MODELING AND PARAMETER SENSITIVITY OF MINE POOL FORMATION IN THE MEIGS MINE OHIO

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Introduction

- **The development and release of mine drainage and formation of mine pools in decommissioned coal mines is an environmental problem for government regulators, mining companies and the communities.**

- **Acid Mine Drainage (AMD) is produced when sulfide minerals in rocks are subjected to oxidizing conditions.**

- **An area impacted by acid mine drainage experiences physical, chemical, and biological degradation.**

Introduction

- Mine pool formation depends on factors such as
  - recharge of water to the mine
  - geology
  - hydrostratigraphy
  - precipitation and infiltration
  - connectivity of the mine with other neighboring mines

- This research is part of a larger project that intends to produce a set of GIS based tools for the determination of the development of mine pools.

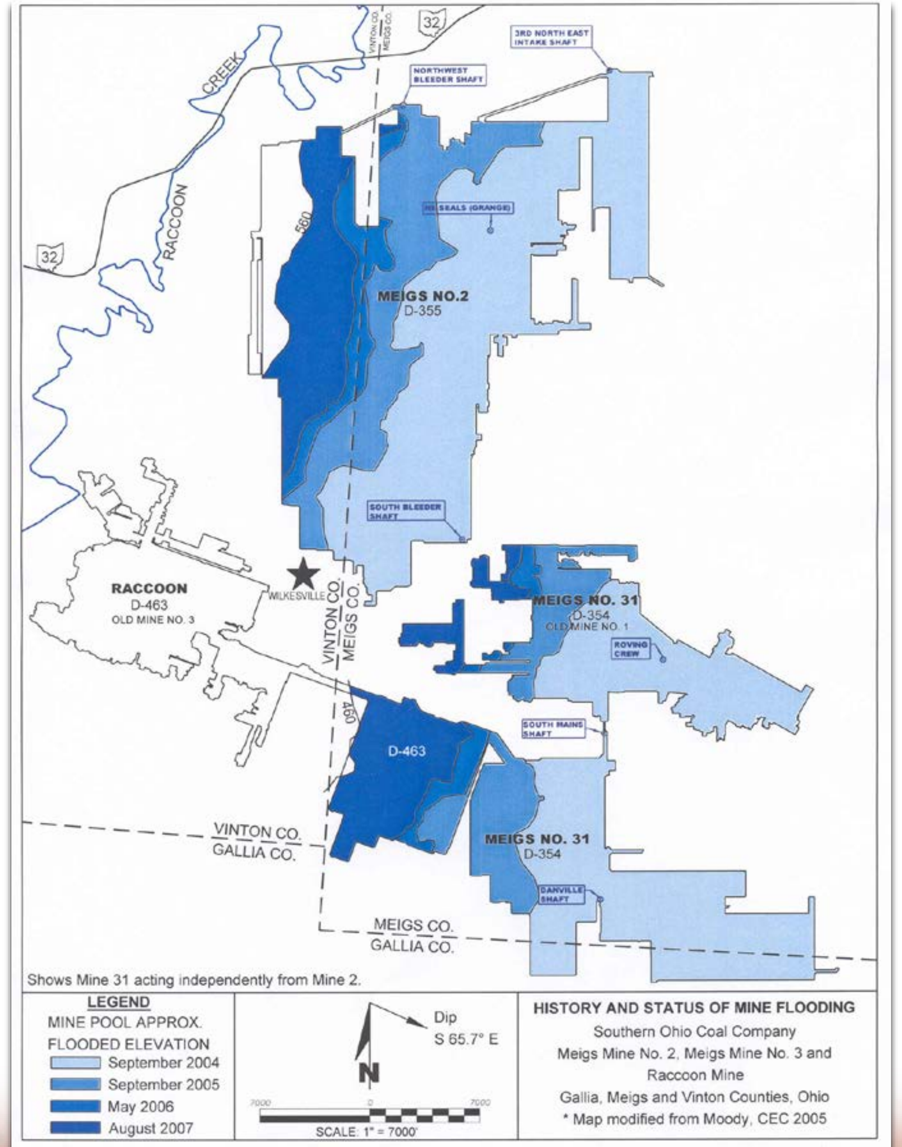
Objectives

Hydrologic modeling of a single mine complex:

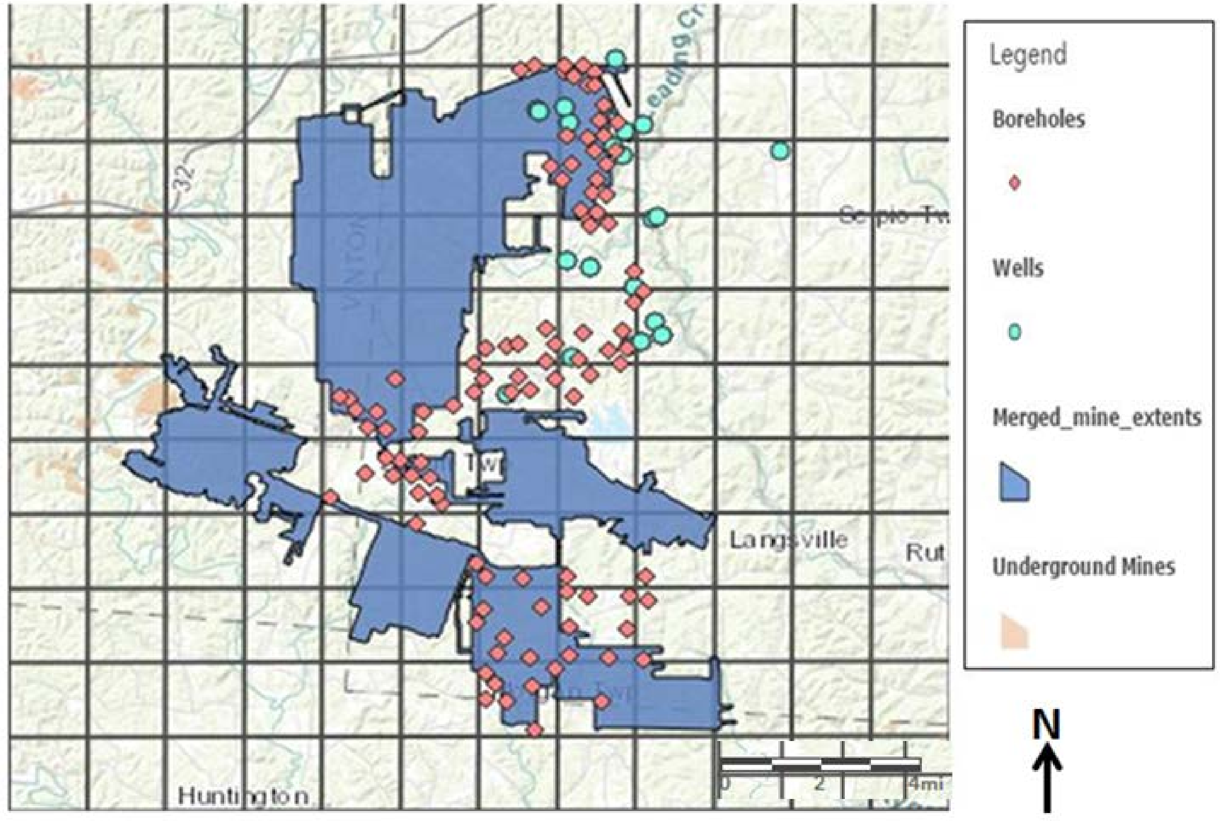
- **To investigate the flow regime of the mine and the response of the water levels in the mine after the mine is closed.**
- **To study the sensitivity of the Meigs Mine Complex hydrogeological parameters that determine the development of mine pools using MODFLOW.**

Hydrologic Modeling Case Study

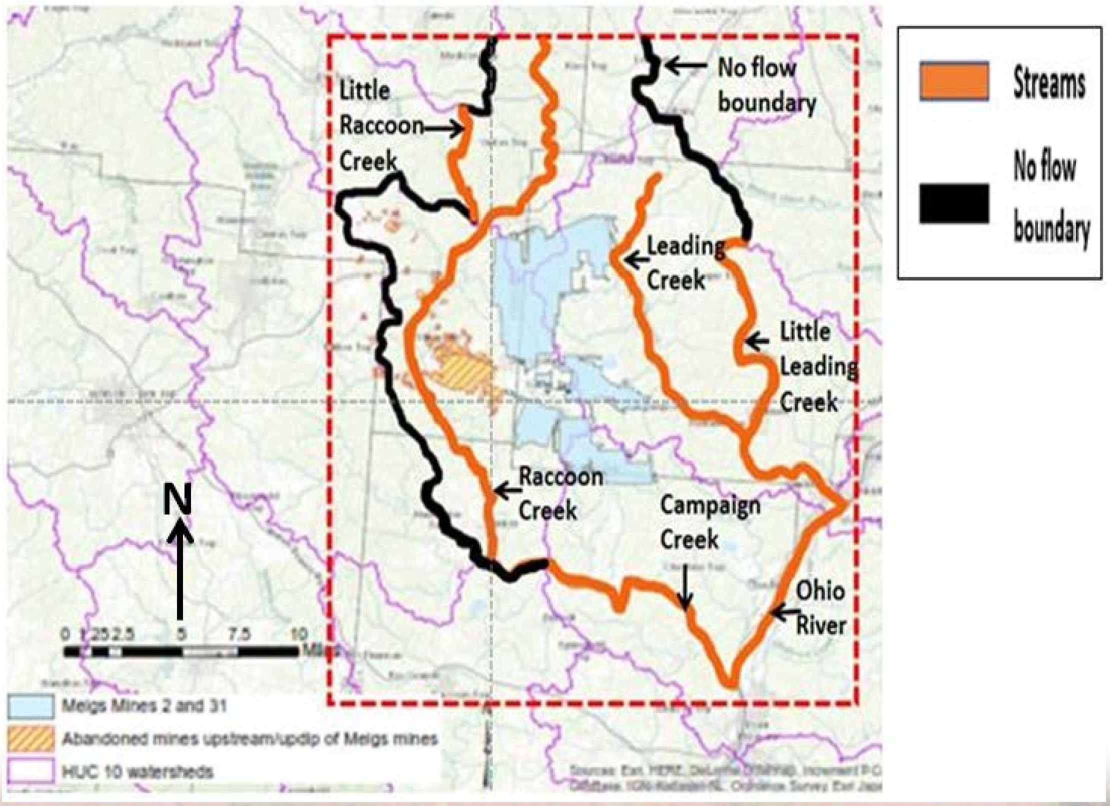
- **The Meigs Mine Complex is an example of a flooded underground mine which has been extensively monitored**



Meigs Mine Hydrologic Data



Hydrologic Model Boundary



Hydrogeological modeling

- **Contacts maps were generated out of the various calculated contact elevation of the boreholes and imported into MODFLOW for model building.**

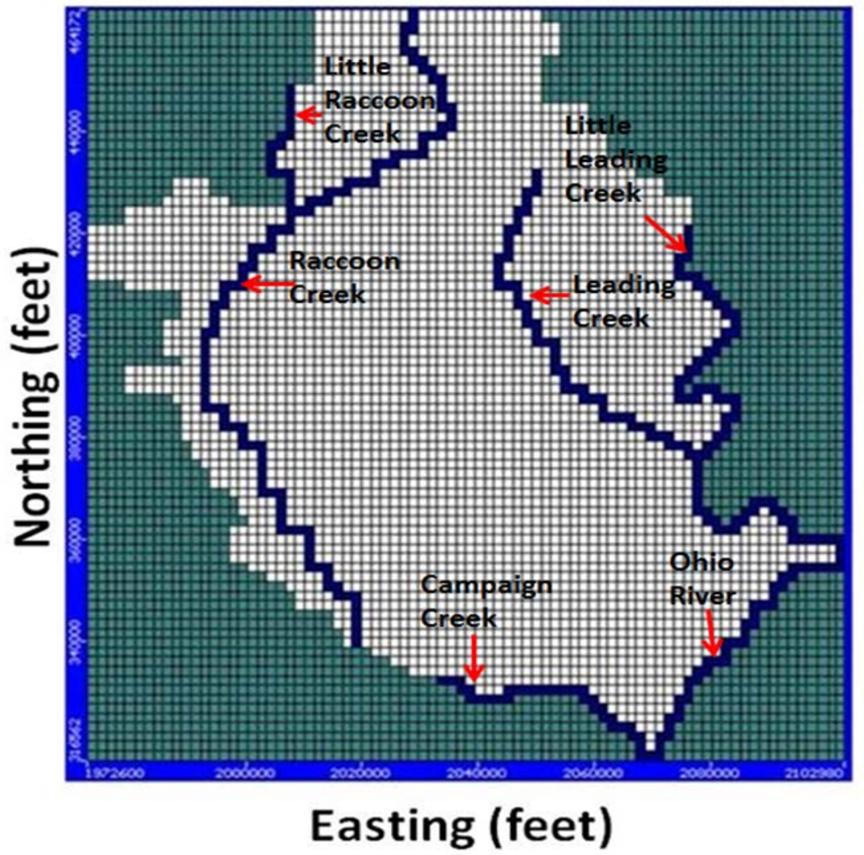
- **The mine area was gridded which created a total of 6,320 nodal points throughout the model.**

Aquifers

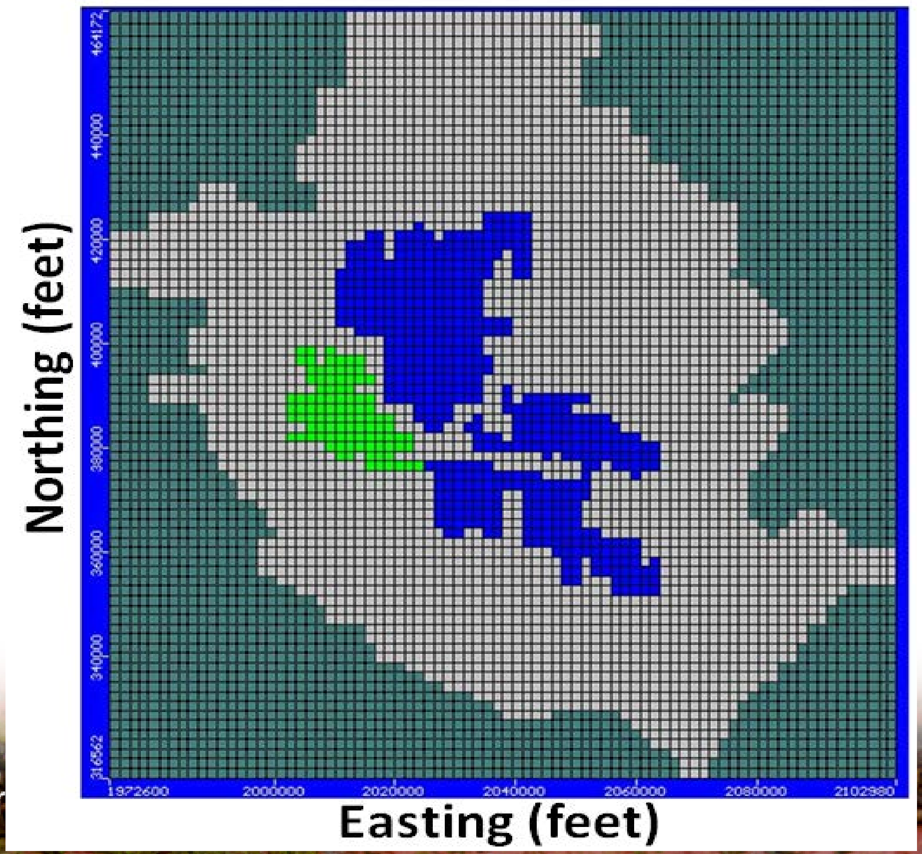
- **Maps of potentiometric elevation in the wells of each aquifer were constructed to determine the flow regime of the area.**
- **The sandstone aquifers were identified as zone A, zone B and zone C.**
- **These aquifers were identified in the cross-sectional view of the MODFLOW grid.**

Boundary conditions of the modeled area

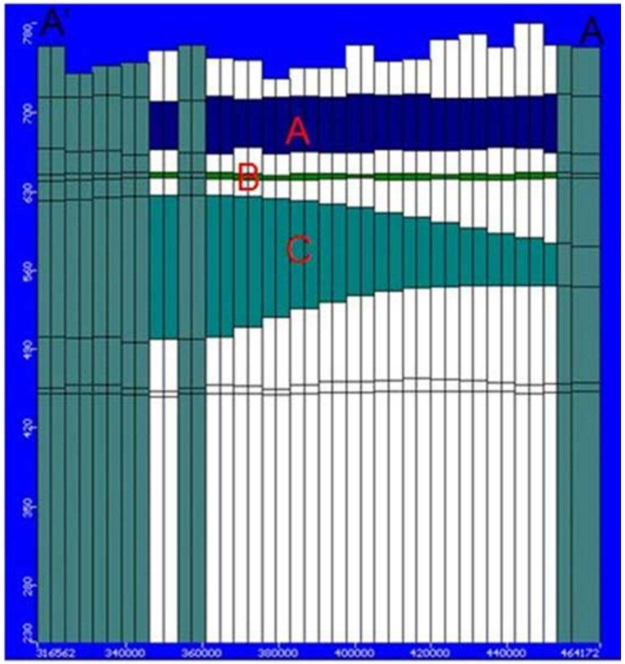
Layer 1 (shale)



Coal layer

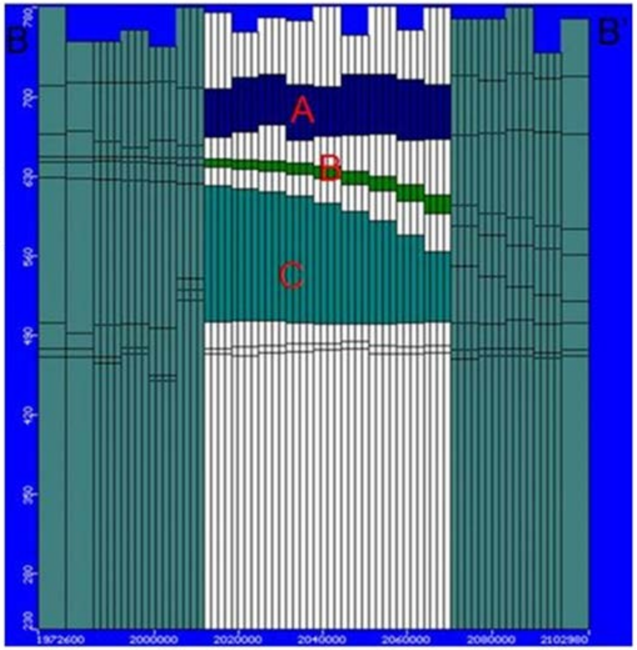


Cross-sectional view of aquifers



Elevation (feet)

Northing (feet)



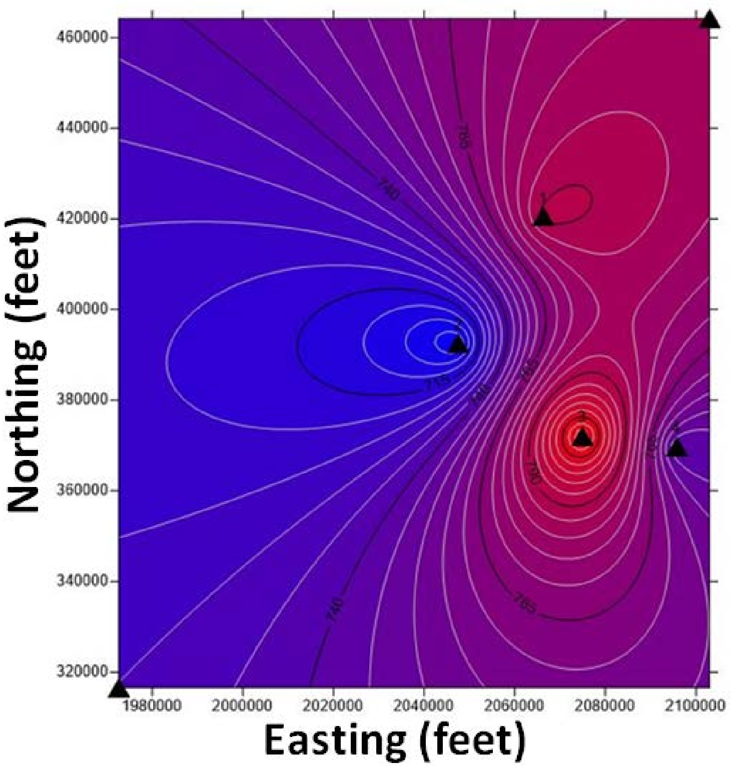
Elevation (feet)

Easting (feet)

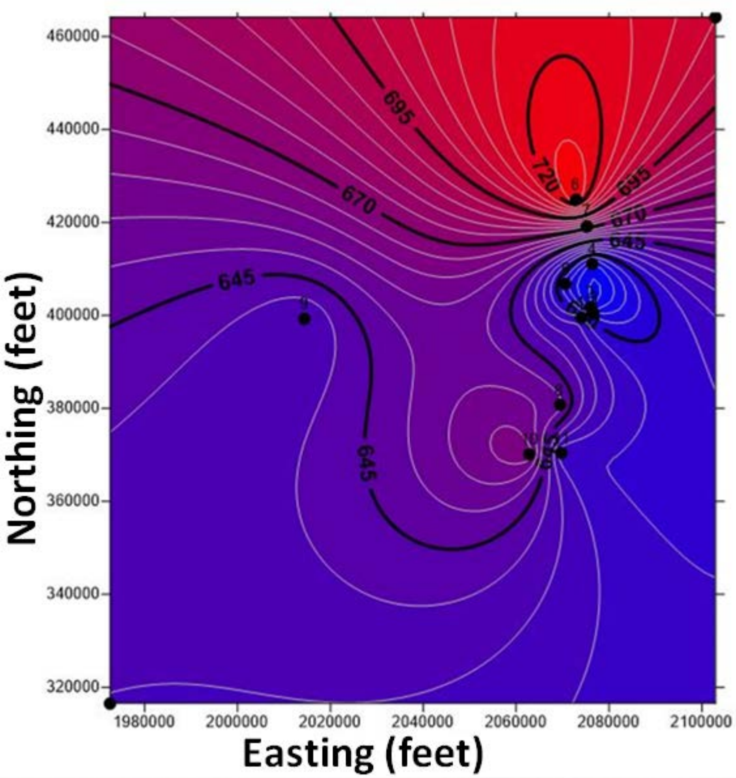
Cross sectional area map of the layers showing
 the aquifers in a South-North directions

Cross sectional area map of the layers showing
 the aquifers in a East-West directions

Potentiometric Head Maps

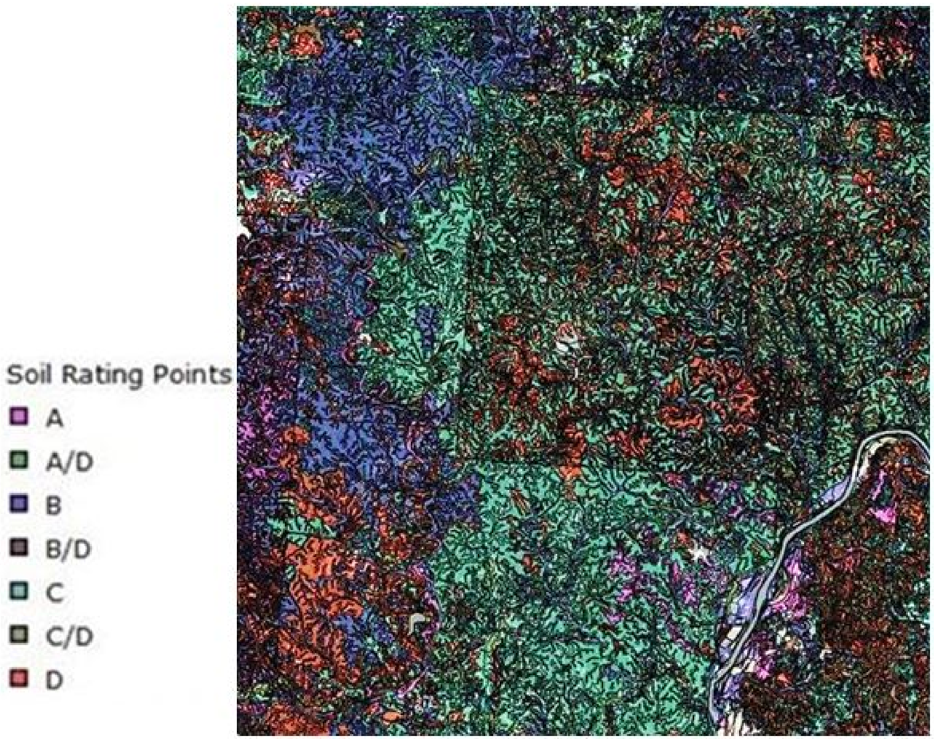


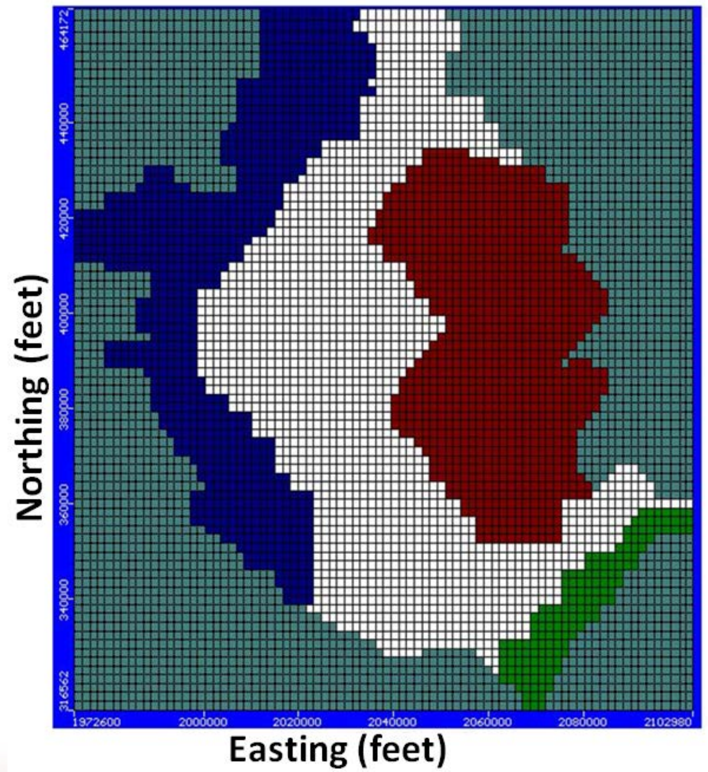
Aquifer A



Aquifer C

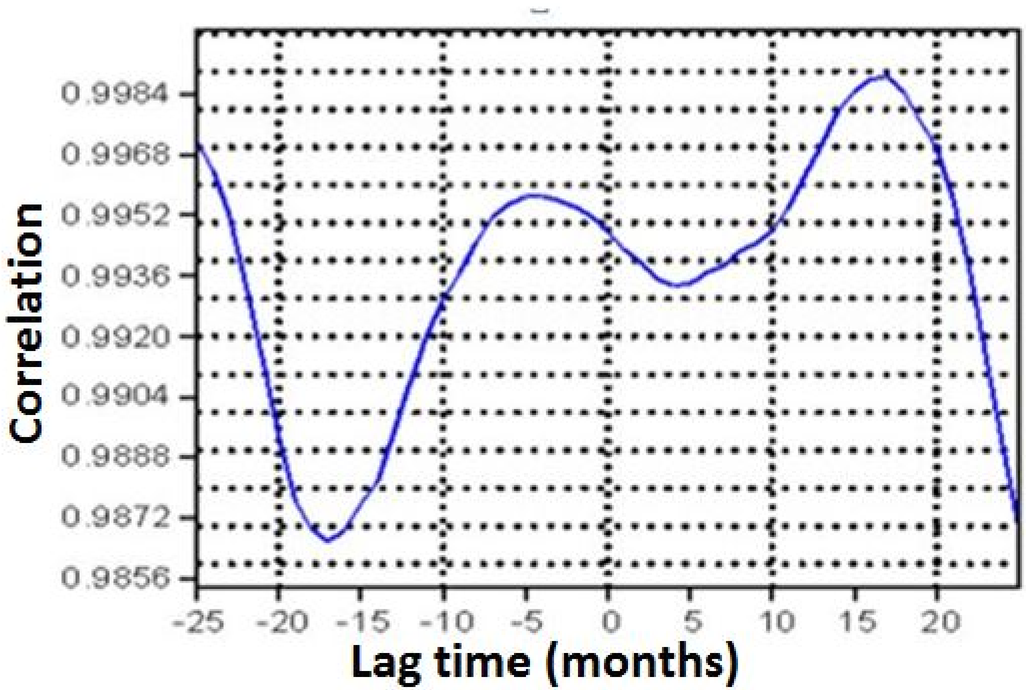
Boundary conditions for recharge zones





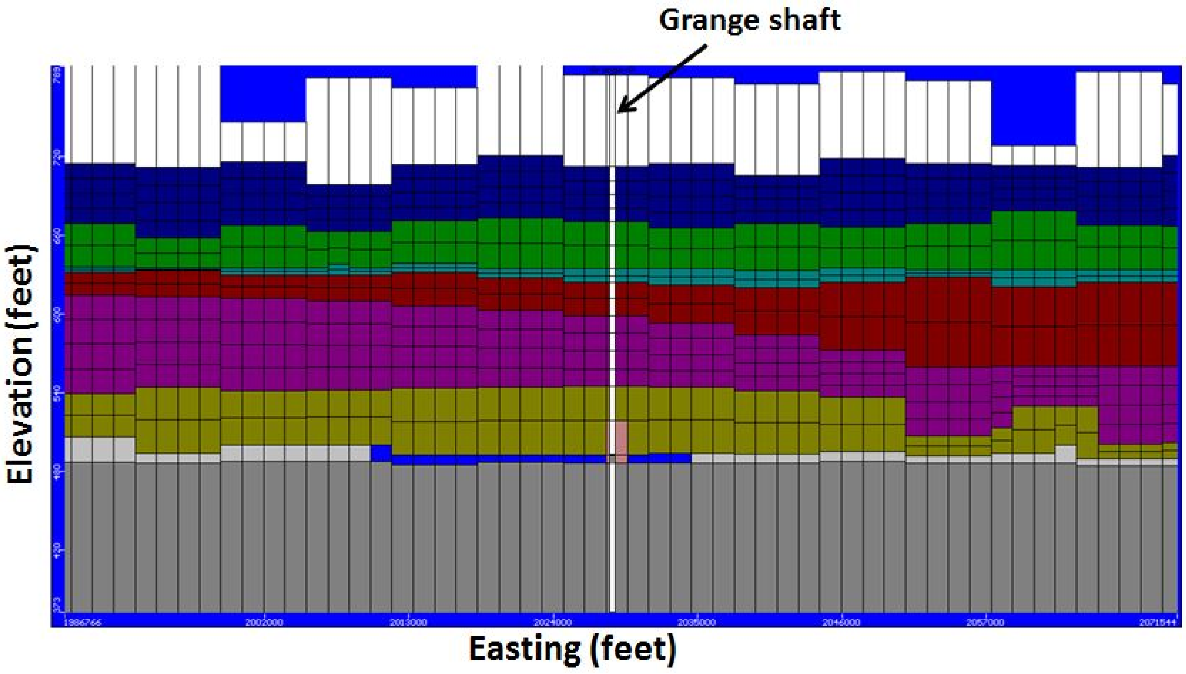
Recharge zone boundary (retrieved from https://websoilsurvey.sc.egov.usda.gov)

Cross-correlogram



A maximum in cross correlation coefficient between accumulated precipitation and pool elevation in the grange shaft with head responding to precipitation after 4 months.

Transient data analysis



With a lag time of 4 months and overburden thickness of 290 feet for the Grange shaft a flow velocity of 2.4 feet/day was calculated.

Hydrogeological modeling

- **Meigs Mine Complex has experienced several stages from active mining to post-mining conditions.**

- **Active-mining conditions and modeling:**
  - **Steady-state model to reproduce water levels in the wells assuming no pumping**
  - **Steady-state model to reproduce water levels in the shafts assuming pumping: to simulate initial water levels during head recovery**

- **Post Mining Conditions:**
  - **The mine was allowed to recover the water levels without pumping from January 2004 until December 2007.**
  - **Water was pumped from the mine from January 2008 until October 2016.**

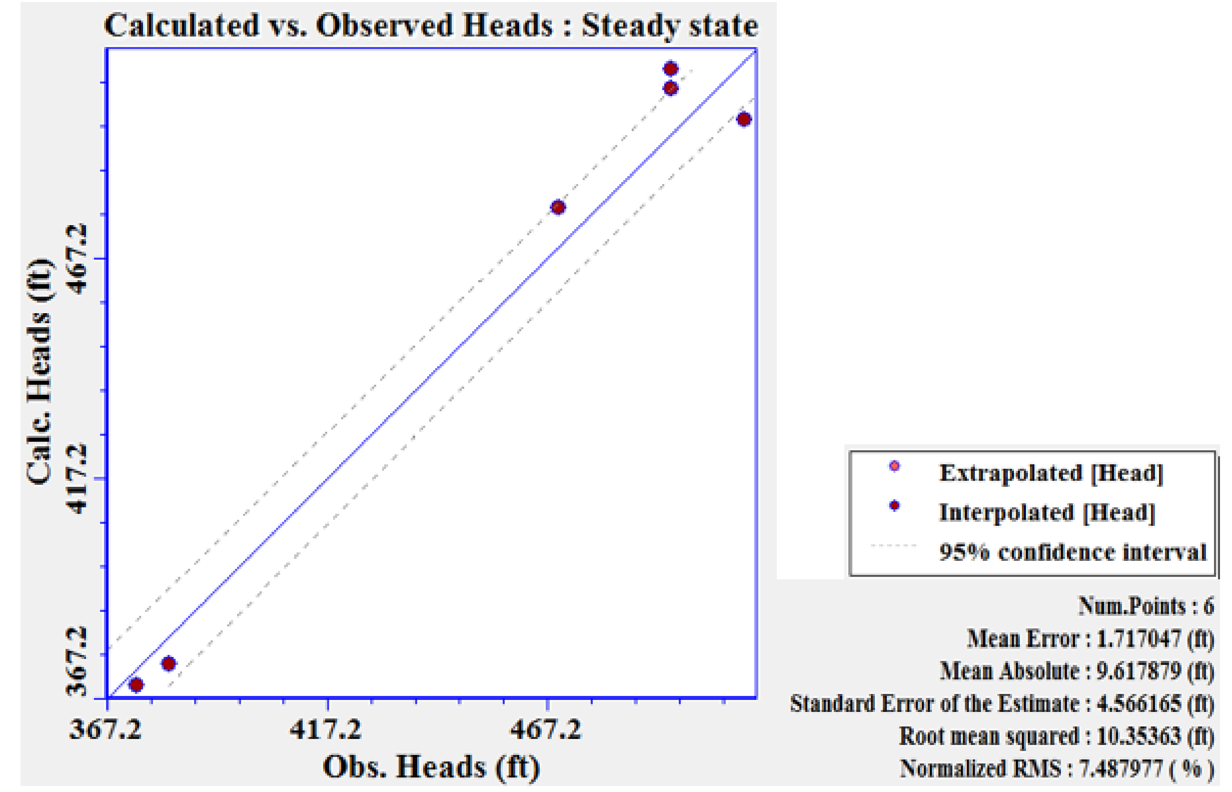
Hydrogeological modeling

- **Post-mining modeling conditions:**
  - **Transient model to simulate the recovery of the water levels during the period of free recovery**
  - **Pumping period after mine closure was not simulated because it is not of interest for this project.**

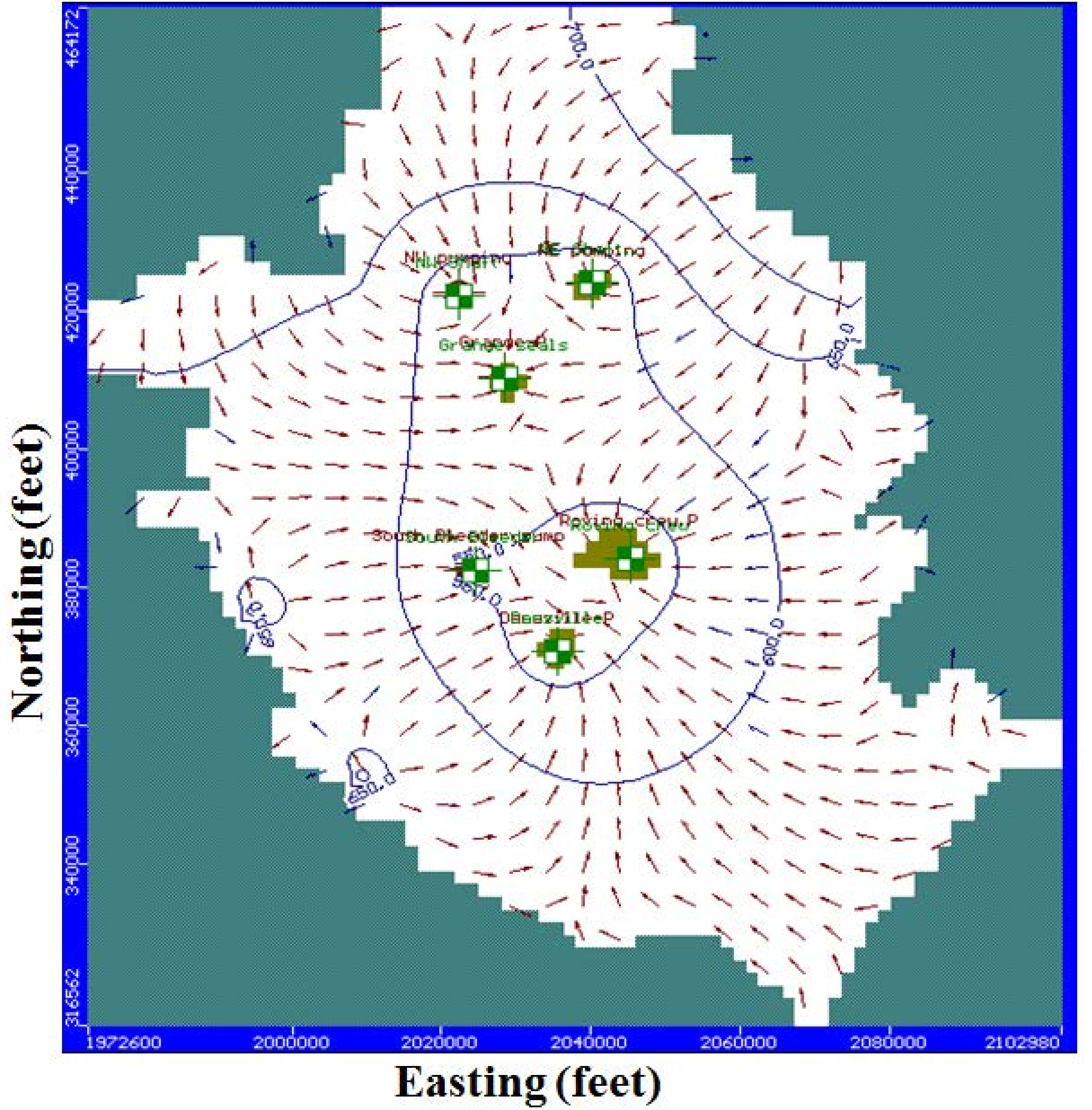
MODFLOW simulations: Active mining

- **A steady-state numerical simulation assuming no pumping (first model) and pumping (second model)**
- **The first model was calibrated changing recharge values and the hydraulic conductivity for each layer until the lowest error values based on calculated heads and observed heads was obtained.**
- **For the second model assuming pumping only the pumping rates were changed.**

Calculated heads versus the observed heads for the steady-state model with pumping during active mining



Second steady state model. Aquifer C flow regime showing equipotential head contour intervals of 20ft. Olive areas constitute areas of unsaturation whiles white areas constitute areas of saturation.



Post mining: Transient-state model

Transient simulations were conducted to

- **Establish the changes in groundwater flow conditions throughout the modeled area with respect to time.**
- **Calibrate hydrogeological parameters during the recovery period of the Meigs Mine Complex.**

- **The recovery period of the Meigs Mine Complex is very important because they reflect how the hydrology responds to the hydrogeological parameters after mining.**

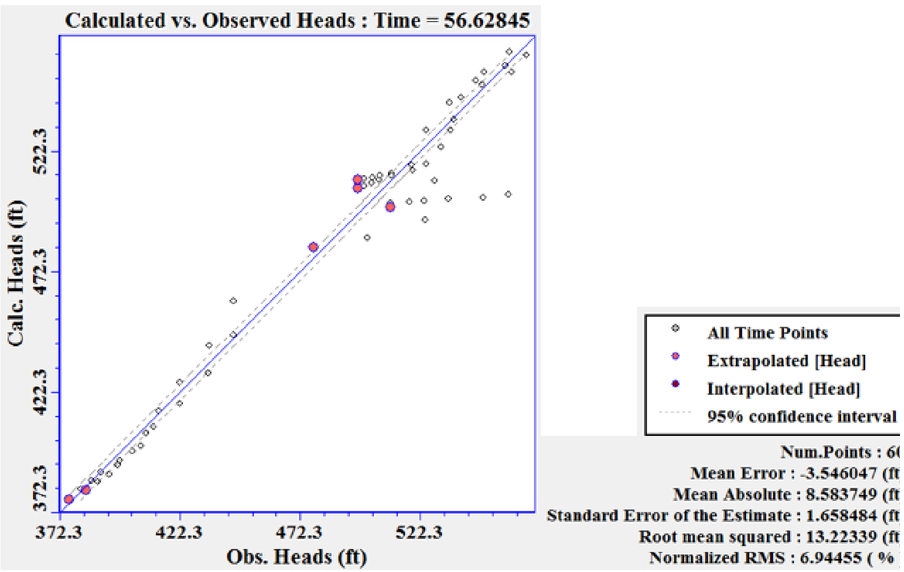
Post mining: Transient-state model

- **The transient simulations were conducted based on the initial conditions of the calibrated model with pumping during active mining.**

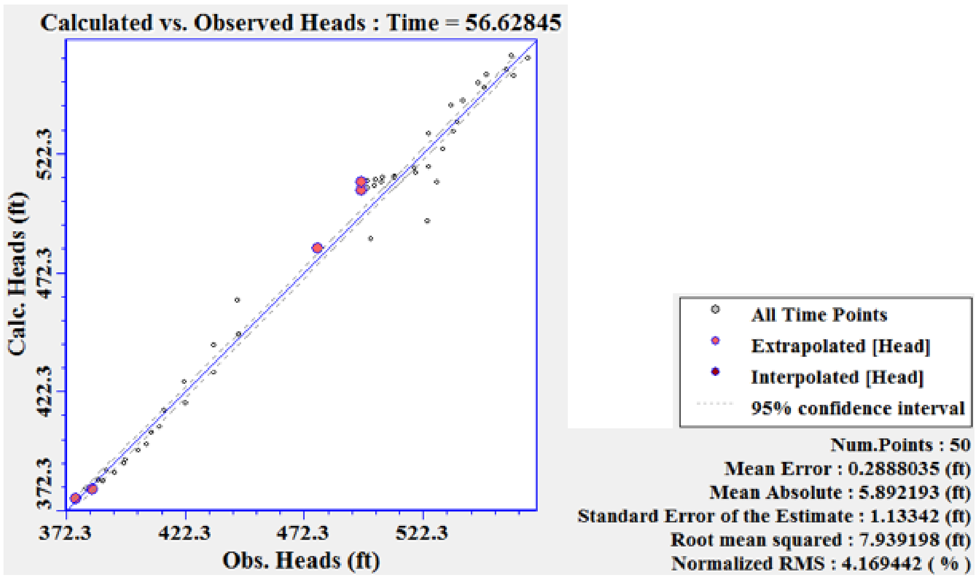
- **Variables such as hydraulic conductivity, specific yield, specific storage and recharges were calibrated for transient simulation.**

- **The transient model was simulated for a period of 4 years (January 2004 to December 2007).**

Transient-Model Result Error

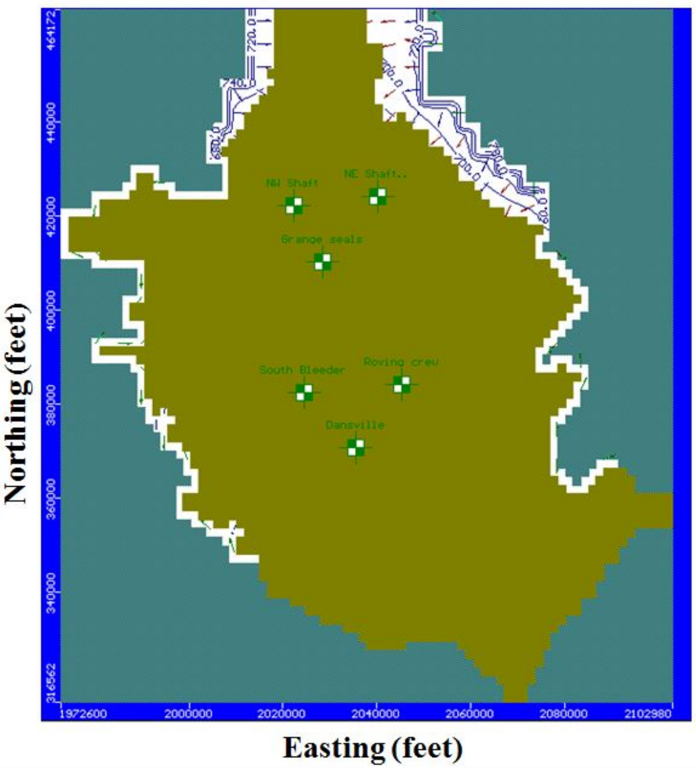


Calculated heads versus observed heads

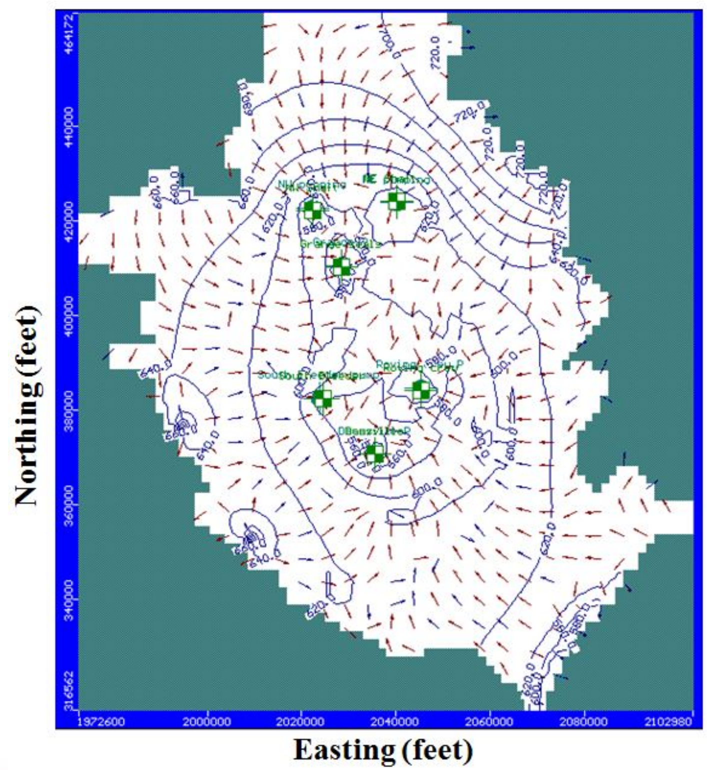


Calculated heads versus observed heads without NW shaft

Transient Model Results



Aquifer A



Aquifer C

Transient-state model

Calibrated hydraulic conductivity values

Lithological Units	Hydraulic conductivity (feet/day)		
	Kx	Ky	Kz
Layer 1 (Shales)	1.1	1.1	1.1
Layer 2 (Sandstones)	6.5	6.5	6.5
Layer 3 (shales)	0.04	0.04	0.04
Layer 4 (sandstones)	0.1	0.1	0.1
Layer 5 (shales)	0.8	0.8	0.8
Layer 6 (sandstones)	14	14	14
Layer 7 (shales 4A)	0.00009	0.00009	0.00009
Layer 7 (shales 4B)	0.0005	0.0005	0.0005
Layer 8 (coal)	0.0001	0.0001	0.0001
Voids	45	45	45
Layer 9 (shale)	0.02	0.02	0.02

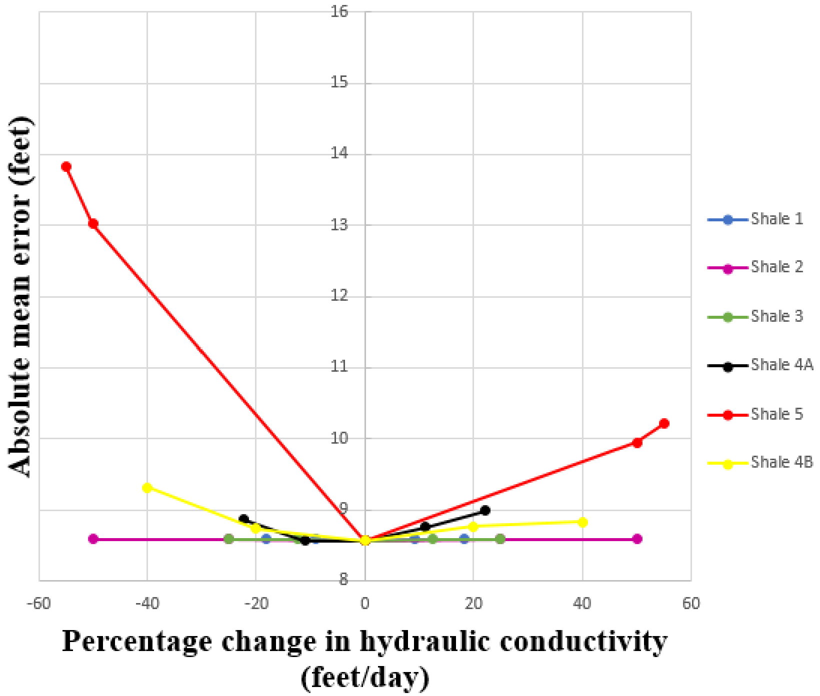
Calibrated recharge values

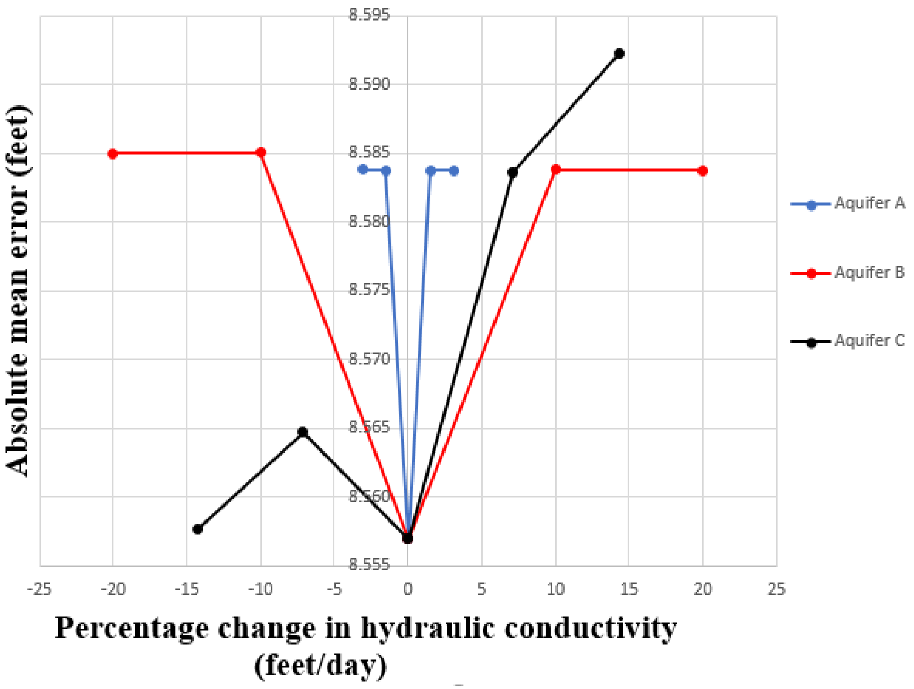
Property	Recharge (Inches/year)
R1	0.1
R2	1.5
R3	1.4
R4	0.01

Units	Hydraulic conductivity (feet/day)
Sandstones	(0.000085 to 1.701)
Shales	(0.000000028 to 0.000566)
Coal	(0.000000028 to 0.000566)

(Domenico and Schwartz 1990)

Sensitivity analysis





Shales hydraulic conductivity

Aquifers hydraulic conductivity

Conclusion

- **Lithological units have high permeability, these results are consistent with highly fractured rocks and secondary permeability due to the exploitation of the coal.**
- **Properties of lithological units closer to the mined coal were very sensitive to the model in both steady and transient state simulations.**

Acknowledgement

- Dr. Dina Lopez
- Dr. Natalie Kruse
- Lindsey Schafer
- Nora Sullivan
- Jen Bowman
- Rebecca Steinberg
- Zachary Matthews
- Robert Barber-Delach