MEMORANDUM

TO: Robert Eranio, Crestview Mutual Water Company

FROM: Gregory Schnaar, PhD, PG (VA)
Tony Morgan, PG (CA), CHG (CA)

DATE: July 14, 2021

SUBJECT: Well No. 7 Nitrate Transport Evaluation

EXECUTIVE SUMMARY

Nitrates are used as a primary indicator for potential septic system contamination of groundwater supplies. Modeling results estimate nitrate concentrations in groundwater of 0.26 milligrams per liter (mg/L) at proposed Crestview Mutual Water Company (CMWC) Well No. 7, which is much less than the groundwater standard of 10 mg/L. **Our analyses and existing nitrate data indicate that Well No. 7 will safely produce water that meets drinking water standards for nitrates.**

This technical memorandum evaluates potential nitrate impacts to groundwater at proposed CMWC Well No. 7 from septic systems within 200 feet (ft.) of the proposed well based on (1) standard modeling techniques using site-specific information; and (2) review of available nitrate data in groundwater from nearby wells. Modeling methods considered processes that reduce nitrate concentrations from septic system effluent, including dilution with precipitation, bacterial transformation from nitrate to nitrogen gas (“denitrification”), and mixing with groundwater. Modeling results are consistent with review of nitrate in groundwater from nearby wells in residential areas, which exhibit nitrate concentrations less than 0.4 mg/L. Sensitivity analyses were conducted to consider a range of conservative assumptions, and in all cases predicted nitrate concentrations are much less than the groundwater standard.

CONCLUSIONS

We conclude that nitrate-N in effluent from septic systems within 200 ft. of the proposed CMWC Well No. 7 is expected to decrease due to a combination of dilution with precipitation, denitrification, and mixing with groundwater. Standard modeling methods predict that the nitrate-N concentration in groundwater from the septic systems is likely to be approximately 0.26 mg/L (as compared to the 10 mg/L groundwater standard MCL), which is consistent with the data from nearby wells in residential areas that exhibit concentrations that have in all cases been less than 0.4 mg/L.

Sensitivity analyses were conducted to test a range of possible conservative site conditions, and resulting predicted groundwater concentrations range from 0.18 to 2.9 mg/L. The sensitivity analyses indicate that even given the more conservative assumptions the groundwater nitrate-N concentration is predicted to be less than the MCL of 10 mg/L.

INTRODUCTION AND BACKGROUND

Daniel B. Stephens & Associates, Inc. (DBS&A) has evaluated nitrate loading to groundwater from residential septic systems in the vicinity of the proposed CMWC Well No. 7 at Alviso Drive and La Patera Drive ("well site").

CMWC Well No. 7 is proposed to be located within the Las Posas Valley groundwater basin, and be screened from approximately 1,040 to 1,080 feet below ground surface (ft. bgs) and from 1,240 to 1,420 ft. bgs (HGC, 2019). Static water-level in the vicinity of the well site is approximately 580 ft. bgs based on measurements at CMWC Well No. 4 located 1,550 ft. to the east-northeast.

A map of septic systems in the vicinity of the proposed wellsite is included as Appendix A. According to this map, two septic systems are located within 200 ft. of the proposed wellhead, and a third is located beyond the very edge of the 200-foot radius. Two septic systems are assumed present within 200 ft. of the wellhead for the purpose of our analysis, and an additional analysis is also conducted considering three septic systems.

NITRATE TRANSPORT ANALYSIS

Nitrate concentration in percolating wastewater

Standard methods were used to estimate the nitrate concentration of water percolating from the septic systems within 200 ft. of the proposed Well No. 7 location. Nitrogen in wastewater that is discharged from the septic systems is subject to the following factors and processes that impact nitrate concentrations, in the following sequential order:

1. Starting total nitrogen concentration: Various nitrogen compounds are present in septic system effluent based on fluids and products that are discharged into the septic system. As discussed below, the concentration of total nitrogen in septic tank effluent generally ranges from 30 to 100 mg/L, with an average of 45 mg/L.

2. Nitrification: Various nitrogen compounds (e.g., ammonium) are transformed to nitrate by microorganisms in the soil, in a process referred to as nitrification. Virtually complete nitrification of nitrogen occurs in well-aerated soils below septic tank disposal fields (Hantzsche and Finnemore, 1992), and therefore other forms of nitrogen are assumed to be completely converted to nitrate.

3. Dilution: As wastewater percolates through the vadose zone towards groundwater it mixes with precipitation recharge, which dilutes and lowers nitrate concentrations.

4. Denitrification: In areas of the vadose zone with relatively high water contents (i.e.,

clayey zones) bacteria are present that will transform nitrate to gaseous nitrogen, therefore removing it from the water and lowering nitrate concentrations.

We used a standard scientific approach to estimate the nitrate concentration in the percolating waters below the septic systems accounting for each of the processes listed above. Nitrate concentrations are often reported as the amount of nitrogen that is in the nitrate ion, referred to as nitrate-as-nitrogen ("nitrate-N"). The average concentration, n_r, of nitrate-N in percolating vadose zone water is given by (Hantzsche and Finnemore, 1992):

$$n_r = \frac{\mathrm{I} * n_w(1-d_n)+\mathrm{R} * n_b}{(\mathrm{I}+\mathrm{R})} \qquad \text{[Eq-1]}$$

where I is the volume rate of wastewater entering the soil averaged over the area that the volume is distributed over, n_w is the total nitrogen concentration of the original wastewater effluent, R is the average recharge rate of rainfall, n_b is the background nitrate-N concentration of rainfall (assumed zero in order to evaluate the septic system impacts separately), and d_n is the fraction of nitrate-N loss due to denitrification.

Table 1 summarizes all input parameters and results for the nitrate transport analysis. A base case analysis was conducted considering representative values of each of the parameters in Equation 1, and a sensitivity analysis was also conducted to evaluate a range of each of the parameters:

- Total nitrogen concentration in the septic system effluent (n_w): An average value of 45 mg/L nitrogen in septic effluent was assumed based on U.S. EPA (2002), and a sensitivity analysis was conducted considering a range of 30 to 100 mg/L based on values reported by U.S. EPA (2002), McCray (2005), Hantzsche and Finnemore (1992), and Leverenz et al. (2002).

- Fraction lost to denitrification (d_n): The fraction of nitrate lost to denitrification was assumed to be 25-percent in the vadose zone, and a sensitivity analysis was also conducted considering 50-percent loss based on U.S. EPA (2006). Significant clay lenses are present in the vadose zone underlying the site that allow for near water-saturated and anaerobic conditions facilitating denitrification. Table 2 presents the conceptual lithology at the Well No. 7 location.

- Precipitation recharge rate (R): Precipitation recharge in the area was assumed to be 1.6 inches per year based on 10 percent of annual average precipitation (16.3 inches per year; PRISM, 2004). A sensitivity analysis was also conducted considering recharge rates ranging from 0.4 to 4.0 inches per year (Flint and Flint, 2014).

- Volume of wastewater averaged over area (I): The average effluent discharge per person is assumed to be 50 gallons per day (Hantzsche and Finnemore, 1992) and the average size of a household is assumed to be 3 people, resulting in 150 gallons per day per septic unit and 300 gallons per day total given the two septic systems. The leaching area of analysis is the 200-foot radius circle surrounding the proposed well site (Appendix A). The resulting wastewater volume averaged over the leaching area is 1.4 inches per year (Table 1). A sensitivity analysis was also conducted considering three septic systems, totaling 450 gallons per day total discharge and therefore equaling 2.1 inches per year averaged over the area.

The resulting estimated nitrate-N concentration in percolating vadose zone water for the base case scenario is 15.6 mg/L (Table 1). Figure 1A presents the results of sensitivity analyses that considered the range of each of the parameters discussed above. Estimated vadose zone nitrate-N concentrations for the sensitivity analyses ranges from 5.8 to 58 mg/L. Higher concentrations are estimated for scenarios with higher initial total nitrogen in the septic effluent, lower precipitation recharge rates, and lower denitrification rates. As discussed below, nitrate in percolating vadose zone water is further reduced due to mixing with groundwater.

Nitrate concentration in groundwater

Nitrate concentrations are reduced as percolating wastewater recharges and is mixed with groundwater. This reduction was estimated by calculation of the dilution attenuation factor (DAF; U.S. EPA, 1996):

$$DAF = 1 + \frac{\mathrm{K*i*d}}{\mathrm{I*L}} \qquad \text{[Eq-2]}$$

where *K* is the aquifer hydraulic conductivity, *i* is the aquifer hydraulic gradient, I_t is the total recharge rate of vadose zone water to groundwater, *L* is the source length parallel to groundwater flow and *d* is the mixing zone depth. This analysis conservatively assumes that there are no additional sources of nitrate attenuation in groundwater (e.g., denitrification).

DAF is defined as the ratio of vadose zone concentration to groundwater concentration after mixing. A DAF of 1 corresponds to a situation where there is no dilution or attenuation. Table 1 presents the assumed values to calculate the DAF. Values of the hydraulic gradient and hydraulic conductivity representative of the area of the well were taken from UWCD (2018). Mixing zone depth (*d*) was assumed to be the aquifer thickness from the top elevation of the aquifer to the bottom elevation of the CMWC Well No. 7 well screen. Based on the conceptual lithology for the area of Well No. 7 and the preliminary Well No. 7 design report (HGC, 2019), we assumed this thickness to be 440 ft., which is the thickness of “hard sand, rocks and clay” and “sand, rock and streaks of clay” (Table 2). Based on these parameter values a DAF value of 59 was calculated (Table 1). A sensitivity analysis was also conducted considering the U.S. EPA (1996) default DAF of 20. The lower DAF value of 20 would be representative of scenarios with lower aquifer hydraulic conductivity, hydraulic gradient or mixing zone thickness, or higher total recharge rate.

Nitrate-N concentration in groundwater (n_d) is calculated from (U.S. EPA, 1996):

$$n_d = \frac{n_r}{DAF} \qquad \text{[Eq-3]}$$

Resulting estimated groundwater nitrate-N concentration is 0.26 mg/L for the base-case scenario (DAF equals 59), which is less than the maximum contaminant level (MCL) of 10 mg/L (Table 1).

Sensitivity analyses were also conducted considering the full range of vadose-zone parameters discussed above (e.g., denitrification rate, septic effluent nitrogen concentration, precipitation recharge) and the default DAF of 20. Results of the sensitivity analyses are plotted on Figures 1B (DAF calculated from site information) and 1C (DAF assumed equal to 20). For the calculated site-specific DAF scenarios (Figure 1B), groundwater nitrate-N concentrations are estimated to range from 0.18 to 0.59 mg/L, with larger values associated with higher initial septic effluent total nitrogen concentrations and lower vadose zone denitrification rates. For the scenarios assuming a default DAF of 20 nitrate-N concentrations are estimated to range from 0.29 to 2.9 mg/L, with larger values associated with lower precipitation recharge, higher septic system total nitrogen concentrations, and lower denitrification rates.

NITRATE DATA IN GROUNDWATER

Nitrate-N data from wells in the vicinity of the proposed well site were compiled in order to evaluate observed data and assess potential impacts to groundwater in the vicinity of Well No. 7. Nitrate-N data for CMWC wells were provided by CMWC, and additional data for wells in the vicinity were obtained from the Ventura County Watershed Protection District (VCWPD), United Water Conservation District (UWCD), and the Safe Drinking Water Information System (SDWIS).

Table 3 presents data from wells in the vicinity of the well site from 2010 - 2020, and Figure 2 displays well locations and the most recent nitrate-N data for each well. All nitrate-N data for area wells from 2010 - 2020 were less than the MCL of 10 mg/L (Table 3) and data from the CMWC wells are typically non-detect with a detection limit of equal to or less than 0.4 mg/L. CMWC wells No. 4 and No. 5 are located within neighborhoods with septic systems. The only well with consistently elevated nitrate-N concentrations greater than 1 mg/L is 02N21W15M04S, which is located to the north of the proposed CMWC Well No. 7 in the vicinity of agricultural land use and not residential land use with septic systems. These results confirm that nitrate-N from septic effluent is not expected to cause exceedances greater than the MCL at Well No. 7.

DEFINITIONS

The following technical terms are used to describe the nitrate transport analysis. Definitions below are adopted from the Cambridge University Press (2021), Weight and Sonderegger (2001) and U.S. EPA (1996):

- Anaerobic: Not needing or without oxygen.
- Denitrification: Breaking up nitrates (chemicals containing nitrogen and oxygen), for example in soil, and releasing nitrogen into the air. Denitrification removes nitrates from water in soils.

- Dilution Attenuation Factor (DAF): Describes the reduction in concentration from mixing of vadose-zone water with groundwater. Equals the ratio of vadose zone leachate concentration to groundwater concentration after mixing. The lowest possible DAF is 1, corresponding to the situation where there is no dilution.
- Effluent: Liquid waste that is sent out from factories or places where sewage is dealt with (such as septic systems).
- Groundwater: Water that collects below the surface of the earth.
- Hydraulic conductivity: A value representing the relative ability of water to flow through geologic material.
- Hydraulic gradient: Slope of the potentiometric surface (elevation that groundwater will rise to in a cased well).
- Infiltration: The process of precipitation waters entering the soil.
- Maximum contaminant level (MCL): The highest level of a contaminant that is allowed in drinking water.
- Microorganism: A living thing that on its own is too small to be seen without a microscope.
- Nitrate-as-nitrogen (nitrate-N): Nitrate concentrations reported as the amount of nitrogen that is in the nitrate ion. Total nitrate concentration equals nitrate-N multiplied by 4.4268.
- Nitrification: The process in which bacteria in the soil use oxygen to change various nitrogen compounds into nitrates.
- Percolate: Water moving through the vadose zone.
- Recharge: The addition of water to a groundwater system.
- Sensitivity analysis: The detailed study of a situation, project, etc. to find out the likely effects of particular actions, changes, etc. In the context of modeling, refers to changing various model assumptions in order to evaluate the impact of those assumptions on the model results.
- Vadose zone: Subsurface zone containing fluid under pressure that is less than the atmosphere. Pore spaces in the vadose zone are partly filled with water and partly filled with air. Located between the earth surface and groundwater.

SIGNATURES

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Figures

Fig 1A. Vadose Zone Water Nitrate-N Concentrations

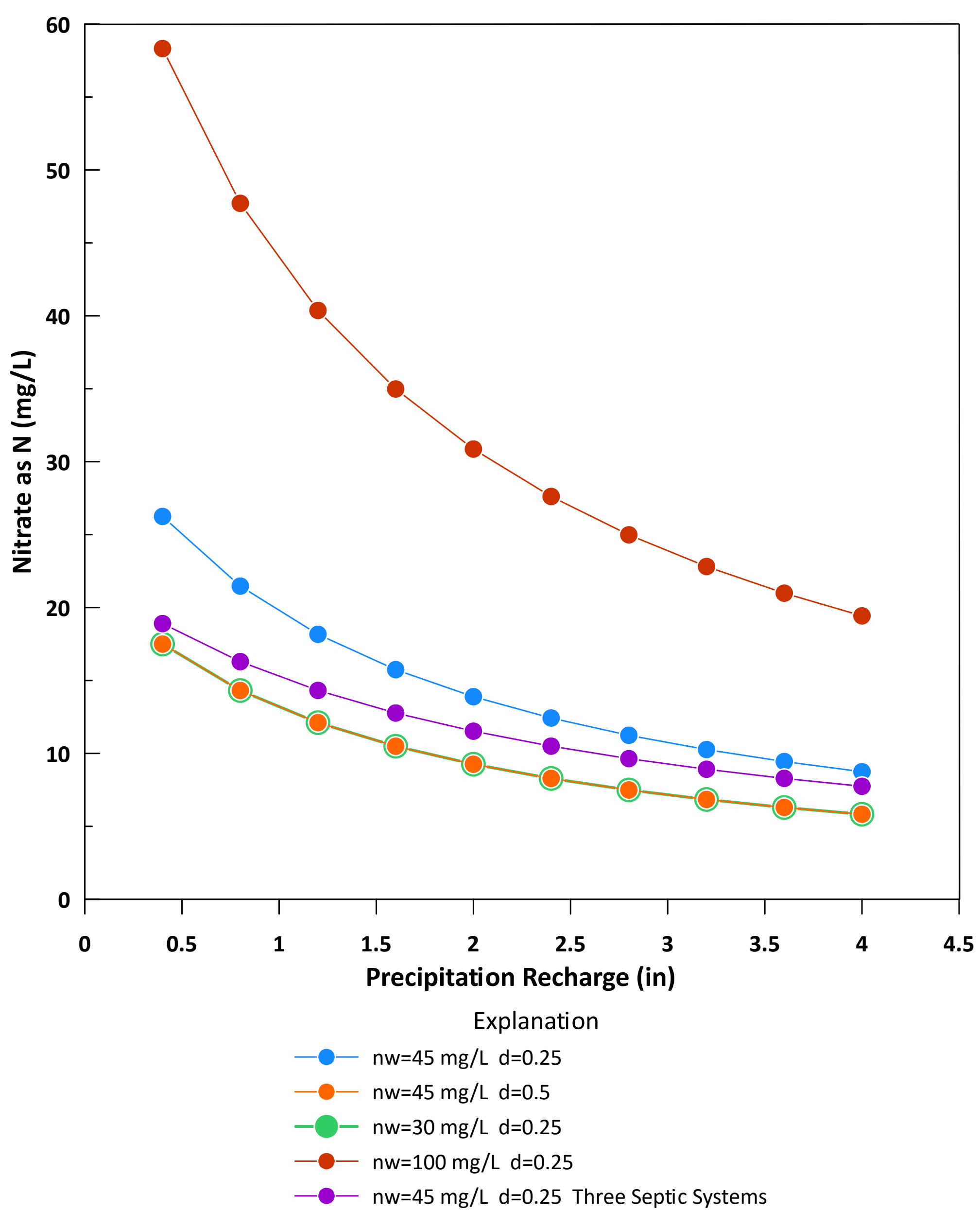


Fig 1B. Groundwater Nitrate-N Concentrations
Variable DAF, Calculated from Site Parameters

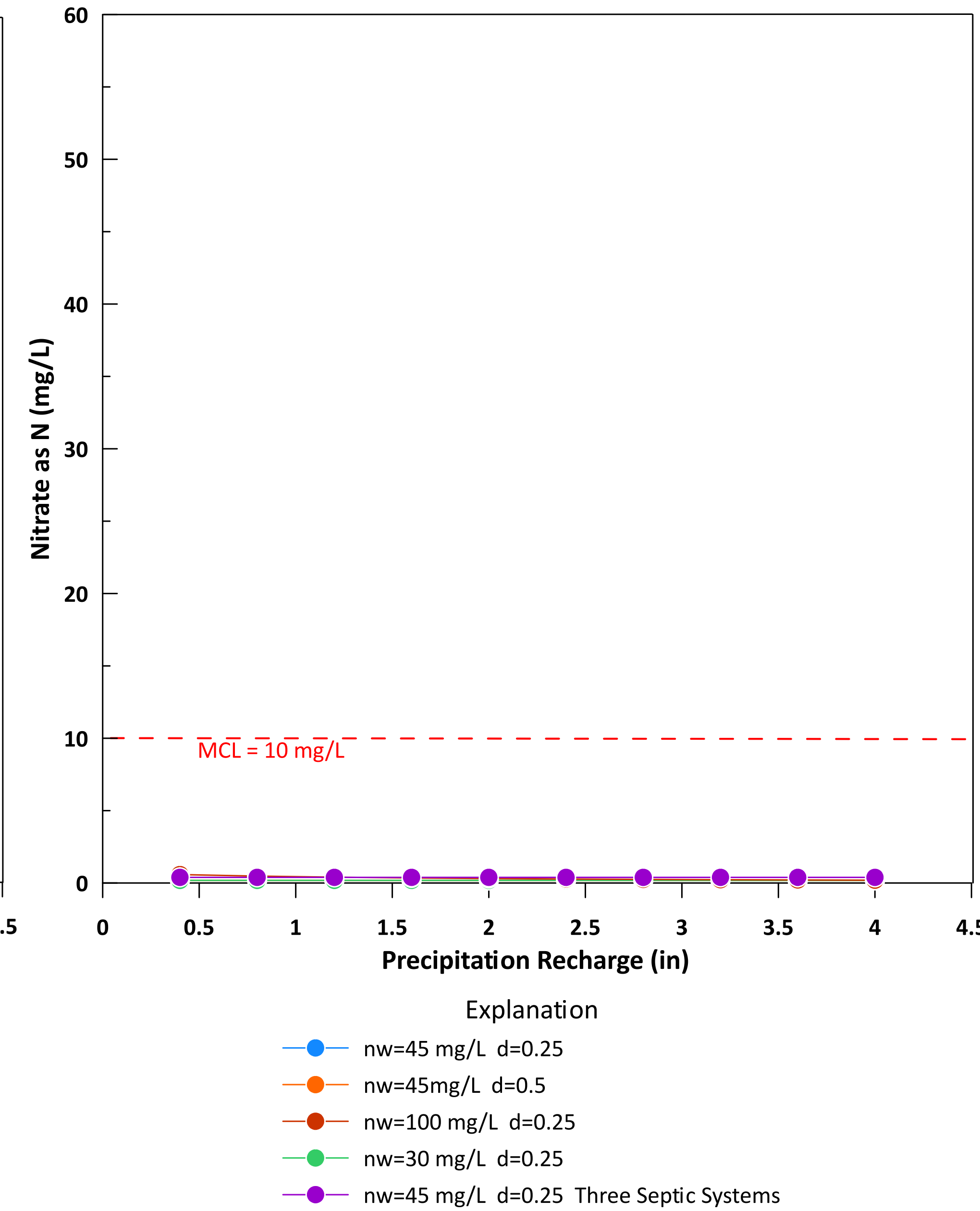
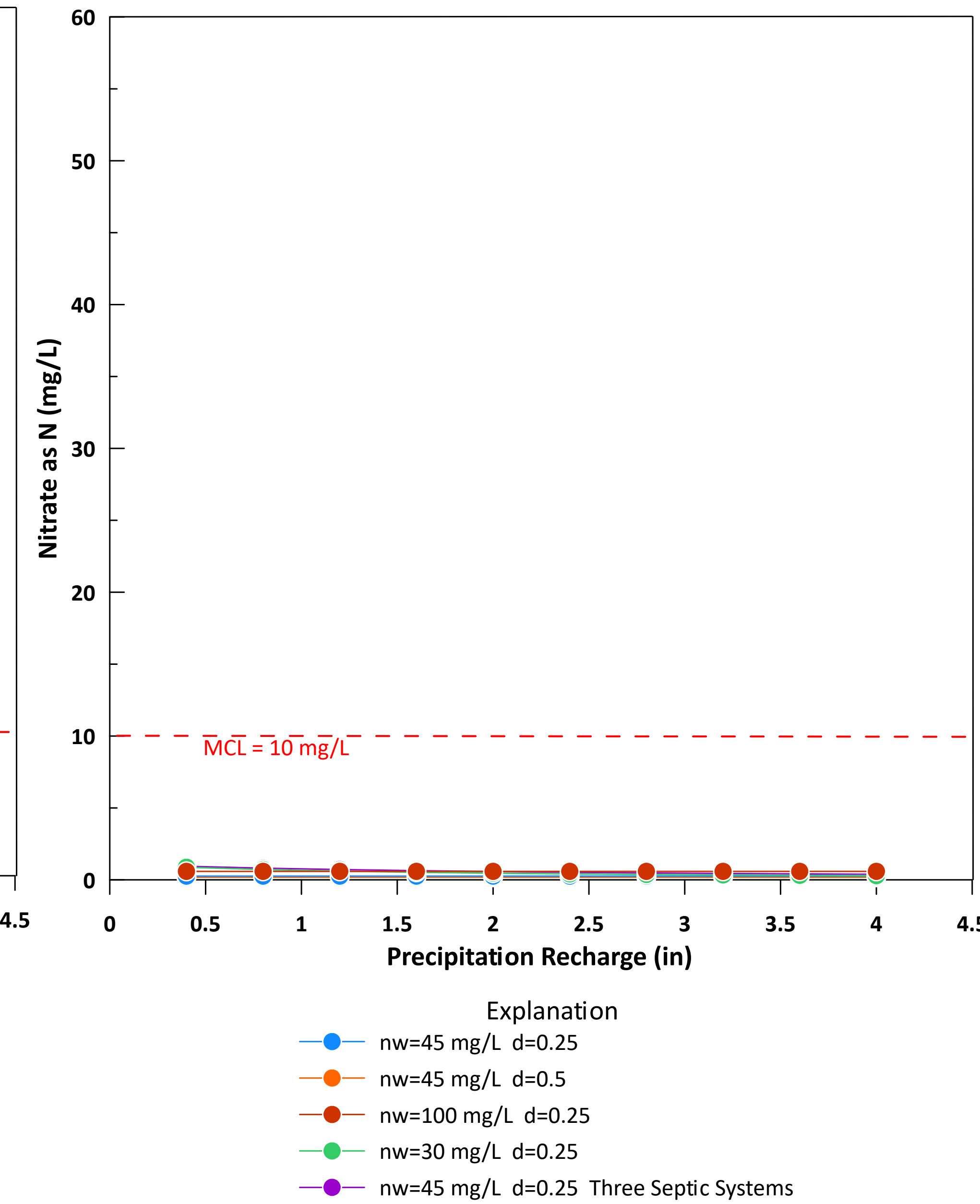


Fig 1C. Groundwater Nitrate-N Concentrations
DAF equals 20



Definitions

nw: Septic effluent total nitrogen. d: Fraction lost to denitricication.

DAF: Dilution Attentuation Factor. MCL: Maximum contaminant level.

K:\PROJECTS\LITIGATION SERVICES\DB20.1430.00 CRESTVIEW MUTUAL WC PATHOGEN TRAVEL TIME\GIS\MXDS\FIG01_SENSITIVITY ANALYSIS.MXD

DBS&A
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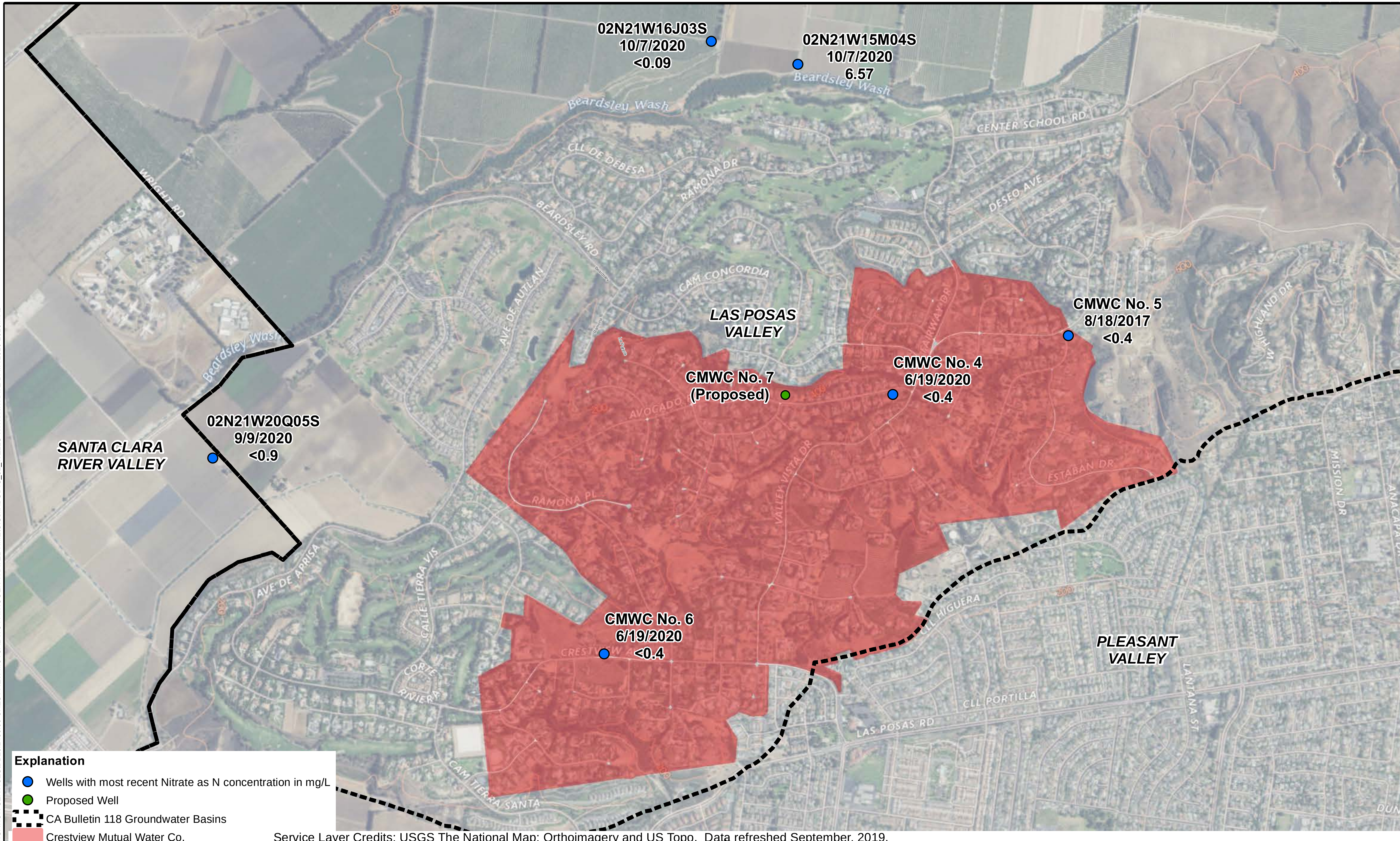
4/15/2021 DB20.1430

CRESTVIEW MUTUAL WATER COMPANY
Sensitivity Analysis, Nitrate Transport Analysis

Figure 1



Service Layer Credits: USGS The National Map: Orthoimagery and US Topo. Data refreshed September, 2019.

N

0 1000 2000 Feet

K:\PROJECTS\LITIGATION SERVICES\DB20.1430.00 CRESTVIEW MUTUAL WC PATHOGEN TRAVEL TIME\GIS\MXDS\FIG_02_WELLS WITH NITRATE DATA 2010-2020.MXD

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CRESTVIEW MUTUAL WATER COMPANY
Most Recent Nitrate-as-N for Nearby Wells, 2010 – 2020

Figure 2

Tables

Table 1. Nitrate Transport Analysis

Symbol	Parameter	Calculation	Value	Units	Source
Step 1: Calculation of Nitrogen Concentration in Septic System Recharge Water					
n_w	Total nitrate as N in septic system waste water	-	45	mg/L	A
A	Leaching area	-	125664	sq-ft	E
P	Average precipitation rate	-	16.27	in	G
d_n	Fraction of nitrate loss due to denitrification	-	0.25	-	B
W	Total wastewater flow volume	W = f x n	300	gal/d	I
			40	ft^3/d	
n_b	Background nitrate concentration, rainfall-recharge		0	-	C
R	Precipitation recharge rate	R = 0.10 x P	1.6	in	D
I	Wastewater volume averaged over leaching area	I = W / A	3.19E-04	ft/d	B
			1.4	in/yr	
n_r	Nitrate-nitrogen in recharge water	$n_r = [In_w(1-d_n) + Rn_b] / (I + R)$	15.6	mg/L	B
Step 2: Calculation of Dilution Attenuation Factor (DAF)					
K	Aquifer horizontal saturated hydraulic conductivity	—	5	ft/day	H
i	Hydraulic Gradient	—	0.005	[-]	H
I_t	Infiltration rate, precipitation and wastewater	$I_t = R + I$	6.91E-04	ft/d	-
			3.0	in/yr	
L	Source length parallel to groundwater flow	—	255	ft	J
d	Mixing Zone Depth		440	ft	K
DAF	Dilution Attenuation Factor	DAF = 1 + [(K*i*d) / (I*L)]	59.4	-	F
Step 3: Calculation of Concentration in Groundwater After Mixing with Applied Water					
n_d	Downgradient nitrate as N	$n_d = n_r / DAF$	0.26	mg/L	F

Sources:

A	U.S. EPA (2002) as cited in McCray et al (2005)
B	U.S. EPA (2006)
C	Assumed to evaluate impact of septic systems
D	Assumed
E	200-ft radius circle around the proposed Well 7 location
F	U.S. EPA (1996)
G	PRISM precipitation data - 30 year normals
H	UWCD (2018)
I	Assumed 150-gal per dwelling unit (Hantzsche and Finnemore, 1992), and two dwelling units
J	Average length parallel to groundwater flow for 200-ft radius circle
K	Approximate thickness, top of aquifer to bottom of well screen

ft = Feet
m = Meter
yr = Year
gal/d = gallons per day
in = inch
mg/L = Milligrams per liter

Table 2. Conceptual Lithology, Well #7

Starting Depth, ft	Ending Depth, ft	Lithologic Description	Source
0	5	Clay Loam	179 Alviso Septic Record
5	10	Sandy Loam	179 Alviso Septic Record
10	15	Clay Loam	179 Alviso Septic Record
15	20	Silt Loam	179 Alviso Septic Record
20	25	Clay Loam	179 Alviso Septic Record
25	30	Sandy Clay Loam	179 Alviso Septic Record
30	35	Clay Loam	179 Alviso Septic Record
35	40	Sandy Loam	179 Alviso Septic Record
40	45	Sandy Loam	179 Alviso Septic Record
45	50	Sandy Loam	179 Alviso Septic Record
50	85	Loamy Sand	Crestview Well #3
85	105	Clay	Crestview Well #3
105	195	Sand	Crestview Well #3
195	215	Clay	Crestview Well #3
215	255	Sand	Crestview Well #3
255	265	Clay	Crestview Well #3
265	300	Sand	Crestview Well #3
300	325	Clay	Crestview Well #3
325	340	Sand	Crestview Well #3
340	348	Clay	Crestview Well #3
348	370	Sand	Crestview Well #3
370	380	Blue clay	Crestview Well #3
380	525	Gray sand & rock	Crestview Well #3
525	940	Blue clay	Crestview Well #3
940	1040	Hard sand, rocks & clay	Crestview Well #3
1040	1380	Sand, rock & streaks of clay	Crestview Well #3
1380	1450	Blue clay	Crestview Well #3

Depth to water approximately 580 ft bgs

Table 3. Nitrate-N for the Surrounding Area, 2010-2020

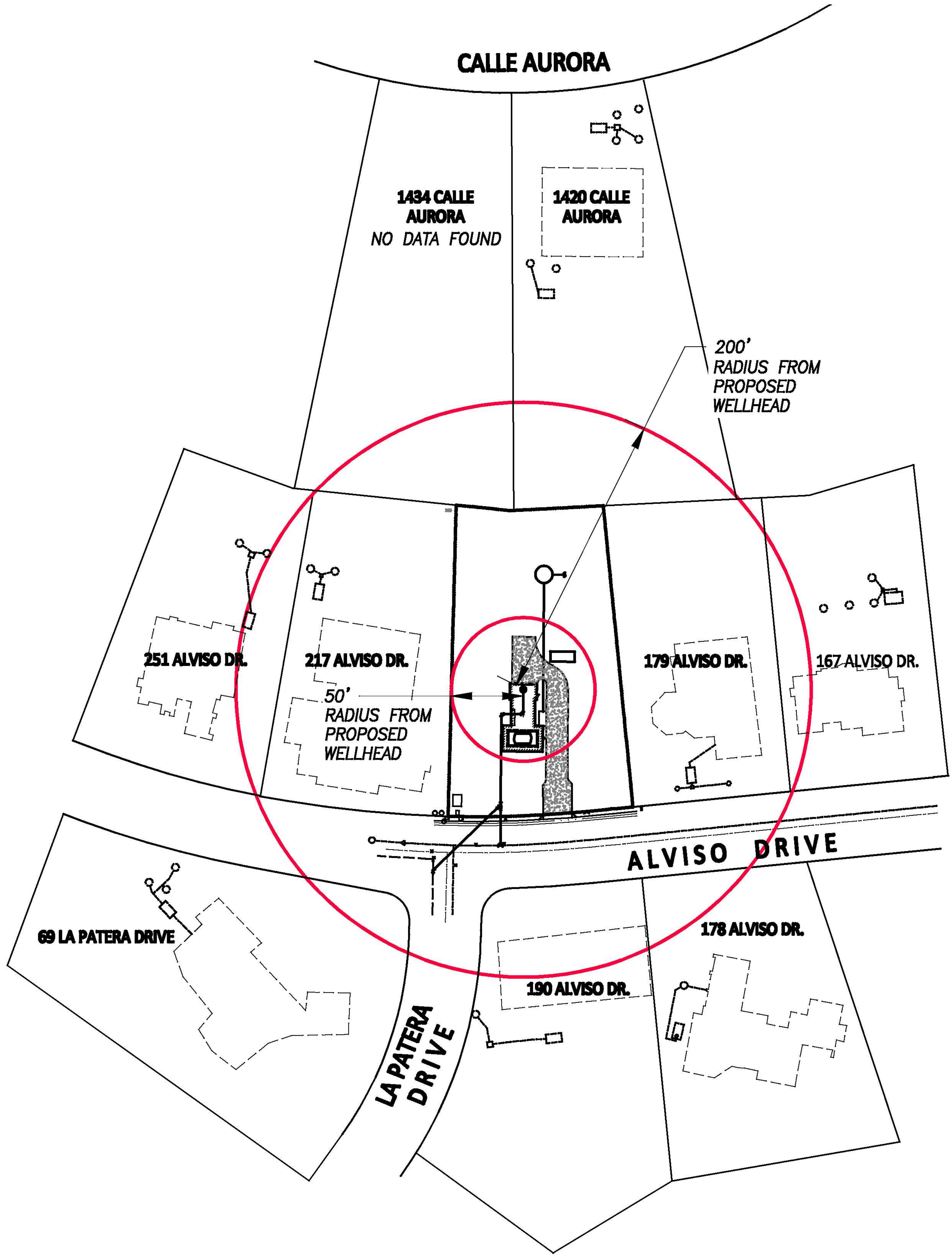
Well ID	Sample date	Result (mg/L)	Source
02N21W15M04S	8/13/2010	3.6	VCWPD
02N21W15M04S	9/15/2011	2.3	VCWPD
02N21W15M04S	8/14/2012	2.3	VCWPD
02N21W15M04S	10/29/2013	3.0	VCWPD
02N21W15M04S	10/22/2014	1.8	VCWPD
02N21W15M04S	8/21/2015	5.5	VCWPD
02N21W15M04S	9/9/2016	2.2	VCWPD
02N21W15M04S	9/28/2017	14.4	VCWPD
02N21W15M04S	11/21/2018	2.7	VCWPD
02N21W15M04S	9/25/2019	3.3	VCWPD
02N21W15M04S	10/7/2020	6.6	VCWPD
02N21W16J03S	10/7/2020	0.09	VCWPD
02N21W20Q05S	8/17/2010	ND	VCWPD
02N21W20Q05S	8/26/2011	<0.09	VCWPD
02N21W20Q05S	8/16/2012	<0.09	VCWPD
02N21W20Q05S	10/22/2013	<0.09	VCWPD
02N21W20Q05S	12/31/2014	0.09	VCWPD
02N21W20Q05S	9/8/2015	0.14	VCWPD
02N21W20Q05S	10/6/2016	<0.09	VCWPD
02N21W20Q05S	10/27/2017	<0.4	VCWPD
02N21W20Q05S	11/28/2018	<0.09	VCWPD
02N21W20Q05S	10/29/2019	0.43	VCWPD
02N21W20Q05S	9/9/2020	<0.09	VCWPD
CMWC No. 4	8/26/2010	<0.09	UWCD
CMWC No. 4	8/9/2011	<0.09	SDWIS
CMWC No. 4	8/28/2012	<0.09	UWCD
CMWC No. 4	4/19/2013	<0.09	SDWIS
CMWC No. 4	8/14/2013	<0.09	SDWIS
CMWC No. 4	8/20/2014	<0.09	SDWIS
CMWC No. 4	8/11/2015	0.1	SDWIS
CMWC No. 4	8/16/2016	<0.1	SDWIS
CMWC No. 4	8/22/2018	<0.4	SDWIS
CMWC No. 4	6/19/2020	<0.4	SDWIS
CMWC No. 5	8/26/2010	<0.09	UWCD
CMWC No. 5	8/17/2011	<0.09	SDWIS

Table 3. Nitrate-N for the Surrounding Area, 2010-2020

Well ID	Sample date	Result (mg/L)	Source
CMWC No. 5	8/28/2012	<0.09	UWCD
CMWC No. 5	8/14/2013	<0.09	SDWIS
CMWC No. 5	8/22/2014	<0.09	SDWIS
CMWC No. 5	8/18/2016	<0.1	SDWIS
CMWC No. 5	8/15/2017	<0.4	SDWIS
CMWC No. 6	8/26/2010	<0.09	UWCD
CMWC No. 6	8/9/2011	<0.09	SDWIS
CMWC No. 6	8/28/2012	<0.09	UWCD
CMWC No. 6	4/19/2013	<0.09	SDWIS
CMWC No. 6	8/14/2013	<0.09	SDWIS
CMWC No. 6	8/20/2014	<0.09	SDWIS
CMWC No. 6	8/11/2015	<0.1	SDWIS
CMWC No. 6	8/16/2016	<0.1	SDWIS
CMWC No. 6	8/9/2017	<0.4	SDWIS
CMWC No. 6	8/22/2018	<0.4	SDWIS
CMWC No. 6	6/12/2019	<0.4	SDWIS
CMWC No. 6	6/19/2020	<0.4	SDWIS

Notes:
CMWC = Crestview Mutual Water Company
VCWPD = Ventura County Water Protection District
UWCD = United Water Conservation District
SDWIS = Safe Drinking Water Information System
<0.4 = Below the reporting limit of 0.4 mg/L
ND = Non Detect, reporting limit not available.
mg/L = milligrams per liter
Nitrate-N = nitrate as nitrogen

Appendix A: Well No. 7 Location and Septic Systems

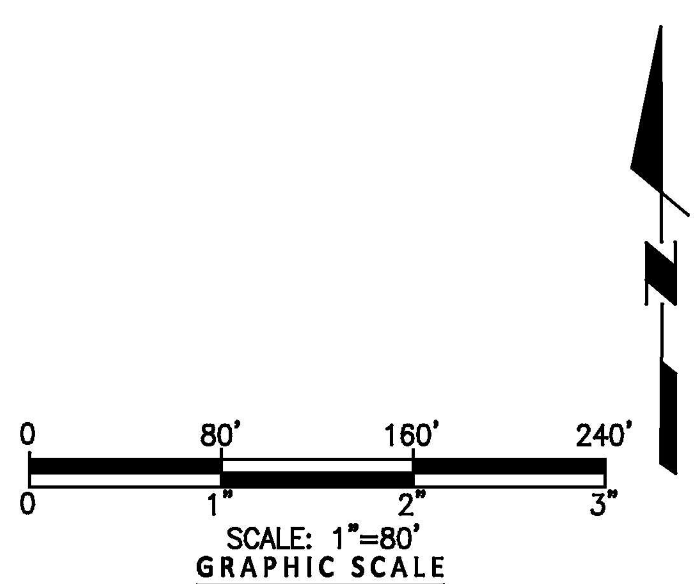


NOTES:

EXISTING SEPTIC/SEEPAGE PIT SYSTEMS LOCATIONS ARE APPROXIMATE. INFORMATION BASED ON ISDS (INDIVIDUAL SEWAGE DISPOSAL SYSTEM), SOURCE IS ENVIRONMENTAL HEALTH DIVISION, VENTURA COUNTY. FIELD VERIFY.

LEGEND:

EXISTING SEPTIC/SEEPAGE PIT SYSTEM COMPONENTS, EACH LOT WILL HAVE DIFFERENT CONFIGURATIONS



REGISTERED PROFESSIONAL ENGINEER
HEATHER M. O'CONNELL
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Exp. 12-31-20
CIVIL
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BY:
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HEATHER O'CONNELL, R.C.E. 73119 DATE

EXISTING SEPTIC EXHIBIT
200' RADIUS FROM WELLHEAD
CRESTVIEW MUTUAL WATER

SHEET x OF | DRAWING NO. xxxxxx