THE UNIVERSITY OF MEMPHIS
Center for Applied Earth Science and Engineering Research

MLGW Aquitard Study; Contract 12064
PROJECT 1-1 EXECUTIVE SUMMARY

Project 1-1: *Determine impact of known breaches in the Sheahan well field, determine presence of new breaches in the well field, and assess impact of Former Custom Cleaners site.*

Objectives

(1) To determine the impact of potential breach spatial configurations within the Upper Claiborne Confining Unit (UCCU) on the presence of modern water at the Sheahan well field in Memphis, Tennessee.

(2) To determine the potential breach configuration that better supports tracer-based data from previous studies.

(3) To assess the vulnerability of the well field to contaminants from the Former Custom Cleaners site.

Summary

- Thinning of an aquitard or its localized absence (referred to as breaches) warrant concern as this limits the protection it affords to water supply aquifers underneath.
- A three-dimensional groundwater model was utilized to investigate leakage pathways into the well field simulating five potential breach configurations under three different hydraulic conductivity values.
    - The model used was a modified version of the newly developed countywide numerical groundwater model developed by Villalpando-Vizcaino (2019).
        - The simulation period of the unmodified countywide model was from January 2005 to December 2016.
        - The countywide model was extended backwards in time to January 1960, in order to simulate flowpaths for modern water (<60 years old) into the well field.
        - The shallow aquifer was simulated as a constant head aquifer due to insuficient water table data for the extended simulation period and limitations of the numerical model when simulating draining aquifers.
    - Five breach spatial configurations were analyzed (Fig. 1):
        1. Parks' (1990) breach to the west of the well field.
        2. Breach inferred from Ivey et al. (2008) in the central part of the well field.
        3. A combination of Parks (1990) and Ivey et al. (2008) breaches that include additional areas where stratigraphic control is scarce (termed Large Breach)
        4. A paleochannel-like configuration (termed Paleochannel) interpreted from the interpolated surface of the top elevation of the UCCU in the vicinity of the well field and supported in part by Pell et al. (2005)
        5. A more extensive interpretation of the paleochannel from the previous configuration (termed Large Paleochannel) expanding further from the well field.

Fig. 1. Maps of the breach spatial configurations analyzed: (A) breach configuration suggested by Parks (1990), (B) breach configuration inferred from Ivey et al. (2008), (C) Large Breach configuration, (D) Paleochannel configuration, and (E) Large Paleochannel configuration.

  - The breaches in the five scenarios were simulated with a horizonal hydraulic conductivity of 0.1524 m/day (Gentry et al. 2006a) that was then varied an order of magnitude above (1.524 m/day) and below (0.01524 m/day) in order to capture unknown variability.
  - Flowpaths were generated by placing imaginary particles at the cells in the model containing the production well screens at Sheahan and tracking them back in time. Herein, the numerical model aimed to find the origin of particles currently present at the well screens.
  - Flowpaths were analyzed in order to calculate estimates for the modern water percentage and the apparent age of the modern water extracted by the production wells in the Sheahan well field.
- Error residuals were calculated in order to determine the breach configuration that better supports tracer-based data from previous studies (Table 1).
  - Mean and mean absolute residuals were calculated as the mean and mean absolute difference, respectively, when comparing:
    1. The simulated water levels to historic water level measurements around Sheahan available in the USGS National Water Information System (2019) for wells Sh:P-061, Sh:P-076, Sh:K-021, Sh:K-066, Sh:K-110 and Sh:K-122.
    2. Apparent age estimates versus published apparent ages of the modern water in Sheahan production wells (Gentry et al. 2006b; Larsen et al. 2003, 2016; Larsen and Waldron 2014).
    3. Modern water percentage estimates against published tracer-based modern water percentages (Larsen et al. 2003, 2016).
  - Out of the 24 production wells in the Sheahan well field, only seven wells have published data on both their modern water percentages and apparent ages; hence, restricting the assessment to the calculated residuals to just these wells (Table 1).

Table 1. Published modern water percentages and apparent ages of the modern water extracted by the target production wells at the Sheahan well field.

Well	Sample date	Apparent age of the modern water (yr)	Source	Modern water (%)	Source
MLGW-078B	10/21/2000	28	Larsen et al. 2003	6.3%, 21.6%	Larsen et al. 2003
	6/15/2005	48.8	Gentry et al. 2006b		
MLGW-055B	10/21/2000	51	Larsen et al. 2003	4.3%, 13.4%	Larsen et al. 2003
MLGW-080A	10/20/2000	48	Larsen et al. 2003	9.4%, 29.9%	Larsen et al. 2003
	11/20/2002	60.6	Larsen et al. 2016	2.5%, 13%	Larsen et al. 2016
MLGW-099	11/19/2002	51.6	Larsen et al. 2016	3.5%, 19%	Larsen et al. 2016
	11/3/2011	39.9	Larsen and Waldron 2014	5%, 8.5%	Larsen et al. 2016
MLGW-087A	10/21/2000	19	Larsen et al. 2003	13.4%, 22.3%	Larsen et al. 2003
	11/20/2002	25.2	Larsen et al. 2016	12%, 18.3%	Larsen et al. 2016
	6/15/2005	24.9	Gentry et al. 2006b		
	11/14/2007	32	Larsen et al. 2016	21%	Larsen et al. 2016
MLGW-088	10/21/2000	16	Larsen et al. 2003	32.3%, 62.9%	Larsen et al. 2003
	11/20/2002	18	Larsen et al. 2016	15%, 23%, 26%	Larsen et al. 2016
	6/15/2005	14.9	Gentry et al. 2006b		
MLGW-086R	11/3/2011	34.9	Larsen et al. 2016	11.3%, 12%	Larsen et al. 2016

- The potential spatial configurations for the breach around the Sheahan well field were ranked against one another and scored according to the mean residuals and mean absolute residuals.
    - Under this scoring scheme, the model with the smallest residual in a given criterion of the three previously decribed was ranked from first (best) to last (worst). The score was calculated as the sum of the rankings obtained for the three criteria, again with a lower score being more favorable.
        - The absence of modern water in any of the seven target wells was considered as additional error, adding five points to its score.
    - The mean and mean absolute residuals composite scores of the models sharing the same spatial breach configuration were summed into a final score to determine the more favorable spatial configuration.
- To assess the vulnerability of the well field to contamination from the Former Custom Cleaners (FCC) site, approximately 1.25 km west of the well field, 20 particles were placed at the water table below the site in every model configuration.
    - The particles were tracked forward in time to identify the particles captured by the production wells at Sheahan and to determine their average travel time(s) to capture.
- Findings:
    - The Large Paleochannel configuration best supported previous observations; thereby, suggesting that a breach approximating a paloechannel-like structure that is more extensive throughout the well field is more likely. The entire feature is not considered a breach, but may be indicative of preferential pathways for groundwater movement and exchange.
        - Previously reported breaches by other authors are less likely to have the shape and limited location they propose.
        - The Paleochannel configuration had the second most favorable score; therefore, paleochannel-like configurations should be the target of future investigations.
    - An analysis of the Sheahan well field is warranted whereby production wells, especially in the central and southern sections, should be sampled for groundwater age and modern water percentage.
    - Data shortcomings were found to significantly impact the results of this study such as: (1) water table and recharge data to successfully model the shallow aquifer as transient and (2) field derived hydraulic properties of the breach.
        - The uncertainty associated with the hydraulic parameters of the breach should be reduced, for which their characterization is a necessary step. Drilling through and obtaining a core from the suspected breach at well MLGW-99 and other nearby suspected locations would prove very beneficial to improving model simulations.
    - Re-application of this method with greater temporal and hydrologic data would very likely lead to an improved comparative assessment of probable breach configurations.
    - A potential vulnerability of the well field to the contaminants present at the FCC Superfund site, particularly of the production wells in the central section (i.e., MLGW-54B and MLGW-57C), was supported by the particle tracking analysis and should be

considered for the development of production schemes that minimize the movement of the contaminants.

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