AEGIS

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Nevada National Security Site (NNSS)
Mission Support and Test Services, LLC. (MSTS)
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PO Box 98521, M/S NLV018
Las Vegas, NV 89193-8521

Attention: Pamela Grant

Subject: Water Supply Well Chemical Analysis and Evaluation

This report presents information, findings, conclusions and recommendations regarding the water chemistry analytical results for six existing water supply wells at the Nevada National Security Site (NNSS) near Las Vegas, Nevada. The goal was to provide NNSS staff with information to support planned well rehabilitation and well operations.

Table of Contents	Page

Figures

Tables

Report Acronyms

ATP	Adenosine triphosphate
ID	Inside diameter
LSI	Langelier Saturation Index
NNSS	Nevada National Security Site
MSTS	Mission Support and Test Services
OD	Outside diameter
ORP	Oxidation-Reduction Potential
PWL	Pumping water level
SWL	Static water level
WSE	Water Systems Engineering.

1.0 Introduction

Aegis Groundwater Consulting, LLC (Aegis) was contracted by the Nevada National Security Site (NNSS)/Mission Support and Test Services (MSTS) under contract PUR-0012754 dated September 12, 2025, to provide consulting services related to groundwater sampling and analysis of chemical and microbiological data from six (6) onsite water supply wells.

2.0 Background

The NNSS utilizes six (6) water supply wells, five (5) for onsite potable water, and the sixth for industrial and construction water only. NNSS staff provided Aegis with readily available information regarding the construction of these six wells, along with the location of these wells. Figure 1 is a highly generalized well location map, and more precise well locations can be found at

https://nevada.usgs.gov/doe_nv/

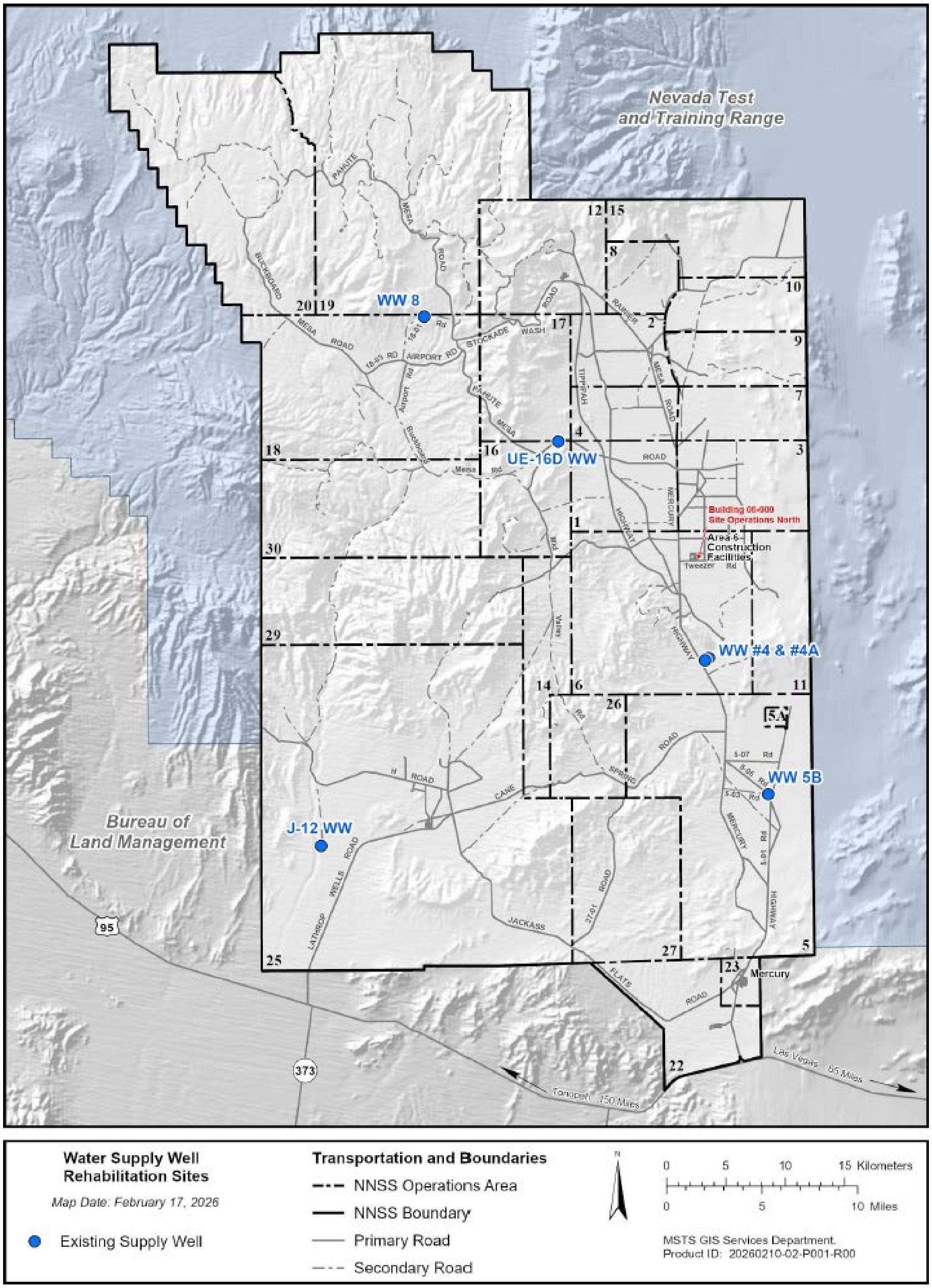
Table 1 presents a basic list of well construction information provided as part of the NNSS background data. A review of the provided well construction information suggests that some of the wells are not cased for their entire reported depth but rather are uncased or open hole completions.

The critical construction feature will be the depth to the “rehabilitation interval”, specifically the screened or perforated section of each well, that would be the focus of cleaning and/or rehabilitation efforts. In some cases, the depth to all screened or perforated intervals may be so much as to warrant consideration as to the potential efficacy of rehabilitation.

Additionally, the diameter of the well or wells, within the rehabilitation interval, may preclude some rehabilitation measures because of the small working diameter of the well.

Aegis will use the abbreviated well designations, as presented in Table 1, for this report.

Well construction data was provided by NNSS. Water quality analysis was performed by Water Systems Engineering (WSE) of Ottawa, Kansas. A review of both well construction and the WSE report is encouraged, as they form the basis of Aegis’ review, conclusion, and recommendations.



This document has been reviewed by a DC/RO and has been determined to be UNCLASSIFIED, not UCNI, and contains no CUI based on current classification guidance. This review does not constitute a review for CUI outside of classification guidance.
Name: Alexander Kisfalvi
Date: 2/18/2026
NNSS eDC/RO ID: 88036

This document has been reviewed by a DC/RO and has been determined to be UNCLASSIFIED, not UCNI, and contains no CUI based on current classification guidance. This review does not constitute a review for CUI outside of classification guidance.
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Figure 1 – Water Supply Wells (Graphic courtesy of NNSS)

Table 1 NNSS Water Supply Wells for Chemical Analysis

Well ID	Location	Depth (ft)	Construction Detail	Year Installed
Well 4	Area 06	1,479	Gravel packed slotted casing	1981
Well 4A	Area 06	1,516	Gravel packed, slotted casing	1990
Well 5B	Area 05	900	Slotted casing	1951
Well 8	Area 18	5,490	Slotted casing	1962
Well J-12	Area 25	1,139	Slotted casing, deepened with open hole	1957, deepened 1968
Well 16D	Area 16	3,000	165' perforated casing	1977

Our understanding is that only Well 16D is not part of the potable water system and is used primarily for construction and industrial use. The other five wells are operated to meet current potable water quality demands.

3.0 Groundwater Sample Collection

Aegis and NNSS staff collaborated on a water well sampling plan for the collection of representative groundwater samples from these six wells. The sampling plan identified well purging times, sample port disinfection, sample collection procedures, and the requested sample analysis. The sampling plan is included in Appendix A.

Aegis provided NNSS staff with prelabeled sample collection bottles, which were provided to Aegis by the contract laboratory, Water Systems Engineering (WSE). NNSS staff collected water samples, along with field measurements during the sampling event. The field records are included in Appendix B. Table 2 summarizes the field records and measurements collected during the October 27, 2025, sampling event.

Once the samples had been collected, the NNSS staff shipped them to WSE under chain-of-custody procedures.

4.0 Laboratory Results

WSE received the samples sent by NNSS field staff. One sample, 5B "casing" had a low concentration of residual chlorine, and was rejected after consultation between WSE, Aegis and NNSS. NNSS resampled Well 5B and submitted the new sample to WSE for analysis. WSE conducted the requested laboratory analysis. Their laboratory report is included in Appendix C.

This report relies on the data provided by WSE for our reporting on findings, discussion of those findings, and our conclusions. As such, we strongly encourage the reader to review and understand the WSE report as the context for our report.

The following sections present an overview of the general physical parameters, general mineral concentrations, and the microbiological results for the six wells. Table 3 summarizes the general physical measurements, Table 4 the general mineral concentrations, and Table 5 the reported microbiological results.

NNSS Well Designation	4		4A		5B		8		J-12		16D	
Sample date	10/27/25	10/27/25	10/27/25	10/27/25	11/18/25	10/27/25	10/27/25	10/27/25	10/27/25	10/27/25	10/27/25	10/27/25
Purge time, min	0	60	0	60	0	60	1	150	0	60	0	60
Collection Time	1022	1123	1010	1112	1236	1338	845	1115	829	930	930	1030
Flow rate, GPM	475	475	450	450	250	250	200	200	600	600	140	140
Purge Volume, gallons	0	28500	0	27000	0	15000	200	30000	0	36000	0	8400
Temperature, C	24.2	24.8	24	24.8	23.2	23.7	21.1	24.8	24.3	26.6	20.2	24.3
Specific conductance, uS/cm	394.7	400.4	389.5	391.1	532	519	197.5	198.5	244.8	263.7	644	657
pH	7.97	7.91	7.93	7.93	8.39	8.49	7.35	7.37	6.84	7.01	7.32	7.23
Turbidity, NTU	24	0.19	15.3	0.17	1.06	0.41	4.04	0.45	41.7	1.07	0.39	0.33
Reported depth, feet	1436		1457		900		2936		878		2117	

Table 2 NNSS Wells – Field Sampling Measurements

Notes: Grey columns are for the “casing” samples, blue columns are for the “aquifer” samples.

Well 5B had the “casing” sample recollected, as indicated by the different sampling date.

NNSS Well Designation	4		4A		5B		8		J-12		16D	
Sample date	10/27/25	10/27/25	10/27/25	10/27/25	11/18/25	10/27/25	10/27/25	10/27/25	10/27/25	10/27/25	10/27/25	10/27/25
Analysis date												
pH	7.67	7.83	7.87	7.84	8.33	8.39	7.47	7.31	6.74	7.06	7.28	7.41
Total dissolved solids, mg/l	285	286	282	277	373	346	131	148	197	199	442	441
Conductivity, uS/cm	396	397	391	385	518	480	182	205	274	277	614	612
ORP, mV	199.8	208	203.9	209.7	334.1	188.1	200.3	199	263.6	198.7	211.9	208.6
Langelier Saturation Index	-0.4	-0.32	-0.21	-0.26	-0.38	-0.25	-1.84	-2.16	-2.1	-1.55	-0.04	0.09

Table 3 NNSS Wells – Collected Samples: General Physical Parameters

Notes: Grey columns are for the “casing” samples, blue columns are for the “aquifer” samples.

Well 5B had the “casing” sample recollected, as indicated by the different sampling date.

NNSS Well Designation	4		4A		5B		8		J-12		16D	
Sample date	10/27/25	10/27/25	10/27/25	10/27/25	11/18/25	10/27/25	10/27/25	10/27/25	10/27/25	10/27/25	10/27/25	10/27/25
Analysis date												
Phenolphthalein Alkalinity*	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Alkalinity*	152	152	140	168	128	148	72	68	88	108	272	288
Hydroxide Alkalinity*	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Carbonate Alkalinity*	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Bicarbonate Alkalinity*	152	152	140	168	128	148	72	68	88	108	272	288
Total Hardness*	80	96	92	96	36	32	16	16	52	50	268	296
Carbonate Hardness	80	96	92	96	36	32	16	16	52	50	268	288
Non-Carbonate Hardness	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	8
Calcium*	72	60	76	60	20	20	8	6	20	28	236	224
Magnesium*	8	36	16	36	16	12	8	10	32	22	32	72
Sodium (as Na)	78.2	77.5	79	80.8	95.6	98.3	34.7	33.5	62.3	62.5	43.2	44.6
Potassium (as K)	5.5	5.4	5.6	5.6	13	13	3.8	3.9	5	5	3.7	3.9
Phosphorus, Reactive (as PO43-)	0.09	ND	0.06	0.06	0.2	0.26	0.33	0.08	27.5	14.6	0.07	0.06
Chlorides (as Cl)	29.6	27.6	19.2	23.6	30.8	24.8	16	14.4	22.4	20.4	28.4	26
Nitrate (Nitrogen)	4.1	4.6	4.2	4.3	3.1	3.2	1.3	1.3	1.8	2.1	ND	ND
Chlorine (as Cl)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dissolved Iron (as Fe2+)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Suspended Iron (as Fe3+)	1.43	ND	0.74	0.04	ND	ND	0.16	ND	0.14	ND	ND	0.02
Iron Total (as Fe)	1.43	ND	0.74	0.04	ND	ND	0.16	ND	0.14	ND	ND	0.02
Iron (resuspended)	2.51	ND	1.69	ND	0.7	ND	0.65	ND	6.38	0.08	0.33	0.05
Copper (as Cu)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Manganese (as Mn)	0.032	0.016	0.013	ND	0.025	0.017	0.035	0.008	0.241	0.069	0.018	0.019
Sulfate (as SO4)	41	41	36	34	62	60	10	10	20	21	62	57
Silica (as SiO2)	61.5	61.8	63.4	64.6	58.9	57.7	46	47.1	62.9	60.1	26.5	30.4
Tannin/Lignin	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Organic Carbon (C)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table 4 NNSS Wells – Collected Samples: General Mineral Concentrations

Notes: Grey columns are for the "casing" samples, blue columns are for the "aquifer" samples.

Well 5B had the "casing" sample recollected, as indicated by the different sampling date.

NNSS Well Designation	4		4A		5B		8		J-12		16D	
Sample date	10/27/25	10/27/25	10/27/25	10/27/25	11/18/25	10/27/25	10/27/25	10/27/25	10/27/25	10/27/25	10/27/25	10/27/25
Analysis date												
Plate count, colonies/ml	31	5	13	29	29	0	31	2	>1500	1,247	35	5
Anerobic bacteria, %	<10	<10	<10	<10	<10	<10	<10	<10	30	<10	40	<10
Sulfate reducing bacteria	Negative	Negative	Negative	Negative	Negative	Negative	Negative	Negative	Negative	Negative	Negative	Negative
Fe/Mn Oxidizing bacteria	Negative	Negative	Negative	Negative	Positive	Negative	Negative	Negative	Negative	Negative	Positive	Negative
ATP (cells/ml) Initial	46000	34000	35000	36000	32000	33000	48000	29000	83000	40000	37000	47000
ATP (cells/ml) 24 Hour	45000	31000	27000	10000	24000	19000	16000	19000	45000	19000	10000	14000
Total coliform	Negative	Negative	Negative	Negative	Negative	Negative	Negative	Negative	Negative	Negative	Negative	Negative
E.coli	Negative	Negative	Negative	Negative	Negative	Negative	Negative	Negative	Negative	Negative	Negative	Negative

Table 5 NNSS Wells – Collected Samples: Microbiological Results.

Note: Grey columns are for the "casing" samples, blue columns for the "aquifer" samples

Well 5B had the "casing" sample recollected, as indicated by a different sampling date

5.0 Findings

The following sections present our findings related to individual well construction, and then the field measurements, along with the laboratory measurements, and the geochemical and microbiological analysis reports from WSE for the six wells. Overall, the findings will be summarized in this section, rather than an exhaustive review of the data tables and appendices.

5.1 Well Construction

The following summarizes key components of the reported well construction, per individual well, as it relates to well maintenance and rehabilitation, as drawn from the NNSS-provided field records.

5.1.1 Well 4

- Rotary air/foam drilling, completed in 1982, to a reported depth of 1438 feet.
- Casing is 13 3/8-inch OD, 12.615-inch ID, 54.5 lb/foot steel.
- Vertically slotted (1/4 inch wide by 8 inch long) well casing from 902 to 1436 feet below grade.
- Static water level (SWL) is reported to be about 842.06 feet below grade (9/8/2025).
- The rehabilitation interval would be SWL to 1436 feet, or about 594 feet of vertically slotted well casing.

5.1.2 Well 4A

- Rotary air/foam drilling, completed in 1990, to a reported depth of 1,516 feet.
- Casing is 13 3/8-inch OD, 12.615-inch ID, 54.5 lb/foot steel from 536 to 1,516 feet.
- Vertically slotted (1/4 inch wide by 8 inch long) well casing from 1,066 to 1,281 feet, and from 1,365 feet to 1,457 feet below grade. There is a blank casing section from 1,281 to 1,365 feet, or about eighty-four (84) feet.
- Static water level (SWL) is reported to be about 842.56 feet below grade (9/8/2025).
- The rehabilitation interval would be about SWL to 1,457 feet, or about 614.5 feet of vertically slotted well casing.

5.1.3 Well 5B

- Cable tool drilling, completed in 1951, to a reported depth of 1,516 feet.
- Top casing is 12-inch ID from surface to about 440 feet, secondary casing (liner) is 10-inch ID, from 440 to 900 feet.
- Vertically slotted well casing from 700 to 900 feet.
    - It is possible that the vertical perforations are Mills Knife slots but could only be confirmed with video log.

- Static water level (SWL) is reported to be about 689.58 feet below grade (9/8/2025).
- The rehabilitation interval would be about SWL’ to 900 feet, or about 210.4 feet of vertically slotted well casing.

5.1.4 Well 8

- Rotary air/foam drilling, completed in 1963, to a reported depth of 5,490 feet.
- Blank casing of varying diameters and wall thickness extends to about 2,940 feet.
- “Gun perforated” 11 ¾-inch OD blank casing is reported from 1250 to 1300 feet, 1450 to 1500 feet, and 1630 to 1780 feet.
- 7 5/8-inch OD slotted liner was installed from 2038 to 2070 feet, and from 2137 to 2170 feet.
- The uncased section of the well is from 2940 feet to 5490 feet.
- Static water level is reported to be about 1,078.44 feet below grade (11/7/2017).
- The rehabilitation interval would be SWL to 2,170 feet, or about 1,091.5 feet of vertically slotted well casing.

5.1.5 Well J12

- Cable tool drilling, originally completed in 1957, at 15 ¾-inch OD to a reported depth of 887 feet.
- Well was deepened in 1968 to 1,139 feet at 12 ¾-inch OD.
- There is a reported perforated interval from about 794 to 867 feet below grade.
- Static water level is reported to be about 739.03 feet below grade (8/27/2025).
- The rehabilitation interval would be about SWL’ to 1,193 feet, or about 454 feet of vertically slotted well casing.

5.1.6 Well 16D

- Initial rotary air/foam and mud drilling was completed in 1977, to a reported maximum depth of 3,000 feet.
- Initial 8 ¾-inch OD hole was advanced to 2,119 feet, to facilitate coring and water sampling. Subsequently it was reamed to 9 7/8-inch OD to 2119 feet.
- 7.0-inch OD/6.456-inch ID blank steel casing (reported casing wall of 0.272 inches) installed to about 2,117 feet and cemented into place.
- Below 2,119 feet, a 6 ¼ inch OD open hole was drilled to the reported total depth of 3,000 feet, for the purpose of additional coring, water sampling and geophysical logging.
- 1981 the 7-inch OD casing was (gun) perforated from 1,145 feet to 1,310 feet, using a total of 260 holes, reportedly two (2) holes per foot of casing.
- Static water level is reported to be about 787.03 feet below grade (7/5/2022).
- The rehabilitation interval would be SWL’ to 1,145 feet, or about 358 feet of ”gun perforated” well casing.

5.2 Groundwater Geochemistry and Microbiology

Findings are presented for both the casing and aquifer samples, and first for individual wells, then a summary of the collective findings. In general, the findings reporting format for the individual wells will be a summary of field “physical” measurements, lab “physical” measurements, general mineral analysis reports, and finally microbiological analysis reports.

Collectively, the field and laboratory data will be summarized by data found to be of interest, from the individual well data, and then presented as highest value, lowest value, and the average value of the four other remaining wells. Specifically, the data will be presented as follows:

- Temperature, pH, specific conductance/conductivity, oxidation-reduction potential (ORP) and the Langelier Saturation Index (LSI). No temperatures were measured by WSE for the samples received.
- General mineral concentrations.
- Microbiology. Discussion of specific bacterial species will be in the “Discussion” section, and in the WSE reports in Appendix C.

Groundwater chemistry, or water “types” are used in our descriptions of the general mineral chemistry of each well. Groundwater types are primarily determined by the concentrations of dissolved ions, which can be categorized into cations and anions, with the “type” being based on the dominant cation and anion. Describing types may aid in understanding chemistry directly related to well issues, and source water origins as seen in aquifer samples.

The following presents our findings for each individual well, starting with the shallowest reported well, then with increasing depth.

5.2.1 Individual Well Geochemistry Findings

The following sections summarize field and laboratory readings and reports for general physical measurements, general mineral chemistry, and microbiological results.

Well J-12: Reported depth of 878 feet below grade

Well J-12 was reportedly rehabilitated in July 2025, about three months prior to this sampling event.

Overall, there is a general consistency between the field and laboratory measurements and reported concentrations, of the casing versus aquifer samples collected from this well. Exceptions will be noted below.

General Physical Measurements - Field

- Lowest measured field pH
- Lowest measured field specific conductance of the six wells.
- + 2.3 C temperature rise between the casing and aquifer sample.
- Highest aquifer sample field turbidity reading reported.

General Physical Measurements – Laboratory

- pH measurements between the casing and aquifer samples were slightly less consistent, with a 0.35 difference.
- Second lowest total dissolved solids concentration, and conductivity (only Well 8 had lower reported values).
- ORP showed the second largest change between the casing and aquifer samples, second only to Well 5B. LSI was the second lowest value, with only Well 8 having a lower value.

General Mineral Concentrations - Laboratory

- The most significant reported value is the elevated reactive phosphorus concentration. The reported concentration is at least one to several orders of magnitude above the other five wells. In addition, this concentration is considered “elevated” relative to most encountered concentrations of reactive phosphorous in wells in the Southwestern United States.
- Resuspended iron concentrations were highest in both the casing and aquifer samples for this well, compared to any of the other five wells.
- Manganese concentrations were highest in both the casing and aquifer samples for this well, compared to any of the other five wells.
- Well J-12 had the second lowest sulfate concentration of the six wells sampled.
- The general geochemical composition of the Well J-12 water could be described as sodium bicarbonate water type. It should be noted that the casing sample could be qualified as a potassium-calcium bicarbonate type water, whereas the aquifer sample is a sodium bicarbonate type water.

Microbiology

- Highest reported plate count of all six wells.
- Second highest reported anaerobic bacteria percentage, but only in the casing sample. The aquifer sample, like all the other wells, was less than 10 percent (<10%).
- Highest initial ATP count for casing samples of the six wells, and second highest aquifer sample count of the six wells.
- Highest 24-Hour ATP count for the casing sample, of the six wells. The same aquifer sample count was reported for this well and two others, which was neither the highest nor lowest.

- Total coliform and E. coli were reported as negative for both the casing and aquifer samples.

Well 5B: Reported depth of 900 feet below grade

Overall, there is a general consistency between the field and laboratory measurements and reported concentrations, of the casing versus aquifer samples collected from this well. Exceptions will be noted below.

General Physical Measurements - Field

- Highest measured field pH in both the casing and aquifer samples.
- No significant difference between casing and aquifer sample temperature.
- Second highest specific conductance measurement.

General Physical Measurements – Laboratory

- Highest laboratory pH measurement.
- Second highest total dissolved solids concentration, and conductivity
- ORP showed the greatest change between the casing and aquifer samples, along with having the highest casing sample value. The reported aquifer sample ORP was consistent with the other five wells. LSI in the aquifer sample was equivalent to two of the other wells, but neither the highest nor lowest reported value

General Mineral Concentrations – Laboratory

- The most significant reported value appears to be the elevated potassium concentration. The reported concentrations are elevated above the reported concentrations for the other five wells.
- Resuspended iron was reported as not detected for this well in the aquifer sample but was present in the casing sample.
- Manganese concentrations within the average concentrations for the six wells, except for J-12, as previously mentioned.
- The general geochemical composition of the Well 5B water could be described as sodium bicarbonate water type, for both the casing and aquifer samples.

Microbiology

- Highest reported plate count of all six wells.
- Second highest reported anaerobic bacteria percentage, but only in the casing sample. The aquifer sample, like all the other wells, was less than 10 percent (<10%).
- Highest initial ATP count for casing samples of the six wells, and second highest aquifer sample count of the six wells.

- Highest 24-Hour ATP count for the casing sample, of the six wells. The same aquifer sample count was reported for this well and two others, which was neither the highest or lowest.
- Total coliform and E. coli were reported as negative for both the casing and aquifer samples.

Well 4: Reported depth of 1436 feet below grade

Overall, there is a general consistency between the field and laboratory measurements and reported concentrations, of the casing versus aquifer samples collected from this well. Exceptions will be noted below.

General Physical Measurements - Field

- Average pH measurement, compared to the other five wells, excluding the highest and lowest measurements.
- Temperature was consistent between the casing and aquifer samples.
- Specific conductance was consistent between the casing and aquifer samples and was the third highest of the six wells.
- Casing turbidity was second highest, while the aquifer sample turbidity was significantly lower.

General Physical Measurements – Laboratory

- pH readings consistent between the casing and aquifer samples, and field measurements.
- Third highest total dissolved solids concentration, and conductivity.
- ORP showed little difference between the casing and aquifer samples. The reported aquifer sample ORP was consistent with the other five wells. LSI was consistent between the casing and aquifer samples, and with the two of the other wells (Well 4A and 5B).

General Mineral Concentrations - Laboratory

- The most significant reported values appear to be calcium, which had the second highest concentration of the six wells; and the elevated total, suspended and re-suspended iron concentrations in the casing sample. The aquifer samples for these constituents were reported as not detected.
- The general geochemical composition of the Well 4 water could be described as sodium bicarbonate water type. It should be noted that the casing sample could be qualified as a calcium bicarbonate type water, whereas the aquifer sample is a sodium bicarbonate type water.

Microbiology

- Average plate count concentration, relative to the other five wells.

- The anaerobic bacteria percentage for casing sample was less than 10 percent (<10%) and aquifer sample, like all the other wells, was less than 10 percent (<10%).
- Third highest initial ATP count for casing samples of the six wells, and second highest aquifer sample count of the six wells.
- Highest 24-Hour ATP count for the casing and aquifer sample, of the six wells.
- Total coliform and E. coli were reported as negative for both the casing and aquifer samples.

Well 4A: Reported depth of 1457 feet below grade

Overall, there is a general consistency between the field and laboratory measurements and reported concentrations, of the casing versus aquifer samples collected from this well. Exceptions will be noted below.

General Physical Measurements - Field

- pH measurements were consistent with the average measurements of the other wells.
- Measured temperature was consistent, overall, with the other wells, except for Wells J12 and 16D.
- Specific conductance measurements were consistent between the casing and aquifer samples.

General Physical Measurements – Laboratory

- pH readings consistent between the casing and aquifer field measurements.
- Third lowest total dissolved solids concentration, and conductivity.
- ORP showed little difference between the casing and aquifer samples. The reported aquifer sample ORP was generally consistent with the other five wells. LSI was consistent between the casing and aquifer samples, and with two of the other wells (Well 4 and 5B).

General Mineral Concentrations - Laboratory

- The most significant reported values appear to be the elevated carbonate hardness, and calcium concentrations. Both reported values for these are the second highest of the six wells. Then total, suspended and re-suspended iron concentrations in the casing and aquifer sample. The general geochemical composition of the Well 4A water could be described as sodium bicarbonate water type. It should be noted that the casing sample could be qualified as a calcium bicarbonate type water, whereas the aquifer sample is a sodium bicarbonate type water.

Microbiology

- Average plate count concentration in the casing sample, relative to the other five wells except for Well J12. The aquifer sample was second highest, only exceeded by Well J12 as well.
- The casing sample was less than 10 percent (<10%) and aquifer sample, like all the other wells, was less than 10 percent (<10%), except for Well J12.
- Third highest initial ATP count for casing samples of the six wells, and second highest aquifer sample count of the six wells.
- Third highest 24-Hour ATP count for the casing and lowest for the aquifer sample, of the six wells.
- Total coliform and E. coli were reported as negative for both the casing and aquifer samples.

Well 16D: Reported depth of 2117 feet below grade

Overall, there is a general consistency between the field and laboratory measurements and reported concentrations, of the casing versus aquifer samples collected from this well. Exceptions will be noted below.

General Physical Measurements - Field

- pH was consistent between the casing and aquifer samples. The reported measurement was neither the highest or lowest, but average with the other three wells which were neither the highest or lowest readings.
- Greatest temperature variance (+4.1 C) between the casing and aquifer samples.
- Highest specific conductance measurement reported, for both the casing and aquifer samples.
- Turbidity measurements were nearly identical between the casing and aquifer samples.

General Physical Measurements – Laboratory

- pH readings consistent between the casing and aquifer field measurements.
- Highest total dissolved solids concentration, and conductivity.
- The casing sample ORP was the third highest reported value, and the aquifer sample ORP was the second highest.

General Mineral Concentrations - Laboratory

- There are several significantly higher or lower concentrations reported in this well, in comparison to the other five wells, as follows:
    - Elevated concentrations of bicarbonate alkalinity, and total hardness.
        - Only well with “non-carbonate” hardness.
    - Elevated concentration of calcium, highest reported.
    - Second lowest sodium concentration
    - Non-detect concentration of nitrate, which was the only non-detect for all six wells.

    - Highest concentration of sulfate
    - Highest magnesium concentration.
- The general geochemical composition of the Well 16D water could be described as calcium bicarbonate water type.

Microbiology

- Average plate count concentration in the casing sample, relative to the other five wells except for Well J12. The aquifer sample was second highest, only exceeded by Well J12 as well.
- The anaerobic bacteria percentage in the casing sample was reported as 40%; whereas the aquifer sample, like all the other wells, was less than 10 percent (<10%).
- The casing sample reported a "positive" for Fe/Mn oxidizing bacteria, but a negative for the aquifer sample.
- Highest initial ATP count for aquifer samples of the six wells,
- Third highest 24-Hour ATP count for the casing and lowest for the aquifer sample, of the six wells.
- Total coliform and E. coli was reported as negative for both the casing and aquifer samples.

Well 8: Reported depth of 2936 feet below grade

Overall, there is a general consistency between the field and laboratory measurements and reported concentrations, of the casing versus aquifer samples collected from this well. Exceptions will be noted below.

General Physical Measurements - Field

- Reported casing and aquifer was about average for the reported measurements from the other five wells.
- Second highest temperature variance (+3.7 C) is between the casing and aquifer samples.
- Lowest specific conductance of all six wells.
- Second highest casing turbidity.

General Physical Measurements – Laboratory

- pH readings consistent between the casing and aquifer field measurements.
- Lowest total dissolved solids concentration, and conductivity.
- The casing and aquifer sample ORP was the second to the lowest reported value.

General Mineral Concentrations - Laboratory

- Overall, the lowest concentrations of general minerals have been reported for this well, out of the six wells, as follows:

  - Bicarbonate and total hardness.
  - Calcium
  - Magnesium
  - Sodium
  - Chlorides
  - Reported non-detect for all iron in the aquifer samples.
  - Sulfate.
- The general geochemical composition of the Well 8 water could be described as sodium bicarbonate water type.

Microbiology

- Average plate count concentration in the casing sample, relative to the other five wells except for Well J12. The aquifer sample was second lowest, only exceeded by Well J12 as well.
- The anaerobic bacteria percentage in the casing sample was reported as <10%; as was the aquifer sample.
- The casing and aquifer samples reported a negative for both sulfate reducing and Fe/Mn bacteria.
- Second highest initial ATP count for casing samples of the six wells,
- Lowest 24-Hour ATP count for the aquifer sample, of the six wells.
- Total coliform and E. coli was reported as negative for both the casing and aquifer samples.

5.2.2 Collective Groundwater Geochemistry Findings

The following are collective findings of the overall water chemistry, field and lab measurements and reported concentrations:

- The shallowest well (J12, 878 feet) and the two deepest wells (16D, and 8, 2117 and 2936 feet, respectively) all showed greater variance in their casing vs aquifer water temperature readings, as follows:
  - J12 + 2.3 C rise
  - 16D +4.1 C rise
  - 8 + 3.7 C rise
- The specific capacitance/conductivity, and pH, were consistent between the field and laboratory measurements, and can be summarized as follows:
  - pH ranged from 7.01 (Well J12 aquifer sample) to 8.49 (Well 5B aquifer sample), with an average of 7.61 for the other four wells in the field measurements; and ranged from 7.06 (Well J12 aquifer) to 8.39 (Well 5B aquifer sample).
  - Specific conductance/conductivity (uS/m) ranged from 657 (Well 16D aquifer sample) to 198.5 (Well 8 aquifer sample) with an average of 393.5 uS/m for the other four wells in the field measurements. The laboratory measurements were very similar to the field measurements.

- Laboratory measurements of the oxidation-reduction potential (ORP, mV)) ranged from a low of 188.1(Well 5B aquifer sample), to a high of 209.7 (Well 4A aquifer sample). The average for the other four wells was 203.6 mV.
- Laboratory measurements of the Langelier Saturation Index (LSI) ranged from a low of -2.16 (Well 8 aquifer sample), to a high of 0.09 (Well 16D aquifer sample). The average LSI for the other four wells was -0.59.
- The chemical composition of casing samples for the six wells varied between potassium bicarbonate (J12) to either calcium or sodium bicarbonate for the other five wells. The chemical composition of the aquifer samples varied between calcium bicarbonate (16D) to sodium bicarbonate for the other five wells.
    - The WSE report refers to both sodium and potassium concentrations and specifically used a term of “overall congested nature” of the water. This specifically refers to the elevated concentrations for several constituents, such as sodium and potassium.
- The biological results indicate that only Well J12 which is the shallowest, are mostly inactive with respect to bacterial growth indicators (e.g., ATP), and the reported values are not excessive in our experience. Well J12 might be considered mildly microbiologically “active”.

6.0 Discussion

The following is a discussion of well as it may relate to well maintenance and well rehabilitation, along with water sampling, field measurements, and laboratory reports as they pertain to comparisons between casing and aquifer samples, suggested casing conditions, and what might be considered ambient groundwater geochemistry in the project area.

One initial observation is well depths. For comparison and discussion purposes, the project site wells are organized into three depth “groups”. Wells J12 and 5B comprise the “shallow” group, wells 4 and 4A the “intermediate” group, and wells 16D and 8 the “deep” group. Wells are depth-grouped because well depth can and will affect well chemistry, and it will also affect maintenance and rehabilitation efforts.

Wells, by age, youngest to oldest as of the date of this report, are as follows:

- 4A (36),
- 4 (44),
- 5B (46)
- 16D (49),
- 8 (64)
- J12 (69).

The average age for these six wells is 53.5 years, with a minimum of 35 years, and a maximum of 74. For general reference, the standard “lifespan” for a well is about 50 years, given construction materials and the overall installation environment. As such 3 of the 6 are less than the standard lifespan, 1 well is 57 years old, and the other 2 far exceed the average lifespan. Well age is a factor in rehabilitation for two primary reasons, which are the likelihood of the well lasting long enough to justify the cost and effort, and the second being that older wells are often considered “at risk” of casing sloughing or complete collapse because of the rehabilitation efforts, whether mechanical, chemical or both.

The wetted interval (maximum depth of rehabilitation less the static water level) is a consideration with respect to the rehabilitation effort. Well hydraulics under pumping conditions suggest that most of the water inflow occurs closest to the pump, and as such it is sometimes a consideration as to whether cleaning the entire wetted interval is cost effective. As such, when wetted intervals are long, then considerations should be given to whether the entire wetted interval should be cleaned. Additionally, considerations with respect to the severity of the suspected perforation obstruction, i.e., mineralogical, microbiological, or both, need to be made.

Well casing diameter will influence possible rehabilitation efforts, as the smaller diameter will reduce the size of tooling and equipment that can access the interior of the well. In general, well casing diameters less than six (6) inches pose challenges for conventional rehabilitation efforts, especially mechanical systems involving brushing, swabbing and airlifting. In aged wells, where casing structural integrity is in question, the proximity of hard tooling to the casing increases the risk of the casing being damaged.

The overall chemistry and microbiology of the shallow depth well group (J12 and 5B) have significant differences in sulfate, manganese, reactive phosphorus, potassium, sodium, magnesium and hardness. These differences persist between the casing and aquifer samples for both wells. With respect to microbiology, Well J12 is significantly different than Well 5B.

The overall chemistry and microbiology of the intermediate depth well group (4 and 4A) have less significant differences in sulfate, manganese, reactive phosphorus, potassium, sodium, magnesium and hardness. These differences persist between the casing and aquifer samples for both wells. One exception to this is the reported concentrations of iron (suspended, total, resuspended), which are elevated above all the other wells in the casing samples, and present in Well 4A aquifer samples. With respect to microbiology, Well 4 has a higher aquifer plate count than 4A, but it is not significantly different than any other well except for Well J12.

The overall chemistry and microbiology of the deep depth well group (16D and 8) are significantly different in silica, sulfate, manganese, chlorides, sodium, magnesium, calcium and hardness. These differences persist between the casing and aquifer samples for both wells. With respect to microbiology, Well 4 has a higher aquifer plate count than 4A, but it is not significantly different than any other well except for Well J12.

Figure 2 presents Stiff Diagrams for each of the well's water chemistry. Stiff diagrams are the creation of groundwater scientist H.A.Stiff, as a graphical means of visualizing cation and anion water chemistry, along with the overall groundwater type or facies. Stiff diagrams graphically represent and facilitate comparisons of water chemistries, by creating a unique polygonal shape for each well. The milligram per liter (mg/l) laboratory results are converted to milliequivalents per liter (meg/l) for more effective comparison, and the scale of the polygons is kept uniform, and so the size of the polygon will represent the total dissolved solids for each well aquifer sample. The following are notable:

- Overall, the major variation in the Stiff diagrams is with the cation concentrations. The general shape of the anion side of the polygons, other than size, is relatively the same. The cation side of the diagram's reinforces the general statement about well depth organization as discussed above.
- Wells J12 and 5B (shallow well depth group) share a moderately similar Stiff diagram shape, with 5B having a slightly higher sodium and potassium "tail". It is possible that these two wells may access a similar aquifer or aquifers.
- Wells 4 and 4 (intermediate well depth group) have nearly identical Stiff diagram plots, which suggests that these wells potentially access a similar aquifer or aquifers.
- Wells 16D and 8 (deep well depth group) are entirely dissimilar with respect to chemistry. The shape and mineralization differences in Well 16D are striking relative to all the other five wells; whereas Well 8 appears to be the least mineralized of the six wells and has a Stiff diagram shape much closer to Well J12.

Figure 3 is a Piper Diagram (named after the originator, Arther M. Piper) plotting both the casing and aquifer sample results. The Piper diagram presents results graphically by presenting cations and anions in the two lower triangles and then combining them into the diamond-shaped polygon in the center of the diagram. The grouping of anions, and the dispersion of the cations further reinforces the finding that the major differences in groundwater chemistry (from these samples) is within the cations, as represented in the lower left triangle. The significance of the water chemistry results and plots with respect to well maintenance and rehabilitation is that there appears to be a larger calcium concentration range which should be kept in mind when acidifying wells (if this is done) so that reprecipitation of calcium carbonate does not occur on the screened/perforated sections of the wells. This would be of particular concern for Well 16D, and possibly others.

Water types along with the Stiff and Piper diagram plots, can be used for assessing potential sources of water, differences in casing and aquifer chemistries, to focus on additional sampling, or alternate approaches to cleaning and rehabilitation. A well that is mineralized, such as well 16D, might have the potential for calcium re-precipitation after acidification, if inadequate purging occurred, or too much time elapsed prior to purging after acidification.

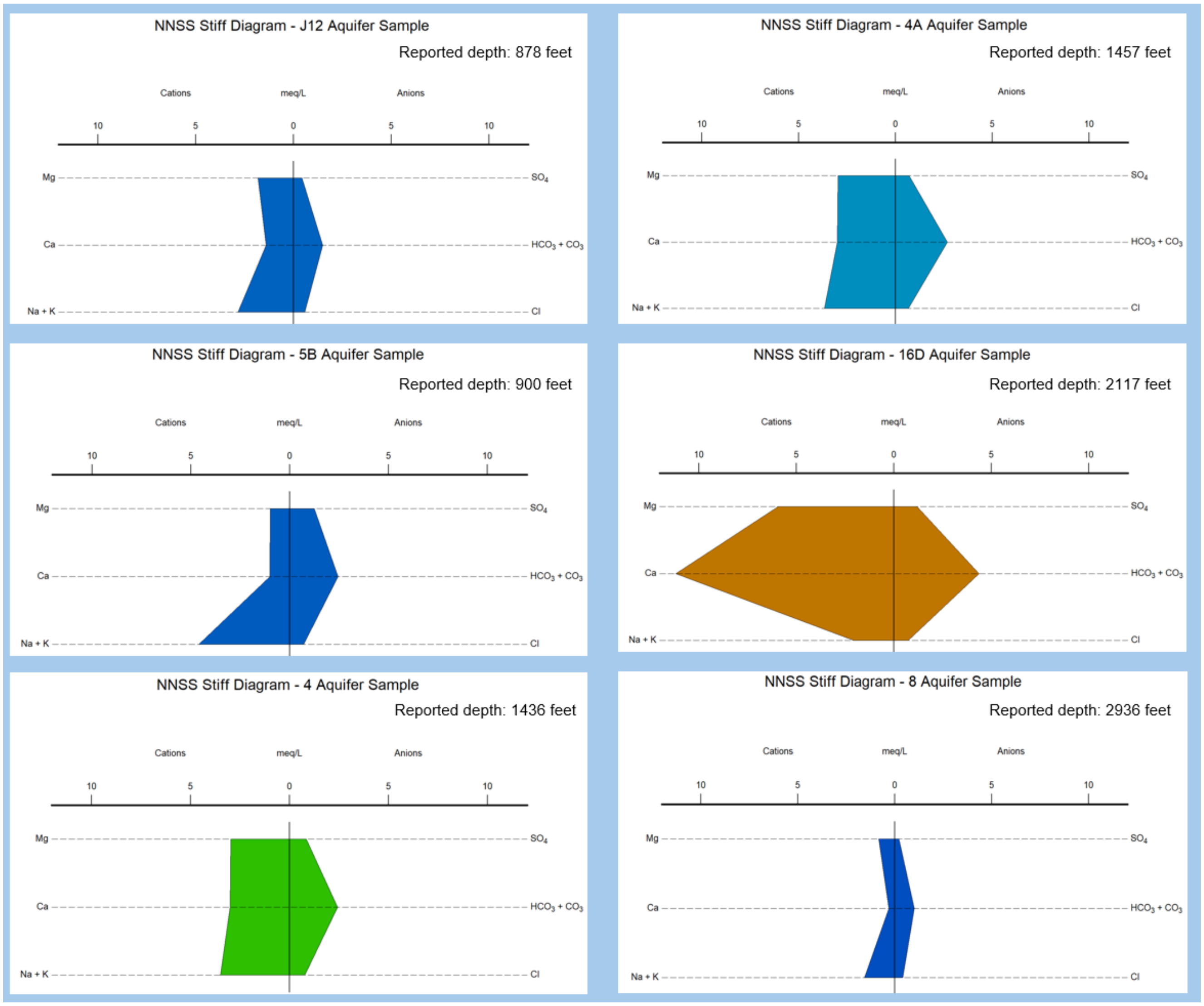

Figure 2 – Stiff Diagrams (Aquifer sample data only)

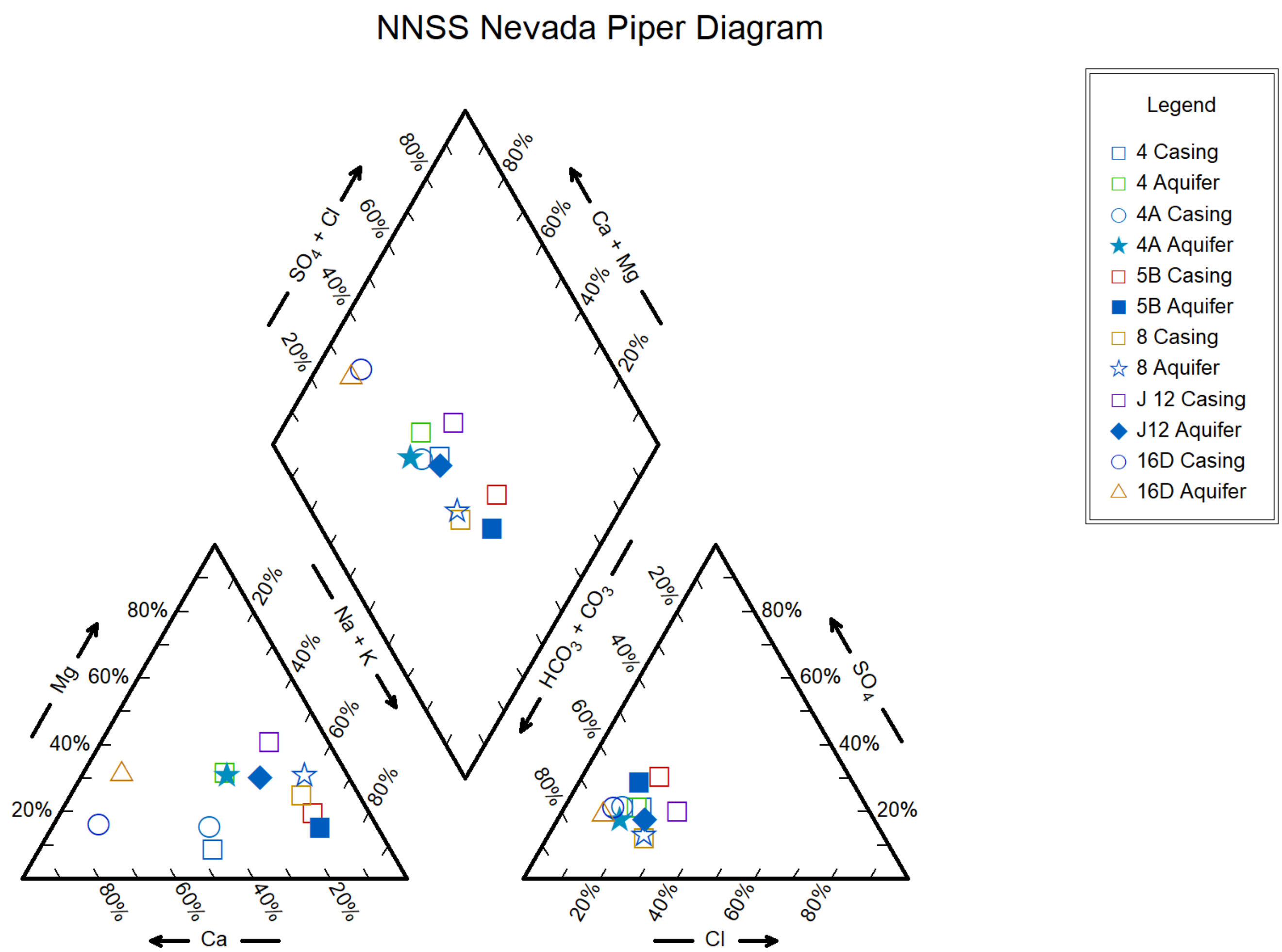

Figure 3 – Piper Diagram, NNSS Wells

7.0 Conclusions

Our conclusions are primarily focused on the feasibility and potential efficacy of cleaning or rehabilitating any or all of the six wells. Age, unknown downhole conditions, well depth and specifically the depth of the “rehabilitation interval”, known water quality concerns, and finally the potential for effectively improving well performance all factor into our conclusions. The following conclusions are presented as geochemical, microbiological, and well conditions, respectively. Our conclusions are based on the provided well data, field sampling records, laboratory reports, and our findings.

There are limited instances of water chemistry differences between the casing and aquifer general chemistry data. All of the aquifer chemistries are similar, except for Well 16D. Well 16D and Well 5B have similar casing/aquifer water types (calcium bicarbonate and sodium bicarbonate, respectively), whereas three wells (J12, 4 and 4A) have calcium bicarbonate casing water types, and sodium bicarbonate aquifer water types. Well 8 has a sodium bicarbonate water type for both casing and aquifer samples. What can be concluded from this is as follows, as it pertains to well maintenance and rehabilitation:

- The presence of the calcium in the casing samples may suggest chemical incrustation of the well casing by calcium carbonate. This might be a function of entrance velocities and the presence of carbon dioxide gas in solution, that when accelerated into the well during the initiation of pumping, decreases pressure just enough to facilitate calcium carbonate deposition on the well casing.
    - This should be visually assessed during video logging of the wells.
    - Evidence of gas in the pump discharge should be noted by field samplers and pump operators.

Groundwater quality is strikingly similar and unremarkable, in most instances. What we can conclude regarding groundwater geochemistry is as follows:

- Well 16D water chemistry appears to be under the influence of a carbonate sequence, geologically speaking, as shown by the elevated calcium, carbonate and bicarbonate concentrations in both water samples. The Piper diagram clearly plots that separation of the cation concentrations away from the remaining five wells, and the overall plot suggests a difference in overall water chemistry.
    - Both samples had somewhat elevated concentrations of calcium, which is a concern for chemical precipitation on the perforated well casing, and the potential for reprecipitation during acid washing, if the chemical solution cannot be effectively neutralized downhole (not advised) or completely removed during rehabilitation.

    - There is a much smaller silica 4concentration in this well, when compared to the other five wells, further suggesting a different geological environment in which the well is completed.
- The remaining five wells all appear to have roughly similar water chemistries, with variations in the cation concentrations. The anion concentrations for these five wells are remarkably similar, with the following exceptions:
- The reactive phosphorus in Well J-12 may be suggestive of some possibly surface contamination, or backflow issue, but there are at least two more likely causes. The WSE report suggests that the reactive phosphorus may be present because of residual drilling fluid, but given the age of the well, this seems to be a lesser probability. Well J12 was rehabilitated a few months prior to the well sampling, and phosphoric acid was used as part of the rehabilitation process. What is not reported is the quantity and concentration of the phosphoric acid used, and if it was neutralized at the surface or in the well. Furthermore, based on the submitted field records, at least three days passed between acid introduction and pumping of the well, reportedly due to mechanical issues with the pumping equipment. This delay could have allowed some percentage of phosphoric acid to naturally neutralize in the well and surrounding formations. This in turn, may have contributed to the reported presence of reactive phosphorus in the well water samples from J12.
    - Of further note is the similar silica concentrations, suggesting that these wells were installed in at least some of the volcanic sequences below the site.

The groundwater microbiology is similarly unremarkable, with the following exceptions:

- Well J-12 has some indications of contamination, perhaps from a surface source, or from a leaking well seal, neither of which can be determined with the existing data set.
- In two instances, positive iron/manganese oxidizing bacteria were reported in the casing samples. This may be the result of normal bacterial corrosion of well casings but should be considered and potentially addressed.

What can be concluded regarding well construction, conditions, and rehabilitation potential are as follows:

- The overall ages of these wells qualify all but one of them (Well 4A) as potentially "at risk", with respect to possibility of exacerbating existing structural issues by introducing rehabilitation processes into the wells.
- With respect to access into the interior of the wells, i.e., well diameters, we can conclude the following:

- Well 16D has perforated casing and a liner with a sub-seven-inch diameter, which will make getting some tooling into the well difficult. Given the use of this well, it may be more effective to restrict rehabilitation to fluid washing with chemistry.
- Well 8 has a liner below 1,941 feet that is just slightly greater than seven inches. Rehabilitation will likely be more effective from an access and efficacy perspective if restricted to the 11” Φ casing above 1941 feet.
- The remaining four wells reported have well casing diameters that while not ideal, will be adequate for most rehabilitation methods.

Without reliable pumping water levels, we cannot calculate current specific capacity for each well. We can assume that pumping water is above the pump depth setting, but this is inaccurate for specific capacity calculations. As such, we cannot conclude what the specific capacity might tell us about the hydraulic condition of the wells.

Overall, what can be concluded is that there are no glaring indicators of chemical or biological well fouling, that the age of the wells and the unknown casing conditions is of concern with respect to the type of rehabilitation that might occur, and efficacy of improving either water quality or operational conditions via rehabilitation will depend on obtaining further data, to more accurately assess rehabilitation efficacy.

8.0 Recommendations

Based on our findings, discussion and conclusions, we offer the following recommendations:

- Conduct downhole video logging of each well. Video logging is the most effective tool available for visually assessing the readily apparent condition of the interior well casing. Structural issues, chemical or biological fouling may be readily apparent, and these observations can be used to refine the rehabilitation plan.
- Consider gyroscopic surveys to assess casing alignment. Wells that are not aligned, or that have shifted over time, may present conditions that could create problems when running rehabilitation equipment into and out of the well.
- For the deeper well, those exhibiting larger temperature variation between the casing and aquifer samples, consideration should be given to conducting temperature surveys. Downhole variations of temperature that are significant may create conditions that need to be considered when preparing the rehabilitation plan.
- Given the depths, and diameters, of most of the wells, we recommend consideration be given to utilizing an oil field tool for the rehabilitation effort. A coiled tubing rig would have the ability to achieve most of the depths, provide for most mechanical rehabilitation efforts, and have a smaller overall “footprint” (operationally and logistically) for addressing the wells.

- Many of the wells have deeper "first perforated" casing depths, and as such, given unknown well conditions, and standard well hydraulics, we recommend that consideration be given to how much of the perforated intervals should be addressed in the well rehabilitation effort.
- Phosphoric acid, 70% "strength", in the proper blend, should be the only acid used for these wells. Furthermore, a bio-dispersant should be used to improve acid efficacy and address disruption of biomass in the wells.
    - Rehabilitation operations should emphasize careful use of acids, acid inhibitors, disinfection chemicals, and neutralizing agents. Use and application of these products should be according to the manufacturer's guidelines.
        - Concentrations and quantities used should be part of the required documentation, per specification and a rehabilitation workplan.
    - Proper introduction, resident time in the well (i.e., "contact time") and then removal of chemical products needs to be planned and adhered to during well rehabilitation operations.
- Prior to chemical rehabilitation, we recommend a well disinfection effort prior to mechanical or chemical rehabilitation. We concur with WSE's recommendation for a chlorinated isocyanurate disinfectant solution.
- Well Specific Recommendations:
    - Well 16D – without video logging information, our recommendation would be to limit rehabilitation of this well to chemical approaches, foregoing mechanical.
    - Well 8 – without video logging information, our recommendation would be to limit rehabilitation of this well to operations above 1,940 feet below grade.
    - Wells 4, 4A, 5B and J12 should be candidates for both mechanical and chemical rehabilitation. Video logging information will be critical for refining the well rehabilitation plan.
        - Well J12 should undergo assessment for the presence of the elevated concentrations of reactive phosphorus. Well J12 is reportedly seventy (70) years old, and the elevated iron and manganese concentrations in the aquifer sample may be indicative of casing deterioration. Well J12 has the highest reported discharge rate, and one of the shallower "depth to first perforation" values. These factors make Well J12 a good candidate for further assessment prior to considering rehabilitation. We recommend video assessment of this well, prior to rehabilitation, to assess the feasibility of rehabilitation.

- Wells 4 and 4A have more reported iron in the aquifer samples but otherwise show similar factors for consideration to Well J12, such as good flow rates and relatively shallow “depth to first perforation”.

9.0 Limitations

The discussions and conclusions presented in this report are based on the following:

- Available data, provided by NNSS/MSTS
- Sampling and field measurements and observations provided by NNSS/MSTS
- Laboratory analytical data provided by WSE
- Work performed by others

It is possible that variations in subsurface conditions could exist beyond the points explored in this assessment. Also, changes in conditions could occur at some time in the future due to variations in rainfall, temperature, regional water usage, or other factors.

The services performed by Aegis were conducted in a manner consistent with the level of care and skill ordinarily exercised by members of our profession currently practicing similar conditions in California. No warranty, expressed or implied, is made.

Appendix A NNSS Water Supply Well Sampling Plan

NNSS Well Sampling Plan

Sampling goal is to collect and analyze representative casing and aquifer samples from each of the six (6) project wells, to produce an initial baseline water quality database useful for well maintenance and operation.

Sampling objectives will be as follows:

- Obtain and assess readily available background data for each of the project wells.
- Provide sampling team with a sampling plan for collecting, securing and shipping samples to the contract lab
- Collect and ship samples

Definitions

Casing sample: A water sample collected just as water reaches the surface after the pump has been started. Conceptually this sample represents the possible water chemistry resident in the well casing, prior to groundwater being drawn into the well.

Aquifer sample: A water sample collected sometime after the pump has started. Conceptually this sample represents the possible water chemistry resident in the aquifer, not in the well casing. In general, this sample is collected after a minimum of at least two (2) well volumes have been pumped from the well.

Well volume: The quantity of water inside the well casing from the static water level (SWL) to the bottom of the well, usually expressed in gallons.

Basic well data follows:

WELL NAME	DEPTH, ft	BUILD YEAR	AGE	PERFORATION INTERVALS	VOLUME, gal	SWL, ft	PWL, ft	DISCHARGE RATES, GPM
4A	1457	1990	35	1066' to 1281', 1365' to 1457'	4126			450
4	1436	1982	43	942' to 1436'	3283			475
5B	900	1980	45	700' to 900'	914			240
8	2936	1957	68	1250' to 1300', 1450' to 1500',1630' to 1780'	9173			200
J-12	878	1957	68	793' to 868'	882			600
16D	2117	1977	48	1145' to 1310'	2338			140

Additional data can be added, as it is developed. Please note that in most cases the well depth is the "cased well depth".

Assumptions

- Pumping rate for each well. This may be available via field measurements or USGS database. To establish initial purge times, the pumping rate is assumed to be two hundred (200) gallons per minute (GPM).

- Drawdown for each well. This may be available via field measurements or USGS database.
- Purging Times (Aquifer Sample Collection Times). The greater well depths, and therefore greater single well volumes will require at least three (3) well volumes as the minimum "turn over". Minimum purge times are listed below. Unless otherwise discussed, please purge for one (1) hour, except for Well 8, which should purge for 2.5 hours:
  - 4A: 28 minutes
  - 4: 21 minutes
  - 5B: 11 minutes
  - 8: 2.5 hours
  - J-12: 5 minutes
  - 16D: 50 minutes
- Ideally, the well will have been "resting" (not pumping) for at least twelve (12) hours or longer, prior to collecting the casing sample.

Field Observations (type and frequency, during purging)

- Flow rate variations
- Discharge color, presence of turbidity or sediment
- Gas Discharge
- Temperature

Sample Labelling System

- WW- 4 Casing, WW- 4 Aquifer
- WW- 4A Casing, WW- 4A Aquifer
- WW- 5B Casing, WW- 5B Aquifer
- WW- 8 Casing, WW- 8 Aquifer
- J-12 WW Casing, J-12 WW Aquifer
- UE-16d WW Casing, UE-16d WW Aquifer

Sample collection process

Field Measurements. When possible, field measure of the following parameters should be obtained during each of the sampling events (e.g., casing and aquifer sample collection):

- Minimum: pH, temperature, electrical conductivity
- Additional: turbidity, total dissolved solids, oxidation- reduction potential (ORP) and dissolved oxygen

The following are basic sampling principles for collection of microbiological samples:

- The sampling ports need to be thoroughly cleaned prior to sample collection. The ports should be free of debris, cleaned with distilled water, and sprayed down with a chlorine solution comprised of distilled water and sodium hypochlorite solution, then rinsed off with distilled water, and allowed to air dry.
- Sample bottles should be stored at ambient air temperature prior to sampling. Do not use chilled/empty sample bottles, this increases the risk of thermal damage to the sample bottles.
- Samplers should wear both protective sanitary gloves, and face masks during sampling, or at any time the sample bottles are open to atmosphere. This is to reduce the risk of inadvertently introducing biological material into the sample bottles.
- Prior to collecting the samples, the sampler should complete the sample labeling process by indicating the date and time the samples were collected. Then the sample label should be covered with clear packing tape (reduces the risk of sample label ink running) and organized for sample collection.
- Sample bottles, which are polyethylene and contain no preservative, should be filled to the top (headspace is not an issue), the bottle cap secured, and placed inside individual Ziploc bags, then placed in the sample ice chests. No preservatives need to be added to these samples.
- Samples will be sent in individual Styrofoam ice chests within cardboard shipping boxes. Extra sampling gloves and packing tape are included, along with Ziplok bags to place the filled samples in, then into the ice chests.
- Blue ice is an acceptable method of cooling samples. Blue ice was not included in the boxed ice chests. Wet ice, if properly sealed to avoid leakage, is an acceptable alternative.
- Sample ice chests need to be adequately sealed tightly for transportation to the contract laboratory, then placed in their respective shipping box. Boxes need to be labeled for shipment to Water System Engineering.
- Pre-paid shipping labels will be included in the boxes.
  Water Systems Engineering, Inc.
  Attn: Lab
  3201 Labette Terrace
  Ottawa, KS 66067

Appendix B NNSS Water Supply Well Sampling Field Records

NNSS WELLS

Location: WW-4 Casing

Sample Date: 12/27/25

Collected By: Dulay, D

OnSite Personnel: Isom, D

Purge Time: Ø   Flow Rate (GPM): 475   Purge Volume (Gal): Ø

Collection Time: 1022

Temperature (C): 24.4

Specific Conductance (uS/cm): 394.9

pH: 7.97

Turbidity (NTU): 24.0

Comments: None

NNSS WELLS

Location: WW-4 Aquifer

Sample Date: 10/22/25

Collected By: Duley, D

OnSite Personnel: Isom, D

Purge Time: 60min Flow Rate (GPM): 475 Purge Volume (Gal): 28,500

Collection Time: 1123

Temperature (C): 24.8

Specific Conductance (uS/cm): 400.4

pH: 7.91

Turbidity (NTU): 0.19

Comments: None

NNSS WELLS

Location: WW-4A Casing

Sample Date: 10/27/25

Collected By: Daley, D

OnSite Personnel: Ison, D

Purge Time: Ø Flow Rate (GPM): 450 Purge Volume (Gal): Ø

Collection Time: 1010

Temperature (C): 24.0

Specific Conductance (uS/cm): 389.5

pH: 7.93

Turbidity (NTU): 15.3

Comments: None

NNSS WELLS

Location: WW-4A Aquifer

Sample Date: 10/27/25

Collected By: Duley, D

OnSite Personnel: Ison, D

Purge Time: 60 min Flow Rate (GPM): 450 Purge Volume (Gal): 27000

Collection Time: 1112

Temperature (C): 24.8

Specific Conductance (uS/cm): 391.1

pH: ~~7.92~~ 7.93 (D 10/27/25)

Turbidity (NTU): 0.17

Comments: None

NNSS WELLS

Location: WW-5B Casing

Sample Date: 10/27/25

Collected By: K CAVANAUGH

OnSite Personnel: TY OLSEN, SEAN SOUSA, DAVE ISOM

Purge Time: Ø Flow Rate (GPM): 250 Purge Volume (Gal): Ø

Collection Time: 1236

Temperature (C): 23.2

Specific Conductance (uS/cm): 532

pH: 8.39

Turbidity (NTU): 1.06

Comments: None

NNSS WELLS

Location: WW-5B Aquifer

Sample Date: 10/27/25

Collected By: J CAVANAUGH

OnSite Personnel: TY OLSEN , SEAN SOUSA

Purge Time: 60min Flow Rate (GPM): 250 Purge Volume (Gal): 15,000

Collection Time: 1338

Temperature (C): 23.7

Specific Conductance (uS/cm): 519

pH: 8.49

Turbidity (NTU): 0.41

Comments: None

NNSS WELLS

Location: WW-8 Casing

Sample Date: 10/27/25

Collected By: M. CAVANAUGH

OnSite Personnel: TY OLSON, SBAN

Purge Time: ~~2 MIN~~ 1 MIN 10/27/25 MC

Flow Rate (GPM): 200

Purge Volume (Gal): ~~400~~ 200 10/27/25 MC

Collection Time: 0845

Temperature (C): 21.1

Specific Conductance (uS/cm): 197.5

pH: 7.35

Turbidity (NTU): 4.04

Comments: None

NNSS WELLS

Location: WW-8 Aquifer

Sample Date: 10/27/25

Collected By: M CAVANAUGH

OnSite Personnel: TY OLSEN , SEAN SOUSA

Purge Time: 2.5HR (150min) Flow Rate (GPM): 200 Purge Volume (Gal): 30,000

Collection Time: 1115

Temperature (C): 24.8

Specific Conductance (uS/cm): 198.5

pH: 7.37

Turbidity (NTU): 0.45

Comments: None

NNSS WELLS

Location: UE-16d WW Casing

Sample Date: 10/27/25

Collected By: A CAVANAUGH

OnSite Personnel: TY OLSEN SHAW SOUSA

Purge Time: Ø Flow Rate (GPM): 140 Purge Volume (Gal): Ø

Collection Time: 0930

Temperature (C): 20.2

Specific Conductance (uS/cm): 644

pH: 7.32

Turbidity (NTU): 0.39

Comments: None

NNSS WELLS

Location: UE-16d WW Aquifer

Sample Date: 10/27/25

Collected By: M. CAVANAUGH

OnSite Personnel: TY OLSEN SEAN SOUSA

Purge Time: 60min (1 HR) Flow Rate (GPM): 140 Purge Volume (Gal): 8400

Collection Time: 1030

Temperature (C): 24.3

Specific Conductance (uS/cm): 657

pH: 7.23

Turbidity (NTU): 0.33

Comments: None

NNSS WELLS

Location: J-12 WW Casing

Sample Date: 10/27/2025

Collected By: Duley, D

OnSite Personnel: Isom, D

Purge Time: Ø   Flow Rate (GPM): 600   Purge Volume (Gal): Ø

Collection Time: 0829

Temperature (C): 24.3

Specific Conductance (uS/cm): 244.8

pH: 6.84

Turbidity (NTU): 41.7

Comments: None

NNSS WELLS

Location: J-12 WW Aquifer

Sample Date: 10/27/2025

Collected By: Duley, D

OnSite Personnel: Ison, D

Purge Time: 60 min   Flow Rate (GPM): 600   Purge Volume (Gal): 36000

Collection Time: 0830

Temperature (C): 26.6

Specific Conductance (uS/cm): 263.7

pH: 7.01

Turbidity (NTU): 1.07

Comments: None

Appendix C NNSS Water Supply Well WSE Laboratory Reports

Date: January 6, 2026

Lab Report No. 23500

Christopher Johnson
Aegis Groundwater Consulting
1177 East Shaw Ave, Suite 101
Fresno, CA 93710

Project Description: NNSS; Wells WW4, WW4A, WW5B, WW8, J-12 WW & UE-16d WW
Samples dated 10/27/2025 & 11/19/2025
Complete Well Profile (6)

Test Description:

The Complete Well Profile analysis is designed for comparative analysis of two samples, typically one static and one pumping sample. The Complete Well Profile utilizes a series of inorganic chemical and microbiological tests to identify fouling and corrosion issues with potential impacts on the operation of the sampled well. The tests include a number of inorganic chemical parameters such as pH, total dissolved solids/conductivity, hardness, alkalinity, oxidation reduction potential (ORP), bicarbonate, carbonates, silica, sodium, potassium, chloride, iron, manganese, phosphate, nitrate, sulfate, and total organic carbon (TOC). Biological assessment is designed to quantify the total bacterial population, identify two dominant populations of bacteria, assess anaerobic conditions, and identify the presence of iron related bacteria and sulfate reducing organisms. Also included are tests for Adenosine triphosphate (ATP), heterotrophic plate count (HPC), and a microscopic evaluation; and in potable systems, total coliform and E. coli coliform presence/absence.

Testing Procedures:

All laboratory testing procedures are performed according to the guidelines set forth in *Standard Methods for the Examination of Water and Wastewater* as established by the American Public Health Association (APHA), American Water Works Association (AWWA), and Water Environment Federation (WEF). Corrosion analyses are performed in accordance with the guidelines as set forth by the National Association of Corrosion Engineers (NACE). In general, these methods are approved by both the Environmental Protection Agency (EPA) and AWWA for the reporting of water and/or wastewater data.

Sample collection and shipment is the responsibility of the customer, performed according to protocol and procedures defined by the laboratory in advance of the sampling event with regards to the specific project and nature of the problem.

Disclaimer:

The data and interpretations presented are based on an evaluation of the samples and submitted data. Conclusions reached in this report are based upon the data available at the time of submittal and the accuracy of the report depends upon the validity of information submitted. Any recommendations presented are based on laboratory and field evaluations of similar fouling occurrences within potable water systems. Further investigative efforts, such as efficiency testing, site inspection, video survey, or other evaluation methods may offer additional insight into the system’s condition and the degree of fouling present.

Client: Aegis Groundwater Consulting
Date: January 6, 2026
Lab Report No. 23500

Re: NNSS; Wells WW4, WW4A, WW5B, WW8, J-12 WW & UE-16d WW
Samples dated 10/27/2025 & 11/18/2025; Complete Well Profile (6)

ND - Not Detected NA - Not Applicable * as $CaCO_3$	WW4 Casing 10/27/2025 (1022)	 Aquifer 10/27/2025 (1123)	Detection Limits
pH Value	7.67	7.83	NA
Phenolphthalein Alkalinity*	ND	ND	4 mg/l
Total Alkalinity*	152	152	4 mg/l
Hydroxide Alkalinity*	ND	ND	4 mg/l
Carbonate Alkalinity*	ND	ND	4 mg/l
Bicarbonate Alkalinity*	152	152	4 mg/l
Total Dissolved Solids	285	286	1.0 mg/l
Conductivity (µm or µS/cm)	396	397	NA
ORP (mV)	+ 199.8	+ 208	NA
Langelier Saturation Index (at 16°C)	- 0.40	- 0.32	NA
Total Hardness*	80	96	4 mg/l
Carbonate Hardness	80	96	4 mg/l
Non-Carbonate Hardness	ND	ND	4 mg/l
Calcium*	72	60	4 mg/l
Magnesium*	8	36	4 mg/l
Sodium (as Na)	78.20	77.50	0.02 mg/l
Potassium (as K)	5.5	5.4	0.1 mg/l
Phosphorus, Reactive (as PO_4^{3-})	0.09	ND	0.06 mg/l
Chlorides (as Cl)	29.6	27.6	1 mg/l
Nitrate (Nitrogen)	4.1	4.6	0.3 mg/l
Chlorine (as Cl)	ND	ND	0.02 mg/l
Dissolved Iron (as Fe^{2+})	ND	ND	0.02 mg/l
Suspended Iron (as Fe^{3+})	1.43	ND	0.02 mg/l
Iron Total (as Fe)	1.43	ND	0.02 mg/l
Iron (resuspended)	2.51	ND	0.02 mg/l
Copper (as Cu)	ND	ND	0.04 mg/l
Manganese (as Mn)	0.032	0.016	0.007 mg/l
Sulfate (as SO_4)	41	41	2 mg/l
Silica (as SiO_2)	61.5	61.8	1.0 mg/l
Tannin/Lignin	ND	ND	0.1 mg/l
Total Organic Carbon (C)	ND	ND	0.3 mg/l

ND - Not Detected NA - Not Applicable * as $CaCO_3$	WW 4A Casing 10/27/2025 (1010)	 Aquifer 10/27/2025 (1112)	Detection Limits
pH Value	7.87	7.84	NA
Phenolphthalein Alkalinity*	ND	ND	4 mg/l
Total Alkalinity*	140	168	4 mg/l
Hydroxide Alkalinity	ND	ND	4 mg/l
Carbonate Alkalinity	ND	ND	4 mg/l
Bicarbonate Alkalinity	140	168	4 mg/l
Total Dissolved Solids	282	277	1.0 mg/l
Conductivity (µm or µS/cm)	391	385	NA
ORP (mV)	+ 203.9	+ 209.7	NA
Langelier Saturation Index (at 16°C)	- 0.21	- 0.26	NA
Total Hardness*	92	96	4 mg/l
Carbonate Hardness	92	96	4 mg/l
Non-Carbonate Hardness	ND	ND	4 mg/l
Calcium*	76	60	4 mg/l
Magnesium*	16	36	4 mg/l
Sodium (as Na)	79.00	80.80	0.02 mg/l
Potassium (as K)	5.6	5.6	0.1 mg/l
Phosphorus, Reactive (as PO_4^{3-})	0.06	0.06	0.06 mg/l
Chlorides (as Cl)	19.2	23.6	2 mg/l
Nitrate (Nitrogen)	4.2	4.3	0.3 mg/l
Chlorine (as Cl)	ND	ND	0.02 mg/l
Dissolved Iron (as Fe^{2+})	ND	ND	0.02 mg/l
Suspended Iron (as Fe^{3+})	0.74	0.04	0.02 mg/l
Iron Total (as Fe)	0.74	0.04	0.02 mg/l
Iron (resuspended)	1.69	ND	0.02 mg/l
Copper (as Cu)	ND	ND	0.04 mg/l
Manganese (as Mn)	0.013	ND	0.007 mg/l
Sulfate (as SO_4)	36	34	2 mg/l
Silica (as SiO_2)	63.4	64.6	1.0 mg/l
Tannin/Lignin	ND	ND	0.1 mg/l
Total Organic Carbon (C)	ND	ND	0.3 mg/l

ND - Not Detected NA - Not Applicable * as $CaCO_3$	WW 5B Casing 11/18/2025 (0824)	 Aquifer 10/27/2025	Detection Limits
pH Value	8.33	8.39	NA
Phenolphthalein Alkalinity*	ND	ND	4 mg/l
Total Alkalinity*	128	148	4 mg/l
Hydroxide Alkalinity	ND	ND	4 mg/l
Carbonate Alkalinity	ND	ND	4 mg/l
Bicarbonate Alkalinity	128	148	4 mg/l
Total Dissolved Solids	373	346	1.0 mg/l
Conductivity (µm or µS/cm)	518	480	NA
ORP (mV)	+ 334.1	+ 188.1	NA
Langelier Saturation Index (at 16°C)	- 0.38	- 0.25	NA
Total Hardness*	36	32	4 mg/l
Carbonate Hardness	36	32	4 mg/l
Non-Carbonate Hardness	ND	ND	4 mg/l
Calcium*	20	20	4 mg/l
Magnesium*	16	12	4 mg/l
Sodium (as Na)	95.60	98.30	0.02 mg/l
Potassium (as K)	13.0	13.0	0.1 mg/l
Phosphorus, Reactive (as PO_4^{3-})	0.20	0.26	0.06 mg/l
Chlorides (as Cl)	30.8	24.8	2 mg/l
Nitrate (Nitrogen)	3.1	3.2	0.3 mg/l
Chlorine (as Cl)	ND	ND	0.02 mg/l
Dissolved Iron (as Fe^{2+})	ND	ND	0.02 mg/l
Suspended Iron (as Fe^{3+})	ND	ND	0.02 mg/l
Iron Total (as Fe)	ND	ND	0.02 mg/l
Iron (resuspended)	0.70	ND	0.02 mg/l
Copper (as Cu)	ND	ND	0.04 mg/l
Manganese (as Mn)	0.025	0.017	0.007 mg/l
Sulfate (as SO_4)	62	60	2 mg/l
Silica (as SiO_2)	58.9	57.7	1.0 mg/l
Tannin/Lignin	ND	ND	0.1 mg/l
Total Organic Carbon (C)	ND	ND	0.3 mg/l

ND - Not Detected NA - Not Applicable * as $CaCO_3$	**WW 8** **Casing** 10/27/2025	**WW 8** **Aquifer** 10/27/2025	**Detection Limits**
pH Value	7.47	7.31	NA
Phenolphthalein Alkalinity*	ND	ND	4 mg/l
Total Alkalinity*	72	68	4 mg/l
Hydroxide Alkalinity	ND	ND	4 mg/l
Carbonate Alkalinity	ND	ND	4 mg/l
Bicarbonate Alkalinity	72	68	4 mg/l
Total Dissolved Solids	131	148	1.0 mg/l
Conductivity (µm or µS/cm)	182	205	NA
ORP (mV)	+ 200.3	+ 199	NA
Langelier Saturation Index (at 16°C)	- 1.84	- 2.16	NA
Total Hardness*	16	16	4 mg/l
Carbonate Hardness	16	16	4 mg/l
Non-Carbonate Hardness	ND	ND	4 mg/l
Calcium*	8	6	4 mg/l
Magnesium*	8	10	4 mg/l
Sodium (as Na)	34.70	33.50	0.02 mg/l
Potassium (as K)	3.8	3.9	0.1 mg/l
Phosphorus, Reactive (as PO_4^{3-})	0.33	0.08	0.06 mg/l
Chlorides (as Cl)	16.0	14.4	2 mg/l
Nitrate (Nitrogen)	1.3	1.3	0.3 mg/l
Chlorine (as Cl)	ND	ND	0.02 mg/l
Dissolved Iron (as Fe^{2+})	ND	ND	0.02 mg/l
Suspended Iron (as Fe^{3+})	0.16	ND	0.02 mg/l
Iron Total (as Fe)	0.16	ND	0.02 mg/l
Iron (resuspended)	0.65	ND	0.02 mg/l
Copper (as Cu)	ND	ND	0.04 mg/l
Manganese (as Mn)	0.035	0.008	0.007 mg/l
Sulfate (as SO_4)	10	10	2 mg/l
Silica (as SiO_2)	46.0	47.1	1.0 mg/l
Tannin/Lignin	ND	ND	0.1 mg/l
Total Organic Carbon (C)	ND	ND	0.3 mg/l

ND - Not Detected NA - Not Applicable * as $CaCO_3$	J-12 WW **Casing** 10/27/2025 (0829)	 **Aquifer** 10/27/2025 (0830)	**Detection Limits**
pH Value	6.74	7.06	NA
Phenolphthalein Alkalinity*	ND	ND	4 mg/l
Total Alkalinity*	88	108	4 mg/l
Hydroxide Alkalinity	ND	ND	4 mg/l
Carbonate Alkalinity	ND	ND	4 mg/l
Bicarbonate Alkalinity	88	108	4 mg/l
Total Dissolved Solids	197	199	1.0 mg/l
Conductivity (µm or µS/cm)	274	277	NA
ORP (mV)	+ 263.6	+ 198.7	NA
Langelier Saturation Index (at 16°C)	- 2.10	- 1.55	NA
Total Hardness*	52	50	4 mg/l
Carbonate Hardness	52	50	4 mg/l
Non-Carbonate Hardness	ND	ND	4 mg/l
Calcium*	20	28	4 mg/l
Magnesium*	32	22	4 mg/l
Sodium (as Na)	62.30	62.50	0.02 mg/l
Potassium (as K)	5.0	5.0	0.1 mg/l
Phosphorus, Reactive (as PO_4^{3-})	27.50	14.60	0.06 mg/l
Chlorides (as Cl)	22.4	20.4	2 mg/l
Nitrate (Nitrogen)	1.8	2.1	0.3 mg/l
Chlorine (as Cl)	ND	ND	0.02 mg/l
Dissolved Iron (as Fe^{2+})	ND	ND	0.02 mg/l
Suspended Iron (as Fe^{3+})	0.14	ND	0.02 mg/l
Iron Total (as Fe)	0.14	ND	0.02 mg/l
Iron (resuspended)	6.38	0.08	0.02 mg/l
Copper (as Cu)	ND	ND	0.04 mg/l
Manganese (as Mn)	0.241	0.069	0.007 mg/l
Sulfate (as SO_4)	20	21	2 mg/l
Silica (as SiO_2)	62.9	60.1	1.0 mg/l
Tannin/Lignin	ND	ND	0.1 mg/l
Total Organic Carbon (C)	ND	ND	0.3 mg/l

ND - Not Detected
NA - Not Applicable
* as $CaCO_3$

	UE-16d WW		Detection Limits
	Casing 10/27/2025	**Aquifer** 10/27/2025	
pH Value	7.28	7.41	NA
Phenolphthalein Alkalinity*	ND	ND	4 mg/l
Total Alkalinity*	272	288	4 mg/l
Hydroxide Alkalinity	ND	ND	4 mg/l
Carbonate Alkalinity	ND	ND	4 mg/l
Bicarbonate Alkalinity	272	288	4 mg/l
Total Dissolved Solids	442	441	1.0 mg/l
Conductivity (µm or µS/cm)	614	612	NA
ORP (mV)	+ 211.9	+ 208.6	NA
Langelier Saturation Index (at 16°C)	- 0.04	+ 0.09	NA
Total Hardness*	268	296	4 mg/l
Carbonate Hardness	268	288	4 mg/l
Non-Carbonate Hardness	ND	8	4 mg/l
Calcium*	236	224	4 mg/l
Magnesium*	32	72	4 mg/l
Sodium (as Na)	43.20	44.60	0.02 mg/l
Potassium (as K)	3.7	3.9	0.1 mg/l
Phosphorus, Reactive (as PO_4^{3-})	0.07	0.06	0.06 mg/l
Chlorides (as Cl)	28.4	26.0	2 mg/l
Nitrate (Nitrogen)	ND	ND	0.3 mg/l
Chlorine (as Cl)	ND	ND	0.02 mg/l
Dissolved Iron (as Fe^{2+})	ND	ND	0.02 mg/l
Suspended Iron (as Fe^{3+})	ND	0.02	0.02 mg/l
Iron Total (as Fe)	ND	0.02	0.02 mg/l
Iron (resuspended)	0.33	0.05	0.02 mg/l
Copper (as Cu)	ND	ND	0.04 mg/l
Manganese (as Mn)	0.018	0.019	0.007 mg/l
Sulfate (as SO_4)	62	57	2 mg/l
Silica (as SiO_2)	26.5	30.4	1.0 mg/l
Tannin/Lignin	ND	ND	0.1 mg/l
Total Organic Carbon (C)	ND	ND	0.3 mg/l

Biological Analysis:

	WW 4		Detection Limit
	Casing	Aquifer	
Plate Count (colonies/ml)	31	5	NA
Anaerobic Growth (%)	<10	<10	NA
Sulfate Reducing Bacteria	Negative	Negative	NA
Fe/Mn Oxidizing Bacteria	Negative	Negative	NA
ATP (cells per ml) Initial	46,000	34,000	NA
ATP (cells per ml) 24 Hour	45,000	31,000	NA
Total Coliform	Negative	Negative	NA
E. coli	Negative	Negative	NA
Bacterial Identification	*Bacillus species*	*Acidovorax delafieldii*	NA
Bacterial Identification	-	*Bacillus species*	NA

	WW 4A		Detection Limit
	Casing	Aquifer	
Plate Count (colonies/ml)	13	29	NA
Anaerobic Growth (%)	<10	<10	NA
Sulfate Reducing Bacteria	Negative	Negative	NA
Fe/Mn Oxidizing Bacteria	Negative	Negative	NA
ATP (cells per ml) Initial	35,000	36,000	NA
ATP (cells per ml) 24 Hour	27,000	10,000	NA
Total Coliform	Negative	Negative	NA
E. coli	Negative	Negative	NA
Bacterial Identification	*Nocardia species*	*Micrococcus yunnanensis*	NA

-	WW 5B		Detection Limit
	Casing	Aquifer	
Plate Count (colonies/ml)	29	0	NA
Anaerobic Growth (%)	<10	<10	NA
Sulfate Reducing Bacteria	Negative	Negative	NA
Fe/Mn Oxidizing Bacteria	Positive	Negative	NA
ATP (cells per ml) Initial	32,000	33,000	NA
ATP (cells per ml) 24 Hour	24,000	19,000	NA
Total Coliform	Negative	Negative	NA
E. coli	Negative	Negative	NA
Bacterial Identification	*Bacillus species*	-	NA
Bacterial Identification	*Crenothrix*	-	NA

	WW 8		Detection Limit
	Casing	Aquifer	
Plate Count (colonies/ml)	31	2	NA
Anaerobic Growth (%)	<10	<10	NA
Sulfate Reducing Bacteria	Negative	Negative	NA
Fe/Mn Oxidizing Bacteria	Negative	Negative	NA
ATP (cells per ml) Initial	48,000	29,000	NA
ATP (cells per ml) 24 Hour	16,000	19,000	NA
Total Coliform	Negative	Negative	NA
E. coli	Negative	Negative	NA
Bacterial Identification	*Clavibacter michiganensis*	*Microbacterium arborescens*	NA
Bacterial Identification	-	*Bacillus species*	NA

	J-12 WW		Detection Limit
	Casing	Aquifer	
Plate Count (colonies/ml)	>1,500	1,247	NA
Anaerobic Growth (%)	30	<10	NA
Sulfate Reducing Bacteria	Negative	Negative	NA
Fe/Mn Oxidizing Bacteria	Negative	Negative	NA
ATP (cells per ml) Initial	83,000	40,000	NA
ATP (cells per ml) 24 Hour	45,000	19,000	NA
Total Coliform	Negative	Negative	NA
E. coli	Negative	Negative	NA
Bacterial Identification	*Enterobacter cloacae*	*Cupriavidus gilardii*	NA
Bacterial Identification	*Pseudomonas citronellolis*	*Delftia acidovorans*	NA

	UE-16d WW		Detection Limit
	Casing	Aquifer	
Plate Count (colonies/ml)	35	5	NA
Anaerobic Growth (%)	40	<10	NA
Sulfate Reducing Bacteria	Negative	Negative	NA
Fe/Mn Oxidizing Bacteria	Positive	Negative	NA
ATP (cells per ml) Initial	37,000	47,000	NA
ATP (cells per ml) 24 Hour	10,000	14,000	NA
Total Coliform	Negative	Negative	NA
E. coli	Negative	Negative	NA
Bacterial Identification	*Micrococcus yunnanensis*	*Bacillus species*	NA
Bacterial Identification	*Micrococcus species*	-	NA
Bacterial Identification	*Crenothrix*	-	NA

<u>Microscopic Evaluation</u>:

WW 4

Casing: Heavy visible bacterial activity, very low crystalline debris, very low plant particulate, very low iron oxide with low iron oxide entrained biomass.

Figure 1: Plant particulate; 200x magnification

Aquifer: Low visible bacterial activity, very low iron oxide with very low iron oxide entrained biomass.

<u>Microscopic Evaluation (*continued*)</u>:

WW 4A

Casing: Heavy visible bacterial activity, very low plant particulate, low iron oxide with moderate iron oxide entrained biomass.

Aquifer: Very low visible bacterial activity, very low iron oxide with very low iron oxide entrained biomass.

WW 5B

Casing: Low visible bacterial activity, very low crystalline debris, very low iron oxide, very low iron oxide entrained biomass with a very low amount of *Crenothrix.*

Aquifer: Very low visible bacterial activity.

WW 8

Casing: Moderate visible bacterial activity, very low iron oxide with very low iron oxide entrained biomass.

Aquifer: Very low visible bacterial activity, very low iron oxide with very low iron oxide entrained biomass.

J-12 WW

Casing: Excessive visible bacterial activity, very low numbers of crystalline debris and larger crystals, very low numbers of protozoa, very low plant particulate, moderate iron oxide with a heavy amount of iron oxide entrained biomass.

Aquifer: Moderate visible bacterial activity, moderate crystalline debris and larger crystals, very low iron oxide with very low iron oxide entrained biomass.

Microscopic Evaluation (*continued*):

UE – 16d WW

Casing: Low visible bacterial activity, very low crystalline debris, very low plant particulate, low iron oxide, low iron oxide entrained biomass with a very low amount of *Crenothrix*.

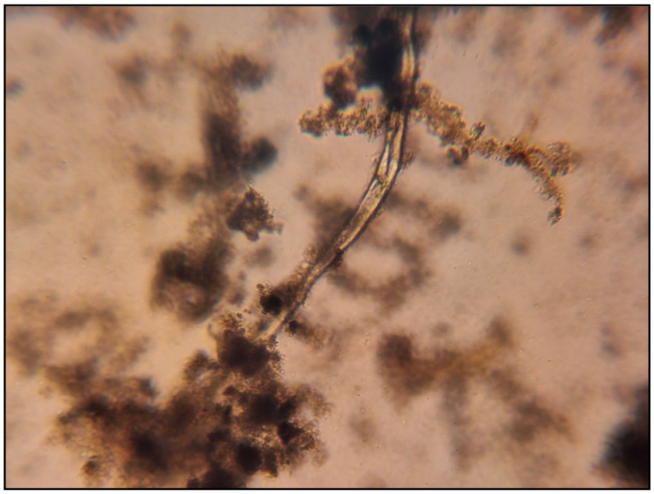

Figure 2: Plant particulate; 200x magnification

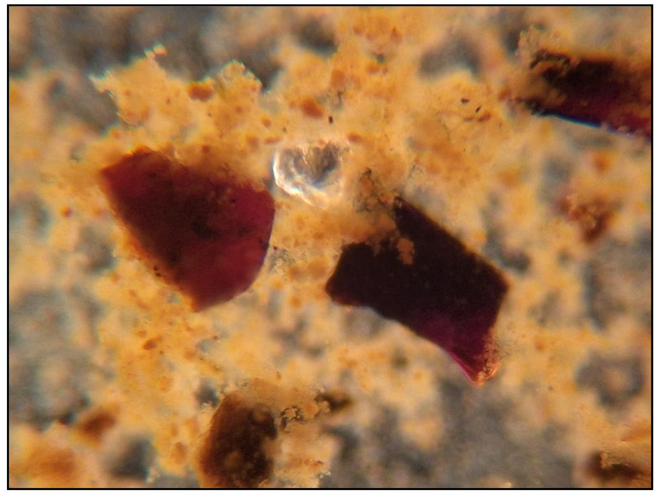

Figure 3: Iron oxide scale; 200x magnification dark field view

Aquifer: Very low visible bacterial activity.

Observations:

Casing and aquifer samples for NNSS Wells WW4, WW4A, WW5B, WW8, J-12 WW and UE-16d WW were collected and submitted to the laboratory for full analysis to aid in developing well maintenance plans. Upon arrival at the lab, the WW4, 4A and J-12 casing samples each exhibited light brown discoloration while the remaining samples were noted to be clear and free of discoloration. The WW8 and UE-16d casing samples, and J-12 aquifer sample each exhibited a minor amount of dark particulate present, while the WW4A and J-12 casing samples had soft, orange biomass present.

Initial testing reported largely neutral pH values, ranging from 6.74 in the J-12 casing sample to 8.39 in the WW5B aquifer sample. Total alkalinity was low within the samples from Wells WW8 and J-12, and highest in the UE-16d samples, with the remaining samples falling within a normal range. The alkalinity contribution in the samples was solely from bicarbonate (HCO^{3-}) ions, as carbonate and hydroxide ions were not identified. Generally, with the exception of the UE-16d, the values suggest a moderate buffering capability within the water chemistry.

The reported Oxidation Reduction Potential (ORP) measurements for the five wells fell within a range considered oxidative. With ORP levels at this point it is sufficient to expect oxidation of metals such as iron and manganese. Generally, among the sample pairs the ORP exhibited minor fluctuations with the exception of the WW5B sample set which showed a sharp decline in the aquifer sample, yet remained oxidative.

Total dissolved solids (TDS) levels, calculated as a function of electrical conductivity, fell within a normal range for the region with the sample set from UE-16d notable as the highest. In general, TDS and conductivity levels exhibited minor fluctuations with pumping of the wells.

The Langelier Saturation Index (LSI) calculation predicts calcium scale formation and the likelihood of chemical corrosion. The calculated LSI values at 16°C were negative for all of the samples with the exception of the UE-16d aquifer sample. The values for the WW8 and J-12WW sample set were the strongest, indicating a more aggressive geochemical environment. Negative values indicate a reduced likelihood of calcium scale development and the potential for chemical corrosion to occur. Positive values reflect a saturated condition with the potential for calcium scale formation. The LSI does not account for the potential of microbial influenced corrosion (MIC), mechanical corrosion, or corrosion from external drivers such as stray current or dissimilar metals usage. Temperature fluctuations can influence LSI values, leading to variation in the environment in deeper well settings.

Water hardness measures the calcium (Ca^{2+}) and magnesium (Mg^{2+}) concentrations in a water sample. Hardness levels were generally low in the samples, trending towards the softer side in five of the wells. Total Hardness was elevated in the UE-16d sample set. Hardness levels at greater than 180 mg/L are considered very hard and highly mineralized with an increased likelihood of scale development. Non-carbonate hardness levels were either not detected or were minimal across the submitted samples.

Potassium and sodium concentrations, while not excessive, were measured at elevated levels in the samples. While not at an extreme point, these values point to the overall congested nature of the water chemistry.

Reactive phosphorus, generally present at minor concentrations, was present in highly elevated amounts in both J-12 WW samples. Phosphorus, as phosphate, is often utilized in polymer form in drilling fluids to increase borehole stabilization as well as many treatment methods to sequester or chelate ions like calcium and iron. The phosphorus presence in the J-12 samples, and the dramatic fluctuation with pumping, suggests a polymer presence or similar external influence on the well.

Dissolved Iron reported as Fe^{2+} (ferrous iron) indicates that iron is present in the water in its reduced, soluble form. Dissolved iron was not detected in any of the six sample sets. Suspended iron, reported as Fe^{3+} (ferric iron), indicates that iron has already been oxidized and is present as insoluble solid particles rather than truly dissolved iron. This points to very different conditions than dissolved Fe^{2+}. Total iron is the sum of the suspended and dissolved forms. Suspended iron and iron total were either not detected or detected in minimal amounts in all the samples, with the exception of the WW4 casing sample. Resuspended iron, is a total iron test that accounts for dissolved and suspended iron as well as iron that has been mobilized or concentrated by bacterial activity. Resuspended iron was detected in elevated levels in the casing samples for WW4, WW4A and J-12 WW. The levels present in WW4 and J-12 casing samples are sufficient to expect iron related fouling is occurring in the well and associated components. Typically, resuspended iron concentrations above 1.0 mg/l indicate an increased potential for iron-related fouling downhole and in the produced water. Elevated resuspended iron concentrations often give direct evidence of iron-oxidizing bacteria and their metabolic activity; however, the iron and manganese oxidizing bacteria Crenothrix were only reported in the WW5B and UE-16d casing samples.

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Manganese, an ion that behaves very similar to iron, was detected in an elevated amount in the casing sample for J-12 WW, declining with pumping. At the level detected within the casing sample, manganese scale is expected, especially in areas seeing more oxidation such as in the vicinity of the pump. The remaining samples fell within the expected levels.

Silica, an important parameter for assessing the potential for abrasion corrosion and sediment infiltration, was elevated in the sample sets from the site. Generally, within the geologic setting, elevated silica concentrations are expected and we evaluate the stability of the values and the presence of crystalline debris. The greatest fluctuation was observed in the UE-16d sample set where a difference of 14.7 occurred. Crystalline debris was noted in the microscopic valuation of the WW4, WW5B, and J-12 casing samples and the UE-16d aquifer sample.

Total Organic Carbon (TOC), a measurement of the total amount of carbon bound within organic compounds, was not detected in any of the sample sets.

Adenosine Triphosphate (ATP) analysis was conducted as part of biological testing of each sample. ATP analysis is a culture independent test used to measure the total concentration of bacteria within a sample. For reference, healthy groundwater supply wells will typically exhibit ATP concentrations that range between 10,000 and 70,000 cells per milliliter (cpm), while wells that are experiencing biofouling will often experience ATP levels of 100,000 cpm or higher. Generally, the samples registered ATP concentrations that are considered low. As the sole exception, the J-12 casing sample initially exhibited a moderate ATP concentration equal to 83,000 cpm. After 24-hours under stable laboratory conditions, a second test was conducted, resulting in a lower ATP concentration of 45,000 cpm, indicating a less problematic population. Overall, the measured ATP values suggest that the wells and supporting aquifer each host a low bacterial population.

The Heterotrophic Plate Count (HPC) is a method designed to estimate the number live, culturable bacteria within a sample. During testing, the well samples exhibited minimal plate growth with the exception of the J-12 samples . The J-12 casing sample returned a plate count that exceeded the upper threshold of the test and declined only slightly in the aquifer sample. Visible microbial activity, reported during microscopic evaluation of the sample, differed from the plate growth with moderate to heavy activity reported in the WW4, WW4A, WW8, and J-12 casing samples as well as the J-12 aquifer sample.

Anaerobic growth, reported as a percentage of the total population, was elevated in the casing samples at 30% in J-12 WW and 40% in UE-16d WW. The remaining samples were limited at less than 10%. Typically, as anaerobic levels increase, biofouling becomes more dynamic with increases in the occurrence of total coliforms and problematic bacteria. Typically, anaerobic levels greater than 15% indicate a more mature and dynamic type of biofilm development. Testing for sulfate reducing bacteria (SRB), a nuisance anaerobe associated with H_2S generation, was negative in all six wells. Sulfate-related bacterial effect water quality in regard to taste and odor as hydrogen sulfide (H_2S) and can impact pH levels, influencing the corrosion potential.

Total coliform testing, to include an evaluation of E. coli specific coliforms, returned negative results among the casing and aquifer sample sets.

Identification of the dominant bacteria within the samples included species of the aforementioned iron and manganese related bacteria, several slime forming species and numerous oil bacteria. Background on the identified species is provided below, in alphabetical order.

Acidovorax delafieldii is an aerobic, gram negative, soil bacterium. The bacteria's presence in the sample is likely a relation to the area of recharge for the well and aquifer, reflecting interaction with the upper soil horizons.

Bacillus is a genus of gram-positive bacteria that can be obligate aerobes or facultative anaerobes. *Bacilli* are widely dispersed in nature, being found in a variety of environments. Generally non-pathogenic, *Bacilli* presence is of concern due to the bacterium's ability to exude large secretions of biomass as a means of attachment and nutrient capture.

Clavibacter michiganensis is an aerobic, gram-positive bacterium. Mostly known for their damaging effects to plants and crops, these bacteria are commonly found in soil environments throughout North America and Europe.

Crenothrix are a genus of sheathed bacteria that oxidize iron and manganese. *Crenothrix* cells are non-motile and can generally be found in a variety of aquatic environments with sufficient organic matter present. Oxidation, resulting from aeration including cascading water or rapid recharge, can stimulate the growth and activity of these bacteria. *Crenothrix* are commonly found associated with other iron and manganese oxidizing bacteria such as Gallionella and Leptothrix. As a result of the oxidation of both iron and manganese, *Crenothrix* sheaths are encrusted with iron and manganese oxides, resulting in a very effective fouling mechanism.

Cupriavidus gilardii is a small, rod-shaped, gram negative bacterium that has been isolated from a number of ecological niches, including plants and soils. *C. gilardii* are considered a rare form of opportunistic pathogen, responsible for infection in immuno-compromised individuals who have direct contact with and significant exposure to, the bacteria.

Delftia acidivorans is a gram-negative, soil-dwelling bacterium, commonly found in the environment.

Enterobacter cloacae is a gram-negative, facultative-anaerobe, rod-shaped bacterium. *E. cloacae* are widely dispersed in the environment, found in water and soil, but also in sewage and dairy products. *E. cloacae* are considered nosocomial (opportunistic) pathogens, responsible for a number of infections such as bacteremia, lower respiratory tract infections, urinary tract infections, and septic arthritis when immuno-compromised patients have direct contact with the bacteria.

Microbacterium arborescens are gram positive, non-motile, predominantly aerobic bacteria commonly found in soils and shallow groundwater environments. *M. arborescens* are alkalophilic, thriving in alkaline environments, partly due to the increased production of exopolymer.

Micrococcus species are common gram positive bacteria found in a variety of natural environments including soil, water, and skin. *Micrococcus* are aerobic, spherical cells that often display bright colored colony growth.

Micrococcus yunnanensis is a gram positive spherical, saprotrophic bacterium that forms dull yellow colonies on nutrient agar. An obligate aerobe, *Micrococcus* are found in soil, dust, water and air, and as part of the normal flora of human skin. Though not a spore former, *Micrococcus* cells are resilient and can survive in harsh environments for an extended period of time. *Micrococcus* is generally thought to be a saprotrophic or commensal organism, though it can be an opportunistic pathogen, particularly in hosts with compromised immune systems.

Nocardia genus is an aerobic actinomycete. The Nocardia are both catalase and gram positive with a branching filamentous nature. Nocardia are generally considered opportunistic pathogens and can cause infections in immune-compromised individuals.

Pseudomonas citronellolis is a gram negative aerobic bacterium that is often isolated from forest soils, especially in heavier pine forests. The bacteria are very similar to *Pseudomonas aeruginosa*, and can produce a very dense biomass like many Pseudomonades.

Microscopic evaluation of all six wells samples noted various levels of visible bacterial activity and biomass present. Iron oxide and iron oxide entrained biomass was noted in both the casing and aquifer samples for wells WW4, WW4A, WW8, J-12 WW and the casing samples for wells WW5B and UE-16d WW.

Plant particulate was also reported in the casing samples for WW4, WW4A, J-12 WW and UE-16d WW. Protozoa, including ciliates and flagellates, were only observed in the J-12 casing sample.

Interpretations and Recommendations:

The wells, constructed between 1957 and 1990, range in depth from 878-ft to 2, 936-ft. No current production or efficiency data was provided with the submitted samples. No aesthetic issues or treatment challenges were documented.

Within the six wells, iron related fouling seems the most likely, with iron concentrations in Well 4a and J-12 exceeding the fouling threshold. Resident microbial populations, as evaluated by ATP testing, generally fell within a normal range for an active well system. Plate growth was highest in the J-12 sample set. Anaerobic growth, generally used to asses a more dynamic form of biofilm development, was elevated in the J-12 and UE-16d casing samples but declined with pumping. Despite populations as a whole being normal, identification of the dominant bacteria noted a fairly diverse and somewhat dynamic level of biodiversity.

Of the submitted samples, calculated LSI values were generally negative. Due to the influence that temperature plays on this calculation and as such, the development of carbonate scale, a temperature survey of the wells is advised to better understand scale potential.

Crystalline debris, observed in several of the samples, is not unexpected given the geologic setting and well designs. However, the fluctuation was observed in the UE-16d sample set may point to an increased presence which could indicate an accumulation of fill within the well.

Due to the nature of the test data, a video log of the wells is advised to visually assess the well structures and level of potential fouling. The video survey should be conducted prior to any cleaning efforts with the results utilized to develop final treatment plans.

In general, due to the relative age of the evaluated wells and the calculated LSI values, use of phosphoric acid is advised for any chemical based treatment effort. Phosphoric acid is a strong mineral acid that operates at a slower rate as compared to other acids. In addition to allowing more control during cleaning, phosphoric acid also does not attack metal structures like hydrochloric or sulfamic acid, reducing the potential for corrosion and structural damage during cleaning. While not excessive, use of a biodispersant such as Johnon Screen's NW-310 is advised to improve penetration and disruption of biomass while also improving the efficiency of the acid and the dissolution of mineral scale presence downhole.

Although the wells tested negative for total coliform presence, several dynamic and potentially problematic microbial species were identified. As such, a separate disinfection effort should be incorporated into any form of mechanical, chemical, or combined rehabilitation efforts employed. Due to the variability among the alkalinity contributions, use of NW-420, a chlorinated isocyanurate (chlorine substitute) is advised to limit the need for pH adjustment.

WSE would be happy to review the video survey once completed and assist in the development of treatment recommendations for the sampled wells. If you have any questions regarding the laboratory results or the interpretations, please contact our office.

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