STUDENT SUMMER INTERNSHIP TECHNICAL REPORT

H-6bR Water density Stratification Investigation

DOE-FIU SCIENCE & TECHNOLOGY
WORKFORCE DEVELOPMENT PROGRAM

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ABSTRACT

The Purpose of this internship was to achieve a real-world experience by successfully integrating myself into the Sandia National Laboratory (SNL) Hydrology team. The main project objective was to achieve a well density profile of well H-6bR, a well located in the Northwest corner of the Land Withdrawal Boundary (LWB) zone on the Waste Isolated Pilot Plant (WIPP) site. The hydrology team oversees characterizing and developing models for understanding the groundwater activity around the WIPP site. Groundwater in the karst terrain is a complicated matter because most models deal with empirical equations that consider averaged values and homogenous flows. However, the geology and hydrologic flows around the WIPP are heterogeneous and our mission is to model this as best as possible. One variable of important consideration is the possibility of stratification occurring in the well is density. A method was developed for well density measurements using an apparatus called a "Snap Sampler." Using this device, the team deployed our gear and retrieved 46 samples at 15 ft intervals of a 300ft water column. In the lab, density was measured and recorded for triplicate in mg/L and the data was input into an Excel worksheet where density averages and a mean were calculated and graphed. Normal pressure transducers give us a mid-formation density average, but with this method using averages throughout the well, the results showed that there were different densities throughout the water column and the densities increased with depth. Gravity seems to be the driving force at work here, but further experiments need to be done on wells with relatively higher/lower transmissivities.

TABLE OF CONTENTS

LIST OF FIGURES

1. INTRODUCTION

The mission of the Hydrology team at SNL is to find better ways to model the groundwater activity at the WIPP site. The Hydrology team, with support from the Geochemistry team, models flow by characterizing the geology and the well water samples that are analyzed in the laboratory. Models adhere to homogenous-like flows adapted from empirical equations because ideal scenarios make them easy to understand and practical in application. Sandia is one of the few teams in the nation using models adapted to heterogeneous flow. On the mission to perfect their modeling, they are always trying to find ways to improve on techniques, develop new methods, and acquire data to improve their modeling.

Density has been low on the priority list because it is easily measured with pressure transducers and not considered an important factor for groundwater modeling when compared to other variables like chemical composition, pH, depth, etc. The team set out to develop a density well profile of a target well and investigate the potential of well-water stratification. Considering stratification may lead to improvement on groundwater modeling of heterogenous flows in karst terrains (Thomas et. al., 2016).

Well-water stratification phenomena occur when waters comprising different constituents with different properties [i.e., salinity (halocline), oxygenation (chemocline), density (pycnocline), temperature (thermocline)] separate to form layers isolating waters with those properties. Normally, density measurements are acquired from water samples obtained from pumping tests, purge events, or the yearly water quality sampling of Waste Isolation Pilot Plant (WIPP) monitoring wells (Bowman, 2019). Subsequently, these samples are obtained from mid-formation making them limited in accounting for a potentially complex density profile of the full water column. As per SP 9-11 (Johnson, 2015), pressure density is calculated using knowledge of the water column height and density of water in the column. This method can measure a relatively accurate average of densities for a water column but does not describe its profile. Therefore, by taking water samples at various depths, map changes are made with density as they relate to well-water stratification which may augment our understanding the heterogeneous nature of groundwater in wells.

This internship involved many aspects including field, lab and office work. Implementing myself into the hydrology team at Sandia National Labs, the tasks were to support the team in different areas as well as primarily taking lead in developing the density well profile of well H-6bR. This well was chosen due to its relatively isolated connectivity and low transmissivity from analyzing past reports showing a unique chemical composition of the groundwater surrounding well H6-bR. Another important factor was that drawdown of adjacent wells didn’t affect well H6-bR and this normally is not the case because of the karst terrain in this area. The geology is very porous and has fractures supporting a very connective gradient within the region. This well contains relatively high amounts of calcium and magnesium not seen in the other wells making it a prime candidate for our density well profiling project. Density measurements are obtained via pressure transducers, but these are measured once as an average at mid-formation level. The team obtained well samples manually with the Snap Sampler method to acquire a total of 46 samples. Afterwards, density measurements were completed for each of these samples and data analysis on Excel producing density measurement graphs. This revealed that the density changes at different depths showing the potential for well-water stratification.

1st on the agenda was to complete all the required training and familiarize with the facility and its staff. The first week was spent on an an extensive list of Specific Procedure (SPs), Test Procedures (TPs) and Nuclear Waste Management Procedures (NPs). Analogous to this, many reports on site assessment and compliance on activity in and around the WIPP site that helped acquaint get acquainted with the hydrogeology and geochemistry. During my second week, the focused shifted to on-online training from the WIPP online directory and learning portal. Completing virtual videos about day-to-day safety and cases of complacency and negligence exemplifying how important it is to understand this potentially hazardous environment, thus laying the foundation for the regulatory driven work done at SNL.

There were many meetings throughout the week, including the day-to-day (D2D) meeting which had the Sandia representatives from both the Geochemistry team and Hydrology team. The D2D served as a reliable line of communication at the beginning of the day that led to many successful executions of tasks. Tasks usually required support and information in order to be successfully completed; the D2Ds insured this from the get-go, leaving no excuses for anything not done. D2Ds kept our team updated on the progress made and whether support might be needed.

In addition to the D2Ds, every Monday there were two critical meetings, Hydrology team meeting and the Manager Review Meeting (MRM). The hydrology team consisted of mentors Amelia Hayes, Dale Bowman (team lead) and Owen Lofton. The team would organize the calendar for upcoming weeks with everyone’s tasks and activities and assure everything that is scheduled will be executed and/or updated with any changes. These helped correlate deadlines and align them with the milestone reports. Budgeting was also an important topic in this meeting for proper allocation of monies.

The MRMs with Manager Antonio Trivet were more focused on personal development and team development. By engaging and exploring in different exercises, the team found itself critically thinking and taking those extra steps to understanding the problem at hand. This meeting served a great deal for understanding how intangibles are a big part of the success of SNL. Starting off Mondays with this meeting would serve as a precursor for the rest of the week and would develop and spark the team chemistry resulting in an efficient and productive week.

Scope/Objective

- The objective of this project is to characterize a density profile of well H-6bR.
- To establish an understanding of how a national lab operates and learn all it takes to drive a real work force/team of scientist and engineers.

Project Background

- Many wells are strategically located around the WIPP site.
- The Culebra Member is considered very important due to transmissivity.
- These wells offer year-round data to the Hydrology and Geochemistry teams.
- The data extracted from the water samples are critical for long term ground water management.

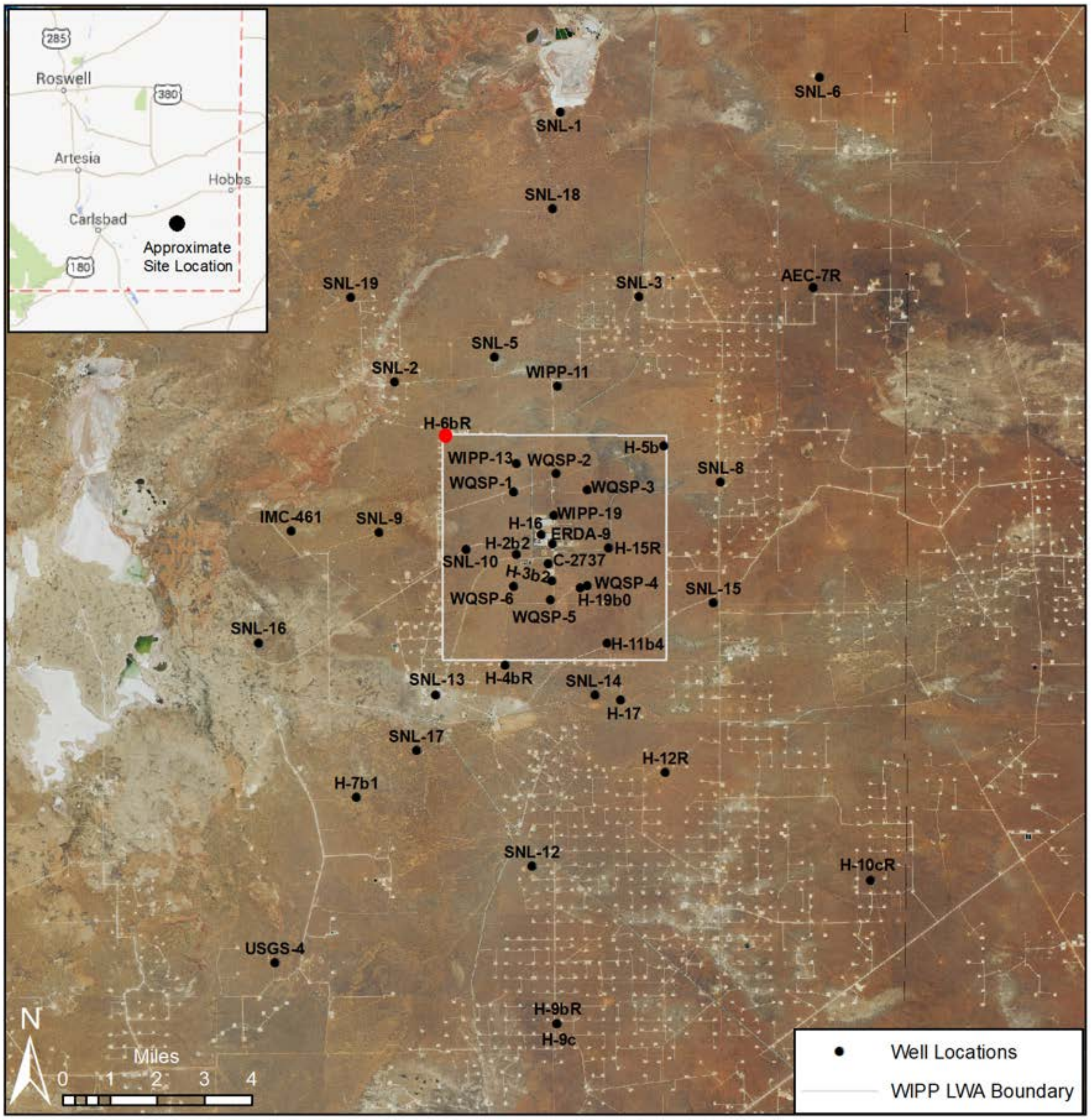

Figure 1. A location map of WIPP monitoring wells. H-6bR is highlighted as a red point.

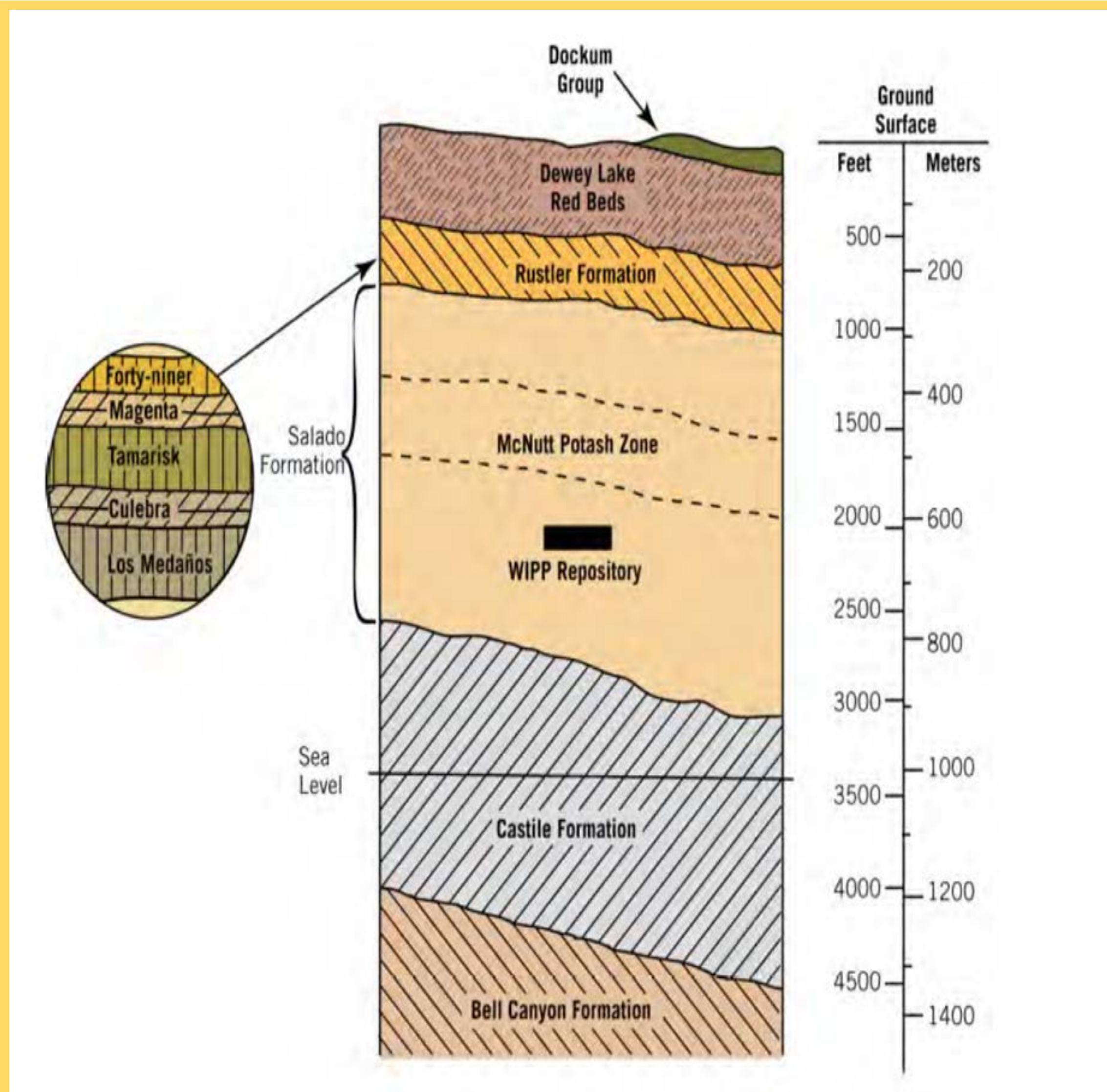

Figure 2: Cross section showing where the Culebra member of the Rustler Formation is located

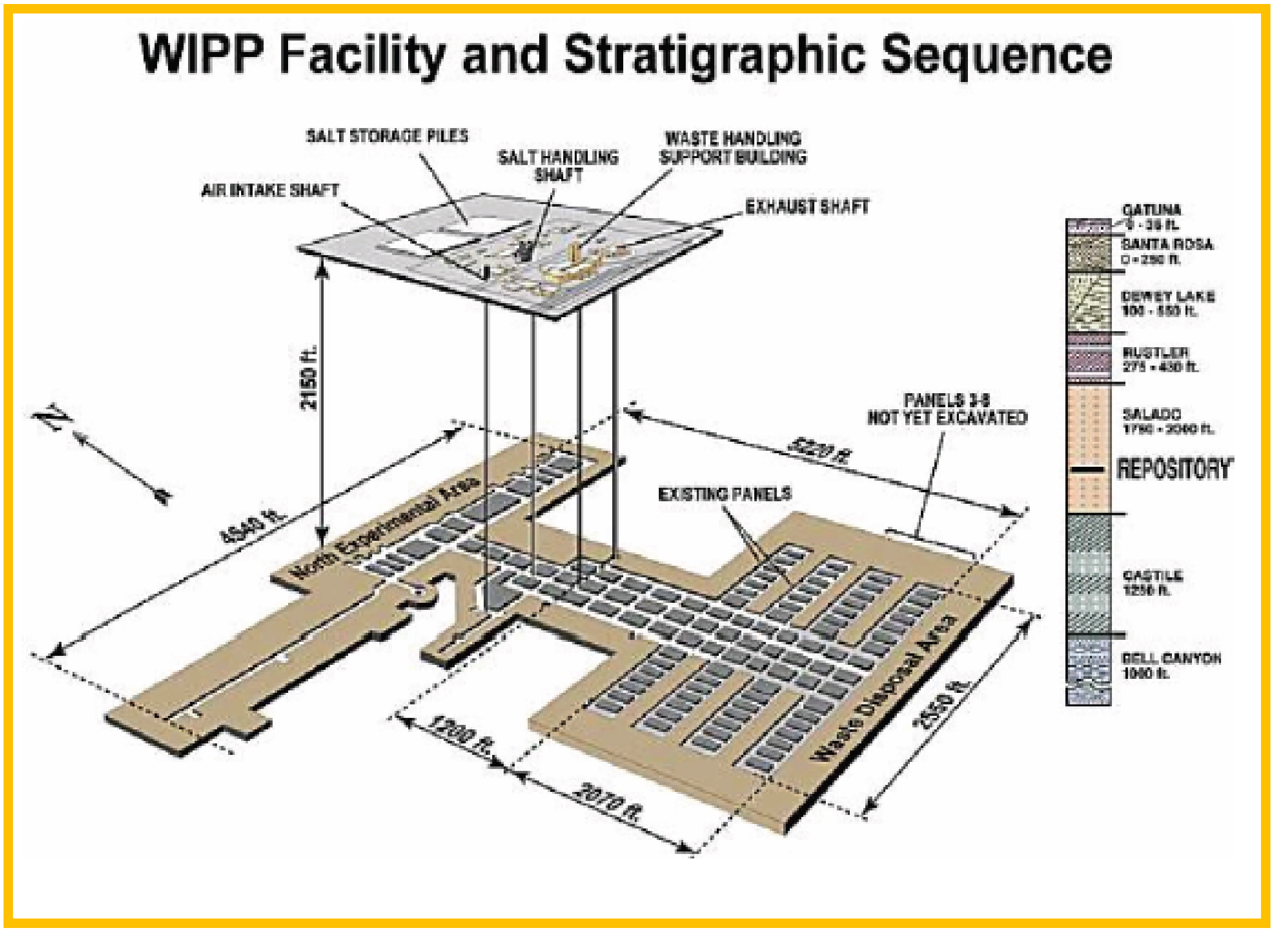

Figure 3: Depiction of the WIPP deep geologic repository and surrounding geology with respect to depth and facility structure located near Carlsbad, NM.

2. EXECUTIVE SUMMARY

This research work has been supported by the DOE-FIU Science & Technology Workforce Initiative, an innovative program developed by the US Department of Energy's Environmental Management (DOE-EM) and Florida International University's Applied Research Center (FIU-ARC). During the summer of 2019, a DOE Fellow intern Alexis Vento spent 10 weeks doing a summer internship at Sandia National Laboratory under the supervision and guidance of Amelia Hayes, senior hydrologists. The intern's project was initiated on June 2, 2019, and continued through August 10, 2019 with the objective of investigating water density stratification of well H6-bR.

3. RESEARCH DESCRIPTION

Sample Acquisition

Well-water samples of H-6bR were acquired using the Snap-Sampler sampling tool. Target sample depths were in increments 15ft for the entire depth of the water column. The Snap-Sampler housing configuration allowed for a sample to be taken at the target 15ft depth and a second sample taken for curiosity and redundancy 4ft below the target depths. Samples were acquired starting at the top of the water column and proceeded progressively to the bottom of the well screen depth. This method was used as to not potentially disrupt or mix shallower samples while obtaining any deeper samples. The sampler was given a 10-minute residence time per set of samples. Longer residence times would have been ideal, but impractical due to the number of samples taken (60). After each sample was collected by the snap-sampler, they were labeled and iced in a cooler. Samples were later transferred to a lab refrigerator to help preserve their water quality constituents. Chain of custodies documentation was processed to account for all samples. The sampling process is detailed in notebook WIPP Water Quality Measurements #1 (WWQM-1) (Vento and Bowman 2019).

Figure 4: SnapSampler Assembly

Figure 5: SnapSampler Assembly 2

Figure 6: Snap Sampler deployment into well H6-bR using a winch and cable setup of SnapSmapler

Figure 7: Well-water Samples iced in cooler

Sample Density Measurement

Sample measurement objectives were to measure the weight of a fixed volume of sample and compare measured weights to that of fresh water. Prior to weighing samples, sealed sample containers were left out so they can reach room temperature; this is done to have all the samples at same temperature. Using a 10 mL Class A Certified volumetric flasks and disposable transfer pipette water samples were transferred until the sample meniscus reached the 10 mL volumetric mark. Measuring volumetric flasks with and without sample using a Mettler AT 400 calibrated scale. Each sample measurement was done as triplicates, results were recorded, and the three values were averaged to attain the density for each sample depth. Calibration of the Mettler AT 400 was kept in record in Calibration Records #14 scientific notebook (Vento and Bowman 2019).

Figure 8: 46 Well water samples on lab bench

4. RESULTS AND ANALYSIS

The first set of data contained several values that reflected outliers, so two sets of replicated data were completed for select samples. Average densities of the triplicate sample measurements are graphed. As a quality assurance measure, an extra step was taken in comparing measured values with 1.034 mg/L and 1.033 mg/L from density measurement reports, Johnson (2008) and Johnson (2018) respectively(Vento and Bowman 2019).

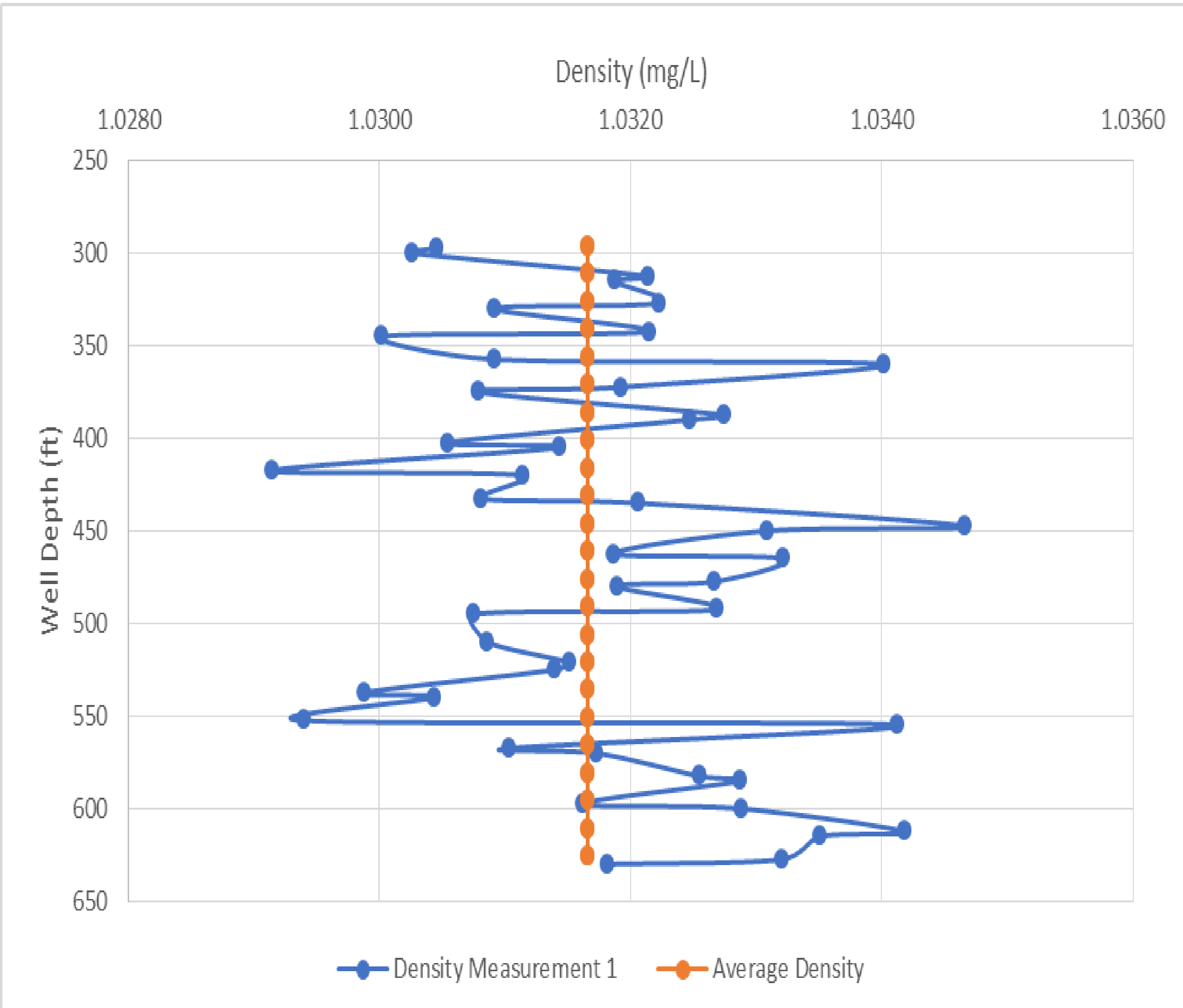

Figure 9: First set of sample measurements from well H-6bR which shows the density fluctuations throughout the well (DM1). Densities range from 1.0290 - 1.0350 mg/L. The orange line represents the average density at 1.0317 mg/L.

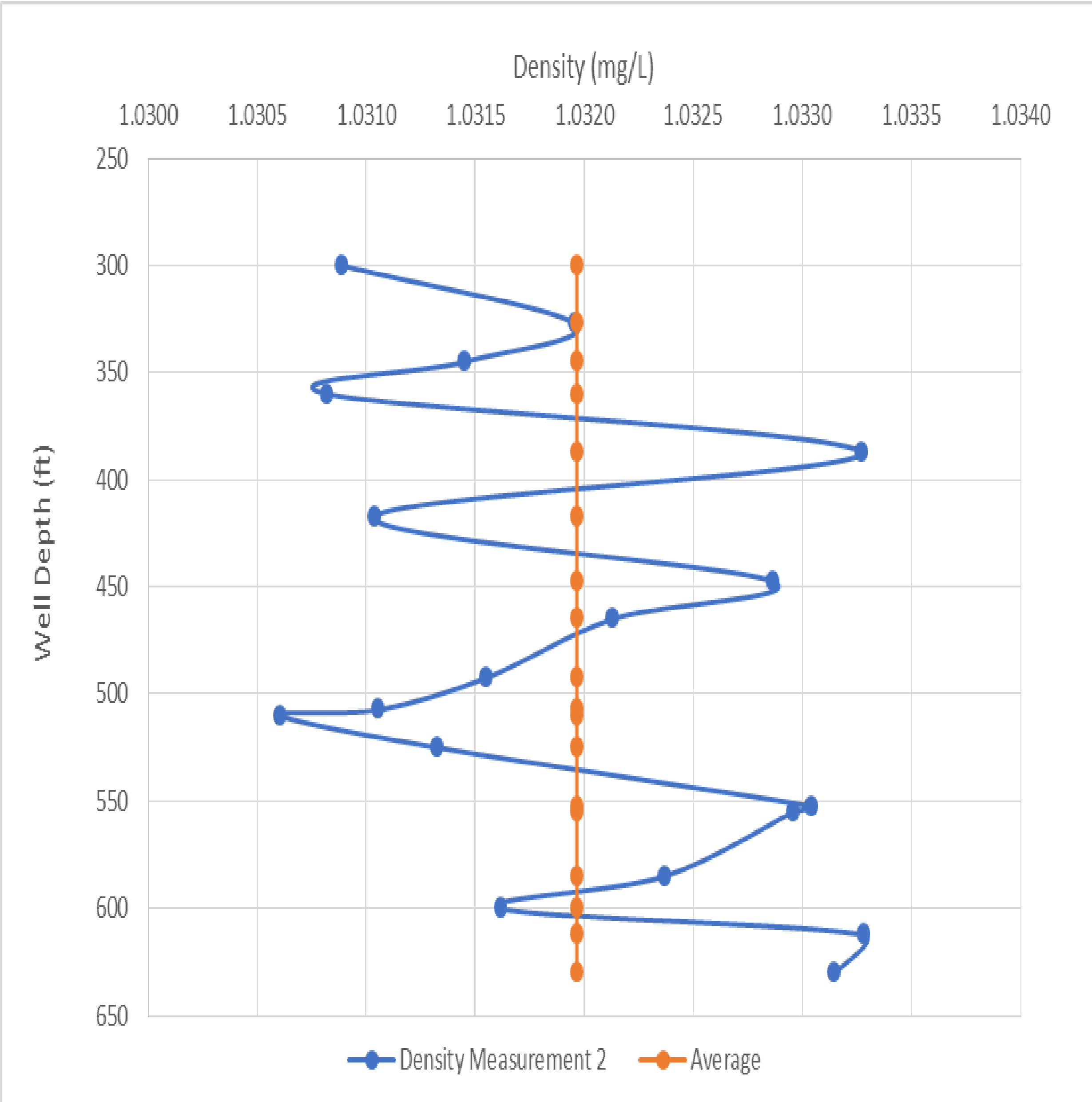

Figure 10: After selecting outliers and intervals of three for point replication the results are shown here in DM2. This figure illustrates a density range of 1.0306 - 1.0335 mg/L and follows values from DM1. The orange line represents the average density of these samples at 1.0320 mg/L.

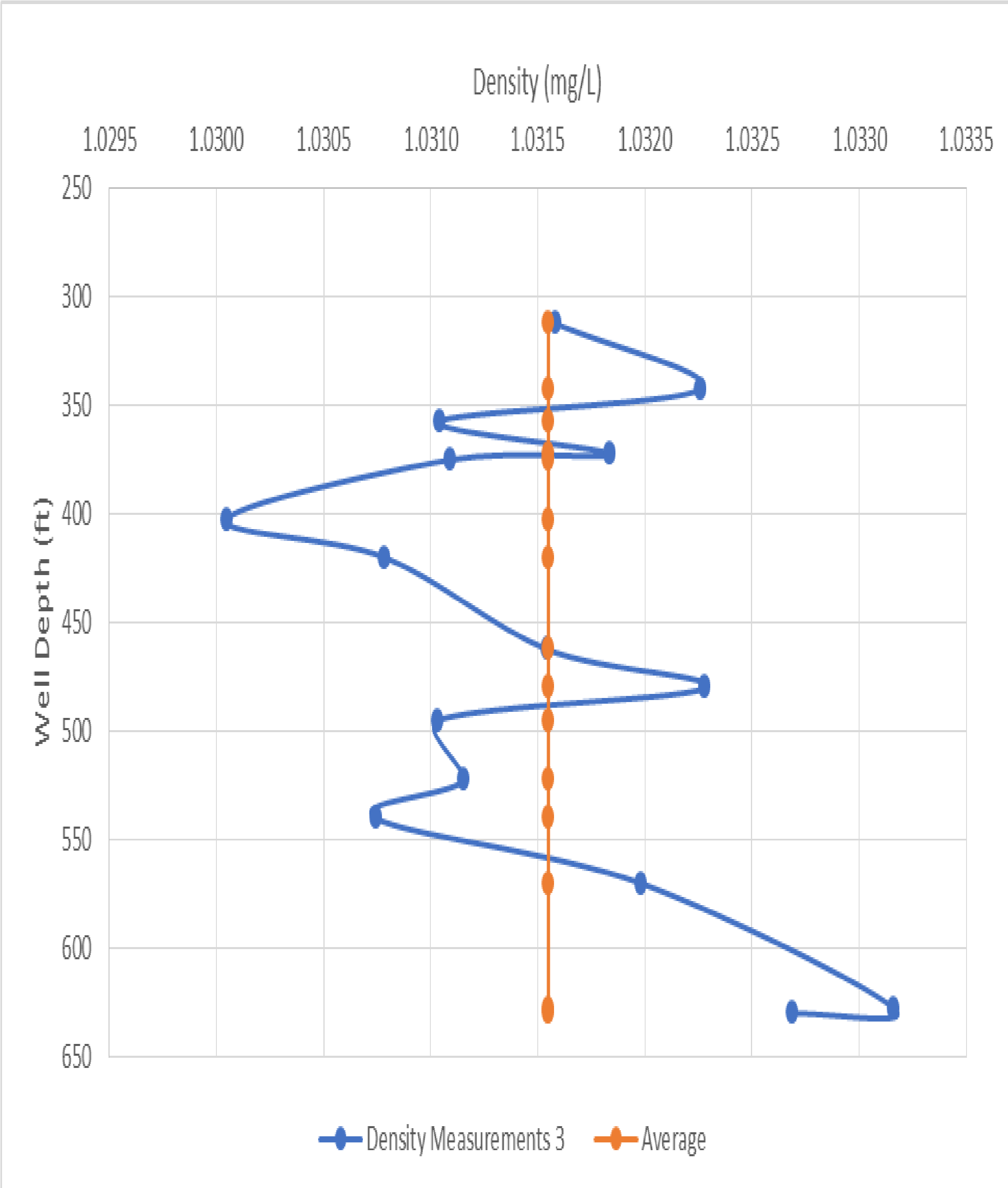

Figure 11: Reconsidering points in remaining intervals not covered in DM2 and some repeated points resulted in graph DM3. The density range of these samples is between 1.0300 - 1.0335 mg/L with an average density represented by the orange line of 1.0315 mg/L.

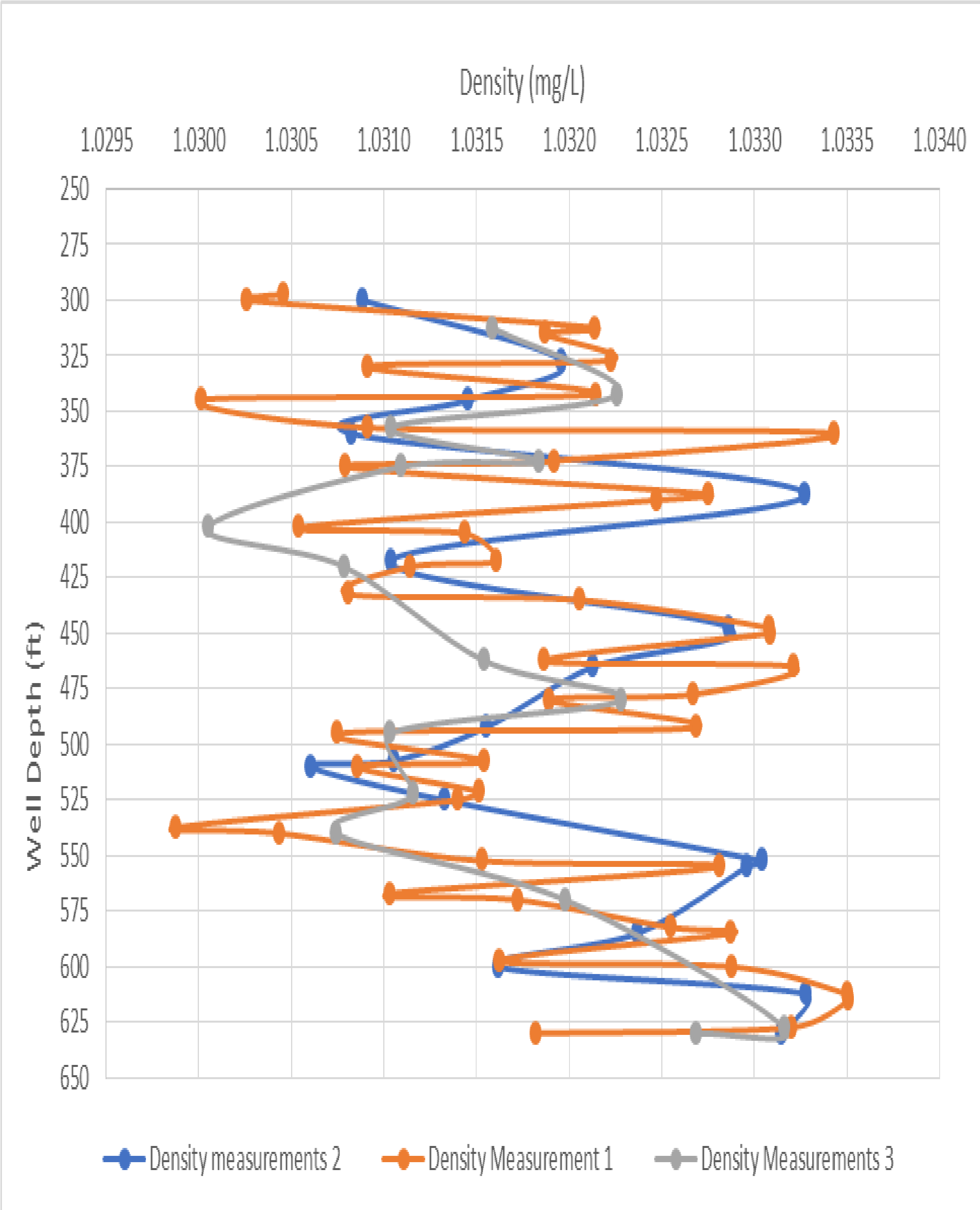

Figure 12: Removing some outliers, we transposed DM1, DM2, and DM3. This graph shows a similar pattern and range between 1.0299 – 1.0335 mg/L for all three graphs. Most replicated points are very close in value with slight variance.

Analysis

With values ranging between 1.0290 and 1.0350 mg/L density measurements (DM1) showed a dispersed pattern with no evident trend varying over the entire water column. Subsequently, some of the density measurements were replicated to confirm DM1 values and to test the methodology error/validity. To test the methodology key points were reconsidered and intervals of three for replication in density measurement 2 (DM2) and then again in density measurement 3 (DM3) graphs. Re-measurement of select points checks that some of our DM1 measurements were outliers. Confirming validity of key points (355ft, 515ft, 525 ft) by confirming some of the initial measurements this also resulted in the presence of measurement outliers which confirmed that single point measurements may be insufficient as part of this method. This method is valid but still suffers from measurement error and possibly requires much repetitive measurement for confirmation.

Many probable physical drivers that would homogenize the water with depth include temperature, refresh rate of new water in the well, and upward dispersion/diffusion. However, they are conflicting by gravity settling constituents in the deeper water. Transposing DM2 and DM3 to augment DM1 and then gain better graphic on the slightly increasing density with increasing depth. This confirms our initial thoughts of the potential few drivers that can counteract gravity in the form of denser fluid consistent to a greater depth.

Chemical drivers can and have existed in the form of oxidation and reduction, but have recently been deterred with fiberglass well casings. Also occasions of mineral growth from solids precipitation provides a secondary source for groundwater constituents.

Because of the unique hydrogeology in WIPP well network, there exists many mechanisms that change water densities. Karst terrain connectivity due to fractures, fissures, and dissolution, natural water flows from the surface, infiltration, and activities associated with well development can disturb the wells' ranges of water influx rate and total dissolved solids (TDS). The transmissivity range of the Culebra exhibits how diverse dissolution and water densities can occur in a single aquifer. Considering the complex nature of heterogeneous geology and brine composition further aquifer analysis needs to be done for proper characterization of water column composition. This method may also lead to more accurate quantification of groundwater flow directions and gradients (Vento and Bowman 2019).

Hydrostatic Pressure Head

The hydrology team is primarily interested in a well-defined pattern of varying density with complexity in the well. The results concluded with potentially linear characteristics showing that this measurement method may not be as well defined as first thought. Subsequently, this entailed a concern in describing the potential affect the mixed densities measured would have on the physical metrics of the water column.

Using the graph in Table 3 values 1.0299 - 1.0335 mg/L, the equation for pressure used

$$\boldsymbol{P} = \boldsymbol{\rho} * \boldsymbol{g} * \boldsymbol{H}$$

and freshwater conversion factors to calculate our maximum and minimum pressure values where $\boldsymbol{P}$ is pressure (units), $\boldsymbol{\rho}$ is density (units), $\boldsymbol{g}$ is gravity (units), and $\boldsymbol{H}$ is head (units). Using these two values were calculated for the change in pressure given the minimum and maximum densities:

$$P_1 = \frac{1.0335\frac{mg}{L} * 447.35ft}{2.31} = 200.15\ psi$$

$$P_2 = \frac{1.0299\frac{mg}{L} * 447.35ft}{2.31} = 199.45\ psi$$

$$\Delta P = P_1 - P_2 = 0.697\ psi,$$

giving a potential pressure difference of 0.697 psi for the water column depending upon where in the column is sample. Using 2.31ft freshwater head per lb. of water pressure, calculation for the potential change in head given the two densities as:

$$0.6972\ psi \times \frac{2.31}{1\ psi}\ Feet\ of\ Freshwater\ head = 1.608\ ft$$

5. CONCLUSION

In the search for understanding the long term groundwater management it is essential to comprehend all the potential parameters that will successfully characterize the geology and hydrology. It is important to consider different variables for the heterogeneous complex nature of hydrogeology at the WIPP site. This project ensued how much density can vary throughout a water column. Just selecting certain points can lead to skewed results that do not justify the well characterization. Many points if not all need to be redone as to not have a bias calculations for the outcome.

Applying this methodology to other wells can lead to understanding the dominant mechanics of groundwater constituents with respect to wells and their relationship to the physical characteristics of the aquifers in which they reside. Realizing hydrologic links between wells helps us have a stronger grasp on the geochemical processes that are being seen and may lead to improved predictions. Understanding this stratification can possibly explain fate and transport of the trace metals and other constituents (Vento and Bowman 2019).

This methodology needs to be applied to other wells to understand the dominant mechanisms of groundwater constituents relative to their residing aquifers and their relationship with these physical characteristics. Making the connections and links of the geochemical processes and hydrology can help us interpret and make predictions of the groundwater flow. Understanding this stratification can perhaps explain fate and transport of the trace metals and other constituents.

The key note from this method is iteration, meaning the repetition of the experiment many times. It is a labor intensive method, but the results show potential valuable data. Due to the heterogeneous nature of groundwater at the WIPP site, their needs to be an account for different dimensions to get a better picture of what is going on in the subsurface. This technique is vulnerable to human error and measurements must be taken with the utmost patience and a dedication to precision and accuracy. As this is an effective procedure to determine well stratification, its application into groundwater characterization should be considered. The stochastic nature of hydrogeology means there are more variables at work to consider as these variables can help predict and model groundwater flow and gradients.

Additional work should focus on three areas:

1) Confirmation of this method using a hydrometer can give quality assurance as a second independent method. Regrettably, for this experiment, the sample bottle sizes were too small to be able to use the hydrometers at SNL.
2) Wells with different hydraulic characteristics for proceeding experiments for comparison. The unique characteristics of well H-6bR gave us a relatively low transmissivity provided depicting gravity dominant stratification. Wells with a higher transmissivity might permit for other processes to dominate and provide other insight.
3) Understanding the chemically dominant TDS components can help serve as links between the geochemical processes and hydrology activity between wells. Some components like NaCl which is dominant at H-6bR can help us chose measurement and detection instrumentation.

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APPENDIX A.

Sample Set: DM1

Sample Number	Depth (ft)	Wt. #1 (g)	Density #1	Wt. #2 (g)	Density #2	Wt. #3 (g)	Density #3	Average Density	% Relative Standard Deviation (RSD)
1-H6BR-296-A	297.35	10.3105	1.0311	10.2929	1.0293	10.3104	1.0310	1.0305	0.0010
2-H6BR-296-B	300.00	10.2889	1.0289	10.3234	1.0323	10.2955	1.0296	1.0303	0.0018
3-H6BR-311-A	312.35	10.3089	1.0309	10.3173	1.0317	10.3379	1.0338	1.0321	0.0014
4-H6BR-311-B	315.00	10.3174	1.0317	10.3030	1.0303	10.3357	1.0336	1.0319	0.0016
5-H6BR-326-A	327.00	10.3186	1.0319	10.3222	1.0322	10.3260	1.0326	1.0322	0.0004
6-H6BR-326-B	330.00	10.3182	1.0318	10.2832	1.0283	10.3260	1.0326	1.0309	0.0022
7-H6BR-341-A	342.35	10.3290	1.0329	10.2989	1.0299	10.3365	1.0337	1.0321	0.0019
8-H6BR-341-B	345.00	10.2787	1.0279	10.2965	1.0297	10.3253	1.0325	1.0300	0.0023
9-H6BR-356-A	357.35	10.3109	1.0311	10.2986	1.0299	10.3179	1.0318	1.0309	0.0009
10-H6BR-356-B	360.00	10.3515	1.0352	10.3331	1.0333	10.3360	1.0336	1.0340	0.0010
11-H6BR-371-A	372.35	10.3035	1.0304	10.3260	1.0326	10.3281	1.0328	1.0319	0.0013
12-H6BR-371-B	375.00	10.3216	1.0322	10.3073	1.0307	10.2948	1.0295	1.0308	0.0013
13-H6BR-386-A	387.35	10.3364	1.0336	10.3053	1.0305	10.3408	1.0341	1.0328	0.0019
14-H6BR-386-B	390.00	10.3065	1.0307	10.3033	1.0303	10.3643	1.0364	1.0325	0.0033
15-H6BR-401-A	402.35	10.3156	1.0316	10.2873	1.0287	10.3133	1.0313	1.0305	0.0015
16-H6BR-401-B	405.00	10.3040	1.0304	10.3244	1.0324	10.3147	1.0315	1.0314	0.0010
17-H6BR-416-A	417.35	10.3043	1.0304	10.3212	1.0321	10.2488	1.0249	1.0291	0.0037
18-H6BR-416-B	420.00	10.3246	1.0325	10.2982	1.0298	10.3114	1.0311	1.0311	0.0013
19-H6BR-431-B	432.35	10.3040	1.0304	10.2948	1.0295	10.3255	1.0326	1.0308	0.0015
20-H6BR-431-A	435.00	10.3101	1.0310	10.3179	1.0318	10.3338	1.0334	1.0321	0.0012
21-H6BR-446-A	447.35	10.3312	1.0331	10.3461	1.0346	10.3625	1.0363	1.0347	0.0015
22-H6BR-446-B	450.00	10.3309	1.0331	10.3263	1.0326	10.3353	1.0335	1.0331	0.0004
23-H6BR-461-A	462.35	10.3206	1.0321	10.3133	1.0313	10.3220	1.0322	1.0319	0.0005
24-H6BR-461-B	465.00	10.3420	1.0342	10.3089	1.0309	10.3455	1.0346	1.0332	0.0020
25-H6BR-476-A	477.35	10.3127	1.0313	10.3086	1.0309	10.3588	1.0359	1.0327	0.0027
26-H6BR-476-B	480.00	10.3370	1.0337	10.2998	1.0300	10.3200	1.0320	1.0319	0.0018
27-H6BR-491-A	492.35	10.3326	1.0333	10.3262	1.0326	10.3218	1.0322	1.0327	0.0005
28-H6BR-491-B	495.00	10.3229	1.0323	10.3038	1.0304	10.2957	1.0296	1.0307	0.0014
29-H6BR-506-A	507.35	10.1030	1.0103	10.3140	1.0314	10.3163	1.0316	1.0244	0.0120
30-H6BR-506-B	510.00	10.2945	1.0295	10.3139	1.0314	10.3174	1.0317	1.0309	0.0012
31-H6BR-521-A	521.14	10.3331	1.0333	10.3160	1.0316	10.2963	1.0296	1.0315	0.0018
32-H6BR-521-B	525.00	10.3392	1.0339	10.3083	1.0308	10.2944	1.0294	1.0314	0.0022
33-H6BR-536-A	537.35	10.3029	1.0303	10.2903	1.0290	10.3031	1.0303	1.0299	0.0007
34-H6BR-536-B	540.00	10.3043	1.0304	10.3074	1.0307	10.3013	1.0301	1.0304	0.0003
35-H6BR-551-A	552.35	10.2888	1.0289	10.2823	1.0282	10.3108	1.0311	1.0294	0.0015
36-H6BR-551-B	555.00	10.3402	1.0340	10.3335	1.0334	10.3502	1.0350	1.0341	0.0008

Sample Number	Depth (ft)	Wt. #1 (g)	Density #1	Wt. #2 (g)	Density #2	Wt. #3 (g)	Density #3	Average Density	% Relative Standard Deviation (RSD)
37-H6BR-566-A	567.35	10.3298	1.0330	10.2875	1.0288	10.3136	1.0314	1.0310	0.0021
38-H6BR-566-B	570.00	10.3343	1.0334	10.3074	1.0307	10.3100	1.0310	1.0317	0.0014
39-H6BR-581-A	582.35	10.3179	1.0318	10.3594	1.0359	10.2992	1.0299	1.0326	0.0030
40-H6BR-581-B	585.00	10.3184	1.0318	10.3454	1.0345	10.3224	1.0322	1.0329	0.0014
41-H6BR-596-A	597.35	10.3346	1.0335	10.2917	1.0292	10.3224	1.0322	1.0316	0.0021
42-H6BR-596-B	600.00	10.3434	1.0343	10.3206	1.0321	10.3224	1.0322	1.0329	0.0012
43-H6BR-611-A	612.35	10.3502	1.0350	10.3474	1.0347	10.3278	1.0328	1.0342	0.0012
44-H6BR-611-B	615.00	10.3297	1.0330	10.3375	1.0338	10.3381	1.0338	1.0335	0.0005
45-H6BR-626-A	627.35	10.3357	1.0336	10.3223	1.0322	10.3381	1.0338	1.0332	0.0008
46-H6BR-626-B	630.00	10.3453	1.0345	10.3318	1.0332	10.2775	1.0278	1.0318	0.0035

Sample Set: DM2

Sample Number	Depth(ft)	Wt. #1 (g)	Density #1	Wt. #2 (g)	Density #2	Wt. #3 (g)	Density #3	Average Density	% Relative Standard Deviation (RSD)
1-H6BR-296-B	300	10.3060	1.0306	10.3095	1.0310	10.3111	1.0311	1.0309	0.0003
1-H6BR-296-B	300	10.3060	1.0306	10.3095	1.0310	10.3111	1.0311	1.0309	0.0003
5-H6BR-326-A	327	10.3193	1.0319	10.3166	1.0317	10.3229	1.0323	1.0320	0.0003
5-H6BR-326-A	327	10.3193	1.0319	10.3166	1.0317	10.3229	1.0323	1.0320	0.0003
8-H6BR-341-B	345	10.3094	1.0309	10.3283	1.0328	10.3059	1.0306	1.0315	0.0012
8-H6BR-341-B	345	10.3094	1.0309	10.3283	1.0328	10.3059	1.0306	1.0315	0.0012
10-H6BR-356-B	360	10.2980	1.0298	10.3075	1.0308	10.3192	1.0319	1.0308	0.0010
10-H6BR-356-B	360	10.2980	1.0298	10.3075	1.0308	10.3192	1.0319	1.0308	0.0010
13-H6BR-386-A	387	10.3076	1.0308	10.3407	1.0341	10.3499	1.0350	1.0333	0.0022
13-H6BR-386-A	387	10.3076	1.0308	10.3407	1.0341	10.3499	1.0350	1.0333	0.0022
17-H6BR-416-A	417	10.3170	1.0317	10.3109	1.0311	10.3033	1.0303	1.0310	0.0007
17-H6BR-416-A	417	10.3170	1.0317	10.3109	1.0311	10.3033	1.0303	1.0310	0.0007
21-H6BR-446-A	447	10.3178	1.0318	10.3347	1.0335	10.3334	1.0333	1.0329	0.0009
21-H6BR-446-A	447	10.3178	1.0318	10.3347	1.0335	10.3334	1.0333	1.0329	0.0009
24-H6BR-461-B	465	10.3277	1.0328	10.3333	1.0333	10.3029	1.0303	1.0321	0.0016
24-H6BR-461-B	465	10.3277	1.0328	10.3333	1.0333	10.3029	1.0303	1.0321	0.0016
27-H6BR-491-A	492	10.2924	1.0292	10.3222	1.0322	10.3320	1.0332	1.0316	0.0020
27-H6BR-491-A	492	10.2924	1.0292	10.3222	1.0322	10.3320	1.0332	1.0316	0.0020
29-H6BR-506-A	507	10.3214	1.0321	10.3079	1.0308	10.3024	1.0302	1.0311	0.0009
29-H6BR-506-A	507	10.3214	1.0321	10.3079	1.0308	10.3024	1.0302	1.0311	0.0009
30-H6BR-506-B	510	10.2843	1.0284	10.3087	1.0309	10.3252	1.0325	1.0306	0.0020
30-H6BR-506-A	510	10.2843	1.0284	10.3087	1.0309	10.3252	1.0325	1.0306	0.0020
32-H6BR-521-B	525	10.3283	1.0328	10.3115	1.0312	10.3000	1.0300	1.0313	0.0014
32-H6BR-521-B	525	10.3283	1.0328	10.3115	1.0312	10.3000	1.0300	1.0313	0.0014
35-H6BR-551-A	552	10.3356	1.0336	10.3163	1.0316	10.3393	1.0339	1.0330	0.0012

Sample Number	Depth(ft)	Wt. #1 (g)	Density #1	Wt. #2 (g)	Density #2	Wt. #3 (g)	Density #3	Average Density	% Relative Standard Deviation (RSD)
35-H6BR-551-A	552	10.3356	1.0336	10.3163	1.0316	10.3393	1.0339	1.0330	0.0012
36-H6BR-551-B	555	10.3297	1.0330	10.3385	1.0339	10.3206	1.0321	1.0330	0.0009
36-H6BR-551-B	555	10.3297	1.0330	10.3385	1.0339	10.3206	1.0321	1.0330	0.0009
40-H6BR-581-B	585	10.3229	1.0323	10.3231	1.0323	10.3251	1.0325	1.0324	0.0001
40-H6BR-581-B	585	10.3229	1.0323	10.3231	1.0323	10.3251	1.0325	1.0324	0.0001
42-H6BR-596-B	600	10.3037	1.0304	10.3082	1.0308	10.3366	1.0337	1.0316	0.0017
42-H6BR-596-B	600	10.3037	1.0304	10.3082	1.0308	10.3366	1.0337	1.0316	0.0017
43-H6BR-611-A	612	10.3144	1.0314	10.3390	1.0339	10.3450	1.0345	1.0333	0.0016
43-H6BR-611-A	612	10.3144	1.0314	10.3390	1.0339	10.3450	1.0345	1.0333	0.0016
46-H6BR-626-B	630	10.3037	1.0304	10.3508	1.0351	10.3399	1.0340	1.0331	0.0024
46-H6BR-626-B	630	10.3037	1.0304	10.3508	1.0351	10.3399	1.0340	1.0331	0.0024

Sample Set: DM3

Sample Number	Depth(ft)	Wt. #1 (g)	Density #1	Wt. #2 (g)	Density #2	Wt. #3 (g)	Density #3	Average Density	% Relative Standard Deviation (RSD)
3-H6BR-311-A	312.35	10.2998	1.0300	10.3198	1.0320	10.3279	1.0328	1.0316	0.0014
7-H6BR-341-A	342.35	10.3260	1.0326	10.3023	1.0302	10.3395	1.0340	1.0323	0.0018
9-H6BR-356-A	357.35	10.3098	1.0310	10.3012	1.0301	10.3202	1.0320	1.0310	0.0009
11-H6BR-371-A	372.35	10.3046	1.0305	10.3230	1.0323	10.3275	1.0328	1.0318	0.0012
12-H6BR-371-B	375	10.3186	1.0319	10.3094	1.0309	10.3048	1.0305	1.0311	0.0007
15-H6BR-401-A	402.35	10.3185	1.0319	10.2741	1.0274	10.3089	1.0309	1.0301	0.0023
18-H6BR-416-B	420	10.3003	1.0300	10.3026	1.0303	10.3207	1.0321	1.0308	0.0011
23-H6BR-461-A	462.35	10.2954	1.0295	10.3167	1.0317	10.3342	1.0334	1.0315	0.0019
26-H6BR-476-B	480	10.3610	1.0361	10.2808	1.0281	10.3266	1.0327	1.0323	0.0039
28-H6BR-491-B	495	10.3084	1.0308	10.3209	1.0321	10.3017	1.0302	1.0310	0.0009
31-H6BR-521-A	522.35	10.3466	1.0347	10.2986	1.0299	10.2895	1.0290	1.0312	0.0030
34-H6BR-536-B	540	10.3102	1.0310	10.3046	1.0305	10.3075	1.0308	1.0307	0.0003
38-H6BR-566-B	570	10.3371	1.0337	10.3142	1.0314	10.3081	1.0308	1.0320	0.0015
45-H6BR-626-A	627.35	10.3491	1.0349	10.3256	1.0326	10.3201	1.0320	1.0332	0.0015
46-H6BR-626-B	630	10.3111	1.0311	10.3519	1.0352	10.3176	1.0318	1.0327	0.0021