Cone Penetrometer

An Enabling Technology for Characterization and Monitoring Systems

Presented at:
Advanced Vadose Zone Characterization workshop

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30-ton CPT Rig

Outline

- **History**
  - CPT use at Hanford
  - Sonic System
- **Characterization Technologies**
  - Sensors
  - Samplers
- **Monitoring Approaches**
  - Soil gas monitoring points
  - Monitoring wells
  - CPT installed Sensor Networks
- **Summary**

History

- Developed in Netherlands in 1934
- 1990 DOE begins working with industry to advance technology for environmental applications.
- >400,000 ft conducted at SRS since 1989
- 4,000 ft conducted at Hanford since 1991
- Basic technology is mature with new tools constantly being added.

CPT at Hanford

- **20 ton testing initiated 1991**
  - **(200 West Area)**
  - 7 Penetrations < 10 ft,
  - 6 Penetrations > 20 ft, 65 ft was max

- **30 ton testing performed 1992**
  (minimally acceptable size)

  - 300 Area - 11 penetrations 40 ft max
  - 3000 Area - 5 penetrations 40 ft max
  - 200-East - 5 penetrations 95 ft max
  - 200-West - 14 penetrations 147 ft max

200-West Penetrations

Near Z Plant

Date	Location ID	30 Ton Depth (ft.)	Target	20 Ton FY91 Depth (ft.)
7/23/92	CPT-DWPH-1-FY92	33.13	40	23.13
7/24/92	**CPT-DWPH-2-FY92**	**110.36**	**180**	**45.40**
7/24/92	**CPT-200W-1**	**147.00**	**180**	**6.70**
7/27/92	CPT-W1129-1	30.21	40	8.90
7/27/92	**CPT-W1129-2**	**116.50**	**180**	**30.40**
7/28/92	W39-79-1	55.30	90	
7/29/92	CPT-W15-5-1	45.40	90	
7/29/92	CPT-W15-5-2	46.90	90	
7/30/92	CPT-W18-247-1	52.70	90	
7/30/92	**CPT-W18-247-2**	**94.00**	**180**	
7/30/92	CPT-W15-84-1	39.00	40	
8/06/92	W-18-247-3	40.40	40	
8/06/92	W-18-247-4	40.00	40	
8/06/92	W-18-247-5	40.00	40	
4/22/99	**B8801**	**65.00**		**Outside SX**

CPT at Hanford

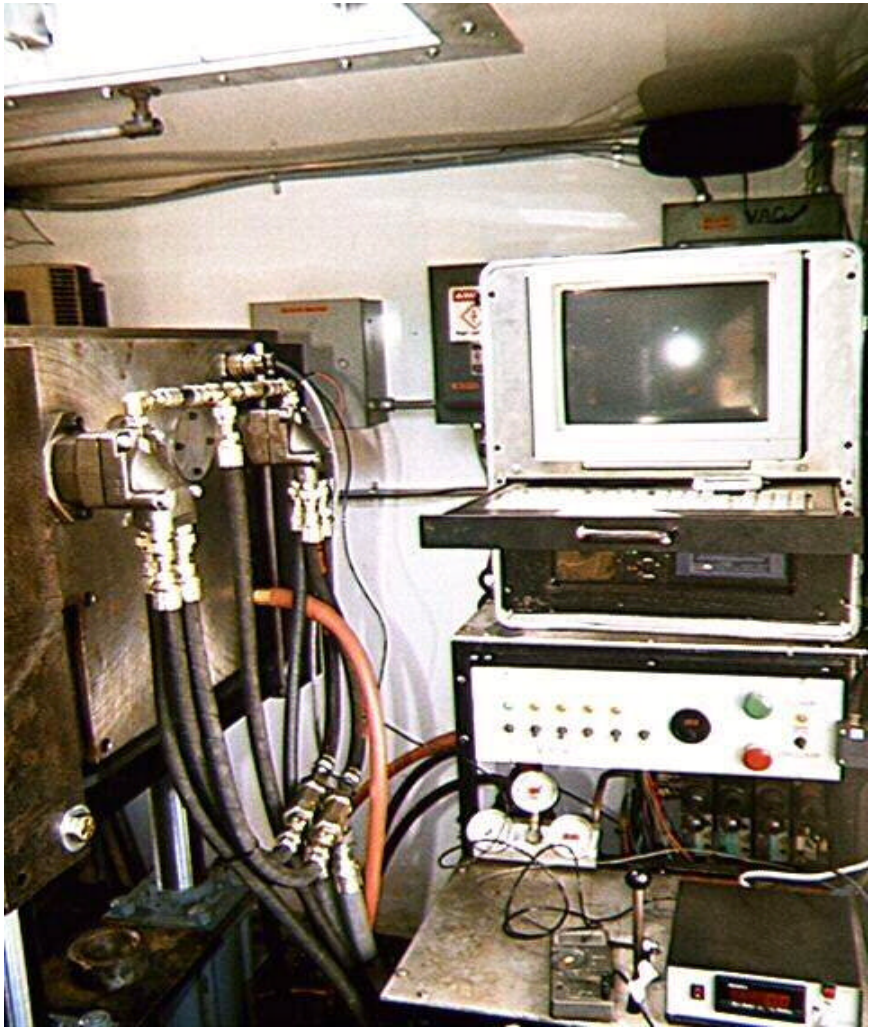
- **DOE 35 ton platform (1996)**

  (160 ft depth pushed in 200-East)

- **Sonic Demonstrated - April 1999**
  - 100D Area
    - 3 penetrations to 7 ft
    - 2 penetrations to 45 ft
  - 200-East Area
    - 1 penetration to refusal at 125 ft (93 ft static push refusal)
  - 200-West Area
    - 1 penetration to refusal at 65 ft

Sonic CPT System

- Sonic-CPT system installed in the CPT truck.
- Two 25-hp hydraulic motors spin the counter rotating eccentric masses.
- The controls / safety shut-off are located in the control box located in the lower right corner.

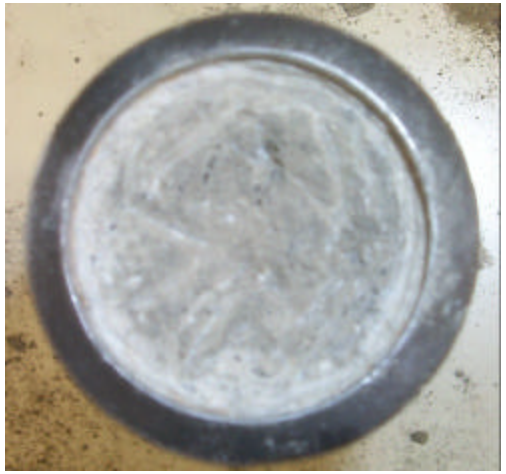


Specific Sonic-CPT Advantages

- Greater penetration depths with standard rod geometry in difficult geologies
- Ability to advance larger rods (e.g. 2 1/4 -in OD) for greater sensor carrying capacity.
- Allow the placement of larger diameter wells for remediation and/or long-term monitoring.
- Allow existing CPT trucks to be as effective as heavy weight trucks.
- Avoid drilling (and added waste generation) where CPT refusal currently occurs.
- Sonic is beneficial in soils with sufficient pore space to create penetration void (i.e gravels and coarse sands.)

Penetration - Summary

- Sonic CPT near SX terminated at a caliche layer using just static penetration.
- Generally should reach top of a caliche layer with static CPT.
- Sonic CPT will increase odds of reaching the caliche.

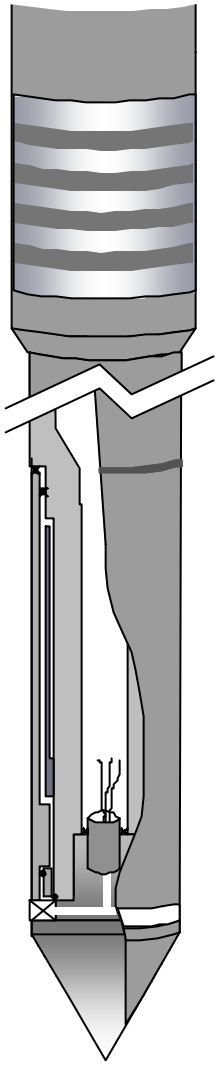


CPT Toolbox

- Characterization Sensors
  - Soil Stratigraphy & Type
  - Soil Moisture and Resistivity
  - Video Imagery
  - Gamma Spectroscopy (beta ?)
  - Raman Spectroscopy
  - Fluorescence Probes
  - pH, Temperature, ORP
  - DNAPL Sensors?
  - Air and Water Permeability
- Sampling
  - Soil, Water, Soil Vapor
- Monitoring System
  - Networked sensors
  - Electrical Resistance Tomography (ERT)
  - Monitoring Wells
- Remediation Installations
  - Steam Injection
  - Soil Vapor Extraction
  - Six-Phase Heating Feasible
  - Reactive Barrier Feasible

SMP Probe Features

- Simultaneous measurement of soil resistivity and apparent dielectric (?$_a$)
- Correlation of dielectric to ? (volumetric soil moisture)
- For saturated sites, porosity = ?
- Dielectric measured at 100 MHz, hence minor influence of conductivity on ?$_a$
- SMP outputs voltage directly into A/D system



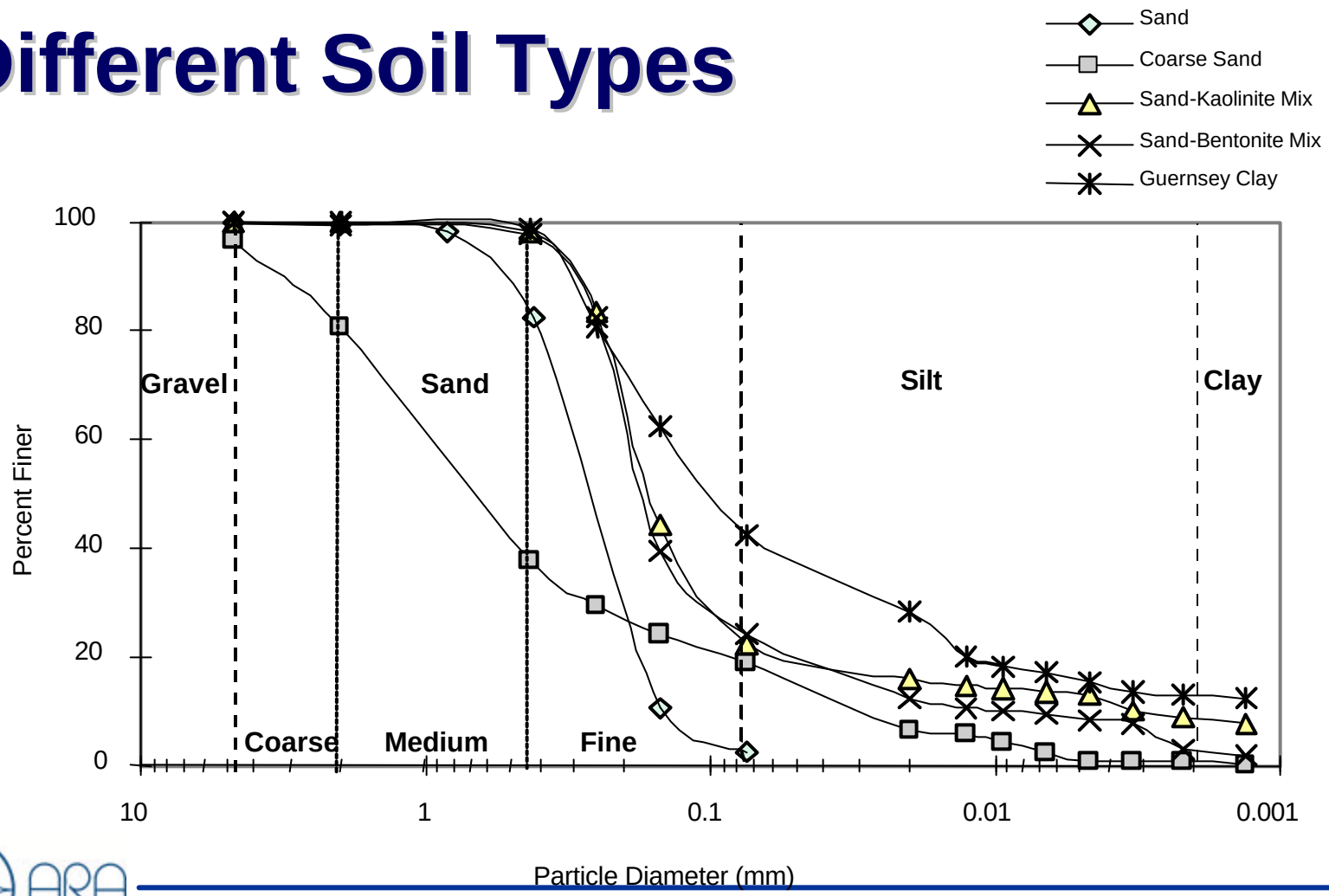
Soil Moisture Probe Development

- Developed CPT probe in 1995
  - CPT probe was evaluated by Argonne National Laboratory under the SCAPS Program
    - Results were most accurate of three moisture sensors tested.
- USDA Phase I study conducted in 1997 for Irrigation Monitoring
  - Laboratory results are presented.
- Working on:
  - USDA Phase II - Additional sensor evaluation and networking.
  - Moisture approach for deep vadose zone applications.

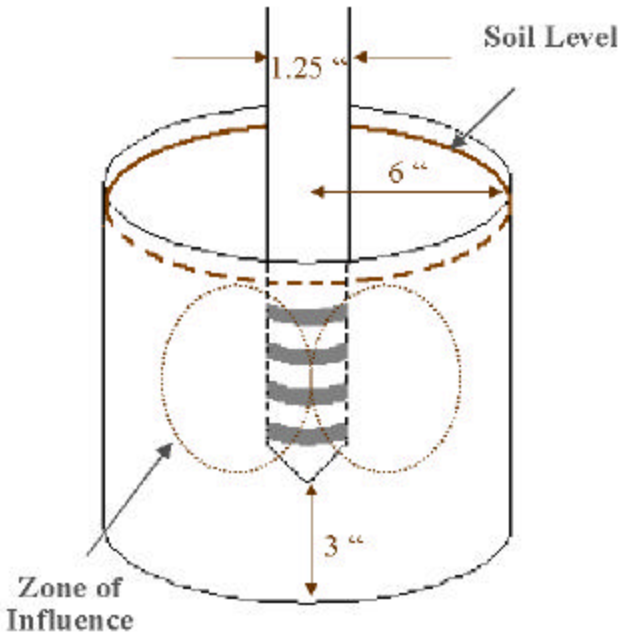
Description of Soil Types

Soil Type (Mixture)	Description	Classification	No. of Tests	Dry Density Range (g/cm^3)	Water Content Range (g/g)
Clean fine sand	Lake Erie fine sand	Laucstrine sand	14	1.51 – 1.63	0.022 – 34.0
Clay	Guernsey clay	Clay – medium swell, low permeability	8	1.36 – 1.41	4.09 – 22.2
Coarse sand	Hocking River coarse sand	Alluvial sand	15	1.59 – 1.70	0.055 – 21.7
Sand-Bentonite 80/20	80 % Fine sand 20 % Bentonite (dry mass)	Laucstrine sand, pure bentonite	14	1.43-1.50	0.51 – 19.5
Sand – Kaolinite 80/20	80 % Fine sand 20 % Kaolinite (dry mass)	Laucstrine sand, pure kaolinite	16	1.43 – 1.51	2.95 – 25.0

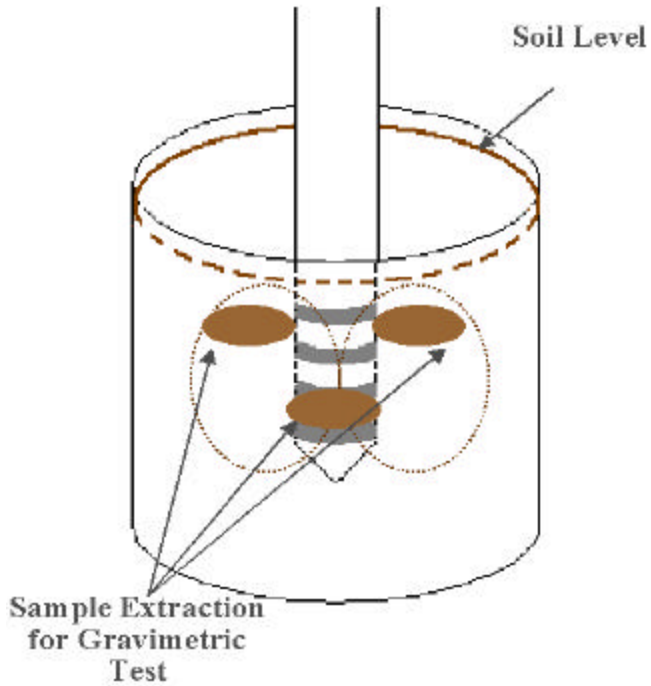
Grain Size Distribution for Different Soil Types



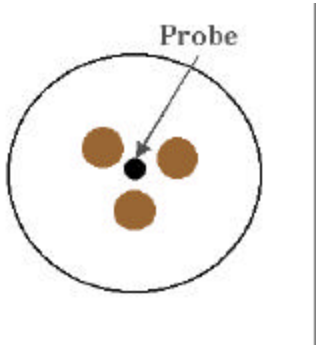
Testing Apparatus



Cross Section of Testing Configuration



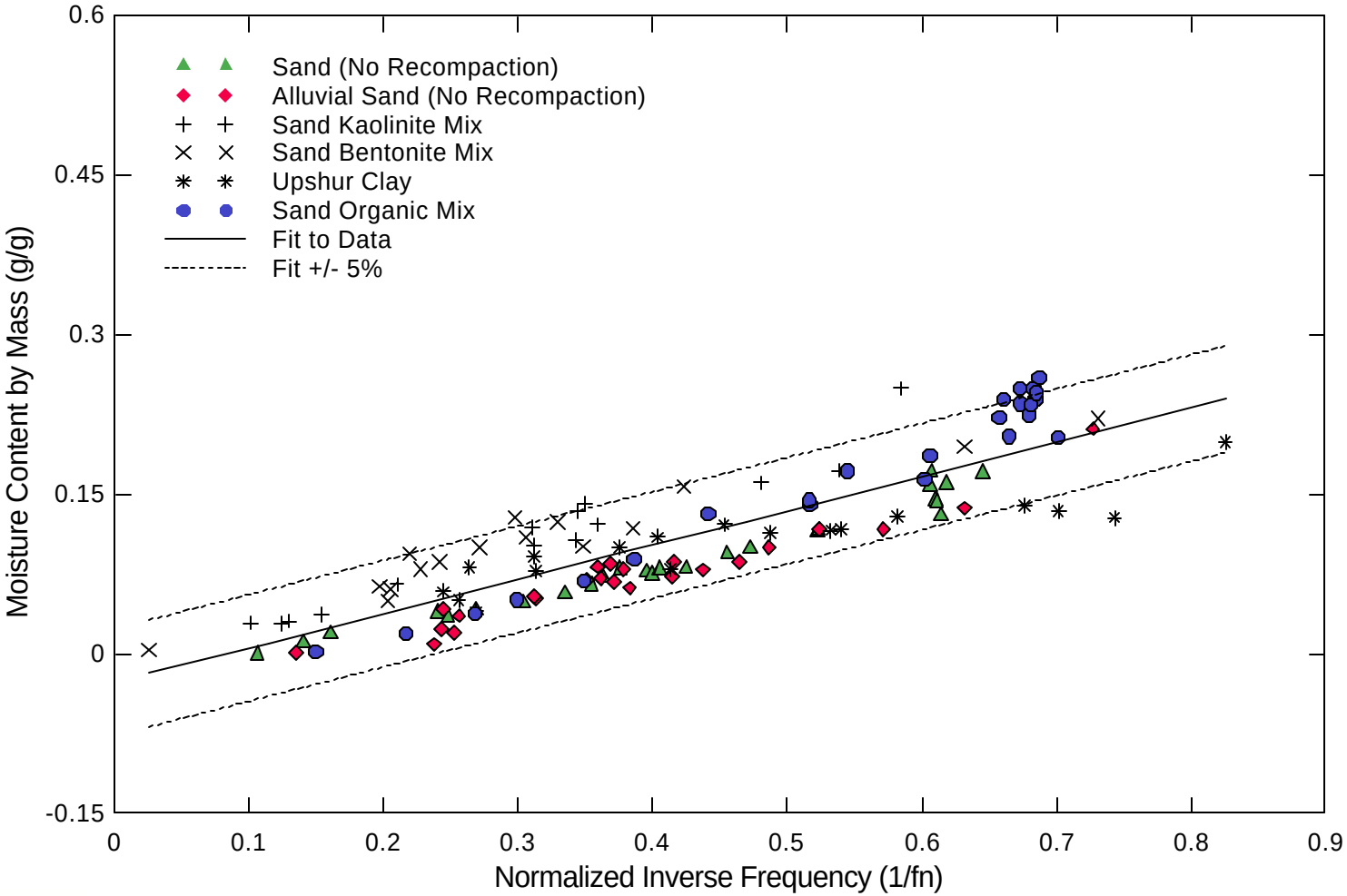
Cross Section of Sample Extraction



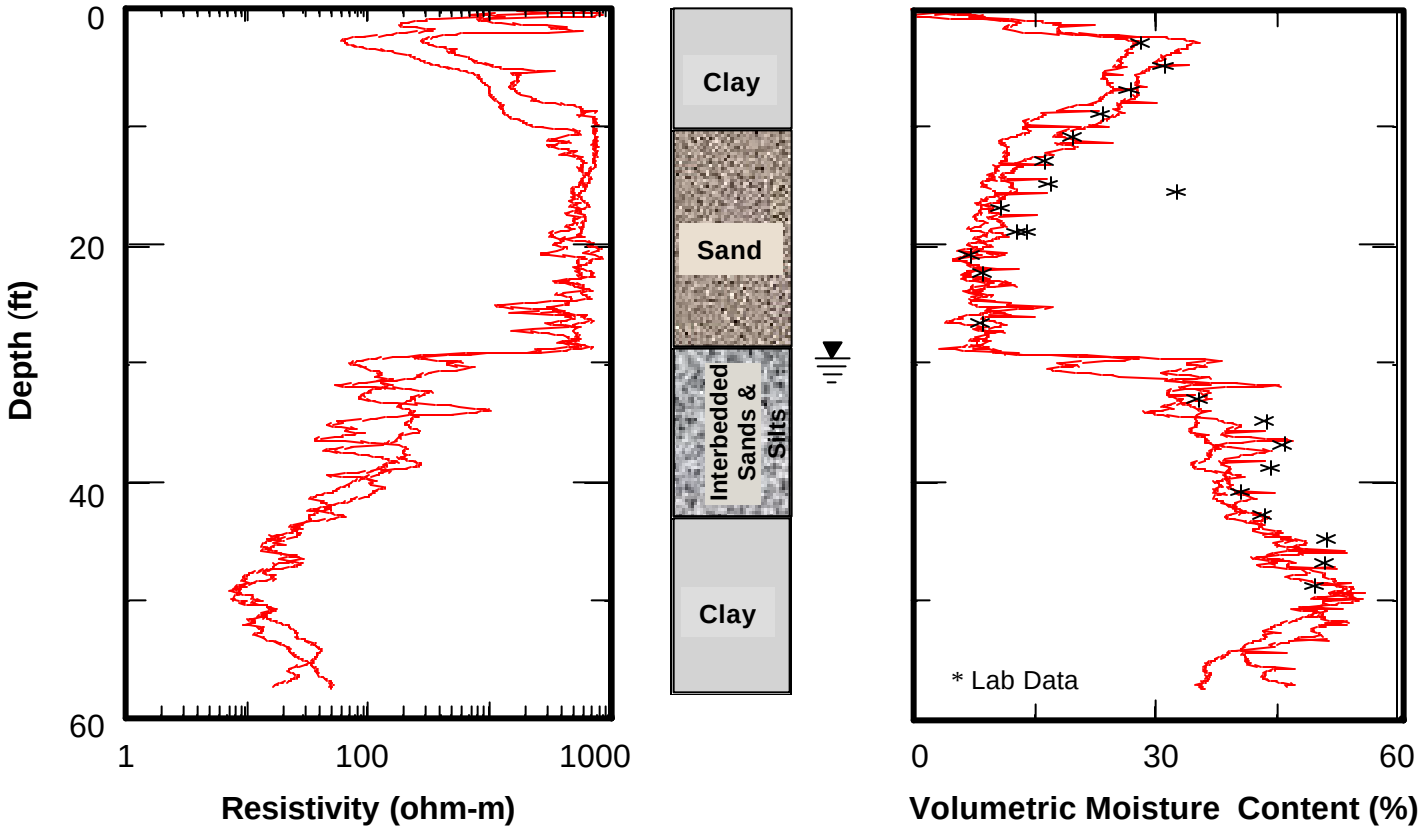
Plan View of Sample Extraction

The SMRT Probe

Calibration Response Curve for the Different Soil Types

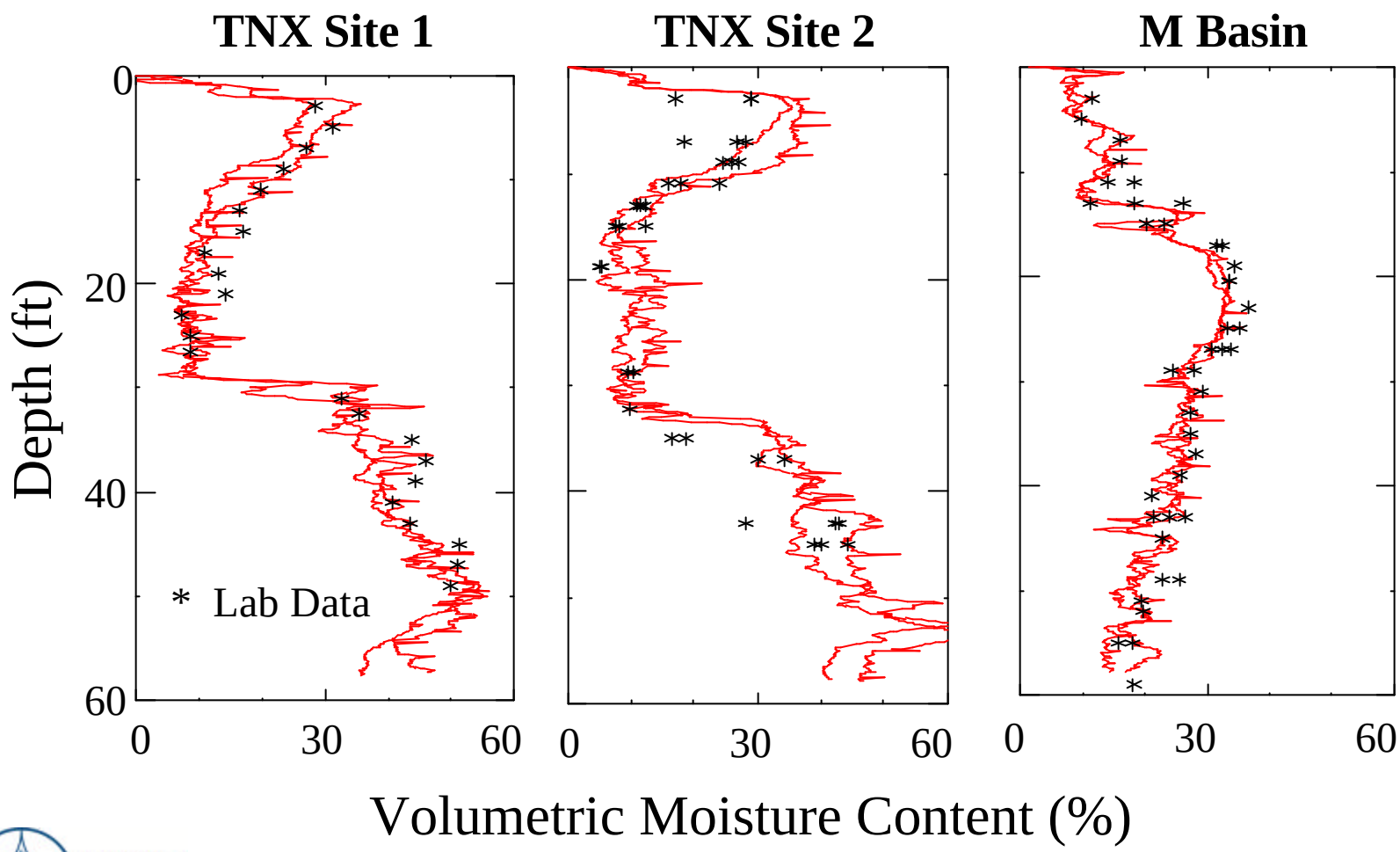


SMP Data Obtained During a Field Trial Showing Resistivity and Soil Moisture Profiles



Vadose Zone Workshop

ARA Soil Moisture Data Obtained at Three Sites

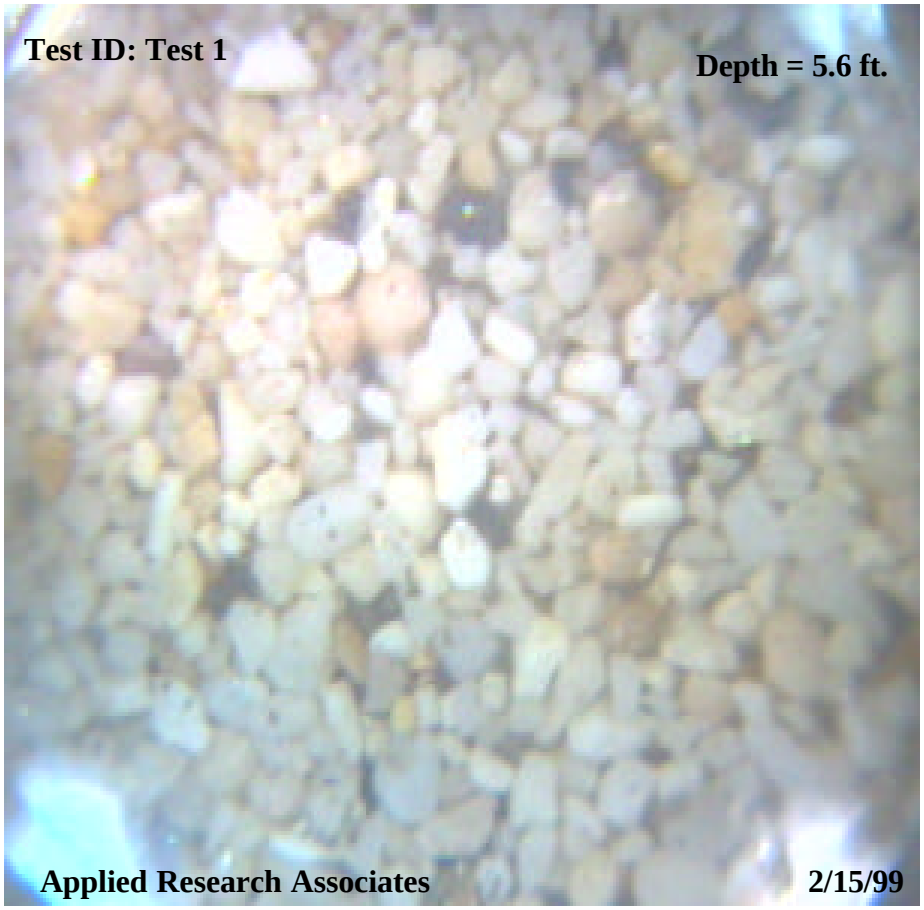


SEA Permeability Probe

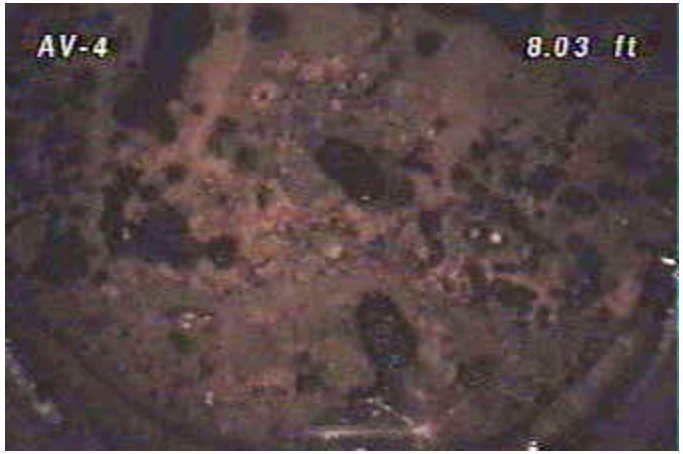
- Measures air permeability of Vadose Zone and saturated hydraulic conductivity of saturated soils.
- Based upon radial flow pressure measurements.
- Demonstrated on site on Nov. 1998.
- Hydraulic conductivity calculated from air permeability indicated good comparison with core samples hydraulic conductivity values.

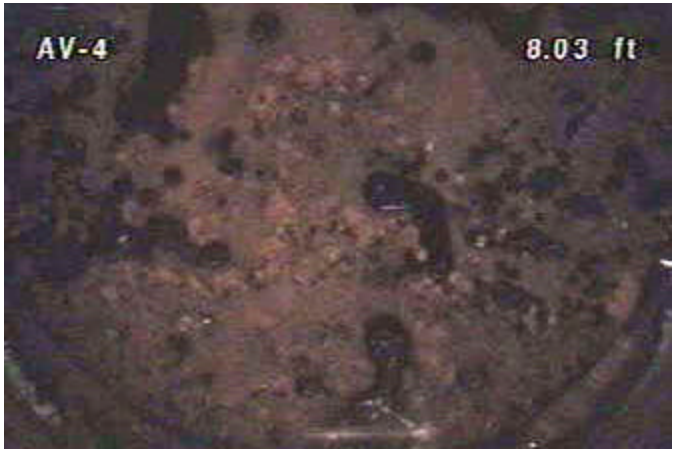
Video CPT Image

- Image has accurate color resolution
- Assists with soil classification determination
- Continuous Video Image of Penetration
- DNAPL's can be seen on video image



Video Cone images of Coal Tars at a site in NY

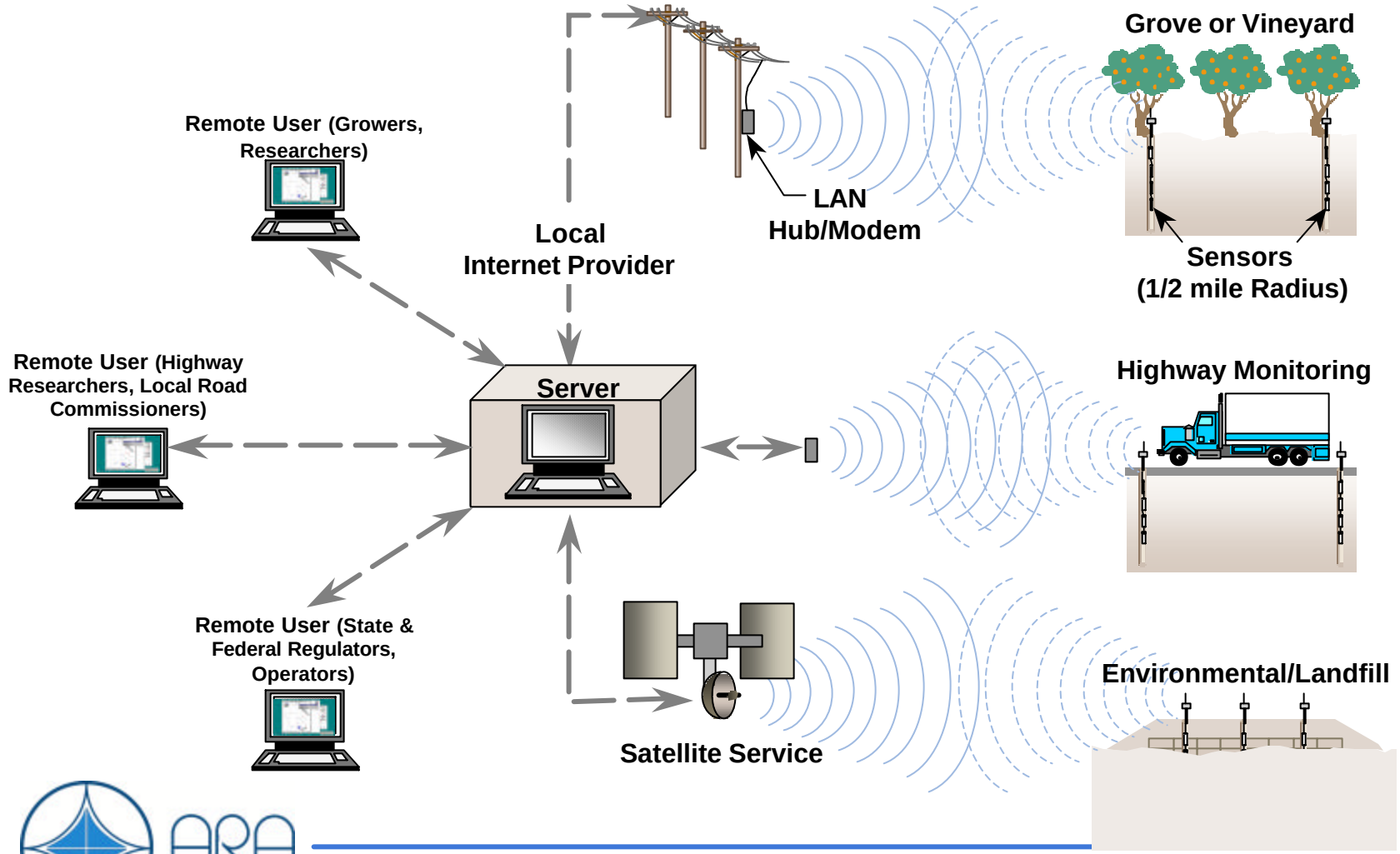




CPT Monitoring systems

- Most CPT sensors are easily networked.
- ARA has developed a WEB based monitoring system that allows access from any internet terminal using standard web-browser software.
- 2 inch PVC well as also easily installed using CPT.
- CPT can be used to install Advanced Tensiometers from Sission at INEEL.
- Other monitoring approaches such as ERT as also easily accommodated.
- CPT offers significant costs savings over traditational monitor well installation approach.

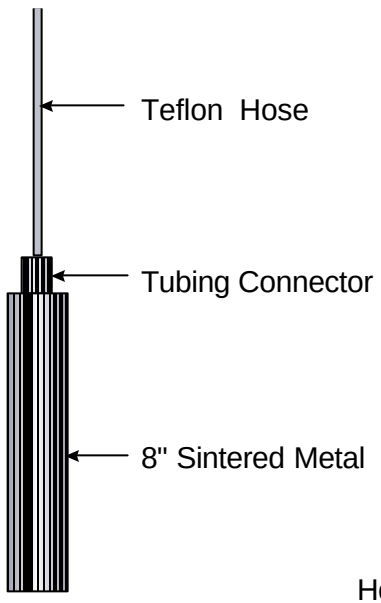
SCHEMATIC OF WEB-DACSSYSTEM



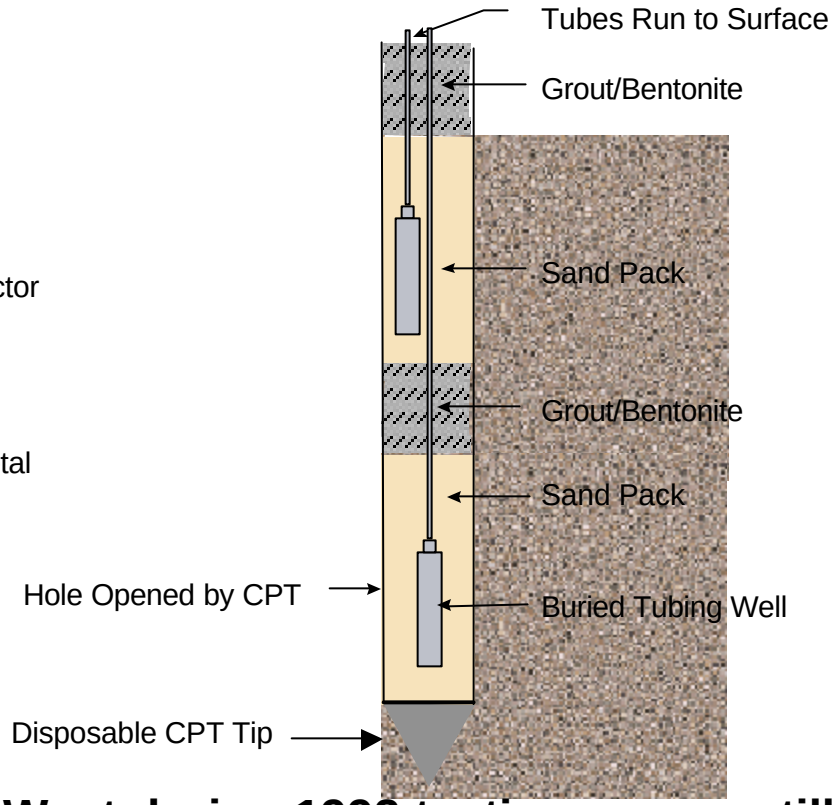
Gas Sampling

Miniature Point Monitoring Wells

Schematic

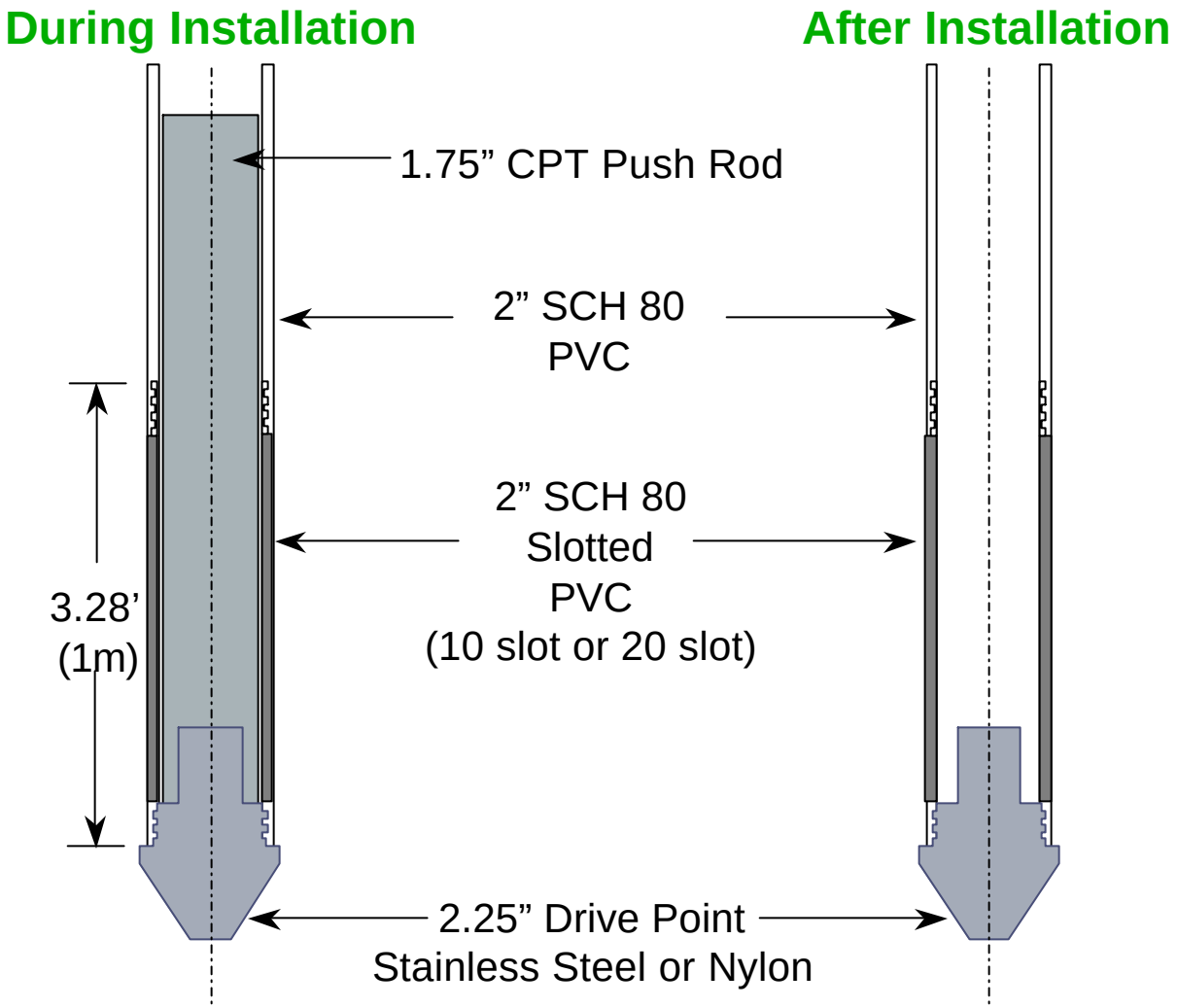


Installation



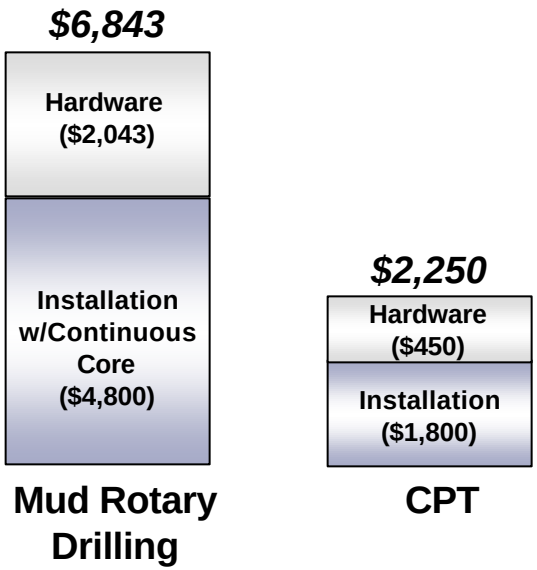
Installed in 200 West during 1992 testing - some still in use today.

CPT Installation of Monitoring Wells



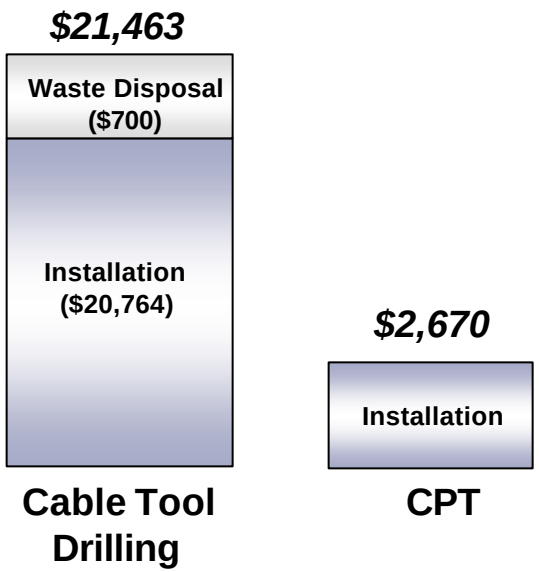
CPT Installed Wells

Installation of a 150 ft Direct Push Well (Savannah River Site)



*Hardware includes, PVC casing, filter pack, bentonite seals, well head, pad

Installation of a 50 ft Soil Vapor Monitoring Well (Hanford Site)



Actual Costs from LANL Environmental Technology Cost-Savings Analysis Project (1991-1995)

CPT Costs

- **Mobilization/ Demobilization:**

  Minimal since truck in area.
- **Daily Costs: $2,800/day (standard work)**
  - daily footage depends on type of work performed but typically 200-300 ft/day
- **Waste Disposal Costs: minimal**

*** Assumes Truck Push Vehicle, not CP Platform**

Summary

- **CPT can have a variety of roles:**
  - Characterization
  - Sampling Activities
  - Monitoring Systems
- **CPT can be used in vadose zone down to the caliche layer in 200 West.**
- **CPT is less expensive than drilling therefore reducing costs or expanding coverage.**
- **ARA soil moisture probe validated in six soil types and three geologies.**
- **Calibration for individual soil samples showed only +/-2% variation from gravimetric determination**