

Delineation of Aquifer Heterogeneities Using Transient Electromagnetic Soundings in the Great Sand Dunes National Park

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Abstract

During the Pleistocene, a laterally extensive unit of clay was deposited in the bed of Lake Alamosa throughout San Luis Valley, southern Colorado. This laterally continuous unit now lies at a depth of about 200 m below ground surface and acts as an aquitard within a siliciclastic aquifer system. The goal of this study is to better characterize changes in the depth, continuity, and thickness of the blue clay near Great Sand Dunes National Park. Variability within the blue clay controls the pressure of confined groundwater and can complicate the monitoring and use of groundwater resources.

Transient electromagnetic (TEM) soundings were used to delineate the continuity of the blue clay near Antelope Springs. TEM data were collected along profiles by inducing electrical currents into the ground at 12 sounding stations. Resistivities in the subsurface were modeled using mathematical inversion and were used to develop a cross-section of inferred lithological properties. The resulting cross-section shows that the top of the blue clay unit has a 50 m decrease in depth over a distance of approximately 1400 m along the profile and then terminates at the interpreted shoreline of the ancient Lake Alamosa. Although this appears to be an anomalous rise of the blue clay unit toward the northeast, post-depositional faulting is considered to be unlikely because of the gentle and gradual slope of the surface. Additional data acquisition and analysis are needed to further investigate whether the heterogeneity in the blue clay is related to pre-depositional faulting, sedimentary processes, or both.

Introduction

- During the Pleistocene epoch a laterally extensive aquitard was deposited in the bed of Lake Alamosa.
- Despite the lateral continuity of the aquitard, or “blue clay”, layer (BCL) evidence reveals that heterogeneities exist in the depth and thickness of the siliciclastic aquifer system.
- Heterogeneities cause variations in confined aquifer water pressure.
- Mapping clay unit will benefit hydrogeological framework

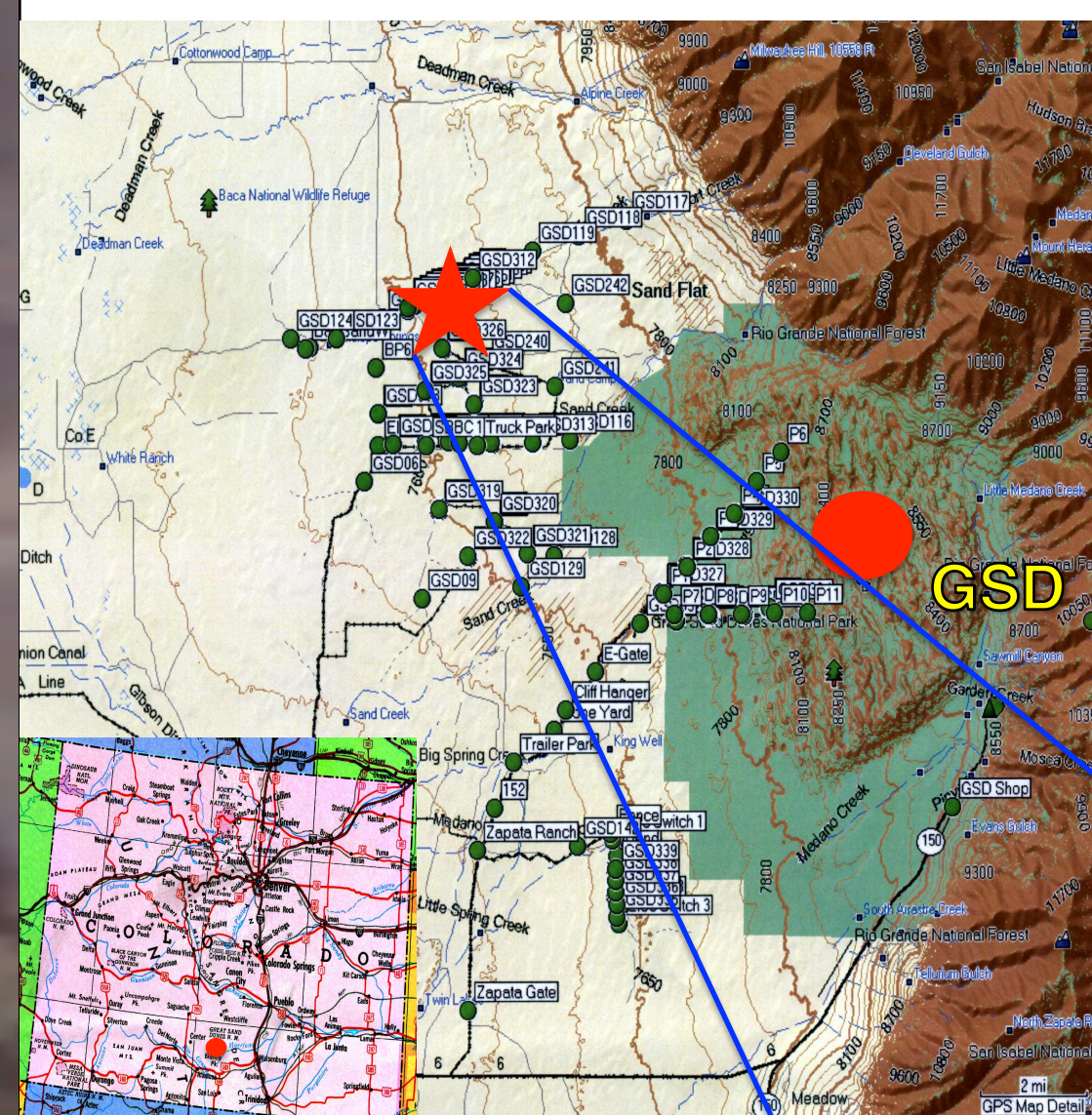
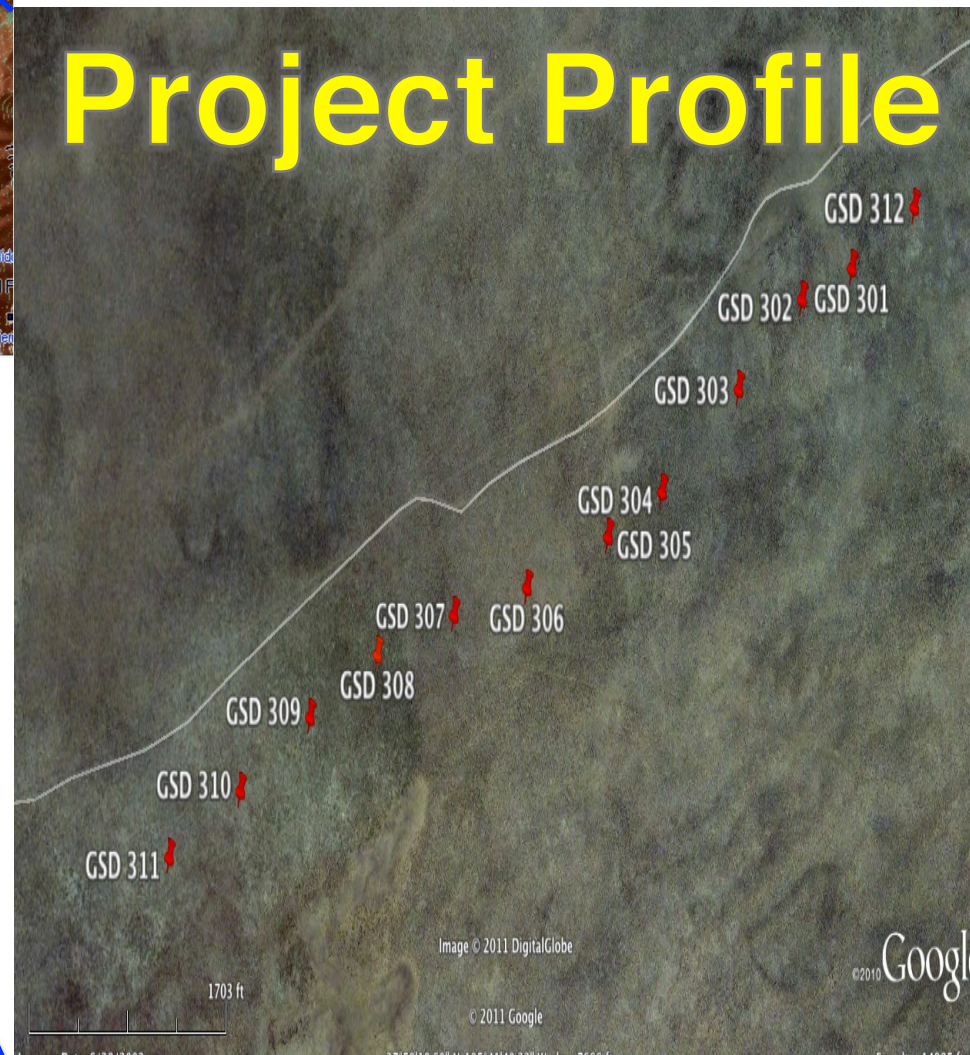


Figure 1. Location of the Great Sand Dunes and the Transient Electromagnetic (TEM) soundings.

Project Profile



Methods

- Transient Electromagnetic (TEM) soundings was used to delineate the subsurface
- Two different types of aquifers
- Unconfined aquifer
- Confined aquifer



Figure 3. EM-57 Transmitter Data Acquisition

- Transmitter loop= 50 m square
- Current= 26AMPS
- Time it takes for current to shutoff in the loop=36 μ s
- Measurement time=10ms that produces Apparent Resistivity Plot

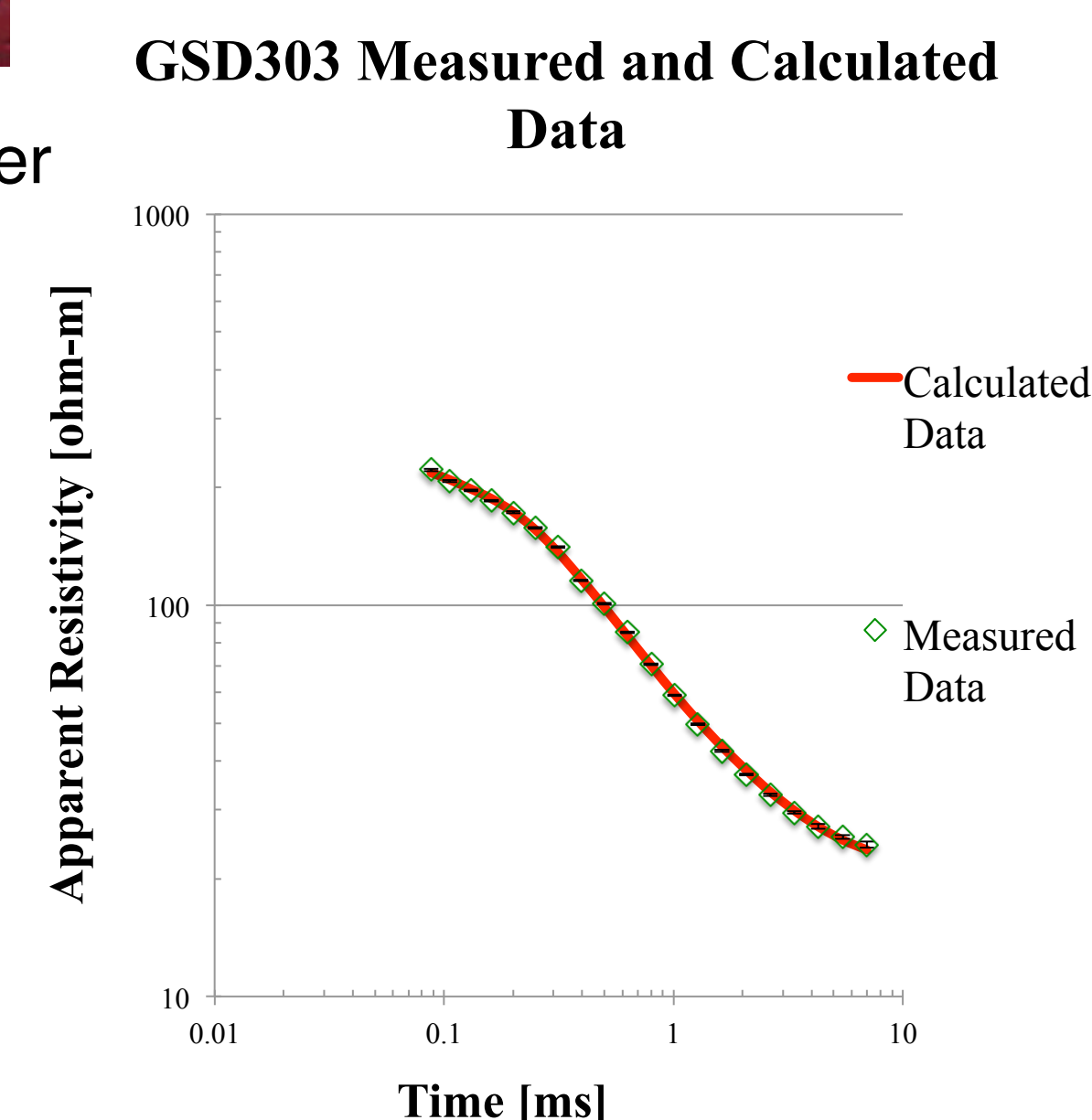


Figure 4. Apparent Resistivity Plot of station 303 measuring resistivity vs. time

Data Analysis

- Mathematical inversion of ARP~ Resistivity vs. Depth Model

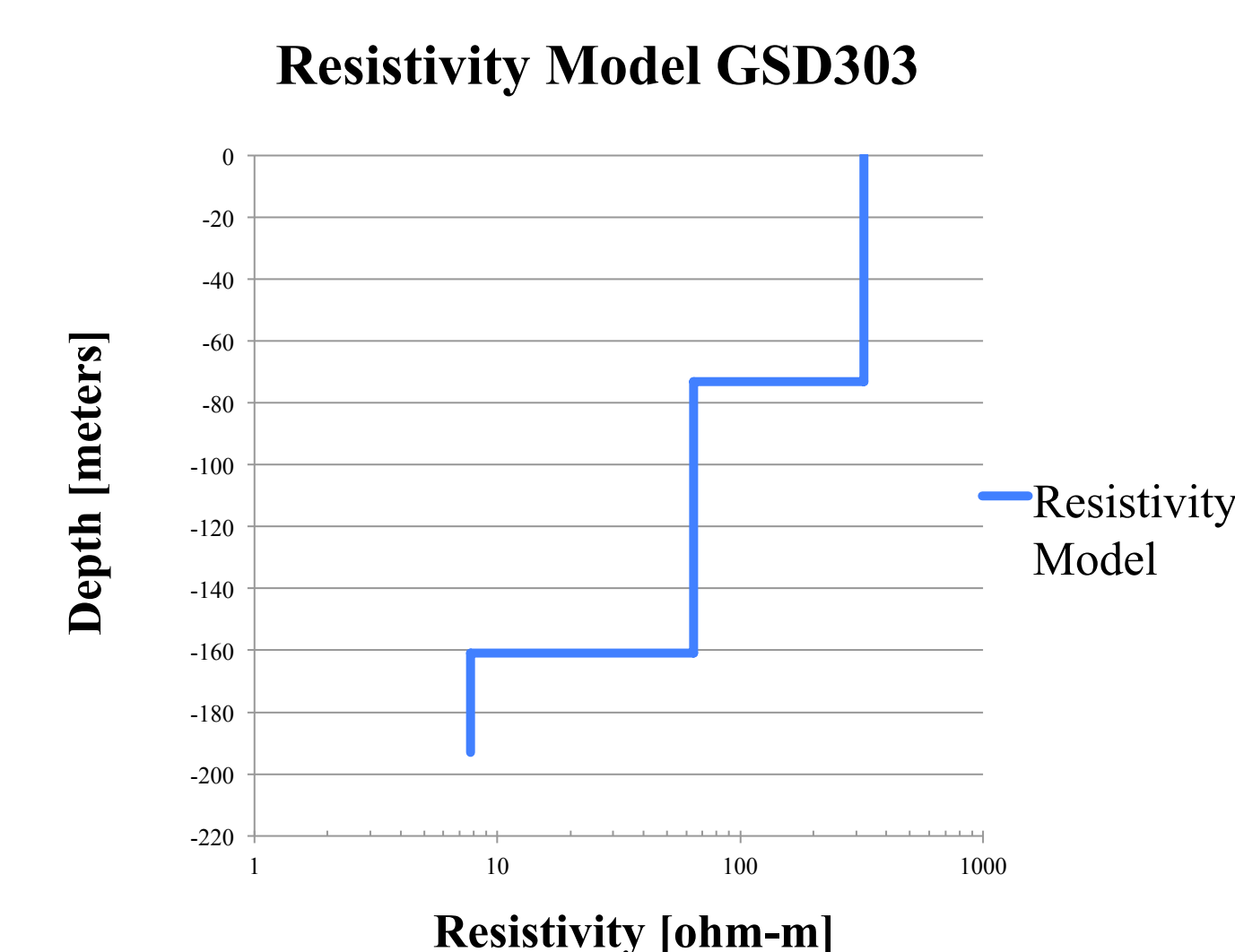


Figure 5. Resistivity vs. Depth Plot

Results

- Resistivity models with uncertainty and cross sections were developed.

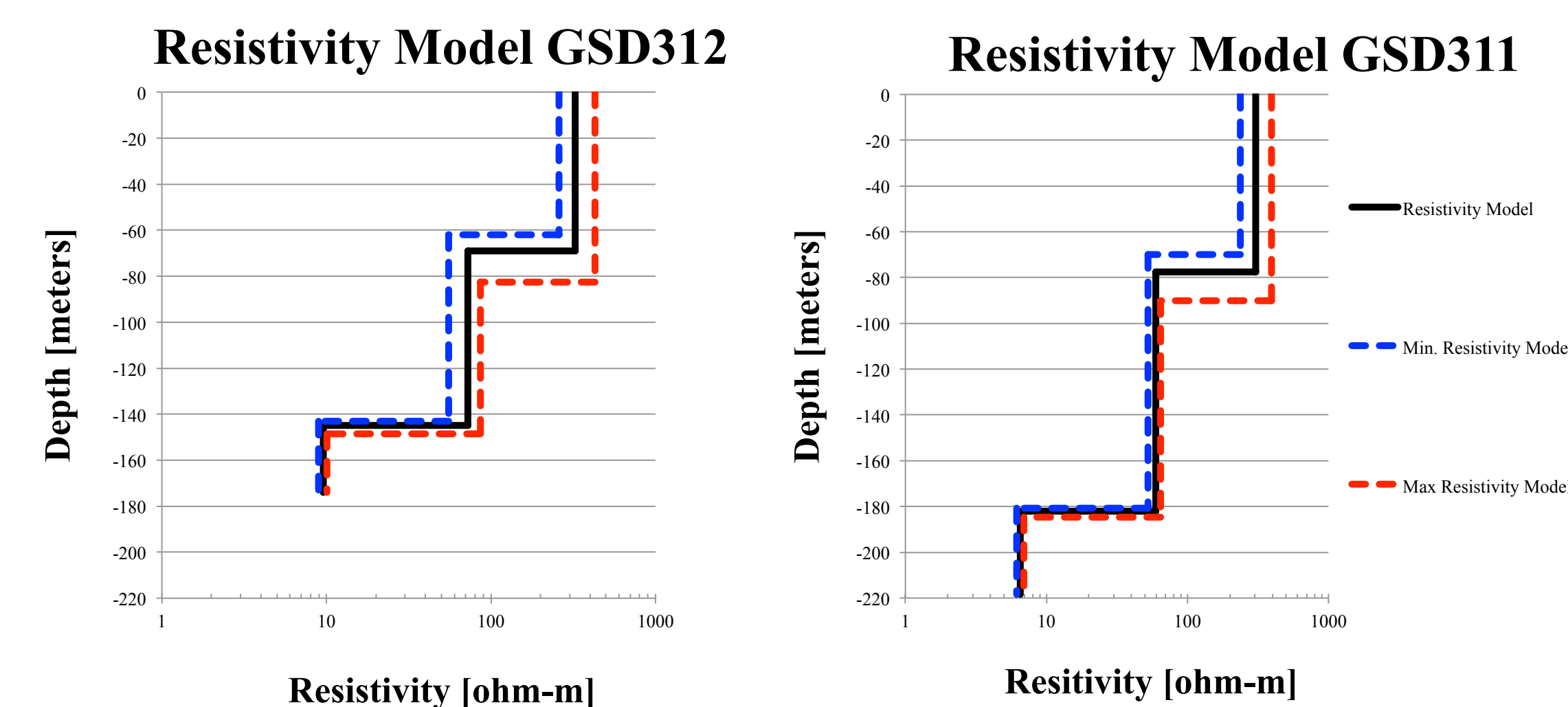


Figure 6: Uncertainty Models for stations '312 and '311

- Depth uncertainty parameter for sand layer~ 20 m
- Depth uncertainty parameter for grey clay layer=less than 10 m

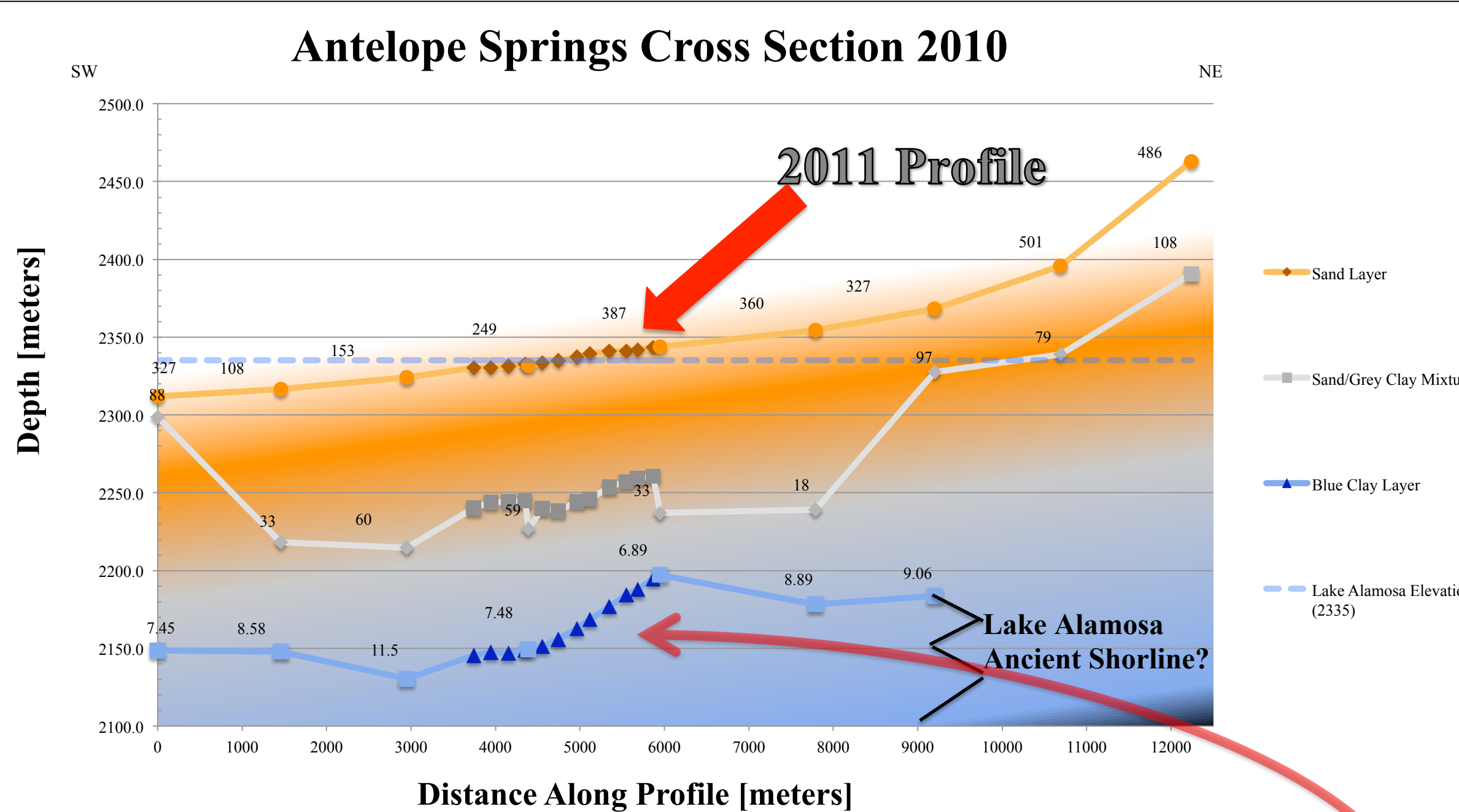
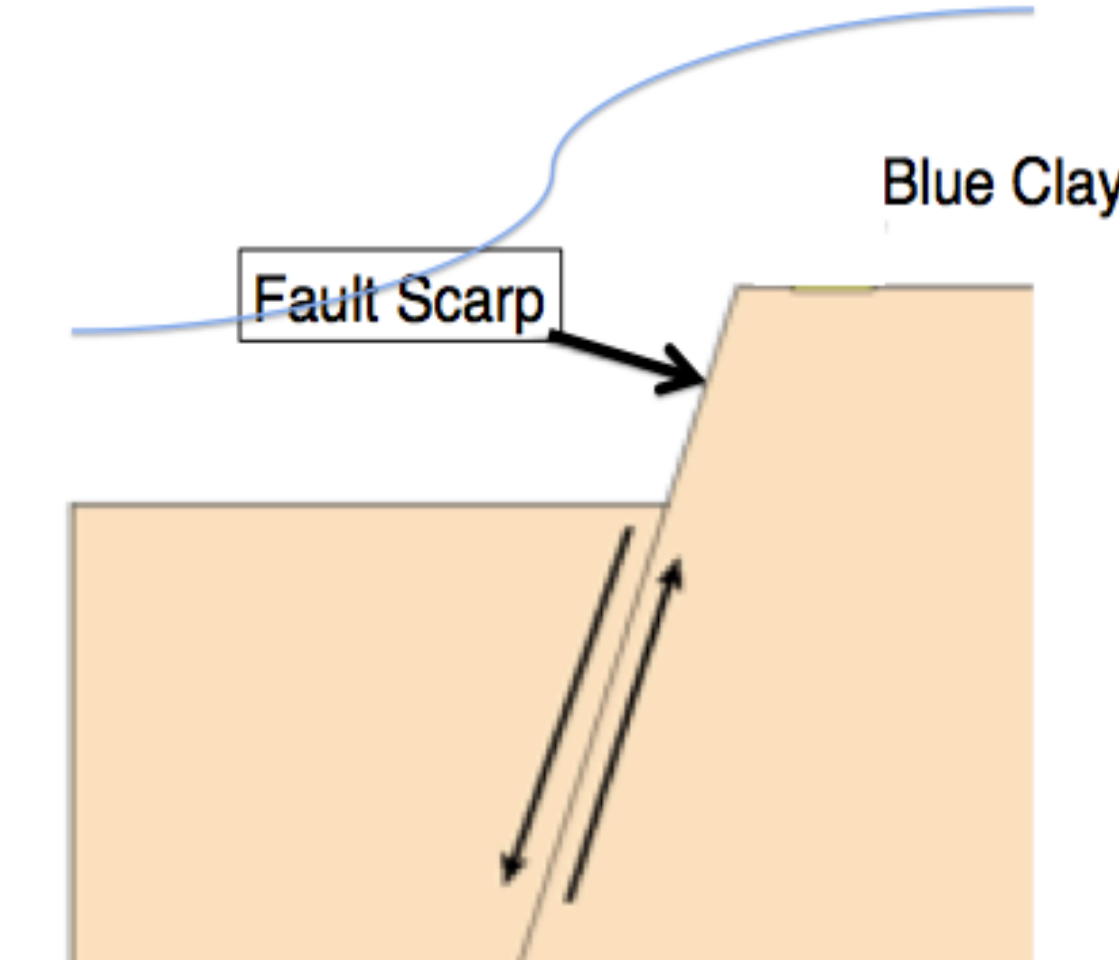


Figure 7: Cross section of the whole profile of Antelope Springs

- Slope gradient of BCL=
 - 1.3° across the whole profile
 - 1.8° from 0-1400 m
- Slope gradient of sand and grey clay layer=
 - Average of .71° across the whole profile
 - Average of .45° from 0-1200 m

- The orientation of the BCL in **Figure 8** is similar to the cross section.
- The BCL is constant, but the fault is a partial barrier to groundwater flow.
- Confined aquifer water level may decrease over time.



Interpretation

- Discontinuity in the cross section
 - The extent of the BCL in the cross section= to the BCL in Isostatic Residual Gravity Graph from previous studies
 - The discontinuity of the BCL is indicative of the lake's prehistoric shoreline
 - Further investigation would be beneficial to understand the hydrological framework.
- Anomalous 50 m decrease in the depth of the BCL
 - The degree of the slope indicates potential faulting
 - Fault is possibly older than the superimposing layers
 - Normal-fault scarping may have occurred
 - Frequent transgression and regression of lake effected the depth of the BCL
- Concerns for future studies:
 - How much does the fault offset?
 - Groundwater can influence potential faulting
 - The effect a normal-fault scarp can have on the confine aquifer
 - Fluctuation of the depth in the grey clay layer

Conclusions

With the use of Transient Electromagnetic soundings, there are indications that fault activity has influenced the heterogeneities that were developed in the blue clay unit. A discontinuity in the blue clay unit was not indicated from the 2011 cross section of Antelope Springs, but further investigation on where the blue clay terminates in the 2010 cross section would be beneficial towards obtaining more knowledge about the hydrology of the area. Concerning the hydrology of the 2011 profile, the blue clay unit is consistently distributed across the profile with an anomalous 50 m increase in depth towards the edge of the basin; thus, the confined aquifers' recharge is not a troublesome factor in Antelope Springs.

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