High-Resolution Methods for Characterizing Spatial Variations in Hydraulic Conductivity in Unconsolidated Formations

Jim Butler

Kansas Geological Survey

2003 AFCEE

Technology Transfer Workshop

San Antonio, Texas

February 27, 2003

Basic Premises

Remediation efforts hindered by insufficient information about subsurface conditions

Better understanding of the hydraulic properties of the subsurface

| | |

More effective remediation strategies

Focus of Presentation

- Three approaches for estimation of spatial variations in hydraulic conductivity (K)
  - All based on direct-push technology
  - Cooperative research program
    - KGS and Geoprobe
    - KGS and HydroSOLVE
  - Viability assessed in controlled field setting
    - Geohydrologic Experimental and Monitoring Site (GEMS)

Current Situation

- Techniques require wells
  - Flowmeter, multilevel slug tests, dipole-flow tests, etc.
    - Vertical variations in K
- What's happening between wells?
  - Considerable uncertainty about lateral variations in K
- Turn towards direct-push methods
  - Access to the shallow subsurface (< 30 m depth)
  - No wells required

Presentation Outline

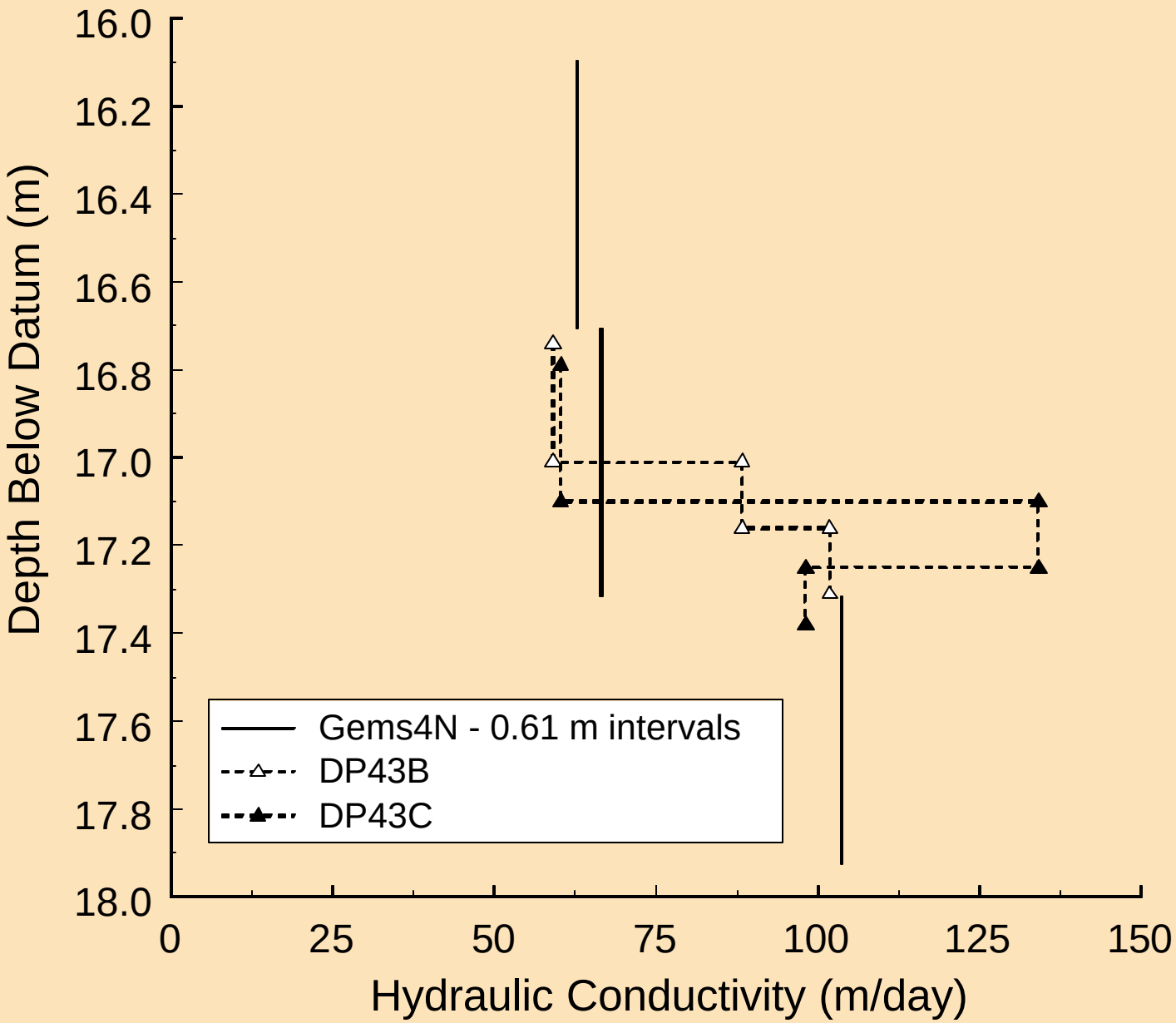
- Shielded-screen slug test
- Hydrostratigraphic profiling
- Direct-push permeameter

Presentation Outline

- **Shielded-screen slug test**
  - **Commercially available**
  - **Single interval**
  - **Considerable detail over that interval**
- Hydrostratigraphic profiling
- Direct-push permeameter

0 CM 5 10 15

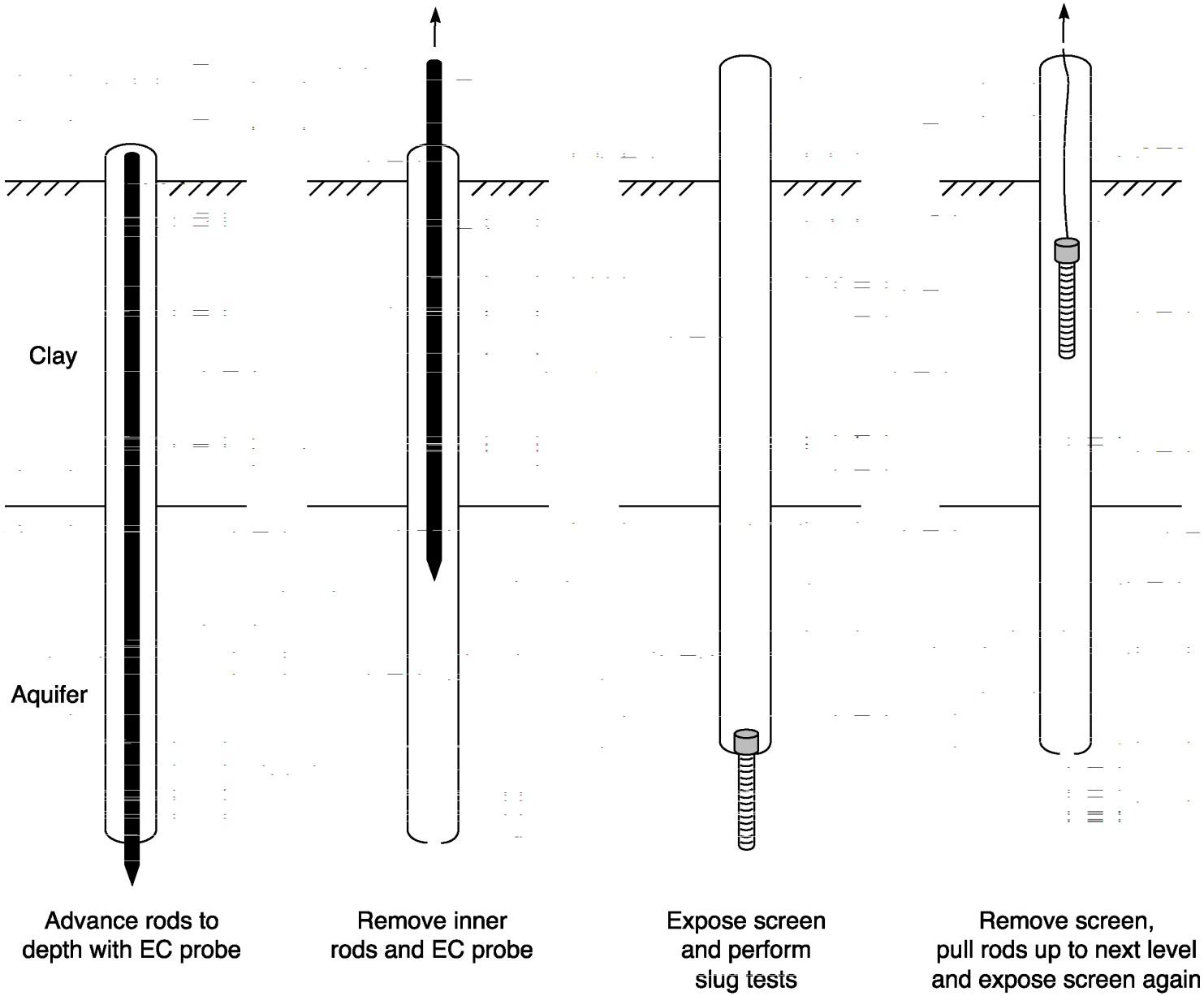
0 CM 5 10 15


16.0
16.2
16.4
16.6
16.8
17.0
17.2
17.4
17.6
17.8
18.0
Depth Below Datum (m)
0
25
50
75
100
125
150
Hydraulic Conductivity (m/day)
Gems4N - 0.61 m intervals
DP43B
DP43C

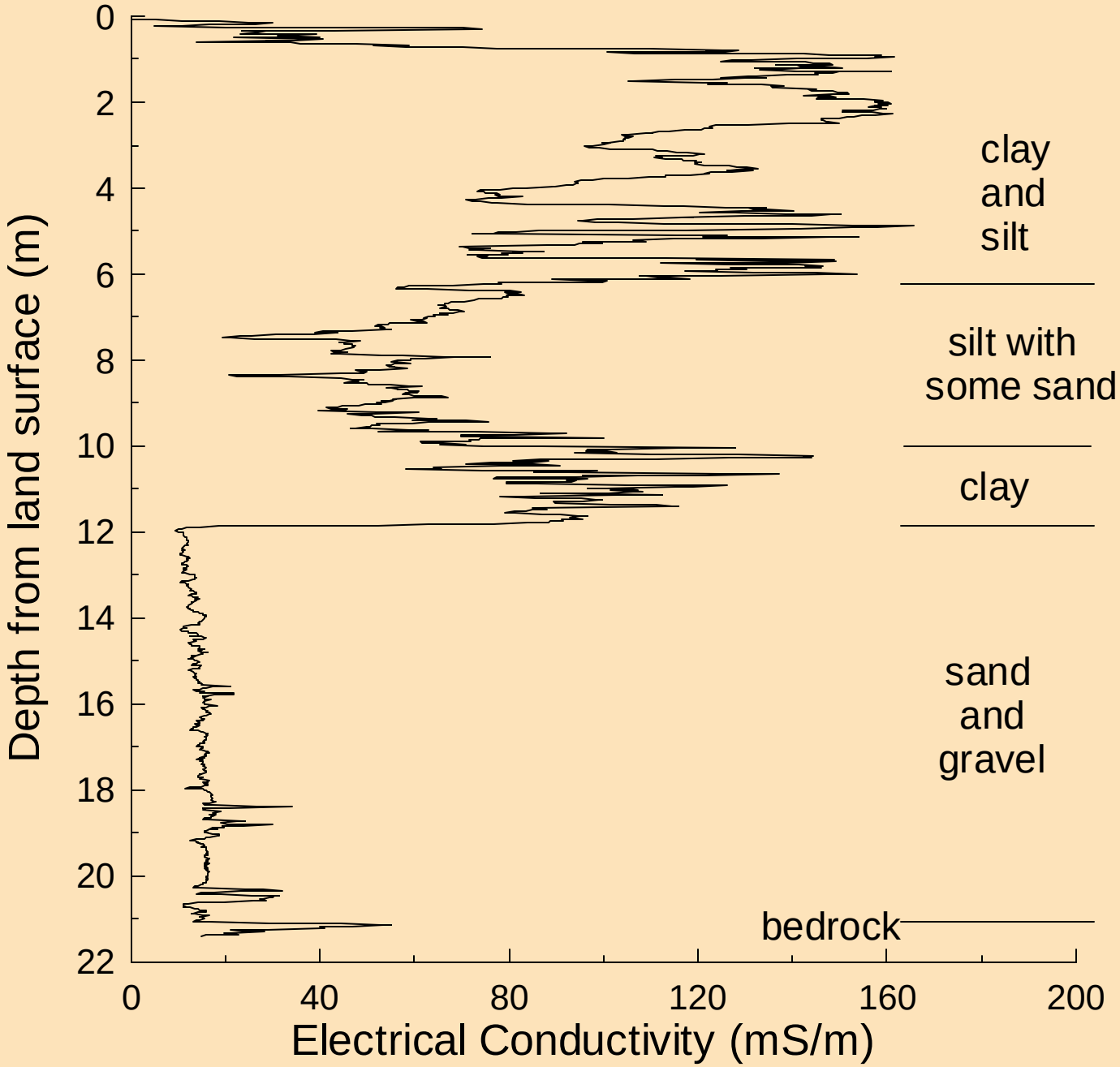
Presentation Outline

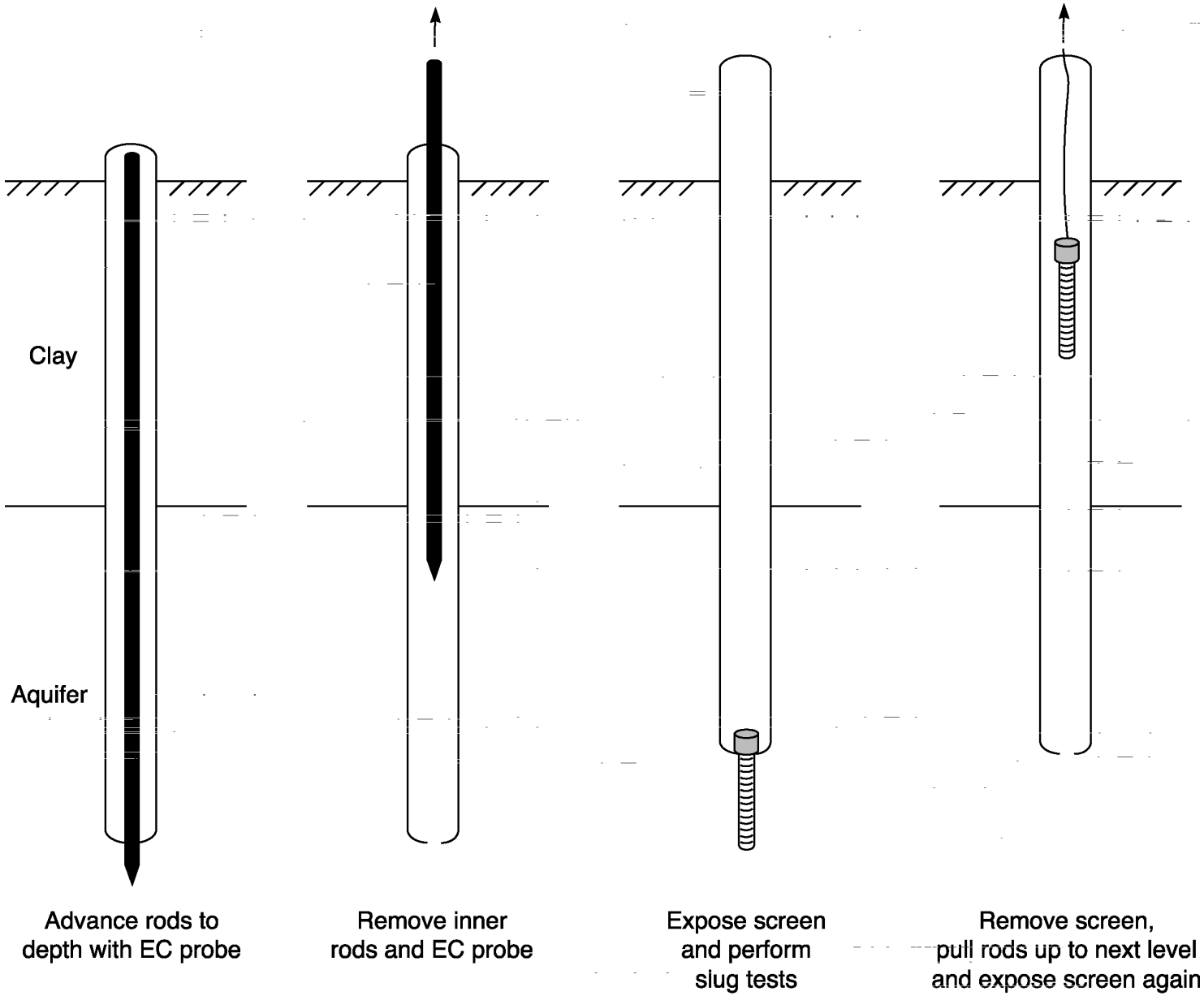
- Shielded-screen slug test
- **Hydrostratigraphic profiling**
  - **Not yet commercially available**
  - **EC logging - lithology**
  - **Slug tests - multiple intervals**
- Direct-push permeameter

1
2
3
4
5
6
7
8
9
10
11
12

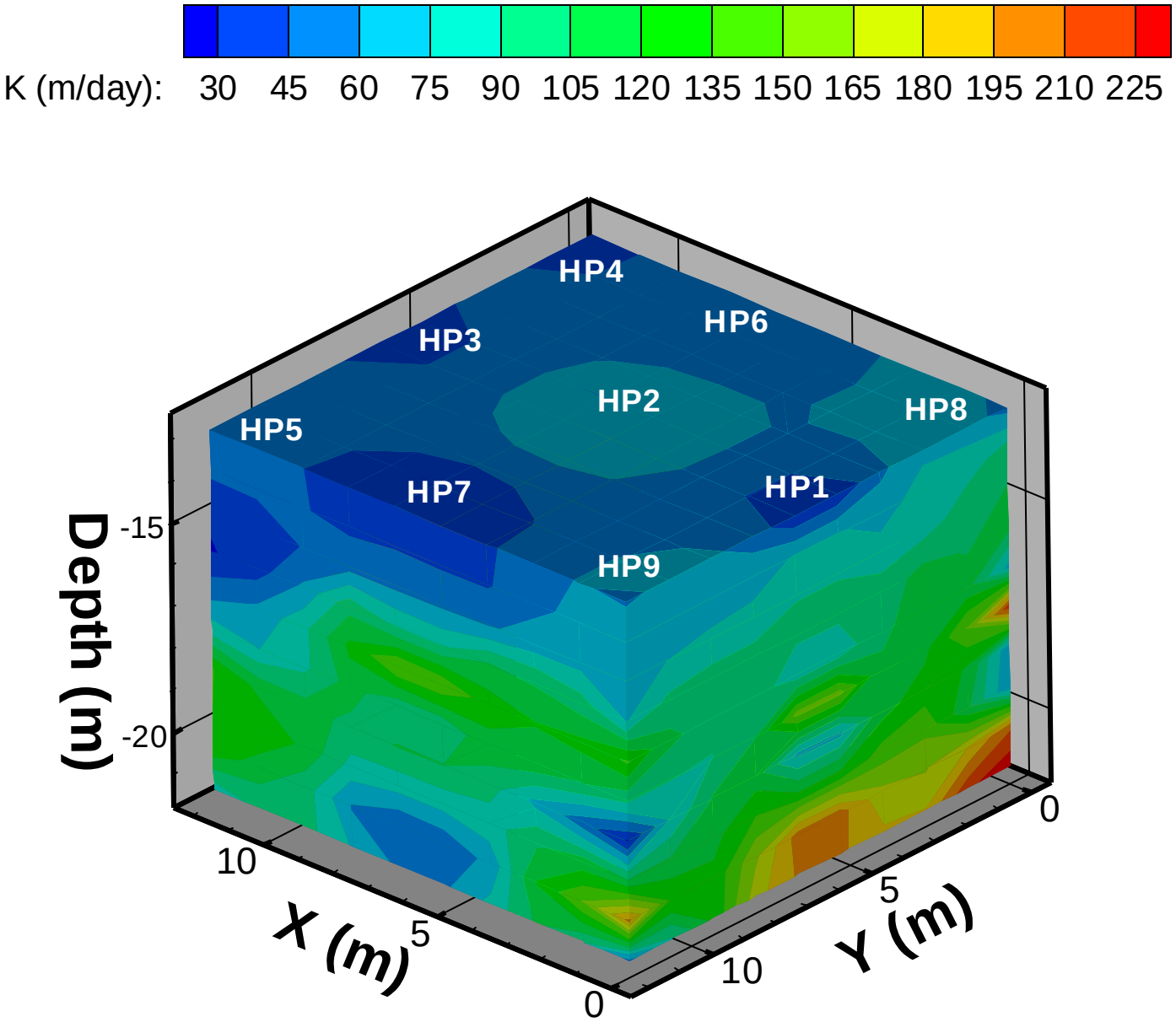

Clay
Aquifer
Advance rods to depth with EC probe
Remove inner rods and EC probe
Expose screen and perform slug tests
Remove screen, pull rods up to next level and expose screen again

not to scale


Depth from land surface (m)
0
2
4
6
8
10
12
14
16
18
20
22
0
40
80
120
160
200
Electrical Conductivity (mS/m)
clay
and
silt
silt with
some sand
clay
sand
and
gravel
bedrock


Clay
Aquifer
Advance rods to depth with EC probe
Remove inner rods and EC probe
Expose screen and perform slug tests
Remove screen, pull rods up to next level and expose screen again

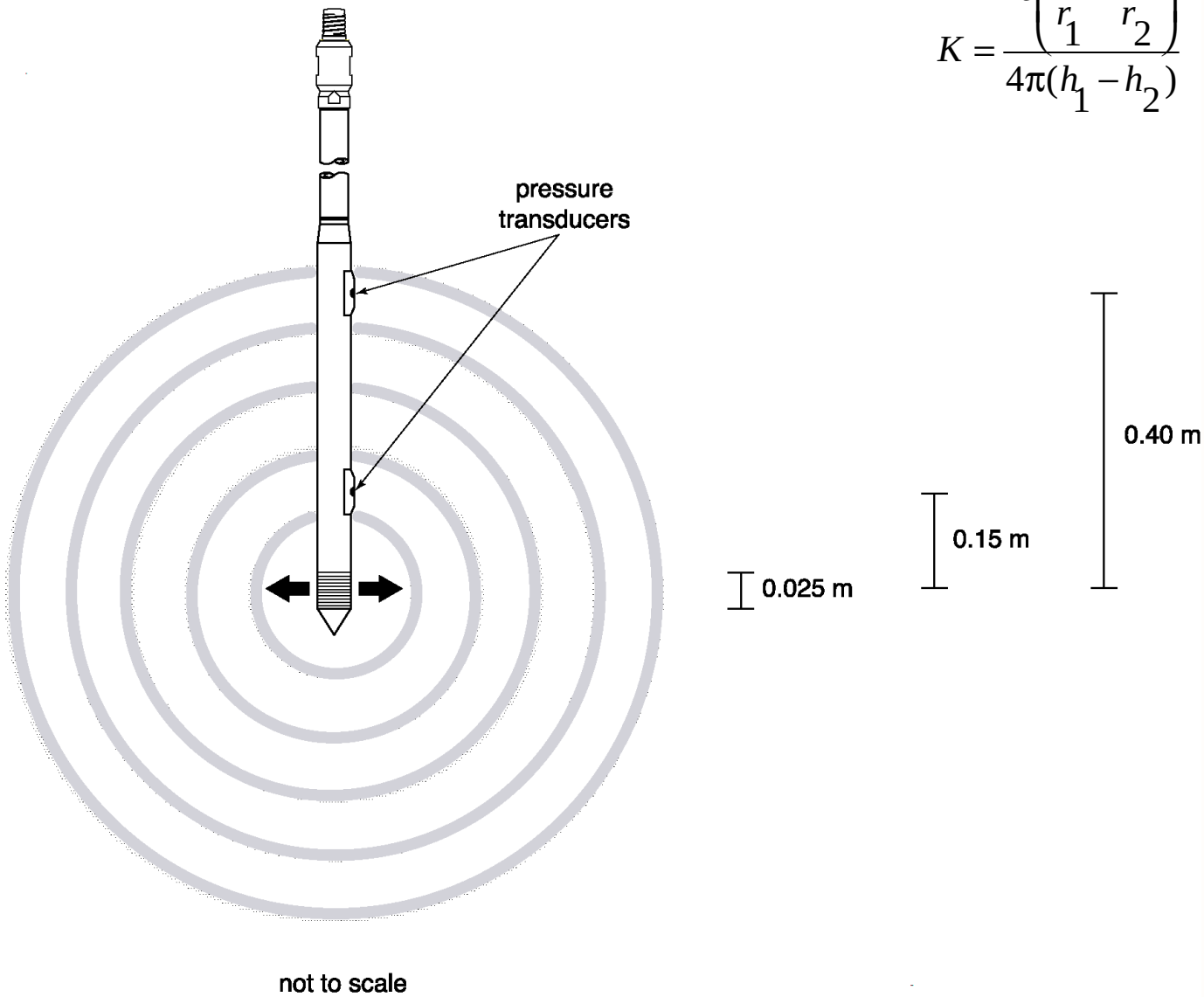
not to scale

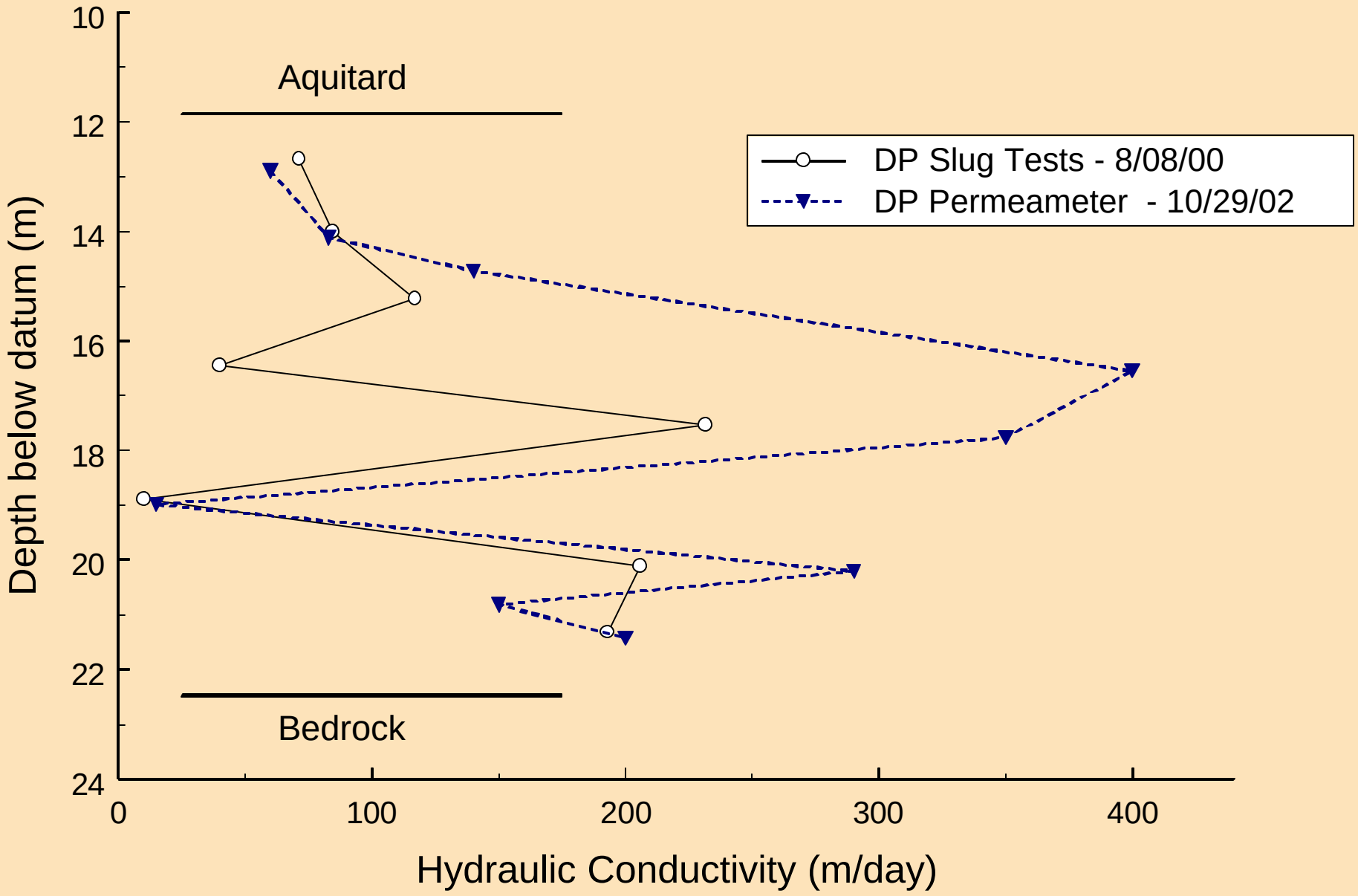

K (m/day): 30 45 60 75 90 105 120 135 150 165 180 195 210 225
HP4
HP6
HP3
HP2
HP8
HP5
HP7
HP1
HP9
Depth (m)
-15
-20
10
5
0
X (m)
0
5
10
Y (m)

Presentation Outline

- Shielded-screen slug test
- Hydrostratigraphic profiling
- **Direct-push permeameter**
  - **Under development**
  - **Relatively rapid**
  - **Lessens impact of near-well disturbances**

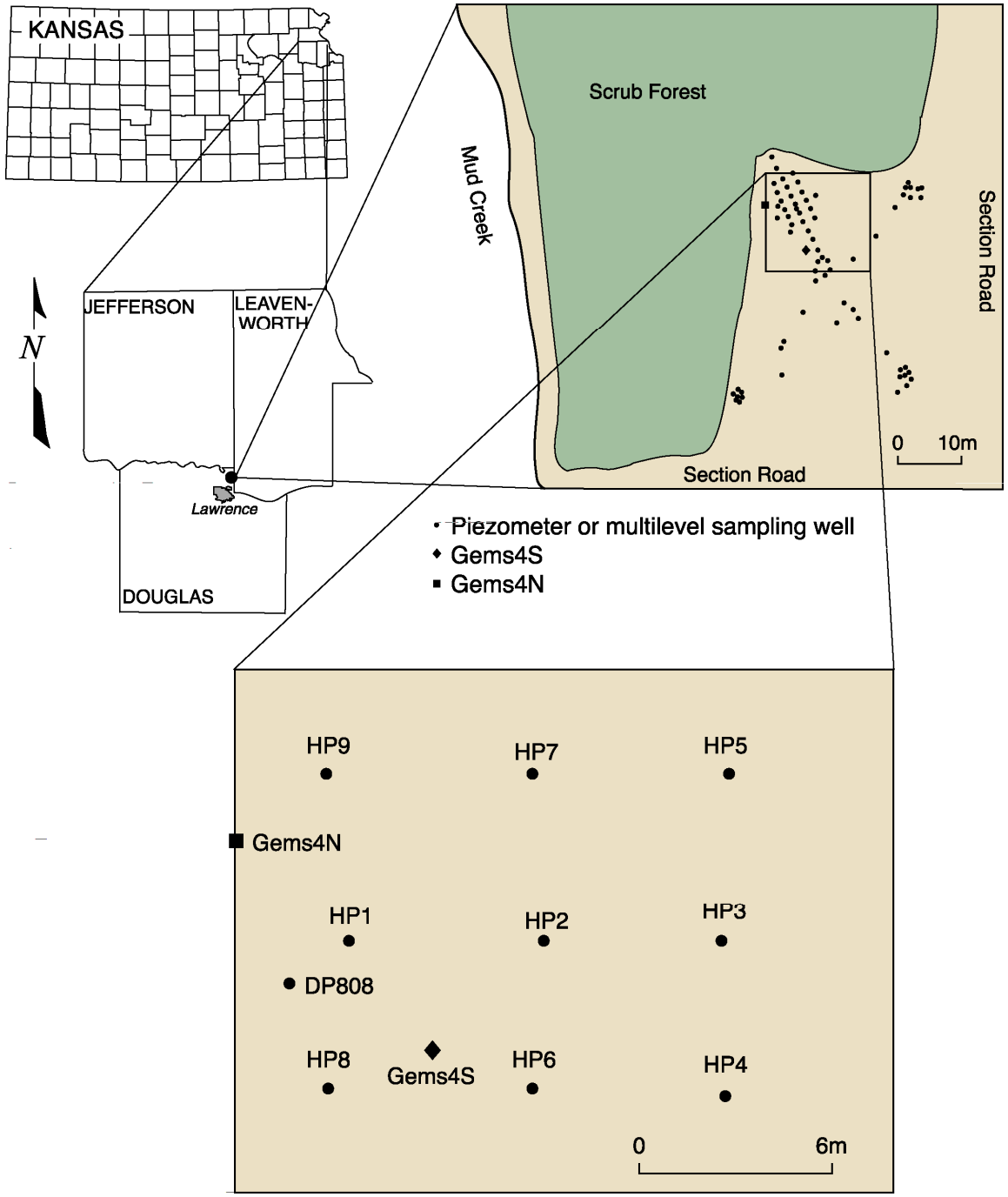
$$K = \frac{Q\left(\frac{1}{r_1} - \frac{1}{r_2}\right)}{4\pi(h_1 - h_2)}$$

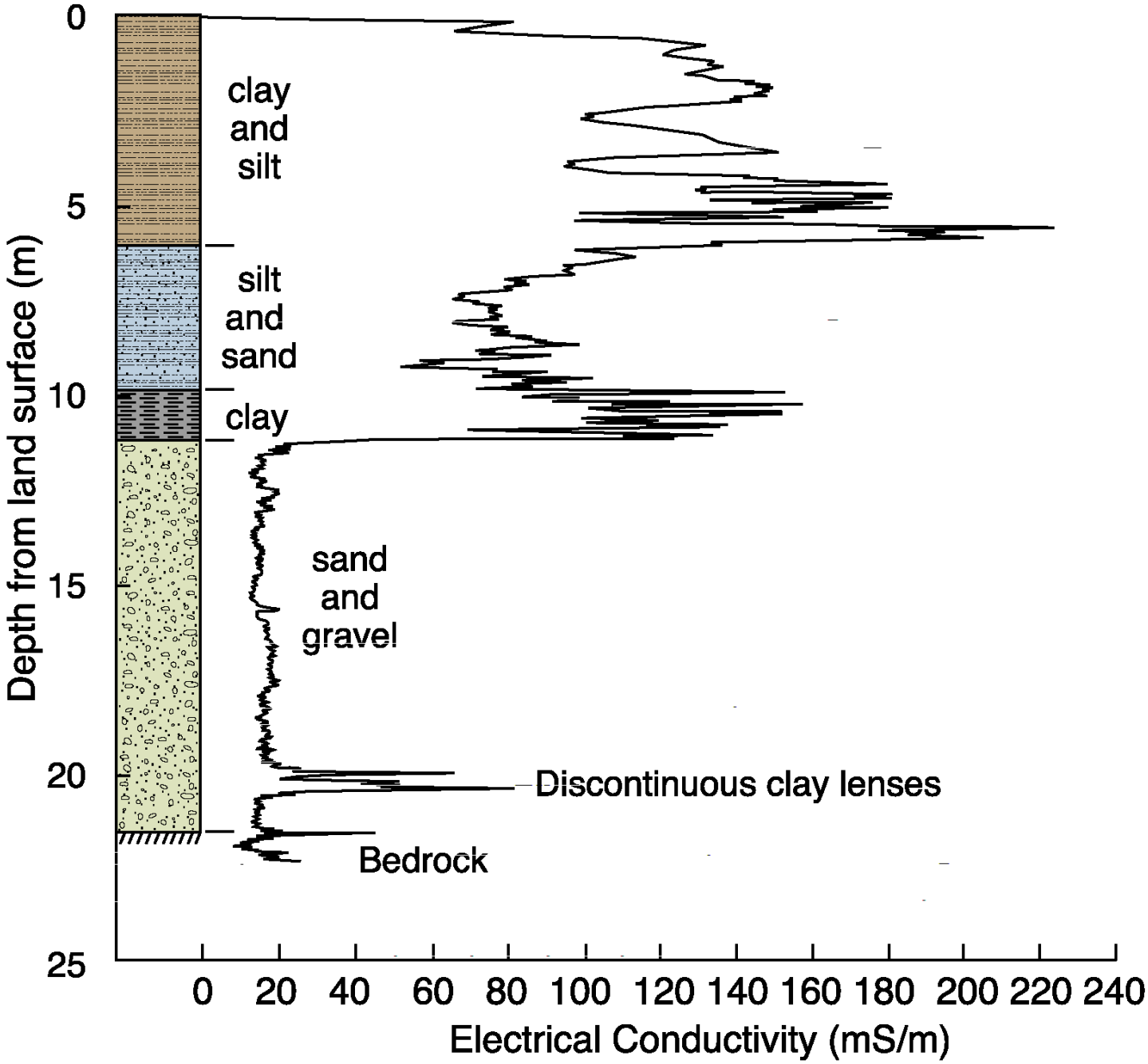


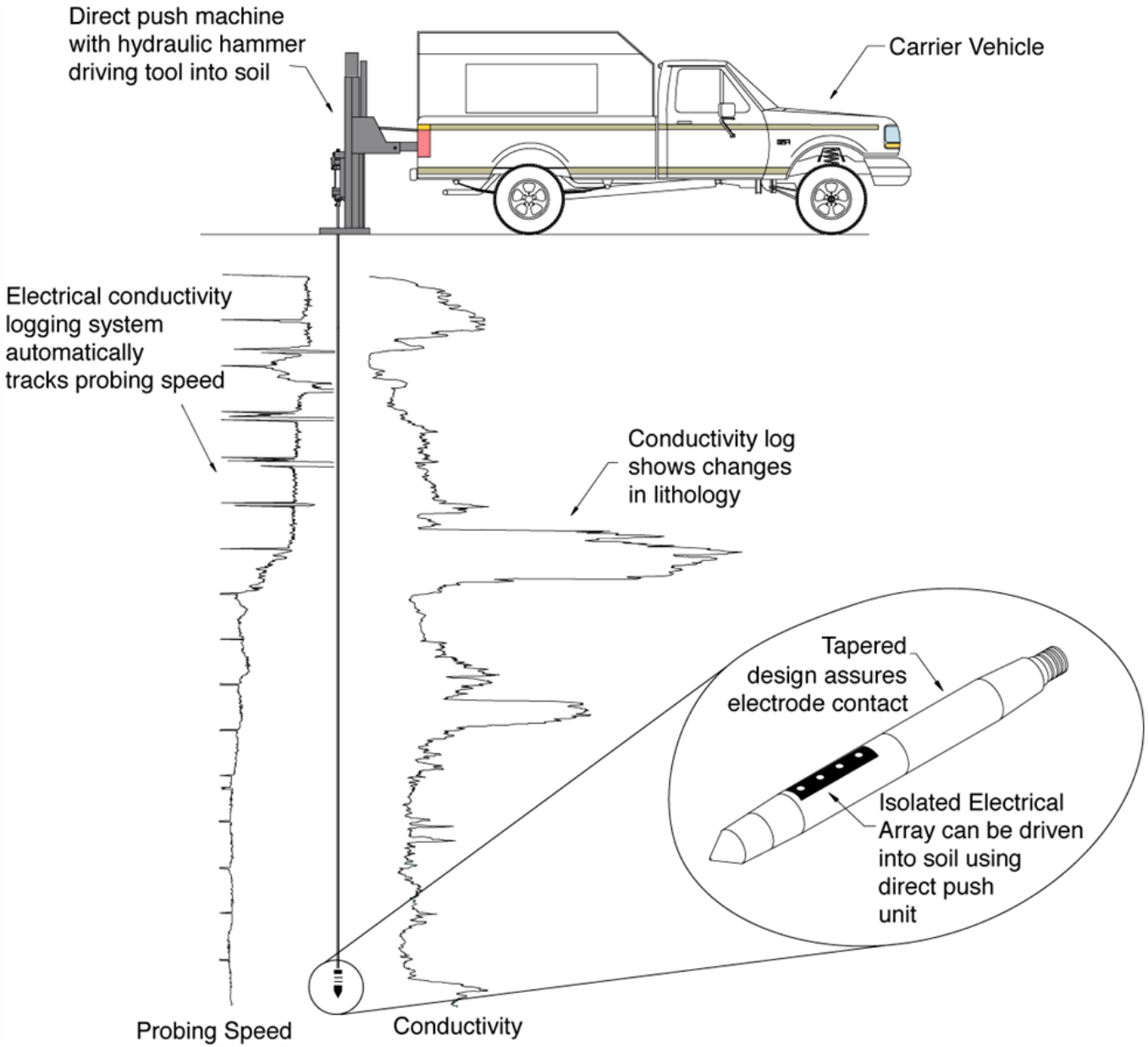

Aquitard
Bedrock
DP Slug Tests - 8/08/00
DP Permeameter - 10/29/02
Depth below datum (m)
Hydraulic Conductivity (m/day)
10
12
14
16
18
20
22
24
0
100
200
300
400

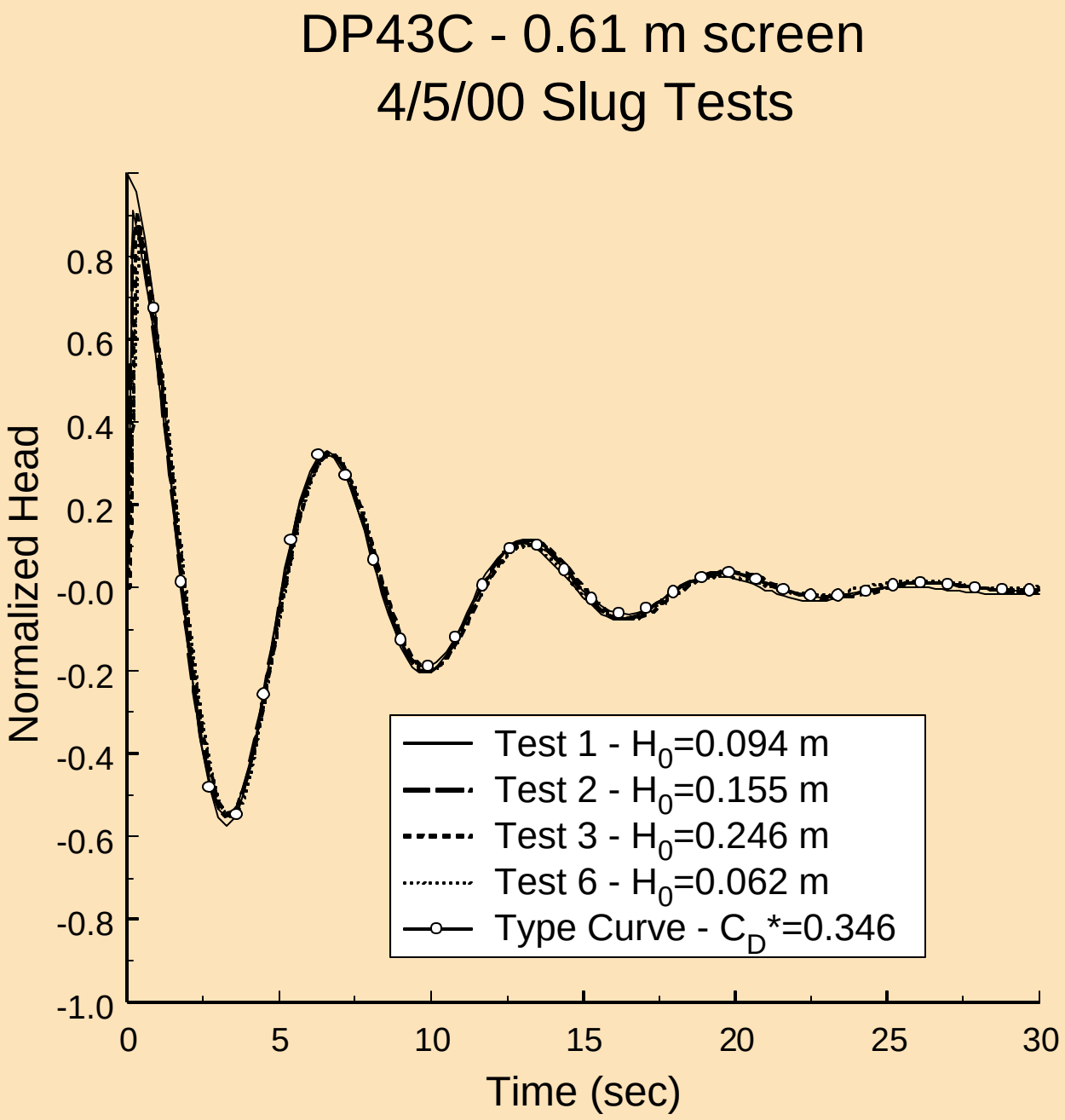
Conclusions

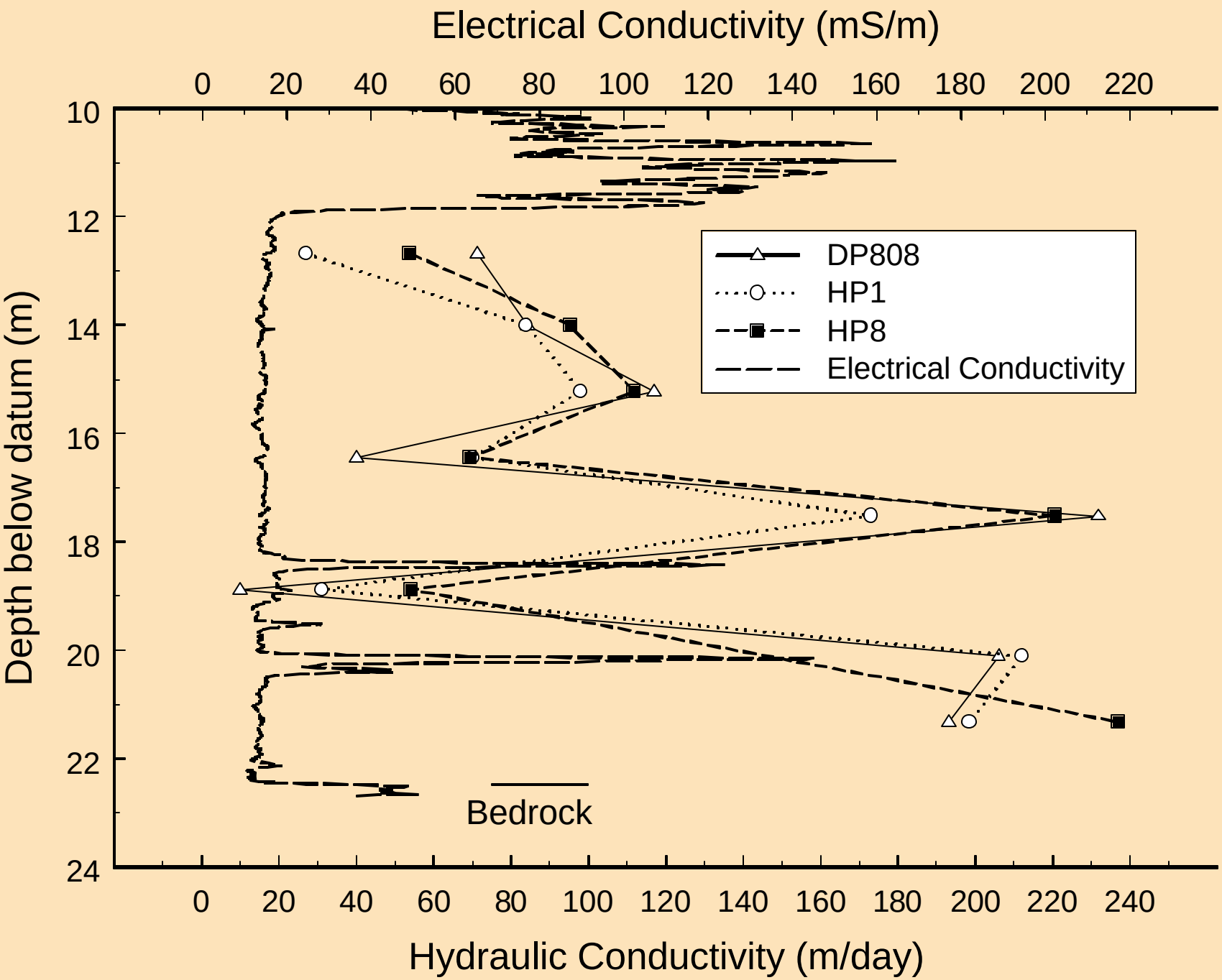
- Currently available
  - Shielded-screen slug test
    - High resolution but single interval
    - Vulnerable to skin effects
- Available shortly
  - Hydrostratigraphic profiling
    - High resolution and multiple intervals
    - Vulnerable to skin effects
- In the future
  - Direct-push permeameter
    - High resolution - near continuous
    - Little vulnerability to skin effects
    - Relatively rapid

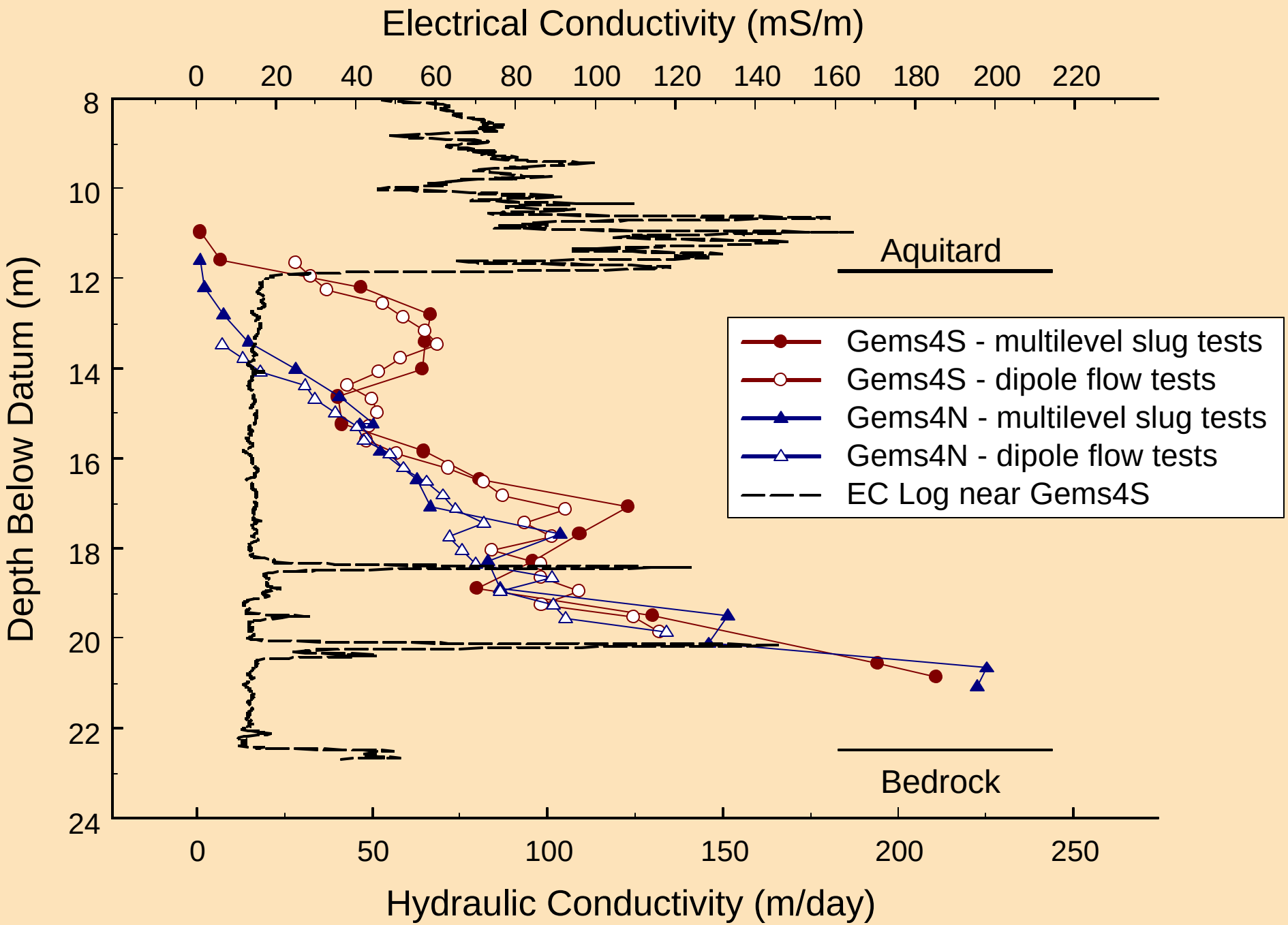

KANSAS
JEFFERSON
LEAVEN-
WORTH
N
Lawrence
DOUGLAS
Mud Creek
Scrub Forest
Section Road
Section Road
0 10m
Piezometer or multilevel sampling well
Gems4S
Gems4N
HP9
HP7
HP5
Gems4N
HP1
HP2
HP3
DP808
HP8
Gems4S
HP6
HP4
0 6m


clay
and
silt
silt
and
sand
clay
sand
and
gravel
Discontinuous clay lenses
Bedrock
Depth from land surface (m)
0
5
10
15
20
25
0
20
40
60
80
100
120
140
160
180
200
220
240
Electrical Conductivity (mS/m)


Direct push machine with hydraulic hammer driving tool into soil
Carrier Vehicle
Electrical conductivity logging system automatically tracks probing speed
Conductivity log shows changes in lithology
Tapered design assures electrode contact
Isolated Electrical Array can be driven into soil using direct push unit
Probing Speed
Conductivity


DP43C - 0.61 m screen
4/5/00 Slug Tests
Normalized Head
0.8
0.6
0.4
0.2
-0.0
-0.2
-0.4
-0.6
-0.8
-1.0
0
5
10
15
20
25
30
Time (sec)
Test 1 - H0=0.094 m
Test 2 - H0=0.155 m
Test 3 - H0=0.246 m
Test 6 - H0=0.062 m
Type Curve - CD*=0.346


Electrical Conductivity (mS/m)
0
20
40
60
80
100
120
140
160
180
200
220
10
12
14
16
18
20
22
24
Depth below datum (m)
DP808
HP1
HP8
Electrical Conductivity
Bedrock
0
20
40
60
80
100
120
140
160
180
200
220
240
Hydraulic Conductivity (m/day)


Electrical Conductivity (mS/m)
0
20
40
60
80
100
120
140
160
180
200
220
Depth Below Datum (m)
8
10
12
14
16
18
20
22
24
Aquitard
Bedrock
Gems4S - multilevel slug tests
Gems4S - dipole flow tests
Gems4N - multilevel slug tests
Gems4N - dipole flow tests
EC Log near Gems4S
0
50
100
150
200
250
Hydraulic Conductivity (m/day)