MOSCA-HOOPER CONSERVATION DISTRICT RECHARGE OPTIMIZATION PROJECT: PROGRESS REPORT

PATRICK O'NEILL[1], KATE ZEIGLER[2], JIM HASBROUCK[3], ETHAN WILLIAMS[2]

[1]Soil Health Services
[2]Zeigler Geologic Consulting
[3]Hasbrouck Geophysics

OVERVIEW

- It all started with a question:

  " Do you suppose we can find recharge sweet spots ? "

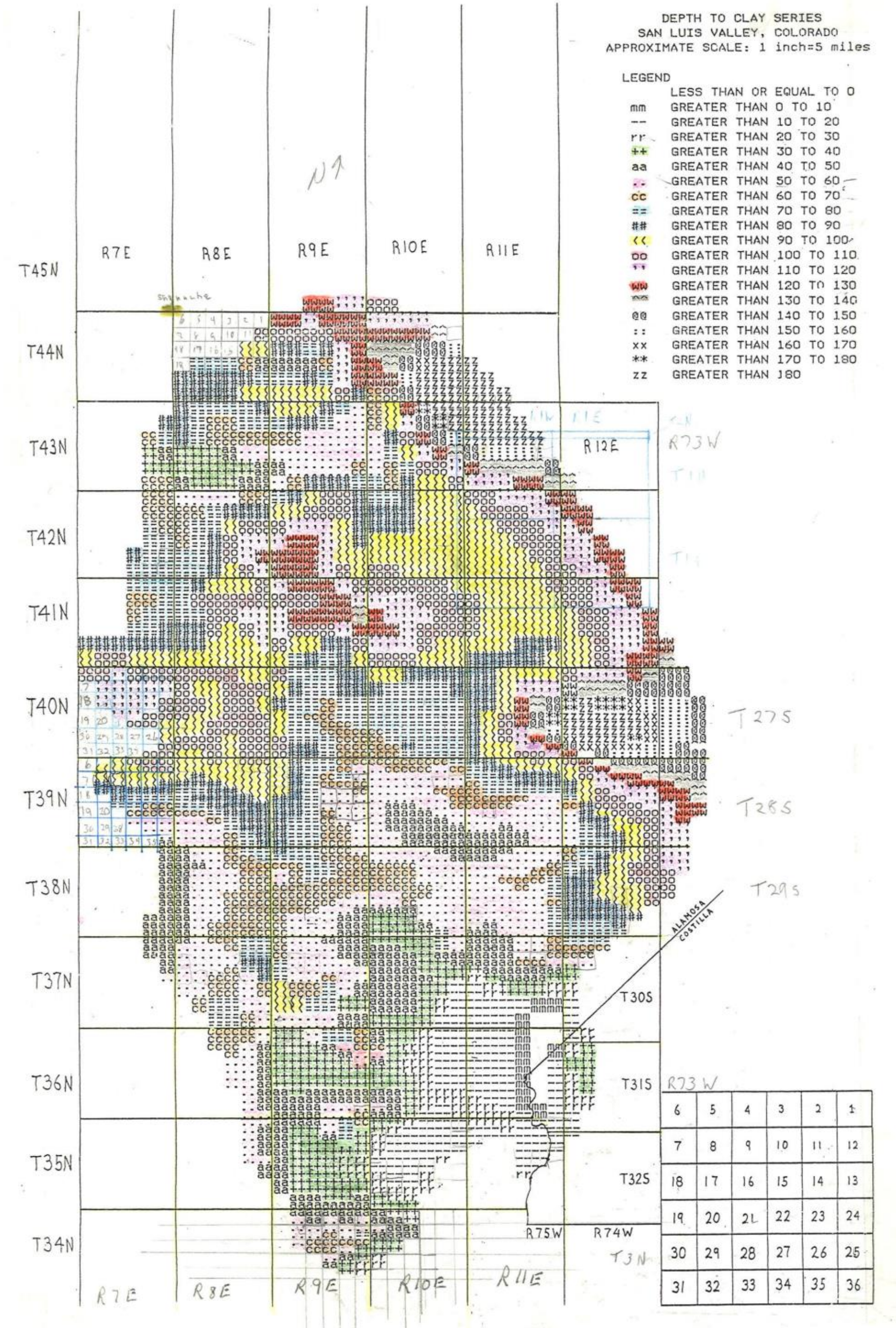
- Project is a pilot study, small in scale by its nature
  - Can we try geophysical imaging to determine where it may be easier to introduce surface water to recharge aquifer system(s) ?

- We proposed to test an area near Mosca and develop 5 linear arrays of electrical resistivity imaging data
  - Testing the observations made by the landowner – Nissen family

TARGETED RECHARGE

- Where should you place your recharge point ?
  - What are the complexities of the deposits below your feet ?
  - Clay layers or lenses can have significant impact on recharge potential, even if the clay layer is thin

- Electrical Resistivity Imaging (ERI) – driving metal spikes into the ground and passing electricity through them
  - Different earth materials respond differently – some conduct, some resist
  - Sand = Higher Resistivity, Clay = Lower Resistivity



ELECTRICAL RESISTIVITY IMAGING

- ERI is a geophysical technique that is used to image the subsurface using differences in the electrical resistivity of materials.
  - During an ERI survey, an electrical current is passed into the earth using paired current electrodes.
  - The potential difference is then measured between a pair of potential electrodes.
  - The apparent resistivity of the material(s) being investigated is processed into resistivity contour maps to show variations along the deployed array and at depth.
  - Resistivity of subsurface materials varies based on composition and water contents.

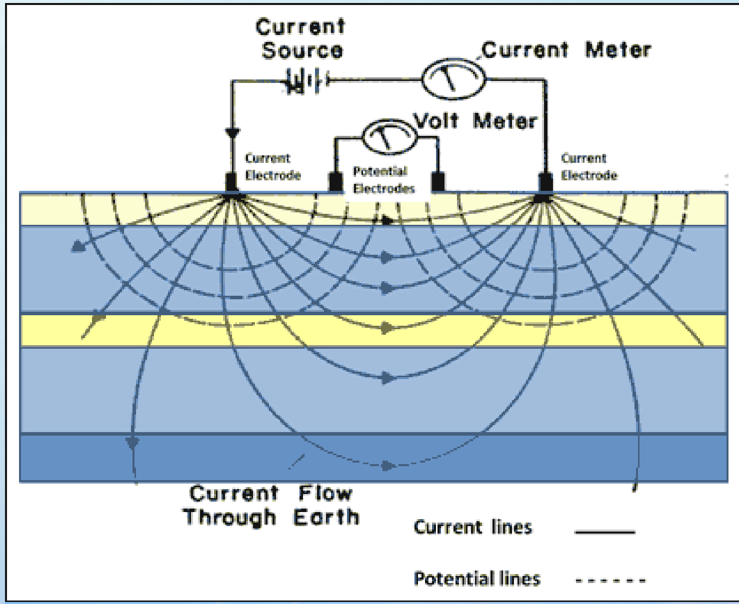
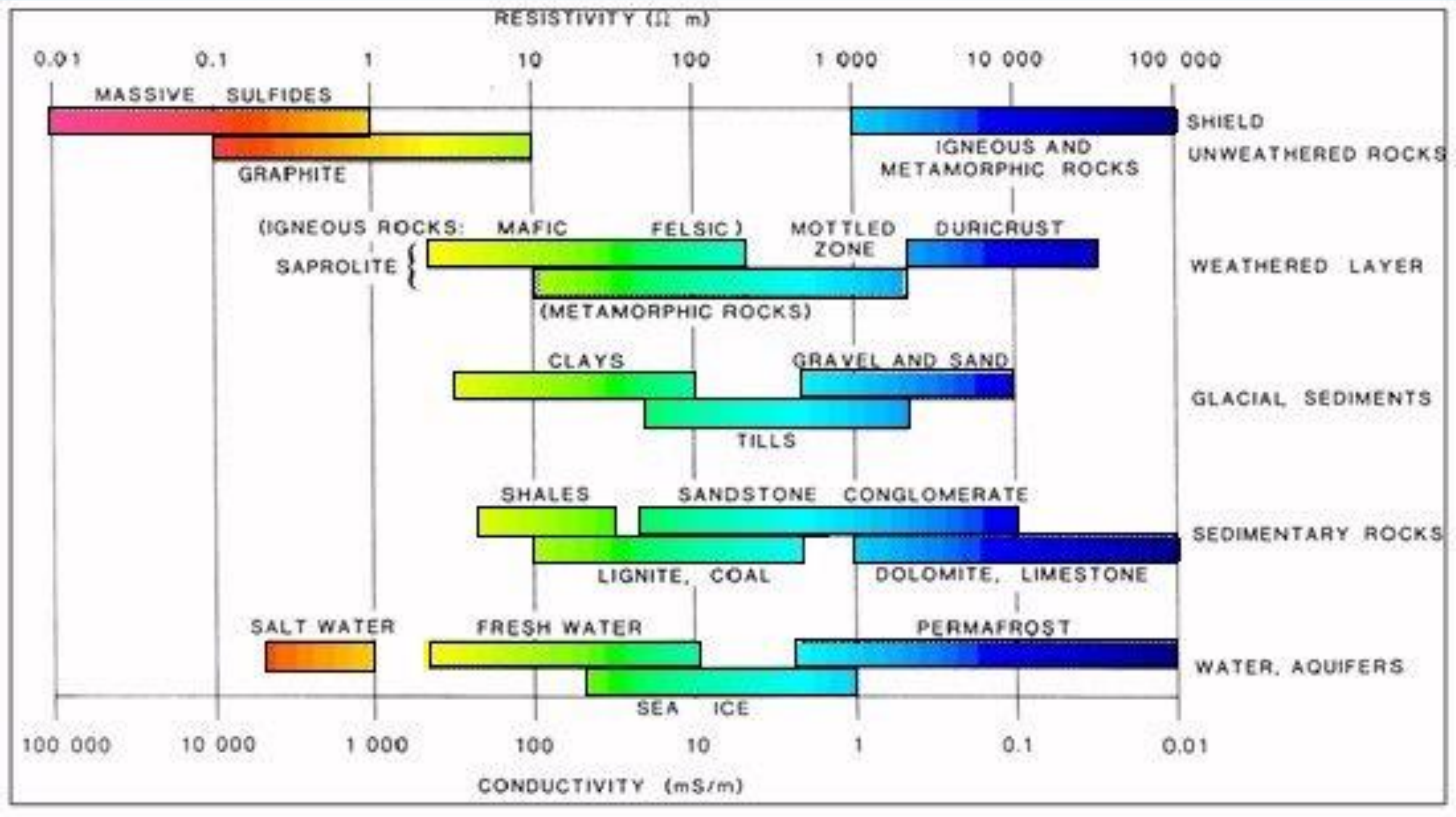


Photo of an array deployed in Puerto Rico to investigate sinkholes.

EARTH MATERIALS & RESISTIVITY



- HTTPS://WWW.EOAS.UBC.CA/UBCGIF/IAG/FOUNDATIONS/PROPERTIES/RESISTIVITY.HTM (UNIV. OF BRITISH COLUMBIA GEOPHYSICAL INVERSION FACILITY, DEPT. OF EARTH, OCEAN & ATMOS. SCIENCES)

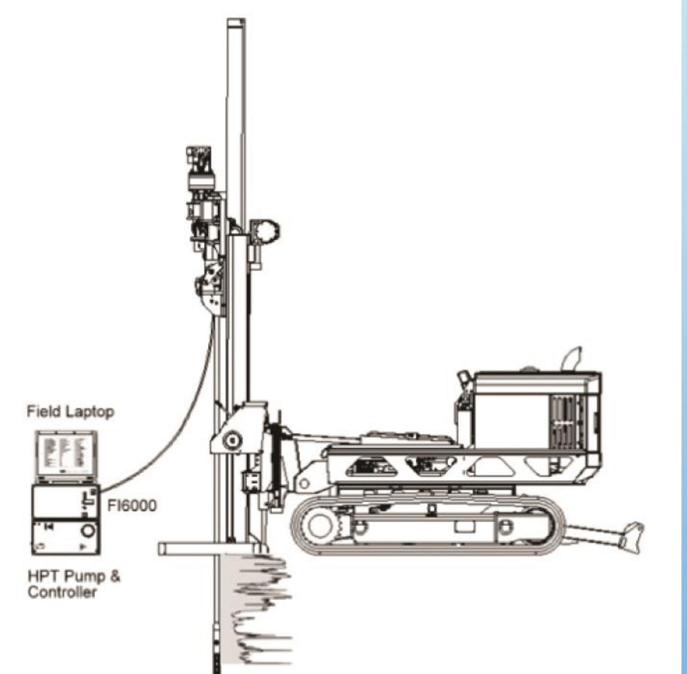
2019 PROGRESS

- RockWorks Model Incorporating 155 Well Logs

  (toggle to website & map)

- 8 ERI arrays were deployed
  - 4 on the northwestern end of the property on a brush quarter and 4 subsequent arrays to the southeast
  - The second set of arrays were used to gather additional data and test observations made for the first 4 arrays

- 5 test wells were drilled on the 4 northwestern arrays
  - Hydraulic profiling tool (HPT) was deployed in each test well, cuttings were collected, and monitoring wells installed



https://geoprobe.com/hpt-system-diagram

This effort was made possible by Nissen Farms volunteering their land for the project.

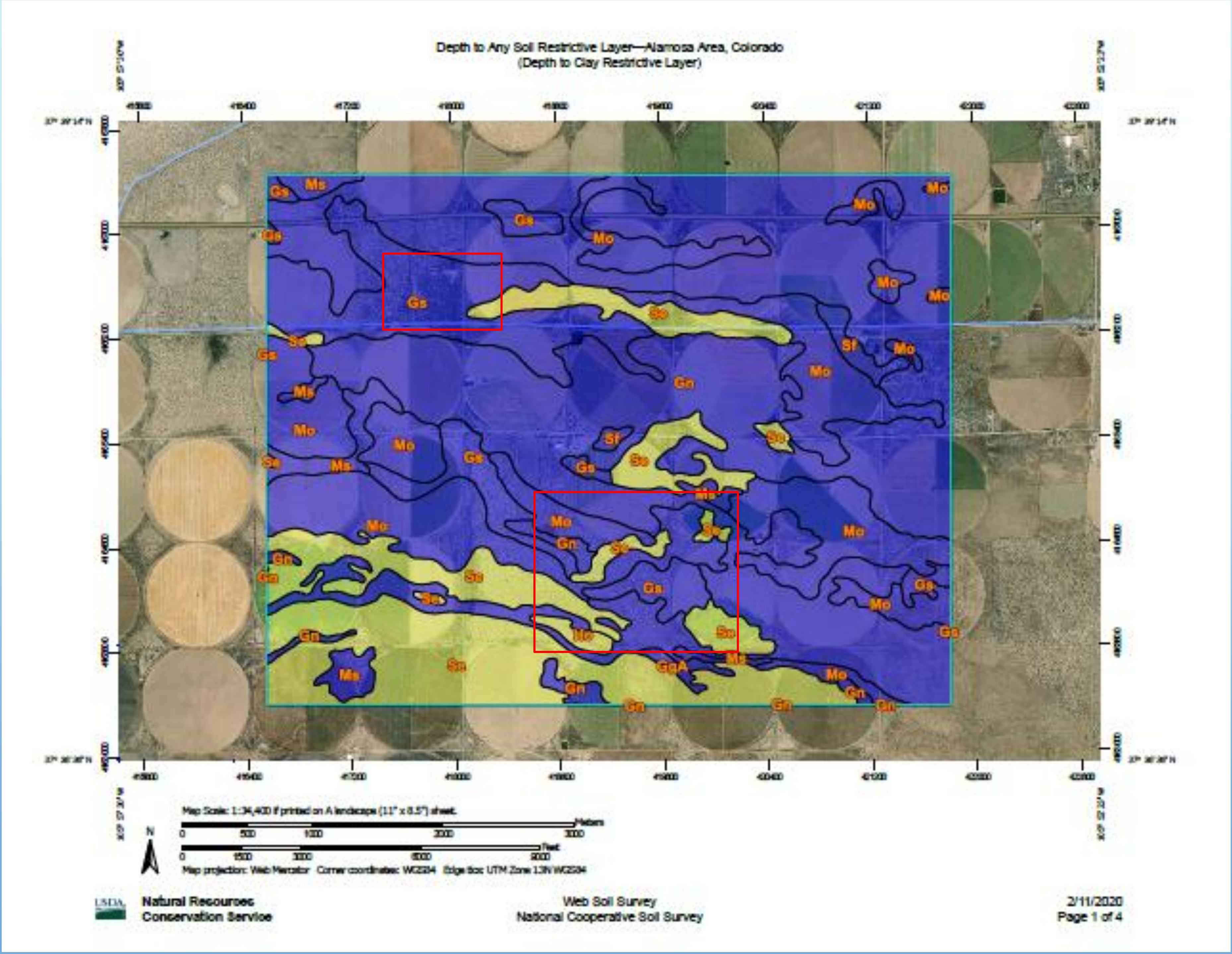
NRCS Web Soil Survey

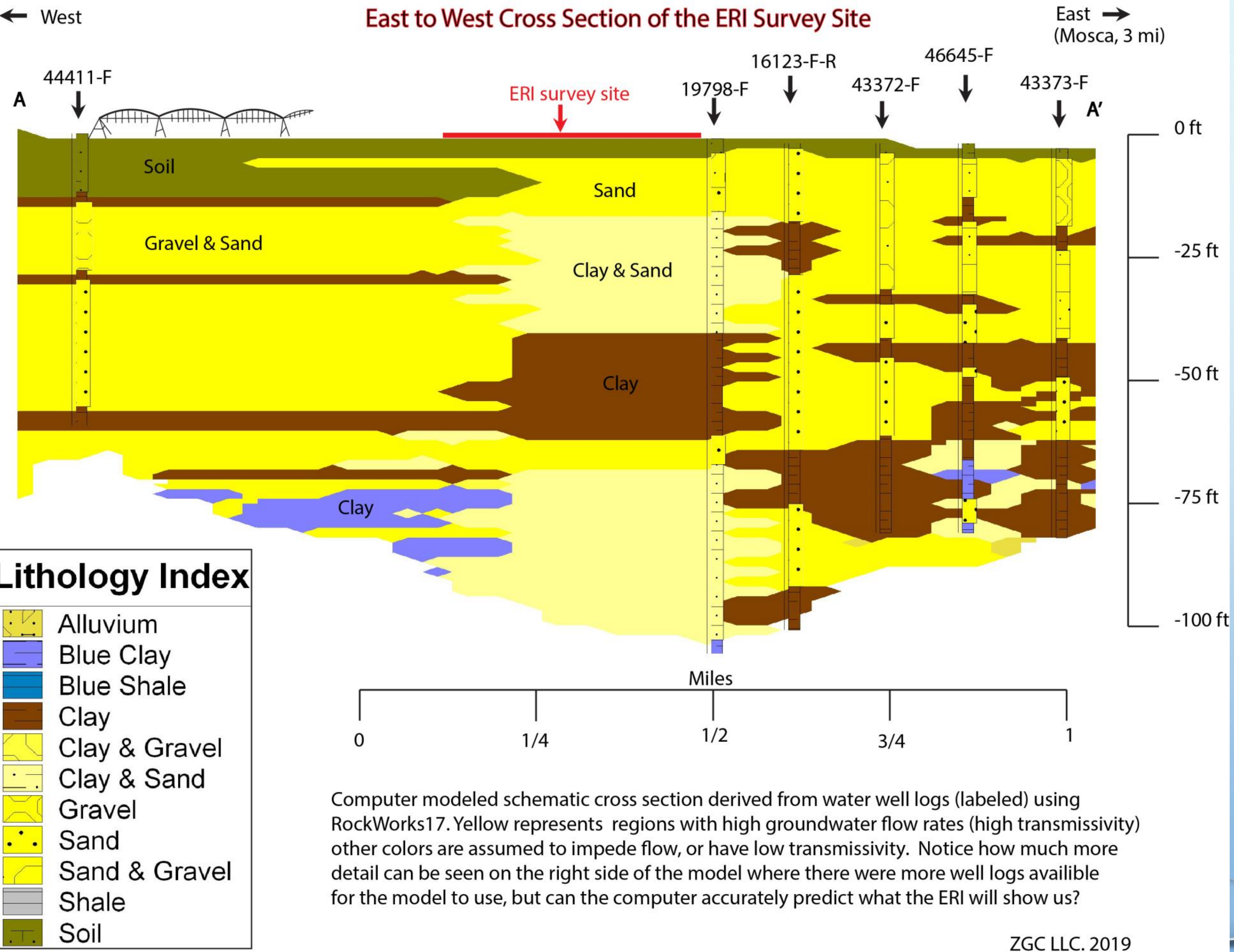
Depth To Restrictive Clay Layer

Blue Shading:
No Clay Restriction 0 - 78”

Green Shading:
Clay 7” - 34” , underlain by Sand 34” to 78”

ERI Sensing from
Soil Surface to 80 feet





Computer modeled schematic cross section derived from water well logs (labeled) using RockWorks17. Yellow represents regions with high groundwater flow rates (high transmissivity) other colors are assumed to impede flow, or have low transmissivity. Notice how much more detail can be seen on the right side of the model where there were more well logs availible for the model to use, but can the computer accurately predict what the ERI will show us?

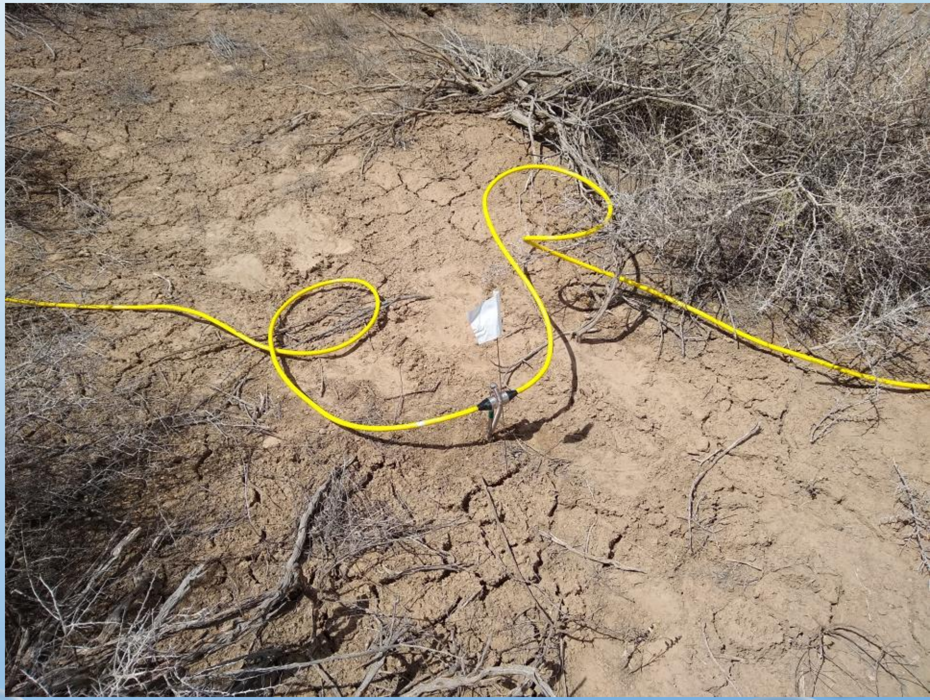
ZGC LLC. 2019

This cross-section was developed using RockWorks and incorporates well log data from previously drilled logs. The RockWorks software package models correlations between wells.

The cross-section runs east west across the northern end of the study area and intersects Line 4.

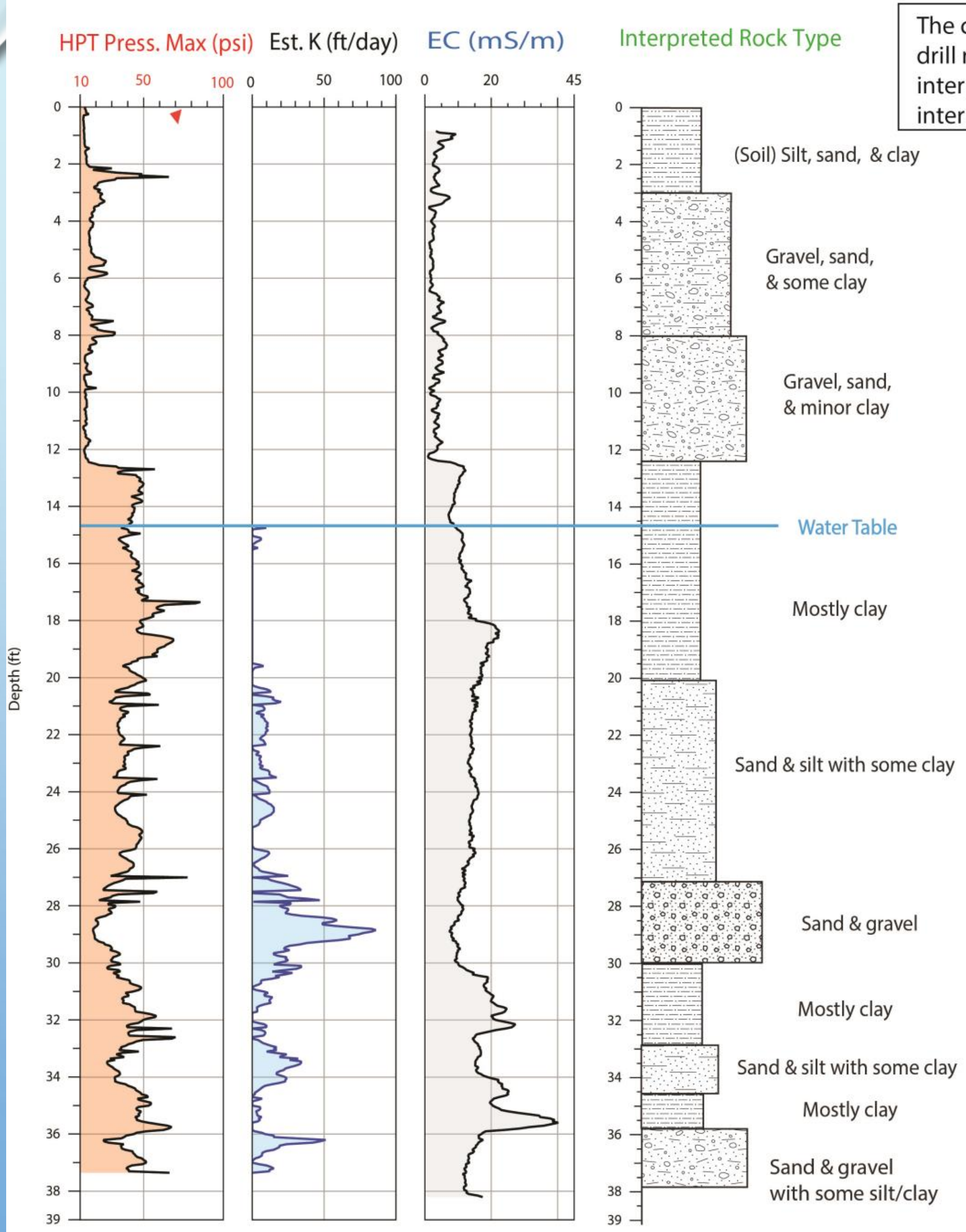
ERI array “brain”

Electrode and cable



Test hole drilling

Understanding Hydraulic Profiling Tool (HPT) Graphs



The curves to your left were created by an HPT as it was pushed directly into the ground by a small drill rig. As the tool is pushed into the subsurface, it collects several pieces of data that can be used to interpret the types of earth materials it encounters. The graphic to the right of the curves shows our interpretations of the rock types. This guide will explain how to read and interpret HPT data yourself!

HPT Press. Max - Thi s is the primary set of data the HPT collects. As the tool is pushed into the ground, it injects a stream of water into the surrounding formation. The curve you see is the amount of pressure created by the water injection. When the HPT is surrounded by gravel, little or no pressure is required for water to flow. However, when surrounded by clay, it is very difficult for water to flow and the pressure increases significantly. Lower pressure = higher formation permeaility = increased groundwater flow, and vice versa!

EC - Electrical Conductivity (EC) is another set of data the HPT collects as it travels through the subsurface. Different earth materials conduct electricity in different ways: for instance, clay conducts electricity very well - so the HPT will record a high EC when it passes through clay. Sand and gravel usually conduct electricity poorly compared to clay, so the HPT will record a lower EC when passing through them. Notice how the HPT pressure curve and the EC curve are very similar!

In some cases, the EC can pick up on other things in the ground. Salt accumulation in soil or groundwater increases conductivity, and can cause the EC curve to spike. We compare the EC curve and the HPT pressure curve carefully to check for any anomolies.

Est. K - Hydraulic Conductivity (abbreviated 'K") is a term that describes how quickly water moves through a given material. Est. K is used in groundwater calculations and computer models, but it can be very difficicult for scientists to know if the K value they're using is correct. Often, scientists use a general K value based on the type of aquifer theyre dealing with - but if an incorrect K value is used, it can dramatically affect the model or calculation they're working on.

The HPT is able to estimate hyrdaulic conditivity by running a 'dissipation test", where it measures how long it takes the aquifer pressure to level out after water injection has stopped. However, the HPT can only run this test when the subsurface conditions are just right. If you dont see a Est. K curve included with the data, it's because the HPT wasn't able to run a sucessful 'dissapation test' on that borehole. A limiation of the HPT is that it will only give est. K values for materials below the water table.

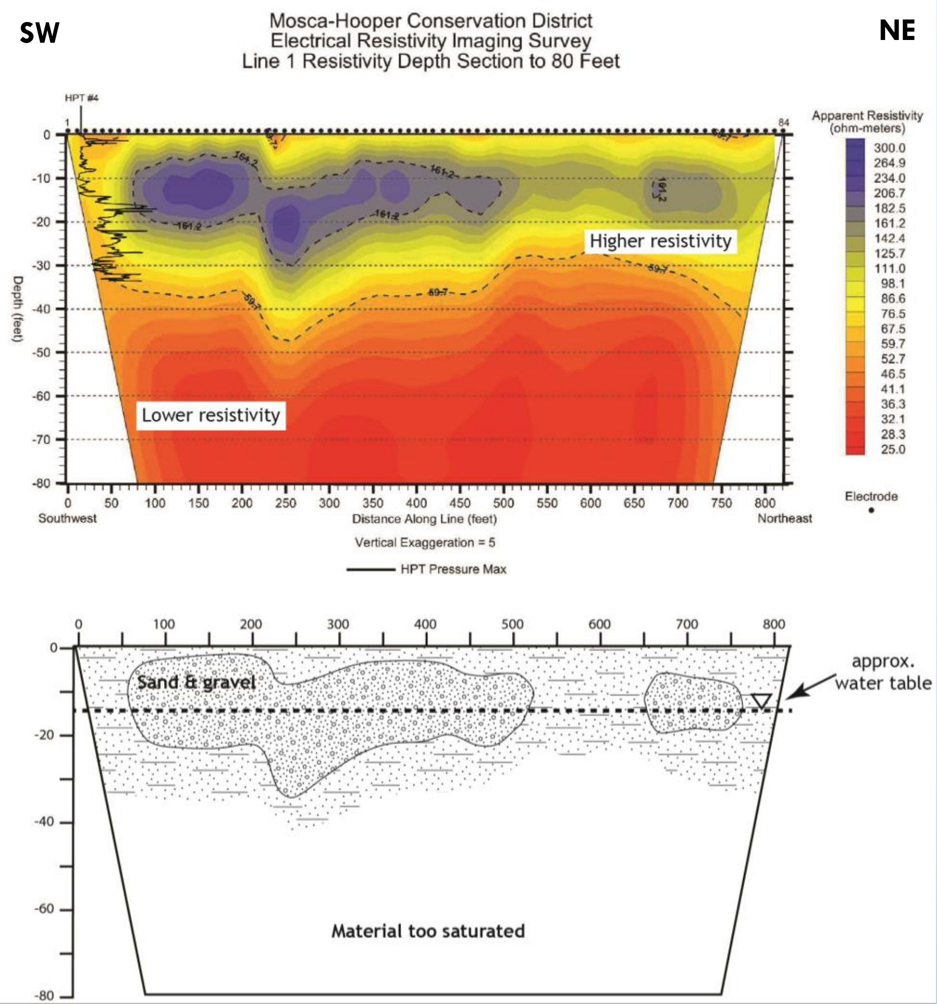
Interpreted Rock Type - By looking at all the data the HPT collected together, we can interpret what type of materials the HPT traveled through. For instance, at 29ft the HPT pressure is low, the EC is low, and the est. K is relatively high. This suggests a material primarily comprised of sand and gravel. At 10 ft the HPT pressure and the EC is low, but because the EC is slightly higher than at 6ft, we interpreted a slight clay component along with the gravel & sand. Here, the materials are above the water table, so the EC is generally much lower - so we have to look closer at the curve to notice the difference.

Vista GeoScience Subsurface Imaging Systems

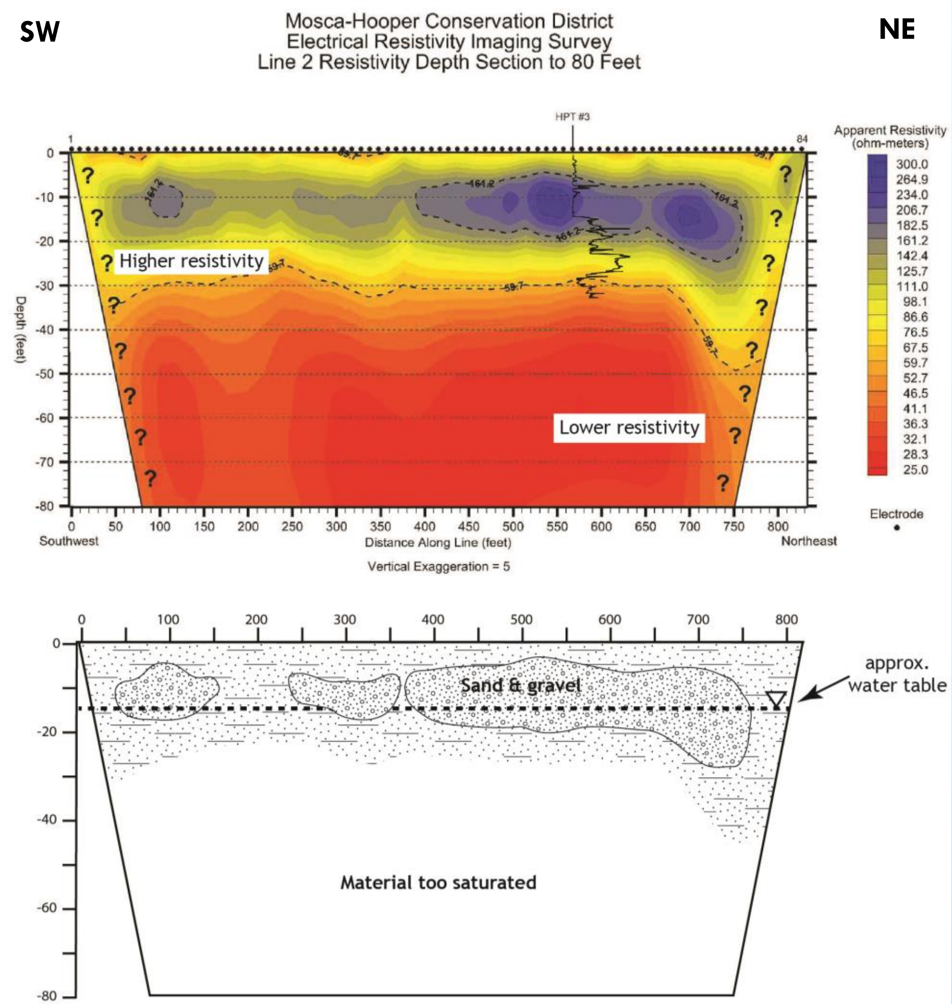
We are pleased to have contracted Vista GeoScience to collect the HPT data for the project.

ERI IMAGES

- The following slides show the ERI images as acquired along with the geology team's interpretations of the rock/sediment type that the ERI image suggests is in the subsurface
  - Caveat! While some of these arrays are parallel and nearby to one another, we urge caution in correlating gravel deposits between arrays
    - River systems are very complex and while these may be related channel deposits, it is not easy to be sure without 3D imaging.



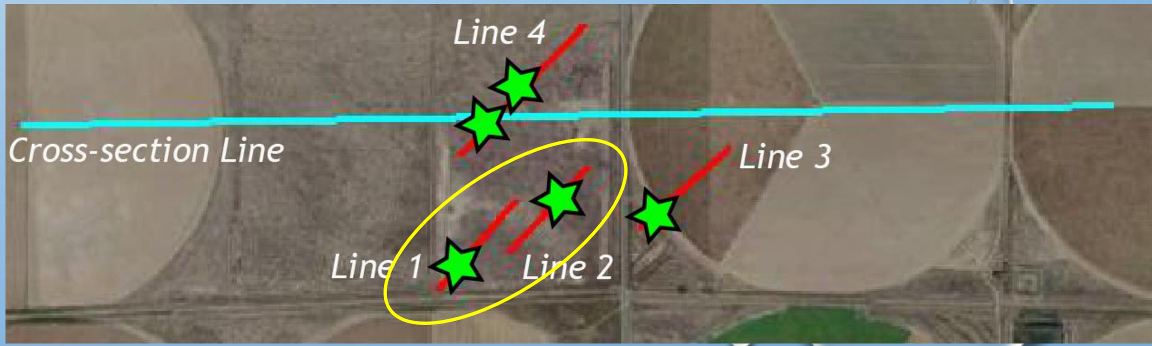
Line 1

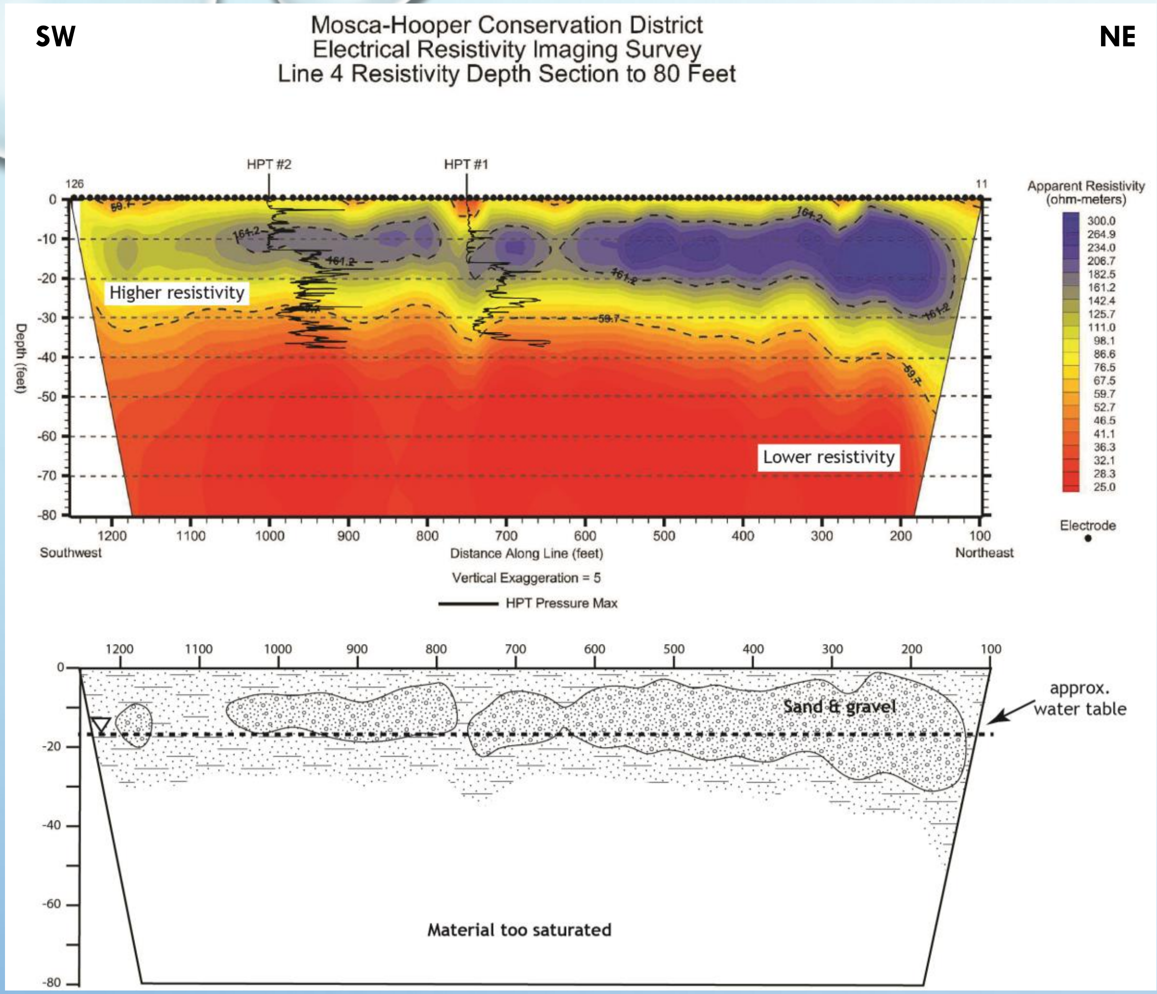


Line 2

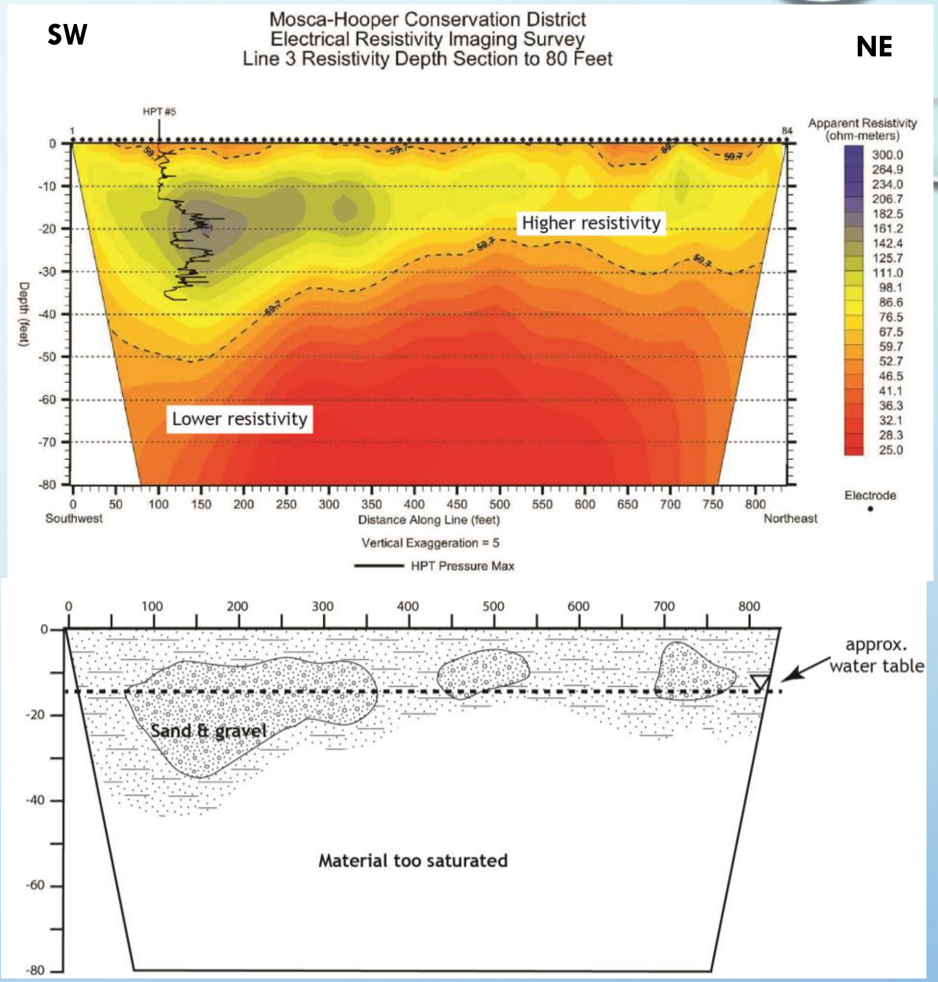
ERI data along with the interpreted sediments below the surface.

Note the HPT data overlaid on each array for lines 1-4.

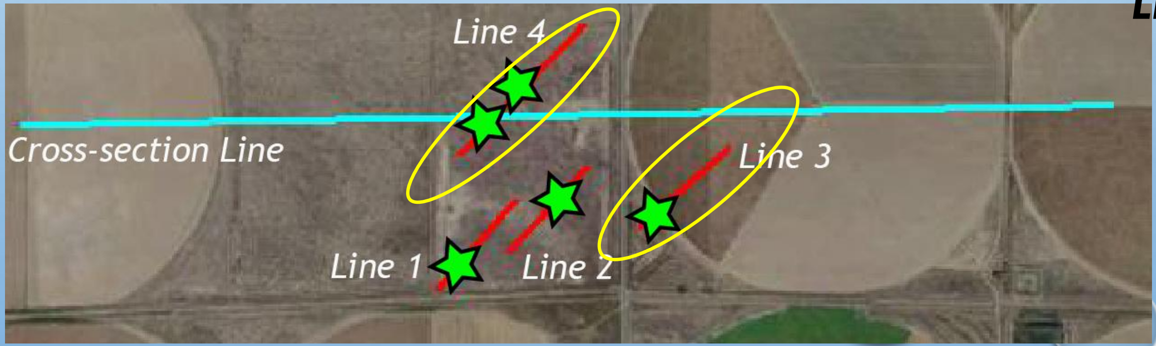


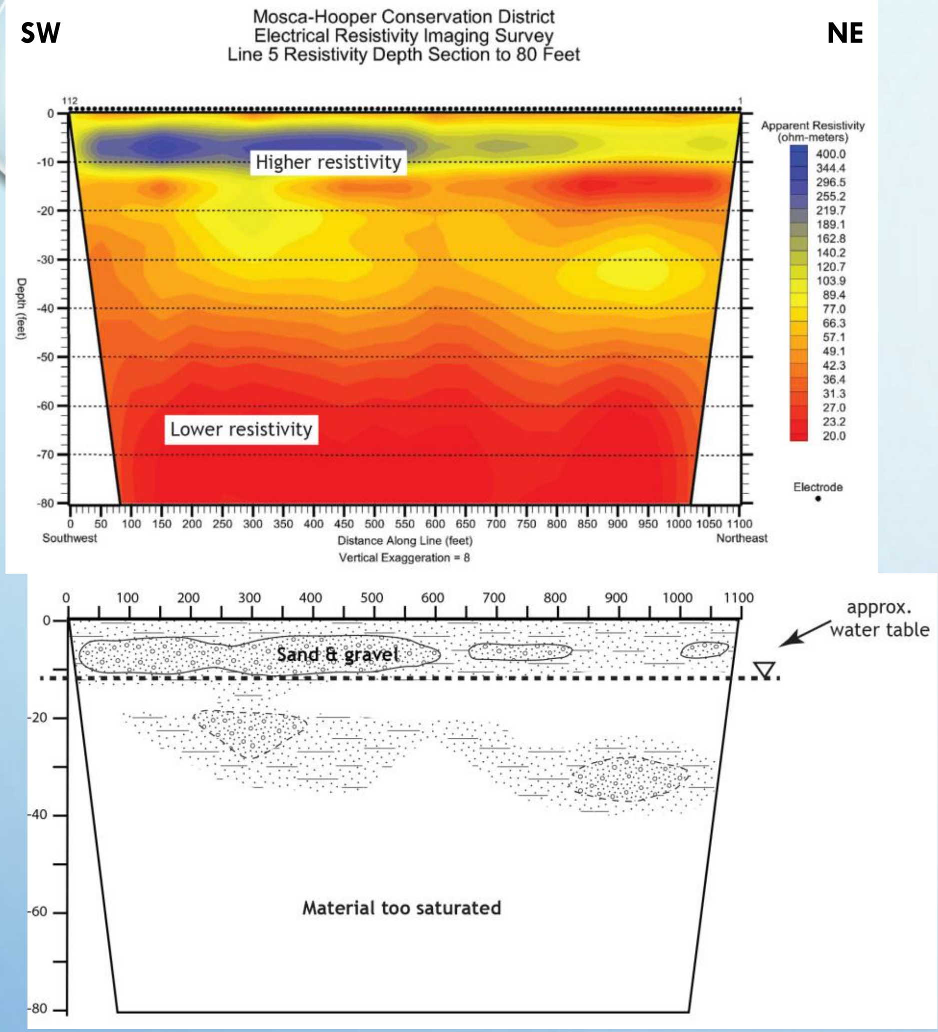

SW
NE
Mosca-Hooper Conservation District
Electrical Resistivity Imaging Survey
Line 4 Resistivity Depth Section to 80 Feet
HPT #2
HPT #1
Apparent Resistivity (ohm-meters)
300.0
264.9
234.0
206.7
182.5
161.2
142.4
125.7
111.0
98.1
86.6
76.5
67.5
59.7
52.7
46.5
41.1
36.3
32.1
28.3
25.0
Higher resistivity
Lower resistivity
Depth (feet)
Southwest
Northeast
Distance Along Line (feet)
Vertical Exaggeration = 5
HPT Pressure Max
Electrode
Sand & gravel
approx. water table
Material too saturated

Line 4

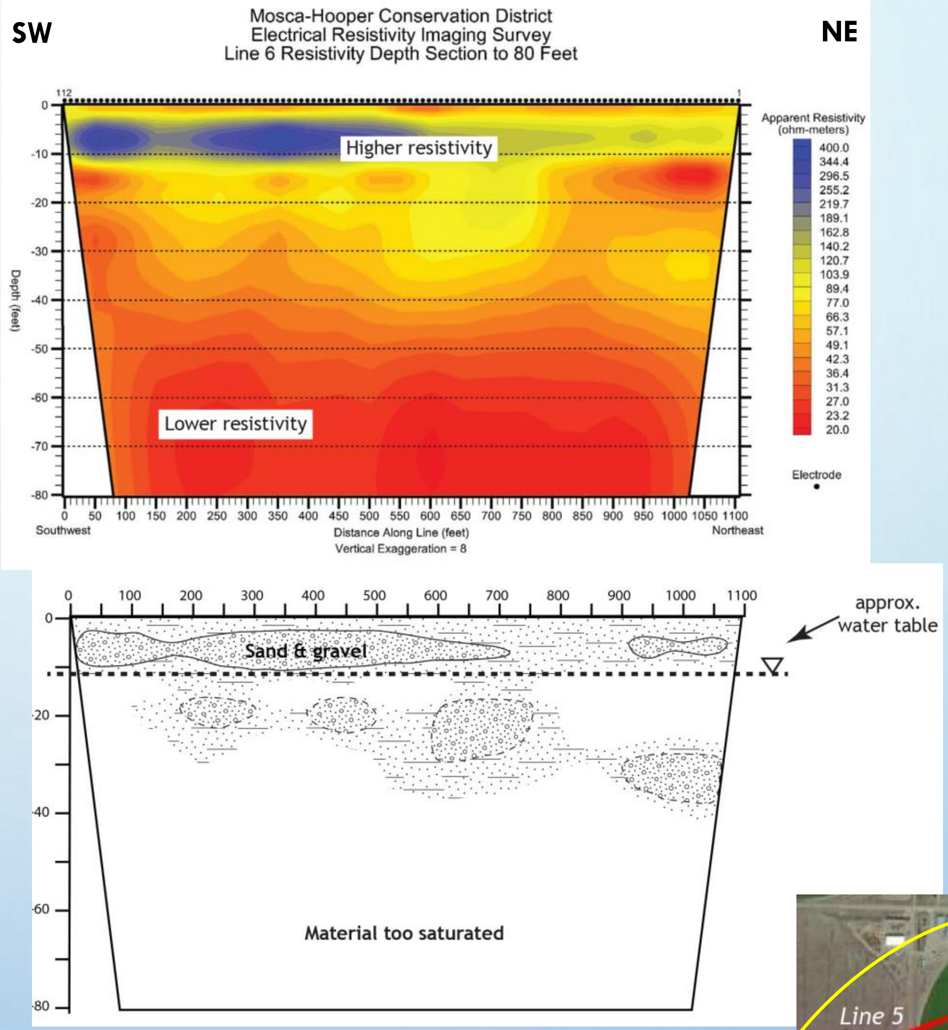

SW
NE
Mosca-Hooper Conservation District
Electrical Resistivity Imaging Survey
Line 3 Resistivity Depth Section to 80 Feet
HPT #5
Apparent Resistivity (ohm-meters)
300.0
284.9
234.0
206.7
182.5
161.2
142.4
125.7
111.0
98.1
86.6
76.5
67.5
59.7
52.7
46.5
41.1
36.3
32.1
28.3
25.0
Higher resistivity
Lower resistivity
Depth (feet)
Southwest
Northeast
Distance Along Line (feet)
Vertical Exaggeration = 5
HPT Pressure Max
Electrode
Sand & gravel
approx. water table
Material too saturated

Line 3


Line 4
Cross-section Line
Line 3
Line 1
Line 2

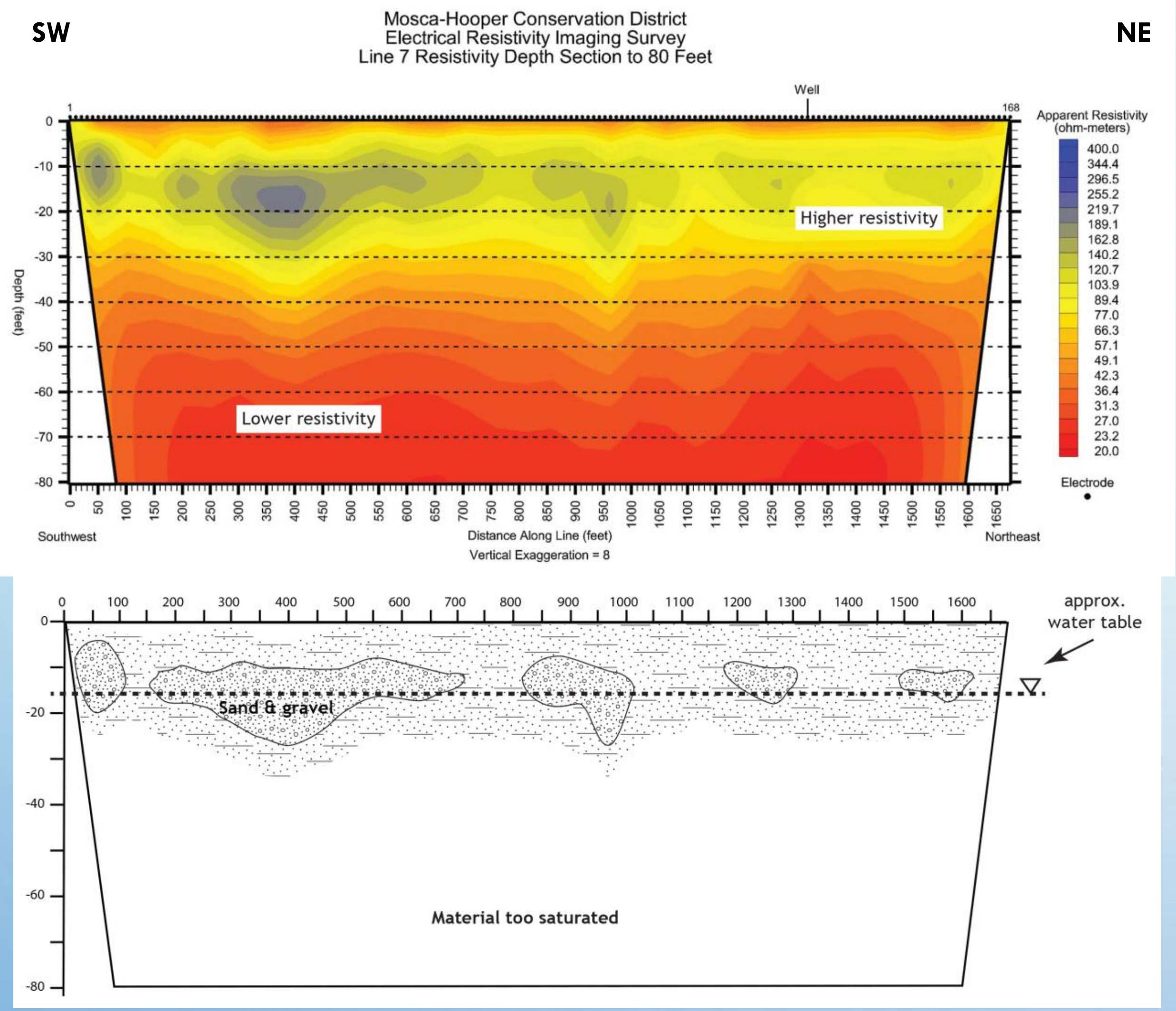

SW
NE
Mosca-Hooper Conservation District
Electrical Resistivity Imaging Survey
Line 5 Resistivity Depth Section to 80 Feet
Higher resistivity
Lower resistivity
Depth (feet)
Apparent Resistivity (ohm-meters)
400.0
344.4
296.5
255.2
219.7
189.1
162.8
140.2
120.7
103.9
89.4
77.0
66.3
57.1
49.1
42.3
36.4
31.3
27.0
23.2
20.0
Electrode
Southwest
Northeast
Distance Along Line (feet)
Vertical Exaggeration = 8
approx. water table
Sand & gravel
Material too saturated

Line 5

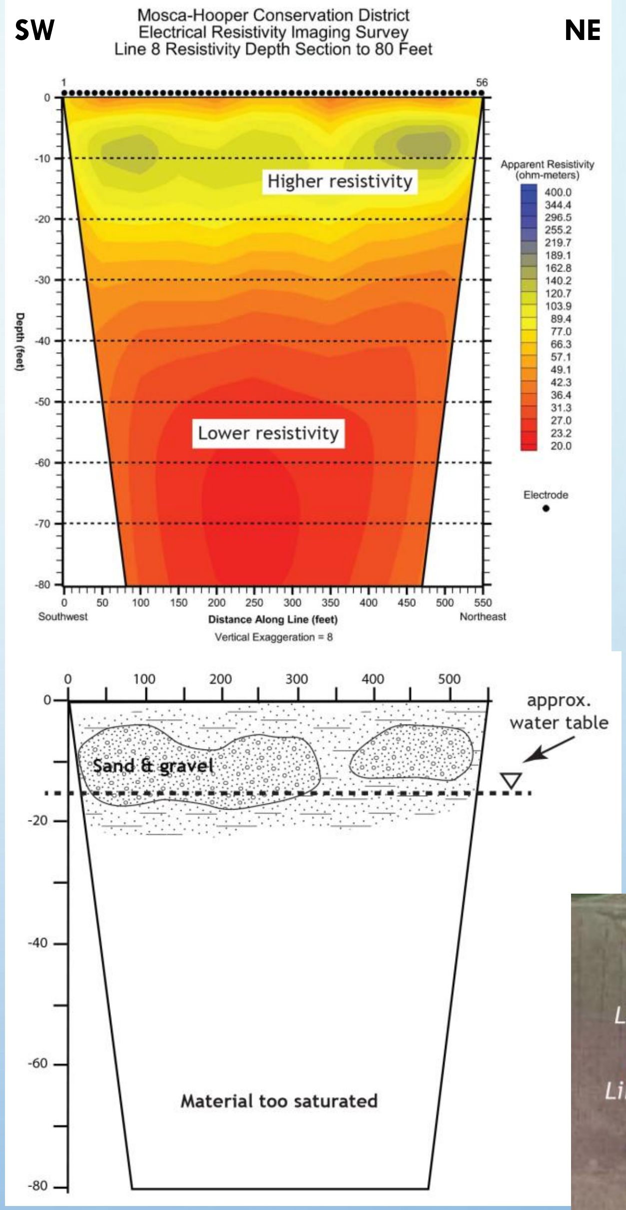

SW
NE
Mosca-Hooper Conservation District
Electrical Resistivity Imaging Survey
Line 6 Resistivity Depth Section to 80 Feet
Higher resistivity
Lower resistivity
Depth (feet)
Apparent Resistivity (ohm-meters)
400.0
344.4
296.5
255.2
219.7
189.1
162.8
140.2
120.7
103.9
89.4
77.0
66.3
57.1
49.1
42.3
36.4
31.3
27.0
23.2
20.0
Electrode
Southwest
Northeast
Distance Along Line (feet)
Vertical Exaggeration = 8
approx. water table
Sand & gravel
Material too saturated

Line 6


Line 5
Line 6
Line 7
Line 8


SW
NE
Mosca-Hooper Conservation District
Electrical Resistivity Imaging Survey
Line 7 Resistivity Depth Section to 80 Feet
Well
Apparent Resistivity (ohm-meters)
400.0
344.4
296.5
255.2
219.7
189.1
162.8
140.2
120.7
103.9
89.4
77.0
66.3
57.1
49.1
42.3
36.4
31.3
27.0
23.2
20.0
Electrode
Higher resistivity
Lower resistivity
Depth (feet)
Southwest
Distance Along Line (feet)
Vertical Exaggeration = 8
Northeast
approx. water table
Sand & gravel
Material too saturated

Line 7


SW
NE
Mosca-Hooper Conservation District
Electrical Resistivity Imaging Survey
Line 8 Resistivity Depth Section to 80 Feet
Apparent Resistivity (ohm-meters)
400.0
344.4
296.5
255.2
219.7
189.1
162.8
140.2
120.7
103.9
89.4
77.0
66.3
57.1
49.1
42.3
36.4
31.3
27.0
23.2
20.0
Electrode
Higher resistivity
Lower resistivity
Depth (feet)
Southwest
Distance Along Line (feet)
Vertical Exaggeration = 8
Northeast
approx. water table
Sand & gravel
Material too saturated

Line 8


Line 5
Line 6
Line 7
Line 8

THOUGHTS SO FAR …

- The location of gravel deposits in the subsurface corresponds nicely with the Nissens' observations.
  - "Quick-Responding Wells" to the west and north versus "Slow-Responding Wells" to the south and east.
- The subsurface deposits are complex, and this complexity needs to be a primary concern in developing recharge features on the landscape
- Existing well logs & landowner insights offer starting point – sensing approach allows for pinpointing best among prospects
- ERI produced good match between test wells & landowner observations – Next Step is to compare ERI to faster method and associated costs to deploy & analyze
  - DUAL Electromagnetic Imaging Device (USGS)