Building a Consensus Vision Using Conceptual Site Models

US EPA Triad Month

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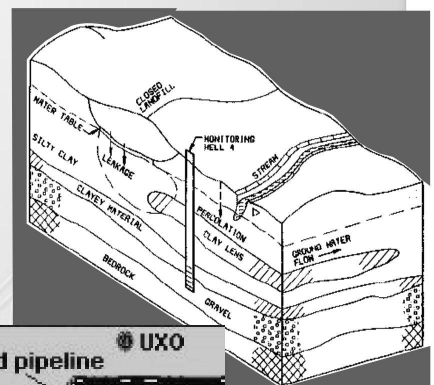
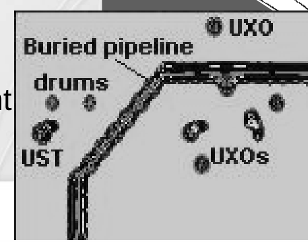
What is a Triad CSM?

- A written and graphical expression of what is known about a site
- Dynamic, living planning tool used throughout project lifecycle
- Used for cleanup efficiency, selection of technologies, and monitoring and measurement strategies optimization
- Through application, the CSM becomes a focal point to establish consensus!





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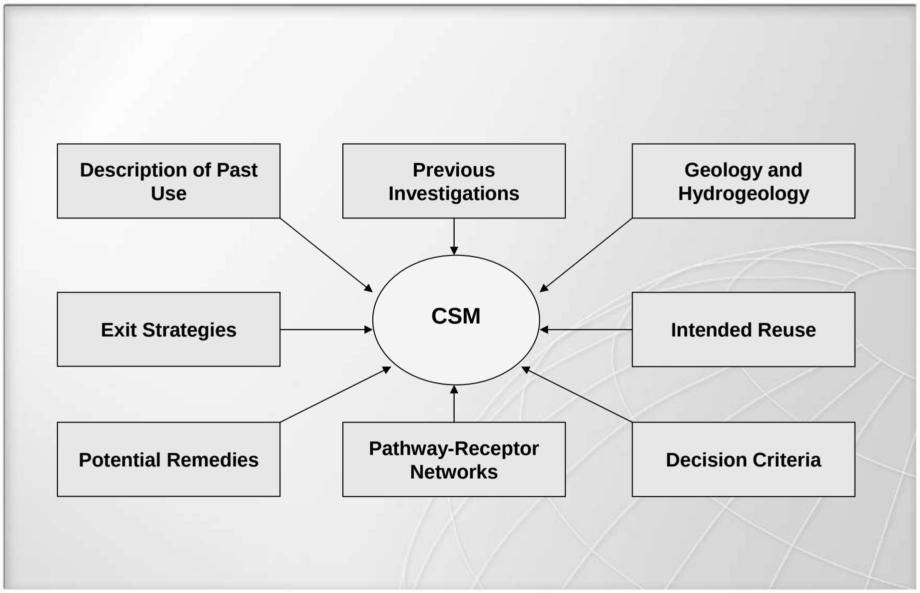
Anatomy of a Triad CSM



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Past Use and Previous Investigations

- Evaluate the following with information from past use and previous investigations:
  - Contaminants of potential concern
  - Potential release mechanisms
  - Location of probable source areas
  - Timing of potential releases
  - Estimate contaminant distributions
  - Evaluate potentially complete pathways
- Gather from all existing data to create and build your CSM

4

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Geology, Hydrology, and Hydrogeology

- Understand and predict contaminant distributions
- Design future investigative activities
- Predict the applicability of methods and technologies

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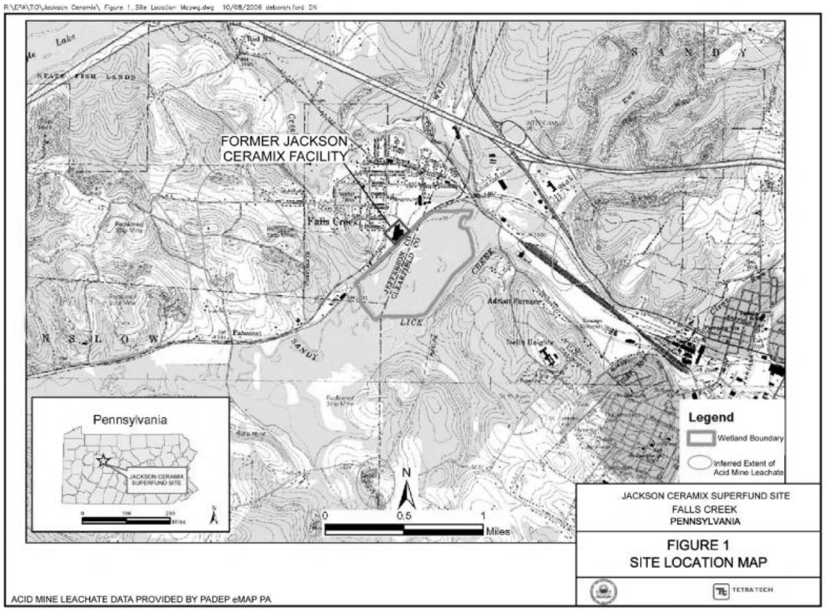
Site Location – Jackson Ceramix



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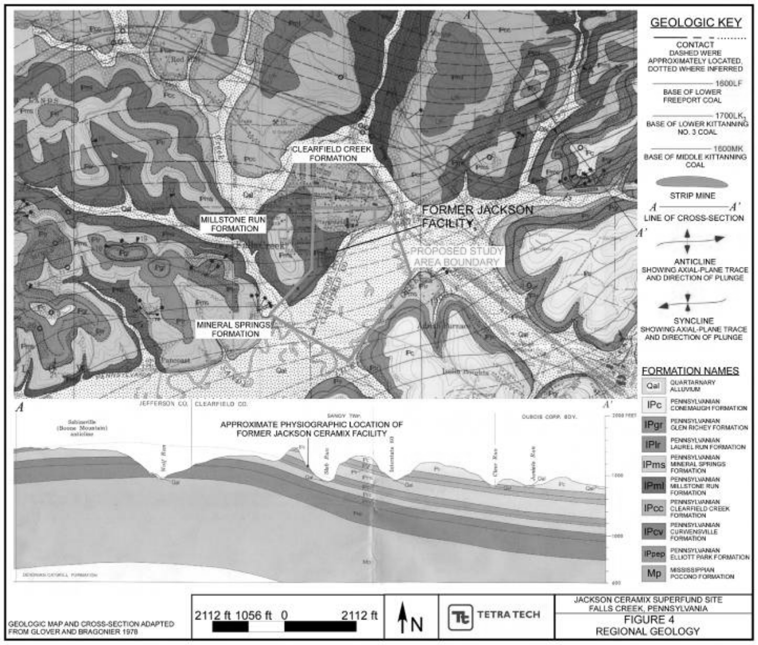
Geology, Hydrology, and Hydrogeology – Jackson Ceramix



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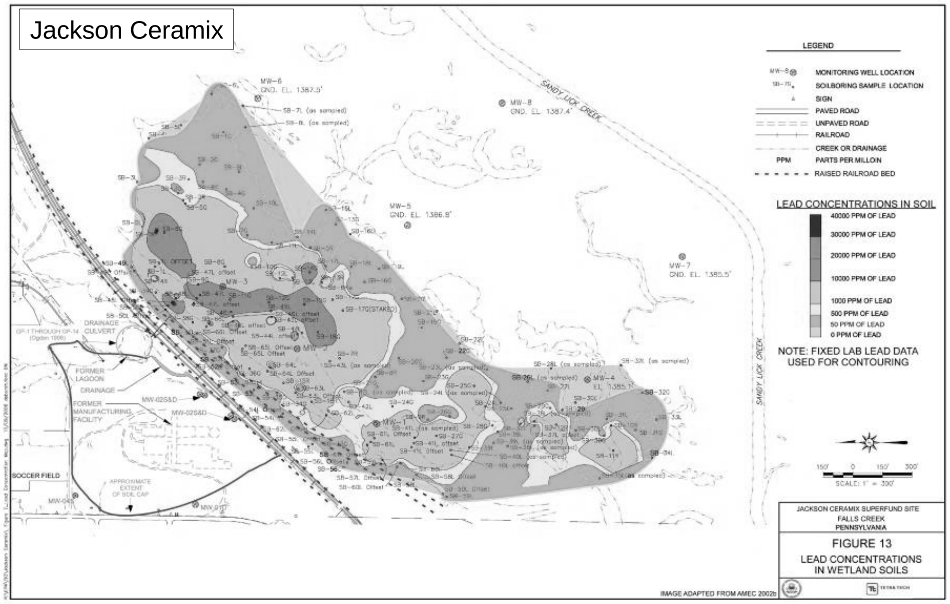
Past Use and Previous Investigation – contamination



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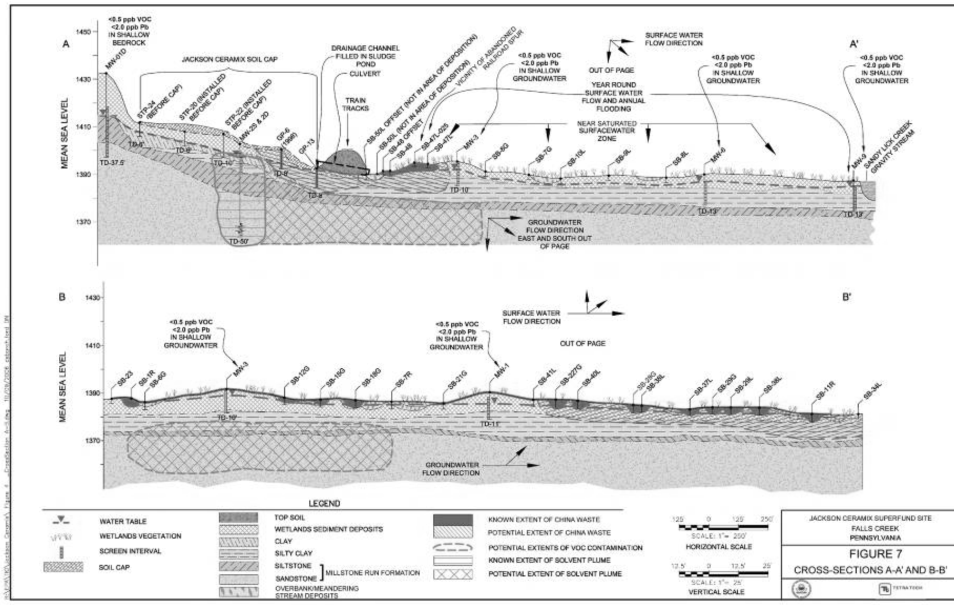
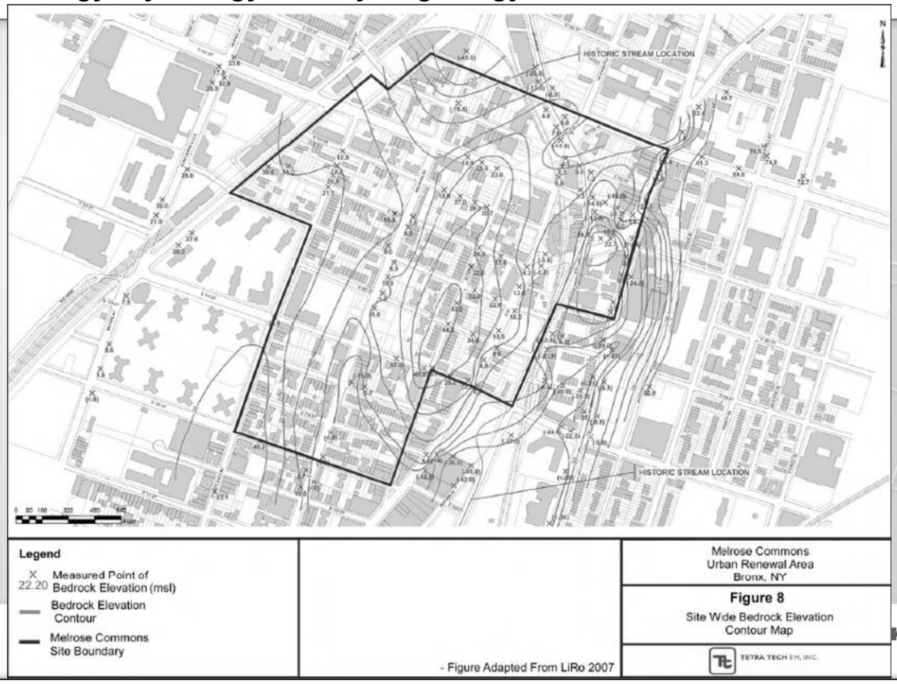
Geology, Hydrology, and Hydrogeology – Jackson Ceramix



Geology, Hydrology, and Hydrogeology – Melrose Commons



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Intended Reuse

- Can dictate decision criteria and action levels
- Used to focus sampling strategies
- Can drive nature of the remedy
- Influenced by property value
- Impacted by public interest

12

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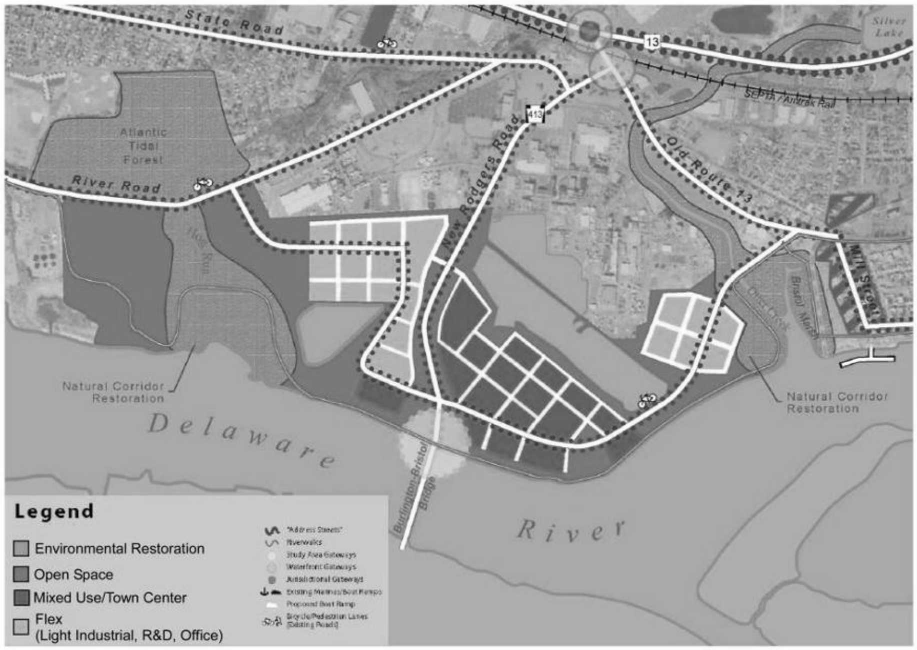
Intended Reuse – Maple Beach

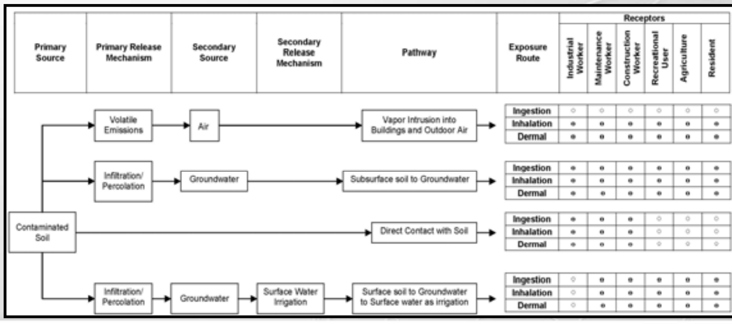
Bristol Township Opportunity Area (Rohm and Haas Property)



13

Pathway-Receptor Network Diagrams

- The CSM should identify all actual and potential pathway-receptor networks
- A pathway-receptor network shows how contaminants migrate from the sources, what receptors they reach, and how the receptors are exposed
- The investigation evaluates each pathway-receptor network



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Using 3D Visualization to Present the CSM

- Modeling programs are unparalleled at depicting CSM data
  - Geology and hydrogeology
  - Contaminant distribution
  - Time sequencing to show groundwater fluctuation, contaminant fate and transport

- Remember, though the look impressive, the model is only as good as the data set it's built on!

15

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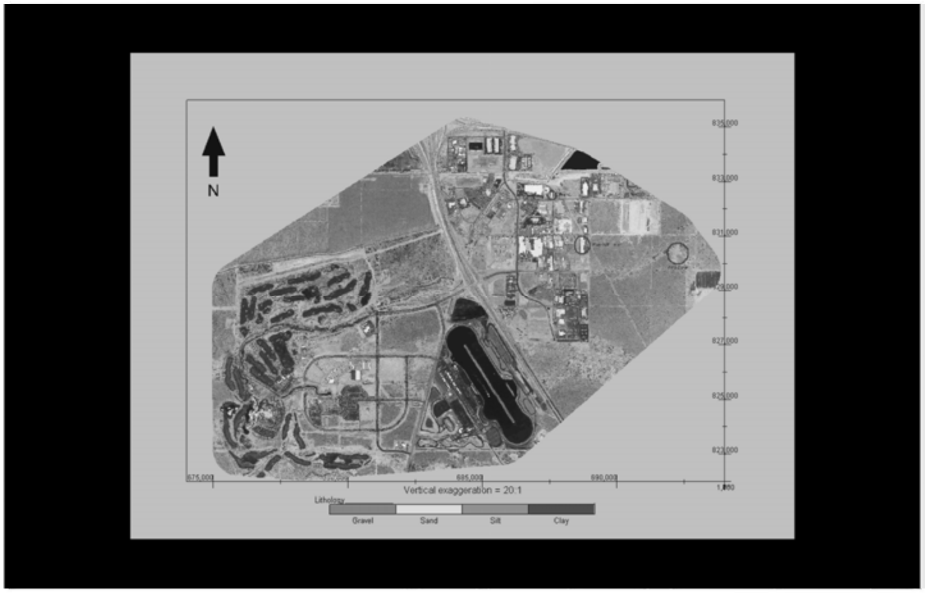
Using 3-D to Understand Complex Geology Beneath a Site



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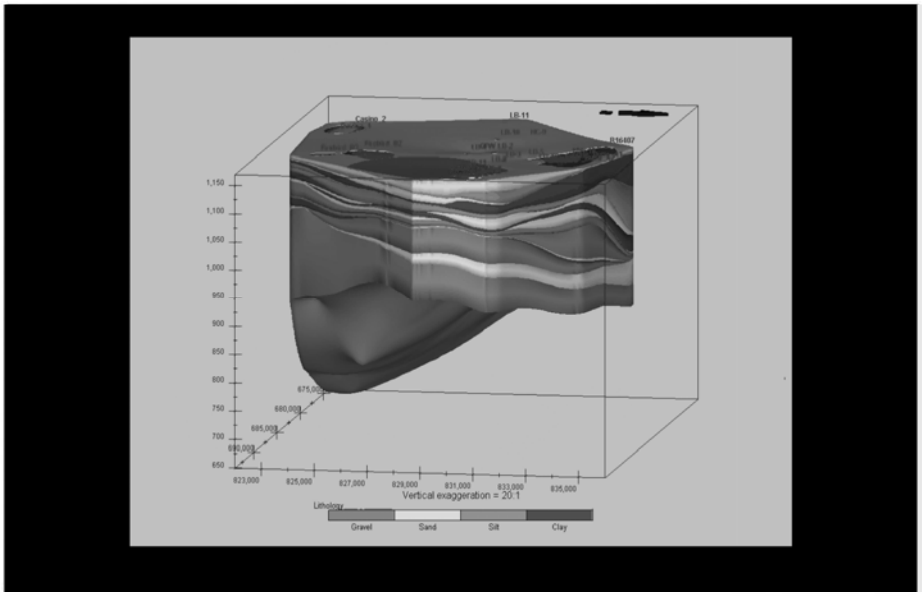
Geologic Environments can Vary Quickly



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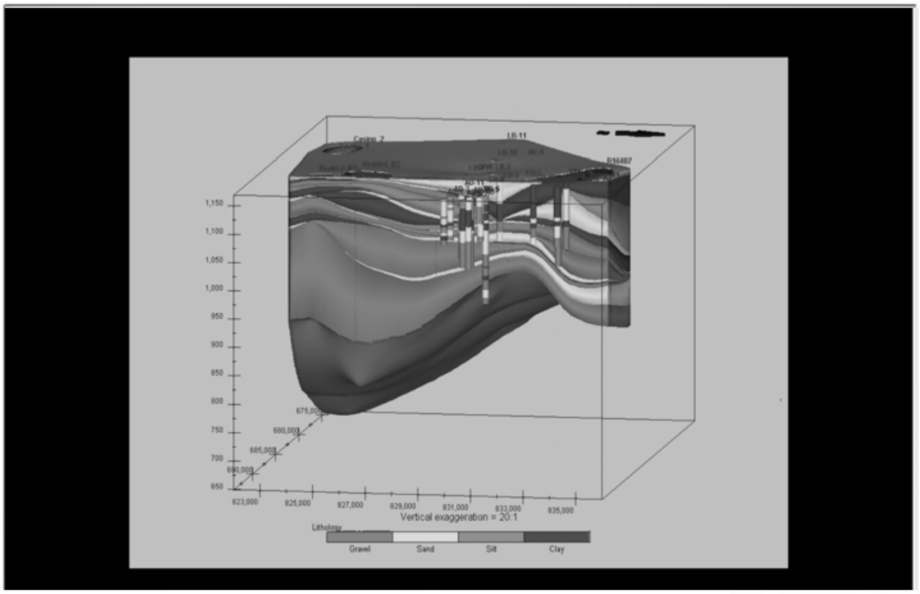
Clay Lenses can Thin Unexpectedly



18

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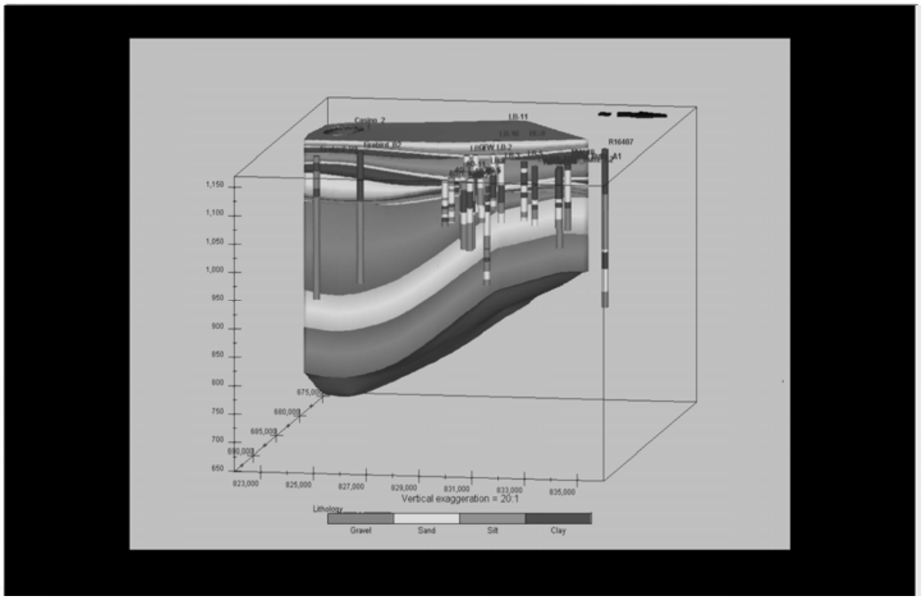
Continuous Clays can Sometimes Pinch Out all Together



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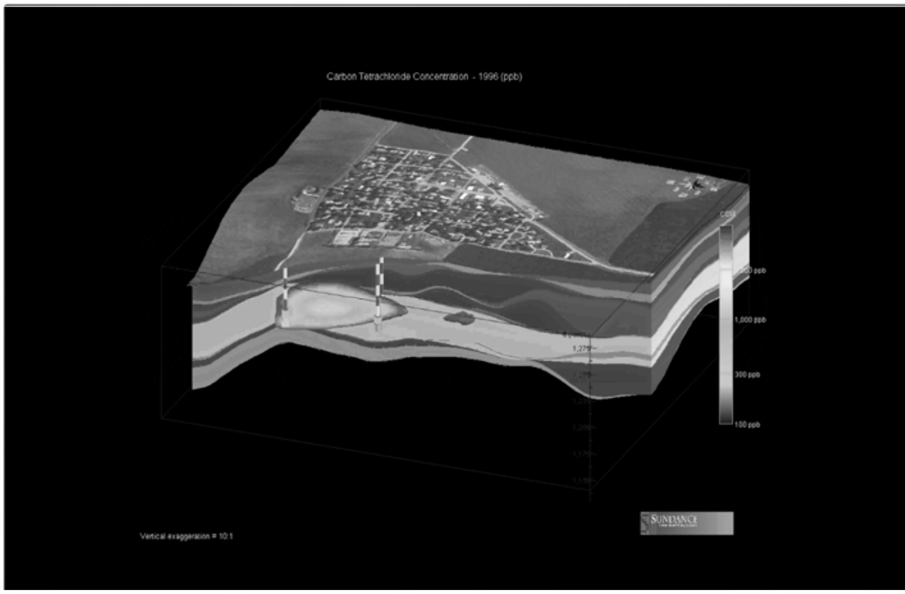
Tracking a Chlorinated Solvent Plume in 3-D over Time to Explain Site Conditions



20

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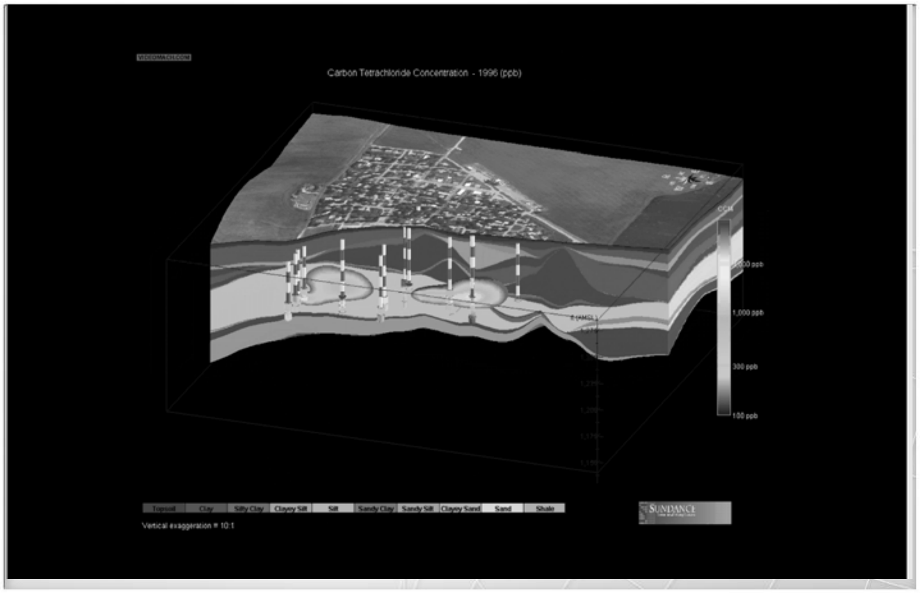
Contamination is Shown in the Context of Geology



21

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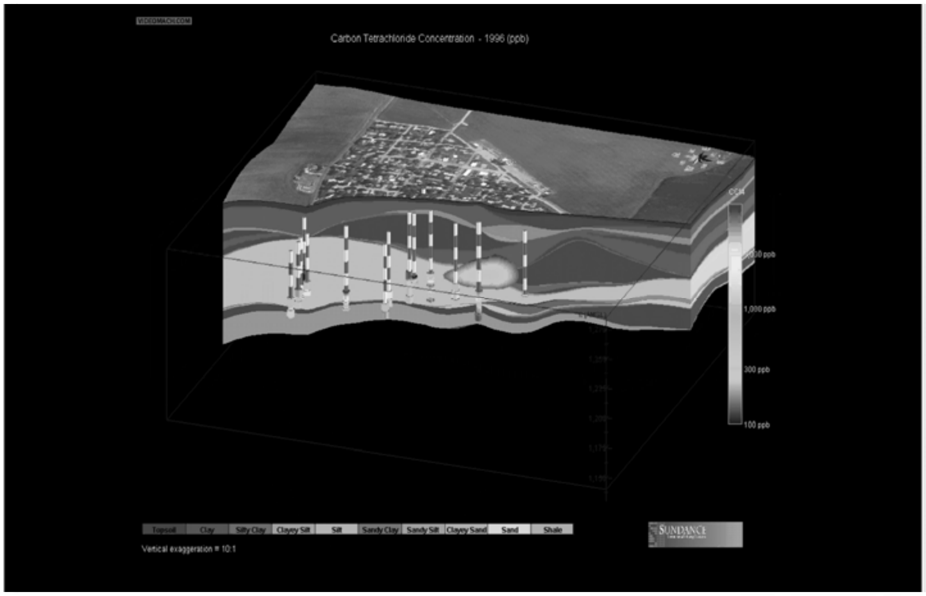
Models can be Used to Predict Time to Cleanup



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Using the CSM to Design a Sampling Strategy

- Using what is known about site conditions, propose an optimized strategy to address data gaps
  - Ask the right questions before designing a strategy
    - What are the site action levels?
    - What is the intended reuse?
    - Do data gaps in understanding contaminant nature and extent exist?
    - What are the threats to human health and environment?

23

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Using the CSM to Design a Sampling Strategy

- Optimize your sampling strategy
  - Commonly, the fewer the mobilizations, the cheaper the investigation costs
  - Use of survey technologies can dramatically reduce the size of the investigation area
  - Field based data collection/management and decision making tools can be used to adapt your strategy in real-time

24

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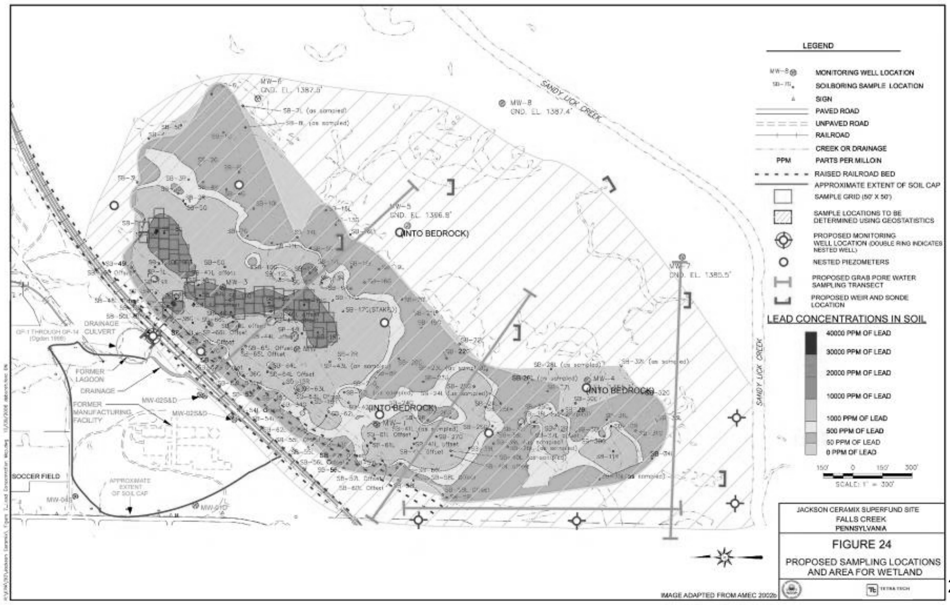
Dynamic Sampling Strategies – Jackson Ceramix



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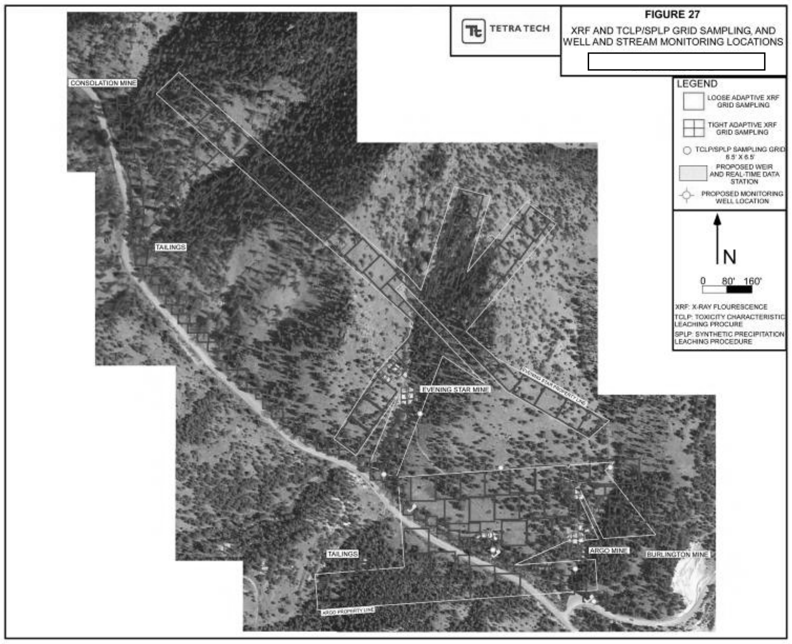
Dynamic Sampling Strategies – Melrose Commons

Dynamic Sampling Strategies – Little James Creek



27

Using a CSM to Build a Consensus Vision

- Present existing information in a tangible and easy to understand format
- Identify obvious data gaps
- Prioritize data collection activities, and design the dynamic work strategy based on the CSM
- Revise CSM on a real-time basis and maintain an environment of trust with stake-holders
- The selling points for dynamic work strategies; they often save time, money, and eliminate uncertainty!

28

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How is the CSM Used?

- A preliminary CSM is used to focus and sequence proposed activities
- A CSM is the poster board upon which data is hung and additional activities optimized
- An updated CSM becomes a detailed model of the site during cleanup for reuse

When the CSM is complete, so is the project!

29

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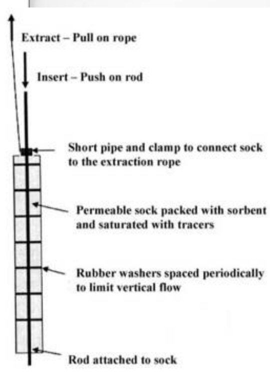
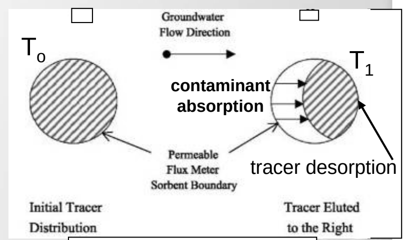
PFM Tool





Modified from Hatfield and others 2004

Uses of PFMs for this study:

- **Nature, extent, flux characterization**

groundwater flux (Darcy velocity)

$$q = \frac{mass}{area \cdot time} = \left[\frac{M}{L^2 T}\right]$$

contaminant flux (J)

$$J = \frac{mass}{area \cdot time} = \left[\frac{M}{L^2 T}\right]$$

contaminant flux averaged concentrations (Cf)

$$C_f = \frac{J}{q}$$

30

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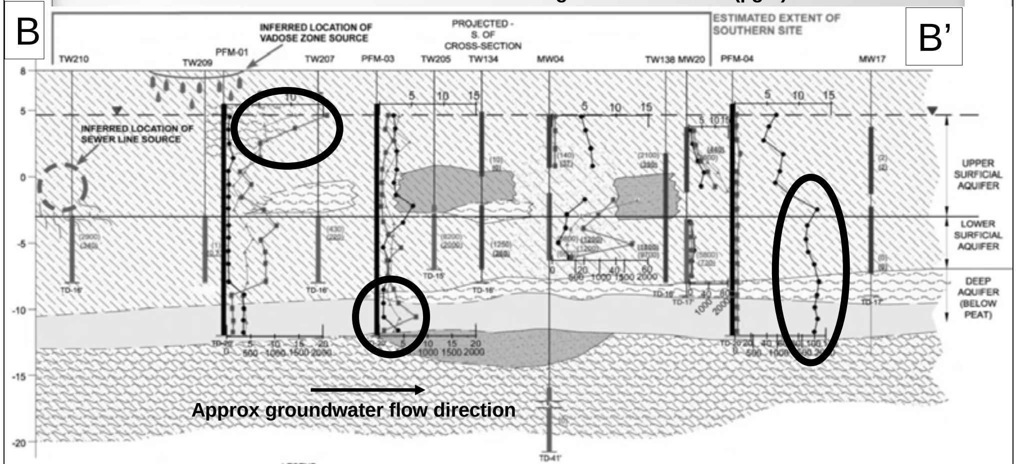
Parris Island Conceptual Site Model Cross-Section

TCE Flux and Averaged Concentrations

- Darcy Velocity (m2/day)
- TCE Flux (mg/m2/day)
- TCE Averaged Concentration (μg/L)



Thank you!

Questions and comments are welcomed!

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Decision Tools for Integration of Triad with Site Management

Tom Palaia

August 6, 2009

Triad Month on EPA's CLU-IN Studio,
Triad Communication/Systematic Planning

Presented By

33

Objectives

- Define the need to integrate copious amounts Triad data into site management (SM) decision making
- Describe how to apply a set of useful data management and decision support tools
- Show that these tools can be used to sustain the long-term viability of Triad approaches

Triad is a Philosophy!

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Problem Statement

- Typical Triad projects collect a ton of data
  - Inevitably, some get “lost” without data management
  - Or are wasted without evaluation tools that can be used in a real-time manner
- If data get “lost” or “wasted”, then uninformed decisions are made
  - Most of the data is useful and important to decision making

Problem Statement (continued)

- Practical and accessible tools are needed to facilitate data evaluation and make informed decisions
  – Anyone can collect a ton of information
  – Real challenge is to optimize data use and collect minimum amount of data to serve as many remedial decisions as possible

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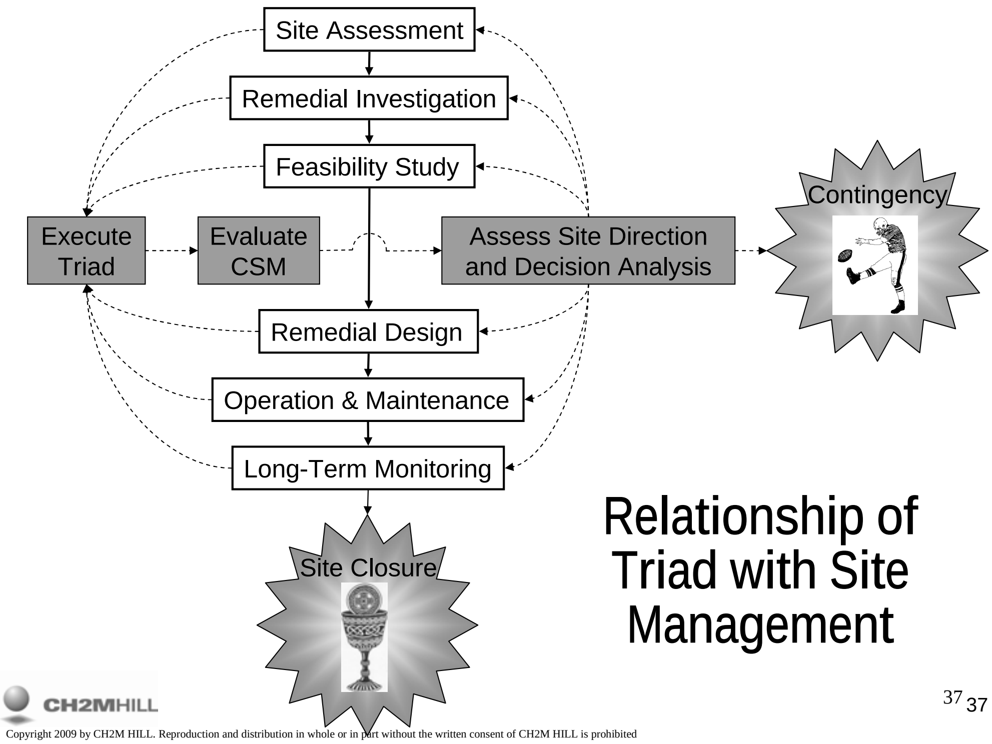

Relationship of Triad with Site Management

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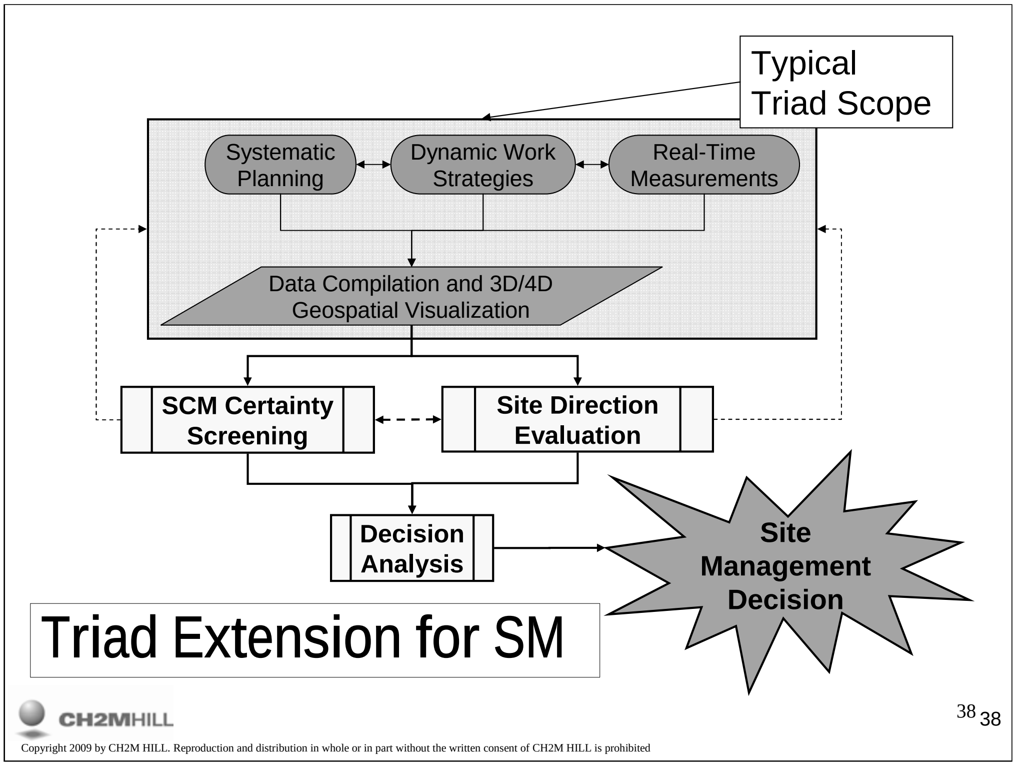
Typical
Triad Scope
Systematic Planning
Dynamic Work Strategies
Real-Time Measurements
Data Compilation and 3D/4D Geospatial Visualization
SCM Certainty Screening
Site Direction Evaluation
Decision Analysis
Site Management Decision
Triad Extension for SM
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Triad Decision Analysis Tools

- Practical real-time data management tools for SM:
  - Conceptual site model (SCM) checklist and certainty screening tool
  - Real-time model for assessing remediation direction
  - Multi-criteria decision analysis (DA) to integrate the data and systematically rationalize a decision
- Applicable to a broad range of SM decisions:
  - Stop investigation and proceed with remediation
  - Implement partial mass removal
  - Define a soil excavation volume
  - Identify a site exit strategy or remedial direction
  - Optimize a remedy implementation

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Project Team Commitment

- These tools are useful only if the project team is committed to consensus
- An engaged project team is a critical success factor for efficient execution of Triad and SM
- Each core project team member must do their homework
- Consensus building is challenging
  - Unfortunately, environmental data are often debatable

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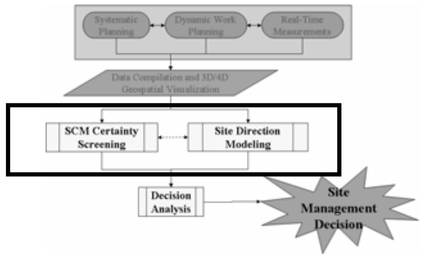
Let's Assume We Have the Triad Data, Now What?

41

CSM and Site Direction Certainty Screening

- Concurrent process of looking at where you're headed and what data you need to get there



- Two synergistic certainty screening tools which assist the project team with the questions:
  - How much data is enough?
  - What is the general site direction?

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CSM Checklist Certainty Screening Tool

- Simple spreadsheet
  - Pulls a lot of data into single resource for efficient review
  - Assesses when enough is enough
- Itemizes components of the CSM
  - Asks specific questions about the level of user's understanding
- Explicitly addresses uncertainties
  - Opens eyes to knowns and unknowns
  - See where discrepancies exist in project team understanding
- Aids group decision-making
  - Lays it all out on the table
  - Requires commitment to detailed data review and scrutiny

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Overview

Item	Criteria	Weight or Importance	Answer (Points)	Score
Technical Factors				
T-1	**Are all above-grade and/or sub-grade contaminant release mechanism(s) identified at the site?**	1.0	3 - 60-90% Complete	3.00
	If the source of the original contaminant release is no longer in use, has it been properly decommissioned, abandoned, demolished, or removed?			-
	If the facility is active, are routine leak tests performed with adequate detection limits to prove that leakage is absent?			-
	If the facility is active, are routine accidental spills adequately contained to prevent a pathway to the subsurface?			-
T-2	Is the presence of mobile- and/or residual-phase LNAPL in the vadose and saturated zones well understood?	1.0	4 - >90% Complete	4.00
	Have measurements of in-well LNAPL thicknesses been made in monitoring well(s)?			-
	Have soil and groundwater samples been collected and physically observed for LNAPL?			-
	Have LNAPL indication tools (laser-induced fluorescence, ribbon sampler, Sudan IV dye, etc.) been used?			-
	Have contaminant partitioning equations been used to back-calculate the potential presence of free-phase LNAPL using soil and/or groundwater sample results?			-
T-3	**Is the source material (e.g., mobile-, residual-, or sorbed-phase contamination that emits mass to the soil gas or groundwater) geometry well characterized?**	1.0	1 - <30% Complete	1.00
	Has the lateral extent of source material been defined to within an appropriate tolerance?			-
	Has the vertical extent of source material been defined within an appropriate tolerance?			-
	Are inconnections of multiple sources, if present, well characterized?			-
	Has contaminant distribution and lithology been correlated (e.g., is the LNAPL trapped within low permeability lithology)?			-
	Has the mass fraction of contaminants in the LNAPL-phase been estimated?			-
T-4	**Is the groundwater contaminant plume geometry well characterized?**	0.6	2 - 30-60% Complete	1.20
	Have all contaminants of concern been identified?			-
	Has the lateral extent of the plume been defined in all principle directions including onsite and offsite areas?			-
	Has the vertical extent of the plume been defined?			-
	Is plume co-mingling, if any, well characterized?			-
T-5	**Are the LNAPL fate and transport mechanisms well characterized?**	1.0	3 - 60-90% Complete	3.00
	Have the contaminant migration pathways been defined from the source to the toe of the plume?			-
	Have the mechanisms of natural attenuation (NA) been defined and assessed with respect to its ability to control LNAPL migration and the plume?			-
	Have site-specific pump/slug/tracer tests been conducted to understand hydraulic parameters?			-
	Has site-specific fate and transport modeling been performed to predict long-term LNAPL and plume configuration?			-
	Has the variability of subsurface conditions been assessed with respect to its temporal impact to the LNAPL and contaminant plume?			-
T-6	**Is the lithology of the site well characterized?**	1.0	4 - >90% Complete	4.00
	Has the site heterogeneity been assessed via continuous boring logs, cone penetrometer testing, or pump testing?			-
	If the site consists of multiple geologic horizons, have bedding planes been assessed?			-
	Has the continuity of lithologic lenses been assessed?			-
T-7	**Are the groundwater-surface water hydraulic interactions well characterized?**	0.0	0 - Not Applicable	0.00
	Have temporal and spatial interactions been assessed and measured?			-
	Have vertical gradients adjacent to the connection been assessed?			-
T-8	**Has adequate exposure/risk assessment been performed to adequately understand existing and potential future human and/or ecological impacts?**	1.0	3 - 60-90% Complete	3.00
	Has an exposure and risk assessment been done for source and plume areas with an adequate set of contaminant concentration data from contaminated media with a potential exposure?			-
	Has adequate sampling been performed to identify contaminants of potential concern?			-
	Has plume stability modeling been performed to assess potential future risk under an expanding plume scenario?			-
	Have all existing and potential future land use scenarios been considered in the context of site zone or land use plans?			-
	Have all existing exposure pathways been considered including dermal, ingestion, inhalation, and indoor air vapor intrusion?			-
	Has leaching of vadose zone contamination been considered?			-
	Has connection between contaminated groundwater and surface water been considered in the risk assessment?			-
Total Technical Factors				*19.20*
Maximum Possible Technical Factor Score				*26.40*
Total Technical Factor Conceptual Site Model Certainty				*72.7%*

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Q&A Data Input Method

Item	Criteria	Weight or Importance	Answer (Points)	Score
Technical Factors				
T-1	**Are all above-grade and/or sub-grade contaminant release mechanism(s) identified at the site?**	**1.0**	**3 - 60-90% Complete**	**3.00**
	If the source of the original contaminant release is no longer in use, has it been properly decommissioned, abandoned, demolished, or removed?			-
	If the facility is active, are routine leak tests performed with adequate detection limits to prove that leakage is absent?			-
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T-2	Is the presence of mobile- and/or residual-phase LNAPL in the vadose and saturated zones well understood?	1.0	4 - >90% Complete	4.00
	Have measurements of in-well LNAPL thicknesses been made in monitoring well(s)?			-
	Have soil and groundwater samples been collected and physically observed for LNAPL?			-
	Have LNAPL indication tools (laser-induced fluorescence, ribbon sampler, Sudan IV dye, etc.) been used?			-
	Have contaminant partitioning equations been used to back-calculate the potential presence of free-phase LNAPL using soil and/or groundwater sample results?			-
T-3	**Is the source material (e.g., mobile-, residual-, or sorbed-phase contamination that emits mass to the soil gas or groundwater) geometry well characterized?**	**1.0**	[redacted]	**1.00**
	Has the lateral extent of source material been defined to within an appropriate tolerance?			-
	Has the vertical extent of source material been defined within an appropriate tolerance?			-
	Are inconnections of multiple sources, if present, well characterized?			-
	Has contaminant distribution and lithology been correlated (e.g., is the LNAPL trapped within low permeability lithology)?			-
	Has the mass fraction of contaminants in the LNAPL-phase been estimated?			-

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Multi-Site Composite – CSM Certainty Evaluation Tool

Item	Criteria	Site A Score	Site B Score	Site C Score	Site D Score	Site E Score	Site F Score	Site G Score	Site H Score	Basewide Average
Technical Factors										
T-1	Contaminant Release Mechanism	0.50	0.80	0.70	0.80	0.80	0.90	0.70	0.80	0.75
T-2	Risk Assessment	0.50	0.75	0.80	0.70	0.75	0.85	0.70	0.85	0.74
T-3	NAPL Assessment	0.65	0.90	0.90	0.75	1.00	0.85	0.85	0.60	0.81
T-4	Source Material Characterization	0.50	0.80	0.80	0.70	0.70	0.70	0.65	0.60	0.68
T-5	Groundwater Plume Characterization	0.50	0.75	0.90	0.75	0.70	0.90	0.85	0.60	0.74
T-6	Fate and Transport Evaluation	0.50	0.50	0.85	0.60	0.90	0.90	0.65	0.65	0.69
T-7	Lithology Characterization	0.80	0.75	0.90	0.80	0.95	0.90	0.75	0.75	0.83
T-8	Groundwater-Surface Water Connection	0.80	*	0.90	0.90	*	*	0.65	0.65	0.78
T-9	Support for Remediation Timeframe Estimates	0.95	0.50	0.95	0.25	0.60	0.50	*	*	0.63
Subtotal Technical Factors		***8.10***	***8.65***	***10.35***	***8.25***	***9.85***	***9.75***	***7.85***	***6.75***	***8.69***
Maximum Possible Technical Factor Score		***12.00***	***12.00***	***12.00***	***13.00***	***12.00***	***12.00***	***11.00***	***10.00***	
Total Technical Certainty (SCM only)		**63.3%**	**71.9%**	**85.6%**	**69.4%**	**80.0%**	**81.3%**	**72.5%**	**68.8%**	**74.1%**

If the current level of certainty is unacceptable to the project team, then additional analysis must be performed in order to increase it.
Criteria that are scored a "Certainty" of 50% or lower are highlighted in RED.
Criteria that are scored a "Certainty" between 50% and 70% are highlighted in ORANGE.
This scoring sheet can be revisited at the end of each analytical phase to re-assess the level of certainty and satisfaction of the project team.

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46

Now that We Understand the CSM Certainty, Now What?

47 47

Real-time Model for Assessing Remediation Direction

- Tackles the question of what direction should remedial efforts be headed
- Site direction is useful to optimize Triad data collection efforts
  - For example, if DNAPL is present, then finer investigation spacing and soil samples may be needed for remedial design
- Results are used to re-assess and re-prioritize Triad data objectives and to focus collection on data to define an Exit Strategy (or come as close as possible)
- Similar format as the CSM Certainty Screening Tool

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48

Remedial Direction Screening Matrix

Item	Criteria	Certainty (%)	Importance (%)	Score
Technical Factors				
1	Is the source on-going and continuing to add mass to the subsurface?	10%	100%	0.1
2	Is there a potential or real risk to human or ecological exposure from the contaminants of the source?	100%	100%	0.0
3	Is residual or mobile DNAPL suspected to be ABSENT in vadose or saturated zone soil samples?	50%	100%	0.5
4	If residual or mobile DNAPL is present, is its architecture amenable to cost-effective remediation?	100%	100%	1.0
5	Is the source geometry well characterized?	0%	100%	0.0
6	Is the extent of the source material of reasonable size/depth for cost-effective remediation?	50%	100%	0.5
7	Is delivery of in-situ amendments into the target treatment zone feasible?	50%	100%	0.5
8	Is a cost-effective technology available and proven to remediate the source to the remedial action objectives?	20%	100%	0.2
9	Are the numeric remedial action objectives realistic (i.e., not MCLs)?	50%	100%	0.5
10	Is the lithology of the source area simple?	20%	75%	0.2
11	Are the aquifer hydraulic conditions within the source area amenable to remediation?	50%	75%	0.4
12	Are quantitative tools available and implementable to provide cost:benefit analysis and remediation progress monitoring?	30%	75%	0.2
13	Is NA activity present which may support, with or without amendment, an MNA polishing step after source treatment?	0%	50%	0.0
14	Have realistic remediation timeframe estimates been set based on site-specific conditions (using SourceDK model or similar)?	100%	50%	0.5
Subtotal Technical Factors				***4.6***
Maximum Possible Technical Factor Score				*12.25*
Management Factors				
15	Are near-term site use goals (i.e., less than 30 years) strict enough to require source area remediation to NFA?	100%	100%	0.0
16	Does current site infrastructure and use allow for relatively unimpeded site remediation activities?	10%	100%	0.1
17	Is there a strong desire to reduce contaminant mass and thereby reduce the environmental burden of future generations?	100%	100%	1.0
18	Are the project stakeholders willing to accept a relatively high level of risk in seeking, and possibly failing, to remediate to NFA?	20%	75%	0.2
19	Is there a strong committment to test new technologies and advance the science of DNAPL remediation?	100%	25%	0.3
Subtotal Non-Technical Factors				***1.5***
Maximum Possible Management Factor Score				*4.00*
TOTAL				**6.1**
Maximum Possible Total Score				*16.25*

TOTAL SCORE INTERPRETATION:

If one or more GREEN cells appear, then the certainty score is irrelevant. MORE aggressive remediation techniques should be strongly considered.

>14	- The site is extraordinarily well suited for aggressive source remediation.
9-14	- Indicators favor some degree of aggressive source remediation, less inherent risk of success with scores at the higher end of the range.
7-9	- Around the 50/50 mark, stakeholders will have to closely weigh the pros and cons of aggressive source remediation.
4-7	- Less aggressive source remediation approached are recommended. Stakeholders should consider alternative less aggressive or partial mass removal technologies
<4	- The project conditions are not amenable to source remediation and stakeholders should consider containment or long-term monitoring/land use control options.

If additional certainty is required by the project team, then additional data collection must be performed in order to close data gaps.
This scoring sheet can be revisited at the end of each data collection phase to assess the level of certainty and the need for additional data.

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Q&A Data Input Method

Item	Criteria	Certainty (%)	Importance (%)	Score
Technical Factors				
2	Is there a potential or real risk to human or ecological exposure from the contaminants of the source?	100%	100%	0.0
	Is the source within a residential area of high potential exposure (ingestion, dermal, inhalation)?			
	Has the indoor air pathway been considered and determined to be complete?			-
	Does the source appear to be leaching contaminants to groundwater at a rate faster than NA can attenuate it (expanding plume)?			-
	Is the contamination within the shallow subsurface (0-15 ft bgs) and accessible by workers?			-
7	Is delivery of in-situ amendments into the target treatment zone feasible?	50%	100%	0.5
	Does source contain small thicknesses of soil containing less than 20% silt/clay?			-
	Is soil uncemented/less dense to allow access with standard DPT?			-
	Does the source exist at depths less than 100 feet below grade?			-
8	Is a cost-effective technology available and proven to remediate the source to the remedial action objectives?	20%	100%	0.2
	Are there case studies of remediation at similar sites that have shown success?			-
	Are chemical scavengers present at only low concentrations (i.e., low TOC for ISCO, low sulfate for ERD)?			
	Is the projected cost of the technology reasonable from a cost:benefit perspective and consistent with long-term site use goals?			-
9	Are the numeric remedial action objectives realistic (i.e., not MCLs)?	50%	100%	0.5

TOTAL SCORE INTERPRETATION:

If one or more GREEN cells appear, then the certainty score is irrelevant. MORE aggressive remediation techniques should be strongly considered.

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50 50

Results Interpretation – Remedial Direction Screening Matrix

Item	Criteria	Score
Technical Factors		
Subtotal Technical Factors		***4.6***
Maximum Possible Technical Factor Score		*12.25*
Management Factors		
Subtotal Non-Technical Factors		***1.5***
Maximum Possible Management Factor Score		*4.00*
TOTAL		**6.1**
Maximum Possible Total Score		*16.25*

TOTAL SCORE INTERPRETATION:

>14	- The site is extraordinarily well suited for aggressive source remediation.
9-14	- Indicators favor some degree of aggressive source remediation, less inherent risk of success with scores at the higher end of the range.
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We've Optimized the Data Collection and Have a General Understanding of Where We're Headed, Now What?

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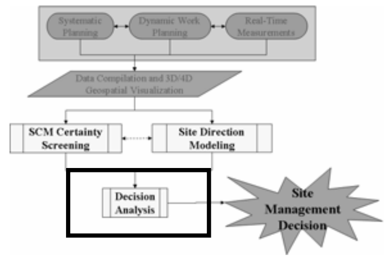
52 52

Multi-Criteria Decision Analysis

- A systematic approach to resolving complex problems involving multiple variables and competing objectives



- Synergies with Triad process include:
  - Allows real-time decision making
  - Evaluates both qualitative and quantitative criteria
  - Quantifies uncertainty
  - Builds consensus among multiple stakeholders

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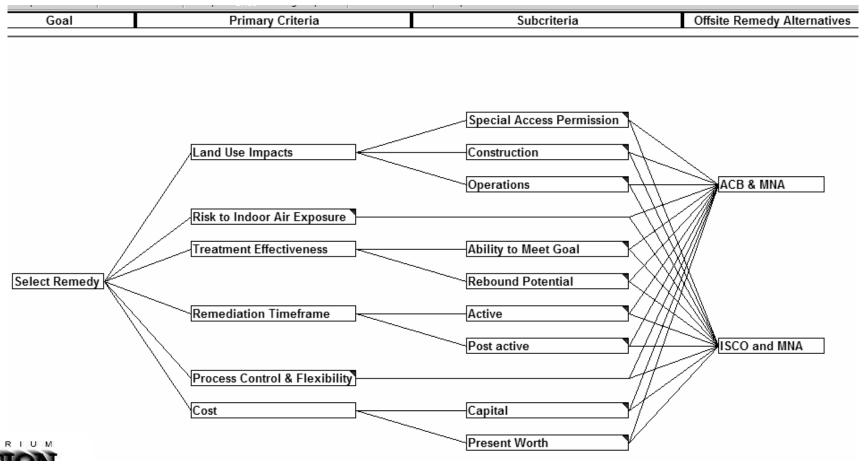
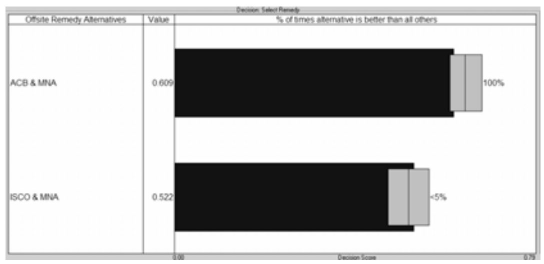
53 53

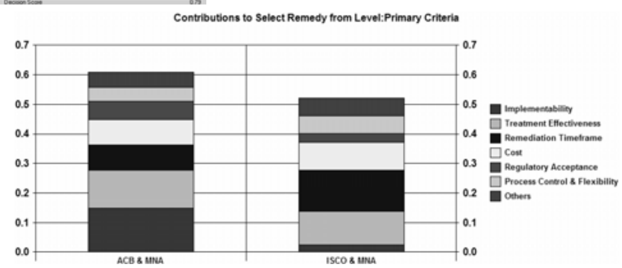
Example DA Input



Criterium DecisionPlus® by InfoHarvest,
http://www.infoharvest.com

Example DA Results





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There You Have It, Data is Collected and Consistent with the Site Direction, CSM Certainty is Benchmarked, and DA Affirms Path Forward

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56 56

Conclusions

- The 3 tenets of Triad are easily assimilated into the full-breadth SM routine
  - For example, “Adaptive Site Management” by the US Navy
- A critical success factor for Triad projects is efficient integration of data into the SM decision making process
  - Consistent with the fast pace of a Triad project
  - Real-time, consensus-driven decision making tools are available to reduce the copious amounts of data to decision focal points
- Well informed decisions advance sites to closure

Triad is a Philosophy!

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Thank You!

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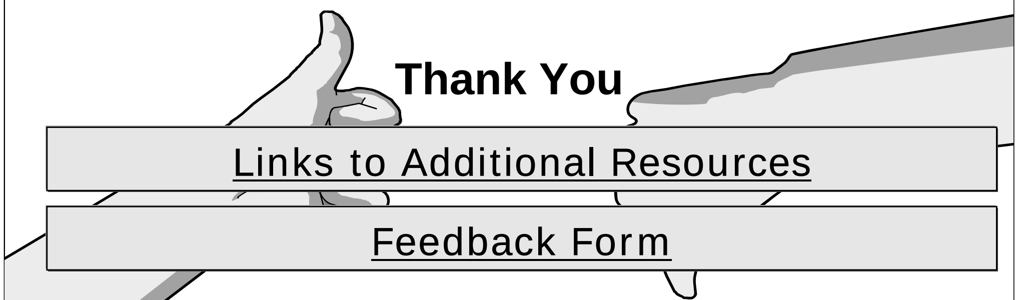
58 58

Thank You

After viewing the links to additional resources, please complete our online feedback form.



Links to Additional Resources

Feedback Form

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59 59