Triad:

Beyond Characterization to Long-Term Management of Groundwater Contaminant Plumes

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Clu-In Webinar Workshop
12 September 2008

TECHNICAL OBJECTIVES

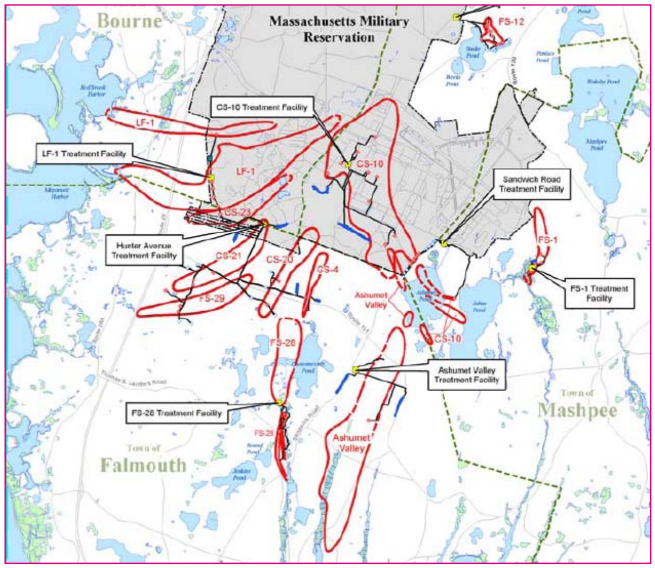
- Present a comprehensive approach to optimized characterization/remediation design/LTM
- Take Triad to next level
  - Use Triad based approaches to develop CSM
  - Use CSM to develop remediation and monitoring strategy
  - Integrate Triad/CSM/LTM components into streamlined process
  - Work towards single mobilization solutions

OUTLINE

- Innovative Direct Push Characterization Techniques
  - Chemical Distributions (MIP, LIF, FFD, UVOST, GeoVIS, ConeSipper, Waterloo*APS* Profiler)
  - Hydraulic Parameter Distributions (HRP, HPT)
  - 3D Flux Model Generation
- LTM Network Design
  - Spatial Considerations (2D/3D)
  - Well Design (ASTM vs. WDS)
- Sensor Technologies
  - Desktop Monitoring
  - Analytes (Today and in Near Future)
  - Components of a Wireless Telemetry System
- New LTM Approaches
  - Automation
  - Rapid Reporting/Assessment/Lines of Evidence

For additional information:
http://clu-in.org/char/technologies/dpanalytical.cfm

Overview of an L&D Plume: Massachusetts Military Reservation (MMR) Site



Adapted from CH2MHill, AFCEE

Massachusetts Military Reservation

- Numerous large & dilute TCE plumes
- Some plumes 2 miles long
- Using Pump & Treat for 10 years
- Over **$400 million** has been spent to date on investigation and cleanup
- The estimated total long term cost: **$850 million**
- Current status: 12 plumes require LTM (at least)

Adapted from
CH2MHill, AFCEE

SEEPAGE VELOCITY AND FLUX

Seepage velocity **(ν):**

$$\nu = \frac{Ki}{\rho} \quad \text{(length/time)}$$

where:
K = hydraulic conductivity
i = hydraulic gradient
ρ = effective porosity

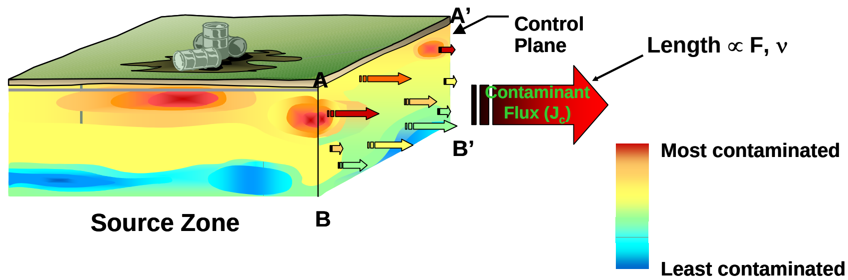
Contaminant flux (F):

$$F = \nu\,[X]$$

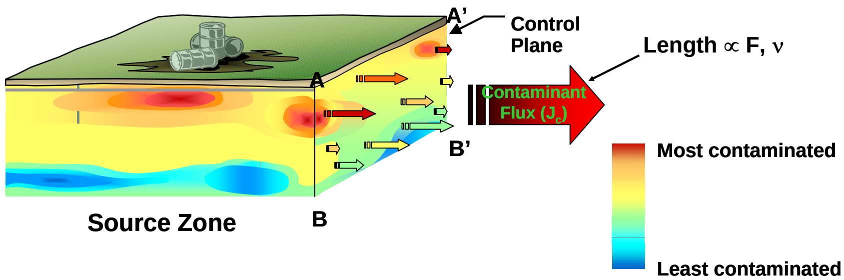
(mass/length^2-time; mg/m^2-s)

where:
ν = seepage velocity (length/time; m/s)
[X] = concentration of solute (mass/volume; mg/m^3)

CONCENTRATION VS. FLUX



CONCENTRATION VS. FLUX



High Concentration ≠ High Risk!!
Concentration and Hydraulic Component

STREAMLINED APPROACH

Plume Delineation

- MIP, LIF, ConeSipper, Field Lab, etc.
- 2D/3D Concentration Representations
- CPT Data for Well Design

Hydro Assessment

- High-Res Piezocone (2D/3D Flow Field, K, head, eff. Por.)
- Conventional Approaches (e.g., Wells, Aq. Tests, etc.)

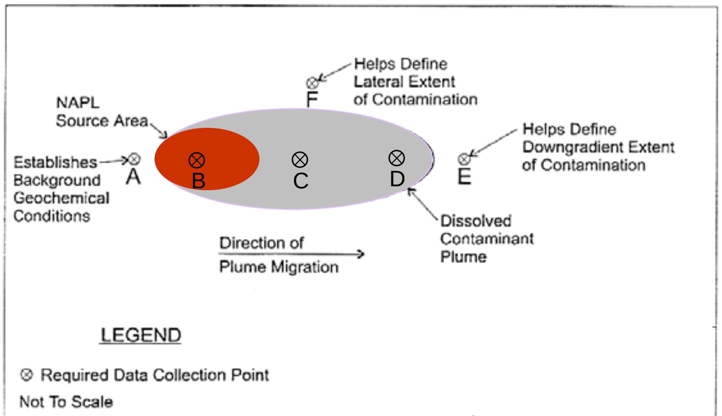
LTM Network Design

- WDS based on CPT Data
- G.S.D. via ASTM D5092
- Field Installations (Clustered Short Screened Wells)

Surveys (Lat/Long/Elevation)

GMS Interpolations (ν, F), Initial Models

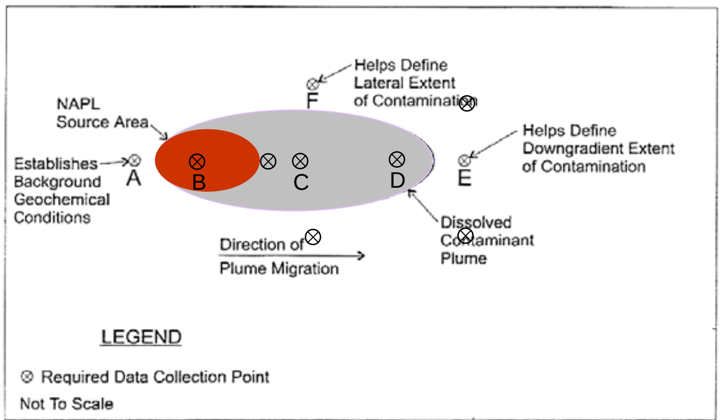
GW Plume Characterization Strategy



Wiedemeier et al., 1996

3D – Depth Specific Info; Wells or Continuous Profile

GW Plume Characterization Strategy



Wiedemeier et al., 1996

3D – Depth Specific Info; Wells or Continuous Profile

CONE PENETROMETER

Self-Contained Field Lab: *Soil Type, Chemistry, Samples, Wells, Hydrogeology, Tracer Injection, Amendments, etc.*

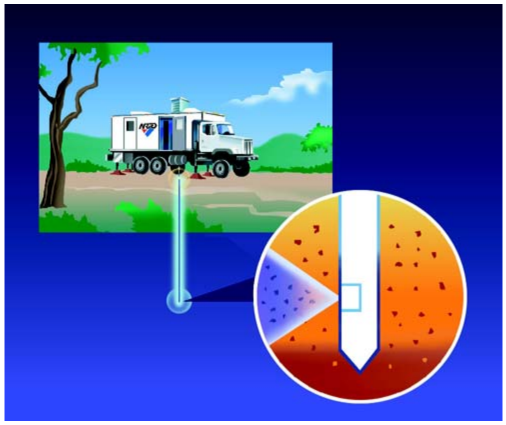
FLUORESCENCE PROBES

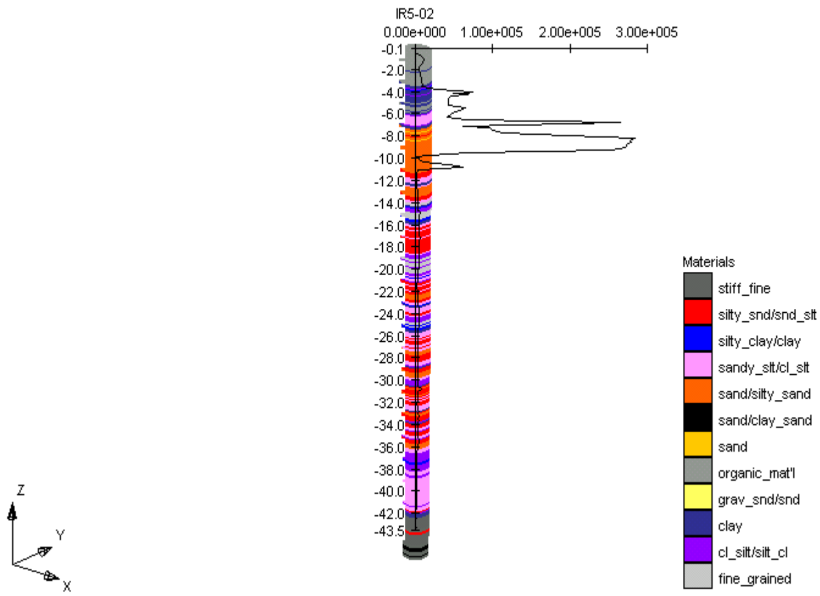
• Fiber optic-based chemical sensor probe equipped with sapphire window;

• Light source induces fluorescence;

• Signal returns to surface for depth discrete analysis;

• Can be coupled with additional sensors (soil type, video, etc.).

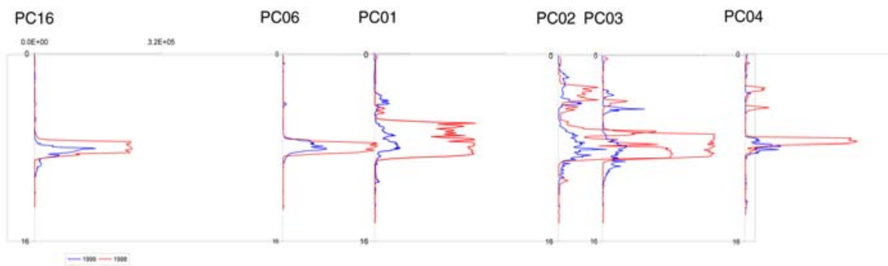



IR5-02
0.00e+000
1.00e+005
2.00e+005
3.00e+005
-0.1
-2.0
-4.0
-6.0
-8.0
-10.0
-12.0
-14.0
-16.0
-18.0
-20.0
-22.0
-24.0
-26.0
-28.0
-30.0
-32.0
-34.0
-36.0
-38.0
-40.0
-42.0
-43.5
Z
Y
X
Materials
stiff_fine
silty_snd/snd_slt
silty_clay/clay
sandy_slt/cl_slt
sand/silty_sand
sand/clay_sand
sand
organic_mat'l
grav_snd/snd
clay
cl_silt/silt_cl
fine_grained

LIF Data

Remediation Performance

(Before and After Steam Enhanced Extraction)



FLUORESCENCE PROBES

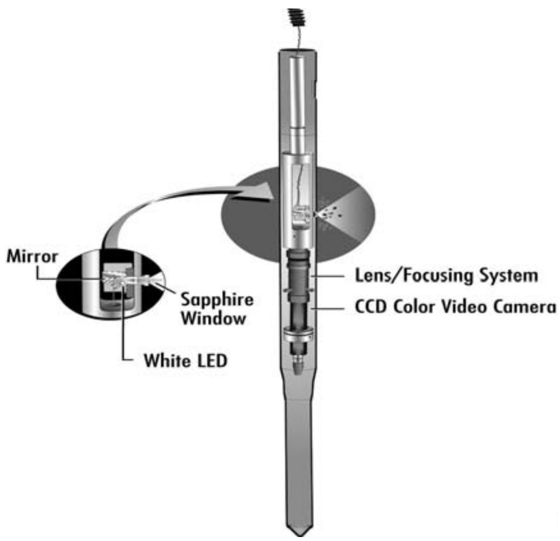
Pro:

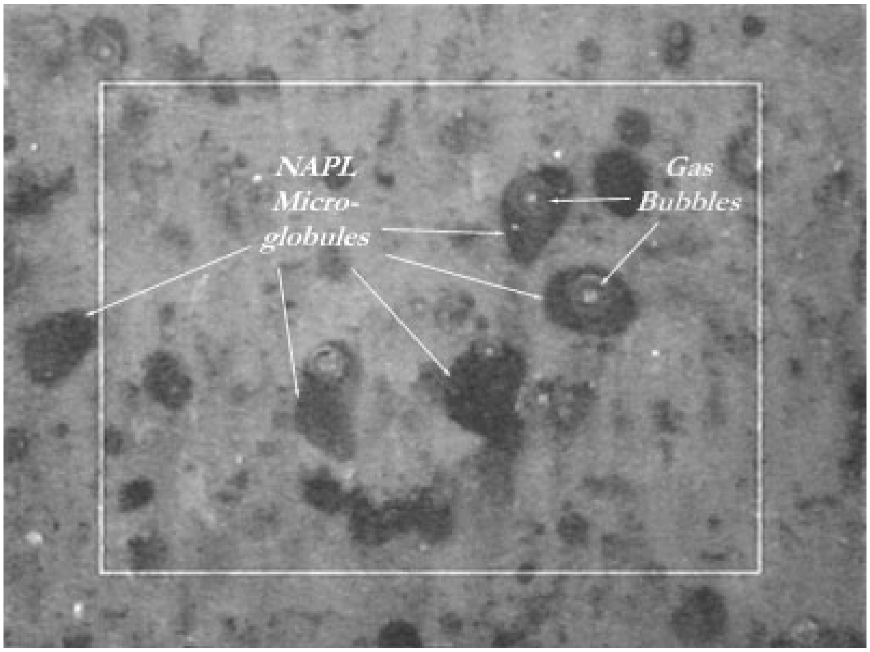
- NAPL evidence based on sensitive UV fluorescence of fuel constituents or co-mingled materials (multi-ring fuel compounds, etc.);
- Can rapidly measure in real time;
- Depth discrete signals;
- Can be coupled with lithologic sensors for correlation, well design;
- Good screening method with high resolution;
- Can use several off-the-shelf energy sources (UVOST, FFD, LIF);
- Cal EPA Certification and ASTM Standard.

Con:

- Limited by lithology;
- False negatives and positives possible due to wavelength dependency;
- Not analyte-specific;
- Semi-quantitative so requires confirmation samples.

GeoVIS


Mirror
Sapphire Window
White LED
Lens/Focusing System
CCD Color Video Camera



Box is 2.5mm x 2mm

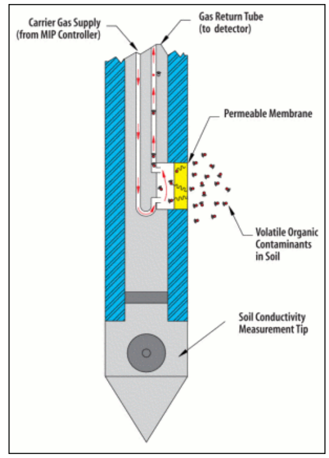
GeoVIS

Pro:
- Unique perspective regarding subsurface reality;
- Only true NAPL confirmation tool;
- Can generate continuous graphic profile;
- Can provide some hydro info (porosity, g.s.d., NAPL saturation).

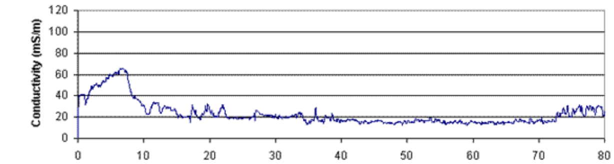
Con:
- Rate of data collection limited by ability to visibly process information;
- Transparent NAPL droplets can be present and not detectable in current configuration;
- Limited by lithology;
- Porosity estimates poor in silty sands;
- Semi-quantitative assessment;
- Pressure or heat front may force droplets away from window.

Membrane Interface Probe

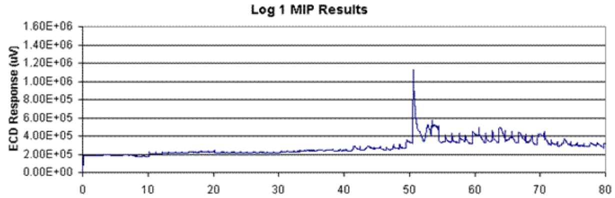
- Screening tool with semi-quantitative capabilities.
- Membrane is semi-permeable and is comprised of a thin film polymer impregnated into a stainless steel screen for support.
- The membrane is placed in a heated block attached to the probe and heated to approximately 100-120 degrees C.
- Analyses of vapors at surface via GC and various detectors.



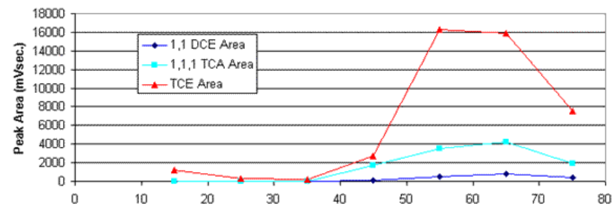
Log 1 Conductivity Results



Log 1 MIP Results



Log 1 MIP/Trap Results



MIP

Pro:
- Excellent chemical screening tool;
- Can generate continuous profile or focus on specific depth;
- Analyte specific;
- Many types of analytes (VOCs, semi-VOCs);
- Can be coupled with lithologic sensors for correlation.

Con:
- When operating with a non-continuous configuration, user needs to determine appropriate target sample depths while "on the fly";
- Constant operational conditions not always possible;
- Bulk fluids can not travel across membrane;
- Semi-quantitative;
- Clogging and carry-over can occur (some work-arounds);
- Limited by lithology;
- Heat front or pressure front may inhibit membrane contact with contaminant.

CONESIPPER

- Soil-gas and water sampler;
- Pneumatic valving;
- 200 foot depth capacity;
- Inert gas used to move samples to surface;
- Up to 80ml samples;
- Downhole decontamination;
- Great for focused MIP confirmation.

CONESIPPER

Pro:

- Depth discrete samples
- Vapor and liquid samples
- Can be coupled with rapid analyses (min. holding time concern)
- Excellent confirmation for MIP, UV Fluorescence, etc.

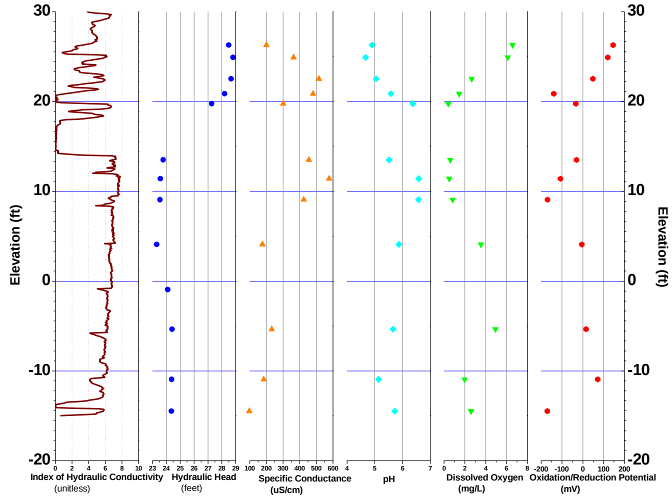
Con:

- Decontamination concerns
- Single depth sample per push (not continuous)
- Not typically coupled with sensors (exceptions)
- Clogging can occur
- Limited by lithology (fines can be difficult)
- Pressure or heat front may cause displacement

WATERLOO^{APS} ADVANCED PROFILING SYSTEM

- Collect samples
- Couple with field analyses (GC, etc.)
- Measure head
- Measure index of K
- Measure physicochem properties (pH, conductance, D.O., redox, T) via in-line flow-through cell
- Can grout through tip

WATERLOO^{APS} ADVANCED PROFILING SYSTEM



WATERLOO^APS ADVANCED PROFILING SYSTEM

Pro:

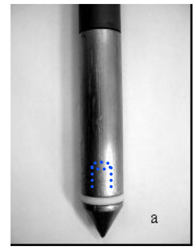
- Depth discrete samples
- Vapor and liquid samples
- Can be coupled with rapid analyses (min. holding time concern)
- Hydro info (head, relative K)
- Excellent confirmation and CSM tool

Con:

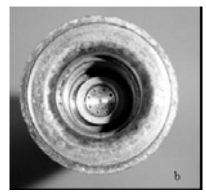
- Limited by lithology
- K values not quantified, so limited modeling capabilities
- Pressure or heat front may cause displacement

High-Resolution Piezocone

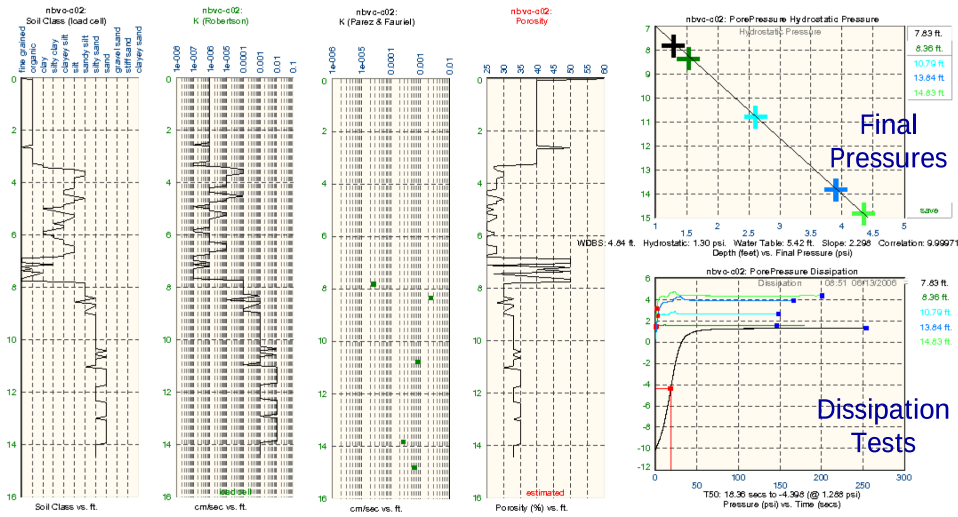
- Direct-Push (DP) Sensor Probe that Converts Pore Pressure to Water Level or Hydraulic Head
- Head Values to ± 0.08ft (to >60' below w.t.)
- Can Measure Vertical Gradients
- Simultaneously Collect Soil Type and K
- K from Pressure Dissipation, Soil Type
- Minimal Worker Exposure to Contaminants
- System Installed on NAVFAC SCAPS
- Licensed to AMS



Custom Transducer

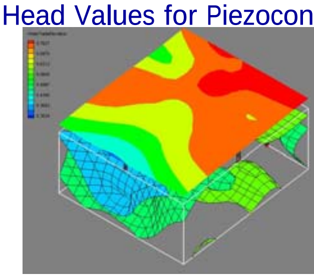


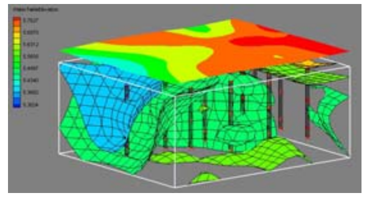
PIEZOCONE OUTPUT

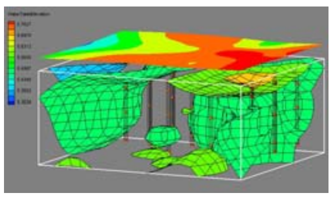


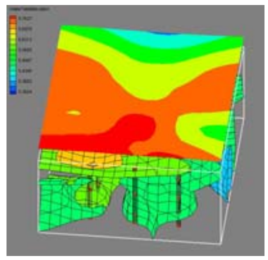
HRP TESTS
(6/13/06)

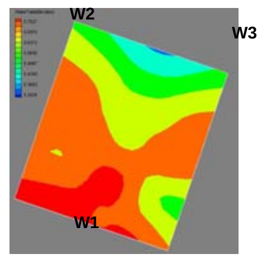
Head Values for Piezocone







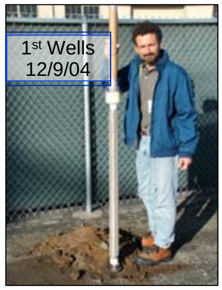




Displays shallow gradient

FIELD EFFORTS


Site Characterization with High Resolution Piezocone 11/22/04

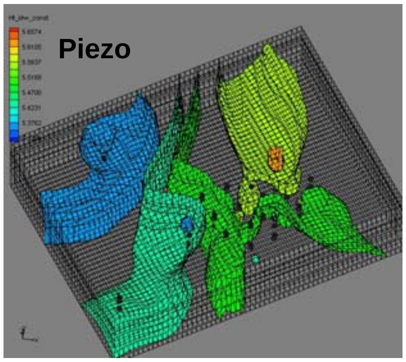

1st Wells 12/9/04

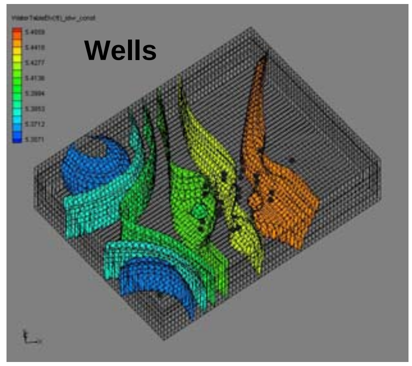

Well Development & Hydraulic Test 8/24/05


Installation ¾" Wells 7/28/05


Field Demo 6/13/06

HEAD DETERMINATION
(3-D Interpolations)





- Shallow gradient (5.49-5.41'; 5.45-5.38' range in clusters over 25')
- In practice, resolution exceptional (larger push spacing)

GMS MODIFICATIONS

Gradient, Velocity and Flux Calculations

- **Convert Scalar Head to Gradient [Key Step!]**

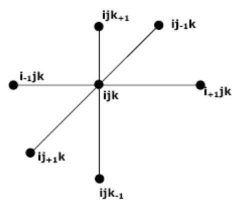
GMS MODIFICATIONS

Gradient, Velocity and Flux Calculations

- ➢ **Convert Scalar Head to Gradient [Key Step!]**

Calculating Hydraulic Gradient

For an interior node:



$$\frac{\partial h}{\partial x} = \frac{\dfrac{h_{i_{+1}jk} - h_{ijk}}{x_{i_{+1}jk} - x_{ijk}} + \dfrac{h_{ijk} - h_{i_{-1}jk}}{x_{ijk} - x_{i_{-1}jk}}}{2}$$

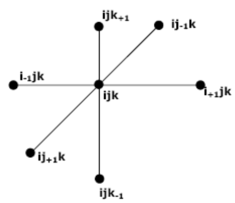
GMS MODIFICATIONS

Gradient, Velocity and Flux Calculations

- ➢ **Convert Scalar Head to Gradient [Key Step!]**
  - ➢ **Merging of 3-D Distributions to Solve for Velocity**
  - ➢ **Merging of Velocity and Concentration (MIP or Samples) Distributions to Solve for Contaminant Flux**

Calculating Hydraulic Gradient

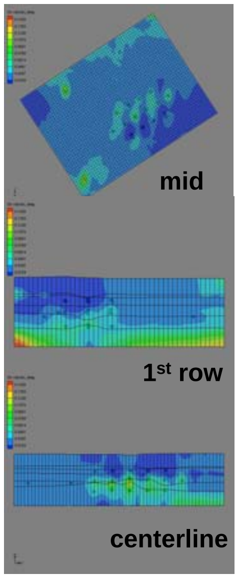
For an interior node:



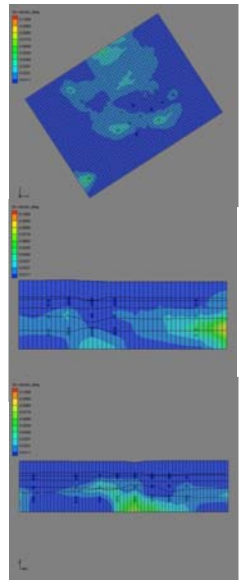
$$\frac{\partial h}{\partial x} = \frac{\frac{h_{i_{+1}jk} - h_{ijk}}{x_{i_{+1}jk} - x_{ijk}} + \frac{h_{ijk} - h_{i_{-1}jk}}{x_{ijk} - x_{i_{-1}jk}}}{2}$$

VELOCITY DETERMINATION
(cm/s)

Well

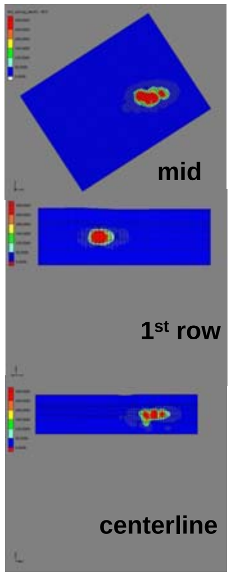


Piezo (mean K)

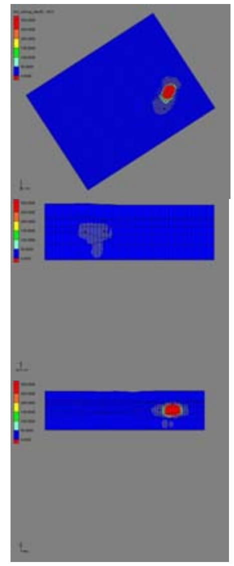


FLUX DETERMINATION
(Day 49 Projection)

Well



Piezo (mean K)

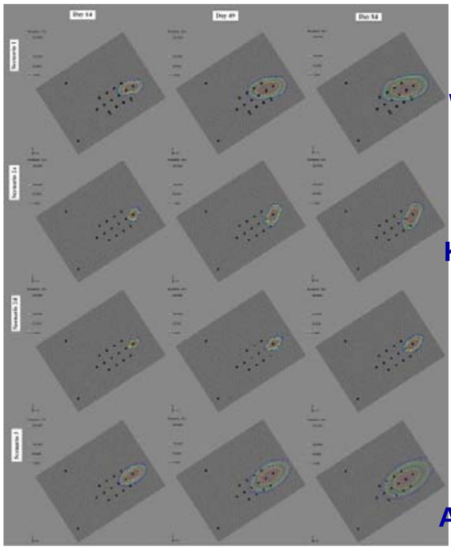


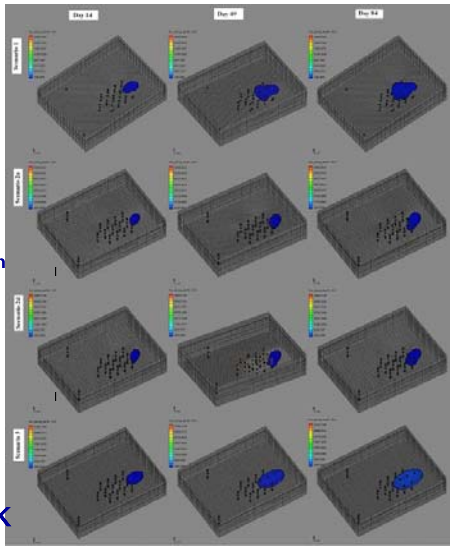
ug/ft^2-day

MODELING
Concentration and Flux

Scenario	Head	K	Porosity
1	Well	Well	Average
2a	SCAPS	SCAPS K_{mean}	SCAPS
2b	SCAPS	SCAPS K_{min}	SCAPS
2c	SCAPS	SCAPS K_{max}	SCAPS
2d	SCAPS	SCAPS K_{lookup}	SCAPS
3	Well	Well	SCAPS
4a	Well	SCAPS K_{mean}	SCAPS
4b	Well	SCAPS K_{min}	SCAPS
4c	Well	SCAPS K_{max}	SCAPS
4d	Well	SCAPS K_{lookup}	SCAPS
5	Unif. grad.	Average	Average

MODELING
Concentration and Flux





ppb

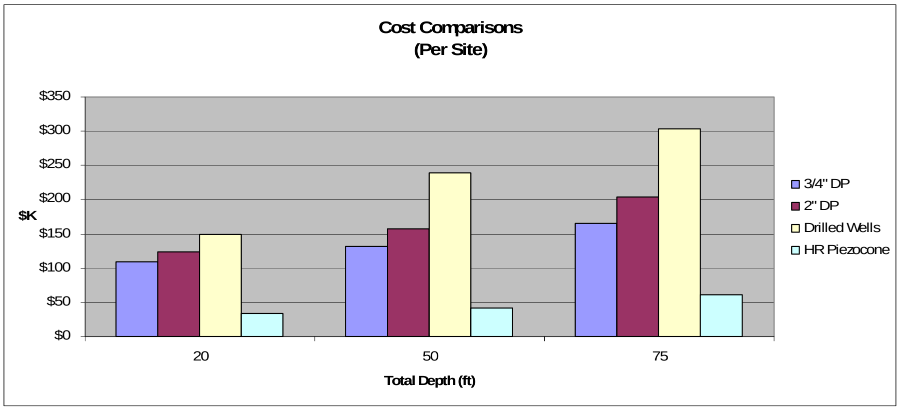
ug/ft²-day

PERFORMANCE

Performance Summary.

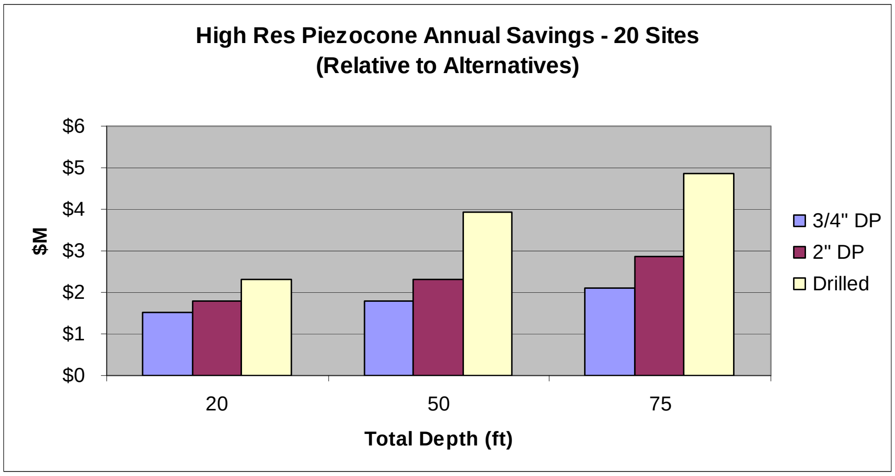
Performance Criteria	**Expected Performance Metric**	**Results**
Accuracy of high-resolution piezocone for determining head values, flow direction and gradients	± 0.08 ft head values	Met Criteria
Hydraulic conductivity (dissipation or soil type correlation)	± 0.5 to 1 order of magnitude	Met Criteria
Transport model based on probes	Predicted breakthrough times and concentrations within one order of magnitude; probe based model efficiency accounts for more than 15% of the variance associated with well based models	Met Criteria
Time required for generation of 3-D conceptual and transport models	At least 50% reduction in time	Met Criteria

FLUX CHARACTERIZATION
Cost Comparisons



"Apples to Apples" – HR Piez. with MIP vs. Wells, Aq. Tests, Samples
10 Locations/30 Wells

FLUX CHARACTERIZATION
Cost Comparisons



Early Savings of ~$1.5M to $4.8M

FLUX CHARACTERIZATION
Time Comparisons

	Days to Complete		
Depth (ft)	Direct-Push Wells	Drilled Wells	HR Piezocone
20	90	104	13
50	99	137	15
75	111	151	19

"Apples to Apples" – HR Piez. with MIP vs. Wells, Aq. Tests, Samples
10 Locations/30 Wells

HIGH-RESOLUTION PIEZOCONE

Pro:

- Rapid site characterization
- Depth discrete hydraulic characterization (can even determine whether confined)
- Vertically continuous soil type data
- Profiles of head, K, effective porosity, and 3D distributions of seepage velocity and flux now possible
- Significantly lower costs relative to conventional methods
- Greater accuracy and usefulness of transport models
- Data can be used for monitoring well design without need for sample collection (e.g., Kram and Farrar well design method)
- Less worker exposure to contaminants
- Updated ASTM standard (D6067)

Con:

- Not applicable when gravels or consolidated materials are present
- Data distributions rely on geostatistical interpolation, so extreme conditions between measurement locations can be difficult to estimate
- Aquifer storage not determined
- Hydraulic head measurements can only resolve changes of 1" or greater.

Final Report: http://www.clu-in.org/s.focus/c/pub/i/1558/

HYDRAULIC PROFILING TOOL

- Measures pressure response of soil to water injections;
- Relative K characterization, but helpful for migration pathway and remediation design;
- Static water levels;
- Refined soil type characteristics (when combined with EC sensor);
- Can be advanced with percussion or hydraulic push rig.

HYDRAULIC PROFILING TOOL

Pro:

- Continuous profiling;
- Useful for remediation design;
- Can be combined with soil type (EC) indicators;
- Excellent conceptual modeling tool.

Con:

- K values not quantified, so limited modeling capabilities;
- Theory behind K derivations may require additional lab effort (but would potentially lead to quantification);
- EC soil type not as resolved in silty sand to sand.

LTM NETWORK DESIGN CONSIDERATIONS

Well Design
- ASTM
- CPT Based (Kram and Farrar)

Well Placement
- 2D vs. 3D (long vs. short screens)
- 3D Spacing

Well Installation
- Prepack Options

ASTM D5092 FILTER PACK

- Granular material of known chemistry and selected grain size and gradation installed in the annulus between screen and borehole wall;
- Filter pack grain size and gradation selected to allow only the finest materials to enter screen during development (well conditioning);
  - 30% finer (d-30) grain size that is 4 to 10 times greater than d-30 of screened unit;
  - Slot size to retain 90-99% of filter pack.

ASTM D5092 FILTER PACK

- Granular material of known chemistry and selected grain size and gradation installed in the annulus between screen and borehole wall;
- Filter pack grain size and gradation selected to allow only the finest materials to enter screen during development (well conditioning);
  - 30% finer (d-30) grain size that is 4 to 10 times greater than d-30 of screened unit;
  - Slot size to retain 90-99% of filter pack.

∴ Formation G.S. ⇒ Filter Pack Design ⇒ Slot Size Selection

ASTM D5092
FILTER PACK AND SLOT CRITERIA

TABLE 1 Recommended (Achievable) Filter Pack Characteristics for Common Screen Slot Sizes

Size of Screen Opening, mm (in.)	Slot No.	Sand Pack Mesh Size Name(s)	1 % Passing Size (D-1), mm	Effective Size, (D-10), mm	30 % Passing Size (D-30), mm	Range of Uniformity Coefficient	Roundness (Powers Scale)
0.125 (0.005)	5[A]	100	0.09 to 0.12	0.14 to 0.17	0.17 to 0.21	1.3 to 2.0	2 to 5
0.25 (0.010)	10	20 to 40	0.25 to 0.35	0.4 to 0.5	0.5 to 0.6	1.1 to 1.6	3 to 5
0.50 (0.020)	20	10 to 20	0.7 to 0.9	1.0 to 1.2	1.2 to 1.5	1.1 to 1.6	3 to 6
0.75 (0.030)	30	10 to 20	0.7 to 0.9	1.0 to 1.2	1.2 to 1.5	1.1 to 1.6	3 to 6
1.0 (0.040)	40	8 to 12	1.2 to 1.4	1.6 to 1.8	1.7 to 2.0	1.1 to 1.6	4 to 6
1.5 (0.060)	60	6 to 9	1.5 to 1.8	2.3 to 2.8	2.5 to 3.0	1.1 to 1.7	4 to 6
2.0 (0.080)	80	4 to 8	2.0 to 2.4	2.4 to 3.0	2.6 to 3.1	1.1 to 1.7	4 to 6

[A] A 5-slot (0.152-mm) opening is not currently available in slotted PVC but is available in Vee wire PVC and Stainless; 6-slot opening may be substituted in these cases.

ASTM D5092
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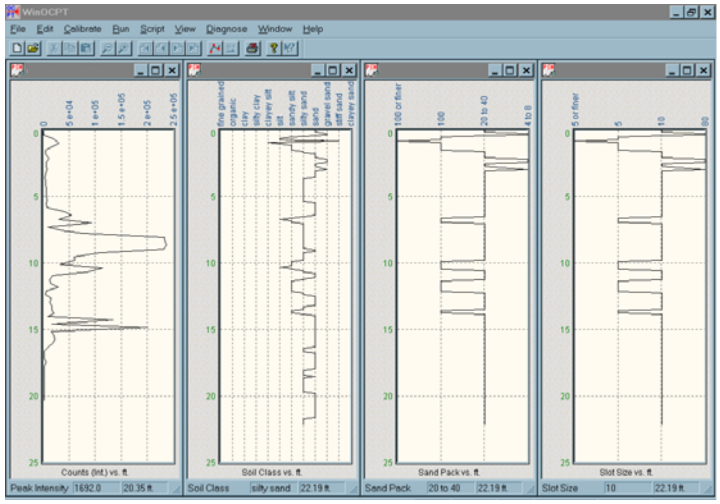
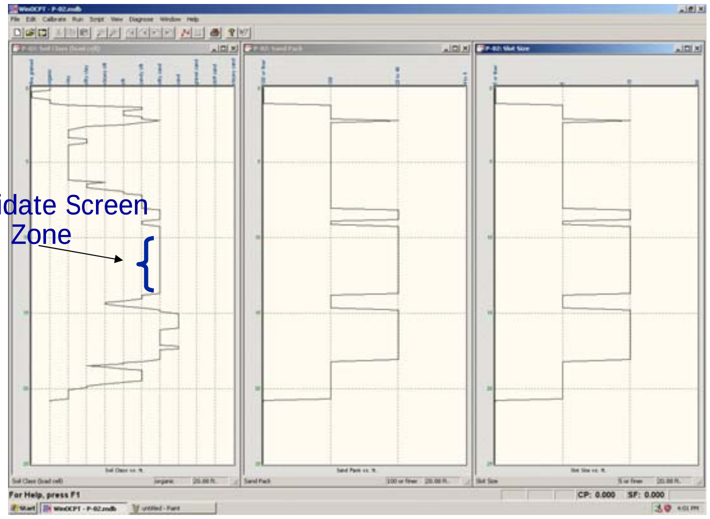
Most Commonly Used:
Not Good For Silty Sands or Finer!

NEW APPROACH FOR WELL DESIGN USING CPT SOIL DATA



Benefits: No need for sieve analysis (no samples); real-time design; customized multi-level design; save $, etc.

CPT-BASED WELL DESIGN



Kram and Farrar Well Design Method

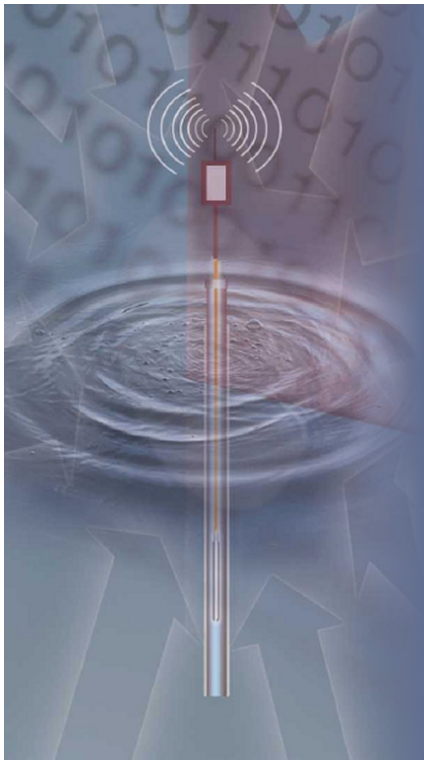
CONTAMINANT FLUX MONITORING STEPS

(Remediation Design/Effectiveness)

- Generate Initial Model (Seepage Velocity, Concentration Distributions)
  - Conventional Approaches
  - High Resolution Piezocone/MIP/Confirmation
- Install Customized 3D Monitoring Well Network
- Monitor Water Level and Concentrations (Dynamic)
- Track Flux Distributions (3D, Transects)
- Evaluate Remediation Effectiveness
  - Plume Status (Stable, Contraction, etc.)
  - Remediation Metric
  - Regulatory Metric?

GREGG'S PORTION

Sensor Technologies
- Desktop Monitoring
- Hydraulic Parameters
- Analytes (Today and in Near Future)
- Components of a Wireless Telemetry System
- Automated Monitoring



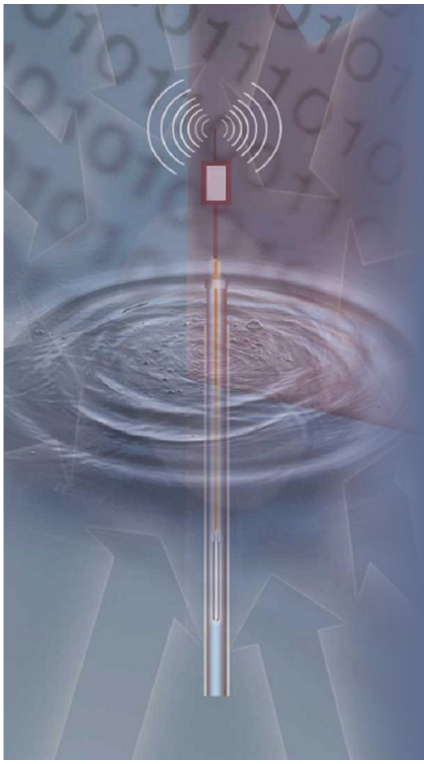
Long-Term Monitoring

Bringing Environmental Data to Your Desktop

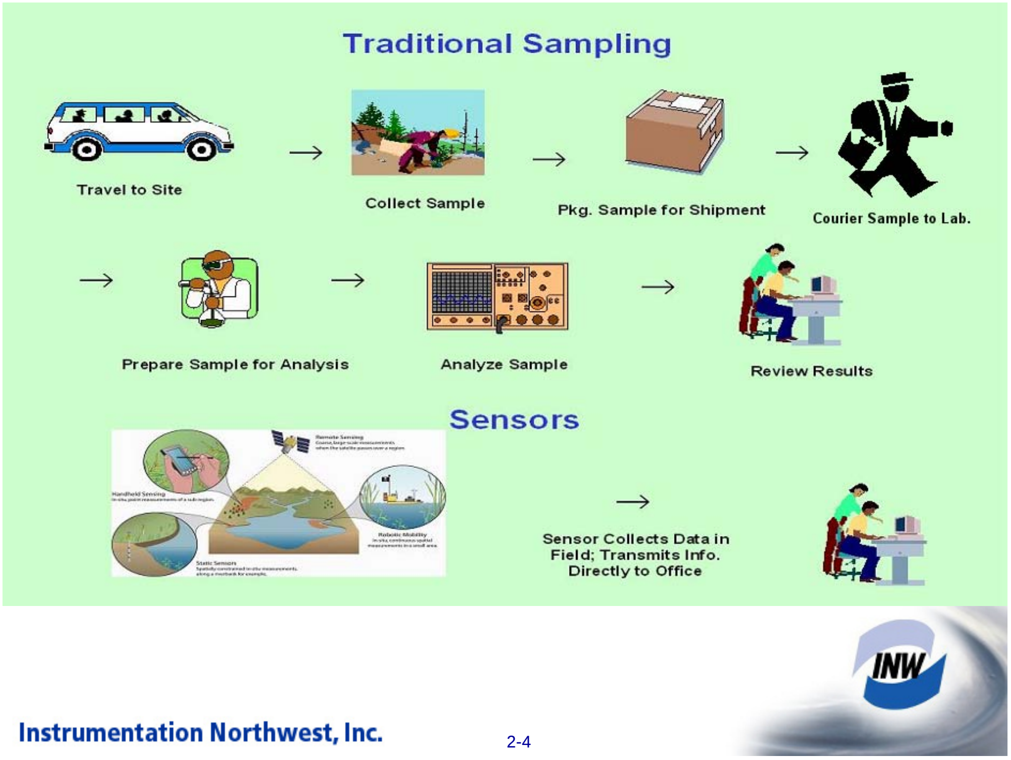
Presented by Gregg Gustafson
Instrumentation NW

Introduction

- Long Term Monitoring Systems
  - Sensors
  - Wireless
  - Software



Overview & Background Sensors vs Sampling

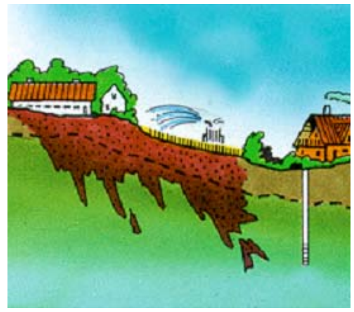

Traditional Sampling
Travel to Site
Collect Sample
Pkg. Sample for Shipment
Courier Sample to Lab.
Prepare Sample for Analysis
Analyze Sample
Review Results
Sensors
Sensor Collects Data in
Field; Transmits Info.
Directly to Office
Instrumentation Northwest, Inc.
2-4

Why monitor real time?

… Early Detection of pollution

Early detection

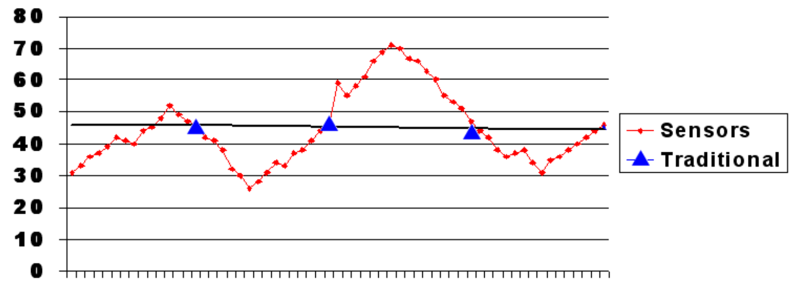
Easy to clean up



Late detection

Difficult to clean up

Why Monitor… Trends and variations



Traditional sampling and analysis methods only collect a limited amount of data; this can miss trends over time

Sensors gather much more data, providing useful information on temporal variations in contaminant levels that can be clearly defined

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Why Monitor… Remediation Performance Monitoring

- Automatically track dynamic parameters via sensors
  - Water level
  - Concentration
  - Etc.
- Route sensor data via software
  - expedited processing
  - Visualization
  - Reporting
- More data points than quarterly sampling
  - Better understanding for remediation evaluation
- Monitor specifically for
  - "Lines of evidence"
  - Plume status

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2-7

Today…

- Decision makers need
  - More data
  - From more locations
  - More frequently
  - Consistent with Triad Principles

Benefits

Technical

- Provides real time data on demand
- Assures accurate coordinated data across entire sites
- Enables monitoring of relatively inaccessible locations
- Improves safety – less need to enter hazardous areas
- Lower carbon footprint!

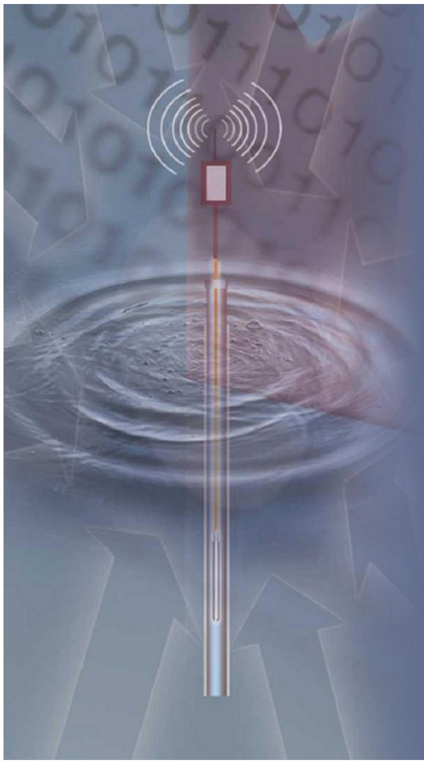
Benefits

Economic

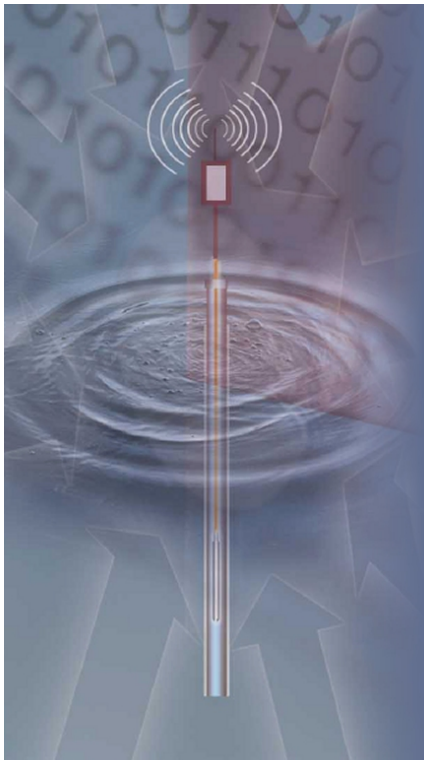
- Reduces expensive trips to each location
- Allows better focusing of staff
- Maximizes early detection of problems
  - Less cleanup cost
  - Less environmental damage
  - Less downtime
- Better information = better decisions

Are Sensors Suitable for Long Term Monitoring?…YES!

- **Useful parameters**
  - Can sensors measure what is needed?
- **Quality measurements**
  - Can sensors provide data that is accurate, stable, and traceable?
- **Ruggedness**
  - Are today's sensors rugged enough for harsh environments and rough handling?
- **Connectivity**
  - Easy to connect to the computer world?



Components of a Monitoring System



Sensors

Sensors - Measuring

- **Sensors must take measurements**
  - Accuracy
  - Drift
  - Range
  - Traceability
  - Resolution
  - Data Storage
  - Power Consumption
  - Immunity to:
    - Temperature Error
    - Noise
    - Shock & Abuse
    - Harsh Environments
    - Leaking

Sensors – Measuring

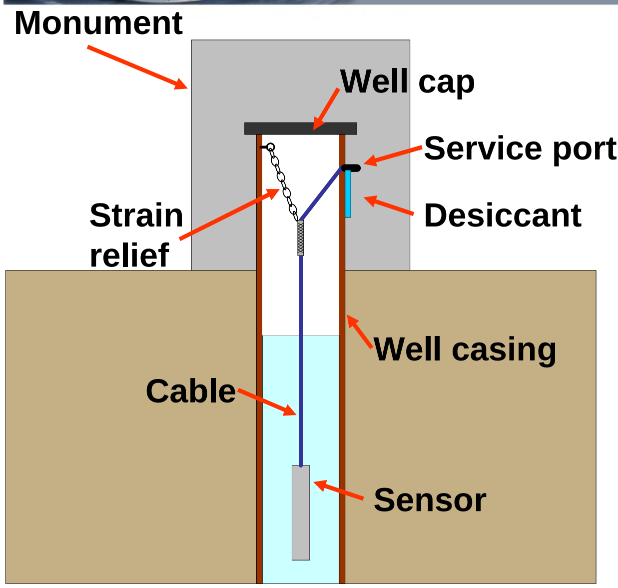
- Useful Parameters – Field Proven
  - Pressure
  - Temperature
  - pH/ISE/Orp
  - Conductivity
  - Dissolved Oxygen
  - Turbidity
  - TCE/ Field analytics

Sensors – Future

- Useful Parameters – In Development
  - Radiological
  - Chlorinated Hydrocarbons
  - Biological
  - RDX
  - Vapor Intrusion Analytes

Installation

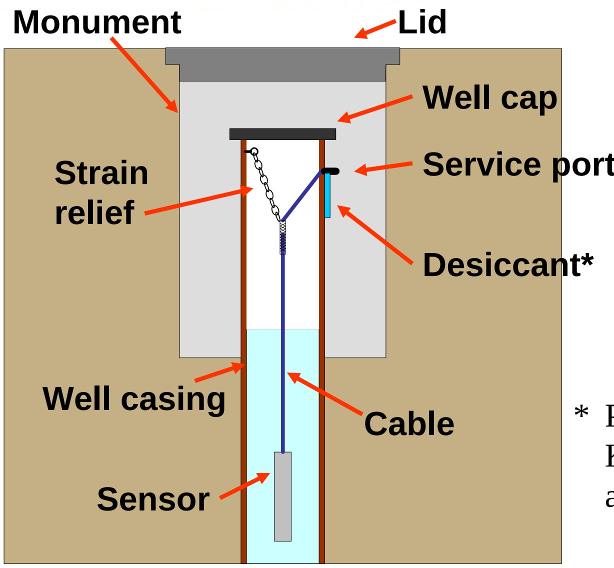
Sensors – Installation



Above Ground Monument

- Steel or fiberglass monument

Sensors – Installation

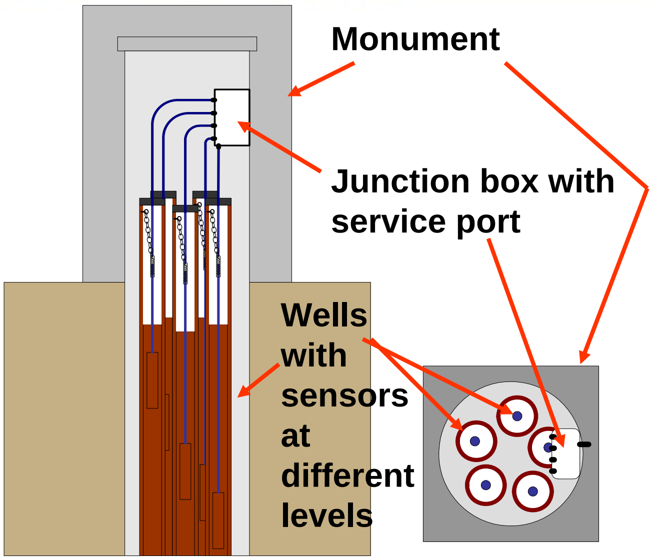


Below Ground Monument

- Steel or fiberglass flush mounted lid

* Prone to flooding!!
Keep desiccant dry or use absolute sensors.

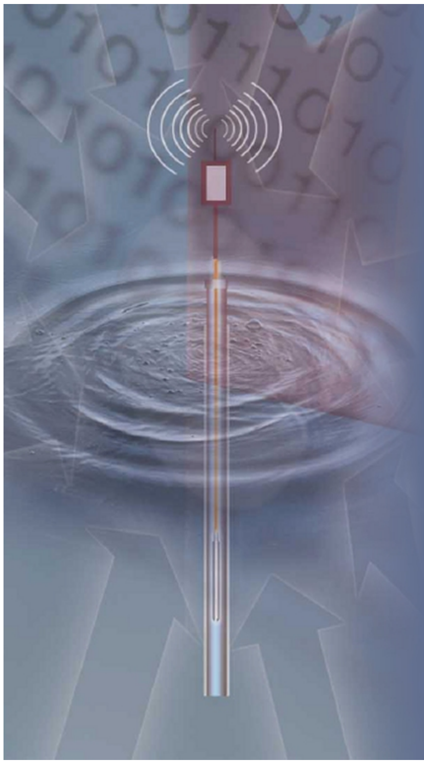
Sensors – Installation



Top view

Cluster Well Installation

- Above or below ground



Telemetry Systems

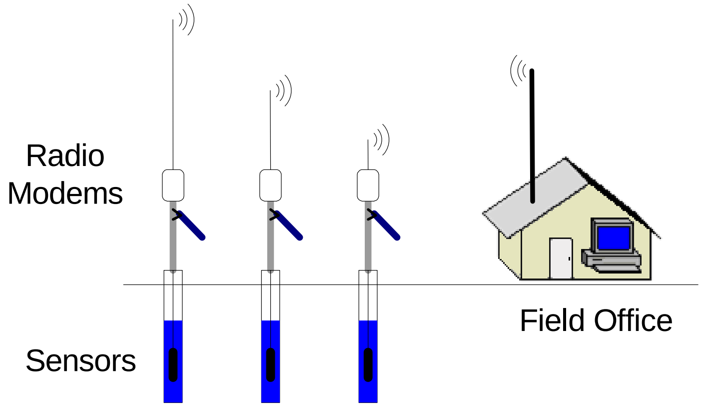
Telemetry Systems

May consist of:

- Radios
  - Single sets for up to about 5 miles
  - Repeater networks for extended coverage
- Modems
  - Cellular IP modems
  - Dialup modems
- Both
  - Networks combining both radios and modems offer great flexibility

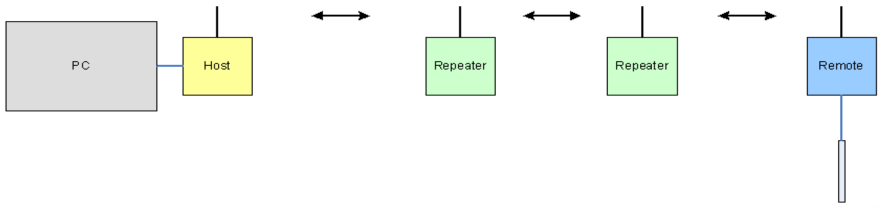
Telemetry- Radios

Typical Installation



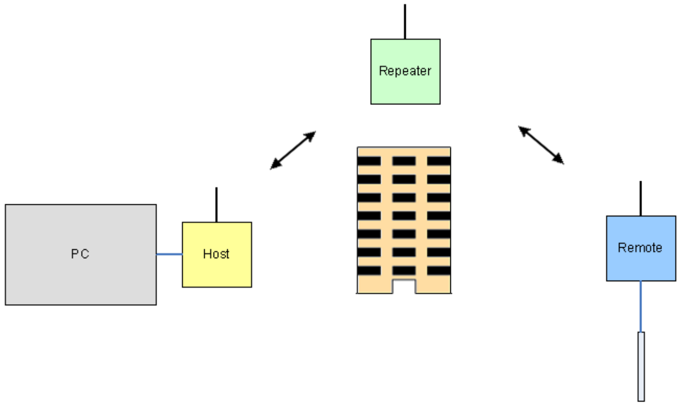
Sample Network – to reach longer distances or difficult locations

1 Radio Host, 2 Radio Repeaters, 1 Radio Remote, 1 Sensor



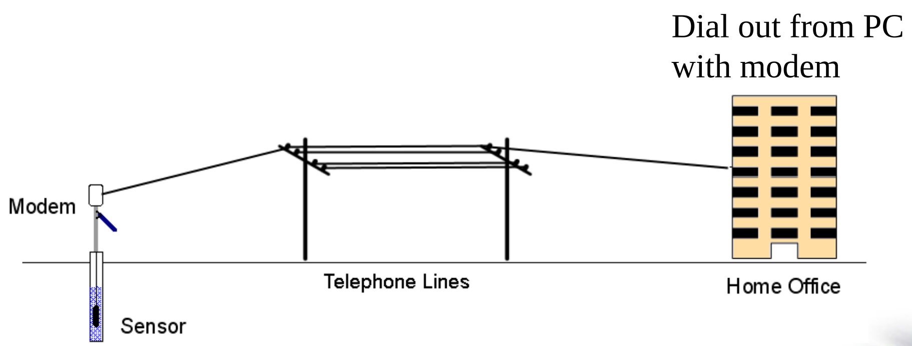
Sample Network – *to avoid an obstacle*

1 Radio Host, 1 Radio Repeater, 1 Radio Remote, 1 Sensor



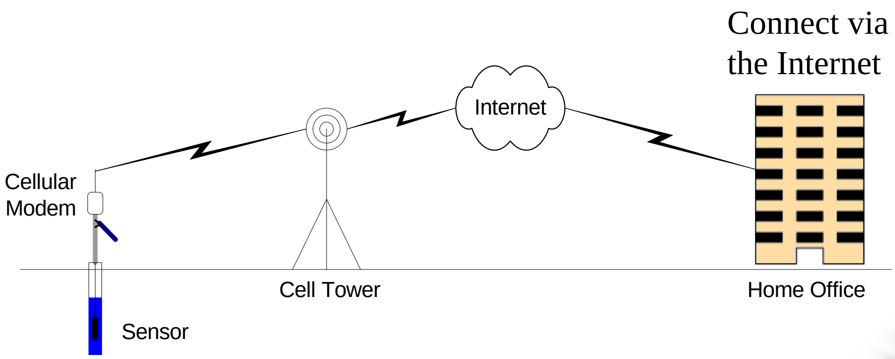
Transmission Systems - Modems

Typical Dial-up Installation



Transmission Systems - Modems

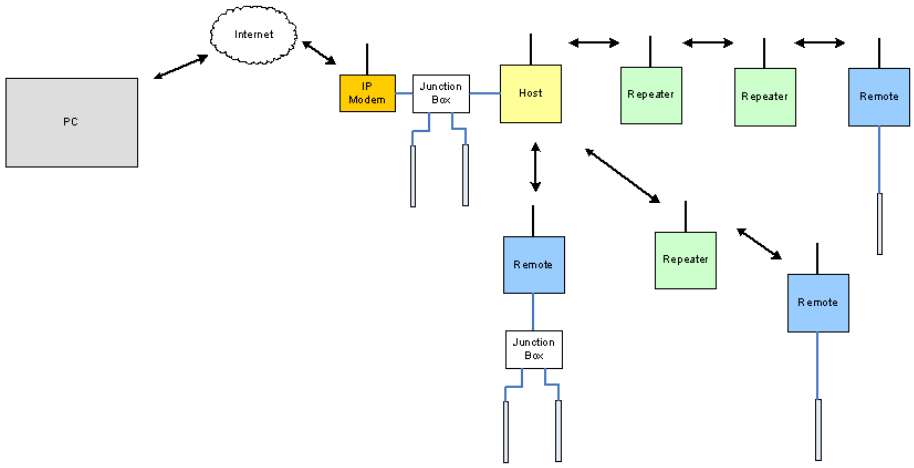
Typical IP Installation



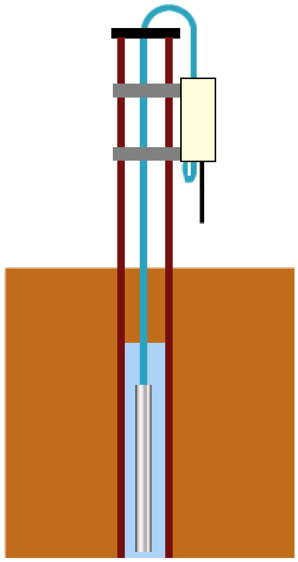
Telemetry Systems- Blended

Sample Network

Complex network including radios and cellular modem



Typical Installations



Sample Mounting on Wellhead

- Strap to wellhead
- Antenna and sensor wiring facing down to reduce leaking

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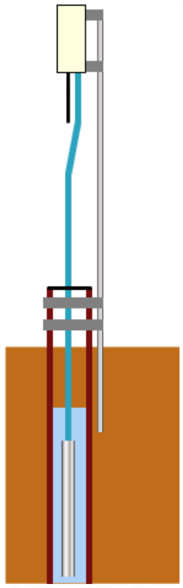
Typical Installations



Sample Mounting on Pole

- Strap enclosure to pole
- Bury pole and strap to well head for support
- Use guy wires as needed
- Antenna and sensor wiring facing down to reduce leaking

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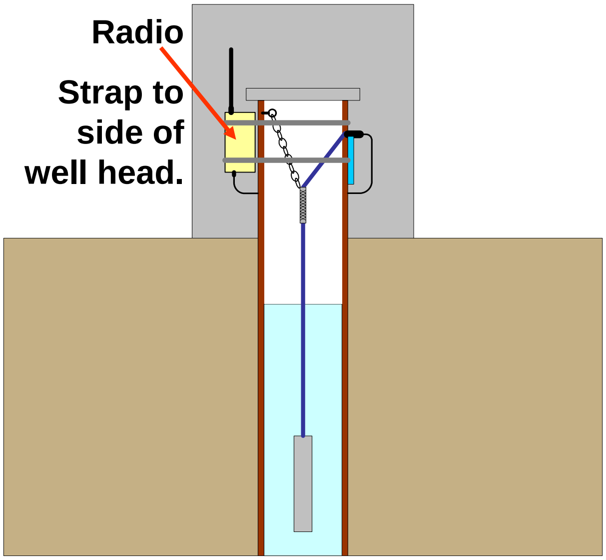
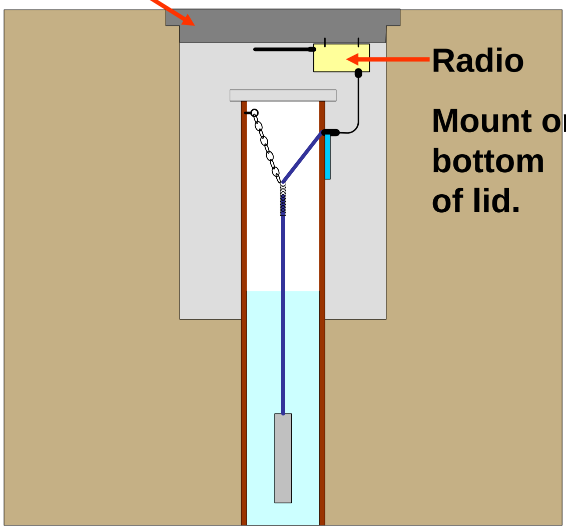
Typical Installations



Above Ground Monument

Use fiberglass (not steel) monument

Typical Installations



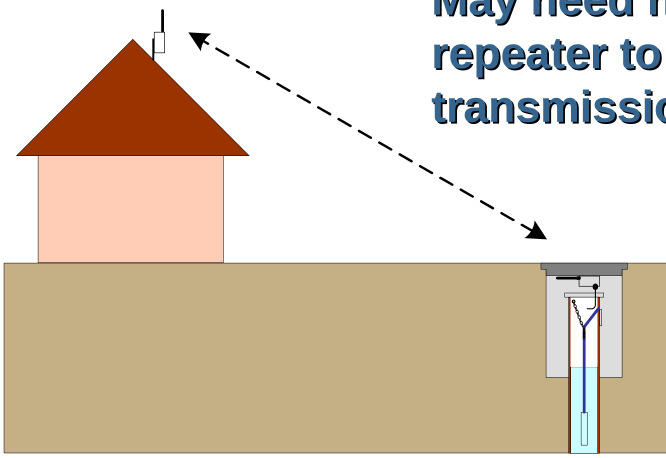
Below Ground Monument

Use fiberglass (not steel) flush mounted lid

Typical Installations

Below Ground Monument

May need nearby repeater to increase transmission distance.



Installation

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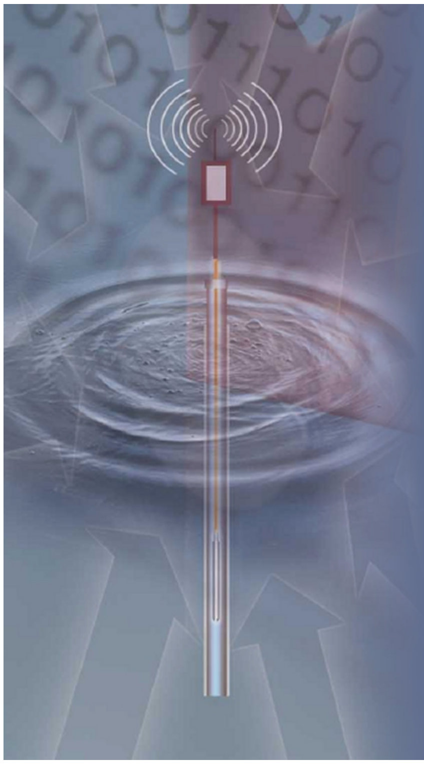
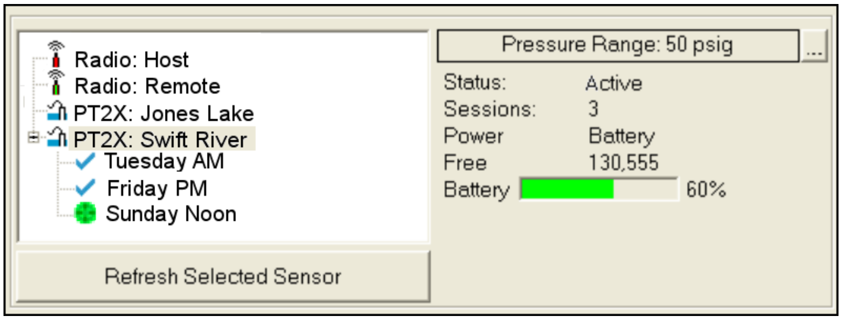
2-34



Software

Software

Reports status of the system



Displays real time readings on demand

Real Time Data

Date / Time	Temperature(degC)	Chloride(ppm)
14-Dec-06 11:33:43	21.6	986
14-Dec-06 11:33:44	21.6	987
14-Dec-06 11:33:45	21.7	990
14-Dec-06 11:33:46	21.8	989
14-Dec-06 11:33:47	22.0	987
14-Dec-06 11:33:48	22.0	986

Software

Controls rate and timing of data collection

Session ID: Well 8932 **PT2X: Smart Sensor**

☑ Delayed Start 29-Jan-2007 08:00:00

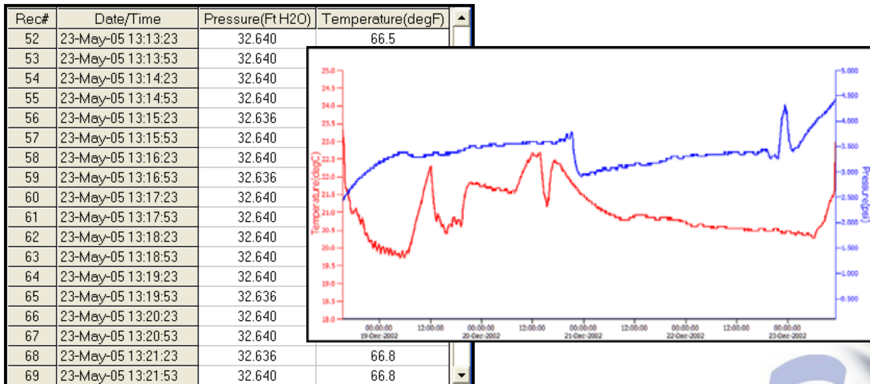
Phase	Polling Interval dd/hh:mm:ss	# Records	Phase Duration dd/hh:mm:ss
1	00/00:00:01	200	00/00:03:19
2	00/00:00:10	50	00/00:08:20
3	00/00:01:00	100	00/01:40:00
4	00/00:30:00	5000	104/04:00:00
5			

Start

Clear

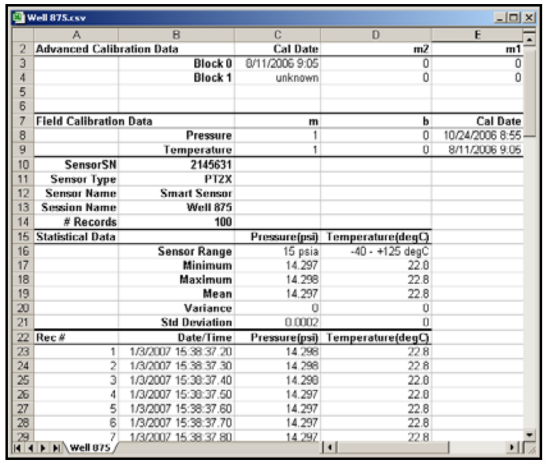
Delete

Uploads and displays recorded data



Rec#	Date/Time	Pressure(Ft H2O)	Temperature(degF)
52	23-May-05 13:13:23	32.640	66.5
53	23-May-05 13:13:53	32.640	
54	23-May-05 13:14:23	32.640	
55	23-May-05 13:14:53	32.640	
56	23-May-05 13:15:23	32.636	
57	23-May-05 13:15:53	32.640	
58	23-May-05 13:16:23	32.640	
59	23-May-05 13:16:53	32.636	
60	23-May-05 13:17:23	32.640	
61	23-May-05 13:17:53	32.640	
62	23-May-05 13:18:23	32.640	
63	23-May-05 13:18:53	32.640	
64	23-May-05 13:19:23	32.640	
65	23-May-05 13:19:53	32.636	
66	23-May-05 13:20:23	32.640	
67	23-May-05 13:20:53	32.640	
68	23-May-05 13:21:23	32.636	66.8
69	23-May-05 13:21:53	32.640	66.8

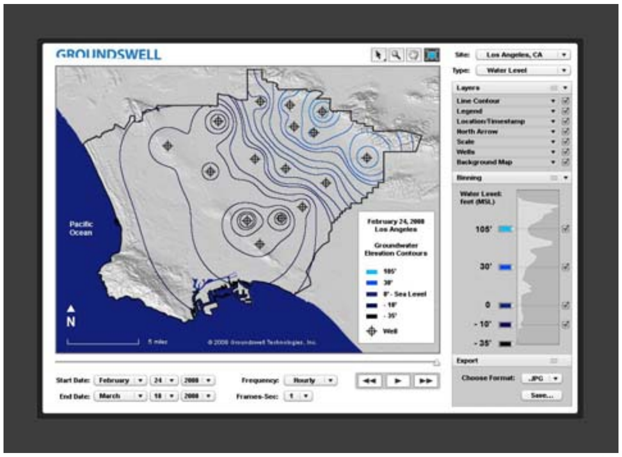
Exports data to other programs


Well 875.csv

	A	B	C	D	E
2	Advanced Calibration Data		Cal Date	m2	m1
3		Block 0	8/11/2006 9:05	0	0
4		Block 1	unknown	0	0
5					
6					
7	Field Calibration Data		m	b	Cal Date
8		Pressure	1	0	10/24/2006 8:55
9		Temperature	1	0	8/11/2006 9:05
10	SensorSN	2145631			
11	Sensor Type	PT2X			
12	Sensor Name	Smart Sensor			
13	Session Name	Well 875			
14	# Records	100			
15	Statistical Data		Pressure(psi)	Temperature(degC)	
16		Sensor Range	15 psia	-40 - +125 degC	
17		Minimum	14.297	22.8	
18		Maximum	14.298	22.8	
19		Mean	14.297	22.8	
20		Variance	0	0	
21		Std Deviation	0.0002	0	
22	Rec #	Date/Time	Pressure(psi)	Temperature(degC)	
23	1	1/3/2007 15:38:37.20	14.298	22.8	
24	2	1/3/2007 15:38:37.30	14.298	22.8	
25	3	1/3/2007 15:38:37.40	14.298	22.8	
26	4	1/3/2007 15:38:37.50	14.297	22.8	
27	5	1/3/2007 15:38:37.60	14.297	22.8	
28	6	1/3/2007 15:38:37.70	14.297	22.8	
29	7	1/3/2007 15:38:37.80	14.297	22.8	

Well 875

Exports data to other programs



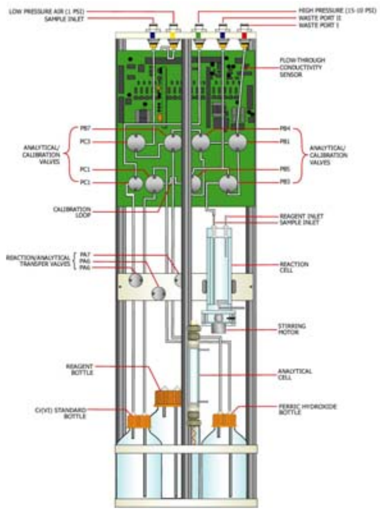
Conclusion

Sensors + Connection Tools + Software

Equals

Better Information
Better Decisions
&
Better Project Management

BURGE UNIVERSAL PLATFORM
TCE, Cr(VI), Explosives, SR^{90}, etc.



BURGE UNIVERSAL PLATFORM
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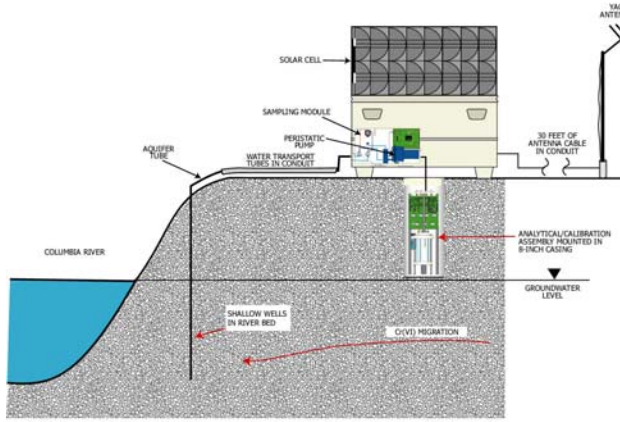

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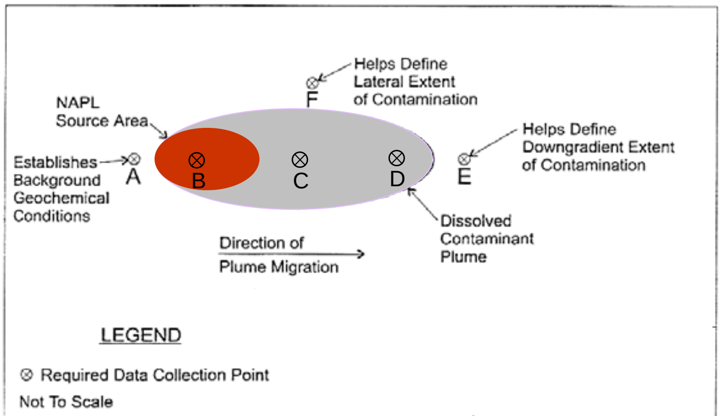
  - Plume Status (Stable, Contraction, etc.)
  - Remediation Metric
  - Regulatory Metric?

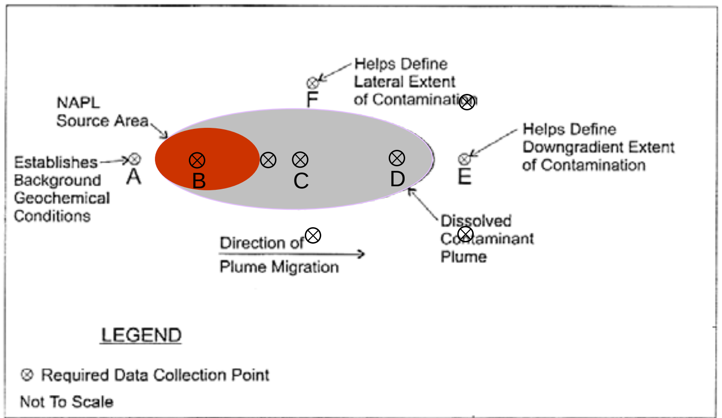
GW Plume Characterization Strategy



Wiedemeier et al., 1996

3D – Depth Specific Info; Wells or Continuous Profile

GW Plume Characterization Strategy



Wiedemeier et al., 1996

3D – Depth Specific Info; Wells or Continuous Profile

SEEPAGE VELOCITY AND FLUX

Seepage velocity (*ν*):

$$\nu = \frac{Ki}{\rho} \quad \text{(length/time)}$$

where: K = hydraulic conductivity (*Piezocone*)

i = hydraulic gradient (*Piezocone*)*

ρ = effective porosity (*Piezocone/Soil*)

Contaminant flux (F):

$$F = \nu\,[X]$$

(mass/length^2-time; mg/m^2-s)

where: ν = seepage velocity (length/time; m/s)

[X] = concentration of solute (*MIP, etc.*)*
(mass/volume; mg/m^3)

*** Dynamic Parameters**

EXPEDITED FLUX APPROACH

Plume Delineation

- MIP, LIF, ConeSipper, Waterloo^{APS}, Field Lab, etc.
- 2D/3D Concentration Representations

Hydro Assessment

- High-Res Piezocone (2D/3D Flow Field, K, head, eff. por.)

LTM Network Design

- Well Design based on CPT Data
- Field Installations (Clustered Short Screened Wells)

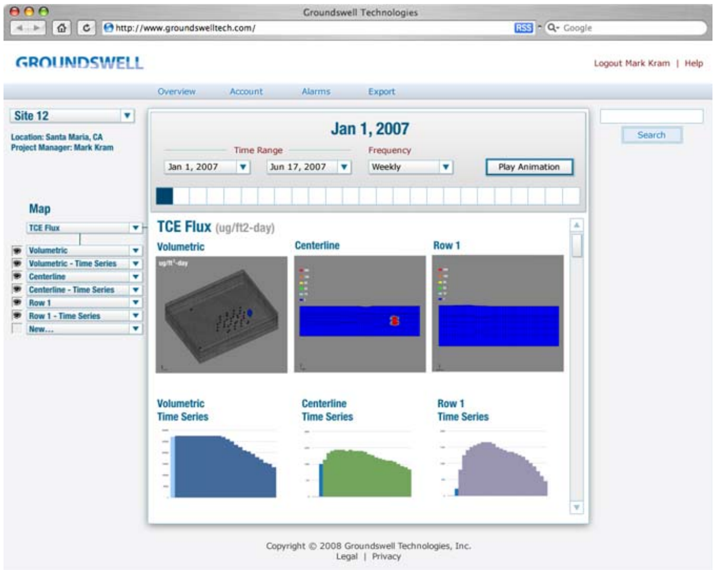
Surveys (Lat/Long/Elevation)

GMS Interpolations (ν, F), Conceptual/Analytical Models

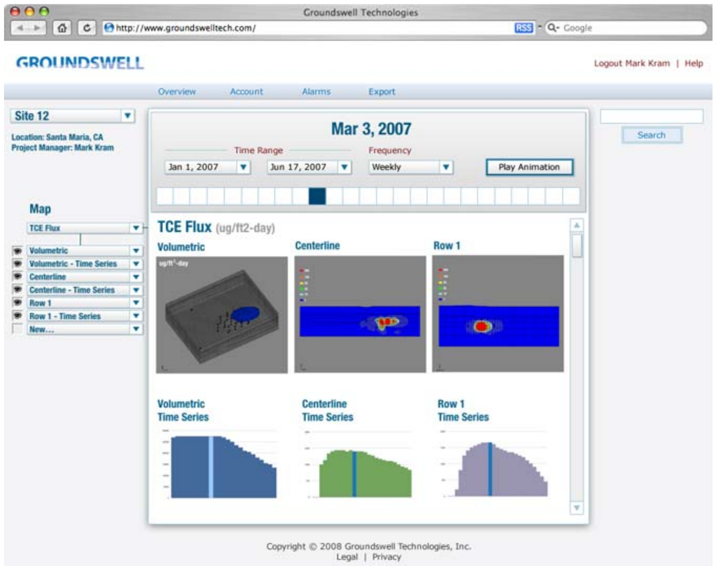
LTM Flux Updates via Head/Concentration

- Conventional Data
- Automated Modeling

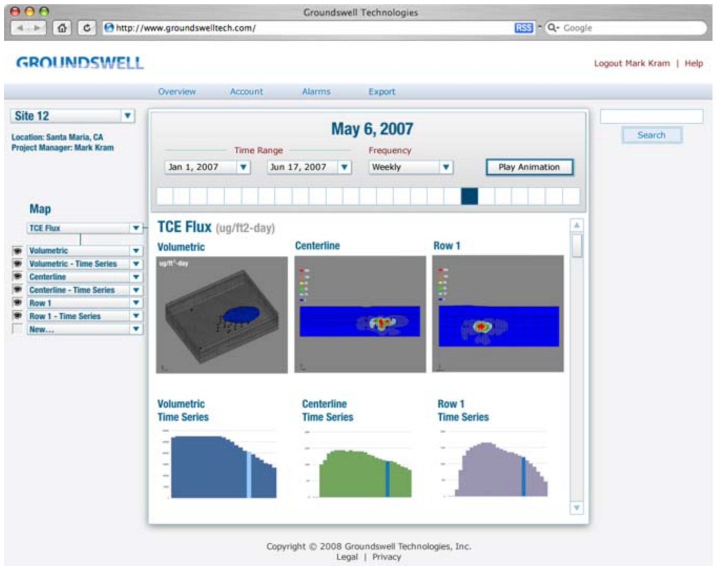
Future Conceptualization



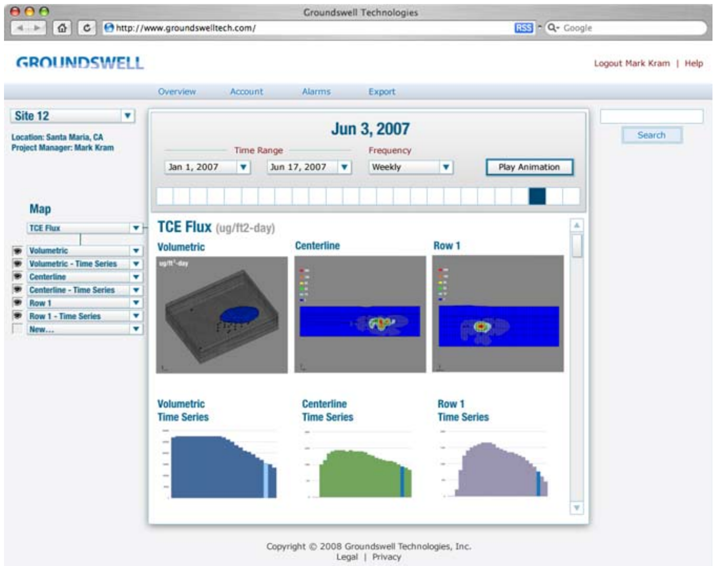
Future Conceptualization



Future Conceptualization



Future Conceptualization



CURRENT / FUTURE
HYDRO SENSORS / APPLICATIONS

Current Sensors:

- TCE, Cr(VI), N-Explosives, SR^{90}, Nitrate, Geochemistry, Water Level, Vapor Chemistry, Pressure, Temp, etc.

Future Sensors/Applications:

- Additional Organic Solutes
- Vapor Monitoring (USTs, Pipe Leaks, Intrusion, etc.)
- Perchlorate
- LTM/MNA
- On-The-Fly Model Update/Calibration
- Landfills
- Hydraulic Containment
- Others?

ENCOURAGING DEVELOPMENTS

- New Sensors Available
- New Sensors Under Development (DHS, nano, etc.)
- New Compatible Technologies (Smart Dust, Motes, Pods, Retriever, Crossbow, INW, MachineTalker, etc.)
- Significant SONs for Sensors and Approach
  - DoD (SERDP)
  - DOE (STTR)
  - DHS (BAA, SBIR)
  - EPA (SBIR)
- Telecommunications & DB Standards

VALUE PROPOSITION

- Gain Precision - True Risks and Strategic Options
- Lower Long-Term Site Management Costs
- Simultaneous Multi-Site Monitoring (Web)
- Monitoring at Practical Time Steps
- Automated Responses

- **Better Product**
  - Automated Real-Time Reporting
  - Quality Decision-Ready Data
  - Flexibility, Data Management, etc.
- **Lower Cost**
  - Time Reduction for Report and Response
  - Legal Protection & Legal Cost Reduction
- **Environmental Protection**
  - Alarm Capabilities
  - Communication/Management
- **Security**
  - Site & Asset Protection
  - Enables Emergency Response Contingencies
- **Multiple Application Markets**
  - Environmental/Security Market Drivers
  - Short Time to Market with Long Term ROI

CONCLUSIONS

- Single-Deployment Solutions Now Possible
- Triad Based CPT Approaches (e.g., LIF, MIP, HRP, W^{APS}, etc.) Save Time/Cost and Lead to Exceptional Plume and Hydraulic Characterization
- Highly Resolved 2D and 3D Distributions of Head, Gradient, K, Effective Porosity, and Seepage Velocity Now Possible Using HRP and GMS
- When Know Concentration Distribution (e.g., via MIP, Conesipper, etc.), 3D Distributions of Contaminant Flux Possible Using GMS
- Exceptional Capabilities for Plume "Architecture" and Monitoring Network Design for Remediation Design and Evaluation
- New Paradigm - LTM and Remediation Performance Monitoring via Sensors and Automation (4D)

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ESTCP – Funded HRP/LIF/MIP/GeoVIS/etc. Demonstrations

NAVFAC ESC – HRP/LIF/GeoVIS Manpower, oversight, matching efforts

Field and Technical Support –

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MANY OTHERS!!!


THANK YOU!
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