“Alternatives for Managing the Nation’s Complex Contaminated Groundwater Sites: NRC, 2013; Key Findings, and Overview of Transition Assessments”

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If a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure, the lead agency shall review such action no less often than every five years after initiation of the selected remedial action.
Technical Constraints: Contaminant Chemistry and Hydrogeology (NRC, 1994)

Contaminant Chemistry

<table>
<thead>
<tr>
<th>Hydrogeology</th>
<th>Mobile, Dissolved (degrades/volatizes)</th>
<th>Mobile, Dissolved (degrades/volatizes)</th>
<th>Strongly Sorbed, Dissolved (degrades/volatizes)</th>
<th>Strongly Sorbed, Dissolved (degrades/volatizes)</th>
<th>Separate Phase LNAPL</th>
<th>Separate Phase DNAPL</th>
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</thead>
<tbody>
<tr>
<td>Homogeneous, single layer</td>
<td>1*</td>
<td>1-2</td>
<td>2</td>
<td>2-3</td>
<td>2-3</td>
<td>3</td>
</tr>
<tr>
<td>Homogeneous, multiple layers</td>
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<td>1-2</td>
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<td>2-3</td>
<td>2-3</td>
<td>3</td>
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<tr>
<td>Heterogeneous, single layer</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
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<tr>
<td>Heterogeneous, multiple layers</td>
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<td>2</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Fractured Rock</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

*Relative ease of cleanup, where 1 is easiest and 4 is most difficult (NRC, 1994)*
### Status of CERCLA Sites

February 27, 2014

http://www.epa.gov/superfund/sites/npl/status.htm

<table>
<thead>
<tr>
<th></th>
<th>Non-Federal</th>
<th>Federal</th>
<th>Totals</th>
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</thead>
<tbody>
<tr>
<td>Proposed Sites</td>
<td>49</td>
<td>4</td>
<td>53</td>
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<tr>
<td>Final Sites</td>
<td>1,162</td>
<td>157</td>
<td>1,319</td>
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<tr>
<td>Deleted Sites</td>
<td>358</td>
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<tr>
<td>Construction Complete</td>
<td>1,085</td>
<td>73</td>
<td>1,158</td>
</tr>
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</table>
Examples of Complex Sites
Attributes of Highly “Complex Sites”

- Large releases of contaminants over long time frames
- Highly heterogeneous subsurface geologic environments
- Some contaminants recalcitrant and persistent
- Levels of contaminants several orders of magnitude above levels allowing for UU/UE (e.g., MCLs)
- Several years of remedial efforts with an indication of “asymptotic” performance – multiple 5-year reviews
- Life cycle costs to achieve restoration exceeding $20-$50 million
Background: Overview of Groundwater Restoration

Unresolved Challenges of Groundwater Cleanup

- Many sites with groundwater contamination remain open and restoration to “unlimited use/unrestricted exposure” (UU/UE) and final “closure” uncertain in a “reasonable” timeframe.
- Long term management of orphan CERCLA sites transitioning to state responsibility following 10 years of operation.
  - 10-15 sites/year into the future according to Jim Woolford, (EPA, 2013).
- States financially constrained – long term management liabilities an issue.

- The “complex site” problem
Conclusions – Size of the Problem

- 126,000 sites that have not yet reached closure is likely an underestimate
- Could not determine the total number of sites with residual contamination above levels allowing for UU/UE
  - Must be > 126,000
- Estimated future cost of $110-127 billion likely an underestimate

- More than 12,000 sites likely “complex”
  - This represents the approximate sum of high priority sites (CERCLA, DoD, DOE, RCRA CA)
“Based on what is known about the effectiveness of remediation technologies (as described in this chapter [4]), the Committee concluded that regardless of the technology used, the complete removal (i.e., restoration) of contaminant mass at complex sites is unlikely. Furthermore, the Committee discovered no transformational remedial technology or combination of technologies that can overcome the current challenges associated with restoring contaminated groundwater at complex sites. At these sites, some amount of residual contamination will remain in the subsurface after active remedial actions cease, requiring long-term management.” (page 114, NRC, 2013)
EPA Recognizes Alternative Approaches Are Needed for Sites Where Restoration is Unlikely

EPA Roadmap
July, 2011
Figure 1: EPA TI Waivers by Fiscal Year (FY 1988 – 2011)

Total Number of TI Waivers = 91
Decision Process Leading to Three Generic End States

- **Remedial Action Objectives Achieved**
  - This would include UU/UE but RAOs could deviate from UU/UE

- **Long-Term Active Management**
  - Operating remedy plus appropriate monitoring, reporting, 5-year reviews, institutional or legal controls, community outreach

- **Long-Term Passive Management**
  - No active remedy but appropriate monitoring, reporting, 5-year reviews, institutional or legal controls, community outreach
  - Consideration of factors to transition to no-monitoring requirements, where appropriate
Metrics to Support “Diminishing Returns” Hypothesis

- Statistical methods confirming declining trend in concentrations.
- Statistical confirmation of target reduction in mass flux/mass discharge.
- For LNAPL recovery, asymptotic performance based on LNAPL/water ratios.
- Risk reduction metric; cost per unit risk reduction.
- Exposure pathways eliminated and risks of residual contamination below threshold levels.
- Sustainability metrics; e.g. GHG emissions per unit mass removed.
Factors to be considered in a Transition Assessment – NRC 2013 Report

- Expanded analysis of costs and risk reduction for viable alternatives including containment.
- Sustainability assessments of options.
- Additional site characterization with advanced diagnostic tools (e.g. to estimate assimilative capacity of aquifer) if justified.
- Risk assessment and risk analysis of post-remedy conditions.
  - Particular focus on level of safety in any containment remedy, active or passive – a risk analysis of residual contamination.
- A risk-based or risk-informed decision process – (see “Science and Decisions” NRC, 1999)
- Expanded community outreach and education.
EPA Risk Management: Aspirational Goals and Permitting Programs

- Aspirational Goals
  - UU/UE in CERCLA
  - MCLGs in SDWA
  - Fishable, swimmable waters in CWA
  - Delany clause -FDA

- Permitting Programs
  - NPDES in CWA
  - NAAQS – MACT Standards
  - RCRA – Containment of hazardous wastes
Empirical Safety Factors in Decision Making

- EPA human health risk assessments
  - Default values – factors from 1 to 1000
    - Linear extrapolation from animal studies for dose-response curve
    - Explicit defaults and missing defaults
  - Exposure assessments – Percentile default values (e.g. soil ingestion rate for children of 200 mg/day, 65th percentile)

- Establishing MCLs
  - MCLGs for potential human carcinogens; MCL based on risk management decision (e.g. analytical limitations)

- Food Quality Protection Act – factor of 10 to protect infants for pesticide limits.
Geotechnical Engineers Methodology for Risk Analysis of Dams: Design Assumptions and Safety Factors

Fig. 1. Factor of safety versus annual probability of failure

F. Silva; T. Lamb; W. Marr, JOURNAL OF GEOTECHNICAL AND GEOENVIRONMENTAL ENGINEERING, Dec. 2008
The Future: LTM as an Infrastructure Problem

- Goal of long-term management “end states”: minimize probability of failure and consequences of same
- A Geotechnical Engineering Perspective: Applying appropriate “best design practices” with “safety factors”
Risk Management Decision is a Trade Off Decision
Concluding Remarks

- Central Theme of NRC 2013 Report
  *How nation should deal with residual contamination post-remedy at large number of sites – transition guidance needed.*

- A persistent “tradeoff” problem requiring leadership and effective communications.

- Ultimately, from a sustainability perspective, there are limits to resource diversion for pursuing restoration. A pragmatic approach to an ethical problem – regulatory flexibility imbedded in all environmental regulations allowing for creative solutions.

- Research efforts needed to ensure that long term management infrastructure meets acceptable residual risk levels and that residual risk is allocated equitably.
Questions?

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