Technical Guidelines for In Situ Sediment Remediation

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Objectives

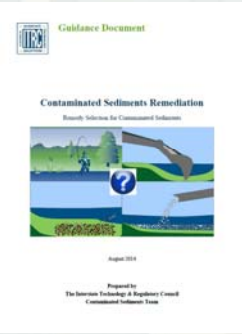
- Supplement Contaminated Sediment Guidance (2005) with Technical Guidelines for Remediation Technologies (Monitored Natural Recovery, In Situ Capping and Removal)
- Provide technical guidelines for evaluating, designing, implementing and monitoring in situ remediation at contaminated sediment sites

Purpose

- Provide guidance for evaluation, design and implementation of contaminant exposure reduction technologies as components of contaminated sediment remediation projects
- Primarily intended for federal and state remedial project managers and remediation practitioners evaluating and designing remedial response actions or non-time-critical removal actions
- Focus is primarily on items that need consideration during design and implementation
- Also identifies data needs, provides screening considerations and assists comparisons among in situ remediation technologies based on effectiveness and implementability under existing site conditions

Sediment Remediation Technologies

- Technologies have been adapting and morphing into additional options, moving from the laboratory to demos and full-scale implementation
- Current set of technologies
  - Monitored Natural Recovery (MNR)
  - Enhanced Monitored Natural Recovery (Thin Layer Capping w/ or w/o Amendments)
  - In Situ Treatment
  - Amended Capping
  - Isolation Capping
  - Environmental Dredging/Removal

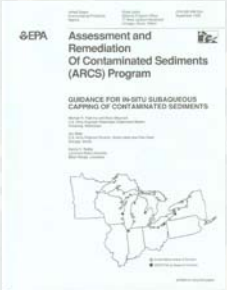


Existing Technical Guidelines

- Environmental Dredging (Sept 2008)
- Monitored Natural Recovery (May 2009)

Existing Technical Guidelines

- In Situ Isolation Capping (June 1998 and Sept 1998)



Needs

Technical Guidelines for Active In Situ Technologies:

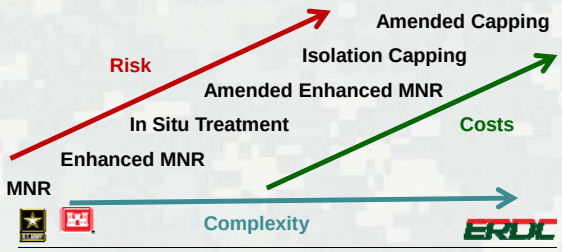
- Enhanced Monitored Natural Recovery (Thin Layer Capping w/ or w/o amendments)
- In Situ Treatment
- Amended Capping
- Update of Isolation Capping based on past 20 years of applications

Goals

- Provide technical guidelines for evaluating, designing, implementing and monitoring active in situ remediation at contaminated sediment sites
- Fill the gaps in the existing set of technical guidelines
- Update capping guidance, existing guidance limited to isolation capping
  - Address thin-layer capping and capping dredging residuals
  - Address new materials and methods including amended (reactive) caps
  - Address cap maintenance and rehabilitation
  - Consider natural recovery and recontamination
- Extend guidance to include enhanced monitored natural recovery (thin-layer capping) and in situ treatment using risk-based principles
- Apply risk-based principles; evaluate reduction in total exposure
  - Reduce concentration
  - Reduce bioavailability
  - Provide isolation

In Situ Sediment Remediation

- Represents a continuum of technologies of progressively greater action and cost to address less favorable site conditions and greater risk



Technical Guidelines

- Overview of Risk Reduction Performance and Components
- Favorable and unfavorable conditions
- Data needs
  - Physical Characteristics
  - Sediment Characteristics
  - Contaminant Characteristics
  - Site Use
- Design and evaluation protocols
  - Lab testing
  - Modeling
  - Materials
  - Quantities
- Implementation and Equipment
- Monitoring

Site Characteristics

- Site characteristics are key to assessing net risk reduction, implementability, permanence, cost-effectiveness and compatibility with site use.
  - Physical Characteristics
  - Sediment Characteristics
  - Contaminant Characteristics
  - Land and Waterway Use Characteristics

Physical Characteristics

Physical Characteristics	*EMNR*	*In Situ Treatment*	*Capping*
Sediment stability	H	H	M
Deposition rate	H	M	M
In-water & shoreline infrastructure	L	M	M
Presence of hard bottom	L	L	L
Presence of debris	L	M	M
Hydrodynamics	H	H	H
Conveyance	L	L	H
Bathymetry and slope	M	H	H
Groundwater advection	H	H	H
Ebullition	M	M	H
Bioturbation depth/intensity	H	M	M

H = critical M = contributing L = unimportant

Sediment Characteristics

Sediment Characteristics	EMNR	In Situ Treatment	Capping
Geotechnical properties	M	M	H
Slope stability	M	H	H
Potential for liquefaction	L	M	H
Erodibility	H	H	M
Potential for resuspension, release and residuals	L	M	M

Contaminant Characteristics

Contaminant Characteristics	EMNR	In Situ Treatment	Capping
Contaminant type (bioaccumulative or toxic)	H	H	M
Contaminant mobility and bioavailability	H	H	H
Contaminant fate and transport	H	H	M
Risk reduction required	H	H	L
Extent of contamination	H	H	H
On-going source impacts	M	M	H
Source materials (e.g., NAPL)	M	H	H
Exposure pathways and risk estimates	H	H	M

Land and Water Use Characteristics

Site Use Characteristics	EMNR	In Situ Treatment	Capping
Cultural and archeological issues	L	M	M
Site accessibility	L	M	H
Current and future waterway use	M	H	H
Current and future land use	L	L	M
Presence of sensitive species or habitat	L	H	H

Enhanced Monitored Recovery

- Acceleration of a proven ongoing recovery process by engineering means, usually the addition of a thin layer of clean sediment to kick-start the burial process and reduce bioactive zone contamination levels, possibly sequestering components
- Placed as a uniform thin (a few inches) layer, or in berms or windrows that can be further distributed by natural sediment transport processes
- Flow control structures for the waterway may be designed and placed to encourage sedimentation

Favorable Conditions for MNR	
Characteristic	**Condition**
Deposition rate	Annual deposition >> annual erosion; net deposition rate > 1 cm/yr
Erodibility	Low shear stress environment under extreme conditions; less than 6 inches of erosion predicted in 100-year event
Horizontal and vertical distribution of contamination	Contaminant conc. increase with depth; depth of peak conc. is greater than 2 ft; surficial bioavailable concentrations are fairly uniform
Required risk reduction	Typically, no more than a factor of 30

MNR vs. EMNR

- Deposition: >1 cm/yr vs. 0.3 cm/yr to 1 cm/yr
- Risk Reduction: < factor of 10 vs. > factor of 20
- Natural Recovery Time: < 10 to 15 yr vs. > 20 yr
- Bioturbation: shallow (< 5 cm) vs. deep (> 10 cm)

In Situ Treatment

- In-place chemical, physical, or biological degradation or sequestration of contaminants in bottom sediments
- Reduce contaminant transfer up the food web by reducing uptake by benthic organisms, predominantly by sequestration
- Reduce direct contaminant flux to the water column
- Application of bentonite, clay polymers, and pozzolanic materials can bind contaminants and reduce permeability
- Enhance in situ contaminant degradation

Favorable Conditions for In Situ Treatment	
Characteristic	**Condition**
Deposition rate	Annual deposition ≥ annual erosion; net deposition rate > 1 cm/yr
Horizontal and vertical distribution of contamination	Contaminant conc. increase with depth; depth of peak conc. is greater than 2 ft; surficial bioavailable concentrations are fairly uniform
Slope	Slopes greater than 10% pose difficulties in placing and retaining amendments and slopes greater than 20% are not suitable for most placement and mixing options
Required risk reduction	Typically, no more than a factor of 100
Groundwater advection	Characteristic net upward velocity < 0.5 cm/day

Capping

- Physical isolation of the contaminated sediment from the benthic environment and water column
- Stabilization of contaminated sediments, preventing resuspension and transport to other sites
- Reduction of the flux of dissolved contaminants into the water column
- Capping materials may include clean sediments, sands, gravels, sand/silt/clay mixtures, or may involve a more complex design with geotextiles, liners, armor stone, reactive amendments and multiple layers.
- Conventional placement equipment and techniques are frequently used for a capping project, but these practices must be controlled more precisely than for conventional placement. Specialty equipment is often required for placing materials in complex capping designs.

Capping

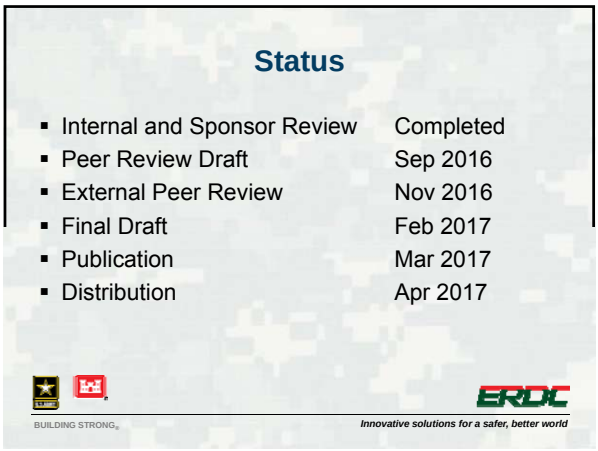
Update includes:

- Integrated design instead of incremental design
  - How thick does it need to be?
- Assesses multi-functionality of materials and layers
- Cohesive cap materials
  - Do I need armoring?
- Contaminant sequestration
  - Do I need an amendment?
  - What type?
  - How much?
  - How long will it last?
- What is the potential for recontamination?
- How do I incorporate habitat?
  - Do I need to have extra material for habitat?

Favorable Conditions for Capping	
Characteristic	**Condition**
Slope	Slopes >15% pose difficulties in placing and retaining capping materials; >25% are not generally suitable
Geotechnical properties	Undrained shear strengths less than 0.5 kPA poses severe restrictions on placement
Contaminant mobility	Kd > 3,000 L/kg
Groundwater advection	Velocity << 1 cm/day unless amendment used; velocities greater than 1 mm/day promote contaminant flux
Required risk reduction	Not critical but generally > a factor of 100
Current and anticipated waterway use	Cap design and water depth must be compatible with waterway use and habitat

Physical Isolation vs. Amended Capping

- Groundwater: < 0.5 cm/day vs. > 1 cm/day
- Mobility: Kd > 10,000 L/kg vs. Kd < 3,000 L/kg
- NAPL: Below residual saturation vs. above
- Allowable thickness: thick vs. thin
- Risk reduction factor: <300 vs. >1000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