SAND2009-7334C

Calibration of the WIPP Culebra Transmissivity Fields

The PEST Conference

November 3rd, 2009, Bethesda, MD

David B. Hart[1], Sean A. McKenna[2], Richard L. Beauheim[3]

Nuclear Energy and Global Security Technologies Center,

Sandia National Laboratories

[1,2]Geoscience Research and Applications, PO Box 5800, MS 0751, Albuquerque, NM, 87185-0751

[1]dbhart@sandia.gov, [2]samcken@sandia.gov

[3]Carlsbad Programs Group, 4100 National Parks Highway, Carlsbad, NM, 88220

[3]rlbeauh@sandia.gov

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-95AL85000. This research is funded by WIPP programs administered by the Office of Environmental Management (EM) of the U.S. Department of Energy.

Introduction

- The Waste Isolation Pilot Plant (WIPP) is the only permanent nuclear waste storage facility operating in the US, and recertification is required every five years
- The Culebra Dolomite is the most hydraulically transmissive layer near the WIPP site, and a calibrated flow model for the Culebra is used for transport calculations that are part of the recertification process

Sandia National Laboratories

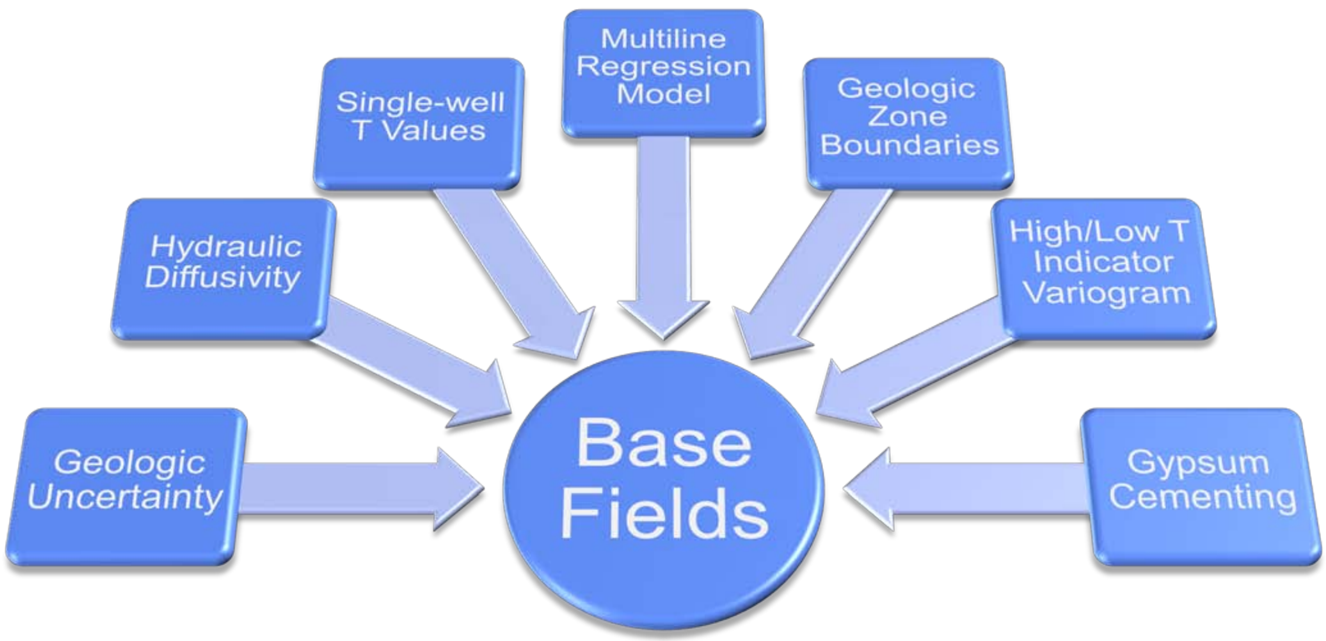
Overview

The calibration process for the Culebra transmissivity fields uses PEST, MODFLOW, and utility software to create at least 100 calibrated fields

Sandia National Laboratories

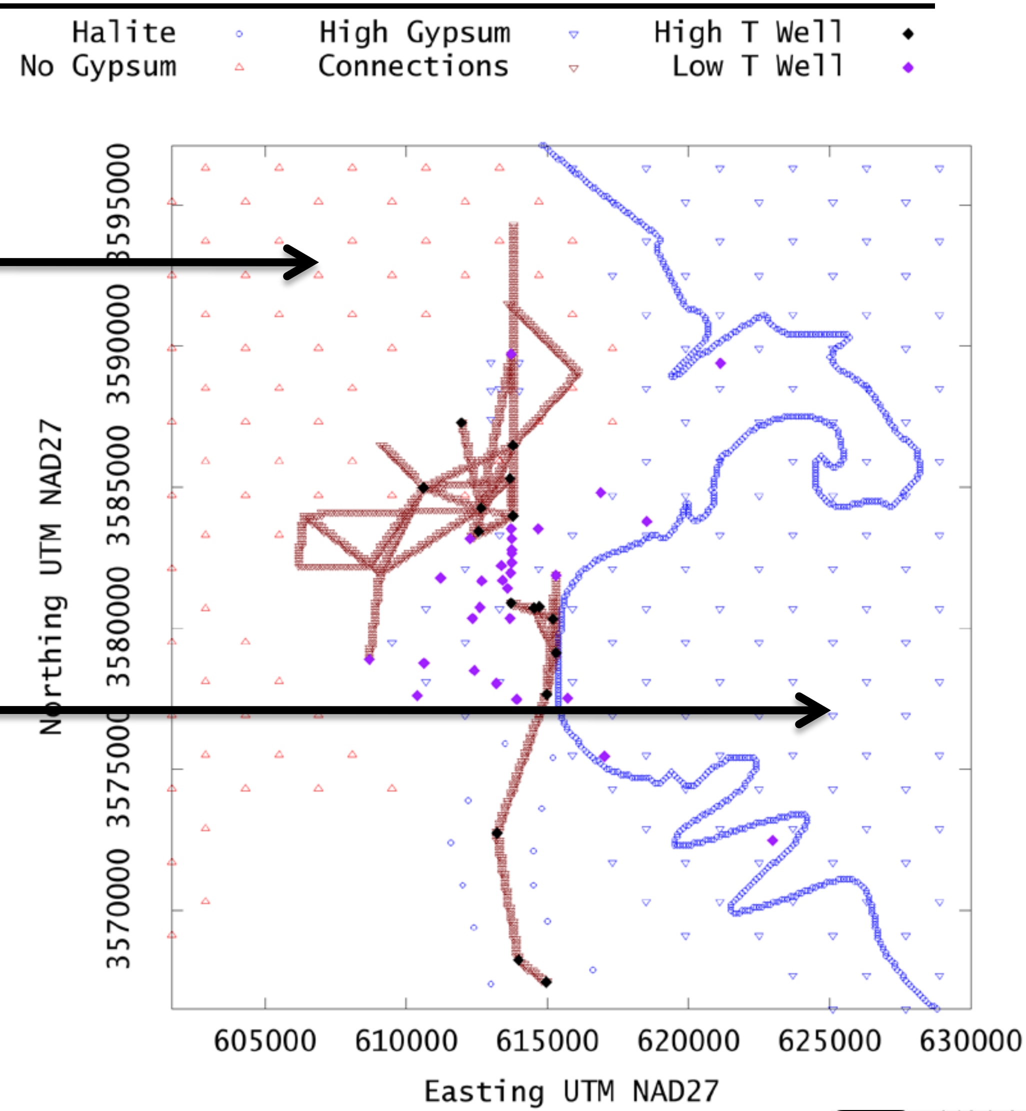
Conceptual Model

- **A complex geologic conceptual model has been developed for the Culebra, with both qualitative and quantitative elements that must be combined and honored when creating the initial base fields**



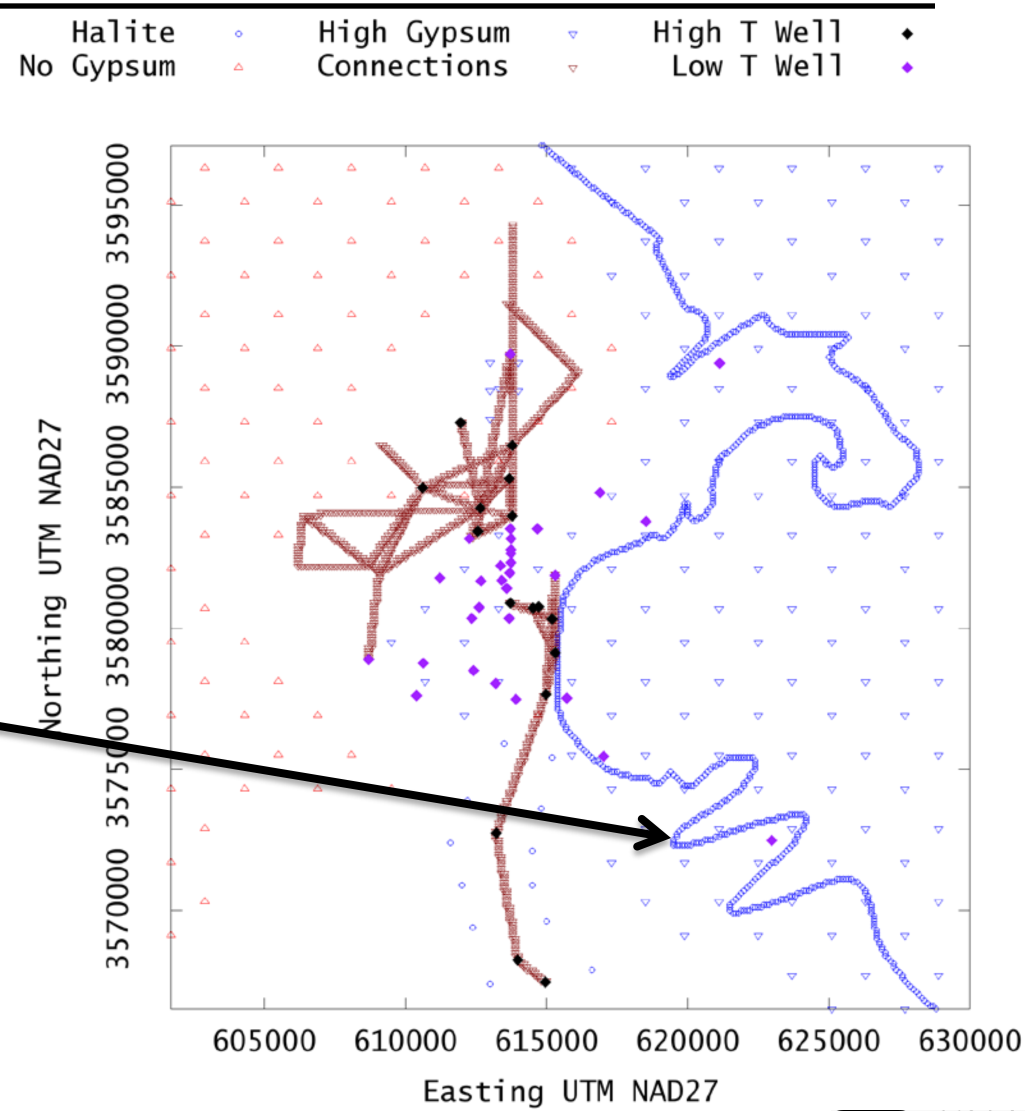
Soft Data Points

- High gypsum and no gypsum areas were gridded, and contributed a 95% likelihood that a nearby point would be low or high T, respectively



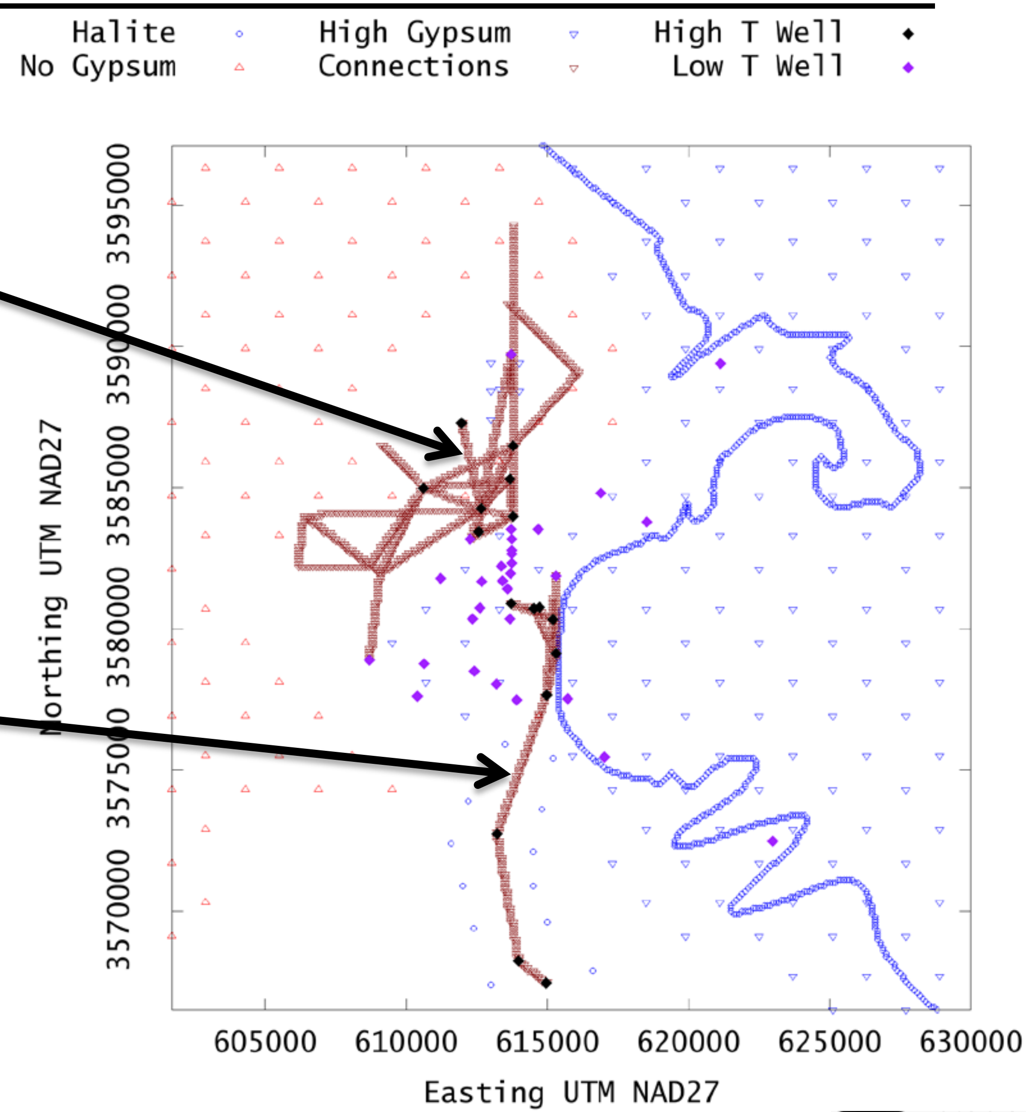
Soft Data Points (2)

- Culebra T is low when halite is present in the units above and below, so the halite margins were added as 100% likelihood of being low T in order to keep high T from crossing the boundary



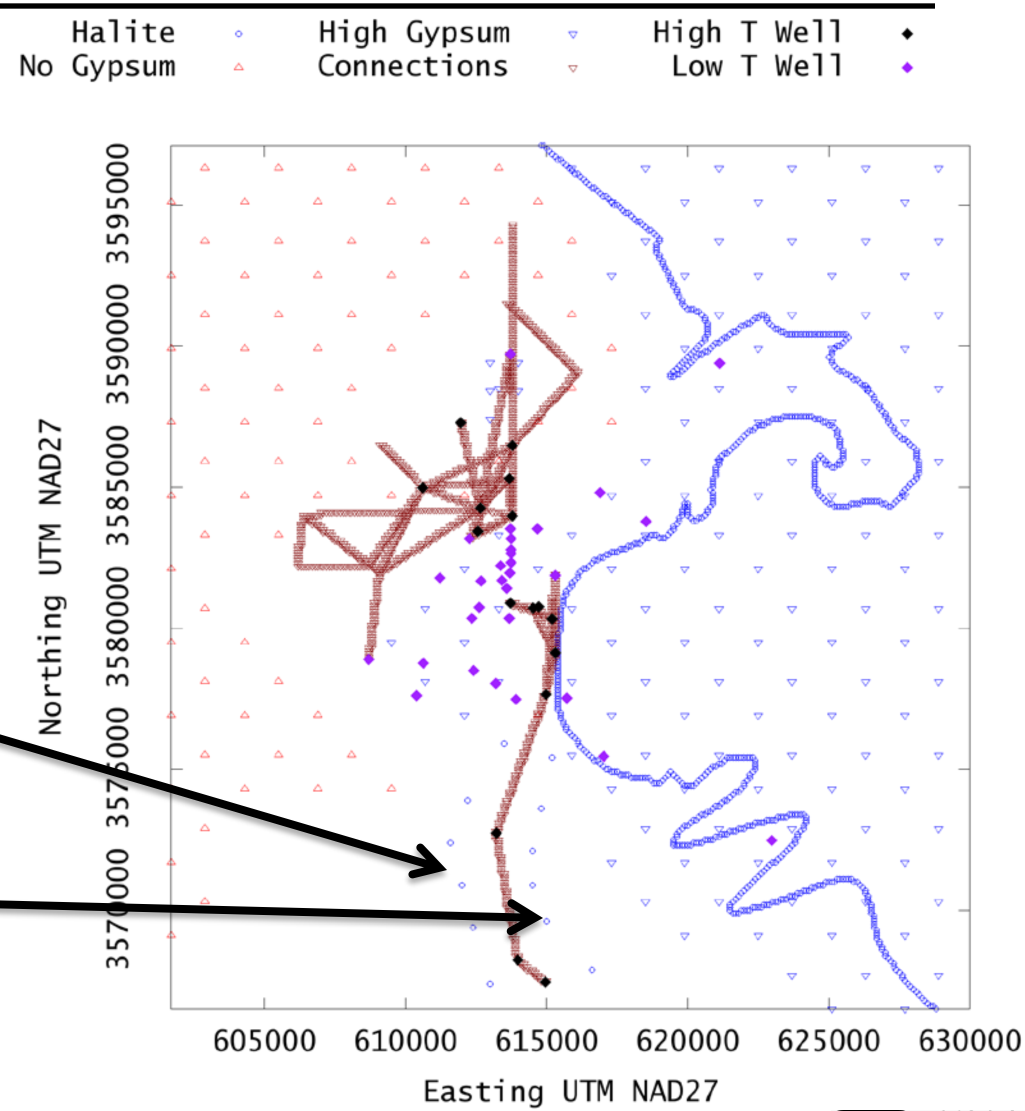
Soft Data Points (3)

- **The high diffusivity connections were added with a 75% likelihood of influencing a nearby cell to be high T**



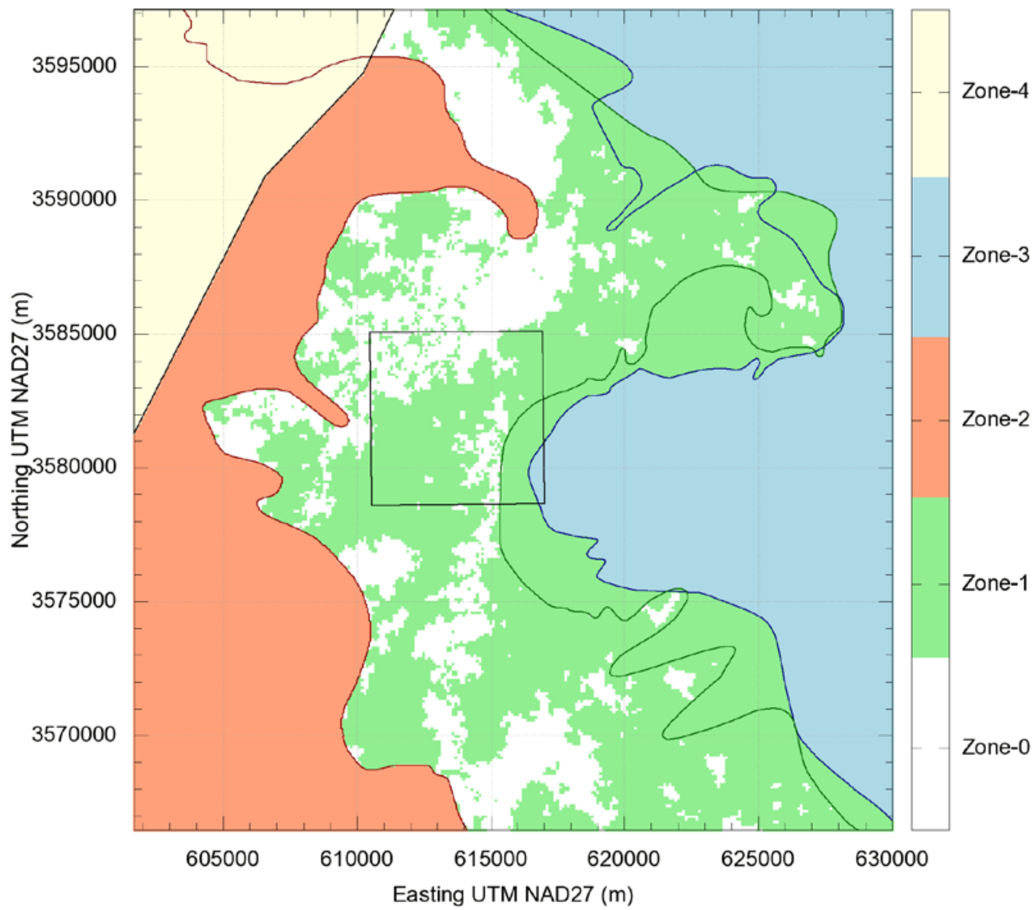
Soft Data Points (4)

- The responses between SNL-14, SNL-12 and H-9 were difficult for MODFLOW to match, so additional low-T soft indicators were added to create the surmised channel effect



Final Base T-Fields

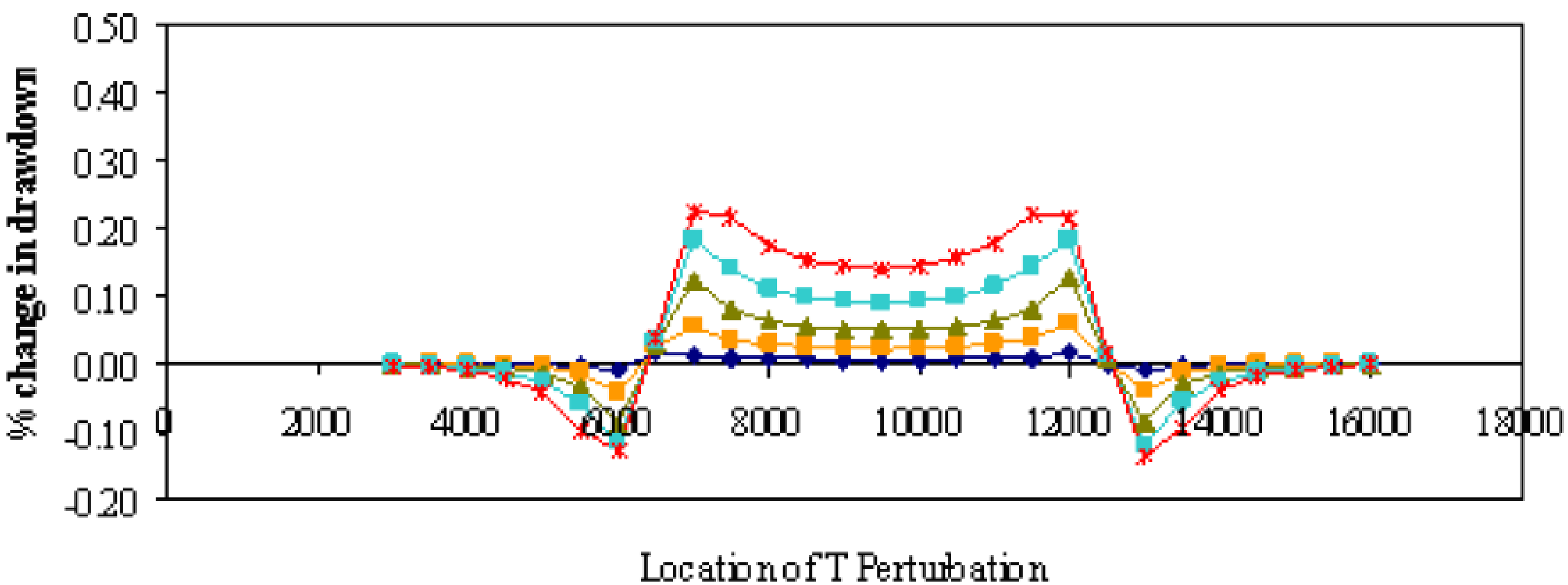
- After SISIM generated the stochastic zones for the center of the model domain, the Salado dissolution zone and the very low T halite-sandwiched zone were added in using a cookie-cutter method.
- The four zones (0-3) could then be combined with the Culebra overburden map to obtain a T value at every cell by using the regression equation for T
- Zone 4 is an area of inactive cells



Sandia National Laboratories

Pilot Points

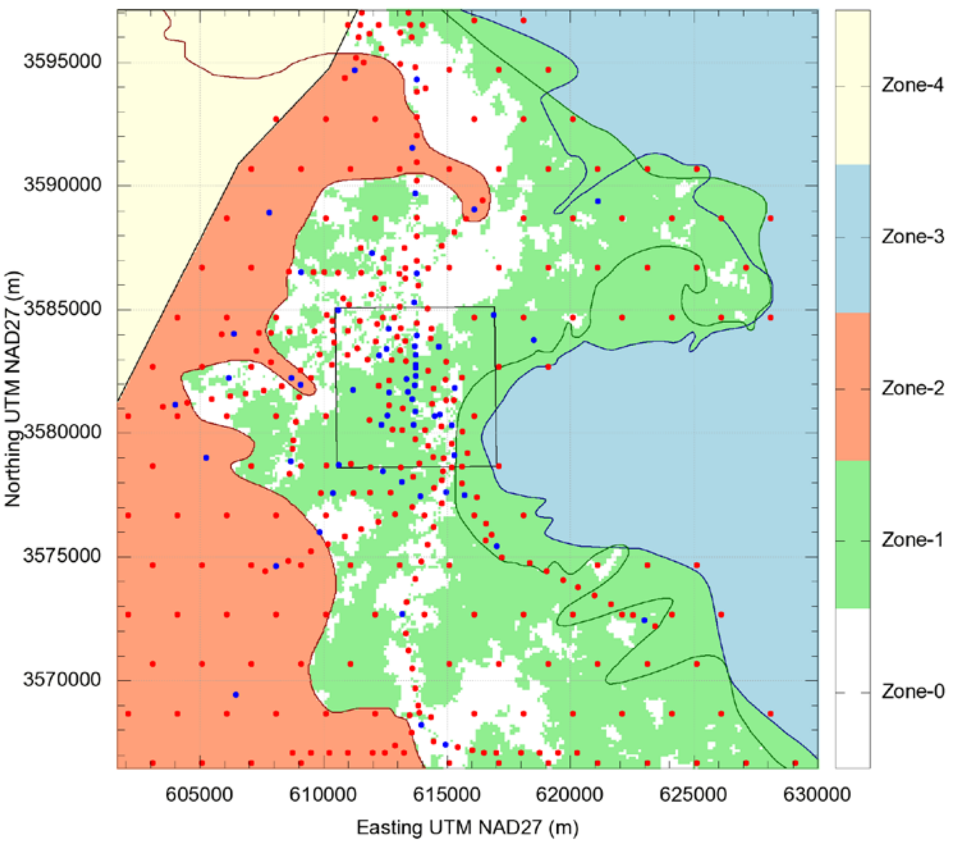
- Previous calibration used 99 pilot points operating only on transmissivity
- Placement of the points has a significant impact on their effect
- SVD assist allowed more points to be considered



Pilot Point Locations

- **Pilot points have most impact on T when placed ~500 m away from the pumping and observation wells**
  - **Allows fixed known values at the wells while maintaining ability to make significant changes to the transmissivity field nearby**
- **Additional points placed along connected paths between pumping and observation wells**
- **Gridded pilot points placed in the background to fill in remaining area**

Transmissivity Points

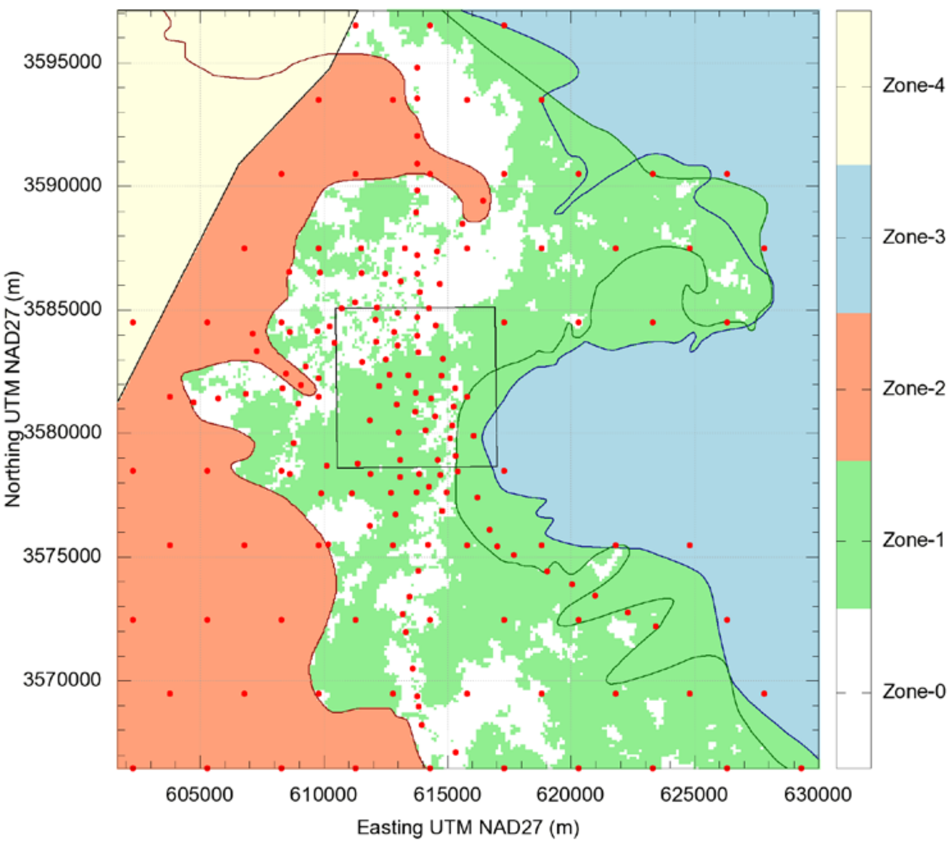


Sandia National Laboratories

Pilot Point Locations (2)

- **Pilot points have most impact on T when placed ~500 m away from the pumping and observation wells**
  - **Allows fixed known values at the wells while maintaining ability to make significant changes to the transmissivity field nearby**
- **Additional points placed along connected paths between pumping and observation wells**
- **Gridded pilot points placed in the background to fill in remaining area**

Horizontal Anisotropy Points

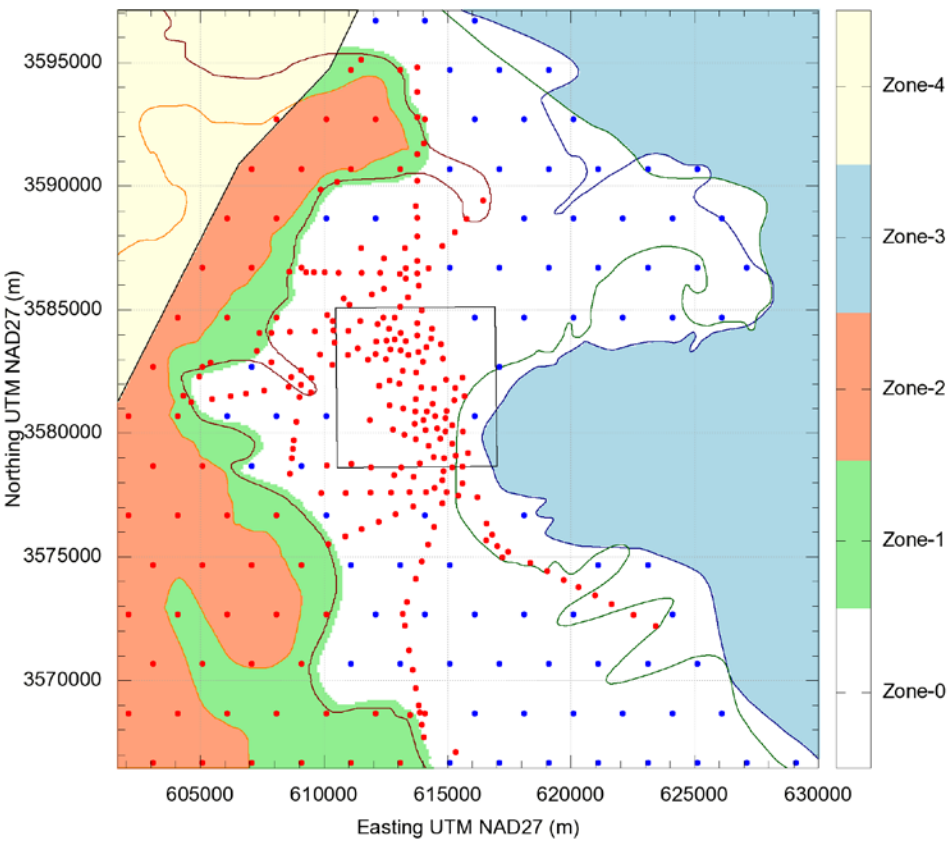


Sandia National Laboratories

Pilot Point Locations (3)

- **Pilot points have most impact on T when placed ~500 m away from the pumping and observation wells**
  - **Allows fixed known values at the wells while maintaining ability to make significant changes to the transmissivity field nearby**
- **Additional points placed along connected paths between pumping and observation wells**
- **Gridded pilot points placed in the background to fill in remaining area**

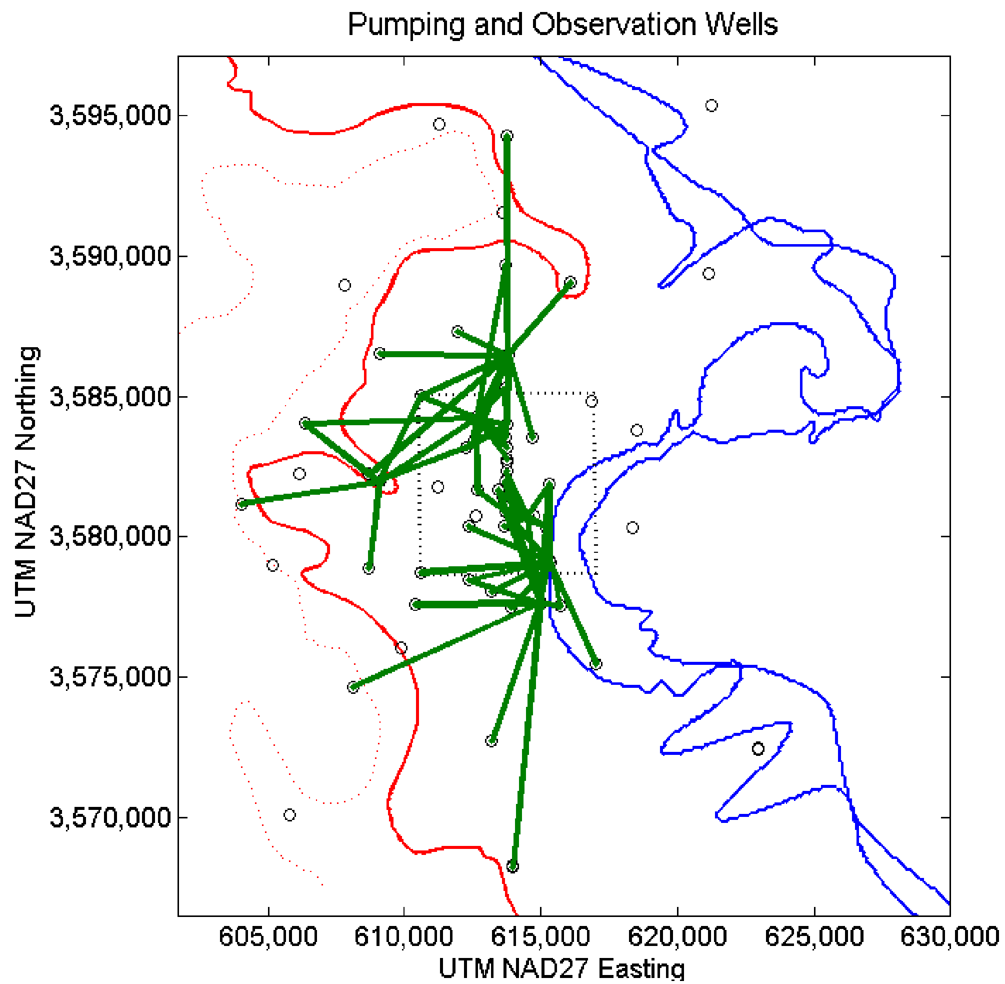
Storativity Points



Sandia National Laboratories

MODFLOW Forward Model

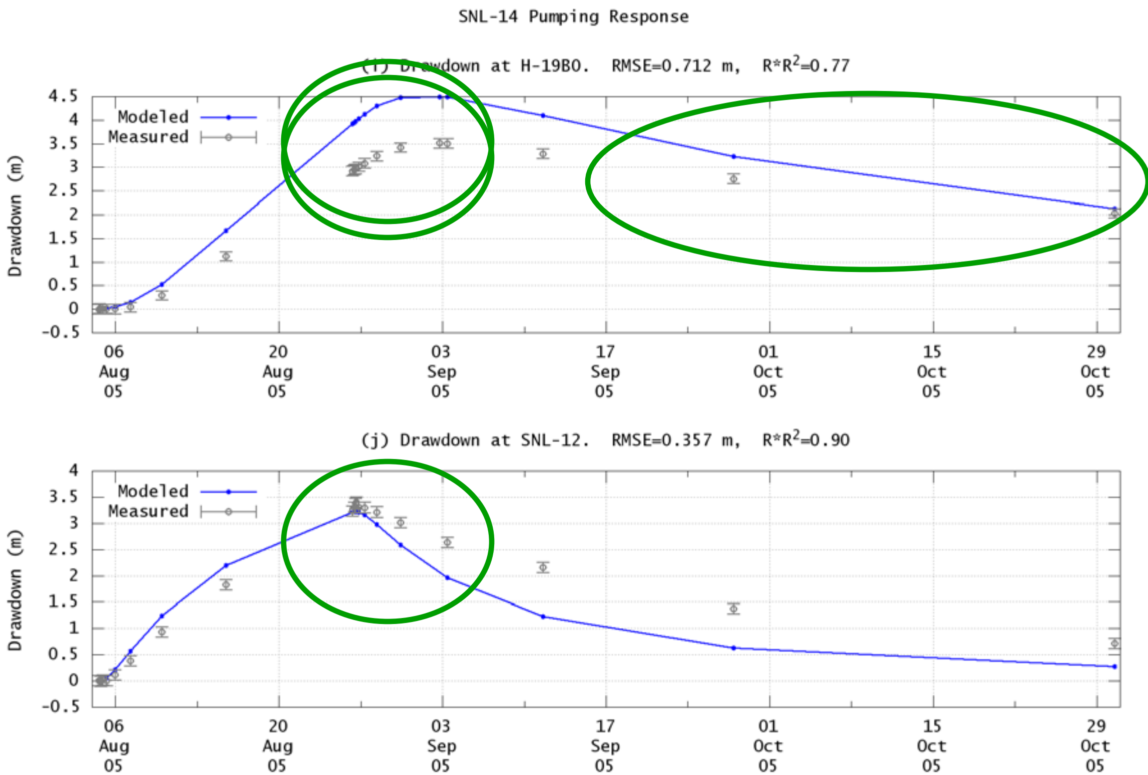
- 9 transient pumping tests were selected for use in the calibration process, with a total of 65 pumping/ observation well pairs
- Pumping time plus recovery ranged from two months to 18 months
- Freshwater head data from 2007 were used to calibrate the steady-state water levels



Sandia National Laboratories

Handling Pumping Tests

- It is a challenge to use a single fixed-interval time discretization and capture details of all responses
  - Different responses peak at different times, which don't always line up with stress periods
  - Logarithmic timing solves part of problem by placing observations with higher density at stress period changes
- Point-by-point error calculation is misleading because the most significant errors may be at only a few points
  - Solved by using both the point-by-point error calculations and by calculating the area between the two curves



Sandia National Laboratories

PEST Configuration

- PEST 9.11 was used, with SVD assist capabilities
- 1200 to 1300 parameters were used, automatically selected based on pilot point locations and the base field zones
- 1380 observations, transient and steady state
- SVD assist selected between 100 and 200 super-parameters from the Jacobian

Computation

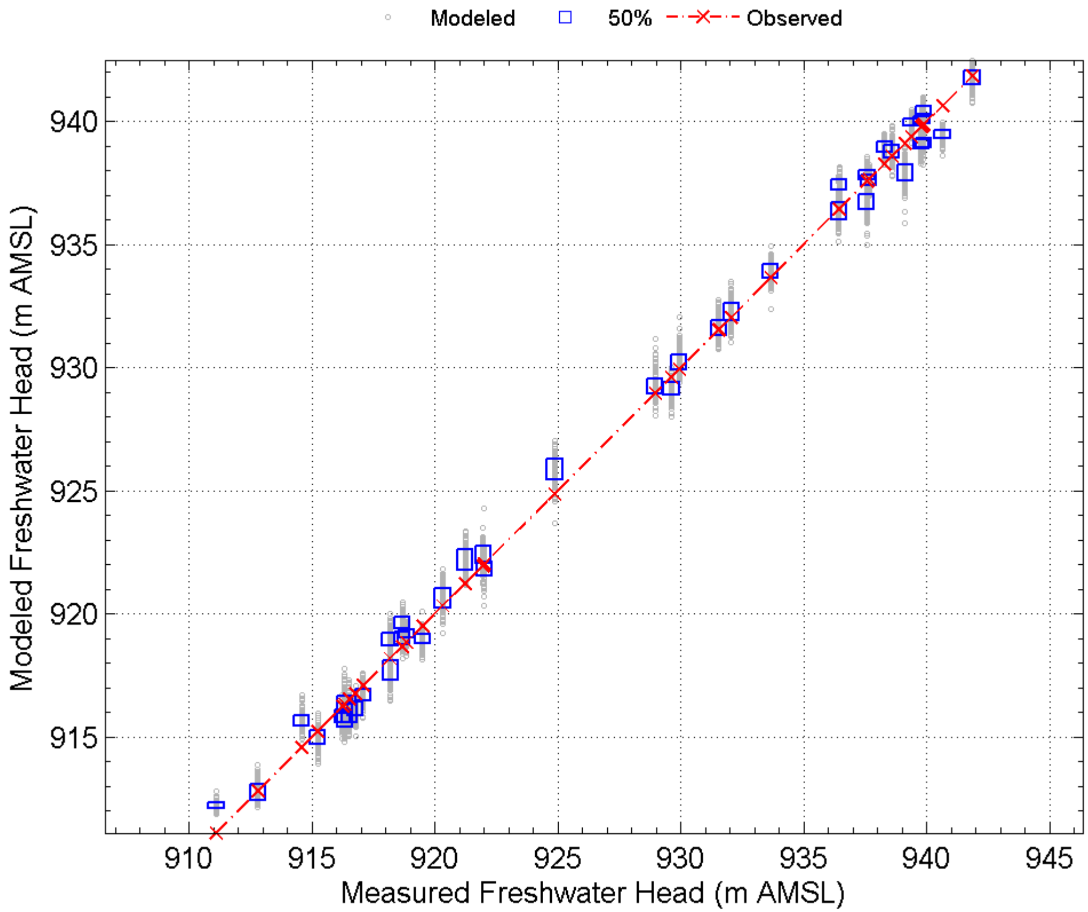
- Calibration was performed on 200 of the 1000 base fields
  - First 100 fields were selected using the fields that best fit SNL-14 pumping test pre-calibration
  - Second hundred were just in order of generation
  - No statistically significant difference in results between the two sets
- 2 Linux clusters with a total of 80 processor cores were used

Total calibration time for a single field: 7 days on 6 PCs

Total calibration time: ~250,000 processor hours / 6 mo.

Steady-State Results

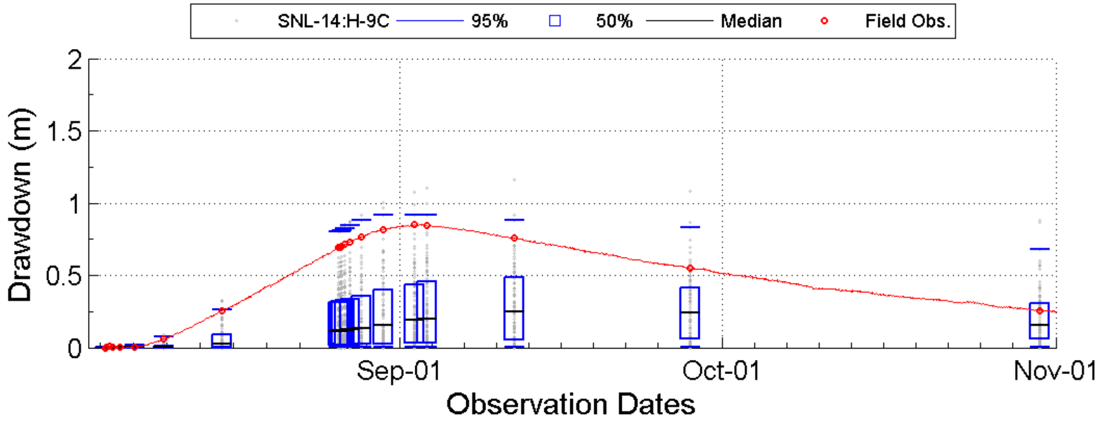
Steady-state head errors reduced to 0.7 m average from over 3 m

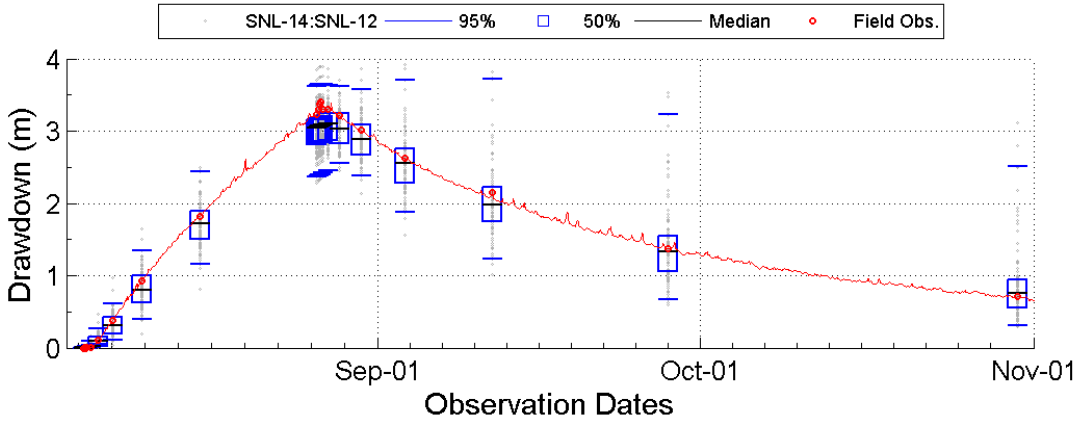


Sandia National Laboratories

Transient Results

Transient observation errors reduced to an average of 0.15 m

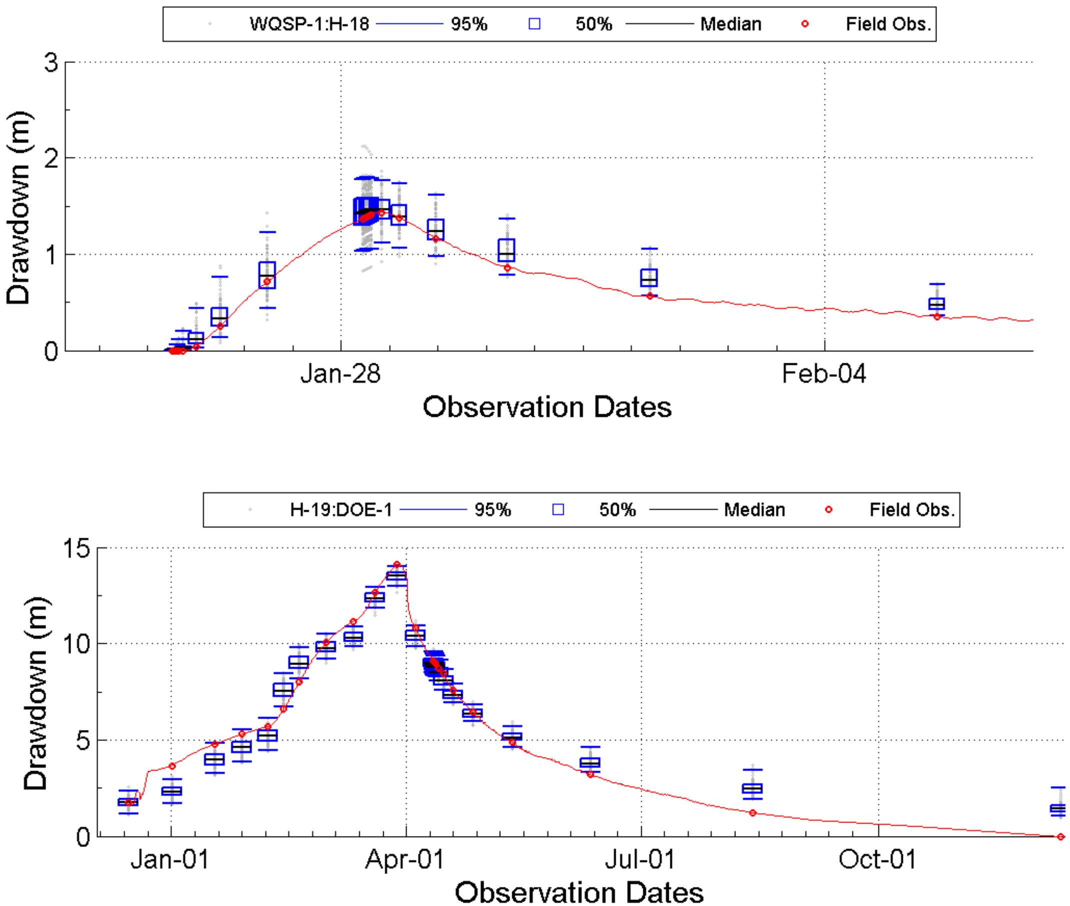




Sandia National Laboratories

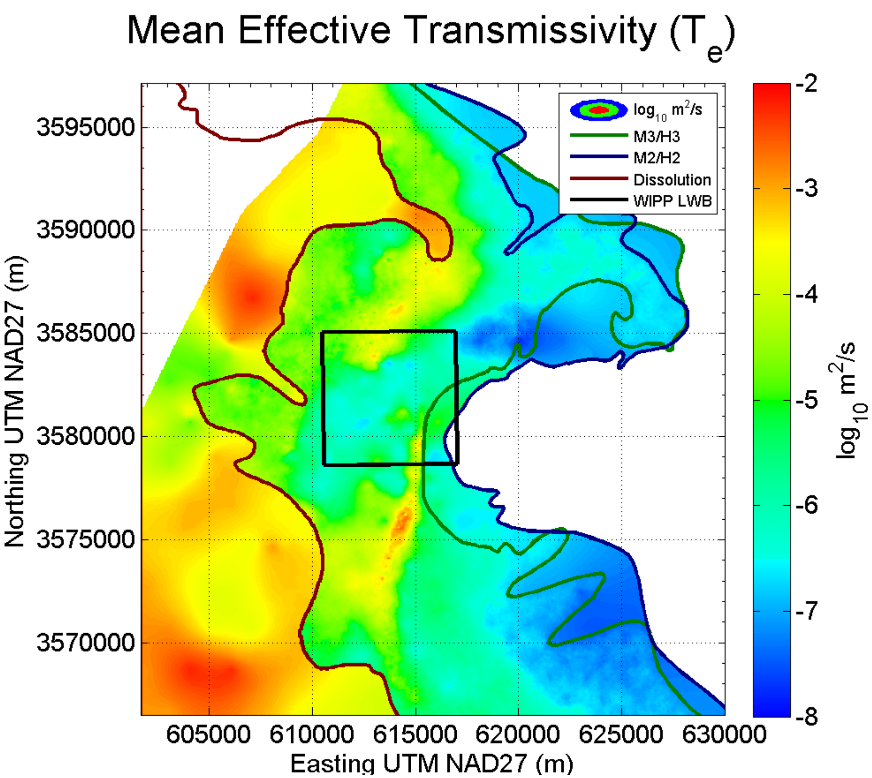
Transient Results (2)

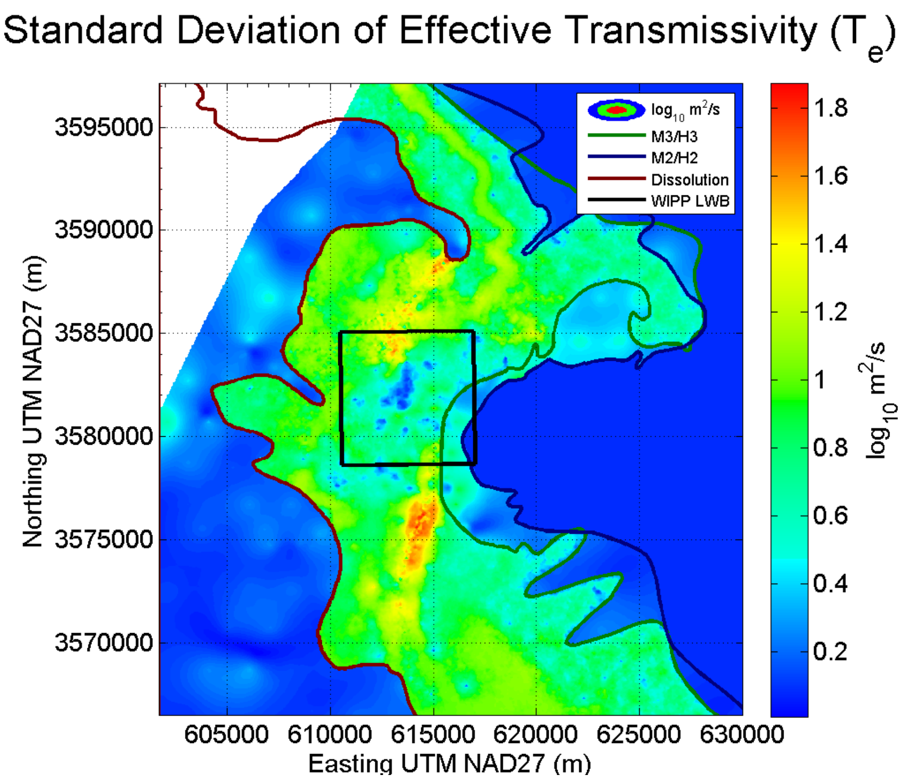
Transient observation errors reduced to an average of 0.15 m



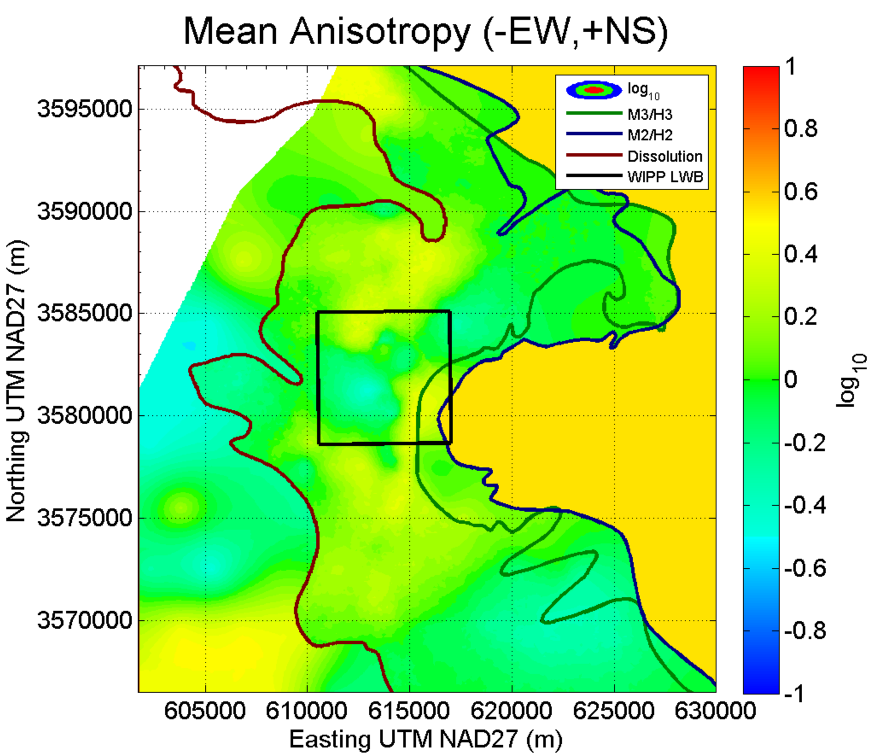
Sandia National Laboratories

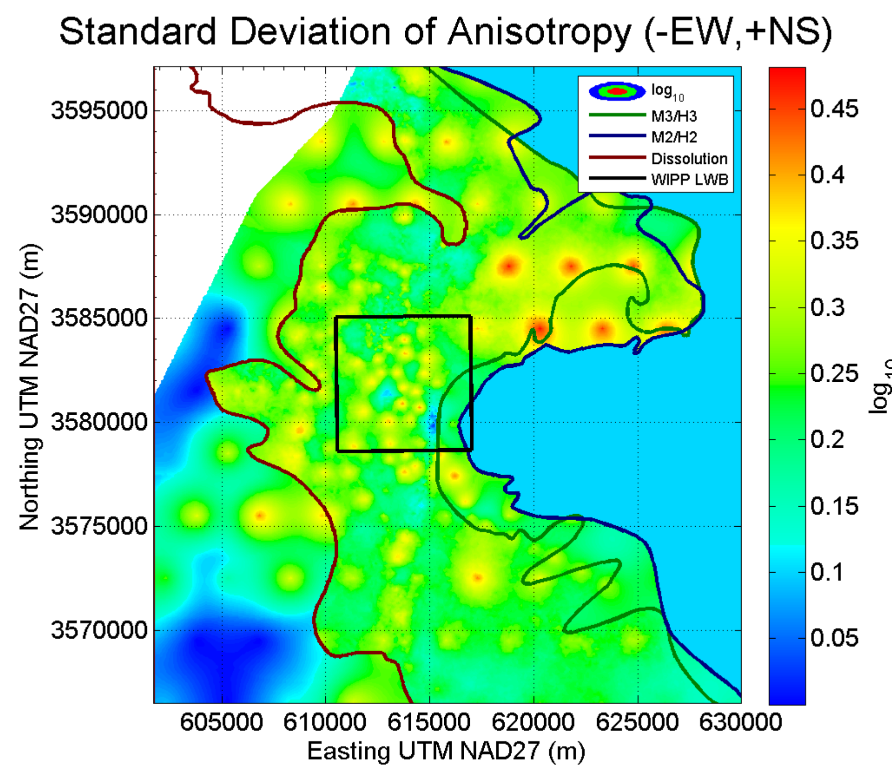
Results—Effective T



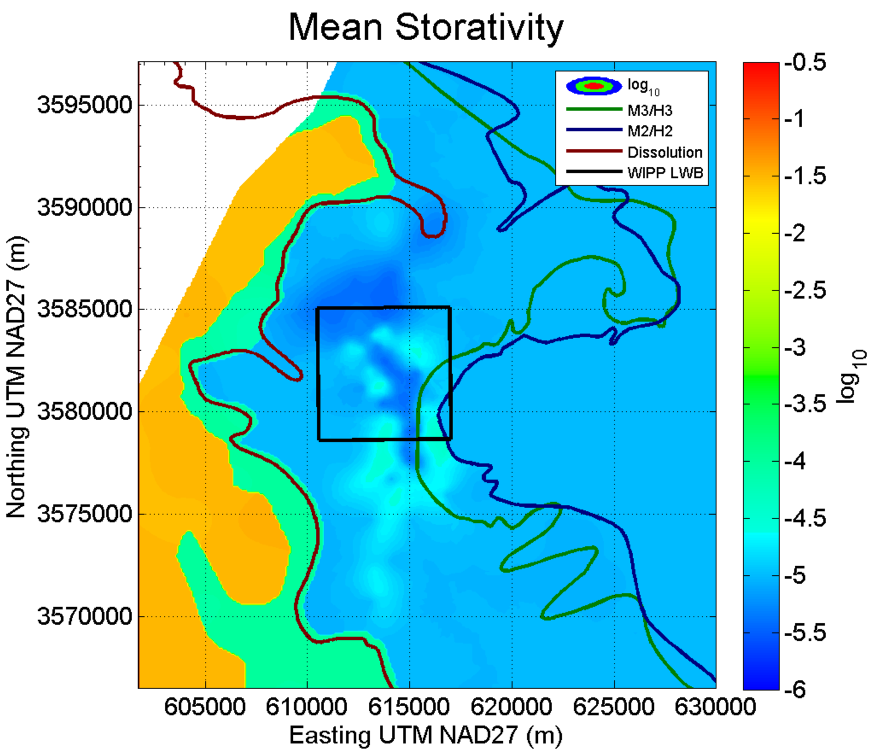


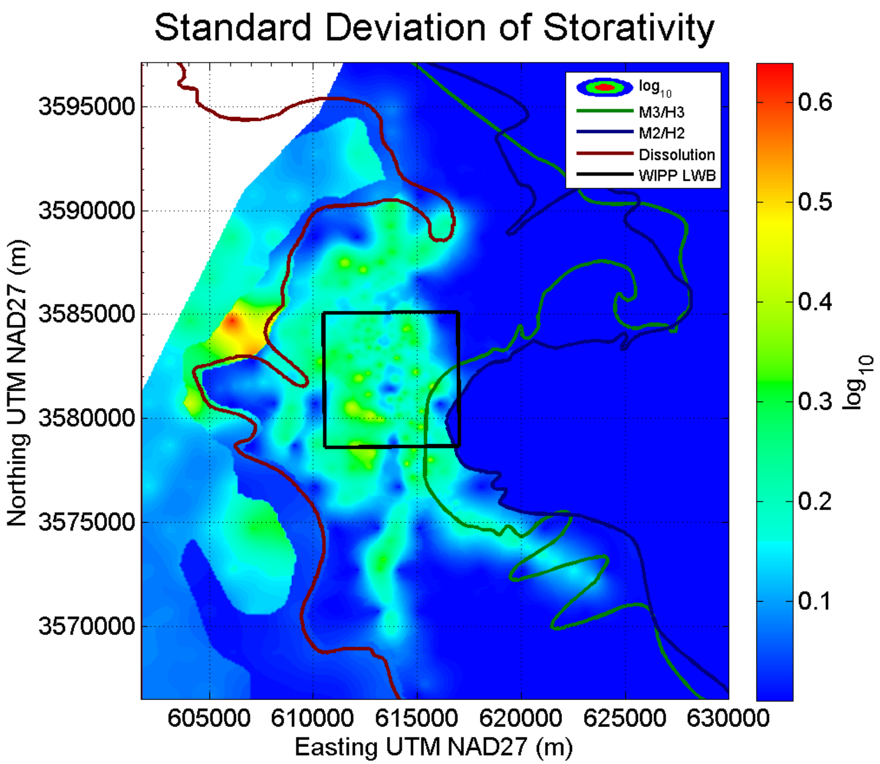
Results—Anisotropy





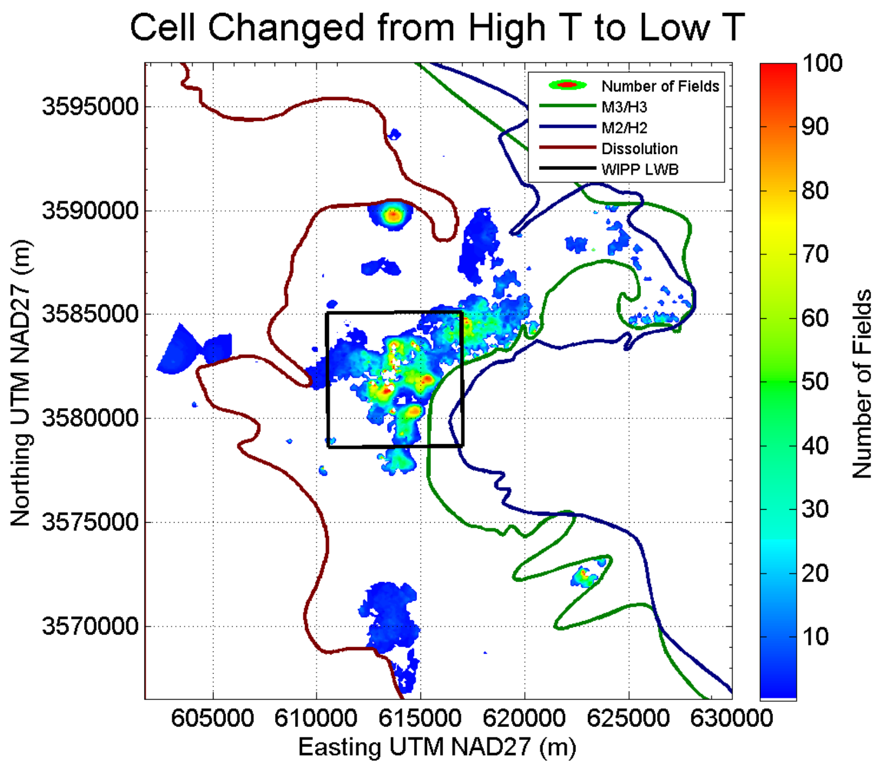
Results—Storativity

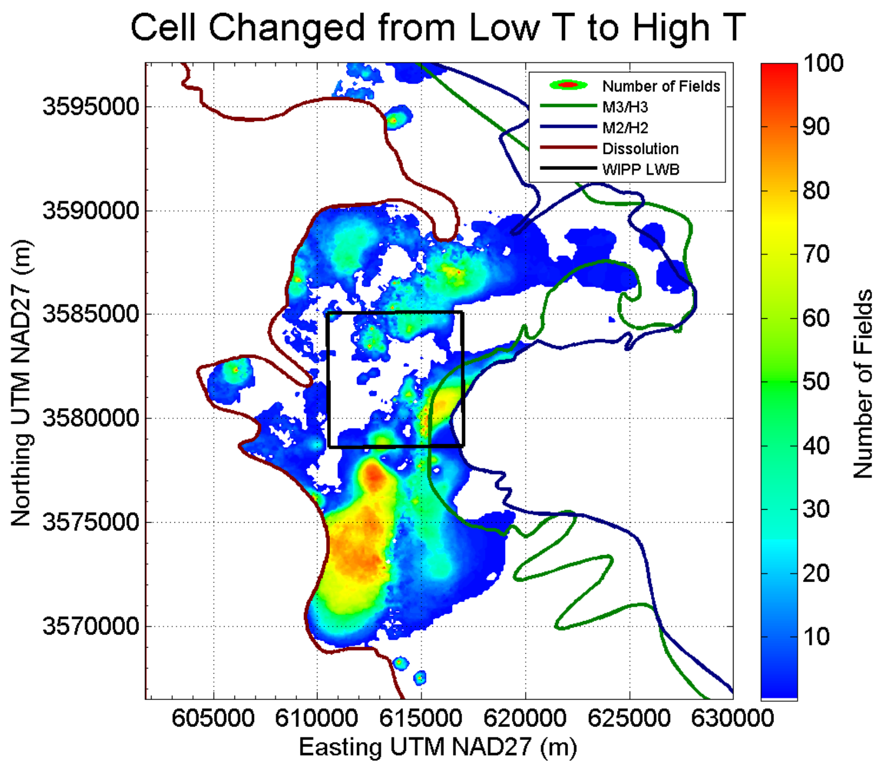




Sandia National Laboratories

Results—T Changes





Sandia National Laboratories

Conclusions

- This study demonstrates the construction of a stochastic ensemble for simultaneously calibrated T, A, and S fields
  - Incorporate prior knowledge from quantitative and qualitative conceptual models
  - Possible due to PEST's flexible zone definitions, pilot point relationships, and SVD-Assist computation expense reductions
- The parameterization is of high enough dimensionality that fine-scale features can be recovered by the estimation

Sandia National Laboratories