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Welcome – Thanks for joining us.
ITRC's Internet-based Training Program

An Overview of Direct-push Well Technology for Long-term Groundwater Monitoring

ITRC Technical and Regulatory Guidance: The Use of Direct-push Well Technology for Long-term Environmental Monitoring in Groundwater Investigations

This training is co-sponsored by the EPA Office of Superfund Remediation and Technology Innovation

Presentation Overview:

Direct-push wells have been used for temporary groundwater monitoring purposes for many years but are generally prohibited for use as long-term groundwater monitoring wells. Recent research indicates that direct-push wells are as well suited for long-term environmental groundwater monitoring purposes as conventionally constructed wells. Since they can be installed for much less expense, direct-push wells are an attractive option. However, most states' regulations prohibit their use indirectly due to the requirement of a minimum annular space.

This training introduces state regulators, environmental consultants, site owners, and community stakeholders to *ITRC Technical and Regulatory Guidance: The Use of Direct-push Well Technology for Long-term Environmental Monitoring in Groundwater Investigations* (SCM-2, 2006), created by ITRC's Sampling, Characterization, and Monitoring Team to assist reviewers in assessing the adequacy of direct-push well projects. This course gives the participant a background in the principles of direct-push wells and presents the state of the art regarding recent research.

ITRC (Interstate Technology and Regulatory Council) www.itrcweb.org

Training Co-Sponsored by: US EPA Office of Superfund Remediation and Technology Innovation (www.clu-in.org)

ITRC Training Program: training@itrcweb.org; Phone: 402-201-2419

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ITRC (www.itrcweb.org) – Shaping the Future of Regulatory Acceptance

- Host organization
- Network
  - State regulators
    - All 50 states and DC
  - Federal partners

    DOE DOD EPA
  - ITRC Industry Affiliates Program
  - Academia
  - Community stakeholders
- Wide variety of topics
  - Technologies
  - Approaches
  - Contaminants
  - Sites
- Products
  - Documents
    - Technical and regulatory guidance documents
    - Technology overviews
    - Case studies
  - Training
    - Internet-based
    - Classroom

The Interstate Technology and Regulatory Council (ITRC) is a state-led coalition of regulators, industry experts, citizen stakeholders, academia and federal partners that work to achieve regulatory acceptance of environmental technologies and innovative approaches. ITRC consists of all 50 states (and the District of Columbia) that work to break down barriers and reduce compliance costs, making it easier to use new technologies and helping states maximize resources. ITRC brings together a diverse mix of environmental experts and stakeholders from both the public and private sectors to broaden and deepen technical knowledge and advance the regulatory acceptance of environmental technologies. Together, we're building the environmental community's ability to expedite quality decision making while protecting human health and the environment. With our network of organizations and individuals throughout the environmental community, ITRC is a unique catalyst for dialogue between regulators and the regulated community.

For a state to be a member of ITRC their environmental agency must designate a State Point of Contact. To find out who your State POC is check out the "contacts" section at www.itrcweb.org. Also, click on "membership" to learn how you can become a member of an ITRC Technical Team.

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ITRC Course Topics Planned for 2008 – More information at www.itrcweb.org

Popular courses from 2007

- Characterization, Design, Construction, and Monitoring of Bioreactor Landfills
- Direct Push Well Technology for Long-term Monitoring
- Evaluate, Optimize, or End Post-Closure Care at MSW Landfills
- Perchlorate: Overview of Issues, Status and Remedial Options
- Performance-based Environmental Management
- Planning & Promoting Ecological Re-use of Remediated Sites
- Protocol for Use of Five Passive Samplers
- Real-Time Measurement of Radionuclides in Soil
- Remediation Process Optimization Advanced Training
- Risk Assessment and Risk Management
- Vapor Intrusion Pathway: A Practical Guideline

New in 2008

- Bioremediation of DNAPLs
- Decontamination and Decommissioning of Radiologically-Contaminated Facilities
- Enhanced Attenuation: Chlorinated Solvents
- Phytotechnology
- Quality Consideration for Munitions Response
- Remediation Technologies for Perchlorate Contamination
- Sensors
- Survey of Munitions Response Technologies
- Understanding the Behavior of LNAPL in the Subsurface
- More in development…

More details and schedules are available from www.itrcweb.org under “Internet-based Training.”

5 **An Overview of Direct-push Well Technology for Long-term Groundwater Monitoring**

Logistical Reminders

- Phone line audience
  - ✓ Keep phone on mute
  - ✓ *6 to mute, *7 to un-mute to ask question during designated periods
  - ✓ Do NOT put call on hold
- Simulcast audience
  - ✓ Use ? at the top of each slide to submit questions
- Course time = 2¼ hours

Presentation Overview

- Direct-push (DP) well technology overview
- Advantages and limitations
- Known regulatory barriers and concerns
- Questions and answers
- Comparative data between DP and conventionally drilled wells
- Case study highlights
- Health and safety
- Stakeholder and tribal concerns
- Links to additional resources
- Your feedback
- Questions and answers

No associated notes.

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Meet the ITRC Instructors

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Keisha D. Long is an Environmental Engineer working for the South Carolina Department of Health and Environmental Control since 1998 in Columbia, South Carolina. She is a Project Manager in the State Superfund program. Her responsibilities include overseeing the assessment, remediation, and clean up of Superfund sites in South Carolina; and overseeing the assessment and cleanup of Voluntary Cleanup Program sites. Previously, she worked in the department's RCRA Corrective Action Engineering Program where she guided clean-up actions for dozens of waste management units at Department of Defense bases including: Charleston Air Force Base, Poinsett Electronic Combat Range, and Shaw Air Force Base. She also provided regulatory concurrence to the regulated community and their consultants in Hazardous Waste Management. She has worked as a remedial project manager in the Federal Superfund and Dry-cleaning Restoration programs. Her responsibilities included assisting the US EPA Region 4 with assessment and cleanup of sites in South Carolina that are listed on the National Priorities List (NPL) and assessing registered dry-cleaning sites. Keisha joined ITRC's Sampling, Characterization, and Monitoring team in 2001 and became the team leader in 2008. Keisha earned a bachelor's degree in civil engineering from Clemson University in Clemson, South Carolina in 1998.

Bradley A. Call, P.E., is a member of the Interstate Technology Regulatory Council’s Sampling, Characterization and Monitoring Team and is a senior environmental engineer with the Sacramento District of the U.S. Army Corps of Engineers. He also serves as the innovative technology advocate for his District, charged with encouraging consideration of emerging characterization and remediation approaches. The District he serves with provides environmental restoration services to Department of Defense facilities in California, Nevada, Utah and Arizona. Mr. Call also participates with the US EPA’s Triad Approach work group. He obtained his bachelor’s degree in civil engineering from the University of Utah in 1989 and his master’s degree in environmental engineering from the University of California at Davis in 2000. Mr. Call’s interests include improving the effectiveness of decision-making (through application of conceptual site models, improving data evaluation, broadening employment of field analytical technologies, and making electronic data management tools affordable for small projects). He is a registered Civil Engineer in the state of California and is a member of the American Society of Civil Engineers and the National Ground Water Association.

William Major works for the Naval Facilities Engineering Service Center in Port Hueneme, CA. He has over 25 years experience with the Navy developing innovative technical solutions to a wide variety of Navy and DoD environmental problems. He currently holds the position of test site manager for the Port Hueneme National Environmental Technology Test Site (NETTS) and is project lead for the ESTCP funded project titled “Demonstration/Validation of Long-Term Monitoring Using Wells Installed by Direct Push Technologies.”

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What You Will Learn…

- A description of direct-push well technology and equipment and installation requirements
- Sampling considerations
- Technology advantages and limitations
- Known regulatory barriers and concerns
- Comparisons between direct push and conventionally drilled wells
- Case studies
- Stakeholder concerns

No associated notes.

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Why Monitoring Wells?

- Used to collect ground water samples at a fixed location over time (short or long-term monitoring)
- Types of wells and method of installation vary
- Guidelines for well installation depend upon individual state regulations

Monitoring wells are used to collect groundwater samples for determining the nature and extent of contamination in an aquifer; data collected from wells are used in risk assessment calculations, and are used to verify that remediation goals have been met.

ITRC's Sampling, Characterization, and Monitoring Team has a mission to develop processes and procedures enabling integration of field sampling and analysis technologies for improved site decision-making. Direct-push wells is one technology that enables us to accomplish that goal.

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What are Direct-push (DP) Wells?

- Installed by static or dynamic push
- DP wells are smaller in diameter
- Were initially deployed for short-term monitoring

An introduction to DP well technology can be found at http://fate.clu-in.org/direct_push/dpp.asp (U.S. EPA Technology Innovation Office)

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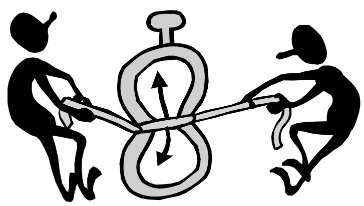
What’s the Big Deal About Direct-push Wells? Why Should I Care?

Potential for Dramatic Cost Savings !!



DP wells can be installed at least 2 times faster than conventionally drilled wells

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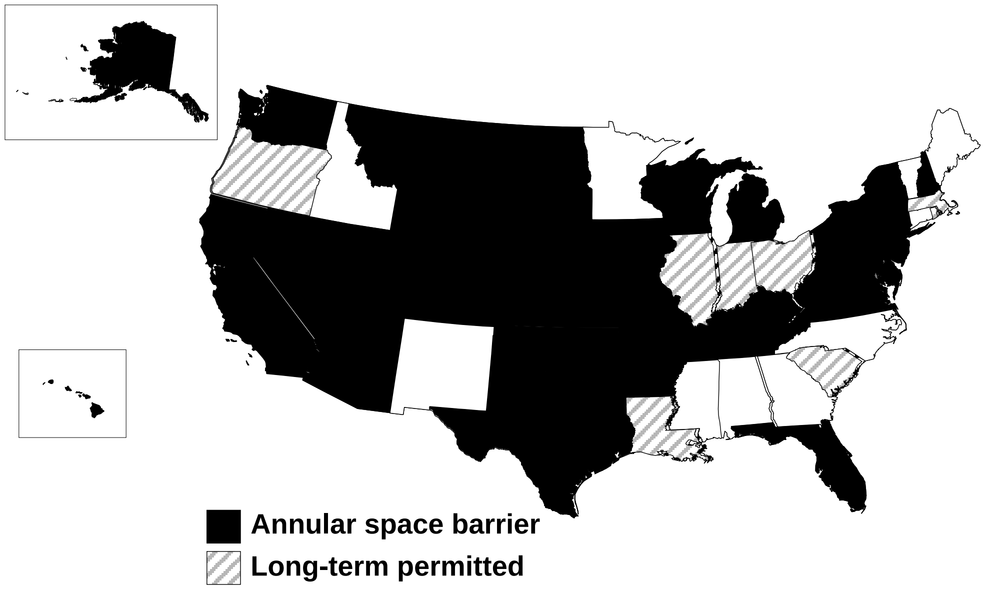
Annular Space Barrier States



State regulations vary: Section 3.3 of the ITRC document, a *ITRC Technical and Regulatory Guidance: The Use of Direct-push Well Technology for Long-term Environmental Monitoring in Groundwater Investigations* (SCM-2, 2006), lists the web links to individual state regulations.

The map on this slide shows the 33 states that have minimum annular space requirements that effectively prohibit the use of direct-push wells and the seven states that have regulations that allow the use of direct-push wells. The unshaded states were ones that fall into the ‘other’ category in that they do not regulate monitoring wells per se, or the SCM team was unable to discover their regulations and/or policies.

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Direct-push Well Systems

- Static force
  - Cone penetrometer
    - 10-30 ton truck
    - Sensors
- Dynamic force
  - Percussion hammer
    - Truck mounted

The percussion hammer units are the most common and can sometimes maneuver into locations that the larger static force units can't access.

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Performance of Technology

- Advantages
  - Less investigation derived waste (IDW)
  - Work faster
  - Work smarter
  - Improve representativeness

    Representative chemistry and field parameter measurements
  - Landowner friendly
  - Less costly

    Inexpensive to install, replace, and abandon
- Disadvantages
  - Not applicable in some geologic conditions
  - Regulatory restrictions

    Not accepted for long-term monitoring in most states
  - Well diameter limitations
  - Cross-contamination potential
  - Potential for higher turbidity

Various studies have found little difference between paired DP and conventionally drilled wells for the analytes investigated

DP wells for long-term use are not accepted in most states

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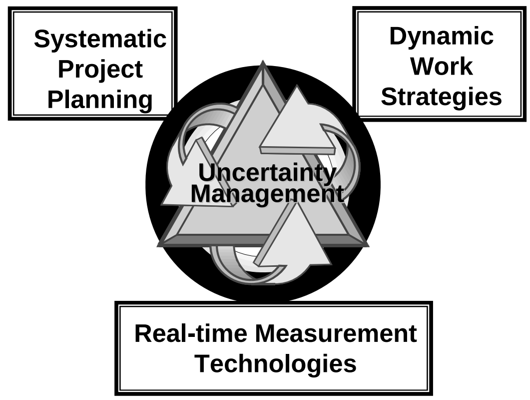
Faster

- Rapid installation and site characterization
  - Installation rate two to five times faster than conventionally drilled monitoring wells
  - DP wells can be integrated into a comprehensive dynamic characterization plan (e.g., the Triad approach)

The Triad Approach



See ITRC ***Technical and Regulatory Guidance for the Triad Approach*** (SCM-1) and associated Internet-based training. More information is available at www.itrcweb.org under "Guidance Documents" and "Internet-based training"

DP wells can be integrated into a comprehensive dynamic work strategy such as the Triad approach. More detail on the Triad approach can be found in the ITRC Technical and Regulatory Guidance for the Triad Approach (SCM-1) available at www.itrcweb.org under "Guidance Documents" and "Sampling, Characterization, and Monitoring" or directly at http://www.itrcweb.org/Documents/SCM-1.pdf. ITRC's Sampling, Characterization and Monitoring team also offers an Internet-based training title, "Triad Approach – A New Paradigm for Environmental Project Management." Information on upcoming classes of this Internet-based training is available at www.itrcweb.org under "Internet-based training" and "Triad Approach." You can access an archive (listen/view slides) of a previous offering of this training by going to: http://cluin.org/live/archive.cfm#itrc (You will have to scroll down to find the course of interest). When you choose to view a course on-line, the link will take you to the course overview page. When you are ready to listen to the training, select Go to Training.

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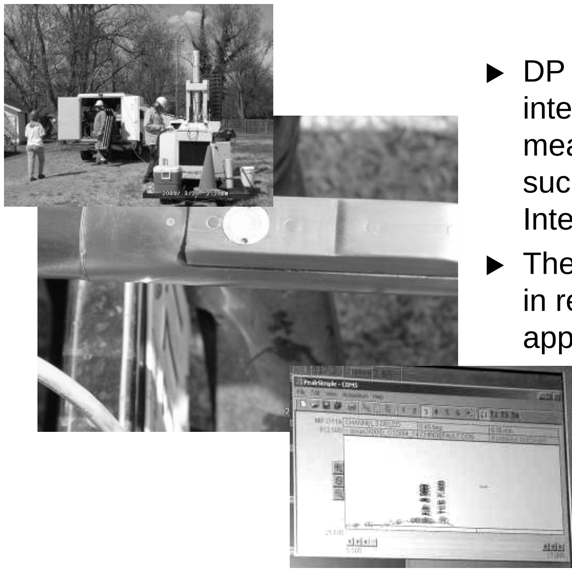
Adaptable to New Sampling Technologies



- DP wells can be integrated with real-time measurement systems such as Membrane Interface Probes (MIPs)
- The ability to acquire data in real time enhances application of Triad

Above are pictures of the MIP in use in the field

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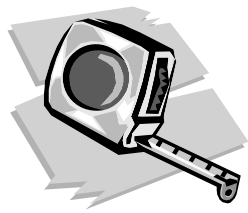
Regulatory Issues

The primary regulatory issue concerning direct-push wells is that most states require a minimum annulus size for a monitoring well. This requirement cannot be met by the direct-push installation technique.



Definition of annulus space: the space between the well casing and the wall of the drilled hole

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Regulatory Concerns

- Well permitting
  - Annular space
  - Well seal
  - Filter pack
- Data acceptability
  - Water level data
  - Chemical data

State regulations often include an annular space requirement

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Examples of State Regulatory Concerns

- Many states require individual variances each time a DP well installation is proposed
- Florida
  - 2” annular space requirement
- Illinois
  - Only temporary (< 1 year) installations allowable
- Oklahoma
  - Borehole requirements restrict DP use

No associated notes.

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DP Technology – Overview of This Part of the Training

- DP well installation
- Construction
- Development
- Sampling
- Hydraulic conductivity – comparability
- Advantages/disadvantages

No associated notes.

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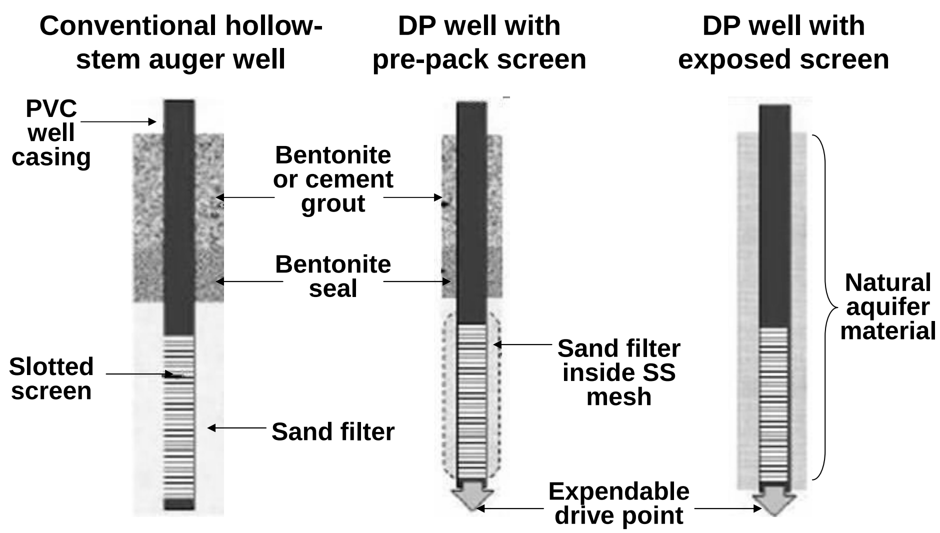
Well Types



No associated notes.

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DP Installation Techniques

- Two general installation categories
  - Protected-screen
  - Exposed-screen
- Both involve
  - Drive rods – typically steel
  - Expendable metal drive points

Direct-push wells can be installed to depths of at least 150 feet. This depends on the available equipment and installation technique used.

When a Cone Penetration Test (CPT) rig is used, a electronic soil type log is generated.

When a hammer type rig is used it is possible to get continuous cores for geologic logging.

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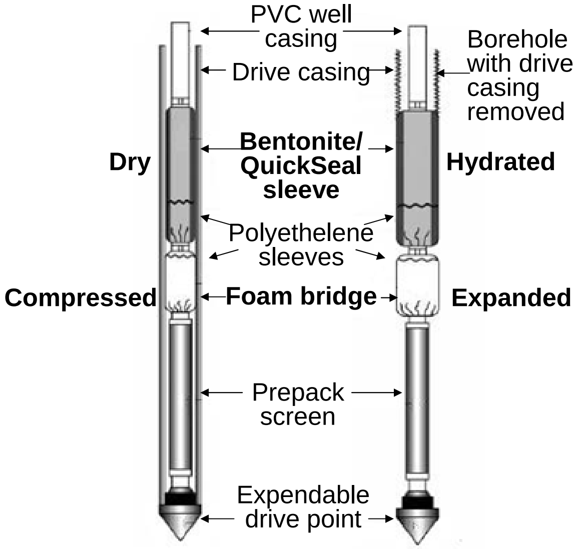
Installation – Protected-Screen

During installation **After retracting drive casing**



- Within the drive rod
- Requires seal and filter pack
- Well screen protected from damage and clogging
- Generally similar to conventional well installation

No associated notes.

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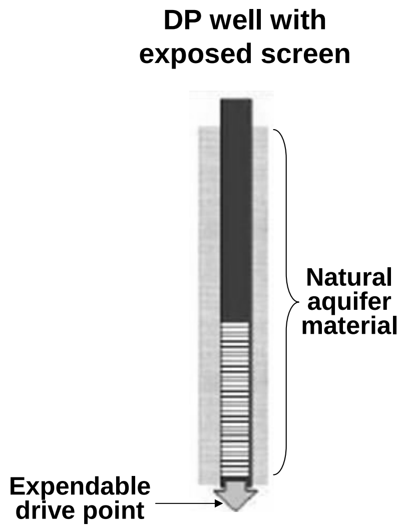
Installation – Exposed-Screen



- Potential damage/ clogging of screen
- Potential cross-contamination issues
- Requires careful well development
- Faster installation
- Less expensive
- Does not allow annular seal

No associated notes.

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Construction Materials

- Well configuration and materials similar to conventional wells
- Common casings
  - Schedule 40 or 80 PVC threaded or flush-jointed casings
- Common sizes
  - ¾, 1, and 2-inch
- Screens

No associated notes.

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Construction Materials (continued)

- Filter-pack
  - Pre-installed
- Grout barriers
  - Plastic
  - Foam
- Seal
  - Pre-installed
  - Tremie pipe

No associated notes.

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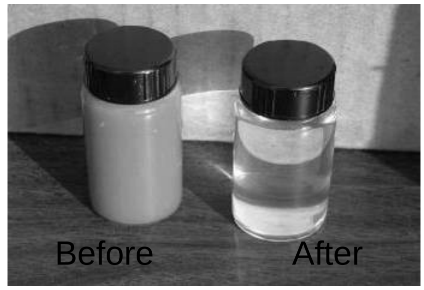
Well Development

- Installation alters borehole wall and adjacent formation
- Development
  - Improves well/aquifer hydraulic connection
  - Removes fines from filter pack
  - Reduces sediment in water samples



No associated notes.

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Development Techniques

For direct-push wells

- Over pumping (purging)
- Mechanical surging
- Water jetting

No associated notes.

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Development Pumping

No associated notes.

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Sampling DP Wells

- Similar to conventional wells
- Purge and sample
  - Purge 3 to 5 casing volumes
  - Ensure groundwater parameters stabilize
  - Collect sample
- Low-flow purge and sample
  - Similar to above, however purge at slower flow rate
- No purge sampling – passive diffusion bags or other passive samplers

Check www.itrcweb.org for details about ITRC's internet-based training on "Protocol for Use of Five Passive Samplers"

For more information about passive diffusion bags, visit ITRC's Diffusion Sampler Information Center (http://diffusionsampler.itrcweb.org).

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Hydraulic Conductivity Study

- Participants
  - Stephen Bartlett (University of Connecticut)
  - Dr. Gary Robbins (University of Connecticut)
  - Dr. Mike Barcelona (Western Michigan State University)
  - Wes McCall (Geoprobe)
  - Dr. Mark Kram (Naval Facilities Engineering Service Center)
- Objective
  - Compare hydraulic conductivity (K) measurements in DP and hollow stem auger (conventional) wells
- Test Location
  - Port Hueneme, California

No associated notes.

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Hydraulic Conductivity Study Activities

- 296 pneumatic slug tests
- Pumping tests
  - Unsteady state
  - Constant head steady state
- Geology
  - Fluvial-deltaic
  - Sand and gravel
- Fully submerged screens

No associated notes.

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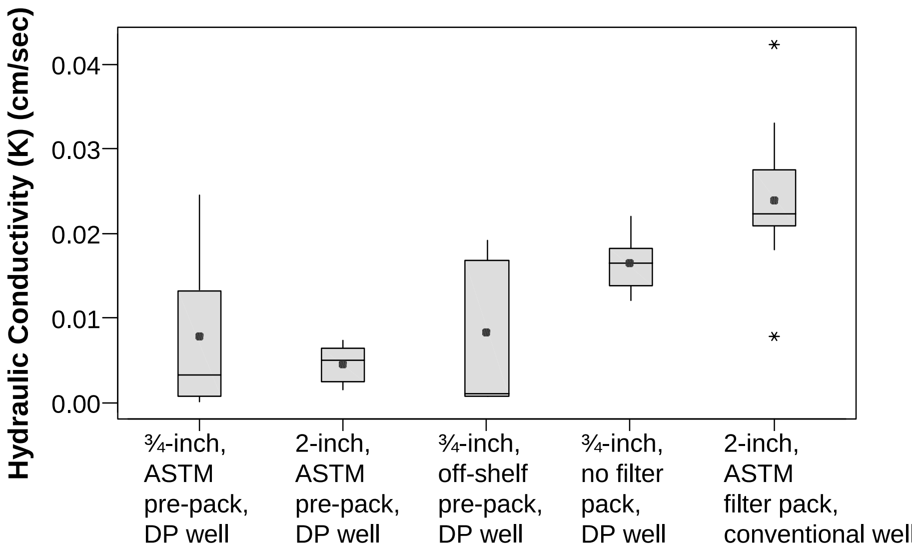
Variability in Hydraulic Conductivity (K) – DP Versus Conventional Wells



The hydraulic conductivity (*K*) of material comprising an aquifer is a measure of the material's capacity to transmit water.

Means are indicated by solid circles.

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Conclusions

- Short duration pneumatic slug tests (<3 seconds) are feasible for high K formations
- K for DP and conventional wells is statistically different but comparable in magnitude
- Study results documented in Navy technical report
  - TR-2252-ENV “Comparison of Hydraulic Conductivity Determinations in Direct Push and Conventional Wells,” Oct 2004

No associated notes.

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Advantages and Disadvantages

- Advantages
  - Less investigation derived waste (IDW)
  - Work faster
  - Work smarter
  - Improve representativeness
  - Landowner friendly
  - Less costly
- Disadvantages
  - Not applicable in some geologic conditions
  - Regulatory restrictions
  - Well diameter limitations
  - Cross-contamination potential
  - Potential for higher turbidity

No associated notes.

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Advantage – Less Investigation Derived Waste (IDW)

- Minimal cutting wastes
- Fewer well development wastes
- Overall, less investigative derived waste (IDW) to manage
- Reduced exposure to contaminated soil
- Reduced costs

No associated notes.

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Advantage – Work Faster

- DP wells can be installed faster
  - Installation rate two to five times faster than conventional wells
- Site characterization can be completed faster

No associated notes.

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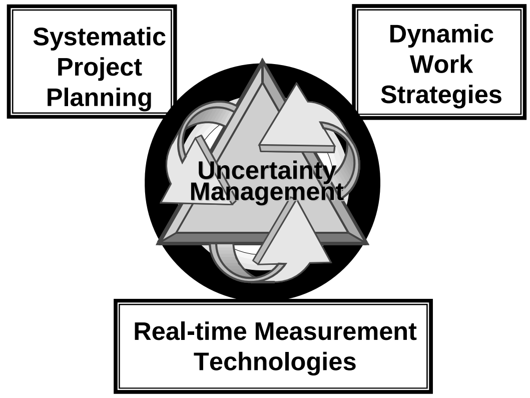
Advantage – Work Smarter

- New work strategies like the Triad approach improve
  - Quality
  - Cost effectiveness
  - Time to complete
- DP wells integrate well with dynamic work strategies component of Triad

The Triad Approach



ITRC Technical and Regulatory Guidance for the Triad Approach (SCM-1) available at www.itrcweb.org under “Guidance Documents” and “Sampling, Characterization, and Monitoring.”

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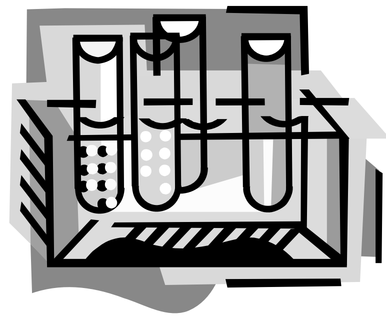
Advantage – More Representative

- Representative chemistry and field parameter measurements
  - Case studies discussed later
- Hydraulic conductivity similar to conventional wells
  - University of Connecticut/ Port Hueneme study
- Overall representativeness improved due to greater affordability of DP wells – install more of them



No associated notes.

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Advantage – Landowner Friendly

- Generally smaller drilling equipment
- Minimal environmental disturbance
- Improved landowner relations
- Less time on site

No associated notes.

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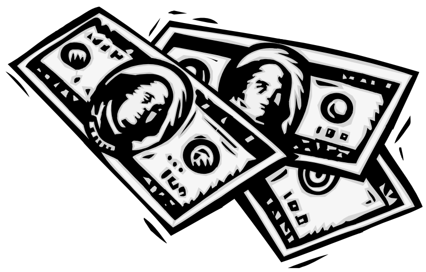
Advantage – Less Costly



- Less expensive to install, replace, and abandon
  - DP wells can be installed at a cost savings ranging from 23% to 65%

No associated notes.

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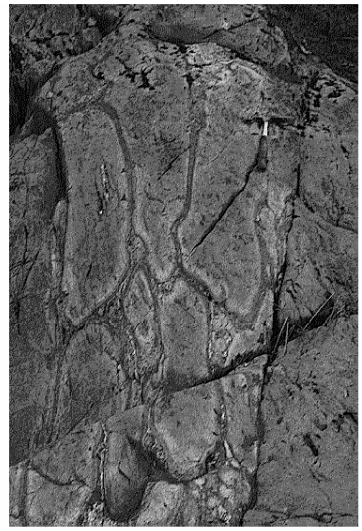
Disadvantage – Not Suitable for Some Geologic Conditions

- Depth of penetration is controlled by the reactive weight or hammer type
- Geologic conditions requiring caution
  - Large particle size
    - Cobbles or gravels
  - Consolidated
    - Bedrock
    - Cemented soils
    - Dense sands



No associated notes.

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Disadvantage – Regulatory Restrictions

- Not accepted for long-term monitoring in most states
  - Annular space requirement
    - Filter packs
    - Sealing
  - Other requirements

No associated notes.

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Disadvantage – Well Diameter Limitations

- Wells limited to a maximum diameter of 2-inches
- This may preclude consideration of DP wells in some situations
- May also be a disadvantage if geophysical logging is required

No associated notes.

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Disadvantage – Cross Contamination Potential

- Improperly installed well (DP or conventional) may allow aquifer cross-contamination
- During DP well installation
  - No outer casing
  - No drilling mud
- Completed DP well
  - DP wells installed with the “exposed screen” method have no annular seal

No associated notes.

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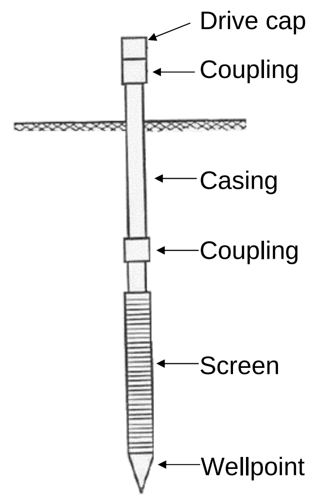
Limitation – Potential for Higher Turbidity

- DP wells installed with the “exposed screen” method have no filter pack
- No filter pack may result in higher turbidity in fine-grained soil conditions
- Properly developed DP wells installed with the “protected screen” method are not subject to this problem



Source: Ohio EPA Technical Guidance, Feb 05

No associated notes.

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Evaluating Application of DP Wells

- The initial evaluation should consider the following
  - Do state and local regulations allow use of DP wells?
  - If not, can a variance be obtained?
  - Are geologic conditions suitable in the study area at the depths of interest?
  - Do I need wells greater than 2-inches in diameter?

No associated notes.

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Questions and Answers

No associated notes.

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ESTCP Sponsored Study – Background

- Environmental Security Technology Certification Program (ESTCP)
- DoD environmental programs
  - $3.9B total in FY04
  - $3.0B in compliance and environmental restoration
- Direct-push wells – commonly used throughout DoD

ESTCP supports environmental technology demonstration and validation for priority DoD requirements.

Goal: Transition technologies for regulatory and DoD end user acceptance

DoD Environmental Programs

-Thousands of facilities; 30 million acres in assets

-Over $43B invested in last 10 years

-$3.9B total in FY04; $3.0B in compliance and environmental restoration

-Significant percentage of budget towards groundwater monitoring and remediation

Direct-push wells are commonly used throughout DoD

-Cost-effective, rapid, etc.

-Port Hueneme National Environmental Technology Test Sites (NETTS) site DP well installations

-Not approved for long-term monitoring and verification sampling

-Well performance comparison study: DP vs. hollow-stem auger wells

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Objectives of Direct-push Well Performance Comparison Study

- Compare groundwater samples
  - Analyte concentrations
- Address long-term monitoring performance
  - Five test sites
  - 13 quarterly sampling events
- Compare spatial variability of co-located duplicate
  - Hollow-stem auger wells
  - DP wells

Do differences in DP and hollow-stem auger well installation methods and materials impact groundwater analyte concentrations?

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DP Well Study Advisory Committee Directed DP Well Study Design

- Site selections
- Individual and well cluster designs
  - ½" to 2" DP wells; prepack and no prepack
  - 2" and 4" conventional hollow-stem auger wells
- Well installation methods – static and dynamic force
- Geologic cross-section
- Test duration for long-term monitoring and seasonal effects
- Data QA/QC
- Statistical analysis and pertinent comparisons

Expert panel

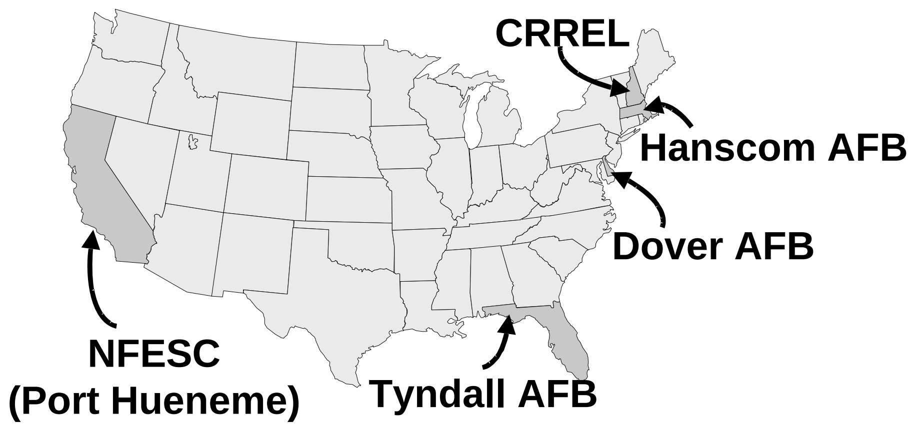
-From industry, universities, EPA and California EPA

-Major contributors to American Society for Testing and Materials (ASTM)

-Convened for Phase I and II

51

Demonstration Locations Phase I



Cold Regions Research and Engineering Laboratory (CRREL) – http://www.crrel.usace.army.mil/
Hanscom Air Force Base – http://www.hanscom.af.mil/
Dover Air Force Base – http://public.dover.amc.af.mil/
Tyndall Air Force Base – http://www.tyndall.af.mil/
Naval Facilities Engineering Service Center (NFESC) – http://portal.navfac.navy.mil

52

Test Sites' Characteristics

Location	# of wells	Geologic character	Depth to groundwater	Contaminants
CRREL	9	Glaciofluvial and Glaciolacustrine	87 - 150 ft	VOCs (TCE), Chlorinated and BTEX
Dover	18	Marine Depositional	15 - 26 ft	VOCs, MTBE, Chlorinated and BTEX
Hanscom	20	Glaciolacustrine	3 - 15 ft	VOCs
Port Hueneme	36	Fluvial Deltaic	5 - 12 ft	MTBE, Chlorinated and BTEX
Tyndall	36	Marine Depositional	3 - 8 ft	VOCs

No associated notes.

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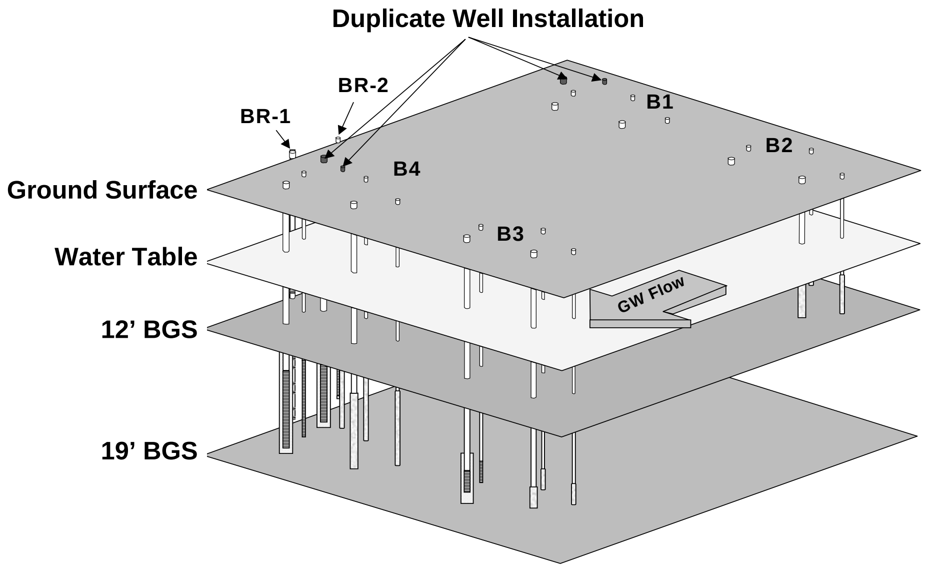
Typical Well Cluster Design



No associated notes.

54

Typical Well Cluster Results – Dover Air Force Base

	Mean Concentrations	
	Hollow-stem auger (HSA) wells	DP wells (no pack)
Specific conductance (µS/cm)	0.188	0.252
pH	5.8	5.4
Temperature (ºC)	16.2	15.3
Magnesium (mg/L)	7.0	9.5
Chloride (mg/L)	18.5	25.7
Ethylbenzene (ug/L)	19.5	29.2

No associated notes.

55

Typical Well Cluster Results – Port Hueneme

	Mean Concentrations				
	2-in HSA ASTM	2-in DP ASTM	¾-in DP ASTM	¾-in DP Conventional	¾-in DP No pack
Manganese (mg/L)	2.21	2.34	2.24	2.35	2.39
Potassium (mg/L)	7.52	6.38	6.73	6.99	6.99
Alkalinity (mg/L)	415	399	404	405	410
Turbidity (NTU)	45	19	6.0	4.3	8.3
Chloride (mg/L)	74	68	68	70	70
MTBE (ug/L)	34.6	40.4	41.5	N/A	N/A

Mean values are > +/- 2 standard deviations from HSA well (column 1)

The highlighted values in this table indicate that the mean value of that particular cell is greater than +/- 2 standard deviations (SD) from the mean value of the HSA well in the same table row. It is common statistical nomenclature to refer to mean values that are two standard deviations apart as having "statistical significant difference".

Looking at the "Chloride (mg/L)" row of the table, you will notice that the 2-in DP well's mean of 68 is highlighted while the ¾-in DP well's mean of 68 is not highlighted. While this appears confusing, it is actually just a function of the data variability (i.e., standard deviation of the mean) being higher in one cell than in the other. This can be best explained through example:

If the 2-in DP well highlighted cell SD = 1.5 then the "mean plus two SD's" = 68 + (2 x 1.5) = **71.** Therefore, the 2-in HSA well mean of **74** (first column) is **greater than** 2 SD's from the 2-in DP well mean of **71** and the two mean values are considered to have a statistical significant difference.

If the ¾-in DP well cell SD = 4 then the mean plus two SD's = 68 + (2 x 4) = **76**. Therefore, the 2-in HSA well mean of **74** is **less than** 2 SD's from the ¾-in DP well mean of **76** and the two mean values are considered to **NOT** to have a statistical significant difference.

In large data sets, such as the ESTCP study, instances of statistical significant differences between well types are expected due to preferential pathways and large spatial heterogeneities of contaminant concentrations in the groundwater. Therefore, it is most important to consider the entire data set and observe the overall trend of these differences. The ESTCP study found no overall trend in these statistical significant differences that would indicate a DP well would consistently produce higher or lower chemical concentrations than an HSA well (i.e., DP and HSA well performance was comparable).

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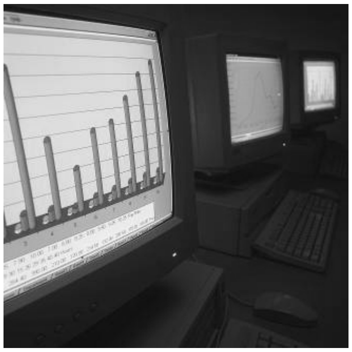
Typical Well Cluster Results – Tyndall Air Force Base

	Mean Concentrations			
	2-in HSA	**1½-in DP No pack**	**1-in DP Pre-pack**	**½-in DP Pre-pack**
Turbidity (NTU)	22	37	43	36
Manganese (mg/L)	0.11	0.1	0.37	0.39
Sulfate (mg/L)	17	13	16	15
Etylbenzene (ug/L)	30	71	40	43
o-Xylene (ug/L)	30	104	49	28
p-dichlorobenzene (ug/L)	18	54	22	18
TCE (ug/L)	54	127	96	55
Toluene (ug/L)	5.5	54	27	4.6

Mean values are > +/- 2 standard deviations from HSA well (column 1)

No associated notes.

Data Compilation and Analysis



- Total of 119 wells in study
- Dataset includes
  - 14 organics
  - 12 inorganics
  - 7 water quality/field parameters
- Over 50,000 analytical data values for 13 sampling events
- Analysis of variance (ANOVA) statistical analysis compares differences in
  - Well locations
  - Well depths
  - Screen lengths
  - Temporal
  - Well type

No associated notes.

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Conclusions

- Statistical analyses indicate DP wells compare favorably to HSA wells
- Where statistically significant differences between well types exist
  - Magnitudes of differences are low
  - Results are random, no trend in differences favoring either well type
  - Management decisions will not change
- ANOVA revealed large differences due to temporal and well depth parameters BUT NOT due to well types
- Low variability for inorganic data
- High variability for some organic data
  - Spatial heterogeneity
    - Trends – temporal and well depth
    - Random distribution – well types
- Triplicate sampling shows very repeatable data

No associated notes.

59

BP Amoco and EPA Regions 4 and 5 Study

- Objective
  - Do differences in DP and HSA well installation methods and materials impact groundwater analyte concentrations?
- Locations
  - Four fuel stations with dissolved-phase hydrocarbon plumes
    - Ohio – 2 sites
    - Georgia – 2 sites

No associated notes.

60

BP/EPA Study Design

- Wells
  - Each site has 3 DP wells installed 2.5 feet from 3 HSA wells
  - 12 well pairs, total of 24 wells analyzed in study
  - HSA wells 2” and 4” diameter
  - DP wells all 1” diameter
  - All wells were exposed screen type – no prepacks or seals
- Screens
  - Intervals varied from 10-15 feet
  - Intervals and depths matched for each DP/HSA well pair
- Sampling
  - Four quarterly samplings events
  - 8 analytes evaluated over all sites; 768 analytical data values
  - Additional 9 geochemistry parameters evaluated at two sites
- Analysis
  - Use of ANOVA statistical methods

No associated notes.

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Sites' Characteristics

Site	Physiographic province	Sediment type	Mean depth to water
Brunswick, GA	Barrier Island Sequence Coastal Plain	Permeable silty and clayey, fine to medium sands	5.1 ft
Marietta, GA	Piedmont Central Uplands	Fine-grained soils and saprolite that mantle bedrock	13 ft
Toledo, OH	Interior Plains, Central Lowlands	Clayey silt with very thin, discontinuous laminae of clay	8.8 ft
Granville, OH	Till Plain	Sandy silt over sand and gravel outwash	17.9 ft

No associated notes.

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BP/EPA Study Statistical Results

- Chemical analysis
  - MTBE – no significant differences at 4 sites
  - BTEX
    - No significant differences at 3 sites
    - DP wells significantly higher than HSA at 1 site
  - Naphthalene – slightly higher concentrations in DP wells but not across all sites
- Geochemical parameters – no significant differences
- Mean hydraulic conductivity (K) for HSA wells 4.4x greater than DP wells
- Total suspended solids for DP wells > HSA wells
  - Surge block development methods removed difference
- Water levels nearly identical for DP and HSA wells

No associated notes.

63

BP/EPA Conclusions and Recommendations

- Statistical analyses indicate DP wells compare favorably to HSA wells
- Where differences exist, analyte concentrations in DP wells were generally higher
- Surge block techniques recommended for development of exposed screen DP wells to reduce turbidity
- Higher hydraulic conductivity (K) in HSA wells than DP wells
  - Calculation of effective radius?
  - Proper DP well development?
  - Within an order of magnitude—affect management decision?

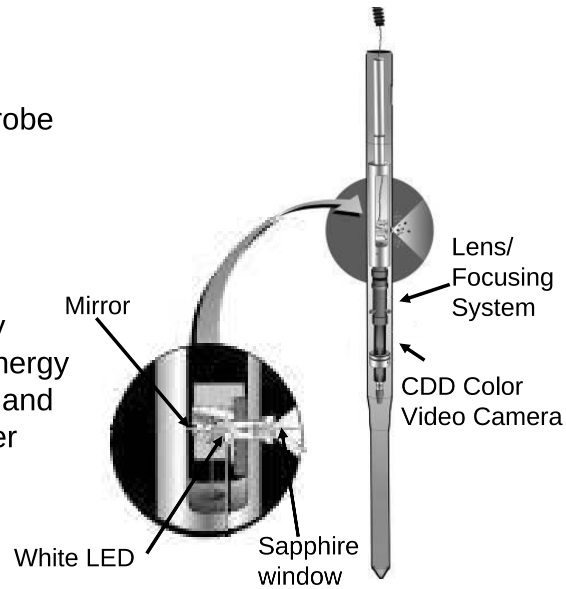
Researchers found no significant difference in MTBE and BTEX concentrations measured in the DP and conventional wells.

For the geochemical parameters (dissolved oxygen, carbon dioxide, ferrous iron, nitrate, methane, alkalinity, and sulfate), they found no significant difference in the concentrations measured in samples obtained from DP wells vs. those from conventional wells. However, they did note that there was only a small amount of data and it exhibited some variability.

64

New Technology: GeoVIS

- Direct-push (DP) microscope sensor probe
- Effective porosity on millimeter scale
- Minimal exposure to contaminated soils
- System used by Navy and Department of Energy Site Characterization and Analysis Penetrometer System (SCAPS)



- GeoVIS sensor probe integrated into conventional DP rig
- LED light source projected into soil continuously or at selected depths
- Light reflected off soil matrix recorded on color video camera
- Video images fed back to computer at surface

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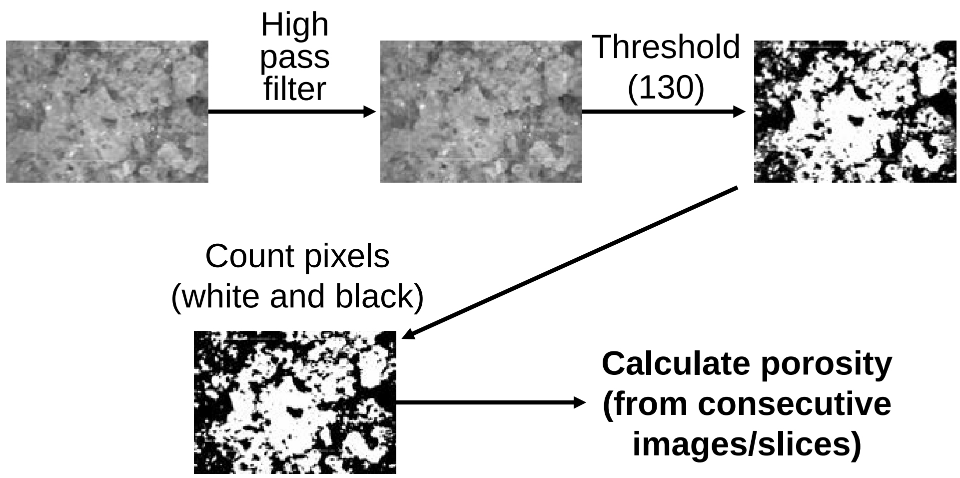
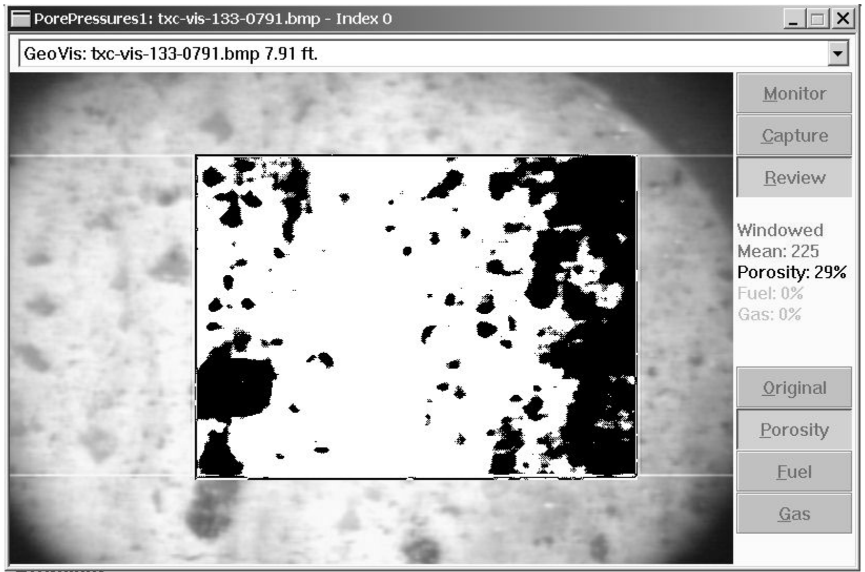
GeoVIS Soil Porosity Estimate



- Video camera image is downloaded to computer
- Original image signal conditioning with high pass filter for better resolution and contrast
- 256 grayscale with black/white threshold set at 130
- Processed image now black white
- Count pixels, black verses white
- Porosity calculated from average of multiple images

GeoVIS Soil Porosity Estimate



•Example porosity calculation

•Screen is 2.5mm x 2.0mm

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New Technology: High-Resolution Piezocone

- Direct-push (DP) sensor probe that converts pore pressure to water level or hydraulic head
- Head values to ± 0.08ft (to >70' below)
- Can measure vertical gradients
- Simultaneously collect soil type and K
- Minimal worker exposure to contaminants
- New system installed on Navy Public Works Center (PWC) San Diego SCAPS

• Ability to measure vertical hydraulic gradients is new and so important to understanding groundwater and contaminant flow

• Real-time and simultaneous collection of soil type and hydraulic conductivity data is not possible with drilled wells

68

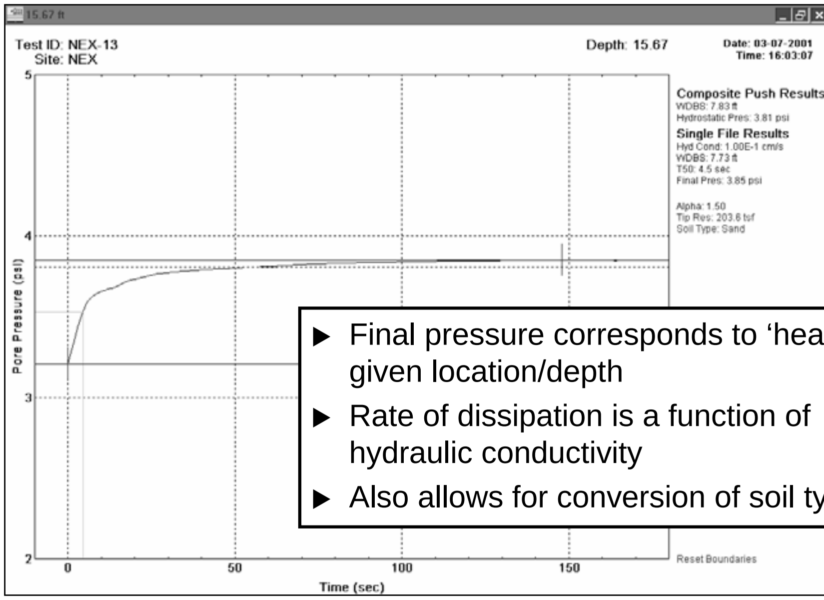
High-Resolution Piezocone

• Load cells measure both skin friction along body and force to push tip through soil

• Brown ring is permeable enabling pressure transducer inside body to measure pore pressure

• Results: real-time soil classification and water level determination

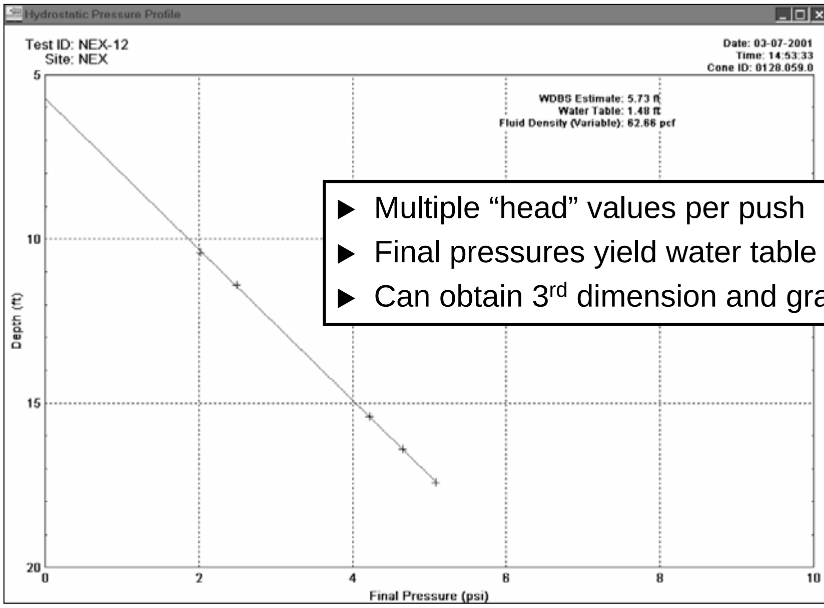
Dissipation Data



- Final pressure corresponds to 'head' at given location/depth
- Rate of dissipation is a function of hydraulic conductivity
- Also allows for conversion of soil type to K

• T50 is the time (seconds) it takes aquifer to recover to half of the final head at a given depth

Water Table Determination



- ▶ Multiple "head" values per push
- ▶ Final pressures yield water table depth
- ▶ Can obtain 3rd dimension and gradients

• Blue marks are "stops" where pressure was measured during the push

• Extrapolate back to get water table depth

• Note straight line through blue marks, this indicates a more homogeneous type soil matrix

• Clay lens and other heterogeneous soil matrix conditions can be identified with pressure head measurements do not line up

• With pore pressure and soil type data, calculation of vertical hydraulic gradients are possible

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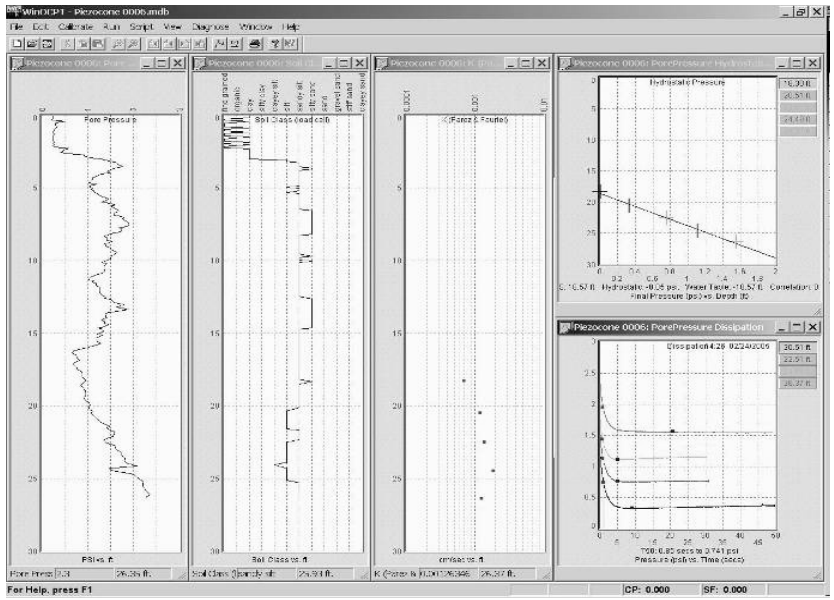
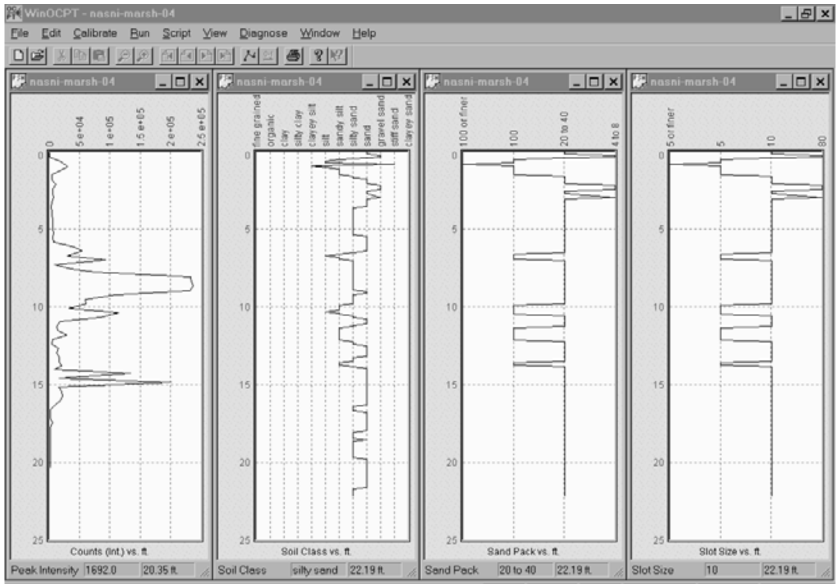
Soil Classification Data



Typical borehole logs – all the things just mentioned – pore pressure, soil classification, K, dissipation, and water level

Well Design Software Based on CPT



•Takes CPT data and automates design and selection of well screen slot size and filter pack according to ASTM standards for specific soil types

•Taking it a step further, the well screen can be placed in higher contaminant zones identified using DP laser induced fluorescence techniques

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Summary – Case Studies and New Direct Push Technologies

- Large DoD savings anticipated from extended use of direct push wells
- Case studies presented cover a wide range of:
  - Contaminants
  - Soil types
  - Well parameters
  - Geographical locations
- Data supports DP well data quality
  - Over 50,000 analytical data values in ESTCP study strongly support
  - BP & EPA study further supports
- Data variance
  - Low for inorganics
  - High from some organic contaminants
- Significant differences do exist between well types but *no trend* was observed in the data sets
- DP wells being pushed into the subsurface allows a large suite of emerging characterization technologies to be implemented

Large DoD savings anticipated from extended use of direct Push wells

Case studies presented cover a wide range of contaminants, soil types, well parameters, and geographical locations

Over 50,000 analytical data values in ESTCP study strongly supports DP well data quality

BP & EPA study further supports DP well data quality

Data variance low for inorganics & high from some organic contaminants

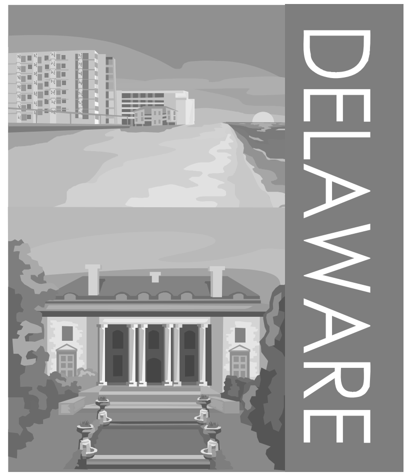
Significant differences do exist between well types but *no trend* was observed in the data sets

The fact that DP wells are pushed into the subsurface allows a large suite of emerging characterization technologies to be implemented.

74

State Case Studies – Delaware

- Types of sites
  - Brownfield, CERCLA, Solid Waste, UST, Voluntary Cleanup
- Contaminants of concern
  - Chlorinated solvents, petroleum, metals, methane gas
- Primary uses of DP wells
  - Permanent and temporary
- Depth range
  - 8-45 ft bgs
- Geological conditions
  - Sandy alluvium, silts, clays, and weathered bedrock



Some problems encountered include the hole collapsing during installation of the DP filter pack, and casings shattering. However, the pre-packed wells are showing representative results and cost savings of 50 to 60% when compared to conventional wells

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Missouri

- Types of sites
  - CERCLA/SARA, UST, landfills
- Contaminants of concern
  - Volatile organics, methane
- Primary uses of DP wells
  - Permanent and temporary
- Depth range
  - 15-70 ft bgs
- Conclusions/findings
  - DP wells could be installed at an average savings of 69%, over conventional 2” monitoring wells

Analysis of data generated during a comparative study (conducted by the Missouri DNR in 1994) indicated direct-push wells could be installed at an average savings of approximately 69% over conventionally drilled 2” monitoring wells. Missouri Department of Natural Resources "An Analysis of Landfill Gas Monitoring Well Design and Construction" available from the "Links to Additional Resources page (http://www.clu-in.org/conf/itrc/directpush/resource.cfm)

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South Carolina

- Types of sites
  - Superfund, RCRA, UST, Drycleaner, Brownfield
- Contaminants of concern
  - Volatile and semi-volatile organics, inorganics
- Primary uses of DP wells
  - Permanent and temporary
- Depth range
  - 4-100 ft bgs
- Geological conditions
  - Piedmont
  - Coastal plain

The SC Drycleaner Restoration Trust Fund has a sampling protocol involving the use of DP technologies

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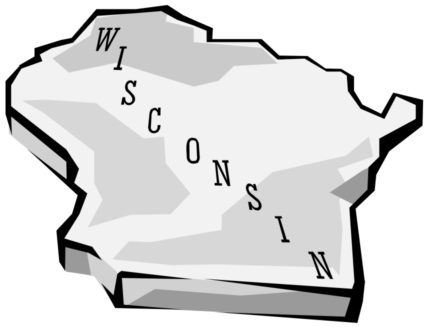
Wisconsin



- Types of sites
  - Agricultural Chemical Cleanup Program, Superfund, UST
- Contaminants of concern
  - Range from pesticides to volatile organics
- Primary uses of DP wells
  - Permanent and temporary
- Depth range
  - < 45 ft bgs
- Geological conditions
  - Till and moraine deposits, loess, outwash deposits

Wisconsin Administrative Code chapter NR 141 specifies standards for design, installation, construction, abandonment, and documentation of groundwater monitoring wells

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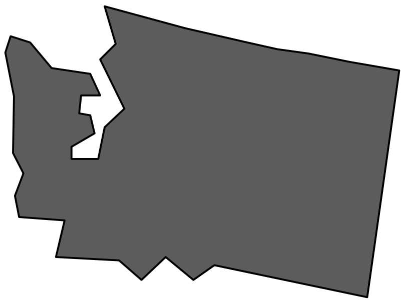
Washington



- Used as standard practice
- Has been used at several major site cleanups
  - Wenatchee Tree Fruit Orchard
  - Hanford (US DOE)
- Regulations governing use of DP wells codified
- Innovative technologies such as laser head cone attachments being used to break up cobbles which limit DP applications

No associated notes.

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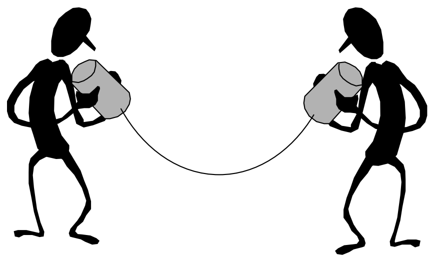
Stakeholders



- Communication with stakeholders early and often is key
- Stakeholders can often drive remediation alternatives
  - Oxnard Plain: Port Hueneme, CA
- Stakeholders must be convinced of the technical effectiveness of DP wells before they can be expected to support their use

Effective communication helps stakeholders gain a greater understanding of the regulatory process, technologies and remediation techniques

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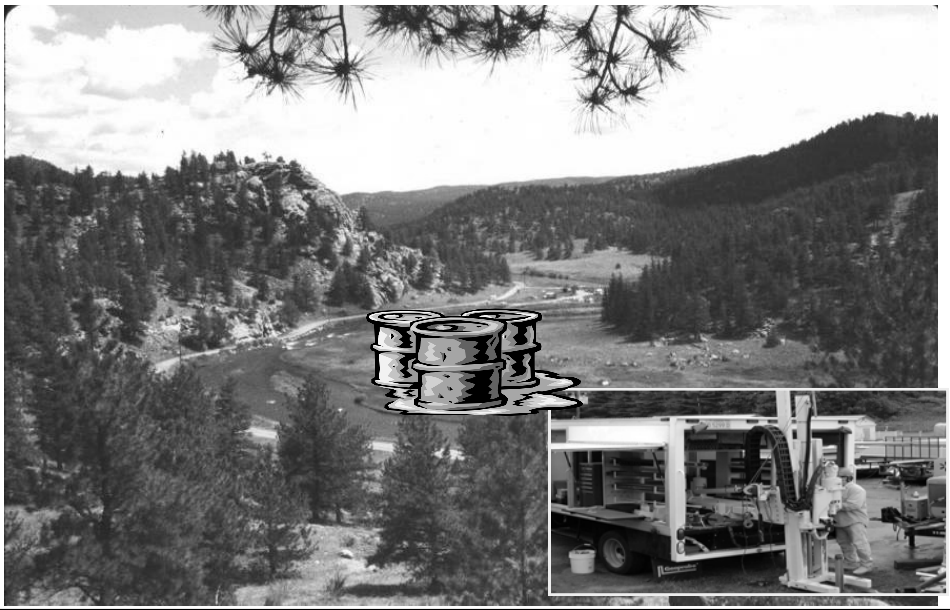
Sensitive Locations



DP well rigs can get in and out of sensitive locations quickly

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Monitoring Well Health and Safety

Safety Issue	Remedy
Hidden (subsurface) obstacles/utilities	Request/conduct a utilities locate prior to initiating work
Flying dust/debris during hammering	Adequate eye protection (safety glasses)
Head injury	Adequate head protection (hard hat)
Feet becoming trapped under probe foot and/or derrick	Keeping feet clear of equipment and wearing steel-toed boots
Hands becoming trapped in equipment	Keeping hands clear of equipment and wearing heavy work gloves
Exposure to hazardous substances	Air monitoring, appropriate respiratory protection, adequate decontamination procedures, adequate personal protective equipment (PPE)

This table lists various health and safety concerns associated with all types of drilling

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Conclusions

- Representative chemistry and field parameter measurements
- Cost savings
- Fewer well development wastes

DP wells result in less investigation derived waste (IDW), less exposure to contaminants, save money, and provide representative data

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Conclusions (continued)

- Installation rate two to five times faster than conventionally drilled monitoring wells
- Minimal environmental disturbance
- Improved landowner relations

DP wells can be installed quickly

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Considerations

- Not applicable in consolidated materials
- Not accepted for long-term monitoring in most states
- Well diameter limitations

Consolidated materials can limit DP installations

If it is necessary to install a well using a casing greater than 2” in diameter, then conventional drilling equipment should be used

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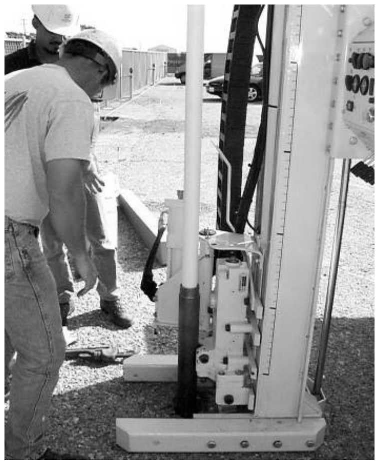
The Bottom Line



- Various studies have found little difference between paired DP wells and conventional wells for the analytes investigated
- DP wells provide an efficient and cost effective means to define the vertical and lateral extent of groundwater contamination
- Also, small diameter DP wells are ideal for use when following the EPA's stringent "low-flow" sampling protocol (EPA 1996)

DP wells provide an efficient cost-effective means to define the vertical and lateral extent of groundwater contamination

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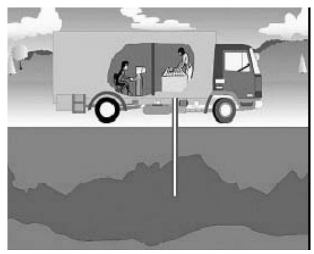
Thank You for Participating

- **Links to additional resources**
  - **http://www.clu-in.org/conf/itrc/directpush/resource.cfm**

- **2nd question and answer session**



Links to additional resources:
http://www.clu-in.org/conf/itrc/directpush/resource.cfm

Your feedback is important – please fill out the form at:
http://www.clu-in.org/conf/itrc/directpush

The benefits that ITRC offers to state regulators and technology developers, vendors, and consultants include:

✓Helping regulators build their knowledge base and raise their confidence about new environmental technologies

✓Helping regulators save time and money when evaluating environmental technologies

✓Guiding technology developers in the collection of performance data to satisfy the requirements of multiple states

✓Helping technology vendors avoid the time and expense of conducting duplicative and costly demonstrations

✓Providing a reliable network among members of the environmental community to focus on innovative environmental technologies

How you can get involved with ITRC:

✓Join an ITRC Team – with just 10% of your time you can have a positive impact on the regulatory process and acceptance of innovative technologies and approaches

✓Sponsor ITRC's technical team and other activities

✓Be an official state member by appointing a POC (State Point of Contact) to the State Engagement Team

✓Use ITRC products and attend training courses

✓Submit proposals for new technical teams and projects