Sourcing groundwater contamination from possible mine drainage in Navarre, Ohio using MODFLOW

By Alexis Lanier

Introduction

- The study area in Navarre, Ohio has several abandoned underground coal mines and evidence of groundwater contamination.
- One mine, Fox 12, was chosen to examine for possible contamination.
- Modeling is a useful tool for sourcing contamination, which is important to improving the efficiency of groundwater remediation.
- This study aims to show that geochemical analysis and modeling together provide an effective means for identifying contamination and that specific use of terms associated with mine drainage is important.

Methods

- Groundwater samples were taken from wells surrounding Fox 12 and were geochemically analyzed for elemental and sulfate concentrations.
    - Measurements of pH were also taken at each sampling location.
- A numerical model was created using MODFLOW to characterize groundwater flow in the area.
- Four layers were used in the model, created based on stratigraphic columns in well logs and IDW interpolation.
    - One sub-layer was used to characterize the mines, underlain by drains.
    - Two aquifers were characterized.
- MODFLOW's river package was used to simulate the Tuscarawas River on the eastern edge of the domain. The well and recharge packages were also used.
- Hydraulic parameters were estimated using published average values typical for the layer's composition.

Results

Well ID	AMDI	Mn Severity	SO_4 Severity
1	88.36	Mild	Moderate
2	88.36	None	Mild

Table 1. Mine drainage assessment of Wells 1 and 2. AMDI is acid mine drainage index (Gray, 1996). Mn and SO_4 are manganese and sulfate severity (Calhoun and Kinney, 2016).

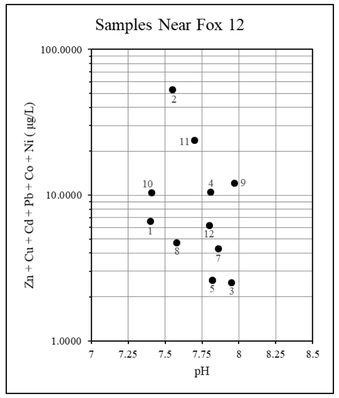

Figure 1. Part of a Ficklin diagram, which represents the typical range of mine drainage, with my samples labeled.

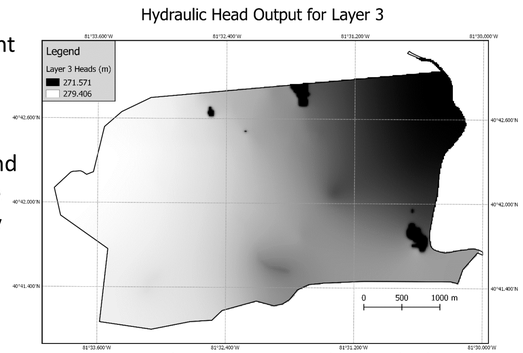

Figure 2. Map showing Layer 4 hydraulic head values (m). White depicts areas of high hydraulic head and black depicts areas of low hydraulic head.

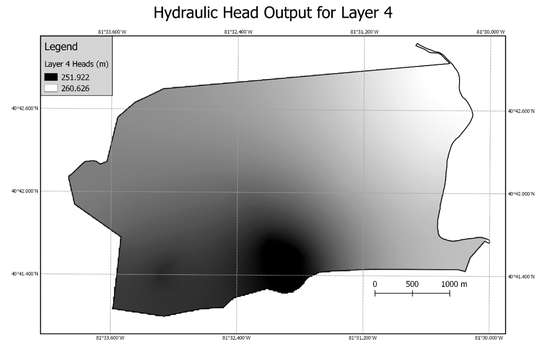

Figure 3. Map showing Layer 3 hydraulic head values (m). White depicts areas of high hydraulic head and black depicts areas of low hydraulic head.

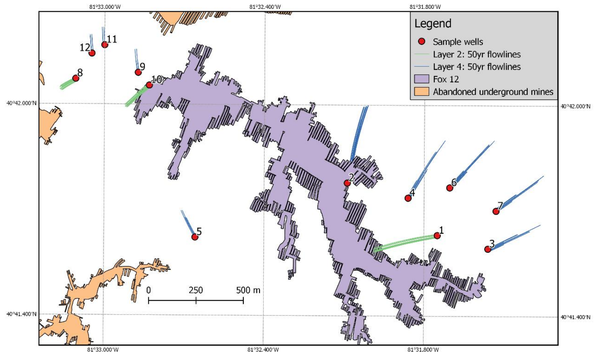

Figure 4. Flowlines show likely contamination path over the past 50 years. Green flowlines indicate wells screening layer 2. Blue lines indicate wells screening layer 4. Orange areas depict abandoned underground mines. Purple mine is Fox 12 (Source: ODNR).

Results

- Despite a near-neutral pH, geochemical analysis indicated that Wells 1 and 2 exhibited higher relative contamination than other wells.
- Modeling showed that groundwater in the two aquifers moves in different directions.
- Particle tracking showed that Wells 1 and 2 tracked flow back to or through Fox 12, while other wells tracked flow elsewhere.
    - Flow to Well 10 leads slightly through the mine as well, but without evidence of contamination, I considered this to be due to model error.

Conclusions

- Contamination in Navarre is mild and limited.
- Geochemical analysis and modeling together proved to be an effective methodology for identifying and quantifying contamination in this area.
- This study has shown that near-neutral waters can still host elevated metal concentrations, so a focus on acidity can be unreliable and consistent terminology is needed to prevent harm.
- Future work should be done to increase the number of wells used in layer interpolation, increasing confidence in modeled flow patterns.

Selected References

- Calhoun, J., and Kinney, C., 2016, Mine drainage impact assessment of Ohio watersheds: Ohio Department of Natural Resources Abandoned Mine Land Program, 115 p.
- Gray, N.F., 1996, The use of an objective index for the assessment of the contamination of surface water and groundwater by acid mine drainage: Water and Environment Journal, v. 10, p. 332-340.
- Harbaugh, A.W., Langevin, C.D., Hughes, J.D., Niswonger, R.N., and Konikow, L. F., 2017, MODFLOW-2005 version 1.12.00, the U.S. Geological Survey modular groundwater model: U.S. Geological Survey Software Release, 03 February 2017, doi: 10.5066/F7RF5S7G.