ACHIEVING DURABLE AND COST EFFECTIVE REMEDIES USING A SYSTEMATIC APPROACH TO REMEDY EVALUATION AND SELECTION
Where Remedy Selections Go Wrong

- Incomplete Hypothesis
- Poor Objectives
- No Technology Screening
- Incomplete Analyses
- Inadequate Funding
Formalized Decision Making
Significantly Reduce Mistakes

Objectives
Technology Screen
Remedial Alternatives
Decision Parameters
Decision Analysis
Sensitivity Analyses
Documentation
Guidelines for Objectives

1. Risk Based

2. Protection vs. Cleanup

3. Technical vs. Prescriptive Regulatory

4. Consider sustainability
   (Environmental effects of remedy)
**Technology Selection & Screening**

<table>
<thead>
<tr>
<th>RESPONSE ACTIONS</th>
<th>TECHNOLOGIES</th>
<th>PARAMETERS</th>
<th>SCREENING RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>INSTITUTIONAL CONTROLS</td>
<td>Start with a comprehensive List</td>
<td>Effectiveness, Implementability, Relative Cost</td>
<td>Perform a Systematic Screening</td>
</tr>
<tr>
<td>CONTAINMENT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COLLECTION/REMOVAL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TREATMENT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DISPOSAL</td>
<td></td>
<td></td>
<td>Finish with a viable list</td>
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</table>
## Development of Remedial Alternatives

<table>
<thead>
<tr>
<th>OBJECTIVE</th>
<th>MEDIA</th>
<th>PATHWAY</th>
<th>ALTERNATIVES</th>
<th>CONTAINMENT</th>
<th>REMOVAL</th>
<th>TREATMENT</th>
<th>CONTAINMENT &amp; ICs</th>
</tr>
</thead>
<tbody>
<tr>
<td>PROTECT HH</td>
<td>SOIL</td>
<td>INGESTION</td>
<td>LAND USE RESTRICTIONS</td>
<td>N/A</td>
<td>SHALLOW SOIL EXCAVATION</td>
<td>IN-SITU STABILIZATION</td>
<td>LAND USE RESTRICTIONS</td>
</tr>
<tr>
<td>DUST</td>
<td></td>
<td></td>
<td>N/A</td>
<td>N/A</td>
<td>SHALLOW SOIL EXCAVATION</td>
<td>IN-SITU STABILIZATION</td>
<td>N/A</td>
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<tr>
<td>EXCAVATION</td>
<td></td>
<td></td>
<td>CONSTRUCTION WORKER REQUIREMENTS</td>
<td>N/A</td>
<td>DEEP SOIL EXCAVATION</td>
<td>N/A</td>
<td>CONSTRUCTION WORKER REQUIREMENTS</td>
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</table>

**Does not meet objective**
<table>
<thead>
<tr>
<th>OBJECTIVE</th>
<th>MEDIA</th>
<th>PATHWAY</th>
<th>ALTERNATIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GROUND WATER</td>
<td>INGESTION</td>
<td>ICs</td>
</tr>
<tr>
<td>PROTECT HH</td>
<td></td>
<td>PROHIBITION</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>VAPOR INTRUSION</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SPREADING</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MASS REDUCTION</td>
<td>N/A</td>
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</tbody>
</table>

*DOES NOT MEET OBJECTIVE*
Case History Using Decision Analysis Software

CDP Hierarchy Chart
Team Effort

Bring the right people to the table...

Use “Delphi Process” to achieve consensus, weighting and scoring
<table>
<thead>
<tr>
<th>Alternatives</th>
<th>Value</th>
<th>Decision Scores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site B</td>
<td>0.716</td>
<td></td>
</tr>
<tr>
<td>Site D</td>
<td>0.702</td>
<td></td>
</tr>
<tr>
<td>Site F</td>
<td>0.583</td>
<td></td>
</tr>
<tr>
<td>Site C</td>
<td>0.486</td>
<td></td>
</tr>
<tr>
<td>Site A</td>
<td>0.484</td>
<td></td>
</tr>
<tr>
<td>Site E</td>
<td>0.339</td>
<td></td>
</tr>
</tbody>
</table>
Contributions to Scores from Elements

- Site B
- Site D
- Site F
- Site C
- Site A
- Site E

Legend:
- Operations
- Ease of Closure
- Environment
- Construction Risks
- Costs
Remediation Case Histories

Upland Harbor Area

Large Groundwater Plume
Site Conditions

Soils
- 0 to 3 ft: Permeable Sand
- 3 to 5 ft: Low Permeability Silt
- 5 to 12 ft: Permeable Sand

Groundwater
- At about 3 ft depth at top of Silt
- Fluctuates with Tidal Ups & Downs
Risk Screening Levels

- Soil benzene - 11 mg/kg.
- Groundwater benzene - 2 mg/L.
- Soil PAH - 5 mg/kg.
- Methane in soil gas -10 % LEL (5,000 ppmv)
- TVH - 1,400 ppmv.
- SPH at a thickness - 0.03 m
Remedial Objectives

- Prevent discharge of SPH to harbor.
- Prevent accumulation of methane & TVH in utility vaults.
- Protect site workers and tenants from COC harmful emissions.
- Protect construction workers from direct contact with COCs.
- Remove SPH to extent practicable.
Remedial Technologies

<table>
<thead>
<tr>
<th>TECHNOLOGIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Sparging with Vapor Control and Treatment</td>
</tr>
<tr>
<td>Air Stripping</td>
</tr>
<tr>
<td>Bio-cells</td>
</tr>
<tr>
<td>Biotreatment</td>
</tr>
<tr>
<td>Catalyzed Oxidation</td>
</tr>
<tr>
<td>Chemical Oxidation</td>
</tr>
<tr>
<td>Contained Recovery of Oily Wastes</td>
</tr>
<tr>
<td>Dual Phase Extraction</td>
</tr>
<tr>
<td>Electrical Resistance Heating</td>
</tr>
<tr>
<td>Excavation Using Conventional Equipment</td>
</tr>
<tr>
<td>Extraction Using Wells or Trenches</td>
</tr>
<tr>
<td>Extraction Wells and Extraction Trenches</td>
</tr>
<tr>
<td>FML Barriers</td>
</tr>
<tr>
<td>GAC Adsorption</td>
</tr>
<tr>
<td>GAC</td>
</tr>
<tr>
<td>Hand-Bailing</td>
</tr>
<tr>
<td>Hydraulic Barriers</td>
</tr>
<tr>
<td>Hydraulically Enhanced SPH and Groundwater Recovery</td>
</tr>
<tr>
<td>Impermeable Barrier with a Passive Gas Collection Layer</td>
</tr>
<tr>
<td>Impermeable Barrier with an Active Gas Collection Layer</td>
</tr>
<tr>
<td>Impermeable Barrier Under Structures</td>
</tr>
<tr>
<td>Land-Farming</td>
</tr>
<tr>
<td>Low Temperature Thermal De-Sorption</td>
</tr>
<tr>
<td>Oil-Water Separation</td>
</tr>
<tr>
<td>Permeable Trenches</td>
</tr>
<tr>
<td>Pipeline Excavation</td>
</tr>
<tr>
<td>Pipeline Tapping and Draining</td>
</tr>
<tr>
<td>Sheet Pile Barriers with Sealed Joints</td>
</tr>
<tr>
<td>Skimmer Pumps</td>
</tr>
<tr>
<td>Slurry Phase Bio-Reactors</td>
</tr>
<tr>
<td>Slurry Walls</td>
</tr>
<tr>
<td>Surfactant Addition</td>
</tr>
<tr>
<td>UV Peroxide</td>
</tr>
<tr>
<td>Vacuum Removal</td>
</tr>
</tbody>
</table>
Alternative 2
Monitoring & ICs

Alternative 3
Containment & ICs

STORM DRAIN
RECENTLY REPLACED
AS AN INTERIM REMEDY

STORM DRAIN REPAIR
OR REPLACEMENT
[BASED ON INSPECTION
AND AS NECESSARY]

SELECTIVE HARBOR
WALL REPAIR

STORM DRAIN REPAIR
OR AS REPLACEMENT
AS NECESSARY

STORM DRAINS

STORM DRAIN

STORM DRAIN

BOUNDARY
4A&B SPH Recovery & ICs

Focused

Boundaries

Expanded

Expanded SPH recovery areas will include one or more of the following technologies:

- Additional recovery wells and/or extraction trenches
- Hydraulically enhanced recovery
NOTE:
APPROXIMATE EXTENT OF EXCAVATION. BOUNDARY IS ASSUMED TO BE BASED ON 0.5 FOOT SPH THICKNESS OBSERVED IN WELLS DURING PAST SEVERAL YEARS OF MONITORING.
Other Alternatives

- 6 SPH Recovery, In-situ Biochemical Treatment and ICs
- 7A Focused SPH Recovery, Containment & ICs
- 7B Expanded SPH Recovery, Containment & ICs
- 8 SPH Recovery, ICs and Containment
- 9 SPH Recovery, ICs and Biotreatment
8 & 9 SPH Recovery, ICs

**Containment**

**Biotreatment**

**NOTE:** Approximate extent of excavation. Boundary is assumed to be based on 0.5 foot SPH thickness observed in wells during past several years of monitoring.

**STORM DRAIN**

**STORM DRAIN RECENTLY REPLACED AS AN INTERIM REMEDY**

**STORM DRAIN REPAIR OR REPLACEMENT (BASED ON INSPECTION AND AS NECESSARY)**

**SELECTIVE HARBOR WALL REPAIR**

**NOTE:** Approximate extent of In-Situ treatment of soil where SPH thickness exceeds 0.01 ft measured in wells during past several years of monitoring.

**OXYGEN DELIVERY MELS**

**SECTION A-A’**

**SCALE (Feet)**

**0 160**

**SLR**

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Alternatives Screened Out

1. No Action
2. Monitoring and Institutional Controls
3. Containment
4. SPH Recovery
Alternatives Evaluated in Detail

5. Soil Excavation
6. In Situ Treatment & ICs
7. Containment, SPH Recovery & ICs
8. Containment, SPH Recovery & ICs
9. Biotreatment, SPH Recovery & ICs
Alternatives Analysis

Remediate OU1C

Effectiveness
- Protect HH&E
- Minimum Residual Risk
- ARARs
- Accom Future Use & Dev
- Reduce TMV
- Protect Community
- Protect Workers

Short-Term Effectiveness
- Environmental Impacts
- Time to Achieve RAO

Implementability
- Technical Feasibility
- Constructability
- Operability
- Reliable Technology
- Ability to Monitor
- Off-Site Permits
- Other Agencies

Community Acceptance
- Administrative Feasibility
- Availability of Service & Materials
- Local Businesses
- General Public
- Direct Capital

Cost
- O&M
- Remedial Contractor
- Dock Workers

Time to Achieve RAO
- 5B SE-15
- 6 IST
- 7A CON & SPH-F
- 7B CON & SPH-E
- 8 SE-7.5 & CON
- 9 SE-7.5 & IST
Results

Contributions to Total Score at Level 2 of the Hierarchy

Cumulative Decision Score

- **Community Acceptance**
- **Implementability**
- **Short-Term Effectiveness**
- **Effectiveness**
- **Cost**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Cumulative Decision Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>7B CON &amp; SPH-E</td>
<td>0.8</td>
</tr>
<tr>
<td>7A CON &amp; SPH-F</td>
<td>0.6</td>
</tr>
<tr>
<td>8 SE-7.5 &amp; CON</td>
<td>0.4</td>
</tr>
<tr>
<td>6 IST</td>
<td>0.2</td>
</tr>
<tr>
<td>5B SE-15</td>
<td>0.0</td>
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</tbody>
</table>
**Conclusion**

*Alternative 7A – Containment, SPH Recovery and ICs* scores higher than the other alternatives primarily because of greater implementability and community acceptance.

In the long term, ongoing operation and maintenance and institutional control results in overall protection of human health and safety, and the environment.
Large Groundwater Plume
Perchlorate Distribution

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Remedial Action Objectives

- Contain the perchlorate and TCE plumes
- Provide drinking water below MCLs
- Ensure continued beneficial uses of natural resources
- Restore groundwater quality within the Plume Area
## Remedial Action Alternatives

<table>
<thead>
<tr>
<th>Alt</th>
<th>Description</th>
<th>Estimate</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>No Action</td>
<td>$0</td>
</tr>
<tr>
<td>2A</td>
<td>Contain &amp; Treat with Water Supply Wells</td>
<td>$134 M</td>
</tr>
<tr>
<td>2B</td>
<td>Base Case Plus Treatment of Agricultural Recycle</td>
<td>$164 M</td>
</tr>
<tr>
<td>3A</td>
<td>Plume Migration Control – Existing Wells</td>
<td>$379 M</td>
</tr>
<tr>
<td>3B</td>
<td>Plume Migration Control – New and Existing Wells</td>
<td>$183 M</td>
</tr>
<tr>
<td>4</td>
<td>Modified Basin Initiatives</td>
<td>$203 M</td>
</tr>
<tr>
<td>5</td>
<td>Intensified Plume Remediation</td>
<td>$681 M</td>
</tr>
</tbody>
</table>
Contributions to Scores

- Reduction of Toxicity
- Short Term Effectiveness
- Cost
- Community Acceptance
- Long Term Effectiveness
- Compliance with APAPs
- Implementability
- Overall Protection of Human Health

ALTERNATIVE

Current Rap
Modified Basin Initiatives
Vertical Control - New Wells
Current RAP with Agricultural Well Treatment
Vertical Control - Existing Wells
Intensified Plume Remediation
No Action

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SLR
In Conclusion

• Set Realistic & Protective Objectives
  • Avoid blind compliance
• Technology Screening
• Comprehensive Alternatives Analyses
  • Apply Delphi Process
• “What if” Scenarios
• Write it up

TOOLS DON’T MAKE DECISIONS
...You Do!