Dockum Group Water: Evaluation of Brackish Groundwater Resources as An Alternative to Ogallala for Water Security in the Texas High Plains

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Abstract

The Ogallala aquifer is the primary source of water in the High Plains of Texas. The aquifer is being used at a rate that far exceeds its recharge. Water augmentation through the use of brackish aquifers is widely being considered by regional water resources planners. The Dockum Group of sediments is a water-bearing formation underlying much of the Ogallala aquifer. Therefore, there is a considerable interest in exploring the utility of this aquifer as an alternative source that can help prolong the life of the Ogallala aquifer.

This ongoing study seeks to establish understand the water quality and geological characteristics of the Dockum hydrostratigraphic unit. Preliminary efforts have been focused on characterizing the vertical salinity profiles over a 10,000 sq. mile study are encompassing Deaf Smith, Randall, Castro, Swisher, Bailey, Hale, Floyd, and Hockley counties. A detailed lithological characterization at a newly drilled test well site in Abernathy, TX (Hale and Lubbock, Counties) was also carried out. The results indicate a general increase in total dissolved solids (TDS) with depth, with TDS increasing in some cases to almost 40,000 mg/L. Lithology characterization has given a high-resolution profile of the aquifer sediments and allowed identification of sand-bearing units and estimate hydraulic conductivity of various aquifer layers. The results of the study are being used to develop models to identify sustainable pumping rates that prevent upconing of saltwater and thereby identify the extent to which the Dockum aquifer can supplement groundwater resources in the Ogallala aquifer formation.

Introduction

The High Plains of Texas have a semiarid climate, and its groundwater supplies over 90% of water used in the region. The Ogallala Aquifer is the region's primary source of water, and it is being used at a rate that far exceeds recharge. The greatest user in the region is agriculture, followed by municipal use. Hydraulic fracturing activities are also on the rise, and require considerable amounts of freshwater resources.

Fig. 1: 30-yr Normal Annual Precipitation

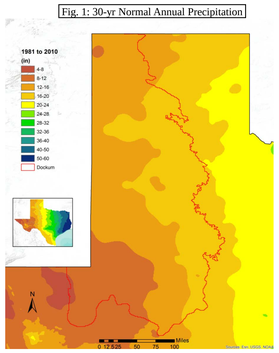
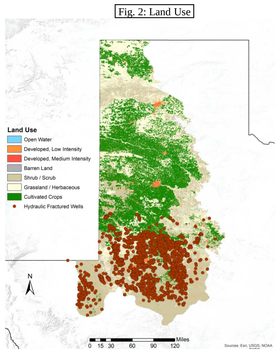


Fig. 2: Land Use



A stakeholder based water plan established that groundwater extraction levels be set such that at least 50 percent of the volume in storage remains after 50 years of pumping. This 50/50 rule forms the state mandated "desired future conditions" (DFC) for the Ogallala Aquifer. The recent state water plan reaffirms this DFC and identifies several water management strategies including but not limited to: conservation, reduction, reuse, as well as exploration of brackish groundwater from other aquifers. The Dockum Group, which underlies much of the Ogallala Aquifer, is viewed as a major alternative source of water in the region (Figure 3).

Owing to its brackish status, the Dockum formation has relatively few wells, and has not been studied as extensively as Ogallala. This situation makes the evaluation of the groundwater resources of this formation a priority.

The overall goal of this research is to establish factors that limit the use of Dockum's water as an alternative to the Ogallala Aquifer. A first phase of the project seeks to construct a better picture of the formations present state by: analyzing available data, establishing a stronger data collection network to fill critical gaps, analyzing Dockum sediments obtained from a drilling site in the

Fig. 3: Dockum Group Extent

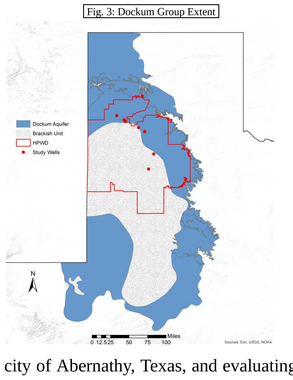
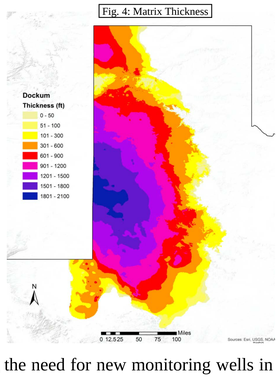


Fig. 4: Matrix Thickness



city of Abernathy, Texas, and evaluating the need for new monitoring wells in the formation.

Brackish groundwater aquifers exhibit salinity stratification which limits how much water can be pumped without causing an upconing of fresher and saline water in the aquifer. Lithology characterization is essential to identify depths at which the aquifer is productive and can also be used to estimate hydraulic conductivity of various aquifer layers.

During the first phase 8 wells have been sampled for salinity stratification over an area, encompassing an area of roughly 10,000 sq. mi., including wells in Deaf Smith, Randall, Castro, Swisher, Bailey, Hale, Floyd, and Hockley counties.

Brackish Water

The term brackish water has slightly different definitions among agencies and institutions studying it. The values given here are approximated using definitions from some government agencies. We will consider any water with less than a 1,000 ppm salinity fresh water, between 1,000 ppm and 10,000 ppm brackish water, with salinity between 10,000 ppm and 35,000 ppm saline water, and over 35,000 ppm brine.

Approximate values for water densities compiled from NGWA, USGS, and EPA. Most water in the Dockum Group can be classified as brackish or saline, with TDS over 1,000 mg/L (George, 2011).

Salinity Characterization

Depth varying salinity measurements were carried out to obtain a better picture of the salinity profile of the formation, and characterize the freshwater-saltwater interface. A total of 8 wells have been measured during the 2015-2016 winter season and the 2016 summer season. As the study advances, more wells will be added.

Fig. 5: Salinity profiling

The wells were measured for water levels, salinity of the water column, and temperature. The logging of electrical conductivity for salinity profiling in groundwater wells has been in practice for several decades. Measurements were made using a Solinst TLC meter, model 107, that measures conductivity groundwater wells has been in practice for several decades. Measurements were made using a Solinst TLC meter, model 107, that measures conductivity in µS/cm with a range of 0 to 80,000 µS/cm, and with an accuracy of 5% of reading. A salinity-TDS calibration curve was developed in the laboratory (Figure 7).

TDS content in the wells sampled ranged from 500 to 40,000 mg/L and similar to those reported by Walton (1989).

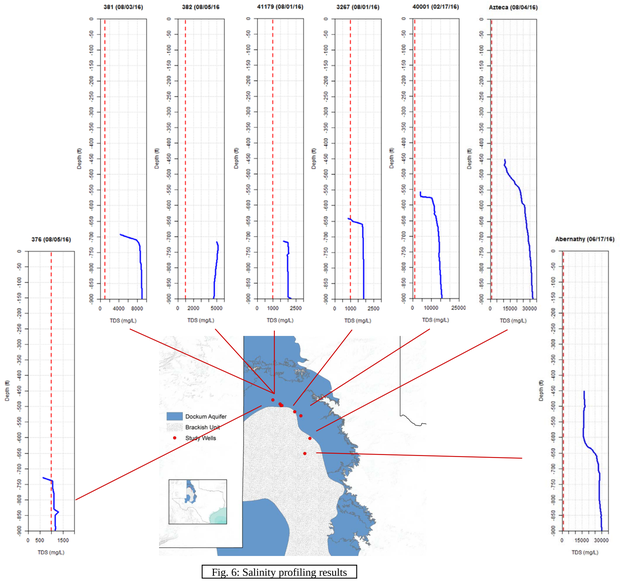


Fig. 6: Salinity profiling results

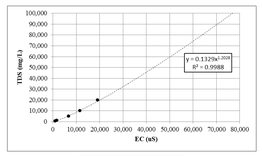


Fig. 7: EC-TDS curve

Lithology Characterization

In February of 2016, a 1,245 ft., Dockum well was drilled in Abernathy, Texas (Fig. 12). Drill cuttings were sampled and processed to obtain particle size distributions (ASTM, 2007) for six, 200 ft. sections, and from these a hydraulic conductivity estimation was made following Hazen's empirical relation (Freeze, 1979) (Hazen, 1892).

The distributions are non-uniform and gap graded (McCarthy, 1977). Of special interest are the layers from -400 to -1,000 ft. The water level is located in this strata, big and sudden jumps from coarse to fine can be seen, combined with high sand and low clay percentages.

Depth Section (ft)	Sand %	Silt %	Clay %	Formation
0 - 200	63.5	11.5	25.0	Ogallala
200 - 400	40.5	14.5	45.0	Dockum
400 - 600	50.9	13.1	36.0	Dockum
600 - 800	40.1	20.9	39.0	Dockum
800 - 1,000	49.3	22.7	28.0	Dockum
1,000 - 1,245	12.9	37.1	50.0	Dockum

Fig. 9: Grain size percentages

Early estimation of hydraulic conductivity from particle size distribution has been used for more than a century. There are several other formulas connecting diameter and quantity of grains with this water transmitting characteristic. We use here Hazen's empirical relation

$$K = Ad_{10}^2$$

where K is the hydraulic conductivity in cm/s, d10 is the effective grain size in mm, and A is a coefficient equal to 1.0.

For the Abernathy well, the results of the hydraulic conductivity estimations are shown at 200 ft. intervals, compared to the particle size distribution and the 06/17/16 TDS profile in Fig. 12. The estimated hydraulic conductivites range from 0.2 – 2.0 ft/yr.

The combination of high-sand/low-clay content, gives some of the higher estimates for hydraulic conductivity in the layers from -400 to -1,000 ft.

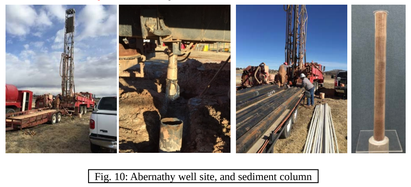


Fig. 10: Abernathy well site, and sediment column

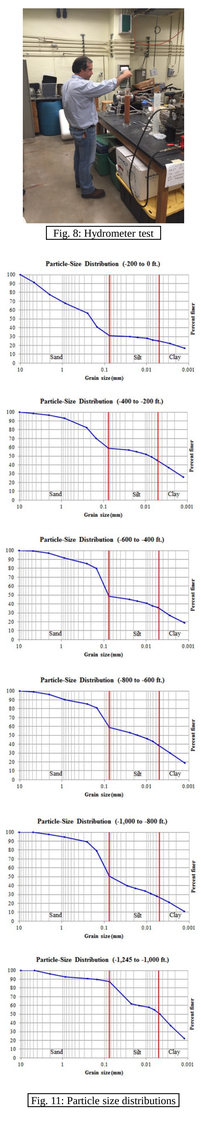


Fig. 11: Particle size distributions

Ongoing Work

As the project advances, it is expected to sample the wells for major ions, characterize the freshwater-saltwater interface, and augment the number of wells sampled to cover data gaps. Owing to the fact that most water in Dockum has a high TDS, there are a limited amount of wells drilled into it since the agricultural industry has had little use for this type of water so far. Figure 11 depicts the areas where there is need for additional monitoring and was ascertained from Kriging standard errors.

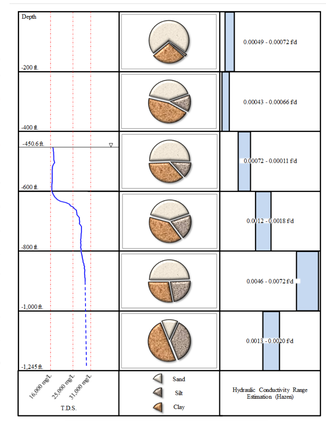


Fig. 12: Results from Abernathy well analysis

Summary and Conclusions

The Ogallala is the major source of water in the High Plains region of Texas. The over-exploitation of this aquifer has spurred the need to identify alternative sources. The Dockum Group sediments that underlie most of the Ogallala formation are being actively looked into as an alternative. The aquifer is however brackish and consists of consolidated sediments with low permeability. This study depicts the salinity variations in the Dockum group which is useful to estimate the amount of water that can be extracted without causing "saltwater upconing". A detailed lithological characterization of a newly drilled test well indicates the permability of the sediments are low and can limit the ease with which the water can be extracted from the aquifer.

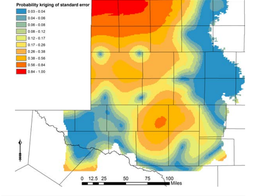


Fig. 13: Probability kriging standard error of indicators

References

Bradley, Robert G., and Sanjeev Kalaswad. "Groundwater resources of the Dockum Aquifer in Texas." Texas Water Development Board, 2003.

Freeze, R. Allan, and John A. Cherry. Groundwater. No. 629.1 F7. 1979.

Hazen, Allen. Some physical properties of sands and gravels: with special reference to their use in filtration. publisher not identified, 1892.

Llano Estacado Regional Water Planning Group. 2016. *Llano Estacado region regional water plan.*

Standard, A. S. T. M. "D422–63 (2007) Standard test method for particle-size analysis of soils." ASTM International, West Conshohocken. doi 10 (2007): 1520.

Walton, N. R. G. "Electrical Conductivity and Total Dissolved Solids—What is Their Precise Relationship?." Desalination 72, no. 3 (1989): 275-292.

Acknowledgments

High Plains Underground Water Conservation District (Jason Coleman, General Manager, Keith Whitworth, and Ray Eads);
Hi Plains Drilling, Inc.
SDA Ogallala Aquifer Program