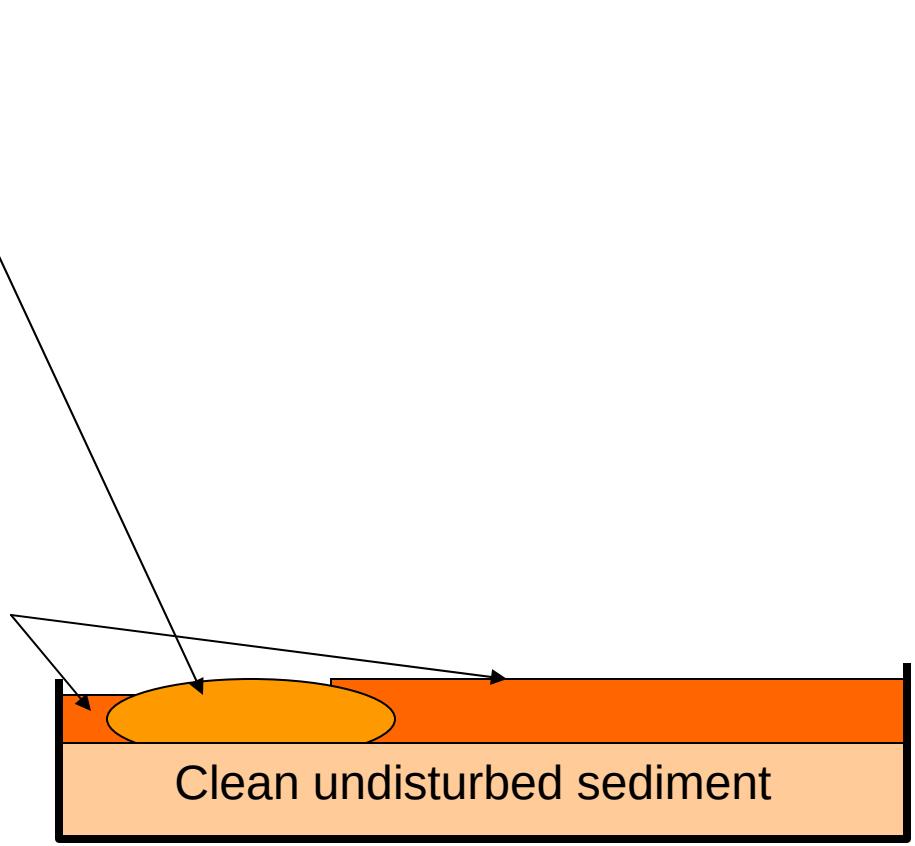
- Should be quantified to estimate short-term exposures during dredging and long-term exposures following completion of dredging
- Both short- and long-term risks associated with exposures should be considered as part of remedy evaluation and selection

Residuals

- Defined as “contaminated sediment found at the post-dredging surface of the sediment profile, either within or adjacent to the dredging footprint.” *p. 23.*

Residuals

- Undisturbed residuals are "contaminated sediments found at the post-dredge sediment surface that have been uncovered by dredging but not fully removed." *p. 24.*
- Generated residuals are "contaminated post-dredging surface sediments that are dislodged or suspended by the dredging operation and are subsequently redeposited on the bottom of the water body." *p. 24.*



Causes of Undisturbed Residuals

- Attempting to dredge sediment which
  - Directly overlies bedrock or hardpan
  - Covers highly uneven surfaces, or debris or boulders which are left in place
  - Located near piers, pilings, or utility crossings which are left in place
- Incomplete characterization of the horizontal and vertical extent of contaminants and/or ability of geostatistical models to adequately represent the distribution of contaminants
- Inappropriate selection of target dredge design elevation
- Development of dredging plans that intentionally do not target complete removal

Causes of Generated Residuals

- Sediments dislodged but left behind and fall to the bottom without being widely dispersed
- Sediment dislodged but left behind by debris-removal operations
- Attempting to dredge in settings that limit the operation of the dredge (e.g., debris fields)
- Sediment that sloughs into the dredge cut from adjacent, undredged areas

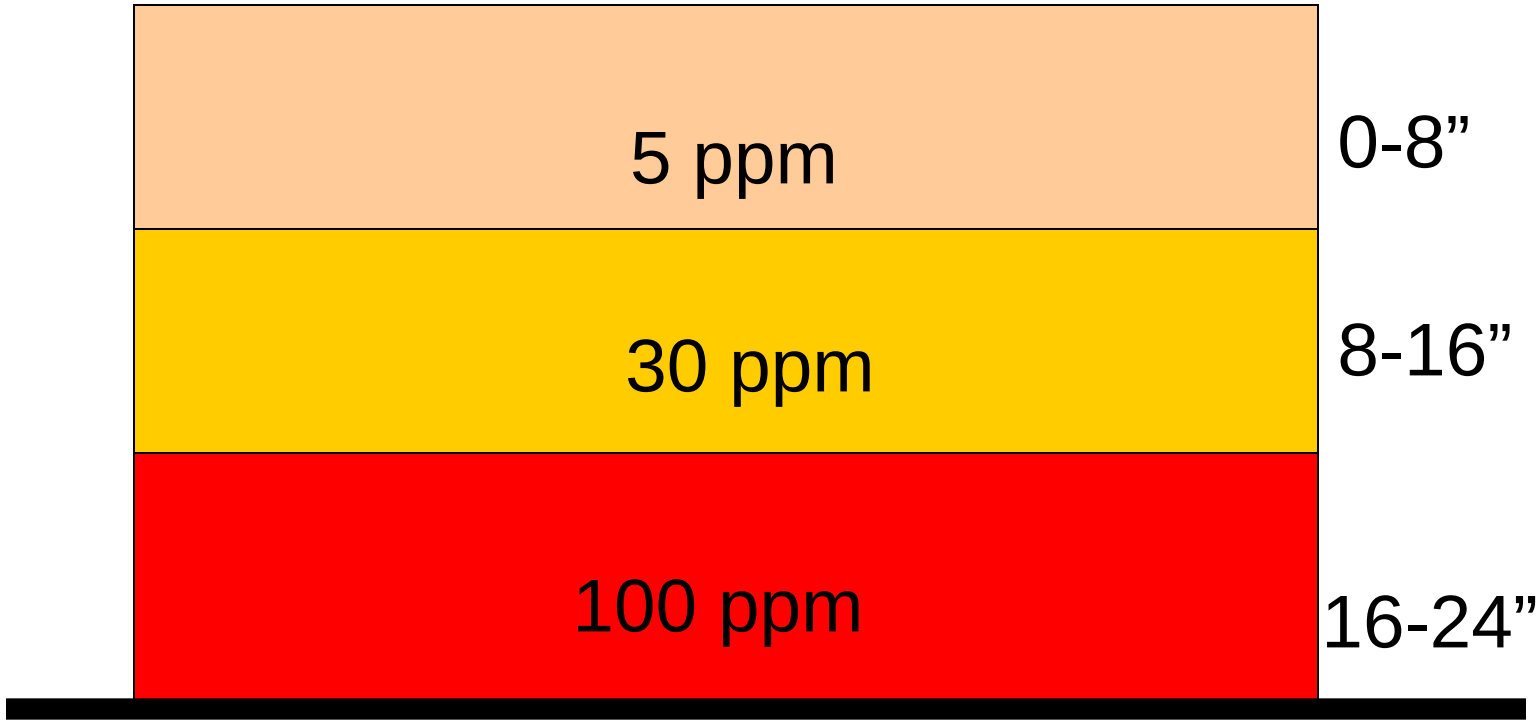
Causes of Generated Residuals

- Sediment moved by slope failures caused by the process of dredging
- Sediments resuspended by the dredgehead that quickly resettle
- Sediments resuspended by dredging or other dredging-related activities that resettle within or adjacent to the dredging footprint

Empirical Data on Residuals

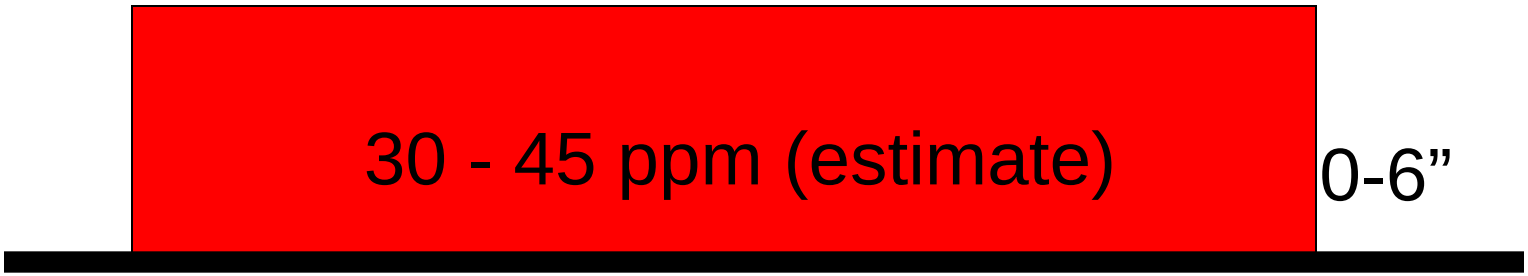
- Field results for pilots and full-scale projects suggest that post-dredging residual contamination levels have often not met cleanup levels
- Measured at 2 – 9% of the contaminant mass dredged during the last production pass
- Data indicate that the presence of hardpan, bedrock, debris, and relatively low dry density sediment (fluff) results in greater generated residuals

Pre-Dredge Contaminant Concentration In Sediment Column



Post-Dredge Surficial (0-6”) Sediment Contaminant Concentrations

Hard pan and/or debris prevented dredge from removing all the contaminated sediment. The buried sediment with high concentrations of contaminant was exposed. The surficial concentration went from 5 ppm to ~30 – 45 ppm.



Residuals and Remedy Selection

- While there is no commonly accepted method to predict the nature and extent of generated residuals, a mass-balance approach from several well-documented dredging projects in combination with site-specific information may be used to develop initial “bounding-level” expectations
- This “bounding-level” expectation should be considered during remedy evaluation and selection

Risk

- Defined as “ the probability or likelihood for an adverse outcome.” *p. 35*.
- Risks are managed meaning that actions are taken to reduce risks to acceptable levels and to manage uncertainties using information about site-specific processes contributing to risks at a site

Types of Risk

- Direct risks
  - Effects on human and ecological receptors exposed to site contaminants
- Indirect risks
  - Loss of cultural practices or recreational opportunities
  - Effects on property values
- Implementation risks
  - Habitat modification/destruction
  - Risks to workers
  - Risks to community
- Residual risks
  - Risks from remaining contaminants following remediation

Temporal Scale of Risk

- Short-term risk
  - Expected to increase due to increases in water column exposures (resuspension and release)
  - Direct toxicity
  - Bioaccumulation
- Long-term risk
  - Determined primarily by changes in exposure resulting from the distribution and nature of residuals

Risk in Remedy Selection

- Comparative net risk evaluation should be used to evaluate and select a remedy
- Includes consideration of:
  - Direct risks
  - Indirect risks
  - Implementation risks
  - Residual risks

For Further Info ...

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