A Review of Best Available Technologies & Approaches for Discrete Zone Groundwater Characterization *and Monitoring*

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RemPlex/NDA Workshop
November 5, 2025

HALEY ALDRICH

Categories of technologies used for discrete-zone groundwater characterization

1. “**Shallow**” (<200 ft) in unconsolidated sediments

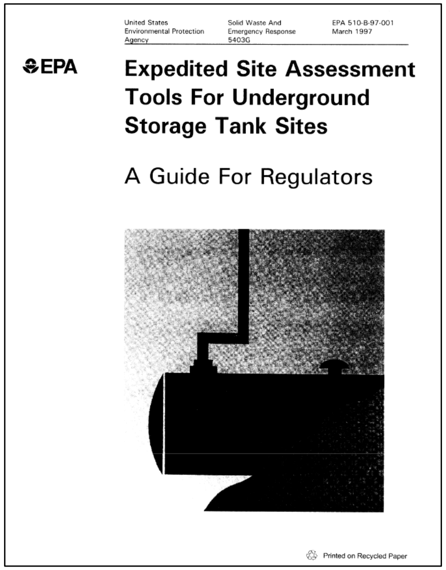
2. “**Deep**” (>200ft) in unconsolidated sediments and rock

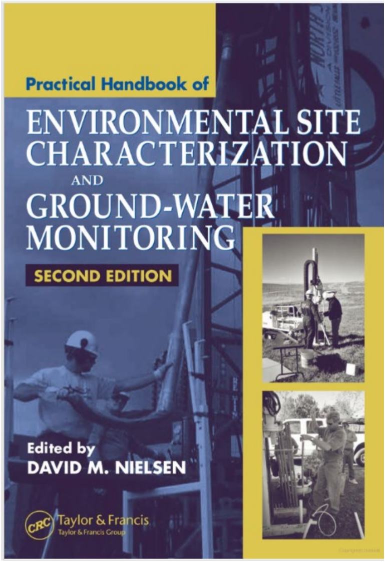
“**Shallow**” (<200 ft) groundwater sampling technologies in unconsolidated sediments

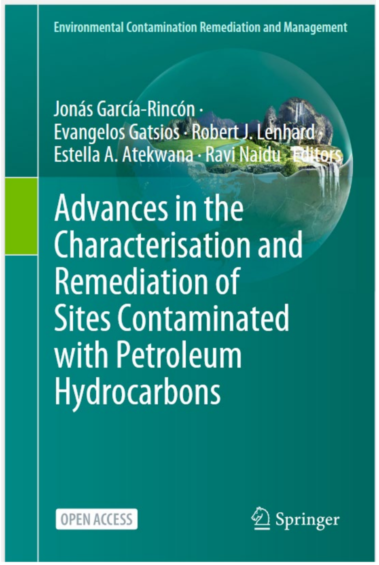
1. One-time sampling

2. Ongoing monitoring

Recommended references for one-time shallow groundwater sampling tools in unconsolidated sediments







Chapter V

Direct Push Technologies

1997

Chapter 6

6

Use of Direct-Push Technologies in Environmental Site Characterization and Ground-Water Monitoring

Wesley McCall, David M. Nielsen, Stephen P. Farrington, and Thomas M. Christy

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2006

Chapter 7

Chapter 7
High-Resolution Characterization of the Shallow Unconsolidated Subsurface Using Direct Push, Nuclear Magnetic Resonance, and Groundwater Tracing Technologies

Gaisheng Liu, John F. Devlin, Peter Dietrich, and James J. Butler Jr.

Abstract Groundwater protection and contaminated site remediation efforts continue to be hampered by the difficulty in characterizing physical properties in the subsurface at a resolution that is sufficiently high for practical investigations. For example, conventional well-based field methods, such as pumping tests, have proven to be of limited effectiveness for obtaining information, such as the transmissive and storage characteristics of a formation and the rate at which groundwater flows, across different layers in a heterogeneous aquifer system. In this chapter, we describe a series of developments that are intended to improve our discipline's capability for high-resolution characterization of subsurface conditions in shallow, unconsolidated settings. These developments include high-resolution methods for hydraulic conductivity (K) characterization based on direct push (DP) technology (e.g., DP electrical conductivity probe, DP permeameter, DP injection logger, Hydraulic Profiling Tool (HPT), and High-Resolution K tool), K and porosity characterization by nuclear magnetic resonance (NMR), and groundwater flux characterization by monitoring the movement of thermal or chemical tracers through distributed temperature sensing

G. Liu (✉) · J. J. Butler Jr.
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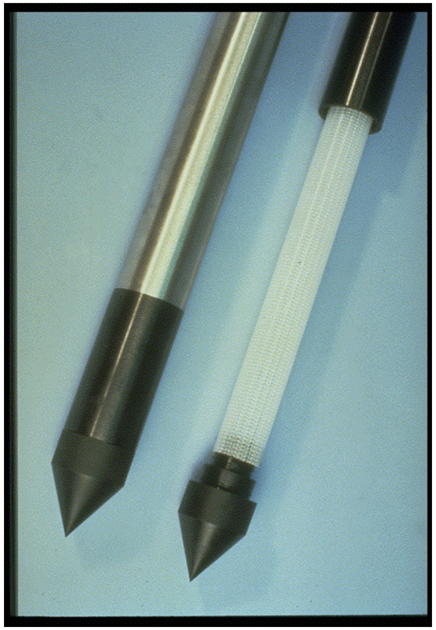
J. F. Devlin

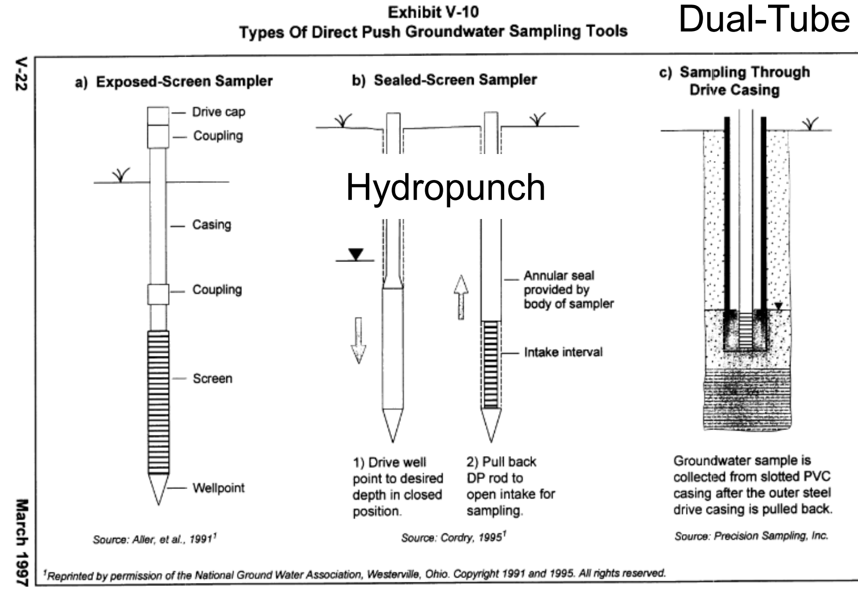
2024

Sealed Screen Sampler, aka "Hydropunch"



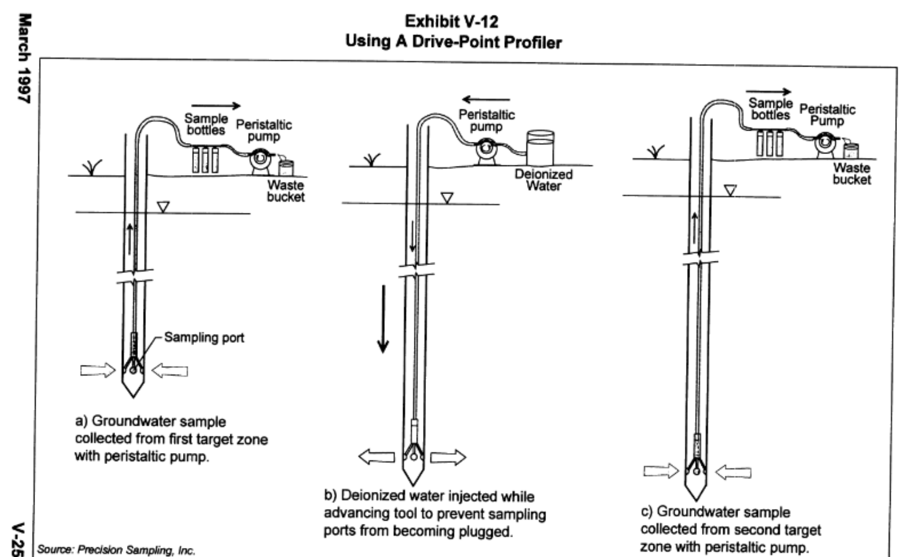
1995

Dual-Tube DP



"Home made" version of Hydropunch

Waterloo Groundwater Profiler, Geoprobe HPT™



“**Shallow**” (<200 ft) groundwater sampling technologies in unconsolidated sediments

1. One-time sampling

2. Ongoing monitoring

Why not conventional single-interval monitoring wells?

Engineered multilevel monitoring systems prevent ambient vertical flow in the boreholes and provide samples from multiple depths

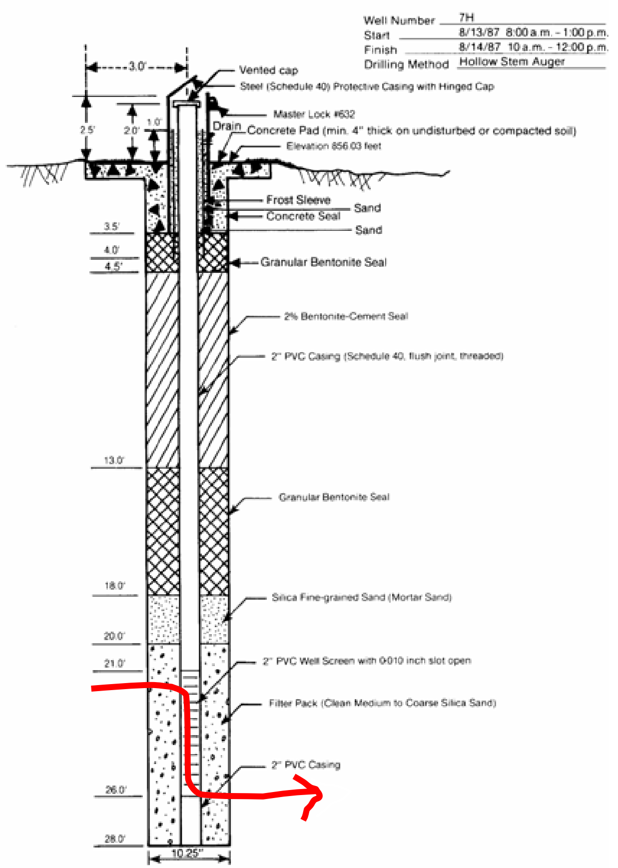


Figure 21. Format for an "as-built" monitoring well diagram.

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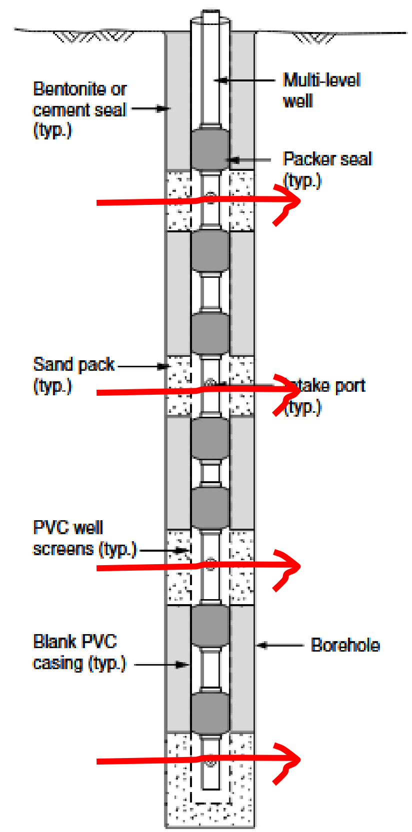
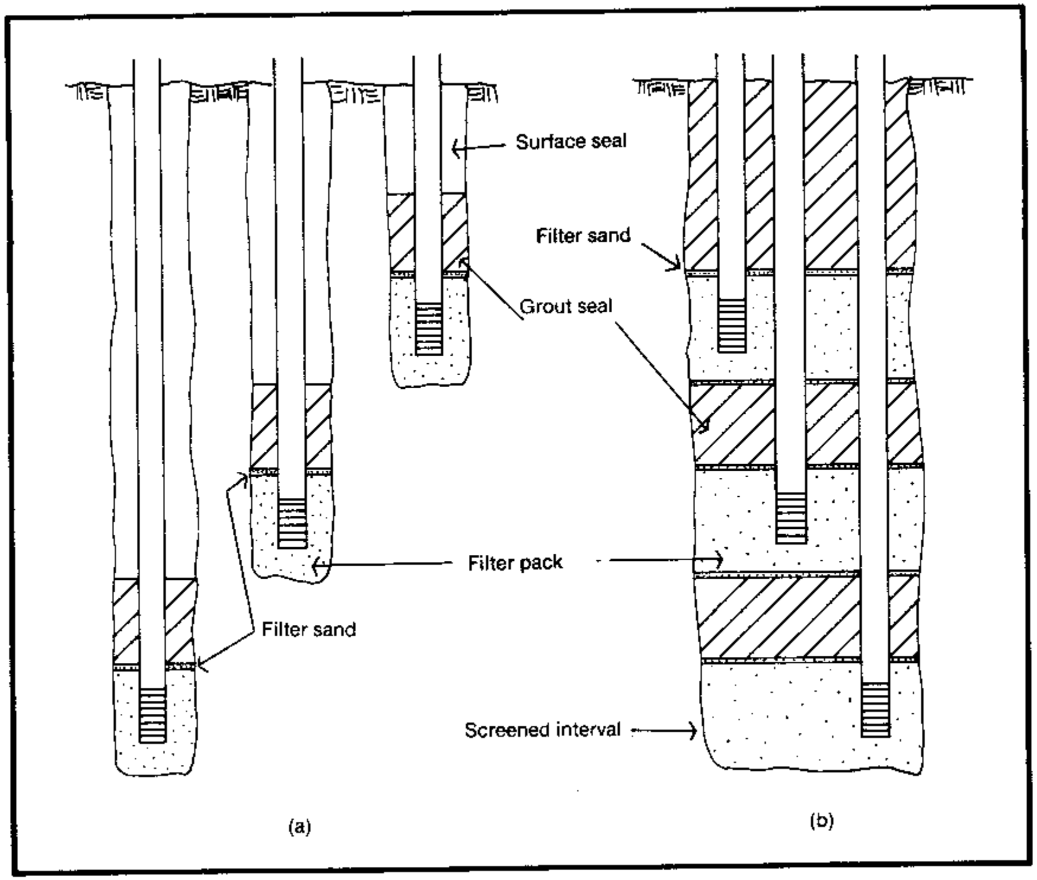


Multilevel groundwater monitoring can be done using conventional monitoring wells

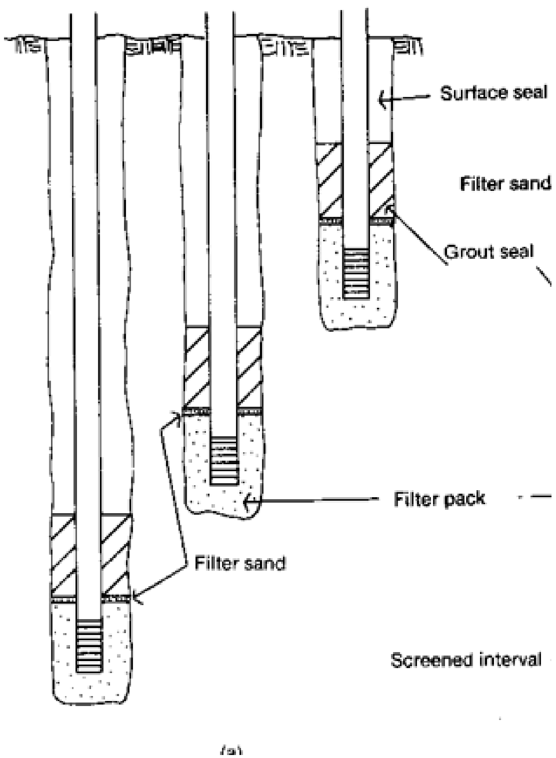
Well Clusters   Nested Wells



'igure 70. **Typical nested well designs: a) series of single riser/limited interval wells in separate boreholes and b) multiple single riser/limited interval wells in a single borehole (After Johnson, 1983).**

Well Clusters

Design



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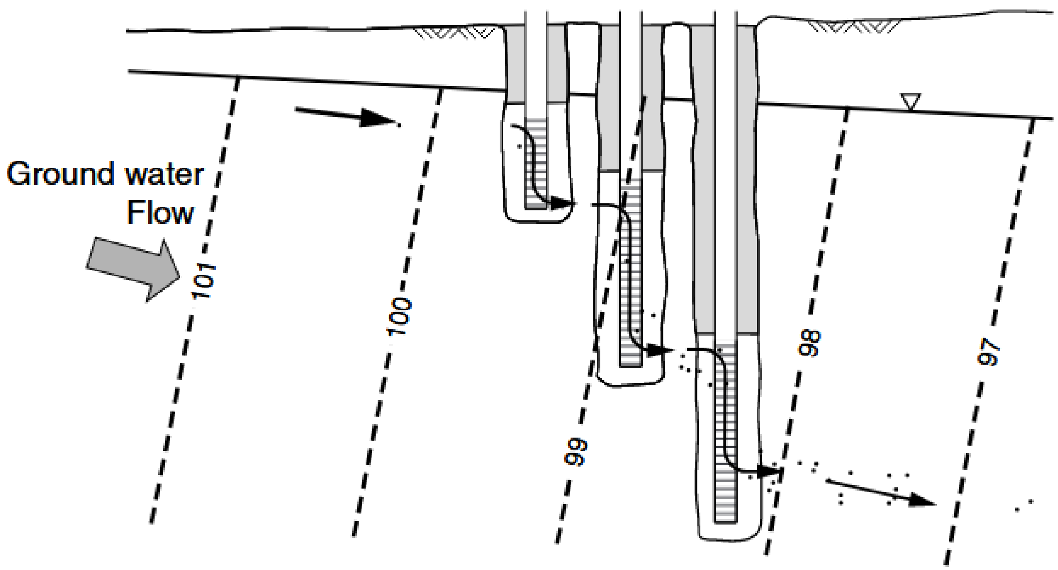
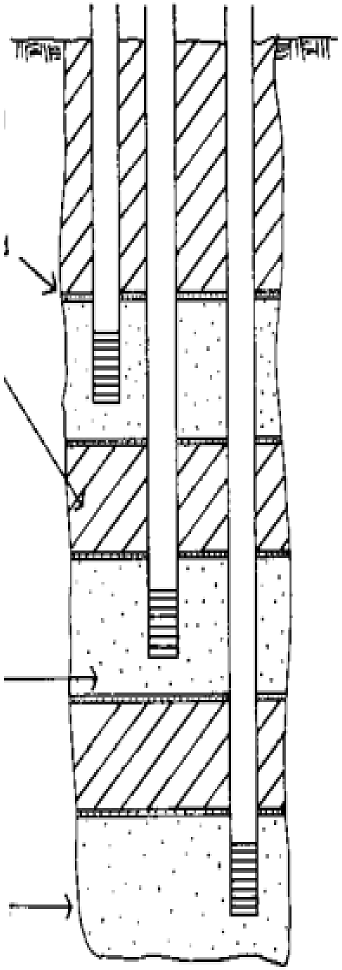
Unintended consequences

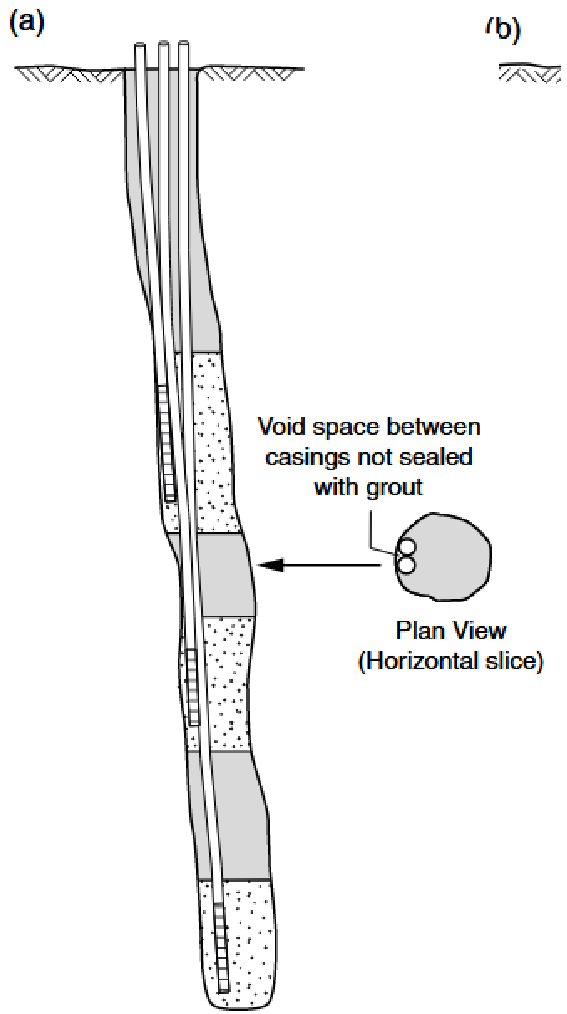


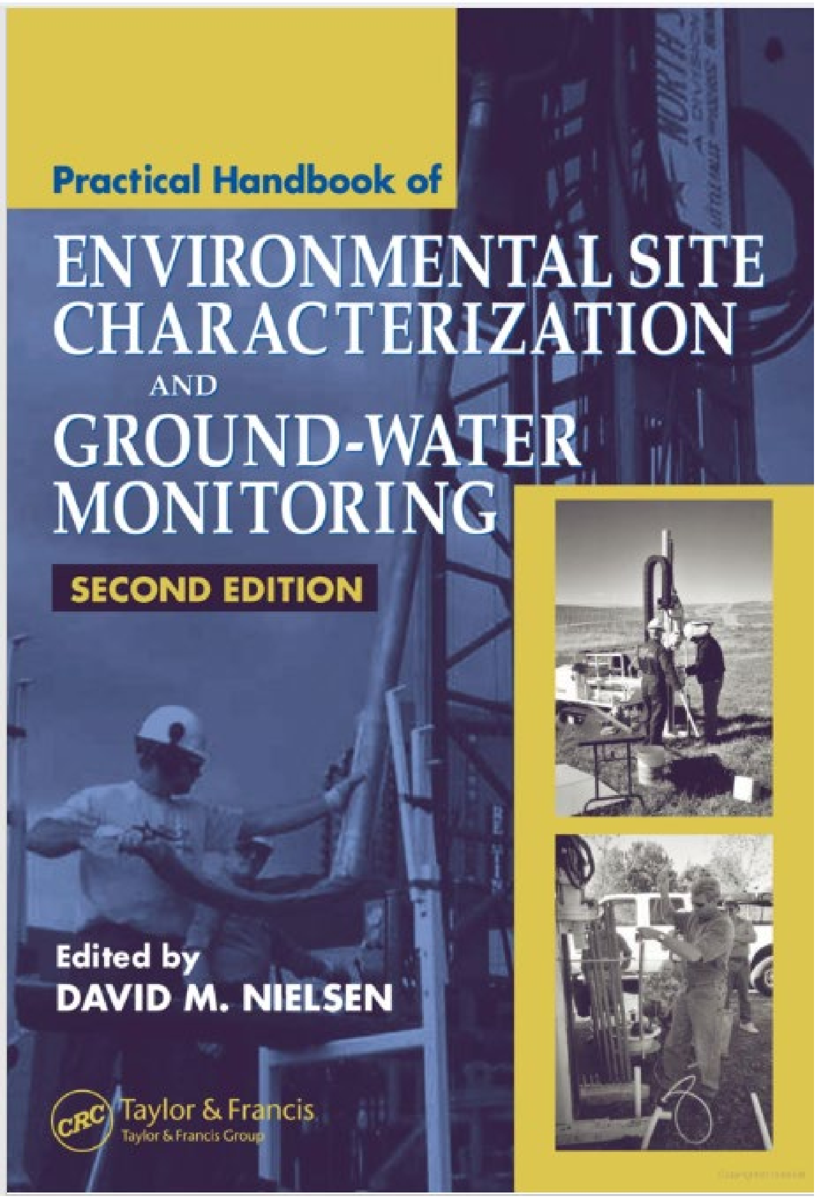
Nested Wells

Design



Reality





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Multilevel Ground-Water Monitoring

Murray Einarson

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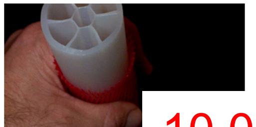
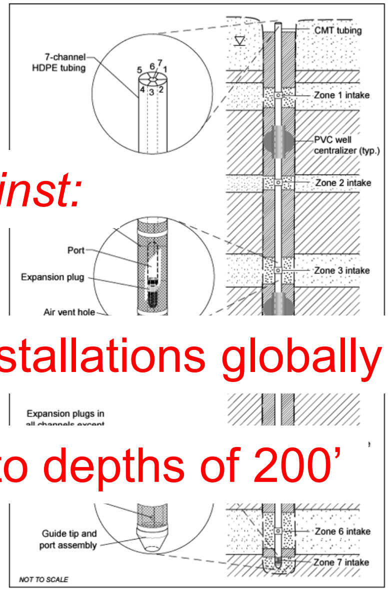
Engineered Multi-level Monitoring Systems (MLS)

Solinst CMT™ System

According to Solinst:

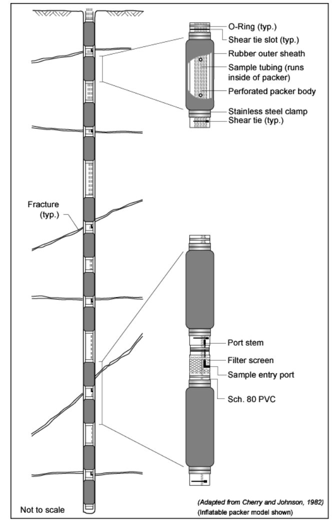




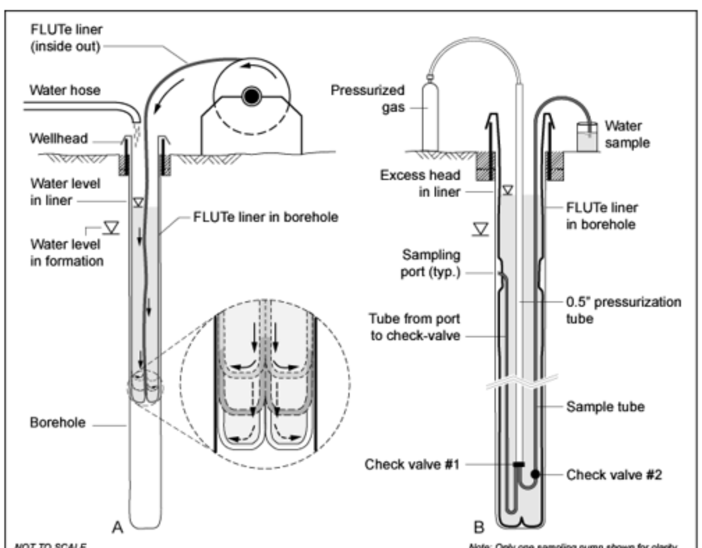
10,000 installations globally

Installed to depths of 200'

Solinst Waterloo System



Water FLUTe™ system



Westbay System

1 – packer

2 – measurement port (pressures, groundwater sampling, limited hydraulic testing)

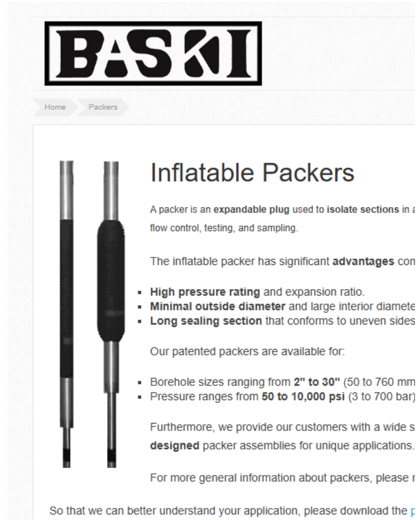
3 – pumping port (development and hydraulic testing)

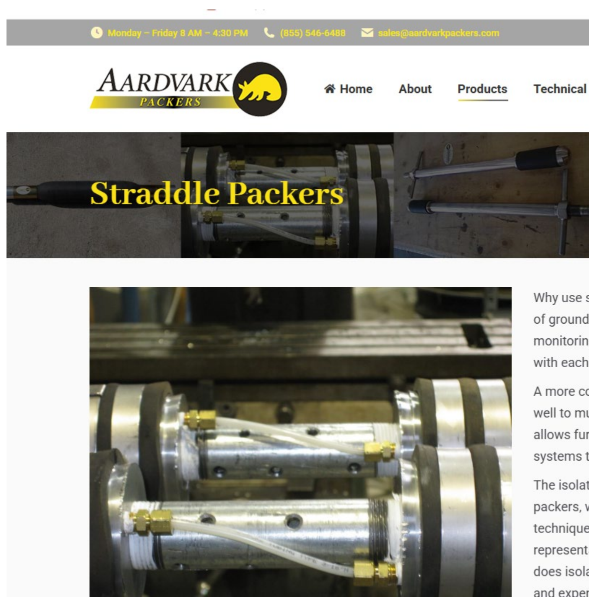
“**Deep**” (>200 ft) groundwater sampling technologies in sediments and rock

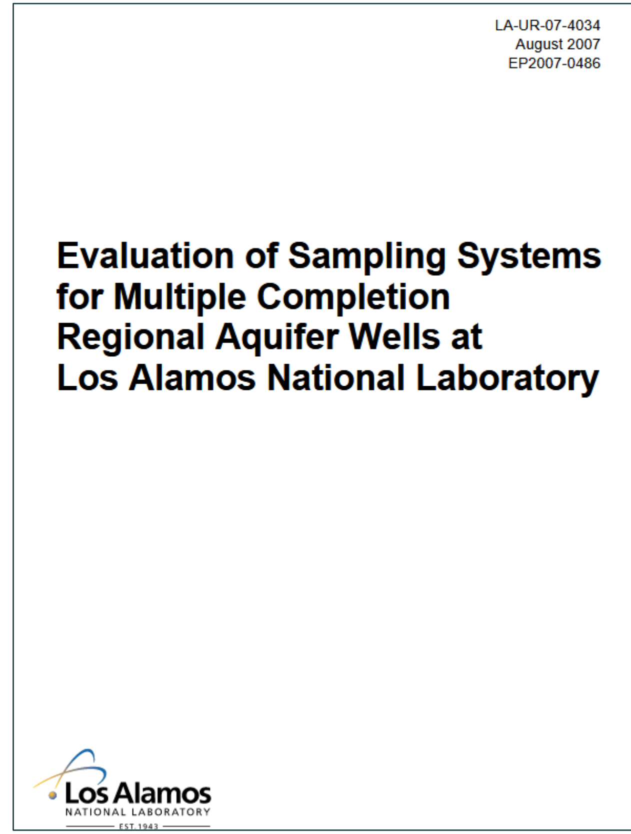
1. One-time sampling

2. Ongoing monitoring

Inflatable straddle packer systems






LA-UR-07-4034
August 2007
EP2007-0486

Evaluation of Sampling Systems for Multiple Completion Regional Aquifer Wells at Los Alamos National Laboratory

Los Alamos
NATIONAL LABORATORY
EST 1943

Sonic drills

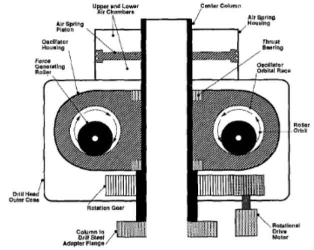
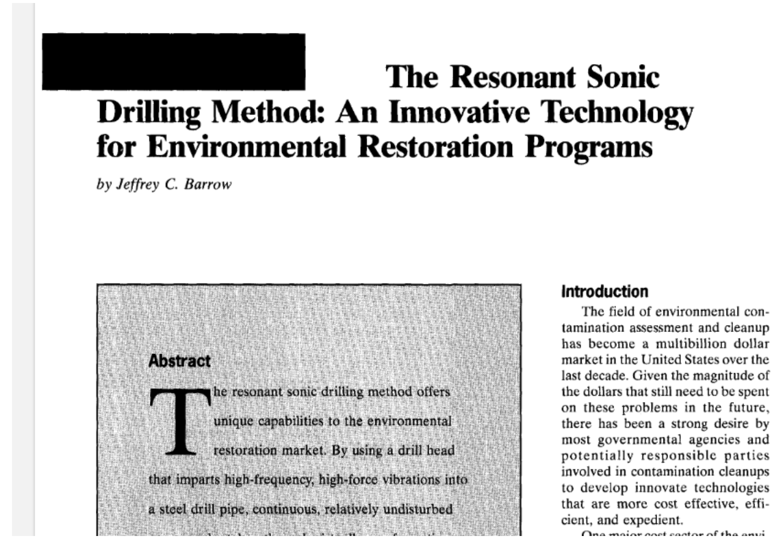


Figure 1. Resonant sonic drill head.

The oscillator housing serves to receive the centrif-



[redacted] The Resonant Sonic Drilling Method: An Innovative Technology for Environmental Restoration Programs

by Jeffrey C. Barrow

Abstract

The resonant sonic drilling method offers unique capabilities to the environmental restoration market. By using a drill head that imparts high-frequency, high-force vibrations into a steel drill pipe, continuous, relatively undisturbed

Introduction

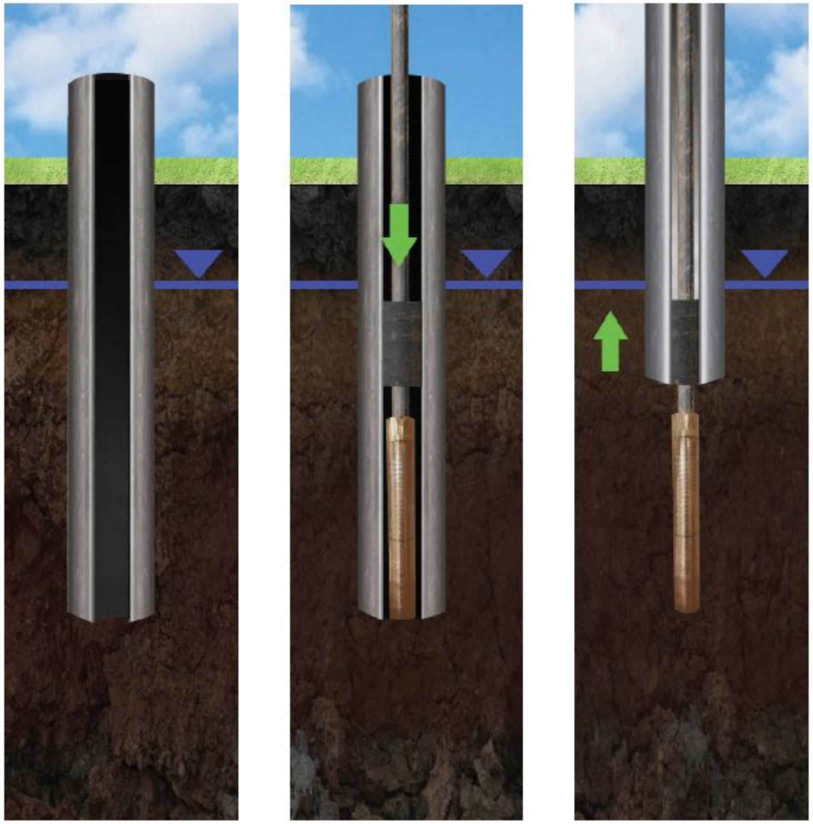
The field of environmental contamination assessment and cleanup has become a multibillion dollar market in the United States over the last decade. Given the magnitude of the dollars that still need to be spent on these problems in the future, there has been a strong desire by most governmental agencies and potentially responsible parties involved in contamination cleanups to develop innovate technologies that are more cost effective, efficient, and expedient.

Packer Isolation System with Sonic Drill

WATER SAMPLING

PACKER ISOLATION METHOD

The packer isolation groundwater sampling system is designed for collection of groundwater samples in dense overburden or bedrock boreholes where the Push-Ahead method may be less effective.



THE PROCESS

1. A sonic drill (typically with a four inch core barrel with six inch override casing) proceeds to the base of the interval from which a groundwater sample is to be collected.
2. Once that interval is achieved, the sonic core barrel is removed from the casing, and a stainless steel screen and packer assembly is inserted to the base of the sonic casing.
3. The sonic casing is then extracted to expose the screened interval to the formation and the packer is inflated inside of the sonic casing to isolate the screen.
4. Purging of the temporary well proceeds until stabilization parameters are met. Groundwater samples are then collected.

BENEFITS

1. Screen lengths may be adjusted to match specific intervals to be sampled.
2. Samples may be collected within any formation through which a sonic rig can drill.
3. Four inch diameter screens may be used which allows for higher purge rates and greater sample depths using larger submersible pumps.

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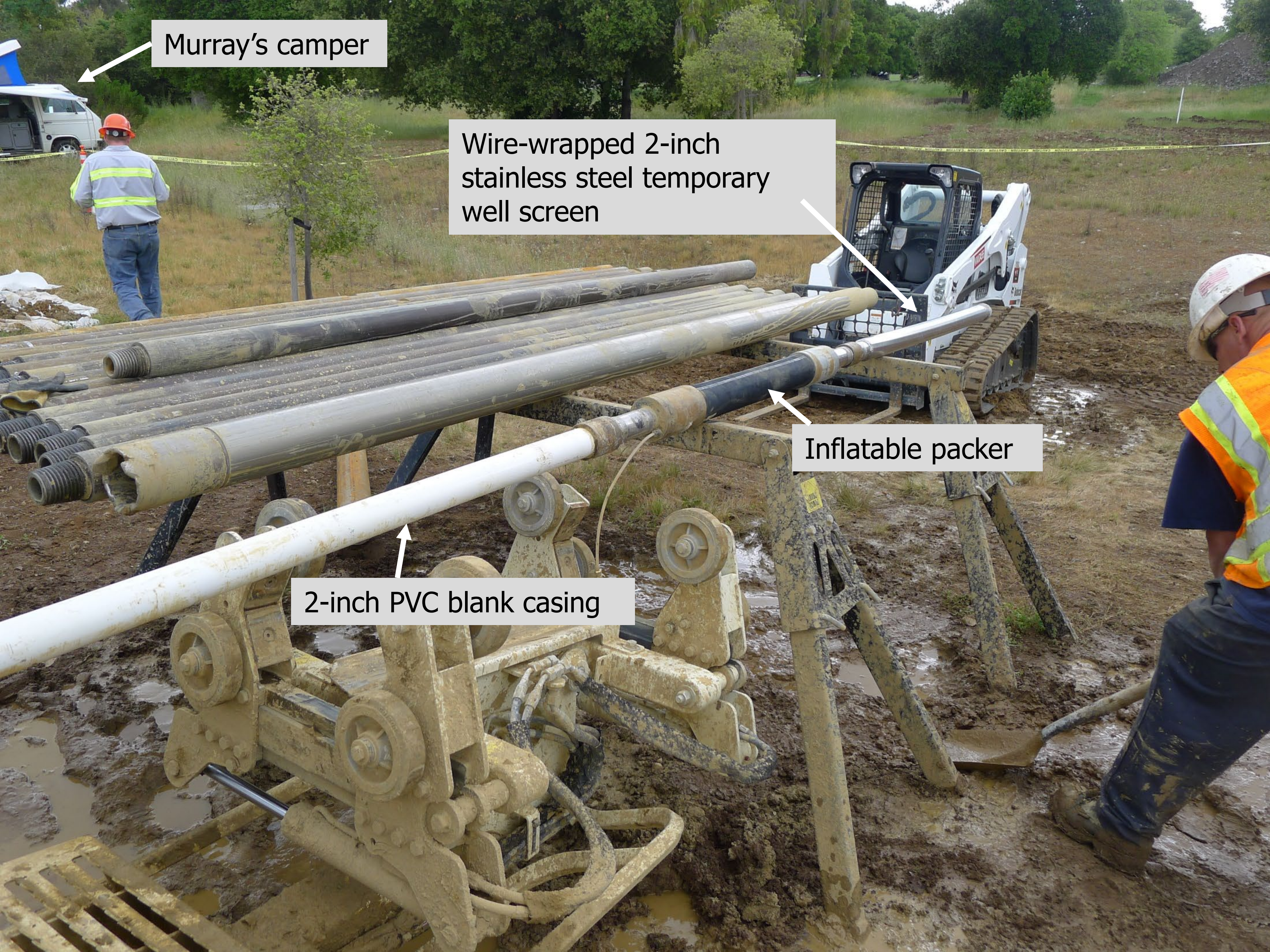

Murray's camper
Wire-wrapped 2-inch stainless steel temporary well screen
Inflatable packer
2-inch PVC blank casing

“**Deep**” (>200 ft) Groundwater Sampling Technologies in Sediments and Rock

1. One-time sampling

2. Ongoing monitoring

Engineered Multi-level Monitoring Systems (MLS)

According to Solinst:

Solinst CMT™ System

10,000 installations globally

7 channel CMTs to 300’

3 channel CMTs to 500’

Solinst Waterloo System

“a few thousand” installations globally

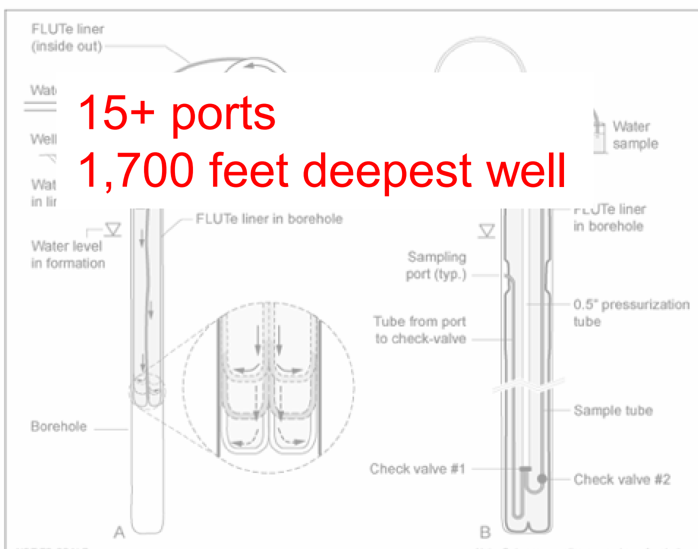
1,000 feet maximum depth

Other than USA, Canada, and the UK – popular Country’s that routinely consider MLSs: Brazil, Denmark, Netherlands, Sweden, and Singapore. Honorable mention to Australia, Taiwan, Italy, and France.

Water FLUTe™ system

15+ ports

1,700 feet deepest well



Westbay System

100+ ports

7,000 feet deepest well

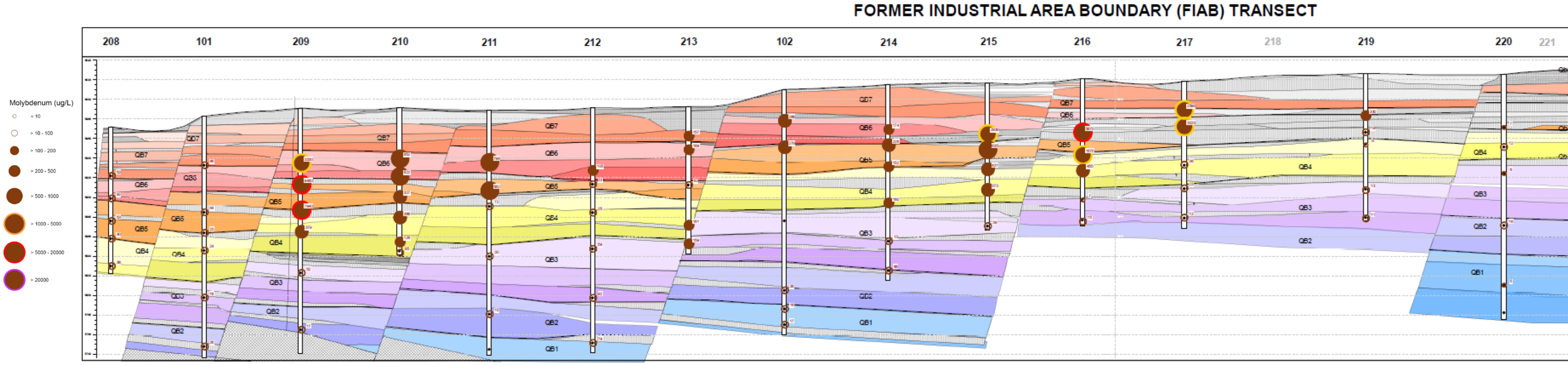
2 – measurement port (pressures, groundwater sampling, limited hydraulic testing)

3 – pumping port (development and hydraulic testing)

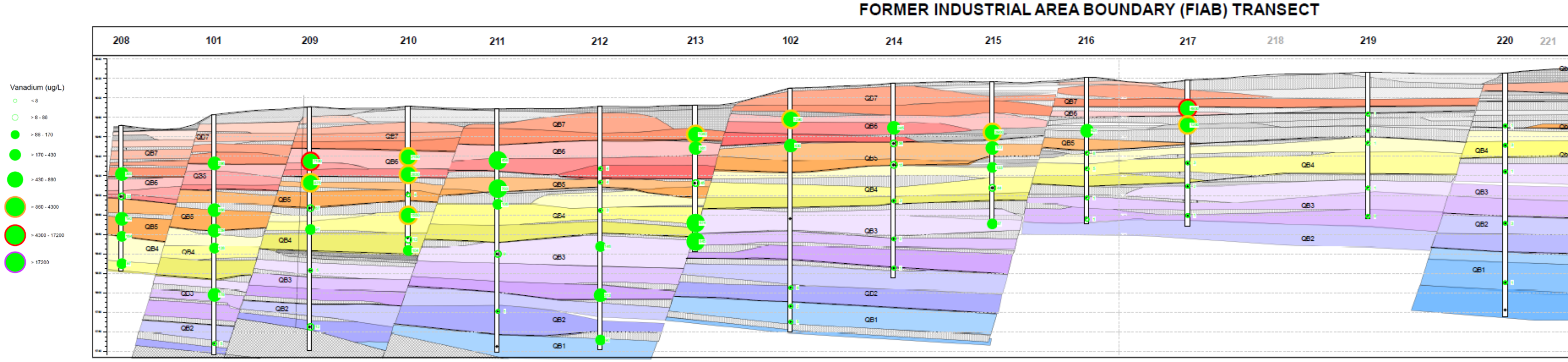
***Check with manufacturer**

Idaho sonic/CMT case study - dissolved Constituents of Concern (COCs) delineated vertically as well as laterally in each transect

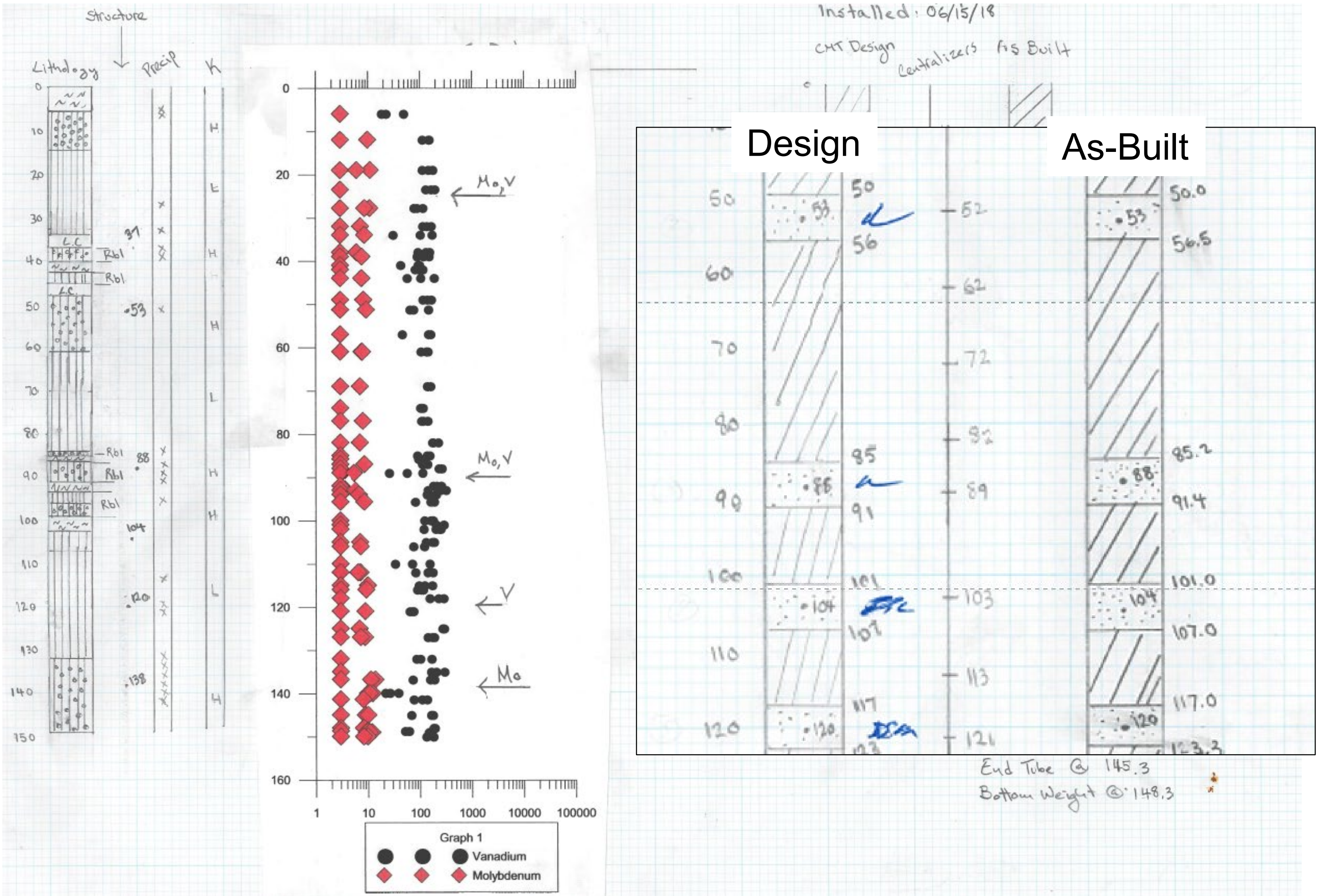
Molybdenum



Vanadium



Example well as-built diagram shows precise placement of sand pack and bentonite seals



Questions?

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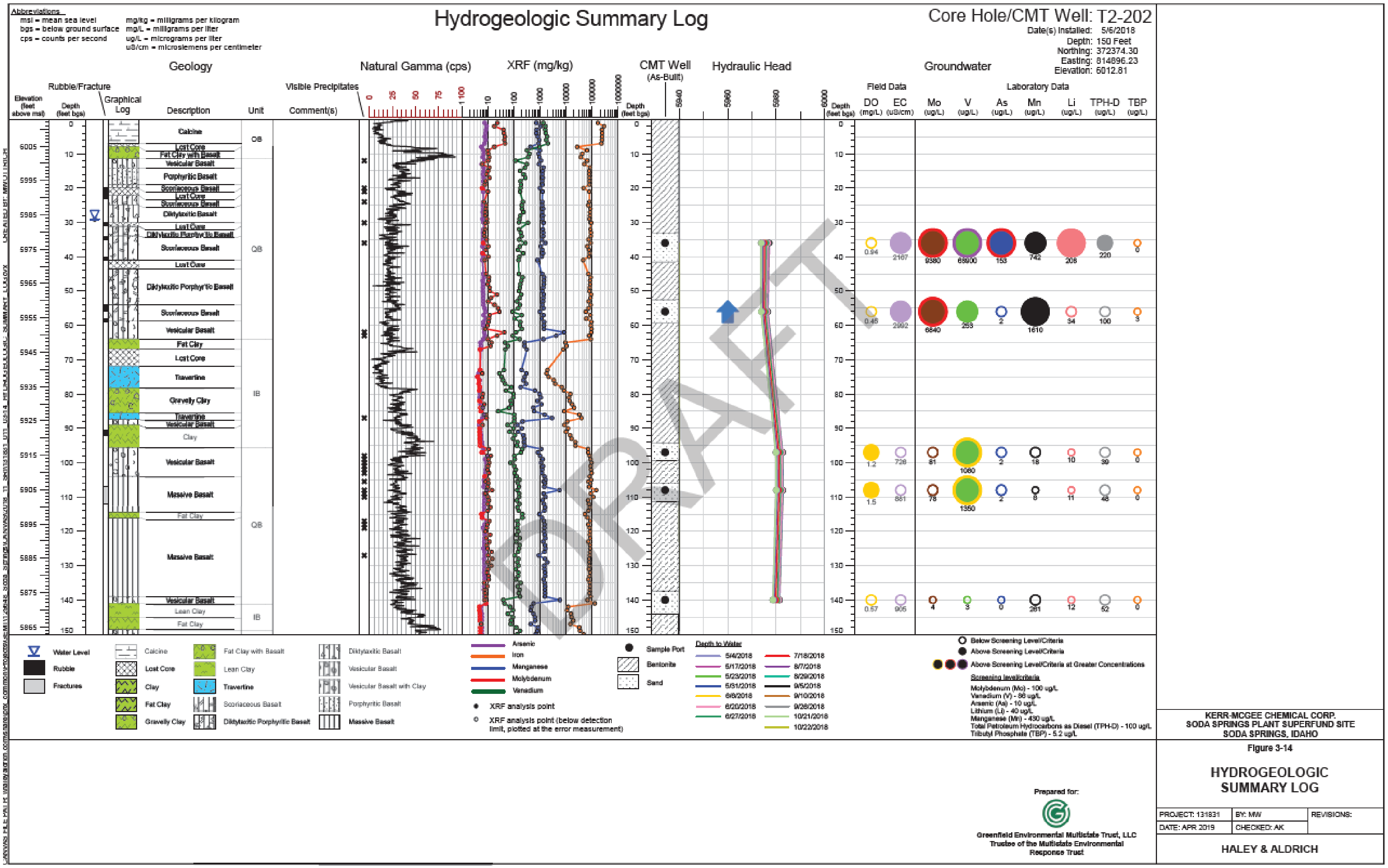
Extra slides

Idaho sonic/CMT case study: Hydrogeologic Summary Log



Continuously cored 200-foot sonic hole with 7-zone CMT monitoring well

Cost comparison of multilevel monitoring technologies (Malcolm Pirnie 2011)

Assumptions

- DTW 10'
- Today depth of wells 150'
- Number monitoring points: 3
- Geology: bedrock
- Borehole size: 6"
- Purpose: Groundwater sampling and water level measurements
- Channels for CMT: 7
- Installation method: sand and bentonite (i.e., no packers)

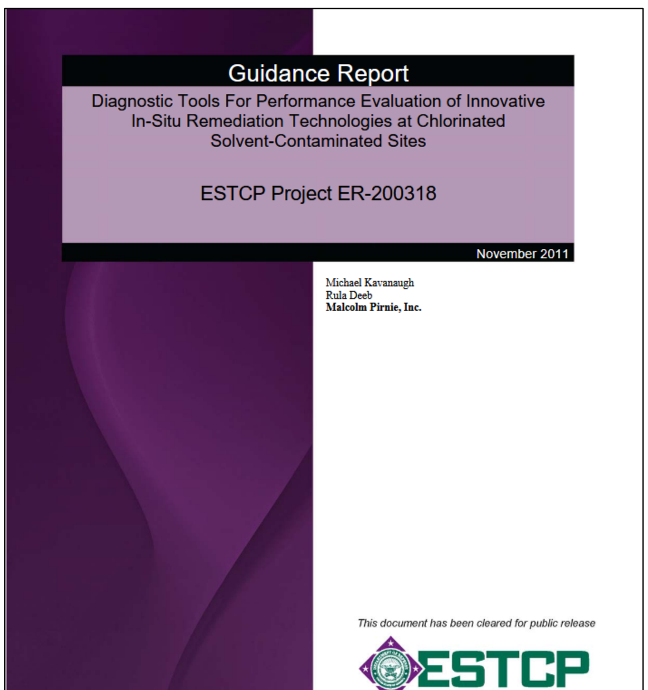

Guidance Report
Diagnostic Tools For Performance Evaluation of Innovative In-Situ Remediation Technologies at Chlorinated Solvent-Contaminated Sites
ESTCP Project ER-200318
November 2011
Michael Kavanaugh
Rula Deeb
Malcolm Pirnie, Inc.
This document has been cleared for public release

Table 3-1. Initial Capital Cost Comparisons for ZIST™ and Multi-Level Monitoring Systems

System	Major Components	Estimated Costs
ZIST™ (BESST, Inc.)	Blatymini pumps; teflon tubing; riser pipe; well screens; bentonite pellets ZIST™ transducer housings; Troll 500 transducers; Troll cables; programming cable	$7,500 (not including transducers) $17,400 (including transducers)
	ZIST™ training for installation and operation (2 days)	$3,500 (includes travel and expenses)
CMT (Solinst, Inc.)	CMT-7-Channel tubing; centralizers; wellhead; installation tool kit	$1,800
	Solinst training for installation and operation (2 days)	$3,600 (includes travel and expenses)
Westbay (Schlumberger)	Plastic MP38 casing	$6,400 (casing components) $1,600 (2-day rental of sampling equipment) $33,000 (purchase of sampling equipment)
	Westbay technical services – for training in equipment operation	$4,000 (includes travel and expenses)
FLUTe	150 ft Water FLUTe with 3 ports Ancillary equipment for installation – pump tube; wellhead roller rental; winch plate rental; pump plate rental; shipping reels	$10,400 (FLUTe only) $2,900 (for ancillary installation equipment)
	FLUTe labor to install system	$6,000 (including travel and expenses)

Materials cost:

- CMT: $1,800
- Westbay: $6,400
- FLUTe: $10,400

Westbay System
86 monitored zones
Well depth = 1,378 feet

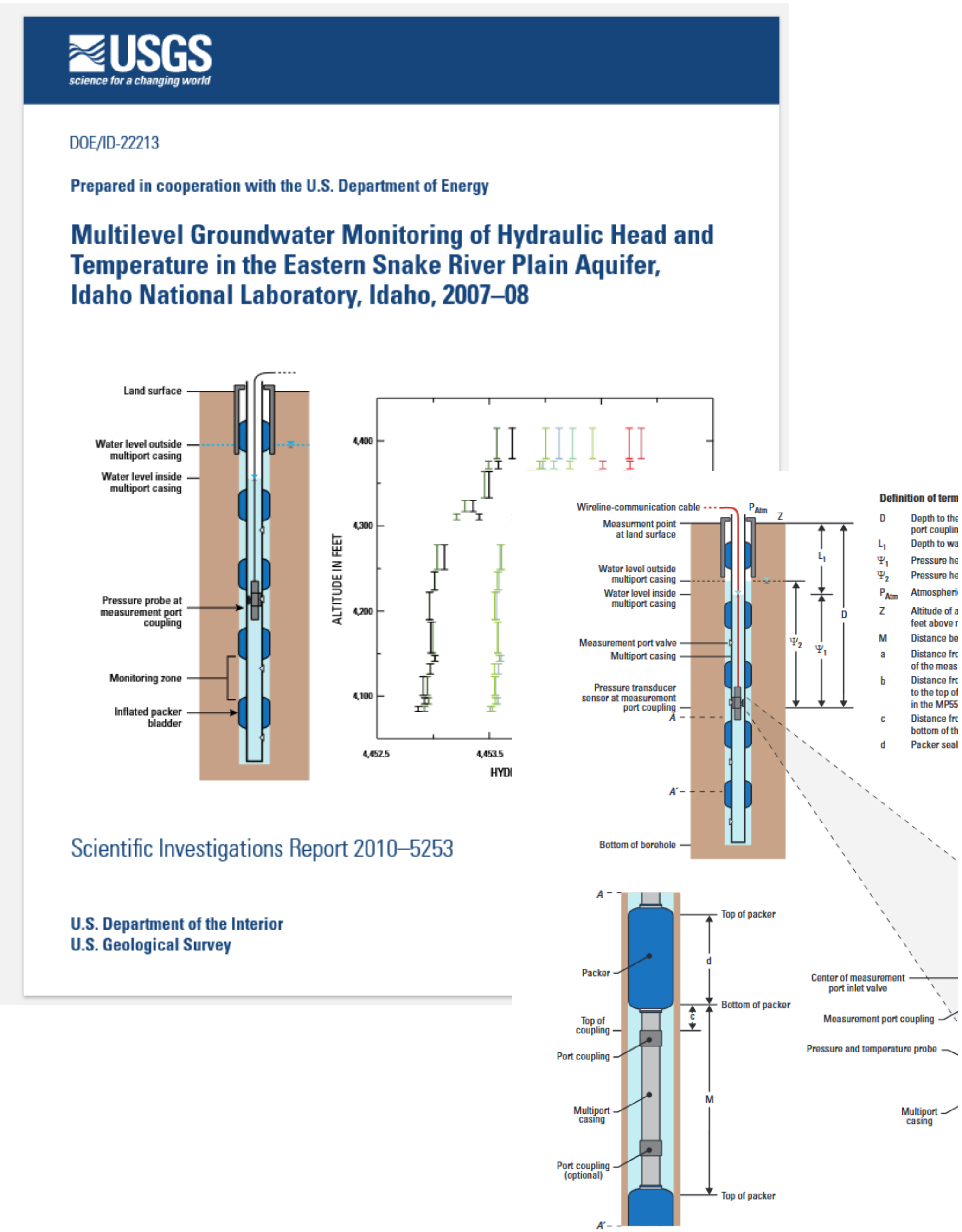


Figure 8. Terms used in the calculation of hydraulic head based on the portable probe position when coupled with a measurement port in the multilevel monitoring system. (Modified from Westbay™, written commun., 2009.)

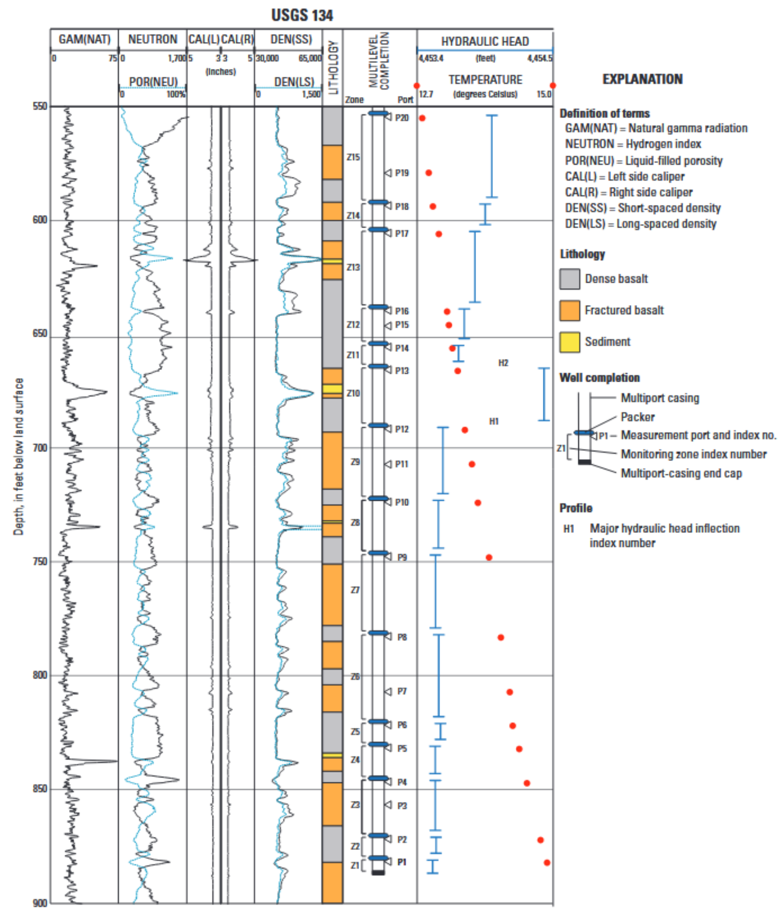
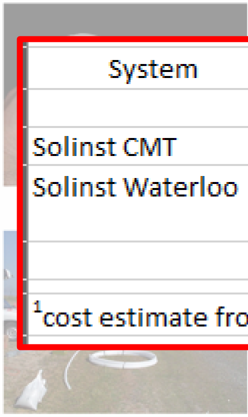


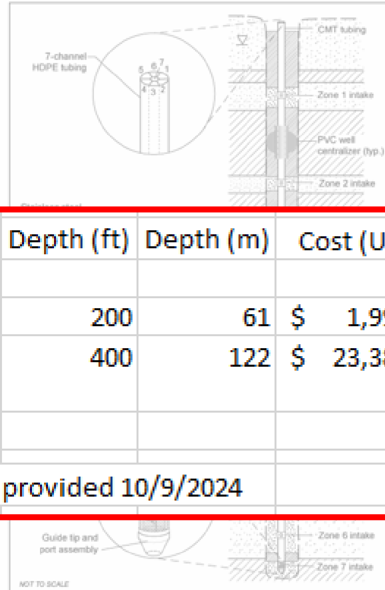
Figure 15. Geophysical traces of natural gamma, neutron, caliper, and gamma-gamma dual density; lithology log; multilevel completion; and hydraulic head and water temperature profiles for borehole USGS 134, Idaho National Laboratory, Idaho, June 2008.

Engineered Multi-level Monitoring Systems (MLS)

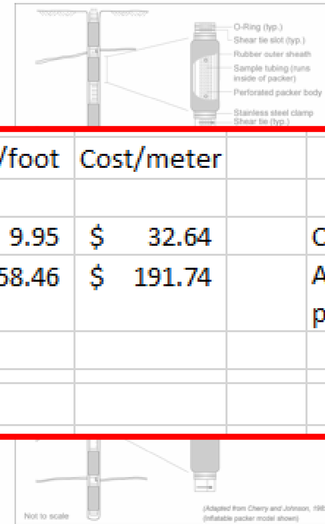
System	Ports	Depth (ft)	Depth (m)	Cost (USD)[1]	Cost/foot	Cost/meter		Discussion
Solinst CMT	7	200	61	$ 1,990.00	$ 9.95	$ 32.64		CMT materials only
Solinst Waterloo	8	400	122	$ 23,383.00	$ 58.46	$ 191.74		All materials, including dedicated pumps and pressure transducers
[1]cost estimate from Solinst provided 10/9/2024								

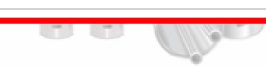
Solinst CMT™ System



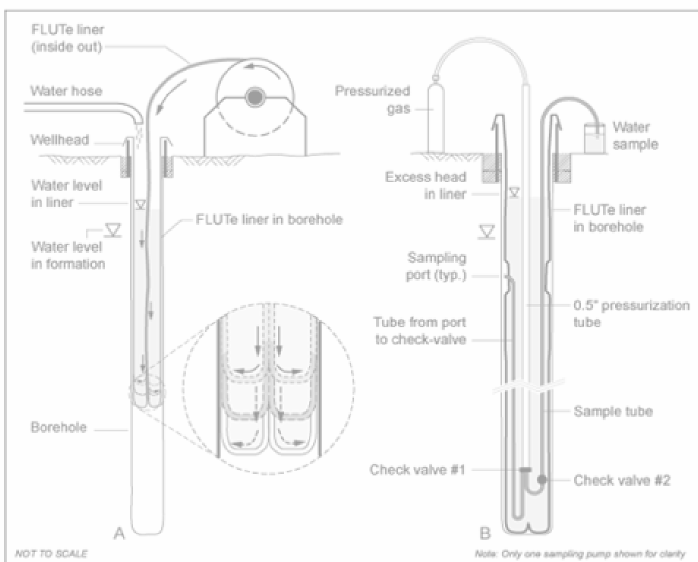


Solinst Waterloo System





Water FLUTe™ system



Westbay System

1 – packer

2 – measurement port (pressures, groundwater sampling, limited hydraulic testing)

3 – pumping port (development and hydraulic testing)

Some of the publications documenting biases in samples collected from long-screened, single-interval monitoring wells. *This isn't a new discovery!*

Bias in groundwater samples caused by wellbore flow

TE Reilly, OL Franke, GD Bennett

Journal of Hydraulic Engineering, 1989 · ascelibrary.org

1989

Design of physical installations and sampling procedures for ground-water monitoring networks, particularly for detection and analysis of possible contaminants, is a topic of great scientific and practical interest at the present time. Recent practice in the design of monitoring networks associated with known contaminant sources sometimes includes an array of monitoring wells with long well screens (up to 50 feet or more). Numerical experiments with a detailed three-dimensional ground-water flow model indicate that significant wellbore flow can occur in contaminant monitoring wells with long well screens that are embedded in homogeneous aquifers with very small vertical head differences in the aquifer. This ``short circuiting'' of flow through boreholes should exist at some level on all scales. Consideration of the general flow pattern within the borehole, the flow pattern in the aquifer adjacent to the borehole, and the process of obtaining water samples from the borehole suggests that in many situations the practice of installing long well screens in contaminant monitoring wells should be abandoned.

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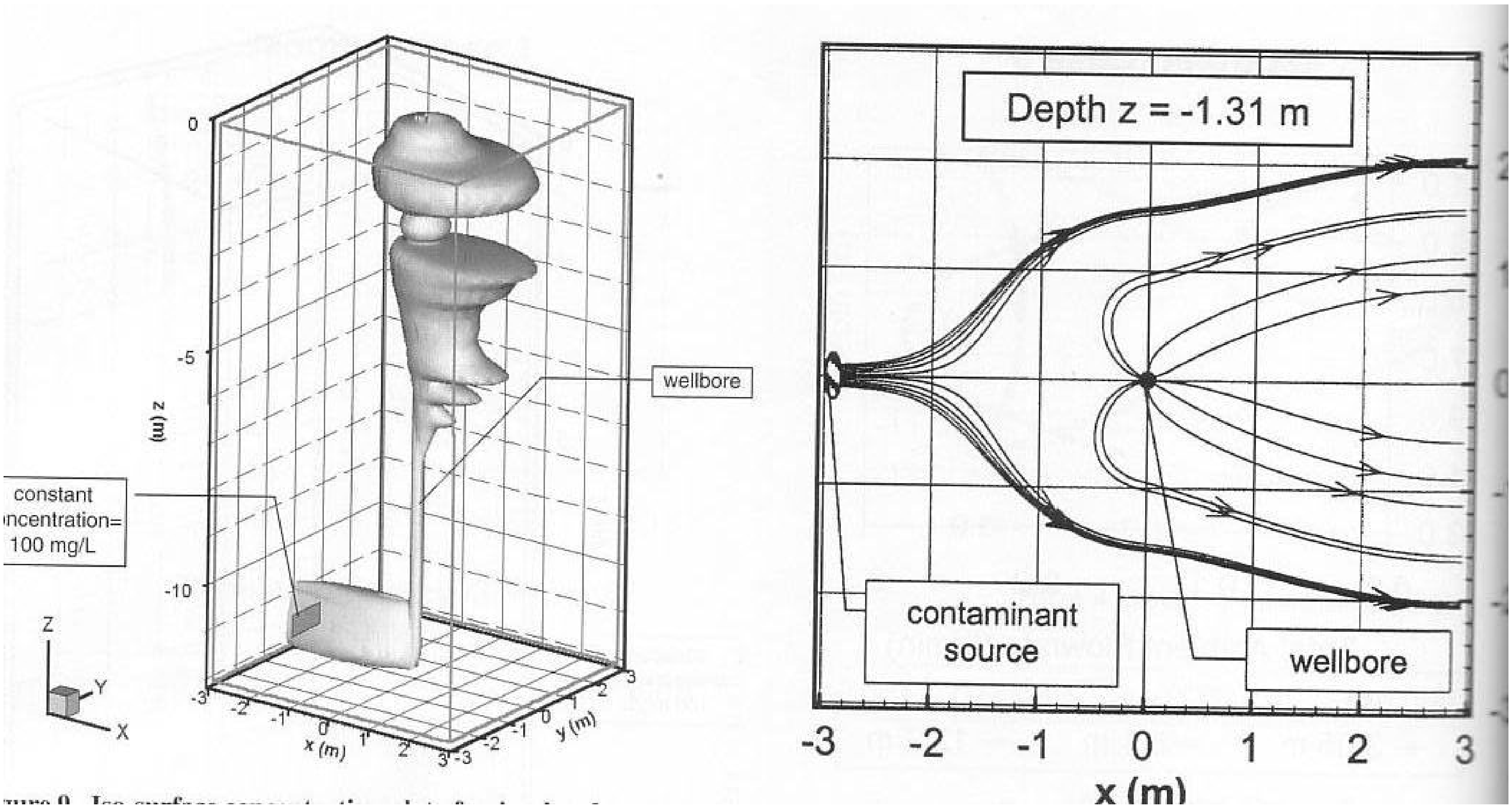
Ambient vertical flow occurs in wells when they are not being pumped



Source: Implications of Observed and Simulated Ambient Flow in Monitoring Wells. Elci, Molz, and Waldrop, 2001

Engineered multilevel monitoring systems are easily installed in multi-screened wells

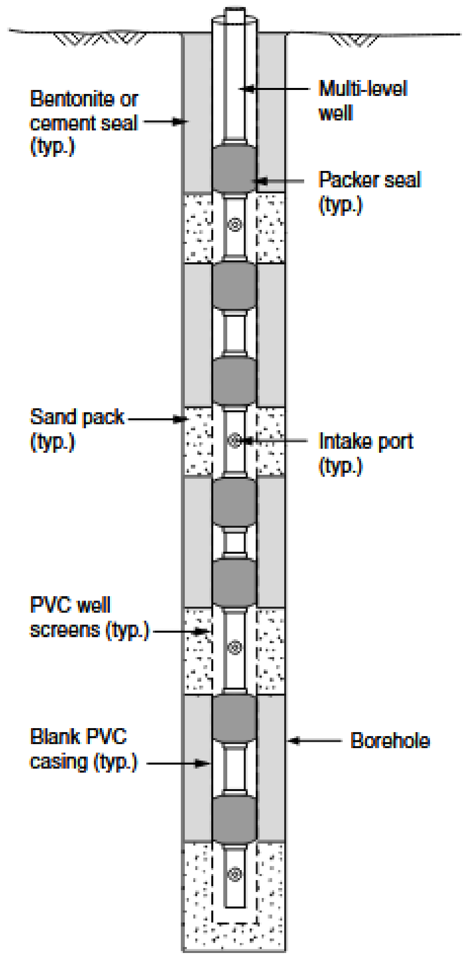


FIGURE 11.12
A dedicated multilevel monitoring system installed inside a steel or PVC well constructed with multiple well screens.