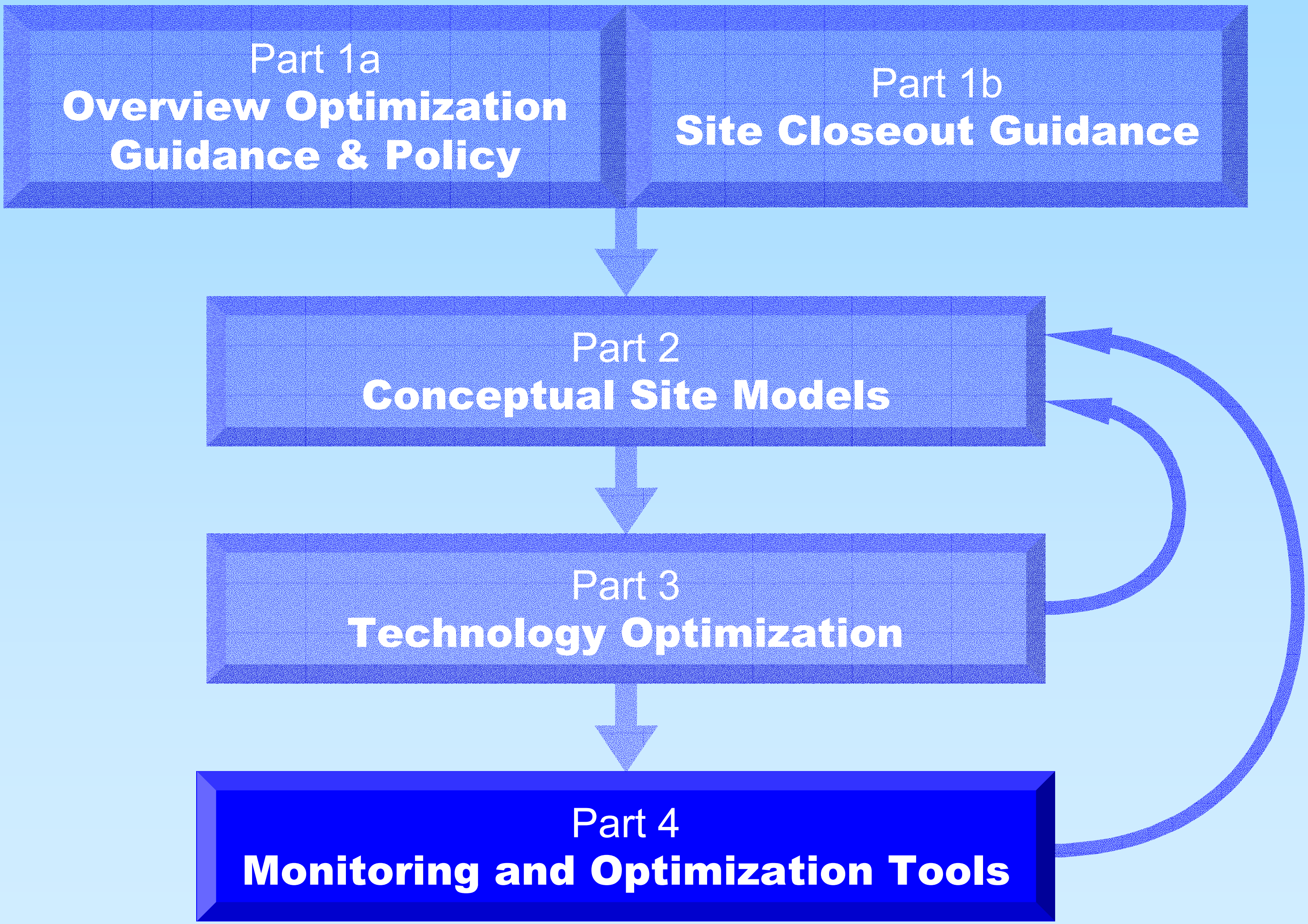
Part 4: Monitoring and Optimization Tools

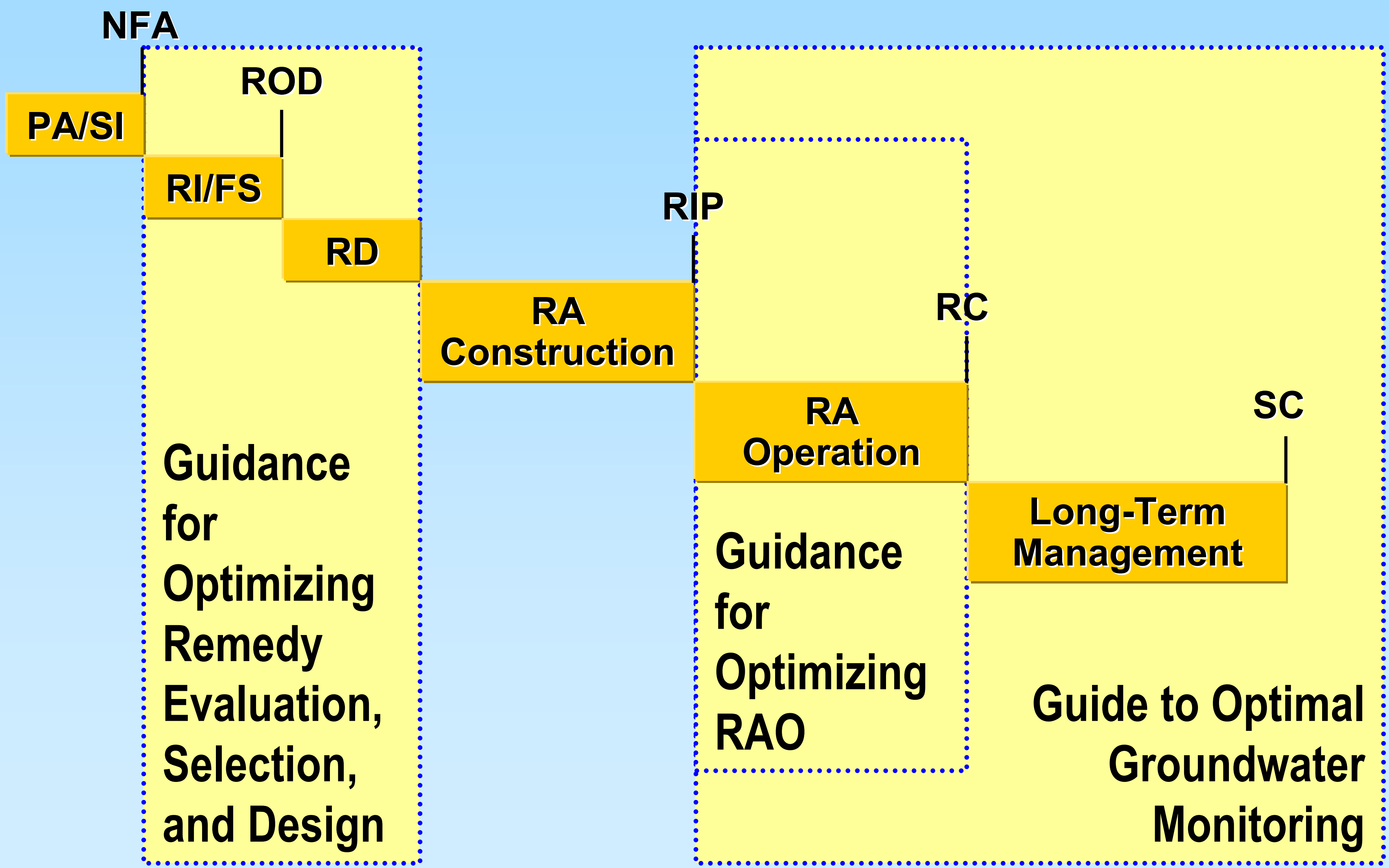
Charles F. McLane III, Ph.D.

McLane Environmental, LLC

RITS Spring 2004: Optimization of Remedial Actions



Guidance Documents and IR Program Phases



Presentation Focus

1. Extensive guidance exists for most optimization goals
2. The guidance describes the effective use of optimization tools and techniques
3. Using these optimizing tools and techniques from the preliminary assessment to site closure can save time and money

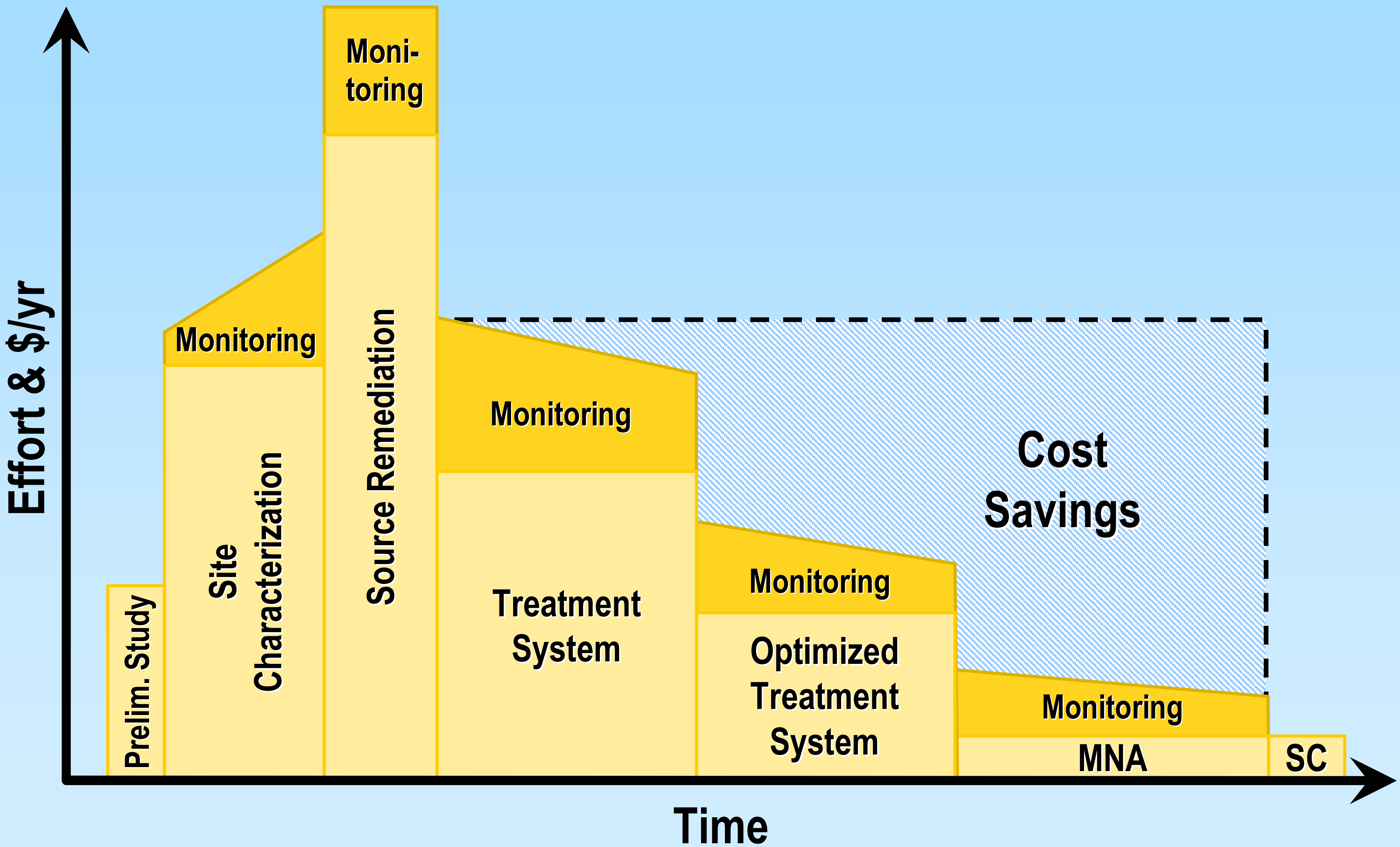
Relevant Guidance for Monitoring and Optimization

- Guidance Documents
  - Field Tools Guidance
    - Technical and Regulatory Guidance for the TRIAD approach: A New Paradigm for Environmental Project Management (ITRC, December 2003)
    - Field Sampling and Analysis Technologies Matrix Version 1.0 (http://www.frtr.gov/site/)
    - EPA Remediation and Characterization Innovative Technologies (http://www.epareachit.org/)
  - GIS and NIRIS
    - NAVFAC will be issuing guidance on NIRIS when it is ready for deployment
    - Navy/Marine Corps GIS Community of Practice (http://www.navy-mc-gis.org)
    - NAVFACilitator – CADD/GIS Policies and Practices (http://navfacilitator.navfac.navy.mil/cheng/enet/tdls/caddgis/caddgis.htm)
  - Statistics Guidance
    - Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance (U.S. EPA, 1989)
    - Procedural Guidance for Statistically Analyzing Environmental Background Data (SWDIV and EFA West, 1998)
    - Guidance for Environmental Background Analysis, Volume 1: Soil (Battelle, April 2002)
    - Guidance for Environmental Background Analysis, Volume 2: Sediment (Battelle, April 2003)
    - Guidance for Environmental Background Analysis, Volume 3: Groundwater (Battelle, April 2004)

Relevant Guidance for Monitoring and Optimization

- **Guidance Documents**
  - **Remedial Action Operation**
    - Guidance for Optimizing Remedial Action Operation (RAO) (NFESC, April 2001)
    - Guidance for Optimizing Remedy Evaluation, Selection, and Design (Battelle, December 2003)
  - **Transition to Monitored Natural Attenuation**
    - Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites (U.S. EPA, 1999)
    - Technical Guidelines for Evaluating Monitored Natural Attenuation of Petroleum Hydrocarbons and Chlorinated Solvents in Ground Water at Naval and Marine Corps Facilities (September, 1998)
    - Methodology for Estimating Times of Remediation Associated with Monitored Natural Attenuation (USGS, 2003)
  - **Long-Term Monitoring**
    - Guide to Optimal Groundwater Monitoring (NFESC, January 2000)

Conceptual Diagram of Typical IR Program Showing Optimization Cost Savings



Presentation Outline

Data Collection & Monitoring

- **Field Lessons Learned**
  - Drilling
  - Purging
  - Monitor Well Installation with a Single Screen
- **Guidance and the Remediation Toolbox**
- **Drilling & Sampling**
  - Site Characterization and Analysis Penetrometer System (SCAPS)
  - Rotosonic Drilling
- **Sampling & Monitoring**
  - Passive Diffusion Bag Sampling (PDBS)
  - Hydrasleeve – No Purge Sampling
  - Remote Monitoring Using Microsparger
  - Membrane Interface Probe (MIP)
  - Waterloo Profiler
  - Continuous Multichannel Tubing (CMT) System
  - Downhole NAPL Ribbon
  - Photoacoustic Multigas Monitors

Data Management

- **NIRIS Program**
- **Environmental Database**
  - Data Management Software & Systems
  - Data Flow
  - Uses & Types of Data
- **GIS & Visualization**
  - Links to Geographic Information Systems (GIS)
  - Spatial Data Analysis
  - Links to Analysis & Modeling
  - Data Visualization

Data Analysis & Optimization

- **Environmental Statistics Applications**
  - Background Concentrations
  - Cleanup Goals
  - Optimizing Well Installation
  - Well Decommissioning
  - Statistical Significance
- **Remedial System Optimization**
  - Guidance, Goals, and Annual Evaluation
  - Model Optimization
  - Applications
  - Case Studies
- **Transition from a Remedial System to Monitored Natural Attenuation (MNA)**
  - Guidance
  - Suitability of MNA as a Remedy
  - Natural Attenuation Software
  - Case Studies
- **Long-Term Monitoring Optimization**
  - Guidance
  - Cost-Effective Monitoring Program
  - Methods
  - Case Studies

How hard is it to sample anyway?

Field Lessons Learned

- Typical methods for sampling
  - Drilling
  - Purging
  - Monitor well installation with a single screen

Field Lessons Learned (cont.)

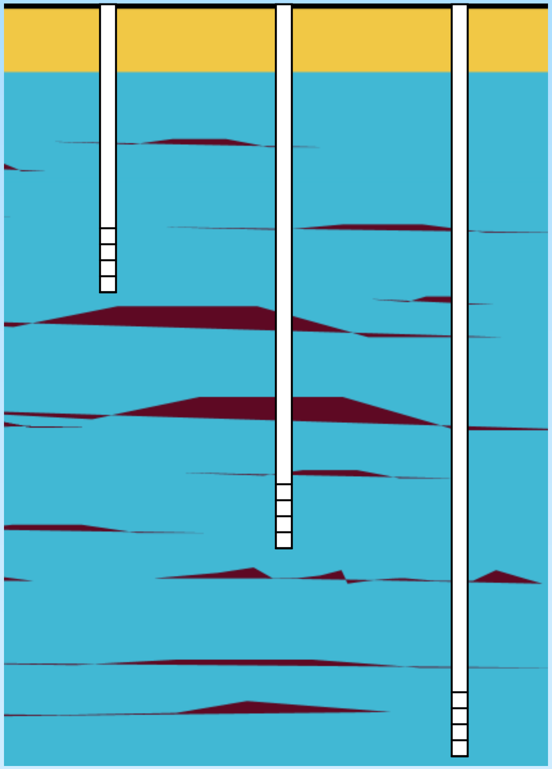
- Drilling (hollow-stem auger, mud and air rotary)
  - Fluids for disposal
  - Soil and cuttings for disposal
  - Split spoon sampling
  - High exposure to contaminated media
  - Typically a large rig/issues with access

Field Lessons Learned (cont.)

- Purging
  - "Three volumes"
  - High purge rates can elevate turbidity
  - Purge water disposal
  - Equipment intensive
  - Problematic in low-yield wells, including slow recovery time
  - Equipment decontamination costs
  - High exposure to contaminated media

Field Lessons Learned (cont.)

- Monitor well installation with a single screen
  - Single depth with single screen
  - Multiple wells at different depths can be expensive
  - Nested wells can be expensive
  - Issues with cross-contamination in nested wells
  - Larger boreholes required for nested wells



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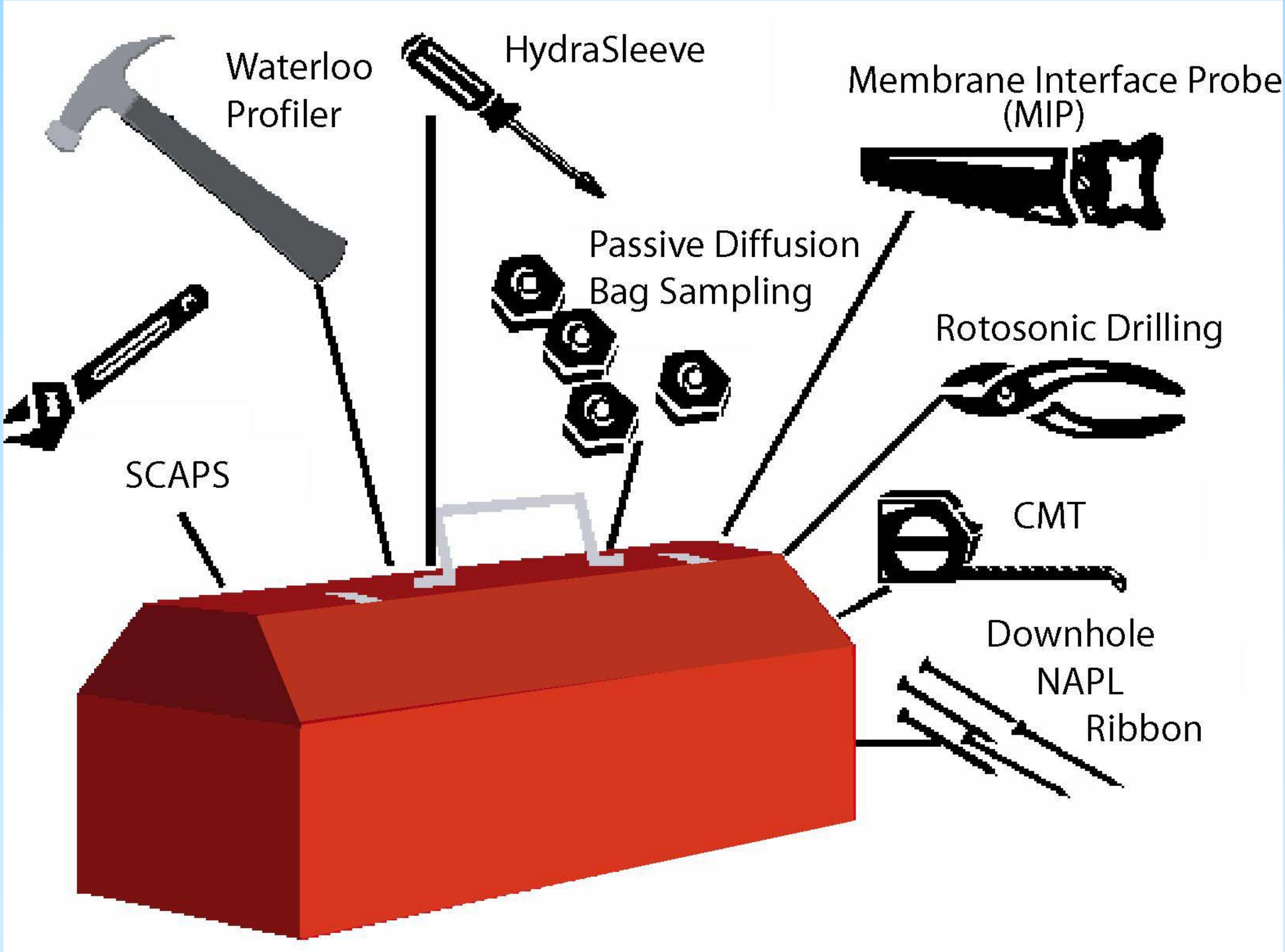
Data Collection & Monitoring: Remediation Toolbox



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Site Characterization and Analysis Penetrometer System (SCAPS)

A cone penetrometer unit mounted on the custom-designed bed of a 20-ton truck, which houses laboratory equipment for rapid analysis.

•Advantages

- Rapid soil analysis
- Delineates subsurface contamination more accurately than widely spaced wells
- Regulator-approved small-diameter well installation
- Significantly reduced characterization costs (up to 50%)

•Limitations

- Limited depth (<200 ft)
- No bedrock
- Reconnaissance sampling
- Possible need for confirmatory boring

http://enviro.nfesc.navy.mil/erb/erb_a/restoration/technologies/invest/access_tools/scaps.htm

http://www.spawar.navy.mil/sti/publications/pubs/td/2744r1/

Rotosonic Drilling

A dual-cased drilling system that employs the use of high-frequency vibration to obtain continuous core samples.

- Advantages
  - Superior core samples
  - Standard diameter holes
  - Unconsolidated and some consolidated rock
  - Deep borings
  - No drilling fluids
  - Fast
- Limitations
  - More expensive
  - Rig availability
  - Not suitable for some geologic formations
  - Drills hot
  - Contaminant drag-down

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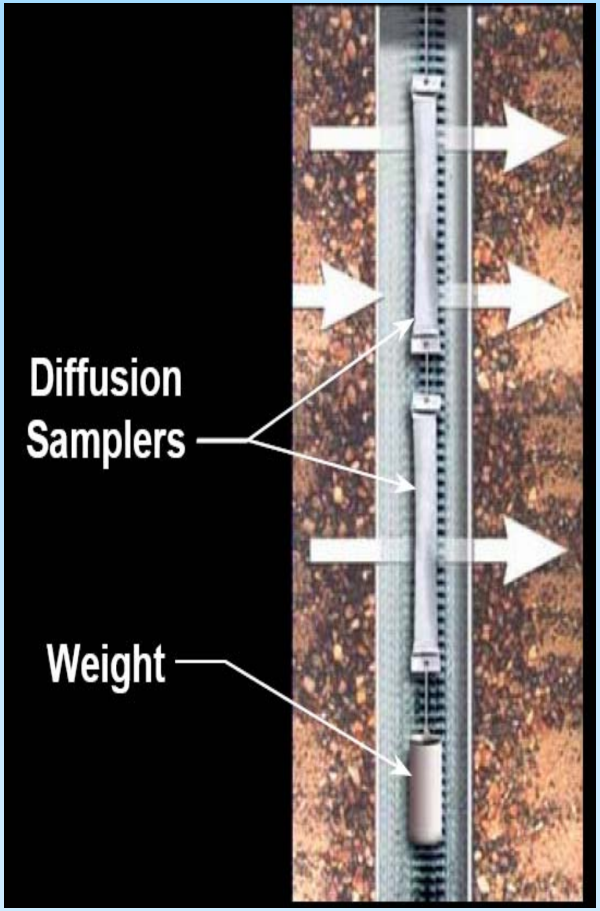
Passive Diffusion Bag Sampling



•Advantages

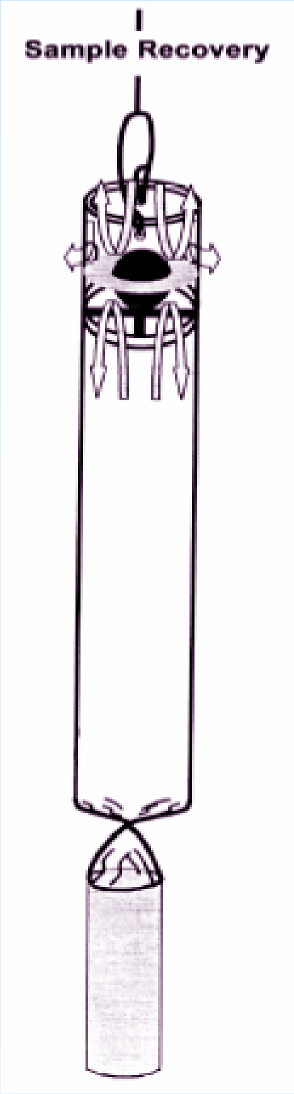
- Easy to use
- No well purging
- Minimal field equipment
- Verifiable results
- Up to 70% savings per sample over traditional purge and bail or low-flow techniques
- Representative of equilibrium conditions instead of "snap shot" like grab samples

•Limitations

- VOCs only
- Not applicable for MTBE, most PAHs, and inorganics/metals
- May need more confirmation studies
- Not applicable for rapidly changing concentrations
- Possible plasticizer contamination
- Equilibration period (cannot accelerate sample collection time)

A low-density polyethylene lay-flat tube that is filled with distilled, deionized water and lowered into a borehole, where contaminants diffuse into the sampler.

HydraSleeve – No Purge Sampling



•Advantages

- Can sample all compounds
- No purge water
- Works in low yield wells
- Up to 70% savings per sample over low-flow/purge sampling

•Limitations

- May need more confirmation studies
- May yield higher VOC concentrations than low-flow sampling
- May increase turbidity

A cylindrical, flexible polyethylene bag with a polyethylene check ball at the top. Upper check valve opens and water moves into the flexible chamber at the selected depth, expanding it until full.

Remote Monitoring Using Microsparger

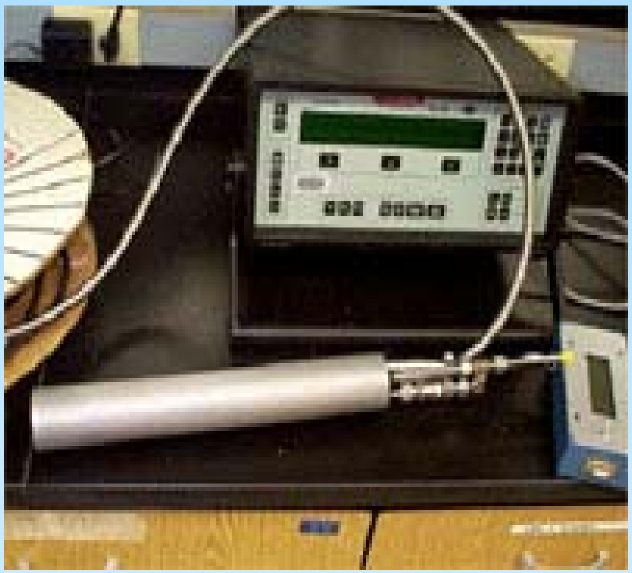


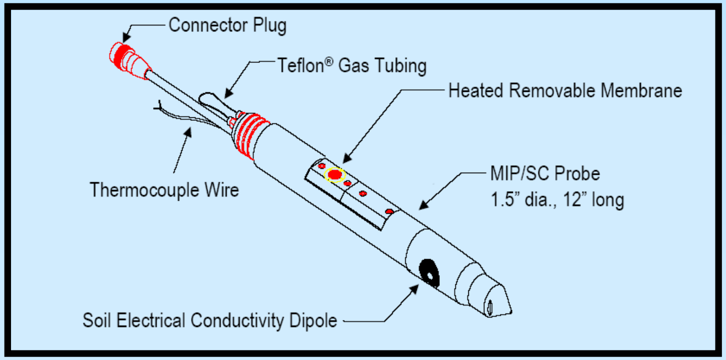
Photo courtesy of Pacific Northwest National Laboratory

- **Advantages**
  - In-situ measurement
  - No purge water
  - Rapid results
  - Cost improvement over conventional laboratory methods

- **Limitations**
  - VOCs only
  - May require confirmatory testing

An in-well probe that aerates groundwater and captures the vapor for VOC analysis.

Membrane Interface Probe (MIP)



•Advantages

- Widely available
- In-situ measurement
- Generates continuous vertical profile
- No purge water
- Rapid results
- Less costly than CPT-deployed sensors
- Simultaneous log of VOCs and soil conductivity
- Operates in vadose zone and saturated zones
- Useful for delineating NAPL source zones
- Rapid site screening

•Limitations

- VOCs only
- High detection limits
- Only works with direct-push
- Limited to unconsolidated sediments
- MIP log provides semiquantitative/qualitative information
- Penetration resistance

A direct-push tool that produces continuous chemical and physical logs of the vadose and saturated zones. The instrument heats the soil and/or groundwater and analyzes the vapor diffused across the membrane.

Waterloo Profiler

Photo courtesy of the ITRC

- **Advantages**
  - Vertical zone specific measurement
  - No vertical mixing
  - More accurate results
  - Can sample & measure
    - Concentrations
    - Hydraulic Conductivity
    - Water Levels
  - No drill cuttings and little purge water

- **Limitations**
  - Unconsolidated aquifers only
  - Discrete-depth probe
  - Long sample collection times in fine-grained units
  - Only provides a snapshot in time of water quality

A direct-push tool that collects depth-discrete groundwater samples in a single hole with one probe entry.

Continuous Multichannel Tubing (CMT) System

•Advantages

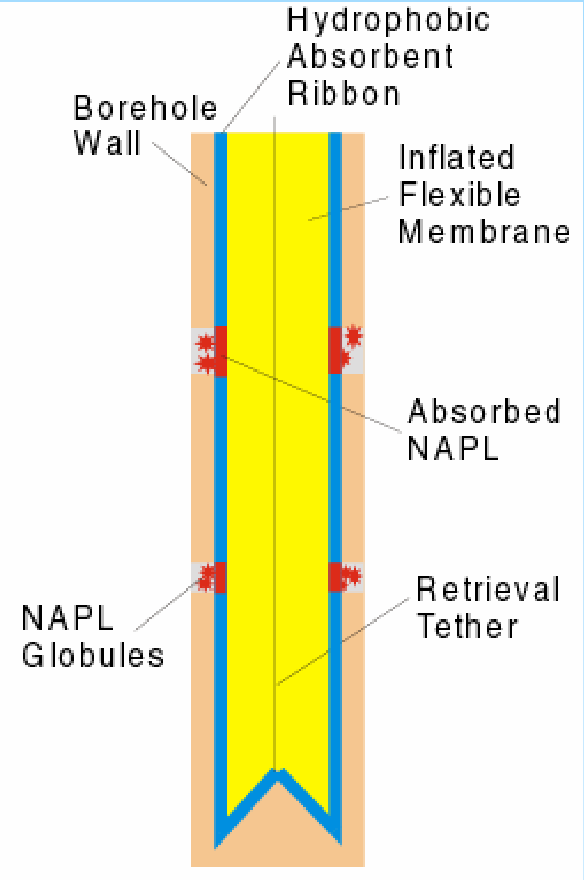
- Up to seven discrete vertical zones
- Both vadose zone (vapor) & saturated zone (water)
- Very little purge water
- Simple reliable construction
- Reduced sampling effort and cost

•Limitations

- Cannot use standard pumps
- Possible cross-contamination of chambers
- Cannot compare results to conventional wells

A multi-level groundwater monitoring system that uses custom-extruded flexible multichannel HDPE tubing to monitor as many as seven discrete zones within a single borehole.

Downhole NAPL Ribbon



•Advantages

- In situ NAPL testing
- Can provide detailed delineation in a borehole
- Little waste material
- Reduced personnel exposure to NAPL
- Amenable to rapid documentation via photography

•Limitations

- Requires stable borehole
- Relatively shallow depths (<50m or 165 ft)
- Relatively ambiguous reaction to some NAPLs may be difficult to interpret
- Wicking may exaggerate NAPL presence
- Potential for false positives and false negatives

A dye-impregnated ribbon installed in a borehole that reacts with NAPL causing a color change.

Photoacoustic Multigas Monitors

Photo courtesy of California Analytical Instruments, Inc.

•Advantages

- Continuous air monitoring
- Samples numerous constituents – MDLs for 280+ gases
- Detects low ppb
- No consumables
- Very little maintenance

•Limitations

- Limited number of gases that can be measured at any given time
- Detection limit for certain gases
- Possible false positives

A continuous gas-phase monitoring system based on infrared photoacoustic spectroscopy.

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Why NIRIS (Navy Installation Restoration Information Solution)?

- NAVFAC-wide, standardized process for IR data management
- Compliant with DoD GIS standards
- Contractor-vendor independent
- Long-term archive of all IR data
- Navy takes control/owns the data
  - Navy RPMs and contractors have access to all IR data
  - Data will not be lost when new contractor takes over

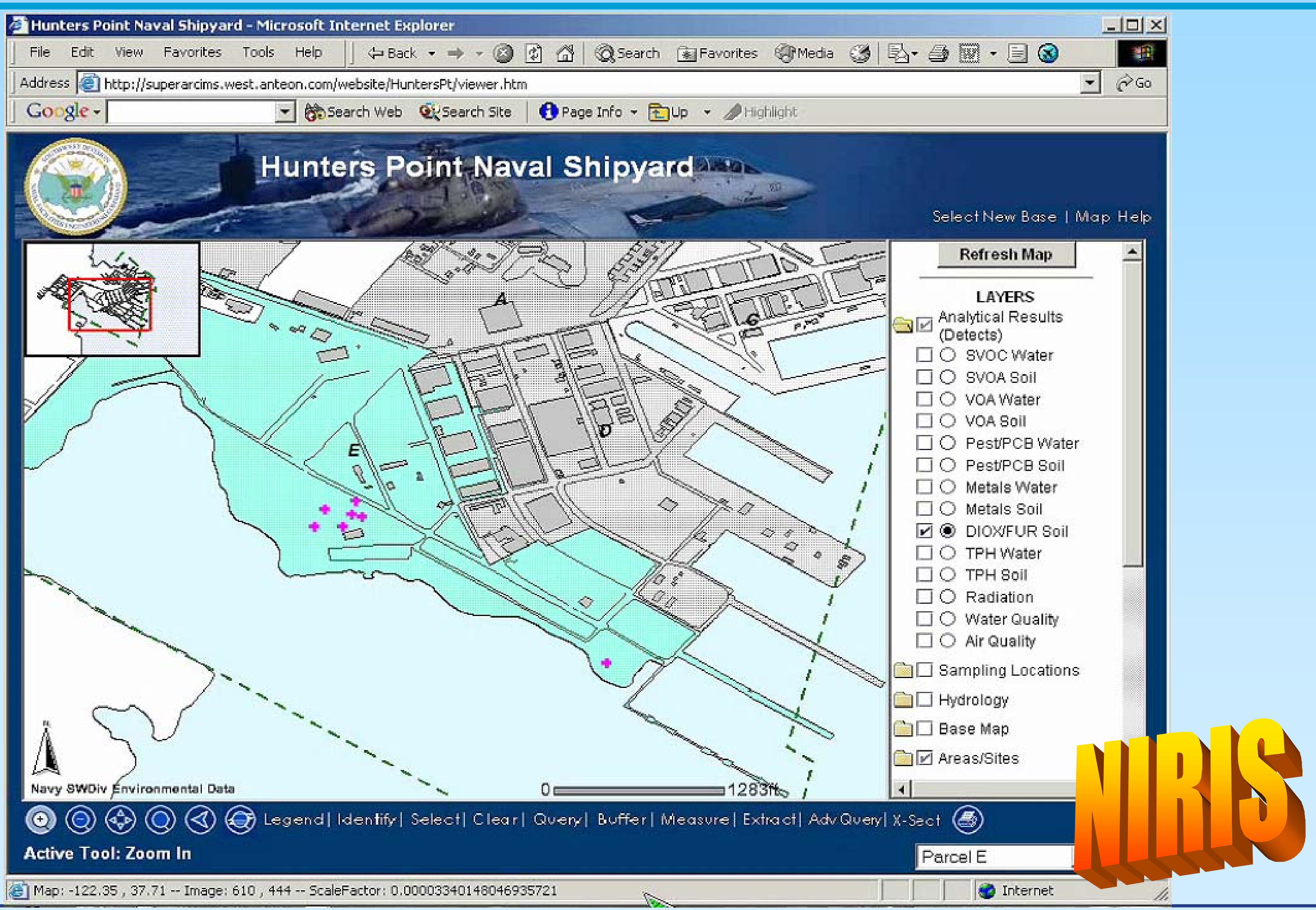
NIRIS

How the Navy Manages its Data

NIRIS – Goals for the IR GIS Workgroup

- Develop common, IR data base structure that is accessible via the Web
- Develop tools to access the data
  - User needs assessment just completed; however, tools may include:
    - Basic GIS functionality – query, display results, overlay aerial photos
    - Data validation tool
    - Time trend analysis
    - Monitored natural attenuation tool
    - Land use control module
    - Export functionality to other software including GMS, EQUIS

NIRIS – How the Navy Manages its Data



NIRIS and GIS Guidance

- NAVFAC will be issuing guidance on NIRIS when system is ready for deployment
- For more information on GIS (e.g., Installation Mapping Guide, Collaborative Forum):

  http://navfacilitator.navfac.navy.mil/cheng/enet/tdls/caddgis/caddgis.htm

  http://www.navy-mc-gis.org

IR GIS Workgroup Members

• Mark Barnes	LANTDIV	• Michael Pound	SWDIV
• Bill Clarno	EFANW	• Lucreatria Holloway	SWDIV
• Debbie Felton	EFANE	• Rob Sadorra	DON HQ
• Josh Fortenberry	NFESC	• Dan Waddill	SOUTHDIV
• Darlene Ige	PACDIV	• Mike Maughon	SOUTHDIV
• Lance Young	PACDIV	• Malgorzata Wright	EFACHES

IR Managers Link
Byron Brant

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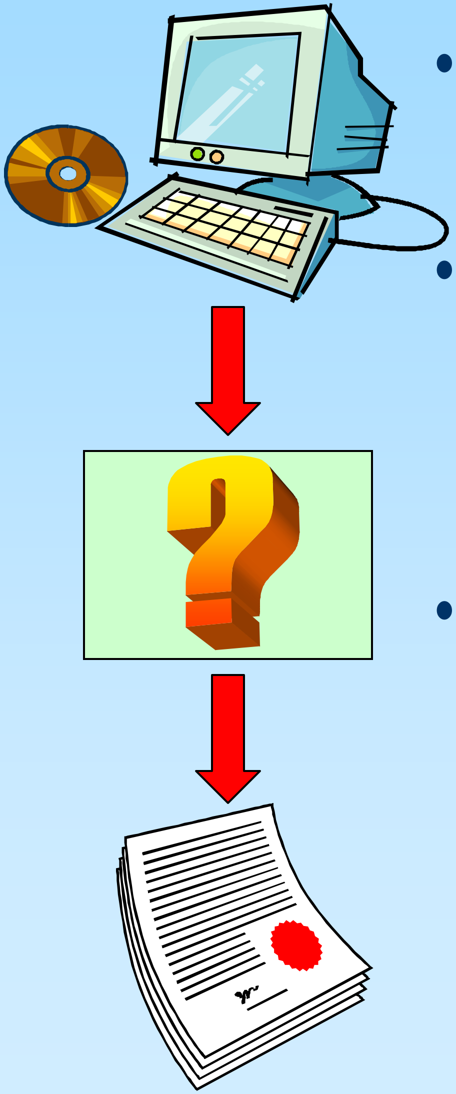
Data Management Software & Systems

- Sophisticated software - - not Excel!
- Environmental database software
  - EQuIS (www.earthsoft.com)
  - TerraBase (http://www.bossintl.com/html/terrabase_details.html)
  - EnviroData (www.envirodatasolutions.com)
  - EQWin (www.gemteck.com)
  - webEDMS (www.iesinet.com/products/web_webedms.php)
  - NIRIS

Data Flow



- Input: Manual or electronic data deliverables (EDDs)
- Queries: Finding what you're looking for . . .
  - Simple one-time search
  - Complex reusable queries
- Reports: Getting data out in a useable format . . .
  - Periodic regulatory reports (e.g. quarterly sampling)
  - Technical reports
  - Data output to secured Web pages
  - Links to GIS, visualization, and modeling software

Uses & Types of Data

- Types of Data
  - Water levels
  - Sampling results
  - Climate data
  - Remedial system performance data
  - Others

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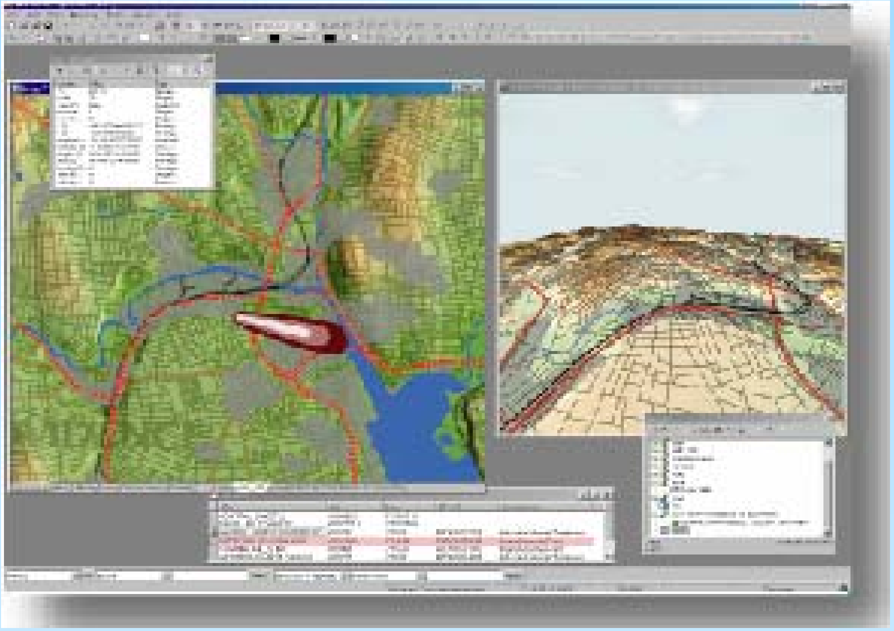
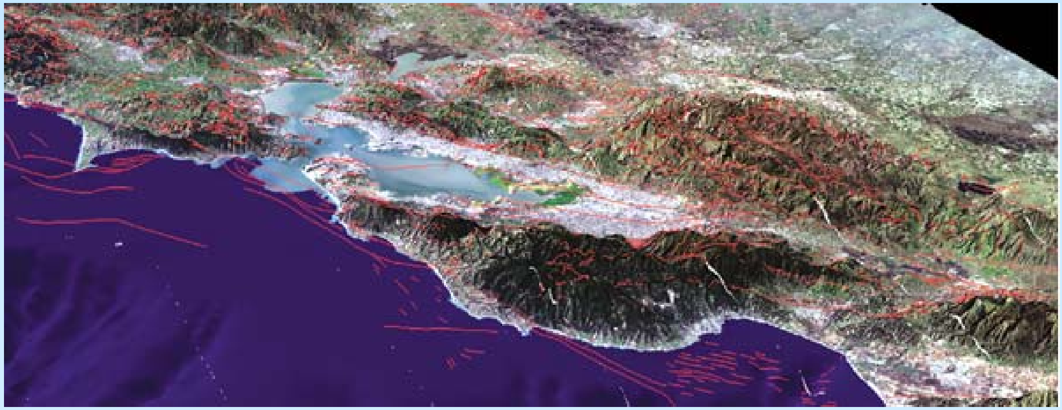
Links to Geographic Information Systems (GIS)

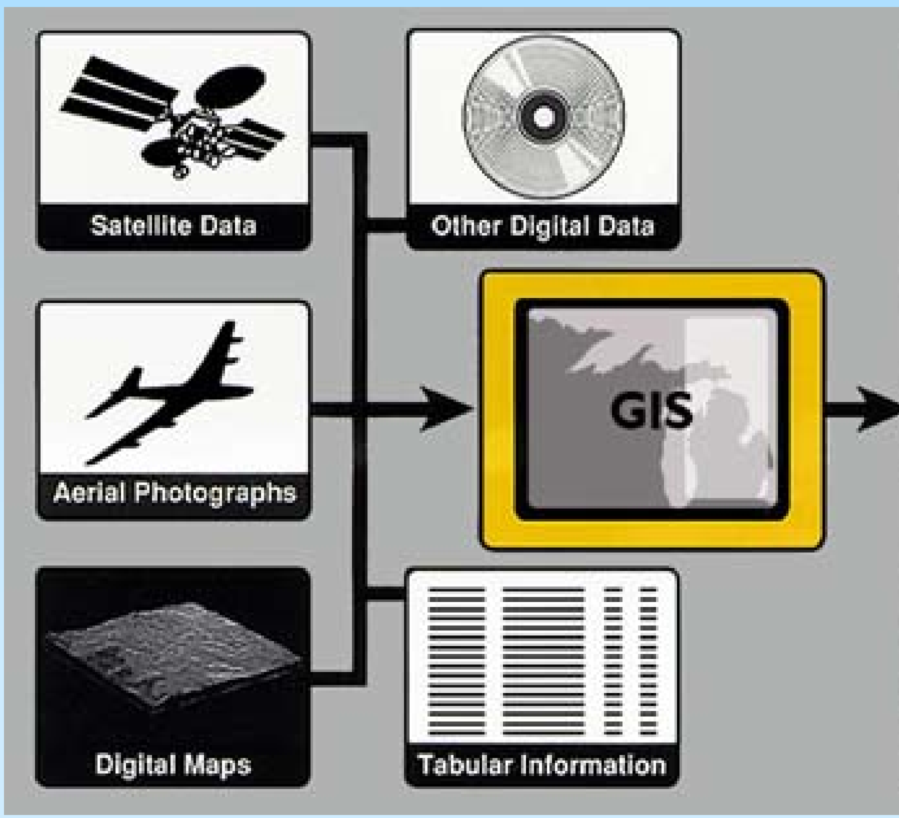
- Well-structured database is the “heart” of the GIS system
- May need to pre-query data into tables to speed system functionality

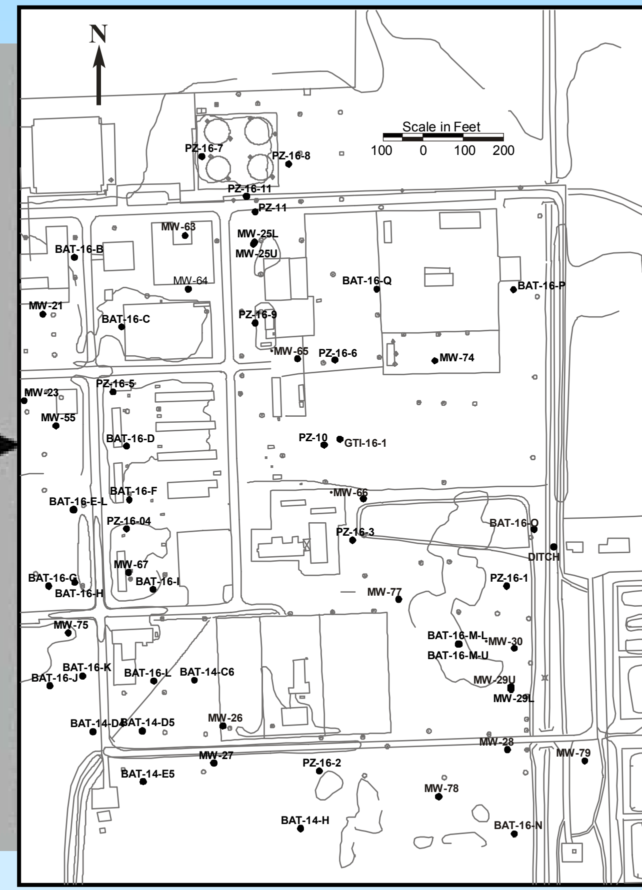




Spatial Data Analysis

- GIS is the conjunction of a computer system, specialized software, and GIS trained technicians/analysts that compose layers of data to represent a geospatial concept





Spatial Data Analysis (cont.)

- **Geographic Information System (GIS)**
  - Analogous to the use of "light tables," where paper maps were layered to evidence geospatial data of differing types
  - A layer may be any of the following: an aerial photo, a vector drawing, an elevation model, etc.
  - Layers may be represented as semi-transparent, allowing the user to identify geospatial trends, develop a decision support system, or otherwise graphically display coincident data that may be disparate and cumbersome outside of a GIS

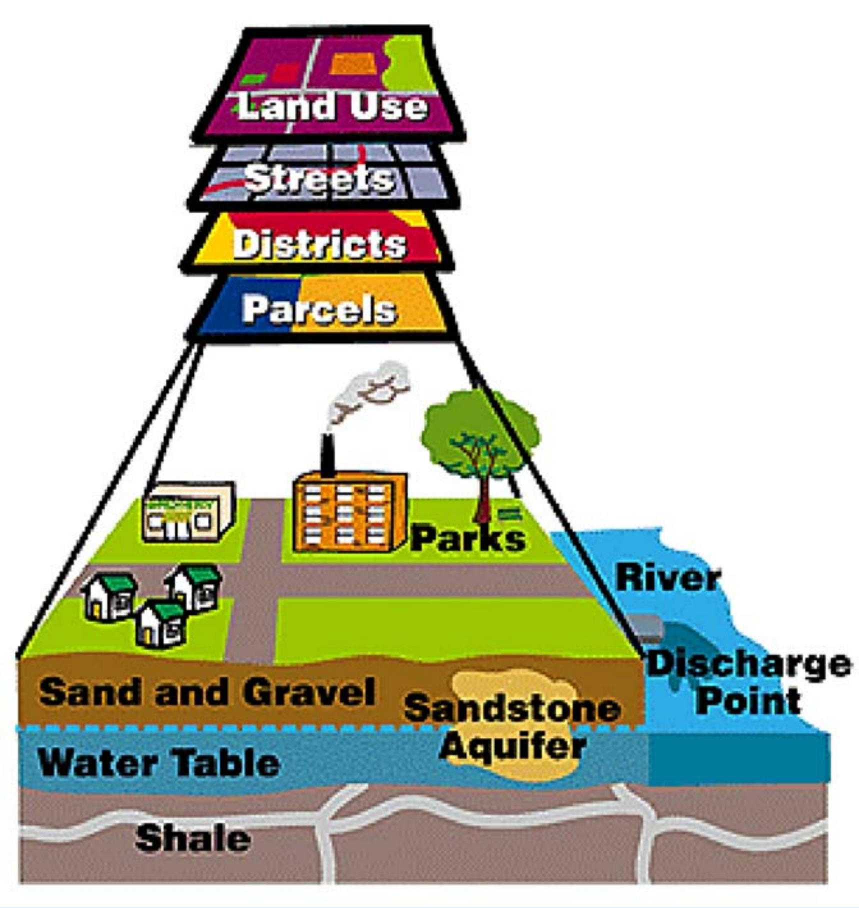
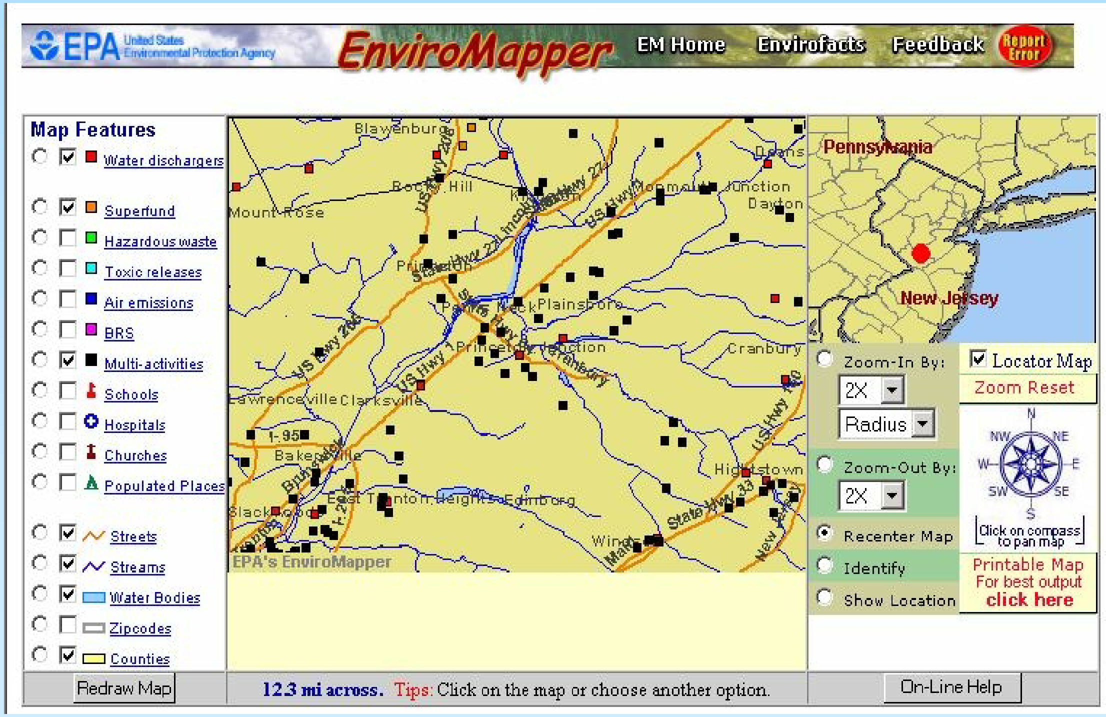


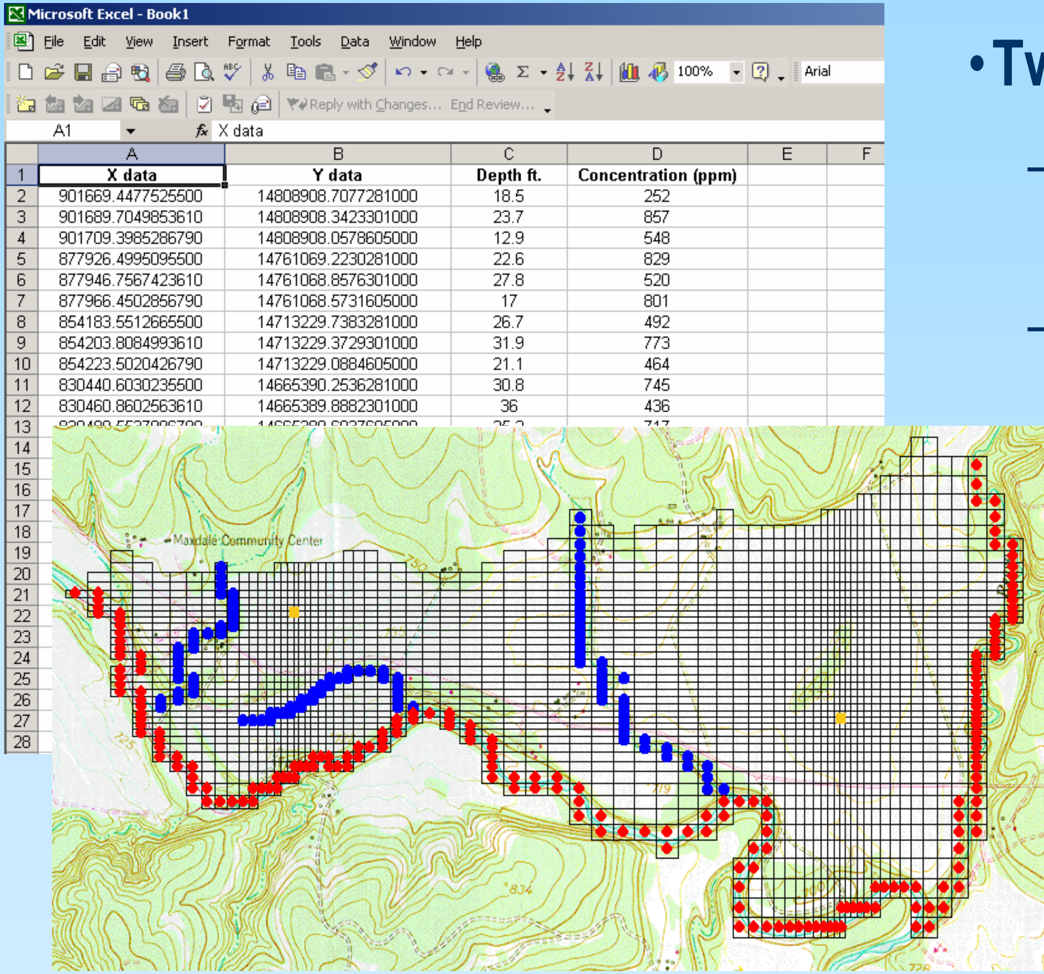
Image courtesy of ESRI

Spatial Data Analysis (cont.)

- Internet Map Service (IMS)
- IMS, commonly known as Web mapping, is an extension of a GIS
  - Specialized software run on Web servers allows any computer with an Internet browser (e.g., Internet Explorer) to achieve basic GIS functionality
- Provides access to your data on the Web

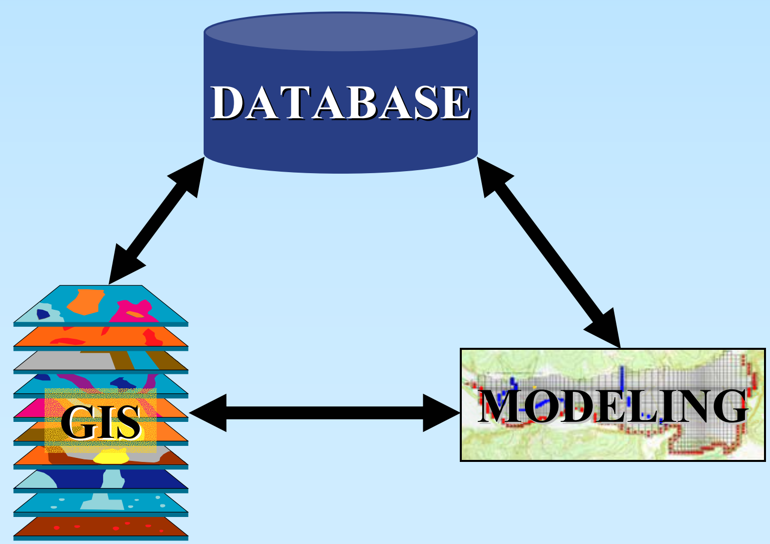


Links to Analysis and Modeling



	A	B	C	D	E	F
1	X data	Y data	Depth ft.	Concentration (ppm)		
2	901669.4477525500	14808908.7077281000	18.5	252		
3	901689.7049853610	14808908.3423301000	23.7	857		
4	901709.3985286790	14808908.0578605000	12.9	548		
5	877926.4995095500	14761069.2230281000	22.6	829		
6	877946.7567423610	14761068.8576301000	27.8	520		
7	877966.4502856790	14761068.5731605000	17	801		
8	854183.5512665500	14713229.7383281000	26.7	492		
9	854203.8084993610	14713229.3729301000	31.9	773		
10	854223.5020426790	14713229.0884605000	21.1	464		
11	830440.6030235500	14665390.2536281000	30.8	745		
12	830460.8602563610	14665389.8882301000	36	436		

- Two Key Links
  - Data out of GIS in proper format and into model
  - Results data out of model and into GIS for georeferenced display



Data Visualization

- Introduction
  - Allows user to visualize subsurface characterization data in two and/or three dimensions (2D/3D)
  - Provides for better conceptual site model (CSM) development from site data
  - Allows user to visualize complex modeling results
  - Provides ability to create presentation graphics for the illustration of concepts to stakeholders

Data Visualization (cont.)

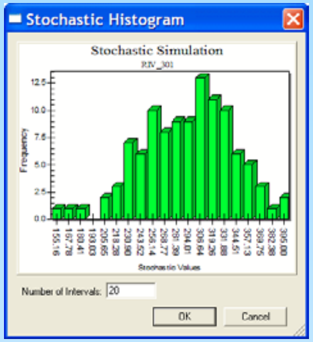
- 2D visualization
  - Surfer
  - Microsoft® Excel
  - SigmaPlot
  - TECPLOT
- 3D visualization
  - EVS
  - TECPLOT
  - EarthVision
  - Groundwater Modeling Programs (Visual MODFLOW, GMS)

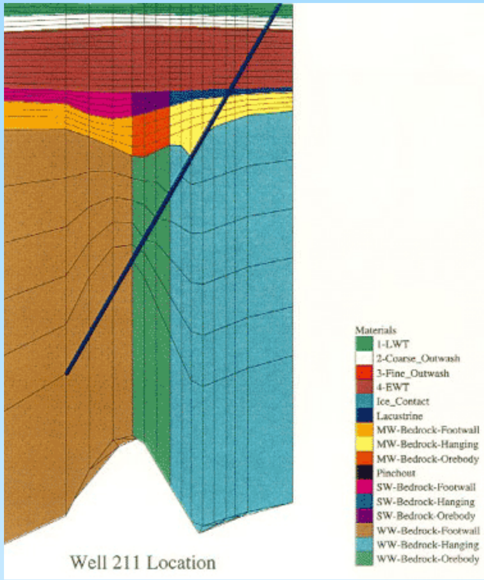
Data Visualization (cont.)

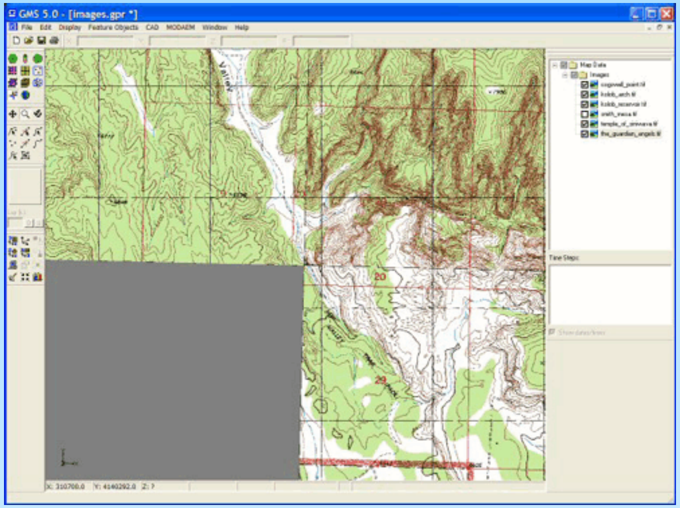
- Groundwater Modeling System (GMS)
  - It's FREE!
  - The DoD, in partnership with the DOE, the U.S. EPA, the NRC, and 20 academic partners, has developed the DoD Groundwater Modeling System
  - GMS provides a comprehensive graphical environment for numerical modeling, tools for site characterization, model conceptualization, mesh and grid generation, geostatistics, and sophisticated tools for graphical visualization

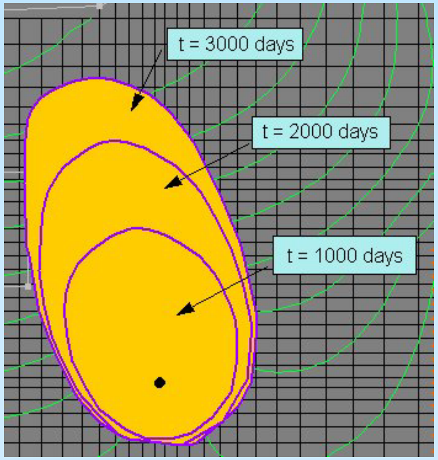
Data Visualization (cont.)

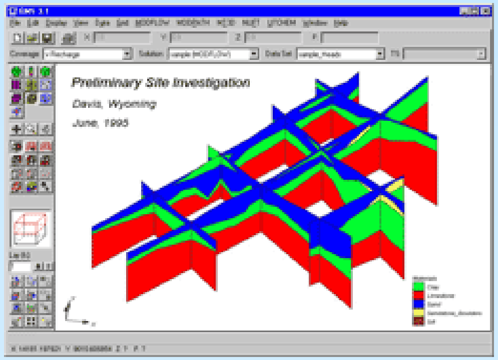
•Groundwater Modeling System (GMS)

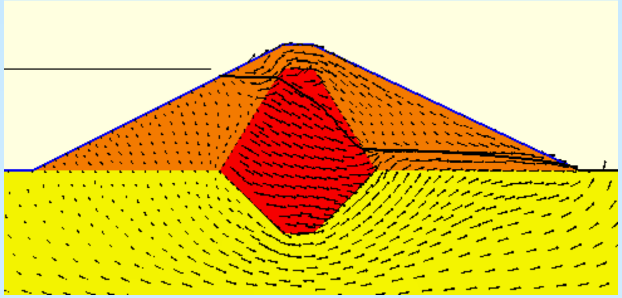




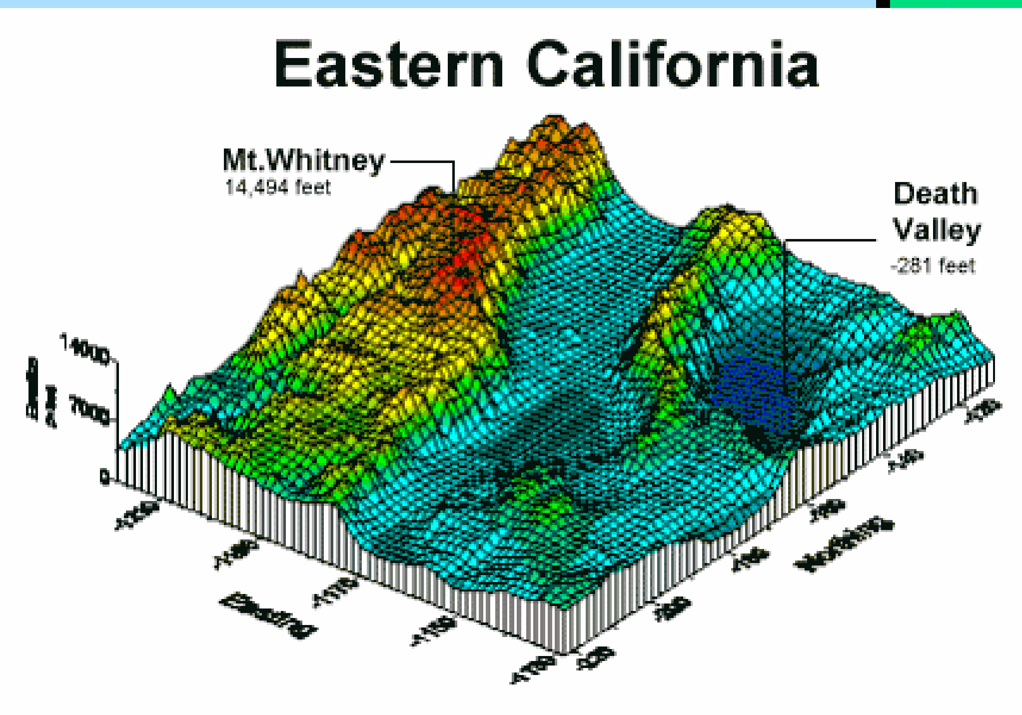


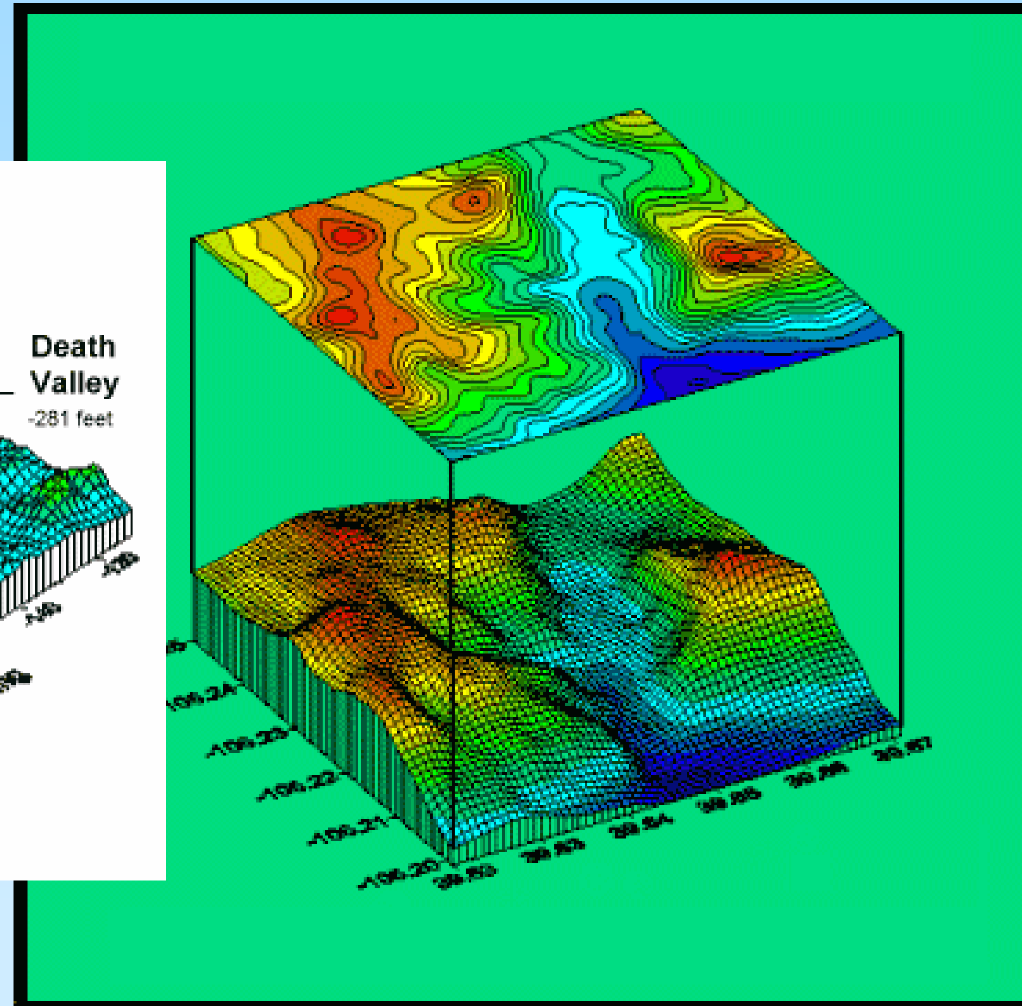






Topographic Information





Images created in Surfer

Contouring Applications

- Water Levels
- Concentrations

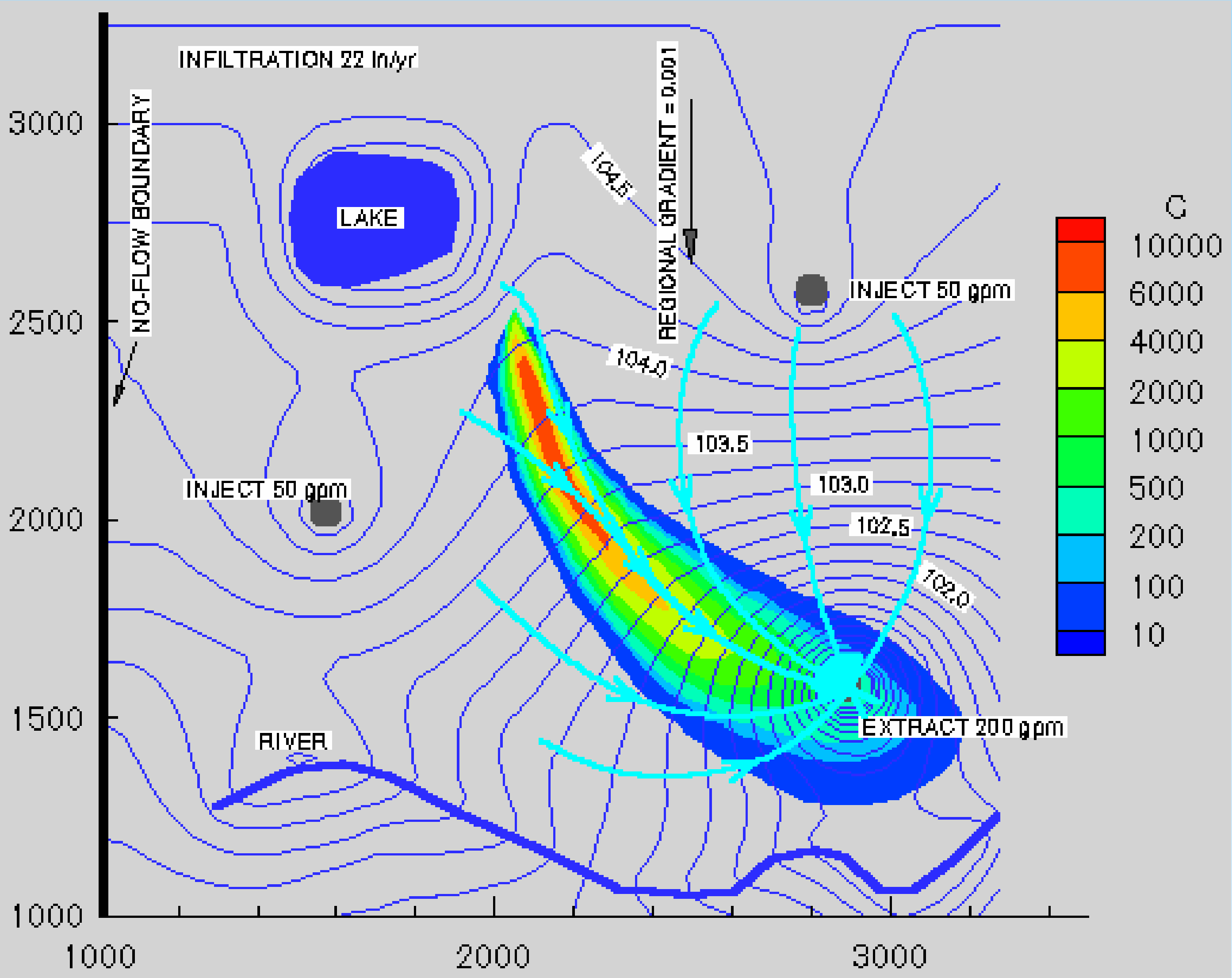


Image created in TecPlot

Hydraulic Conductivity Field

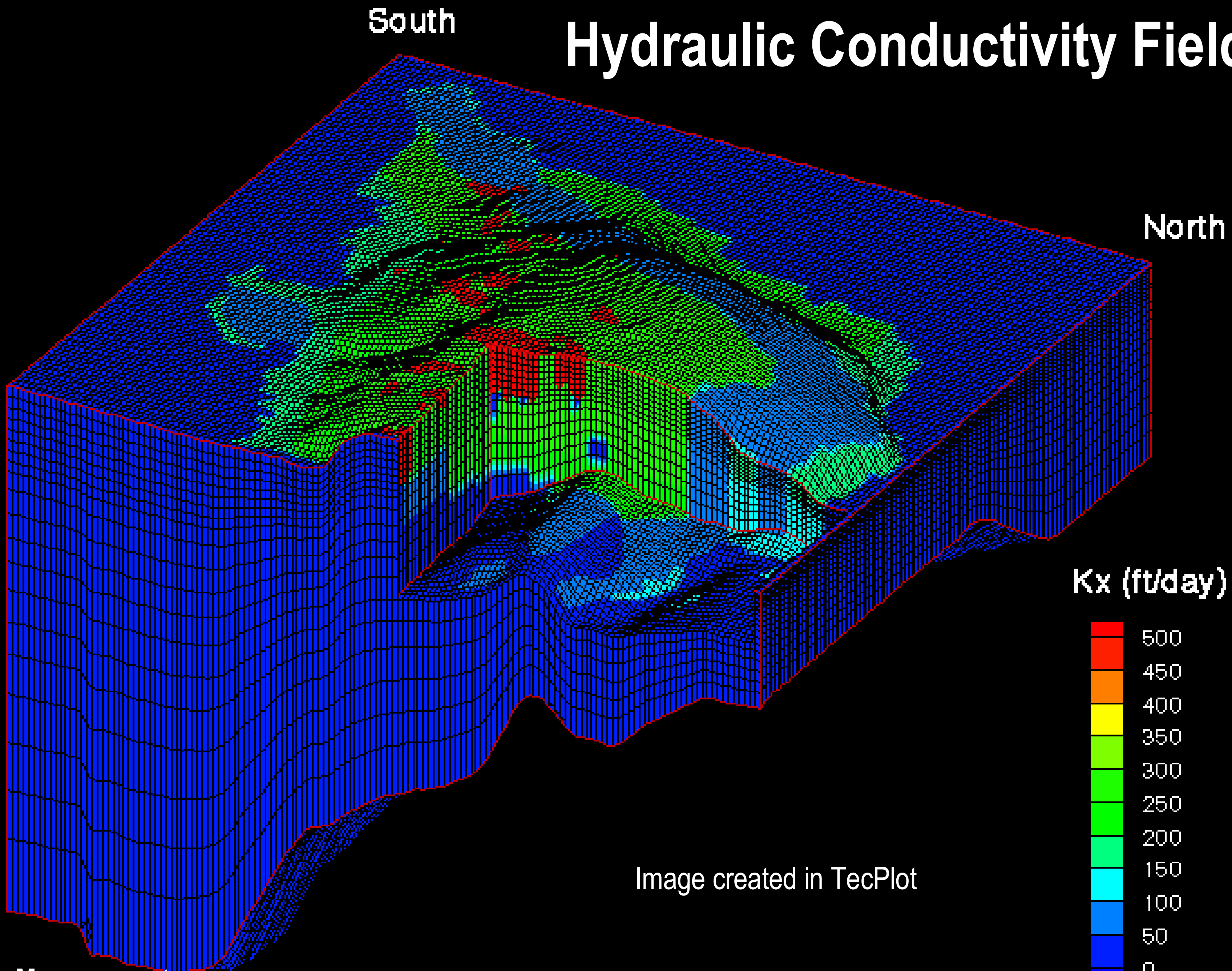


Image created in TecPlot

Particle Tracking

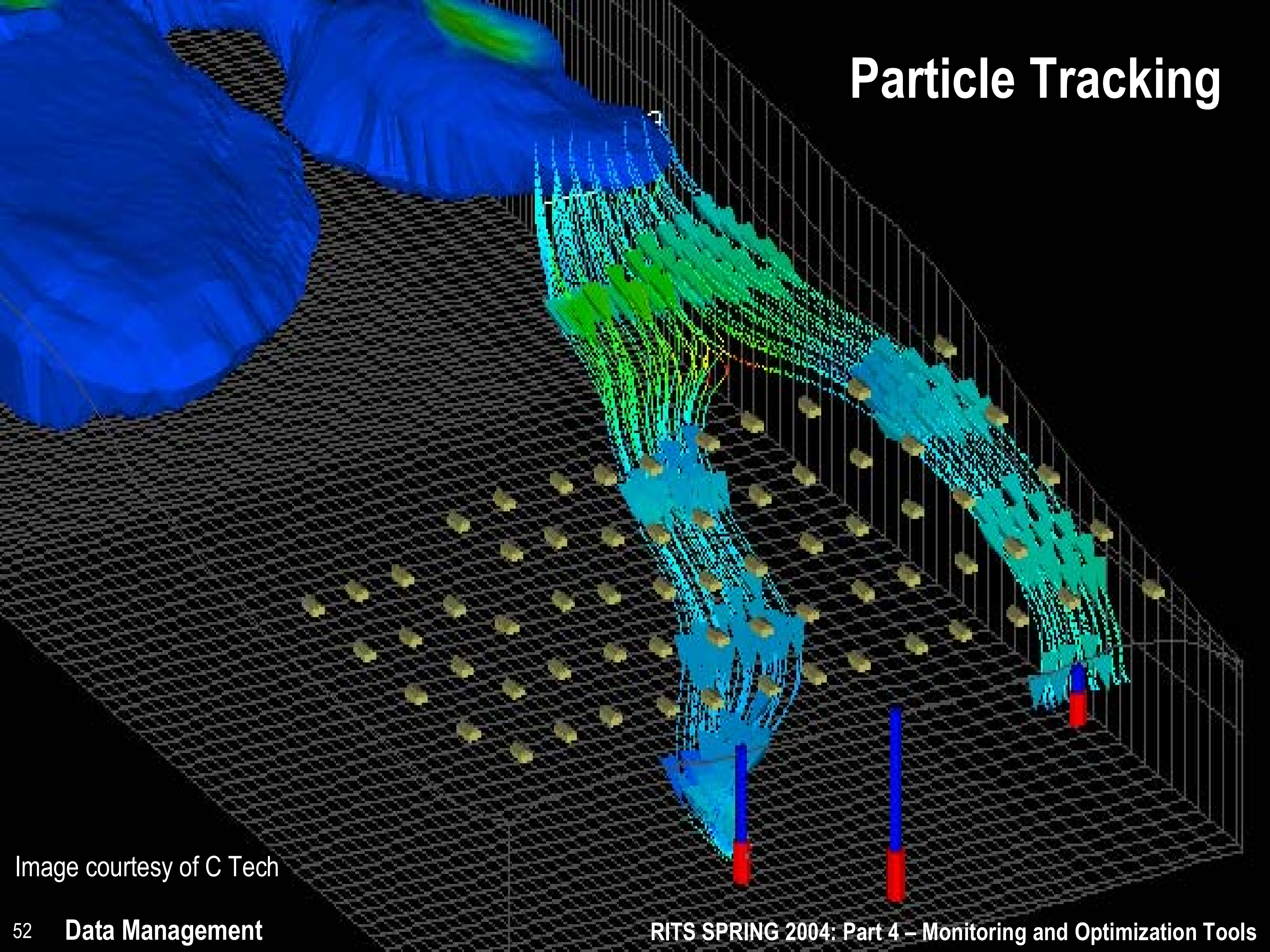


Image courtesy of C Tech

CSM Representation

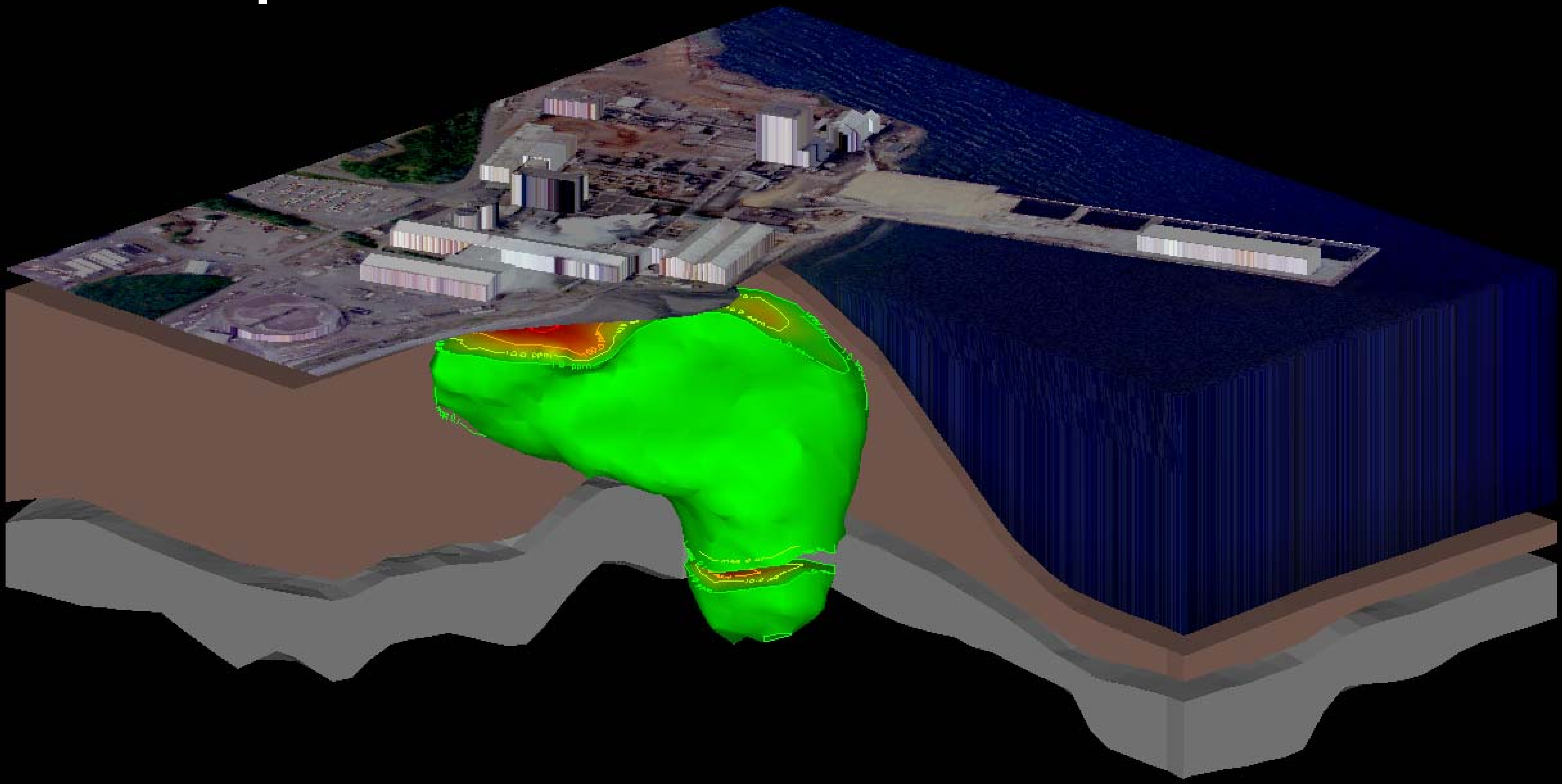
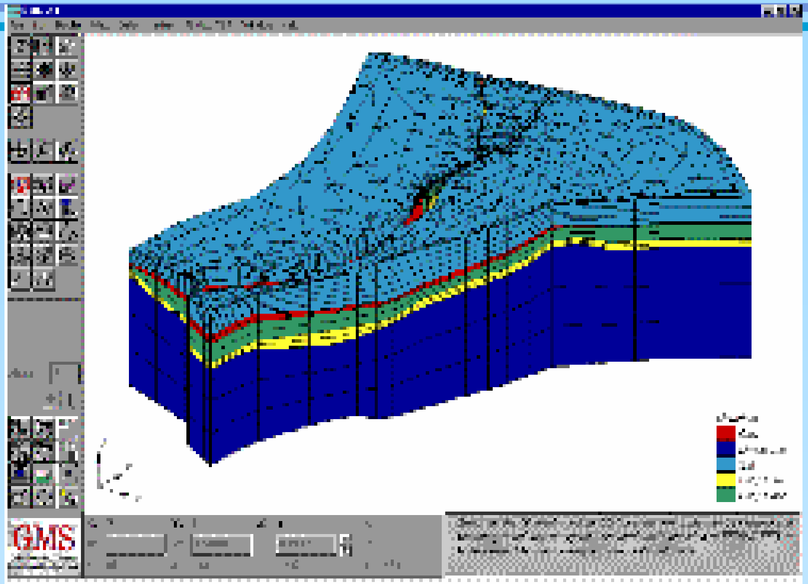
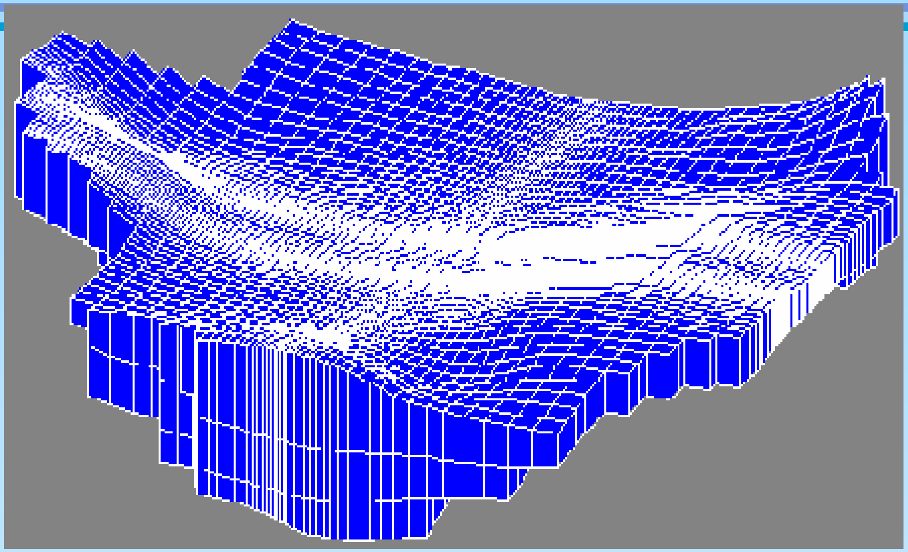
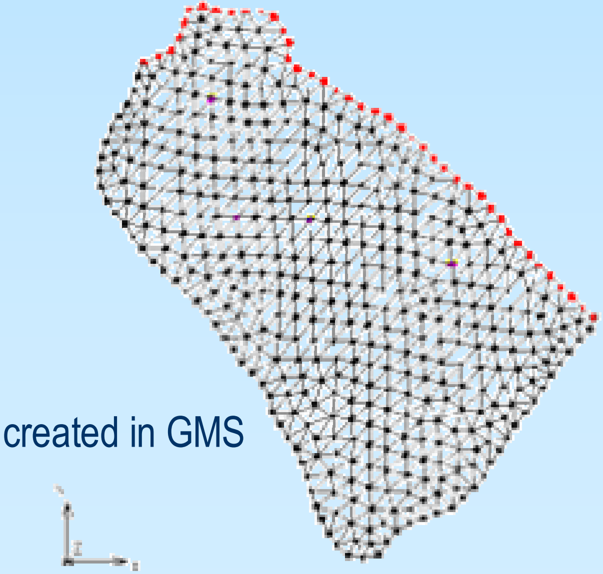


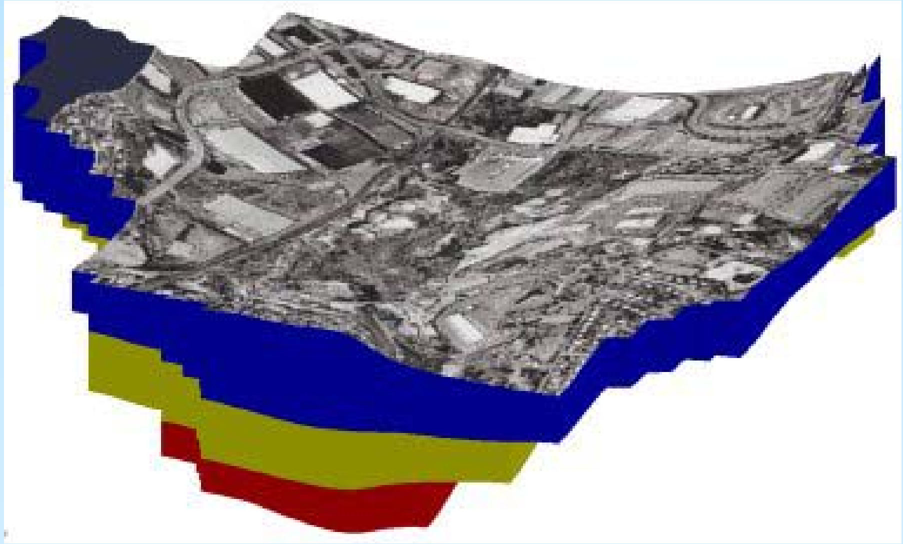
Image created in EVS

Groundwater Modeling System Representation



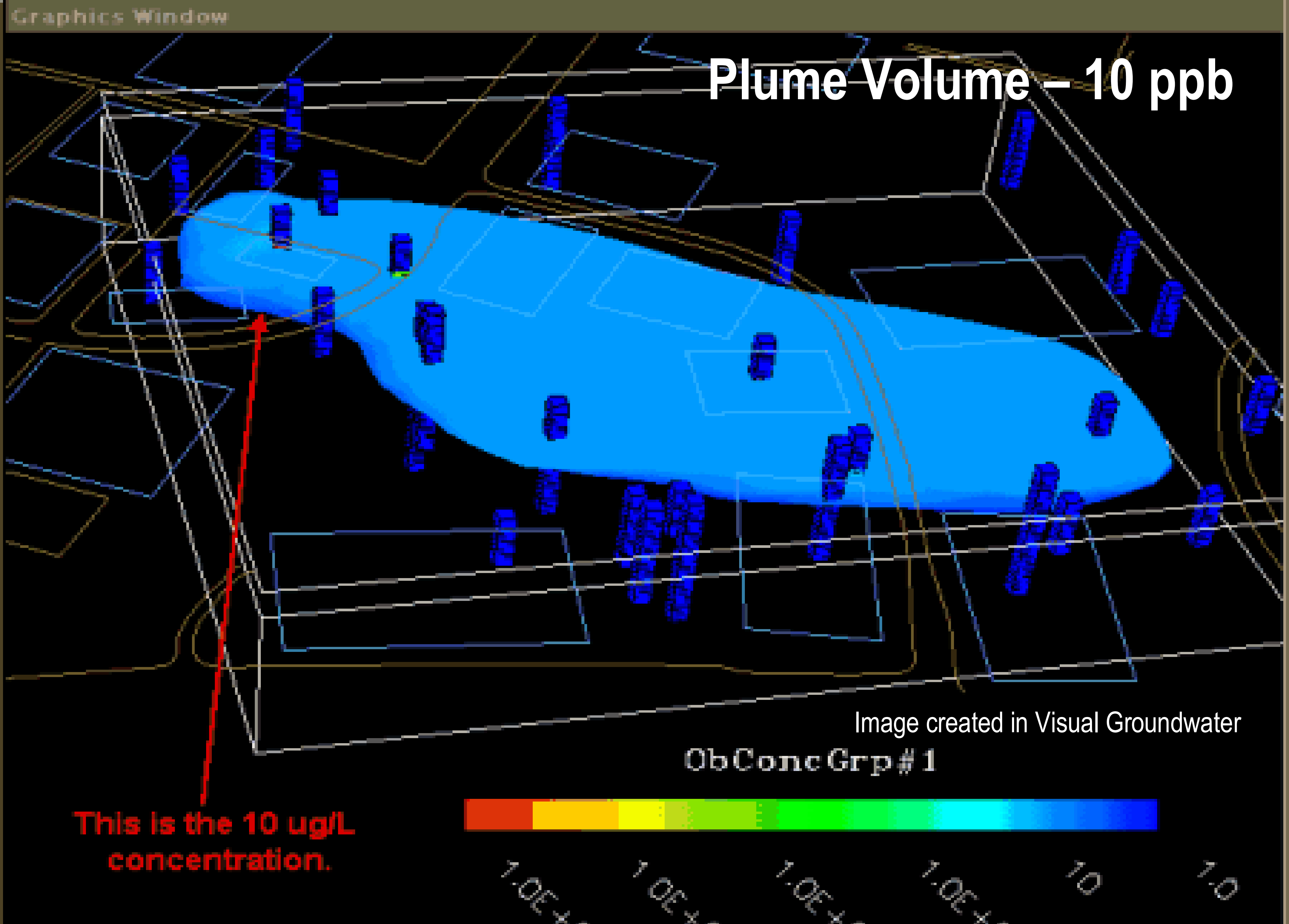






Images created in GMS

Plume Volume – 10 ppb



Plume Volume – 1,000 ppb

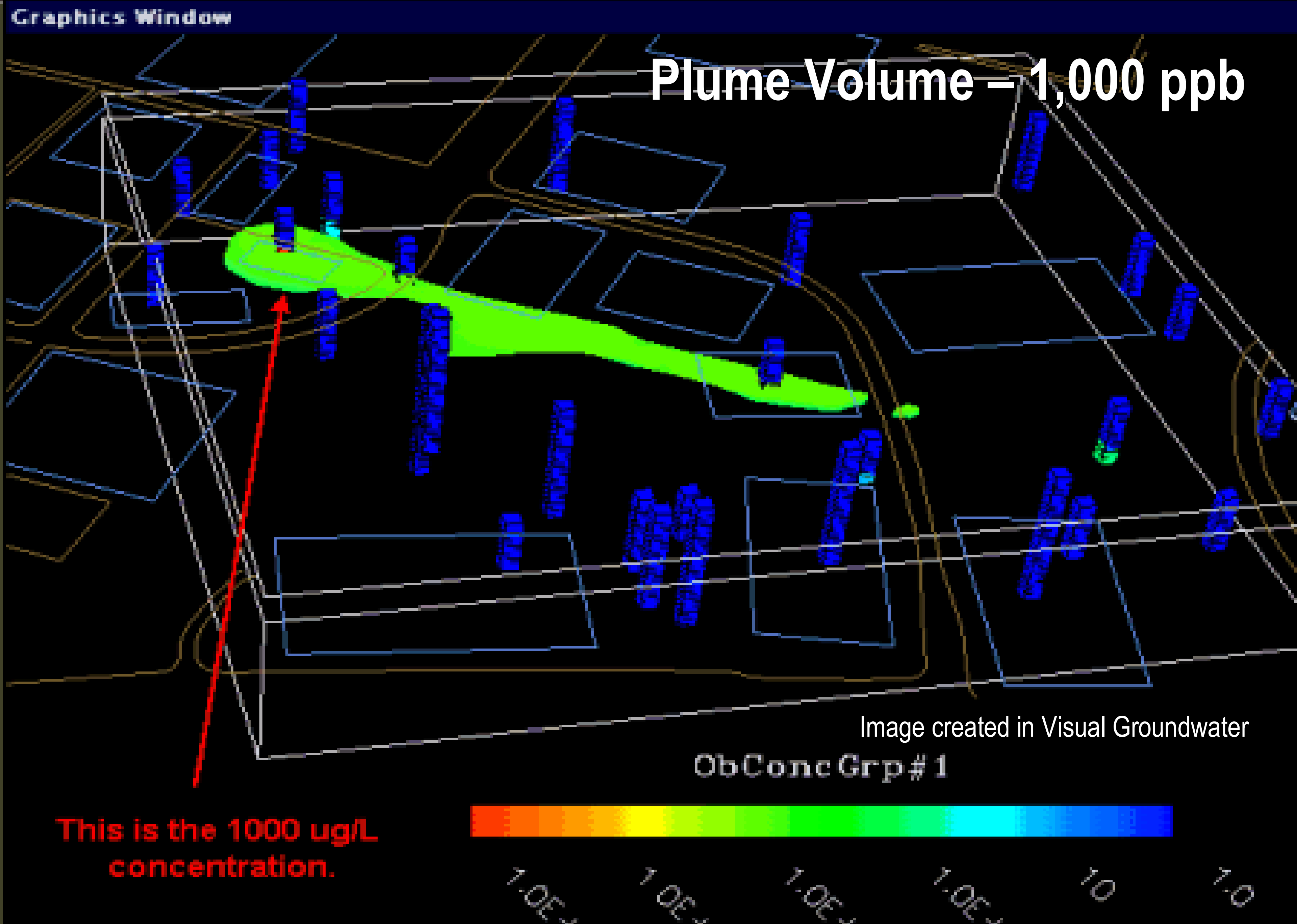
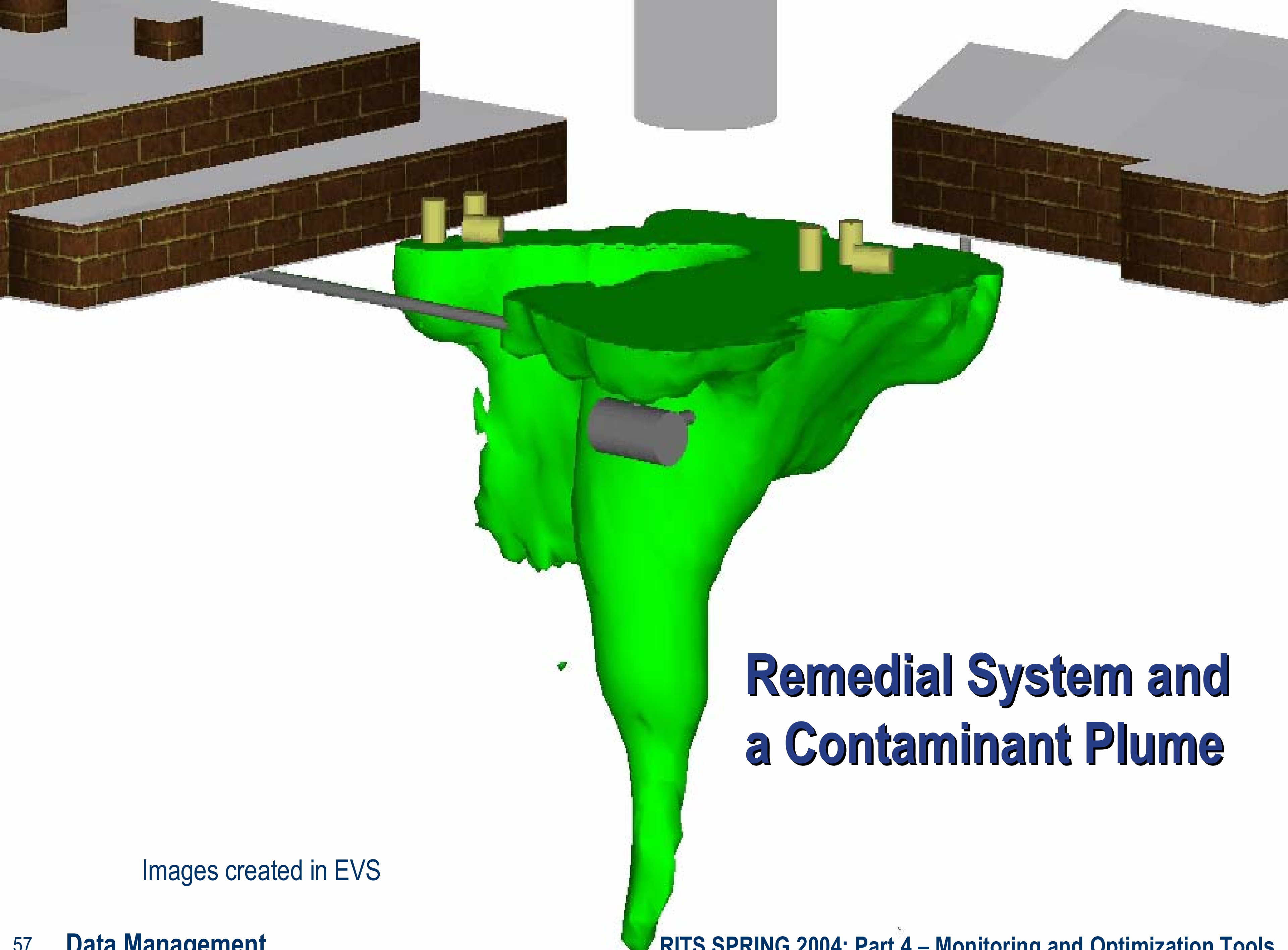


Image created in Visual Groundwater



Remedial System and a Contaminant Plume

Images created in EVS

Data Visualization (cont.)

- Benefits of 3D data visualization
  - Dissolved plume volume estimates
  - Dissolved mass estimates
  - Soil excavation volume estimates above cleanup standard
  - Effectiveness of remedial system (plume volume reduction)
  - Rapid, cost-effective plume/contaminated soil cross-sections
  - Increased understanding of fluid flow and contaminant transport

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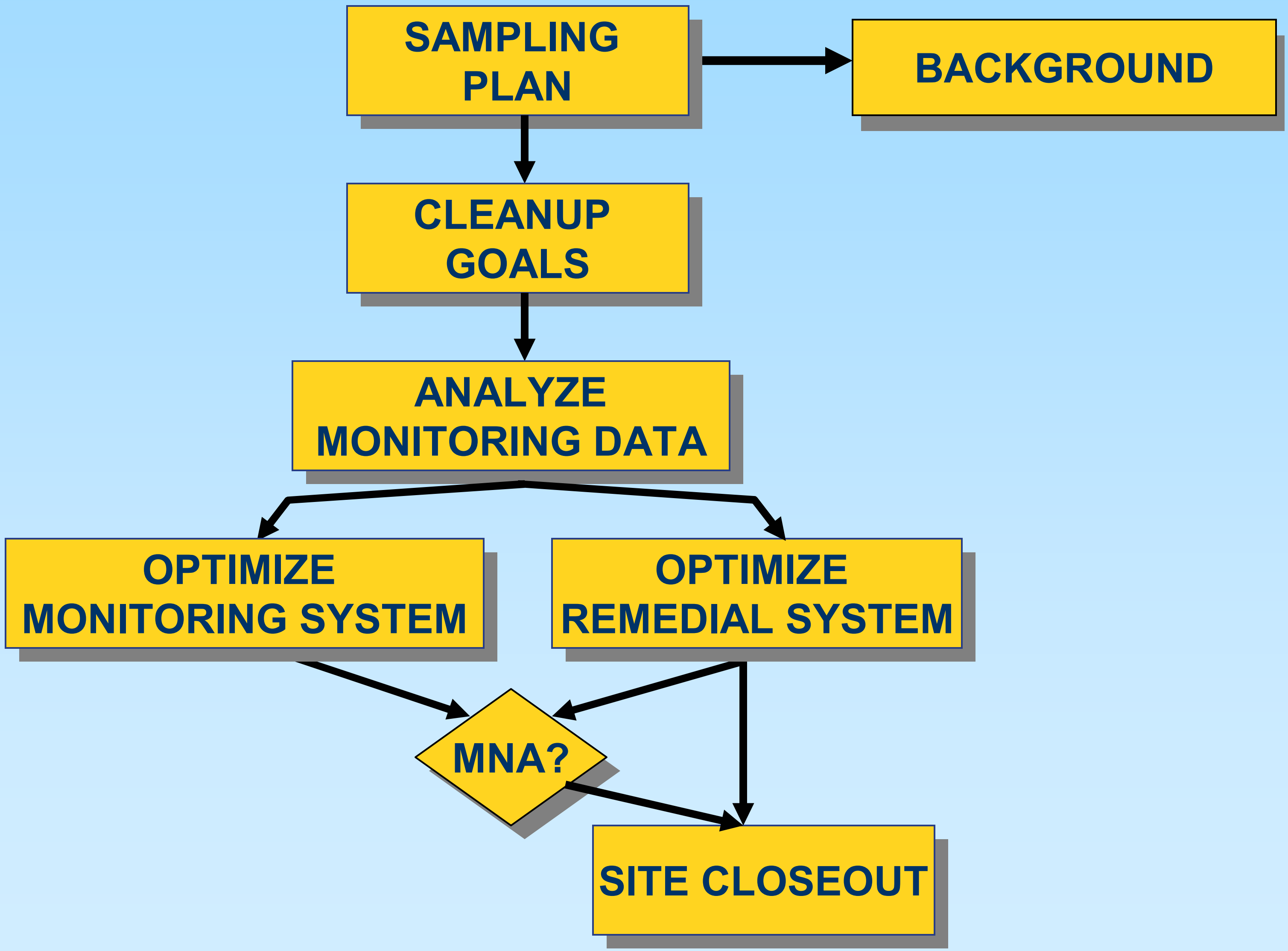
Environmental Statistics Applications

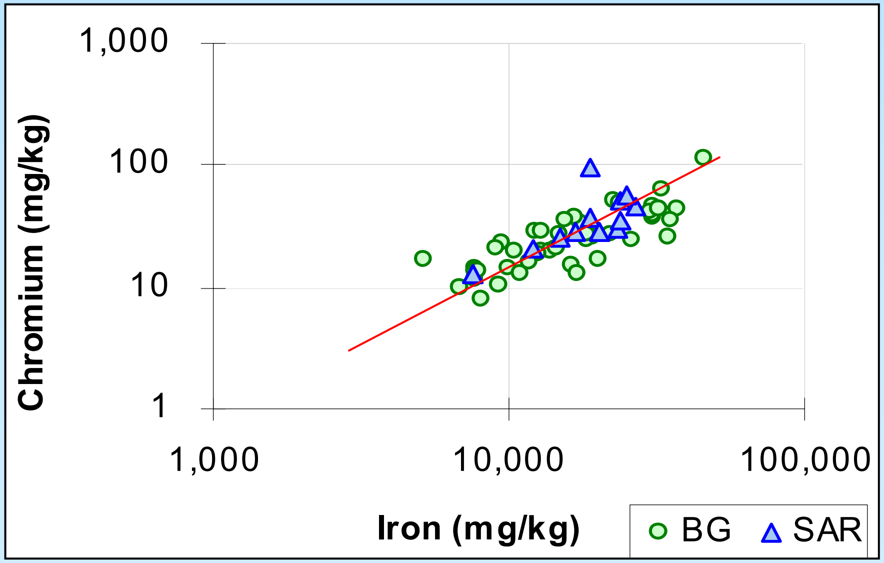
S T A T I S T I C S



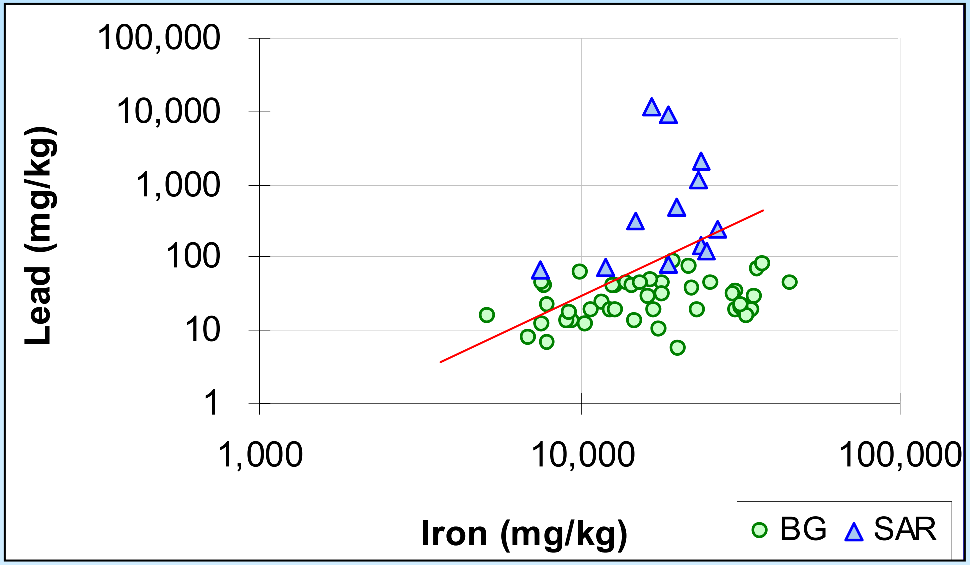
Environmental Statistics Applications

- Evaluation of soil background concentrations
  - Statistical site to background test
  - Geochemical analysis

San Juan NAS, Small-Arms Range



San Juan NAS, Small-Arms Range



Source: J. Myers (2004) – Shaw Environmental

Environmental Statistics Applications

Setting cleanup goals – Superfund example

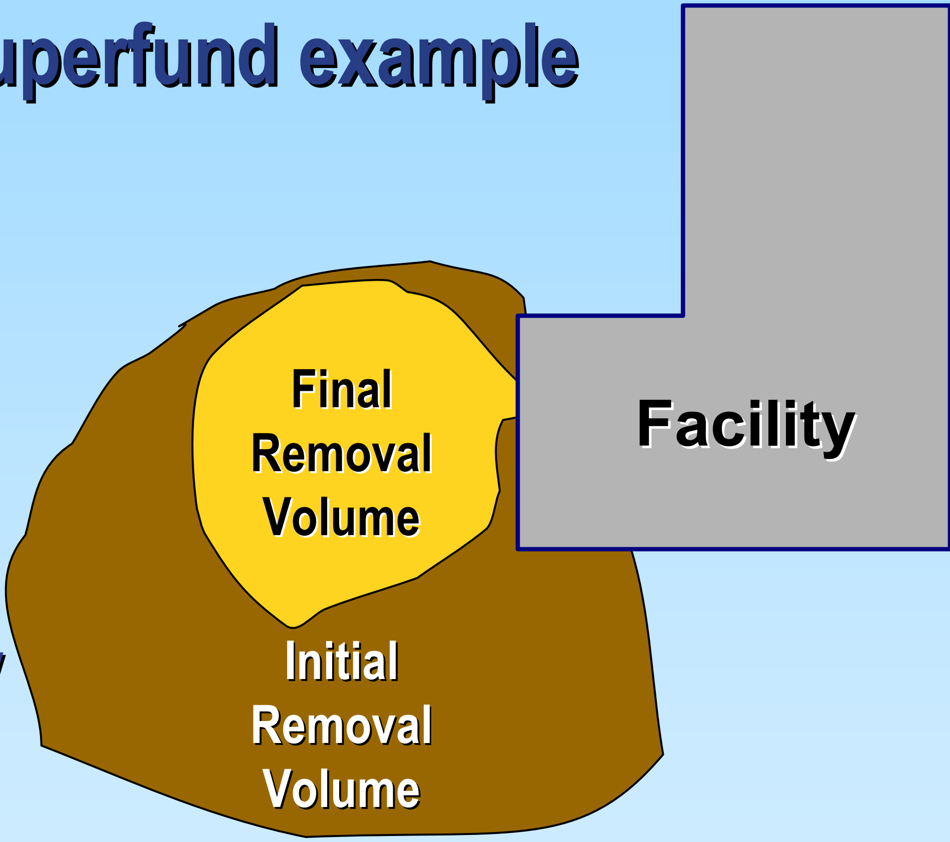
Original soil removal volume

+

Statistics

=

Excavation volume reduction by 66% and $20 million saved



Source: Bowers et. al 1996

Environmental Visualization Software (EVS): Drill Guide – Optimizing Well Installation

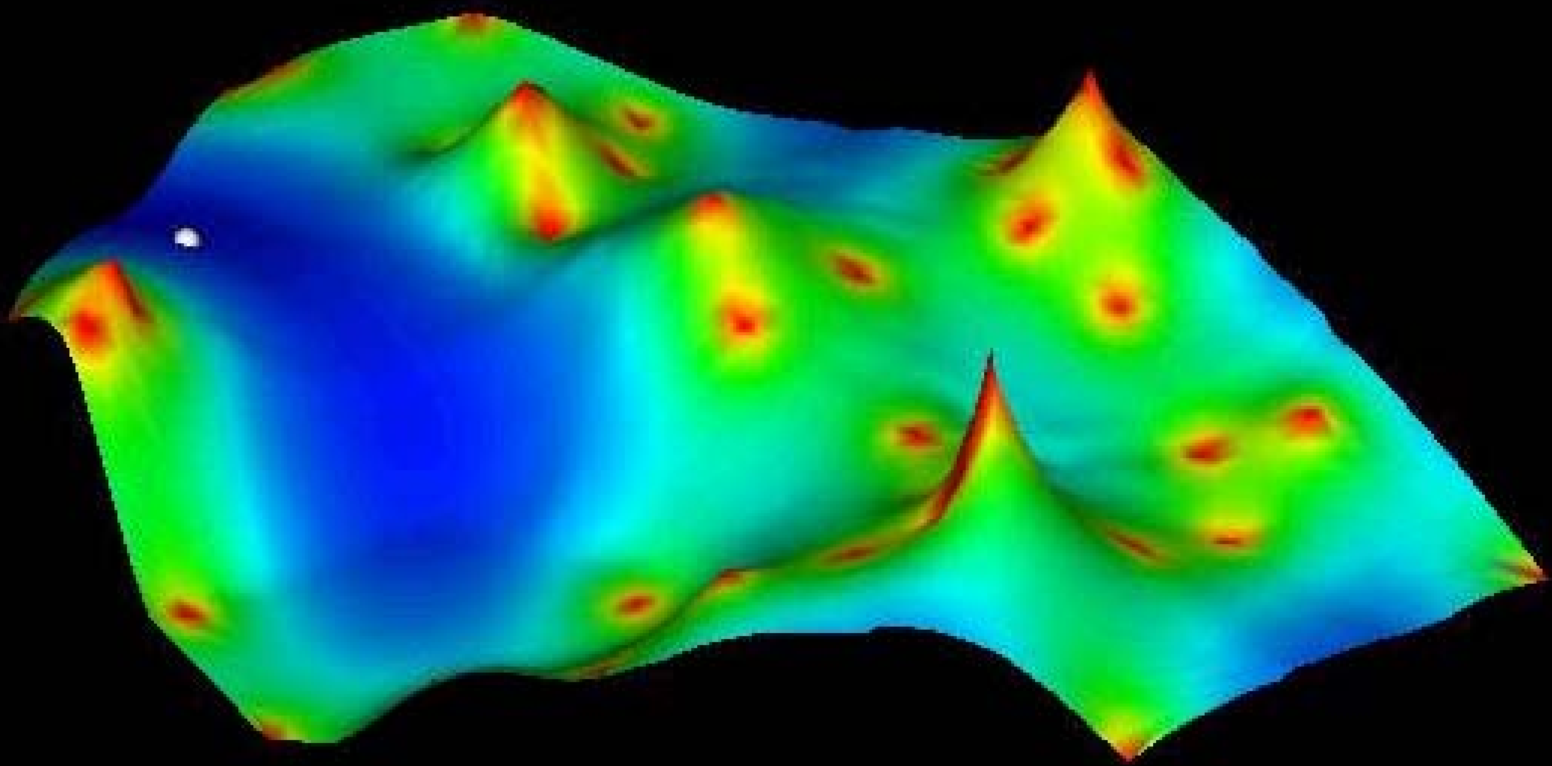
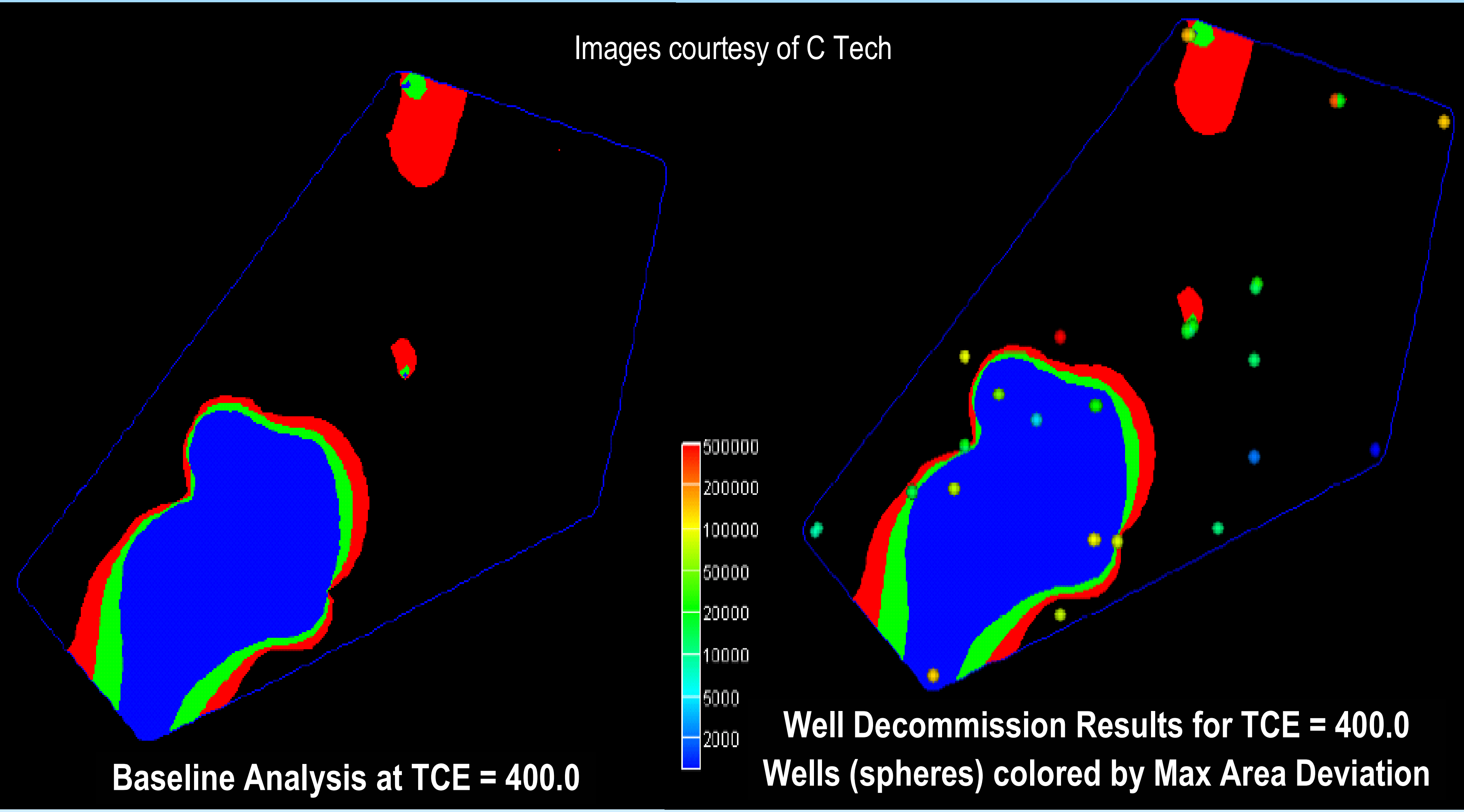
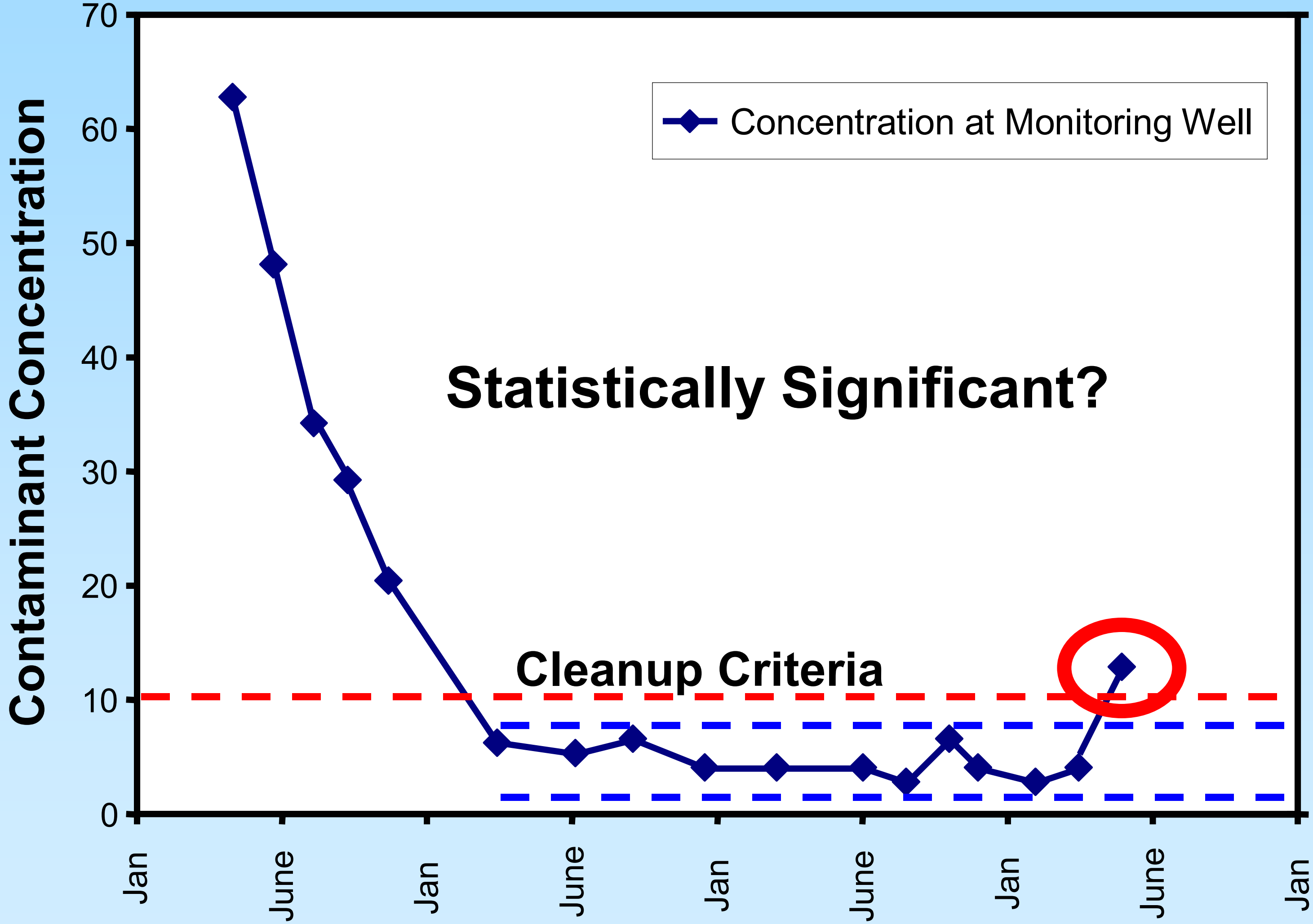


Image courtesy of C Tech

EVS – Well Decommissioning



Environmental Statistics Applications



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Remedial System Optimization

Guidance: Guidance for RAO (NFESC, April 2001)

Goals

- Achieve site closeout in shortest time
- Minimize cost of IR projects

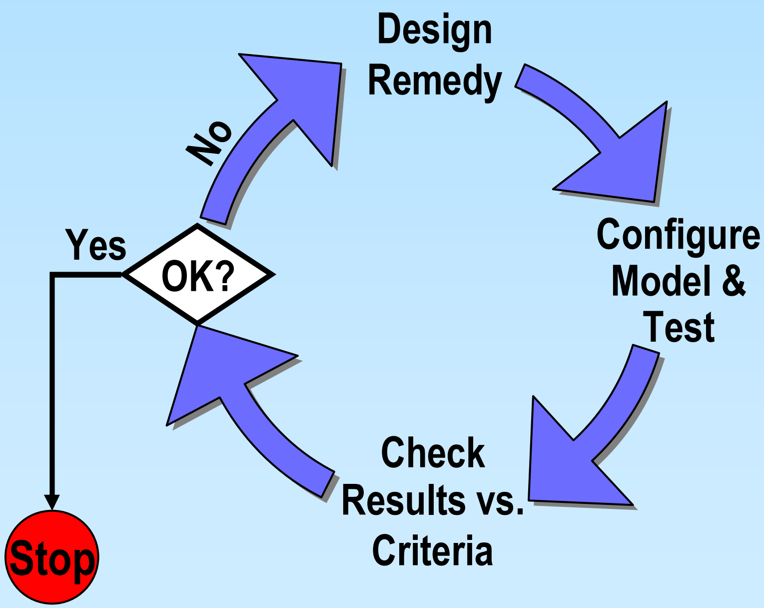
Annual Evaluation

- Evaluate RAO project conditions
- Generate optimization recommendations
- RSE checklists

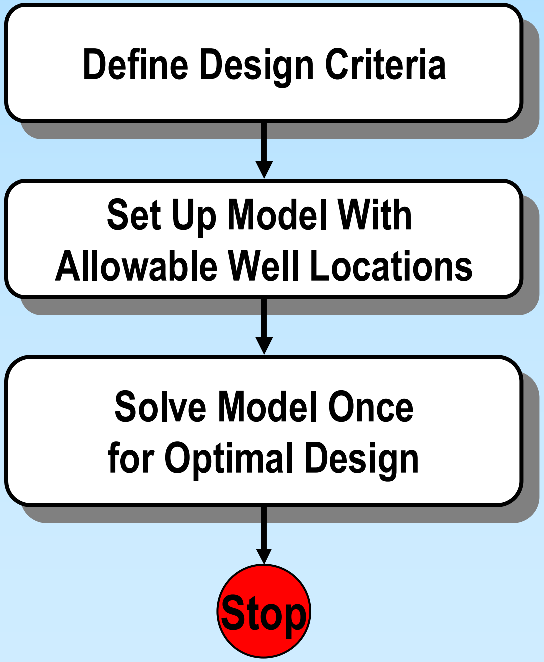
Remedial System Optimization (cont.)

Model Optimization: Powerful tool for speeding cleanup that eliminates trial & error

Traditional Approach



Optimal Design Approach



Remedial System Optimization (cont.)

Applications

- Sites in remedial design planning phase
  - Can help design optimal layout of hydraulic extraction wells
- Existing pump and treat systems
  - Can reduce operating costs by optimizing pumping rates to maximize effectiveness while minimizing volume of water removed
- Other treatment systems

Remedial System Optimization (cont.)

Case Studies

- Umatilla Chemical Depot, Oregon
- Toole Army Depot, Utah
- Former Blaine Naval Ammunition Depot, Nebraska

More Information and Guidance:

http://www.frtr.gov/estcp/ESTCP%20Project%20Technical%20Report/TR-2237-ENV%20Vol%20I.pdf

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Transition from a Remedial System to MNA

- Guidance: Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites (U.S. EPA, 1999)
- "Where the sources of contamination have been controlled, dissolved plumes may be amenable to MNA because of the relatively small mass of contaminants present in the plume."
- "EPA expects that MNA will be most appropriate when used in conjunction with other remediation measures."

Transition from a Remedial System to MNA (cont.)

Suitability of MNA as a Remedy

- Will the contaminants be affectively addressed by natural attenuation processes?
- Is the plume stable and what is the potential for its migration?
- Is there potential for unacceptable risks to human health or environmental resources?
- What is the MNA timeframe vs. all other appropriate remedies?

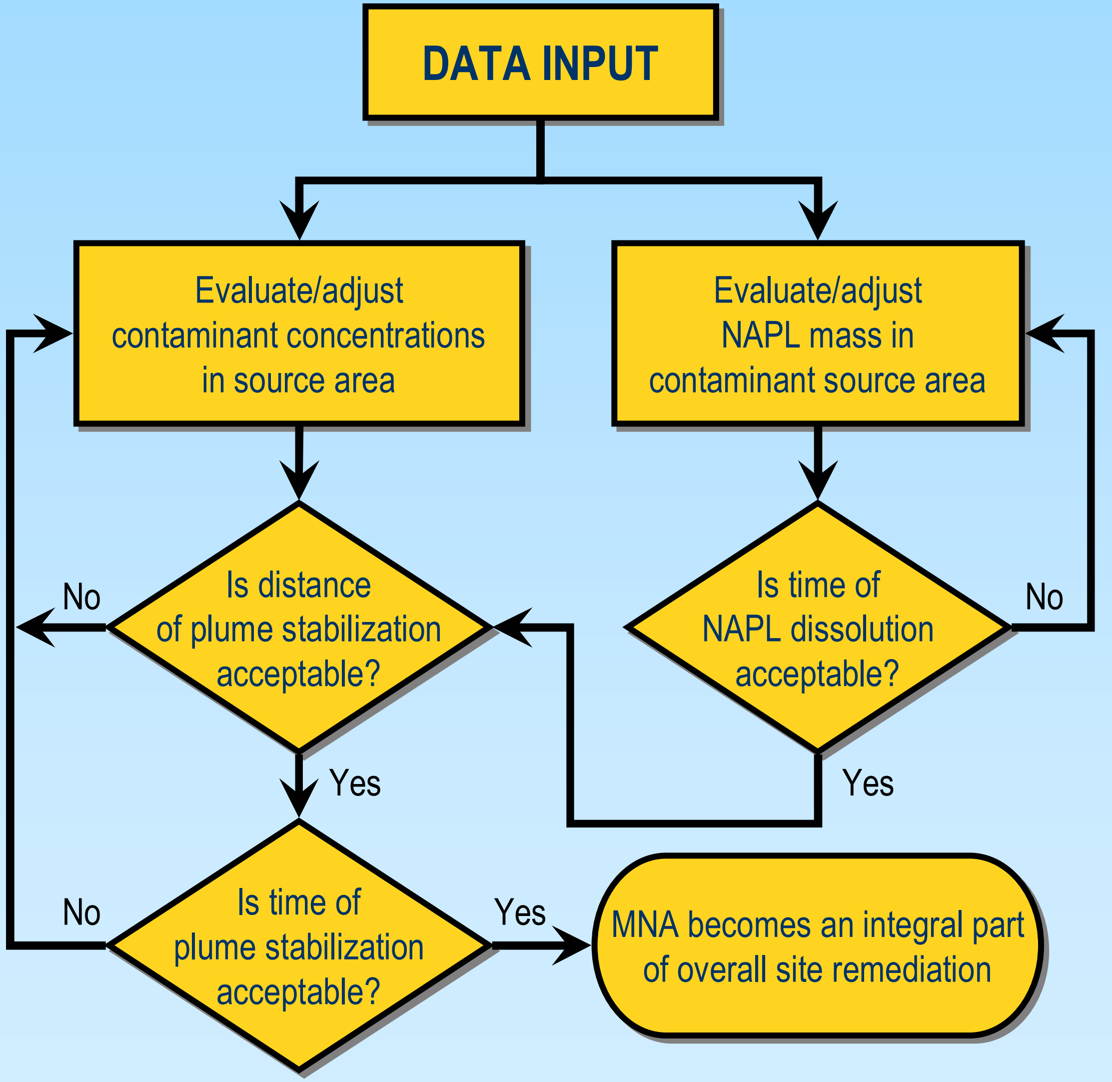
- "Sites where the contaminant plumes are no longer increasing in extent, or are shrinking, would be the most appropriate candidates for MNA remedies."

Transition from a Remedial System to MNA (cont.)

<u>Natural Attenuation Software (NAS)</u>

- Distance of plume stabilization
- Time of plume stabilization
- Time of NAPL dissolution problems

- For petroleum hydrocarbons and chlorinated ethenes
- Designed to aid the user in assembling and organizing the data needed to estimate time of remediation
- Guidance – Methodology for Estimating Times of Remediation Associated with Monitored Natural Attenuation (USGS, 2003)



Transition from a Remedial System to MNA (cont.)

Case Studies

- Long Beach Naval Shipyard IR Sites 1 and 2, Long Beach, California
- Coastal Systems Station, Panama City, Florida
- Naval Air Engineering Station, Lakehurst, New Jersey
- Naval Submarine Base, Kings Bay, Georgia (application of NAS)

More Information:
Guidance for Optimizing Remedy Evaluation, Selection, and Design (Battelle for NAVFAC, December 2003)
http://www.terra-kleen.org/pdf/Chapter4.pdf
http://water.usgs.gov/pubs/wri/wri034057/pdf/WRIR-03-4057.pdf

Navy MNA Guidance:
http://enviro.nfesc.navy.mil/erb/erb_a/support/wrk_grp/artt/mna1198.pdf

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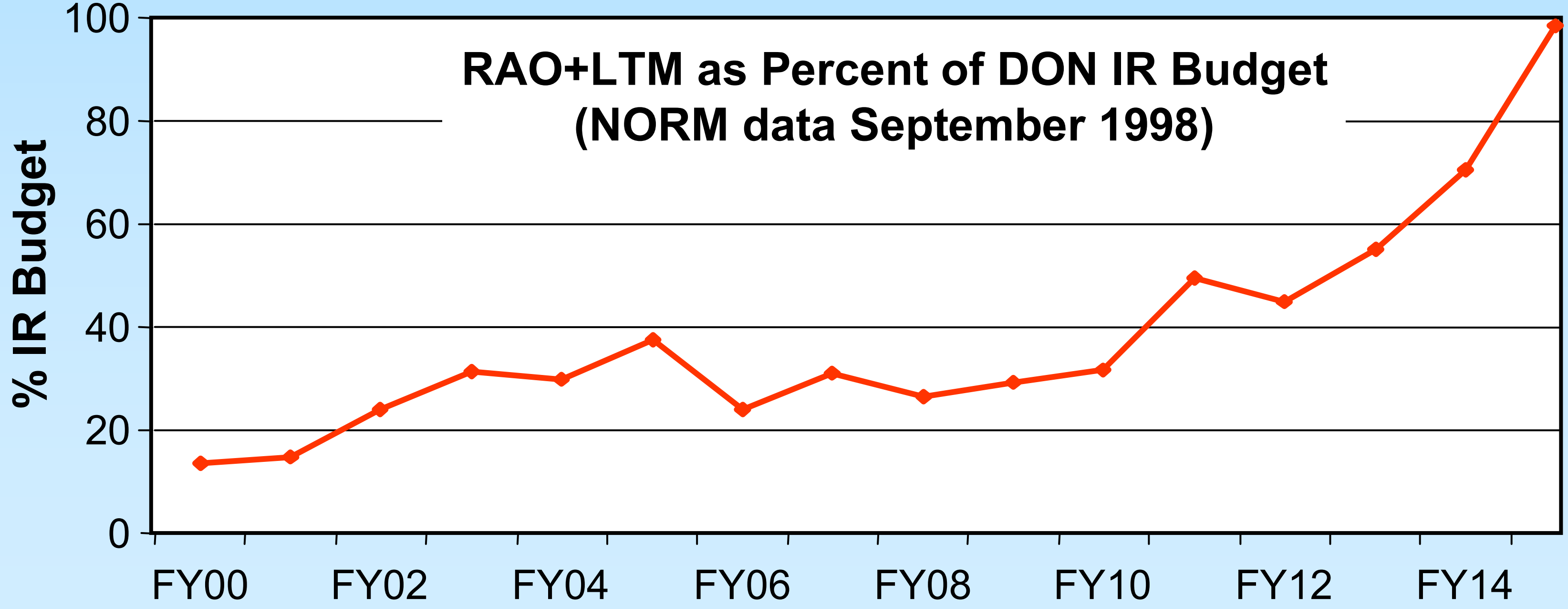
Long-Term Monitoring Optimization

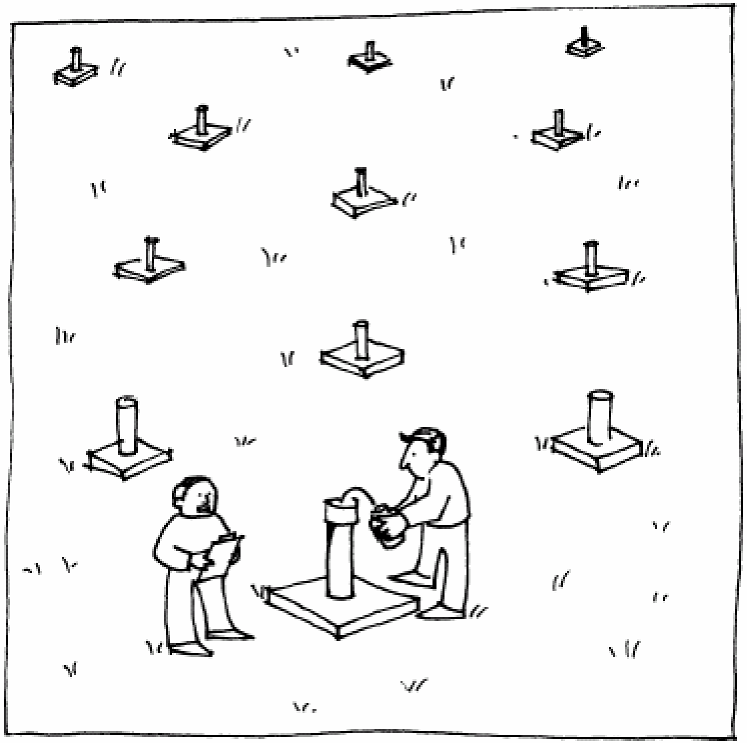
Guidance: Guide to Optimal Groundwater Monitoring (NFESC, January 2000)

- As the IR programs at DON installations mature, more money is spent on monitoring
- As monitoring program costs become a significant portion of the IR program budget, it becomes increasingly important to evaluate these programs in terms of cost effectiveness



Long-Term Monitoring Optimization (cont.)

- The five strategies that ensure a cost-effective monitoring program:
  - Reduce the number of monitoring points
  - Reduce the monitoring duration and/or frequency
  - Simplify analytical protocols
  - Ensure efficient field procedures
  - Streamline data management and reporting



Hurry up… it's almost time to start the next sampling round!

Long-Term Monitoring Optimization (cont.)

Reduce the number of monitoring points

- Hydrogeologic & qualitative assessment
  - Relevancy
  - Reliability
  - Regulatory
- Spatial redundancy (geostatistical analysis)
- Decision criteria for reducing spatial redundancy

Long-Term Monitoring Optimization (cont.)

Reduce the monitoring duration and/or frequency

- Aquifer flow calculations to determine monitoring frequency and duration
- Temporal redundancy – concentration trend analysis and statistics to optimize monitoring frequency and duration
- Decision criteria for reducing frequency and duration

Long-Term Monitoring Optimization (cont.)

Simplify analytical protocols

- Focus on contaminants of concern
- Eliminate background chemicals
- Comparison to regulatory standard
- Indicator species
- Quality control (QC) samples
- Decision criteria

But we've always done it this way…

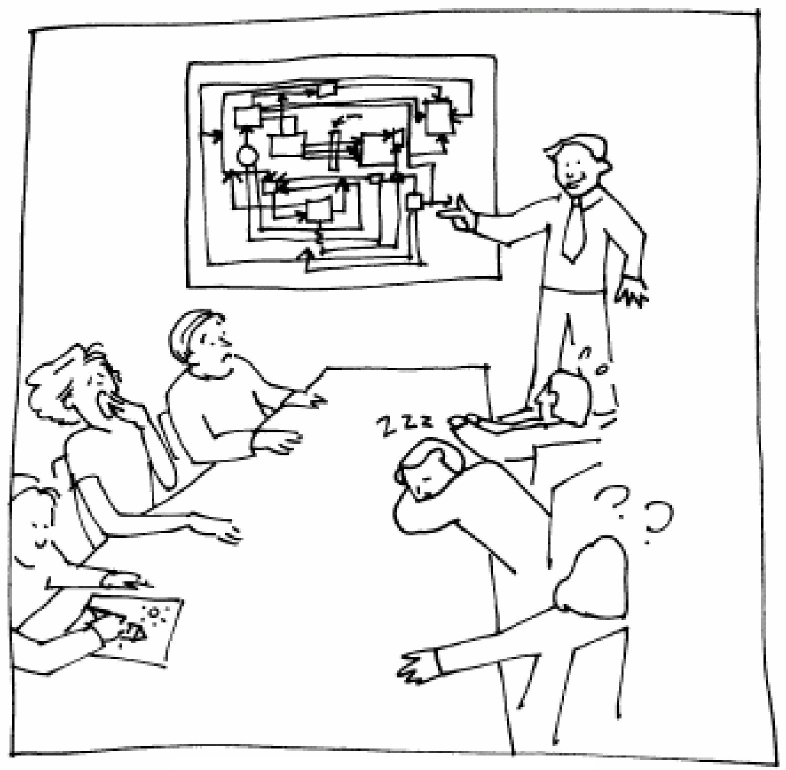
Ensure efficient field procedures

- Low-flow purging
- Dedicated equipment
- Diffusion samplers

Long-Term Monitoring Optimization (cont.)

Streamline data management and reporting

- Statistical and geostatistical tools
- Graphical and tabular formats
- GIS
- Custom databases
- Electronic data



It's really quite simple!

Long-Term Monitoring Optimization (cont.)

Methods

- GTS Algorithm – AFCEE
- MAROS (Monitoring and Remediation Optimization System)
- MNO (Monitoring Network Optimization) – Parsons
- CES (Cost-Effective Sampling) – DOE/LLNL
- Others

Long-Term Monitoring Optimization (cont.)

Case Studies

- **Naval Weapons Station Industrial Reserve Plant Dallas, Grand Prairie, Texas**
- **Marine Corps Base Camp Lejeune, North Carolina**
- **Naval Air Station Patuxent River, Maryland**

More Information:

http://enviro.nfesc.navy.mil/erb/erb_a/support/wrk_grp/raoltm/case_studies/dallasfinal(11-15-99).pdf

http://enviro.nfesc.navy.mil/erb/erb_a/support/wrk_grp/raoltm/case_studies/MCBCampLejeune.pdf

http://enviro.nfesc.navy.mil/erb/erb_a/support/wrk_grp/raoltm/case_studies/paxriver(11-15-99).pdf

Navy Guidance:

http://enviro.nfesc.navy.mil/erb/erb_a/support/wrk_grp/raoltm/case_studies/Int_Final_Guide.pdf

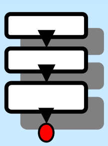
Monitoring and Optimization Tools – Summary

- Attempt to optimize at each phase of the IR process
- Many new tools are available

Field investigation and monitoring

Data management

GIS and visualization



Remedial system optimization

MNA becomes an integral part of overall site remediation

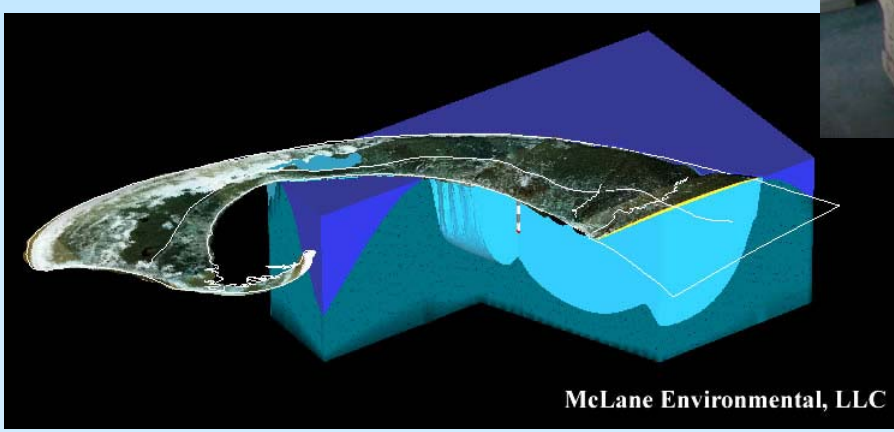
Transition from source control to MNA

Long-term monitoring optimization

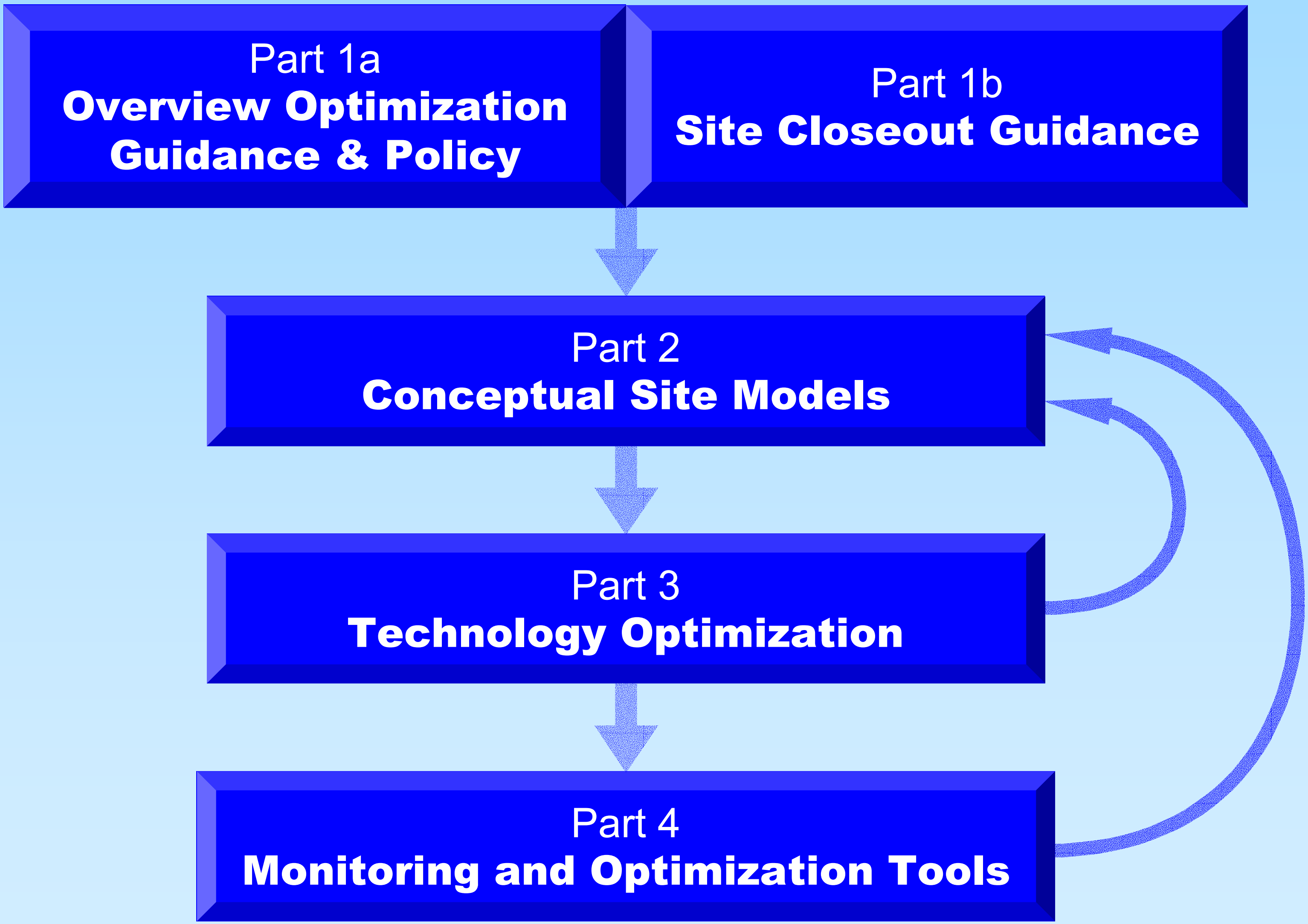
Monitoring and Optimization Tools – Summary (cont.)

- New tools hold promise for:
  - Streamlined characterization
  - Streamlined monitoring and efficient remedial systems
  - Accelerated cleanup
  - Cost savings
- Some tools and techniques may require specialized training

Questions and Discussion



RITS Spring 2004: Optimization of Remedial Actions



Points of Contact

- Adrianne Saboya, Public Works Center (PWC), San Diego, CA (TRIAD, SCAPS)
  - Email: adrianne.saboya@navy.mil
  - Phone: (619) 524-6949
- Dr. Mark Kram, NFESC, Port Hueneme, CA
  - Email: mark.kram@navy.mil
  - Phone: (805) 982-2669