Technical
Memo

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To: Darren Parkin, Natural Resources Manager, City of Laramie

From: Mark Stacy, PG and Freddy Tremblay, Wenck Associates, Inc.

Date: October 1, 2020

Subject: Casper Aquifer Nitrate Loading Study, Laramie, Wyoming

Introduction

Wenck Associates, Inc (Wenck) has completed a nitrate loading study of the discharge associated with current and future build-out scenarios to simulate their effects on the Casper Aquifer. Encompassing approximately 79 square miles, the Casper Aquifer Protection Overlay Zone (APOZ) lies east of the City of Laramie (City) extending eastward to the crest of the Laramie Range. The northern boundary extends 6 miles north of city limits and the southern boundary 6 miles to the south as shown on **Figure 1**. The APOZ is positioned atop the Casper Aquifer which supplies water to approximately 400 rural residences in Albany County and approximately 60% of Laramie's water supply (Wittman Hydro Planning Associates (WHPA), 2008).

Typically, Wyoming subdivision development regulations consider nitrate loading impacts of the applicant's subdivision to the underlying aquifer during the subdivision permitting review process. Given that this approach does not address cumulative impacts and that multiple subdivision developments may have a cumulative impact, the City commissioned Wenck to develop a broader understanding of the potential nitrate loading effects of both current and future development that could potentially occur within the APOZ. Wenck collaborated with the City to identify the areas of current and future build-out. Potential areas for future build-out excluded lands owned by state, federal, and certain private interests. The City was interested in the potential nitrate loading to the Casper Aquifer under a variety of future development scenarios, specifically certain zoning designations and their associated lot sizes. Wenck modeled future development scenarios using the following lot sizes: 35 acre-lots with agricultural zoning designations, 5-acre lots for rural residential zoning, and 2-acre lots for small lot residential zoning.

The Wyoming Department of Environmental Quality (DEQ) recommends using the Wehrmann volumetric loading model to assess potential nitrate impacts to downgradient water users and to make determinations of county subdivision approval according to Appendix A of Wyoming DEQ Chapter 23. This model was used to estimate the potential downgradient nitrate concentration based on effluent moving westward across the APOZ. The modeling is based on the following concentration and volume factors: groundwater moving through the area, infiltrating precipitation, and effluent discharge. The model assumes no denitrification processes occur because of soils located above the aquifer. As such, the model assumes that there is no attenuation of nitrate as effluent leaves the leach field and enters the aquifer. Using the available data documented in this report, Wenck has modeled the impacts to the aquifer and downgradient users based on two scenarios: current build-out and future build-out. In addition, two nitrate effluent concentrations were used in this study: 40 mg/L and 55 mg/L. Both concentrations are used for the purpose of performing a sensitivity analysis on nitrate loading to the aquifer. As mentioned above, future build-out scenarios are predicted for areas that could be developed based on housing densities categorized by zoning types (i.e. small lot versus rural). The model was prepared using water quality data provided by the City and U.S. Geological Survey. These data are included in **Appendix A**.

Geologic Setting

The APOZ is located along the eastern margin of the Laramie Basin on the western flank of the Laramie Range. The Basin is a broad, north-plunging syncline bounded by the Medicine Bow Mountains to the west, Laramie Range to the east, and Front Range to the south. The Laramie Range was uplifted by compressional forces during the Laramide orogeny causing generally uniform stratigraphic dips between 3 and 5 degrees to the west, with rocks striking north south. The uplift was not entirely uniform, and faults and folds locally interrupt the dip regime (WHPA, 2008).

The rocks that comprise the Casper Aquifer include saturated portions of the Casper and Fountain Formations with a combined thickness ranging from 0 to 750 feet (Lundy, 1978). The Fountain Formation is irregularly distributed throughout the APOZ and includes continental, arkosic sandstone, with minor amounts of siltstone. The Casper Formation unconformably overlies both the Fountain Formation and Precambrian basement rock where the Fountain is absent. The Casper Formation is composed of a series of interbedded sandstones and limestones with minor amounts of shale. Casper sandstones are generally fine grained, well sorted sub-arkoses that are typically well-cemented (WHPA, 2008). Casper limestones are microcrystalline and fossiliferous. The Satanka Shale unconformably overlies the Casper Formation and is composed of red shale with interbedded siltstone and sandstone layers. The Satanka Shale is exposed along the western margin of the Laramie Range. The location of the APOZ and geologic units in its vicinity are noted in **Figure 2**.

Hydrogeologic Conditions

The Casper Aquifer is the primary source of potable water for the City's wells and springs as well as serving domestic and industrial water needs. The saturated thickness varies throughout the aquifer with a minimum saturated thickness of zero feet along the crest of the Laramie Range and a maximum thickness of 712 feet immediately west of the Casper-Satanka contact near the City (Thompson. 1979). Because the Casper Aquifer pinches out to the east, a saturated thickness of zero feet was assumed for modeling purposes. The aquifer is confined by the overlying Satanka Shale, where there is sufficient shale thickness, and the underlying Precambrian rocks. Bounded by the Spur Wellfield to the north and Simpson Springs to the south, the APOZ contains approximately 1 million acre-feet or 326 billion gallons of groundwater (Hinckley and Moody, 2015). The Casper Aquifer extends approximately 50 miles north-northwest of Laramie and at least 21 miles south of the Colorado-Wyoming border (WHPA, 2008). Water enters the aquifer as recharge primarily from rainfall and snowmelt from March through August. Recharge is negligible in the fall and winter due to frozen ground conditions that inhibit infiltration. Though annually variable, recharge is estimated to be 1.4 inches/year and is presented as an input to the model on a steady-state water balance basis (Lundy, 1978). For modeling purposes, the nitrate concentration of infiltrating precipitation is assumed to vary based on the nitrate concentrations observed in wells located within the recharge area.

The permeability of the aquifer is associated with either porous sandstone or fractured sandstone and limestone. As a result, groundwater flow through these rocks includes both intergranular and conduit flow. Intergranular flow occurs within the unfractured, permeable sandstones and conduit flow occurs primarily through cavities or fractures associated with dissolution, faults, folds, joints, and partings along bedding surfaces. Conduit flow can yield large quantities of water to wells and supplies much of the municipal water supply. Additionally, all major springs that discharge from the aquifer are located on or near major faults.

The direction of groundwater flow in unfaulted parts of the aquifer is generally westward from the Laramie Range towards the Laramie Basin. Hydraulic gradients vary from 0.02 to 0.06 throughout the APOZ and were estimated based on a potentiometric map prepared by WWC Engineering (2006). Intergranular porosity of the rocks composing the aquifer varies significantly from nearly impermeable limestones to porous sandstones (up to 30%). Test pumping of wells completed in the Casper Aquifer revealed hydraulic conductivity varied greatly between fractured and unfractured medias. The vertical and horizontal hydraulic conductivities are anisotropic due to the fractured character of the aquifer. Unfractured areas had hydraulic conductivities of 0.1 to 2.6 feet per day (ft/day) and 17 to 40 ft/day where fractured (Lundy, 1978). Storage coefficients for the Casper Aquifer range from 0.001 to 0.006 indicating that the aquifer is confined to slightly leaky (WHPA, 2008).

Water Quality Model Setup

Following Chapter 23 of the Wyoming DEQ Rules and Regulations, Wenck evaluated downgradient changes in nitrate concentrations using the Wehrmann Model. The Wehrmann Model is a mass balance equation typically used to estimate nitrate loading impacts of only one subdivision to the underlying aquifer. However, the model was used to estimate the potential cumulative nitrate concentrations at the western margins of the APOZ to gain a broader understanding of the potential impacts of several future development scenarios. The basis for using the model in this larger development context is that it is one that DEQ already uses to make subdivision determinations, it allows for comparison with future models and their inputs developed for local subdivisions, and it generally uses hydrogeologic data that have already been documented.

Like all models, the Wehrmann Model computes estimates. Those estimates are only as good as the assumptions used to make the model, and the data input to the model. One assumption of the Wehrmann model that is not particularly helpful is that it assumes all wastewater is “new” water, and therefore, the resultant nitrate concentration cannot exceed the input nitrate concentration. The U.S. Environmental Protection Agency (EPA) primary drinking water standard for nitrate is 10 mg/L (USEPA, 2020). Although the modeled nitrate concentration cannot exceed the value input to the model, any resultant nitrate concentration over 10 mg/L is problematic. As such, this model limitation does not diminish the value of the model results in understanding the circumstances where problems may arise.

For modeling purposes, Wenck separated the APOZ into five aquifer blocks, each corresponding to a wellfield or spring which serve the City and are sourced by the Casper Aquifer. The Wehrmann Model was applied separately to each of these aquifer blocks to avoid oversimplifying the geologic and hydrogeologic variations of the Casper Aquifer and to assess potential impacts to the City’s wellfields. Due to the heterogeneity, lateral extent, and availability of water quality data for the aquifer, subdividing the APOZ allowed for better local estimation of nitrate concentrations that correspond to the various City wellfields. The aquifer blocks were determined on the basis of the 2005 potentiometric map of the APOZ considering the direction of groundwater flow (WWC Engineering, 2006). From the north end of the APOZ to the south, all five aquifer blocks correspond with the following features: Spur Wellfield, Turner Wellfield, Pope Springs Wellfield, Soldier Springs Wellfield, and Simpson Springs, each of which are shown on **Figure 1**. Current Albany County zoning designations are shown on **Figure 3** in relation to the modeled aquifer blocks.

Wenck acquired water quality data from the City for the wells and springs located in upgradient and downgradient areas corresponding to each aquifer block to establish current conditions. Additional water quality data for some areas were obtained from the U.S. Geological Survey. In the model, upgradient nitrate concentrations were used to simulate concentrations of nitrate, which likely occurs as the Casper Aquifer is recharged by percolating precipitation. Downgradient nitrate concentrations in domestic wells were compared with data from the City's wellfields. Wenck assumed there would be only household water use and did not include groundwater pumped for lawn irrigation in the model. **Table 1** shows upgradient versus downgradient nitrate concentrations compared against the location of each wellfield or spring, listed from the northern end of the APOZ to the south. Nitrate concentrations listed in **Table 1** are noted in **Appendix A** and the locations of the wells used for this water quality data analysis are shown on **Figure 1**.

Table 1: Upgradient versus Downgradient Nitrate Concentrations

Modeled Aquifer Block	Upgradient Nitrate Concentration (mg/L)[1]	Downgradient Nitrate Concentration (mg/L)[2]
Spur Wellfield	1.4 (Mathis #1)	1.7 (USGS 412332105321201)
Turner Wellfield	1.4 (Peter)	1.6 (USGS 411727105305901)
Pope Springs Wellfield	3.0 (Klein)	1.8 (USGS 411638105314001)
Soldier Springs Wellfield	3.0 (Klein)	1.6 (Jensen)
Simpson Springs	1.1 (Bryant)	1.6 (Wohl)
1 – Wells from which samples were collected are listed in parenthesis, sourced by the City. 2 – Sourced by the USGS' National Water Information System or the City.		

To determine the number of current lots and their associated wastewater volume, Wenck used GIS to tally the number of registered addresses as of 2020 within the APOZ. Current address GIS data were acquired from Albany County and were used to establish current build-out conditions in each aquifer block, as shown on **Figure 4**. The number of lots considered for the current build-out scenario, separated by modeled aquifer blocks, are summarized in **Table 2**. According to the U.S. Census (2019), Albany County has an average of 2.24 people per household. For modeling purposes, an average number of two bedrooms per lot was assumed. For this reason, a septic effluent volume of 280 gallons per day (gpd) per lot was assumed per Chapter 25 of Wyoming DEQ's Rules & Regulations (DEQ, 2018). Two nitrate concentrations were used in the model: 40 mg/L based on Chapter 23 of DEQ's Rules & Regulations (DEQ, 2012) and 55 mg/L based on the results of the Albany County Septic System Impact Analysis (Wenck Associates, 2019).

To estimate the number of lots available under future build-out scenarios, Wenck collaborated with the City to identify lands that could potentially be developed within the APOZ. Lands considered "undevelopable" were excluded from the model, and included lands owned by the U.S. Bureau of Land Management, the City of Laramie, Mountain Cement Co., the State of Wyoming, the University of Wyoming, Albany School District, WYDOT, Union Pacific, and the Pilot Hill Area. Land already occupied by current residents was determined by excluding any parcel which contains a registered address as of 2020. For the remaining developable lands shown on **Figure 5**, Wenck assumed three future build-out scenarios using Albany County Zoning Designations. The zoning designations range from least to most dense and include agricultural, with a housing density of one dwelling unit per 35 acres; rural residential, with a housing density of one dwelling unit per 5 acres; and small lot residential, with a housing density of one dwelling per 2 acres (Albany County Planner, 2015). The remaining developable land was devised by the same modeled aquifer blocks used for the current build-out scenario and further divided assuming either an agricultural, rural residential, or small lot residential zoning designation to determine the number of lots. The number of lots considered for all future build-out scenarios, separated by modeled aquifer blocks, are summarized in **Table 2**.

Table 2: Current versus Future Build-out Lot Inputs

Modeled Aquifer Block	Current Build-Out	Future Build-Out		
	Number of Lots	Number of Lots Agricultural Zoning[1]	Number of Lots Rural Residential Zoning[2]	Number of Lots Small Lot Residential Zoning[3]
Spur Wellfield	45	446	2854	7067
Turner Wellfield	199	519	2442	5805
Pope Spring Wellfield	235	243	291	375
Soldier Springs Wellfield	13	15	29	53
Simpson Springs	22	34	105	238

1 – Assumes a housing density of 1 lot per 35 acres.
2 – Assumes a housing density of 1 lot per 5 acres.
3 – Assumes a housing density of 1 lot per 2 acres.

Water Quality Modeling Results

Using the hydrogeologic and water quality data available, Wenck estimated nitrate concentrations at the City's wellfields and springs downgradient of each aquifer block under current build-out conditions. The results of current build-out modeling efforts are compared against actual nitrate concentrations measured at the City's wellfields and springs in **Table 3**. For these current build-out conditions, nitrate concentrations were calculated using both Wyoming DEQ's assumed septic effluent nitrate concentration and the concentration measured through the Albany County study, 40 mg/L and 55 mg/L, respectively, and are included in **Table 3**. Detailed current build-out model results are included in **Appendix B** based on the available data and assumptions made.

Table 3: Current Build-Out Model Results

Modeled Aquifer Block	Developed Land Considered in Model (acres)	2020 Measured Wellfield Nitrate Concentrations (mg/L)[1]	Modeled Nitrate Concentrations (mg/L)[2]	Modeled Nitrate Concentrations (mg/L)[3]
Spur Wellfield	1,460	1.74 (Spur 1)	1.71	1.84
Turner Wellfield	838	1.72 (Turner No. 2)	3.45	4.25
Pope Springs Wellfield	913	2.08 (Pope No. 2)	4.64	5.68
Soldier Springs Wellfield	833	2.20 (Soldier Springs)	2.25	2.35
Simpson Springs	679	2.37 (SI-1)	1.62	1.81

1 - Wells or springs from which samples were collected are listed in parenthesis.
2 – Assumes a septic effluent value of 40 mg/L.
3 – Assumes a septic effluent value of 55 mg/L.

Under current build-out conditions, both measured and modeled nitrate concentrations fall below the EPA drinking water standard of 10 mg/L. While measured nitrate concentrations range from 1.72 to 2.37 mg/L, the modeling results estimate nitrate concentrations within ~1.0 mg/L of concentrations actually measured at the Spur Wellfield, Soldier Springs, and Simpson Springs as shown in **Table 3**. At the Turner and Pope Springs Wellfields, modeled concentrations are double those measured at the wellfields, likely due to the current level of development in these aquifer blocks. The disparity between measured and modeled values may attest to the dilution effect as effluent enters groundwater stored in the aquifer. Modeling revealed noticeable changes to nitrate concentrations when septic effluent nitrate levels were increased from 40 to 55 mg/L. The most notable changes occurred in the Turner and Pope Springs Wellfield blocks where nitrate concentrations increased up to 1 mg/L when septic effluent nitrate levels were increased.

Wenck modeled three future build-out scenarios using Albany County Zoning Designations to estimate the potential cumulative nitrate loading affect to the Casper Aquifer. This assessment evaluated the potential nitrate concentrations assuming all lots had been built upon and did not consider variations in growth. Model inputs used for the current build-out efforts were also used for future build-out scenarios, but the number of septic systems increased to the number of developed lots shown in **Table 2** assuming each new lot would have a septic system. The results of these modeling efforts are presented in **Table 4** and detailed inputs and assumptions for the three scenarios are included in **Appendix B**.

Table 4: Future Build-Out Model Results

Modeled Aquifer Block	Amount of Developable Land (acres)[1]	Agricultural		Rural Residential		Small Lot Residential	
		Modeled Nitrate Concentrations (mg/L)[2]	Modeled Nitrate Concentrations (mg/L)[3]	Modeled Nitrate Concentrations (mg/L)[2]	Modeled Nitrate Concentrations (mg/L)[3]	Modeled Nitrate Concentrations (mg/L)[2]	Modeled Nitrate Concentrations (mg/L)[3]
Spur Wellfield	14,000	4.30	5.43	14.60	19.73	23.12	31.56
Turner Wellfield	11,200	6.33	8.25	17.15	23.27	25.37	34.68
Pope Springs Wellfield	279	4.72	5.80	5.21	6.48	6.04	7.64
Soldier Springs Wellfield	80	2.29	2.41	2.56	2.78	3.00	3.40
Simpson Springs	433	1.90	2.21	3.52	4.45	6.04	7.95
1 - Developable land in addition to that identified in the current build-out scenario							
2 – Assumes septic effluent nitrate concentration of 40 mg/L.							
3 – Assumes septic effluent nitrate concentration of 55 mg/L.							

The amount of land that could be developed in the future within any of the five aquifer blocks has a significant effect on potential impacts to nitrate concentrations, as shown in **Table 4**. The Spur Wellfield block has the most potentially developable land with 14,000 acres, followed by the Turner Wellfield block with 11,200 acres. There is currently an abundance of land with a private zoning designation (**Figures 1 and 5**) in these modeled aquifer blocks that could be subdivided for future development. The least available developable land is located within the Soldier Springs Wellfield block with only 80 acres of land. Much of the Soldier Springs Wellfield is already developed or owned by entities such as Mountain Cement Co. or the U.S. Forest Service (**Figures 1 and 5).**

Modeling of the agricultural development scenario indicated slight to moderate increases in nitrate concentrations. Under agricultural lot sizes, nitrate concentrations remained below the EPA drinking water maximum contaminant level (MCL), and similar to but higher than concentrations estimated under the current build-out modeling. Nitrate concentrations rose up to 2 mg/L when septic effluent nitrate levels were increased. The most notable change occurred in the Turner Wellfield block where concentrations increased by 1.92 mg/L as a result of increasing the effluent nitrate concentration. This is likely due to the large amount of developable land located in the Turner Wellfield aquifer block theoretically contributing larger amounts of nitrate to the aquifer.

Under a rural residential zoning designation, the model estimated moderate to unacceptable nitrate concentrations, particularly within the Spur and Turner Wellfield blocks where adverse impacts to the Casper Aquifer could occur. Modeling indicated nitrate concentrations would increase slightly within the Pope Springs, Soldier Springs, and Simpson Spring blocks, but still have a relatively low to moderate impact on the Casper Aquifer due to the limited number of developable acres. Modeled nitrate concentrations in these model blocks remained below the EPA MCL. However, nitrate concentrations in the Spur and Turner Wellfield blocks exhibited unacceptable increases. Modeled nitrate concentrations in those two blocks increased to levels above the EPA MCL of 10 mg/L. Increasing the nitrate effluent concentration further affected the Spur and Turner Wellfield blocks, elevating nitrate concentrations from 14.60 to 19.73 mg/L at the Spur Wellfield and from 17.15 to 23.27 at the Turner Wellfield.

Modeling results revealed that a small lot residential zoning designation could have adverse impacts on the Casper Aquifer, primarily to water users served by the Spur and Turner Wellfields. Nitrate concentrations were estimated to exceed the EPA MCL within both the Spur and Turner Wellfield blocks. This is likely due to an abundance of developable land and the nature of the modelled development within both wellfield blocks, as shown on **Figure 5**. Nitrate concentrations estimated by the model in other modeled blocks besides the Spur and Turner Wellfields generally fell below 6.0 mg/L and were below the MCL. When a sensitivity analysis was run under this zoning designation, the most notable increases occurred within Spur and Turner Wellfields where nitrate concentrations increased by 8.44 and 9.31 mg/L, respectively. Simpson Springs increased by 1.91 mg/L and the remaining wellfields or springs increased by less than 1.6 mg/L.

Conclusions

The Wehrmann model is the regulatory model approved by the Wyoming DEQ in Chapter 23 of its rules and regulations. DEQ recommends using the Wehrmann volumetric loading model to assess potential nitrate impacts to downgradient water users and to make determinations of county subdivision approval according to Appendix A of this chapter. In general, the Wehrmann model yields nitrate concentration estimates assuming no denitrification of the leachate occurs as it percolates through the unsaturated zone, and all nitrate loaded leachate seeps into the same aquifer from which groundwater is drawn. Wenck believes this model approach is appropriate for the APOZ because adsorption and denitrification processes in the APOZ appear to be limited based on the Albany County Septic System Impact Analysis (Wenck, 2019). There are many mapped fractures and faults that are prevalent throughout the APOZ where conduit flow could cause rapid introduction of nitrate to the Casper Aquifer. Due to these features, the Wehrmann model may underestimate the downgradient nitrate concentrations. Overall, the model generally provides estimates of nitrate concentrations that can be used on a qualitative basis to assess the potential impacts and help inform planning decisions.

Results of the modeling completed for both current and future build-out scenarios indicated the following:

1. Under current build-out conditions, the Casper Aquifer in each of the five modeled aquifer blocks generally remains below 5 mg/L of nitrate. Nitrate concentrations with no further buildout are anticipated to remain within EPA drinking water standards.

2. Modeling of current buildout conditions yielded similar nitrate water quality concentrations as exhibited downgradient at the current wellfields, particularly for the Spur Wellfield, Soldier Springs Wellfield, and Simpson Springs. Modeled nitrate concentrations at Turner and Pope Springs Wellfields were elevated by comparison with water quality data from these wellfields.

3. Future build-out modeling under agricultural zoning suggests that development of the APOZ under a 35-acre lot spacing would have some impact on the aquifer, but the model estimates that nitrate concentrations will remain below 10 mg/L (EPA MCL).

4. Results of the future build-out modeling scenarios indicate that the Pope Springs, Soldier Springs, and Simpson Springs modeled aquifer blocks are likely to see nitrate concentrations rise, but remain below 10 mg/L. It should be noted that an increase to 5 mg/L nitrate in the City's wells could lead to increased frequency of sampling. There is little developable land within these aquifer blocks to significantly affect downgradient nitrate concentrations.

5. The model estimates that development to a level equal to Rural Residential Zoning of the Spur and Turner Wellfield blocks will result in elevated nitrate concentrations that exceed 10 mg/L. Nitrate concentrations at this level exceed the EPA MCL.

6. Finally, the model estimates that development to a level equal to small lot residential (2-acre zoning) within the Turner and Spur Wellfields will adversely impact the Casper Aquifer. If this zoning designation were used in these areas, nitrate concentrations would exceed EPA drinking water standards at both Spur and Turner Wellfields.

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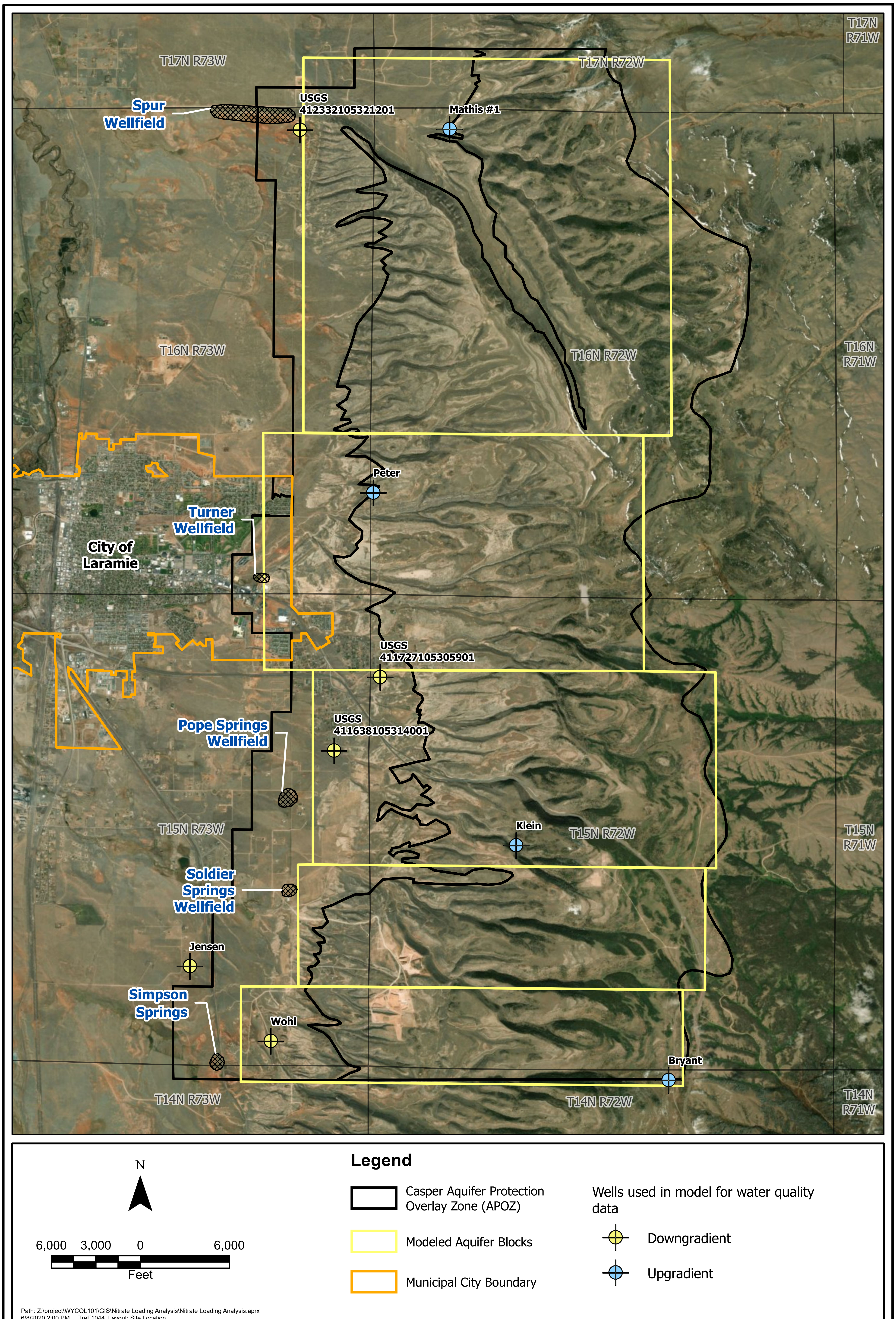
Figures



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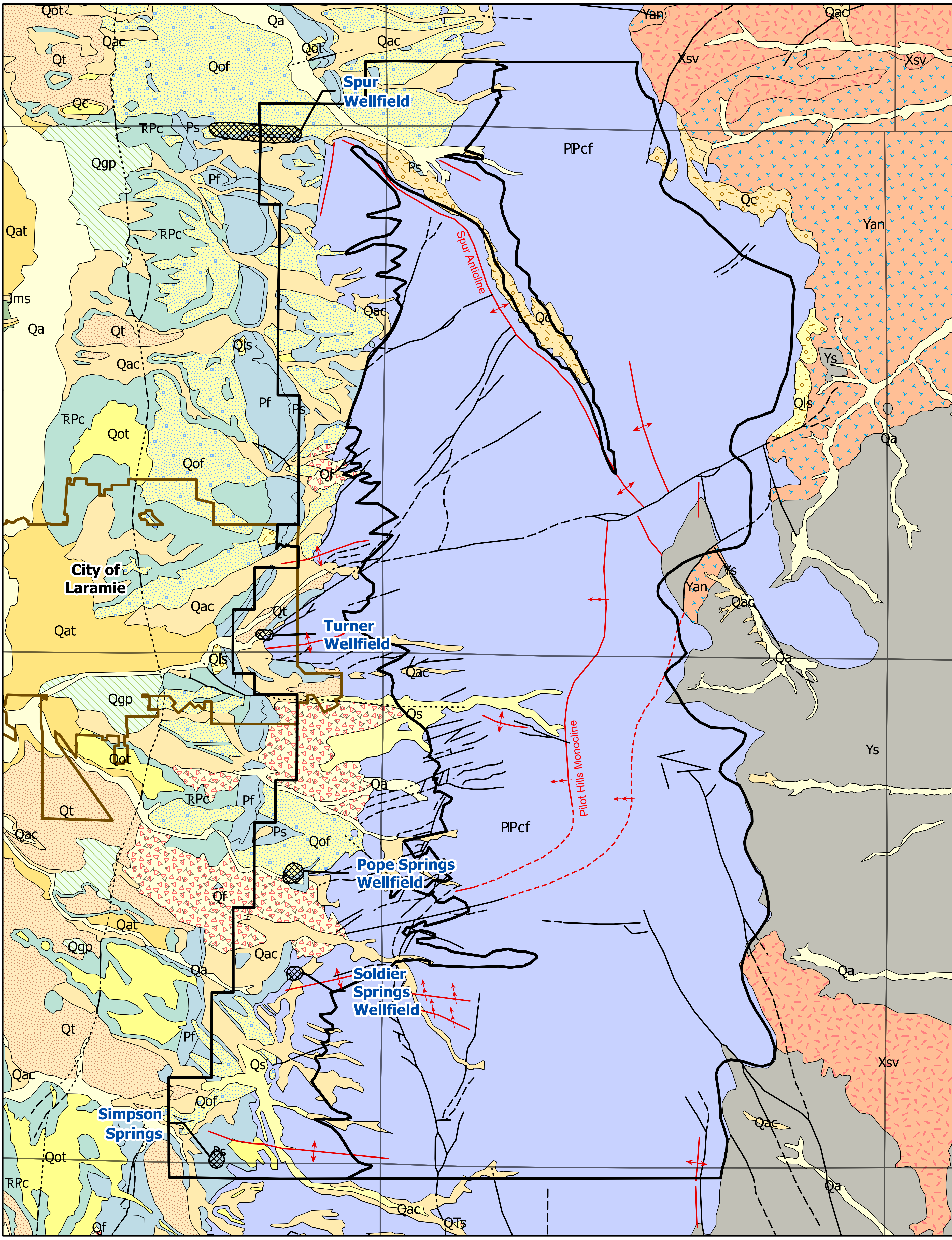
SITE LOCATION		Figure 1



Source: Geologic map of the Laramie 30' x 60' quadrangle, Albany and Laramie Counties, southeastern Wyoming

6,000 3,000 0 6,000
Feet

Legend

- Municipal City Boundary
- Casper Aquifer Protection Overlay Zone

Map Symbols

- Fault
- Approximate Fault Location
- Concealed Fault
- Fold
- Approximate Fold Location

Geologic Units

Qa	Alluvial deposits
Qat	Mixed alluvium and terrace deposits
Qs	Wind-blown deposits
Qc	Colluvium
Qac	Mixed alluvium and colluvium
Qf	Alluvial fan deposits
Qt	Terrace Deposits
Qls	Landslide deposits
Qgp	Gypsite deposits
Qof	Older alluvial fan deposits
Qot	Older terrace deposits
QTs	Wind-blown deposits
Jms	Morrison and Sundance formations - undivided
ŦPc	Chugwater Formation
Pf	Forelle Limestone
Ps	Satanka Shale
PIPcf	Casper and Fountain Formation
Xsv	Sherman Granite
Yan	Laramie Mountains anorthosite and norite
Ys	Metasedimentary and metavolcanic rocks

Path: Z:\project\WYCOL101\GIS\Nitrate Loading Analysis\Nitrate Loading Analysis.aprx
6/8/2020 2:00 PM TreF1044 Layout: Geologic Map

CITY OF LARAMIE

GEOLOGIC MAP

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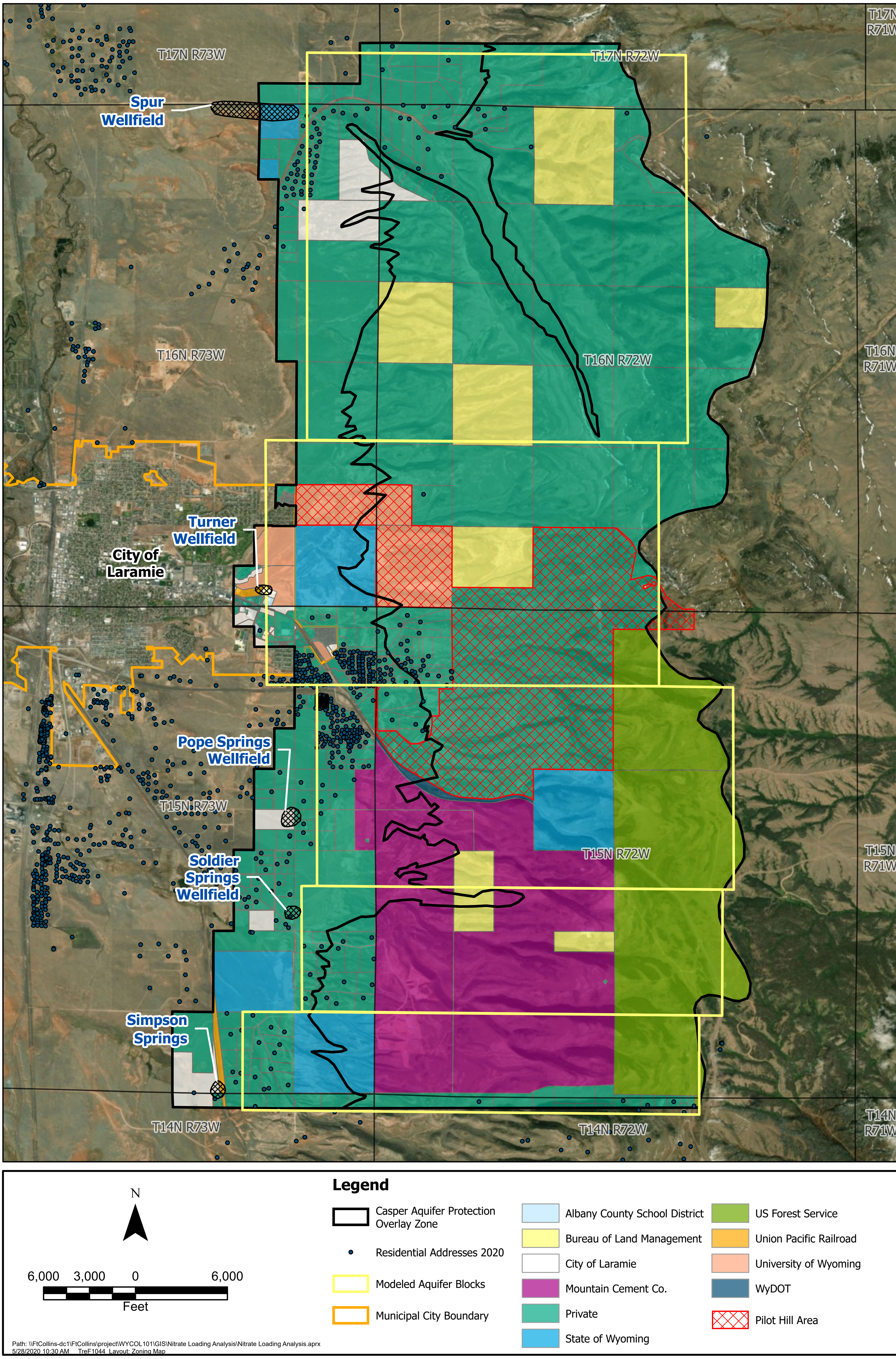
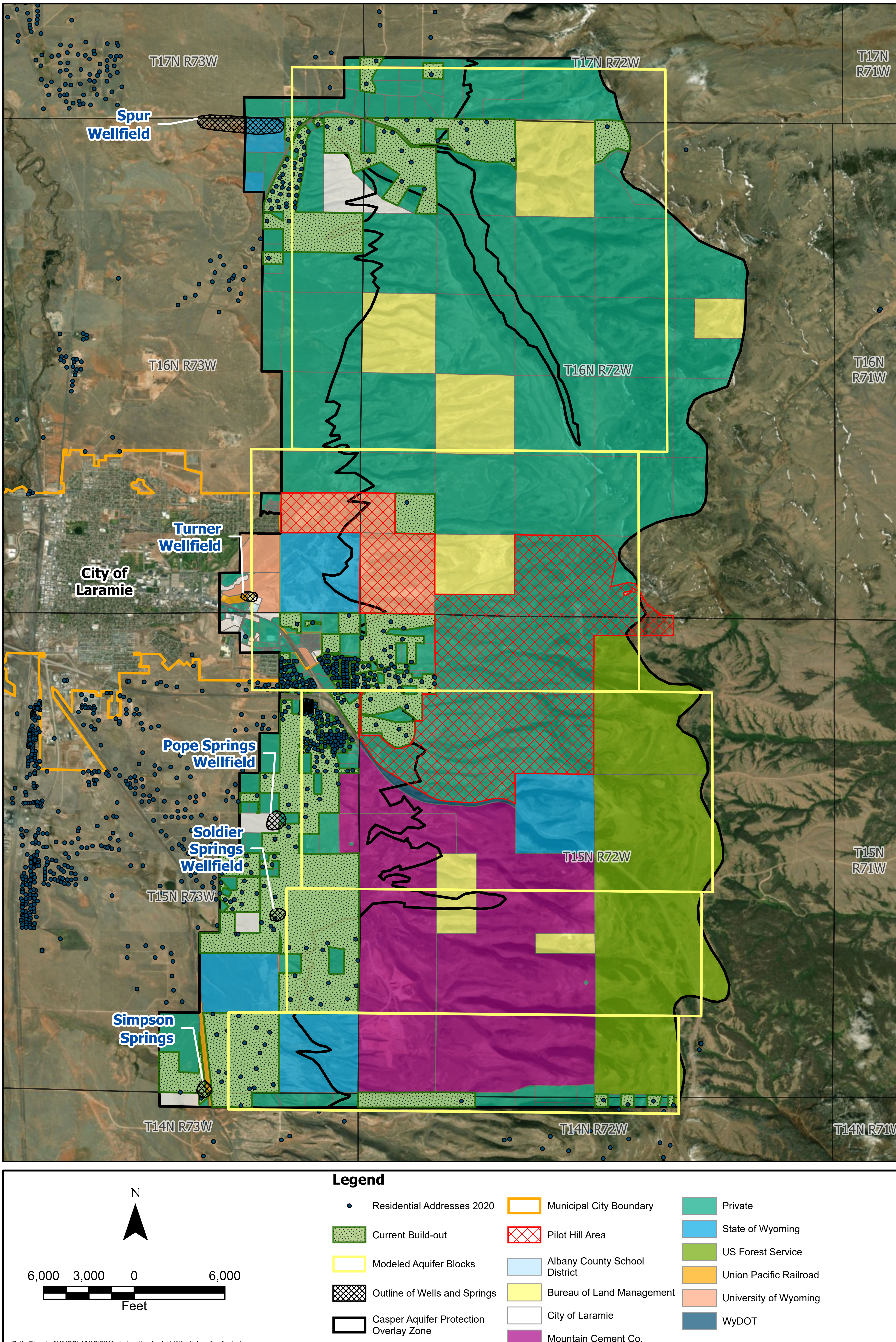
JUN 2020

Figure 2



CITY OF LARAMIE	WENCK	MAY 2020
ZONING MAP	Responsive partner. Exceptional outcomes.	Figure 3



CITY OF LARAMIE

CURRENT BUILD-OUT

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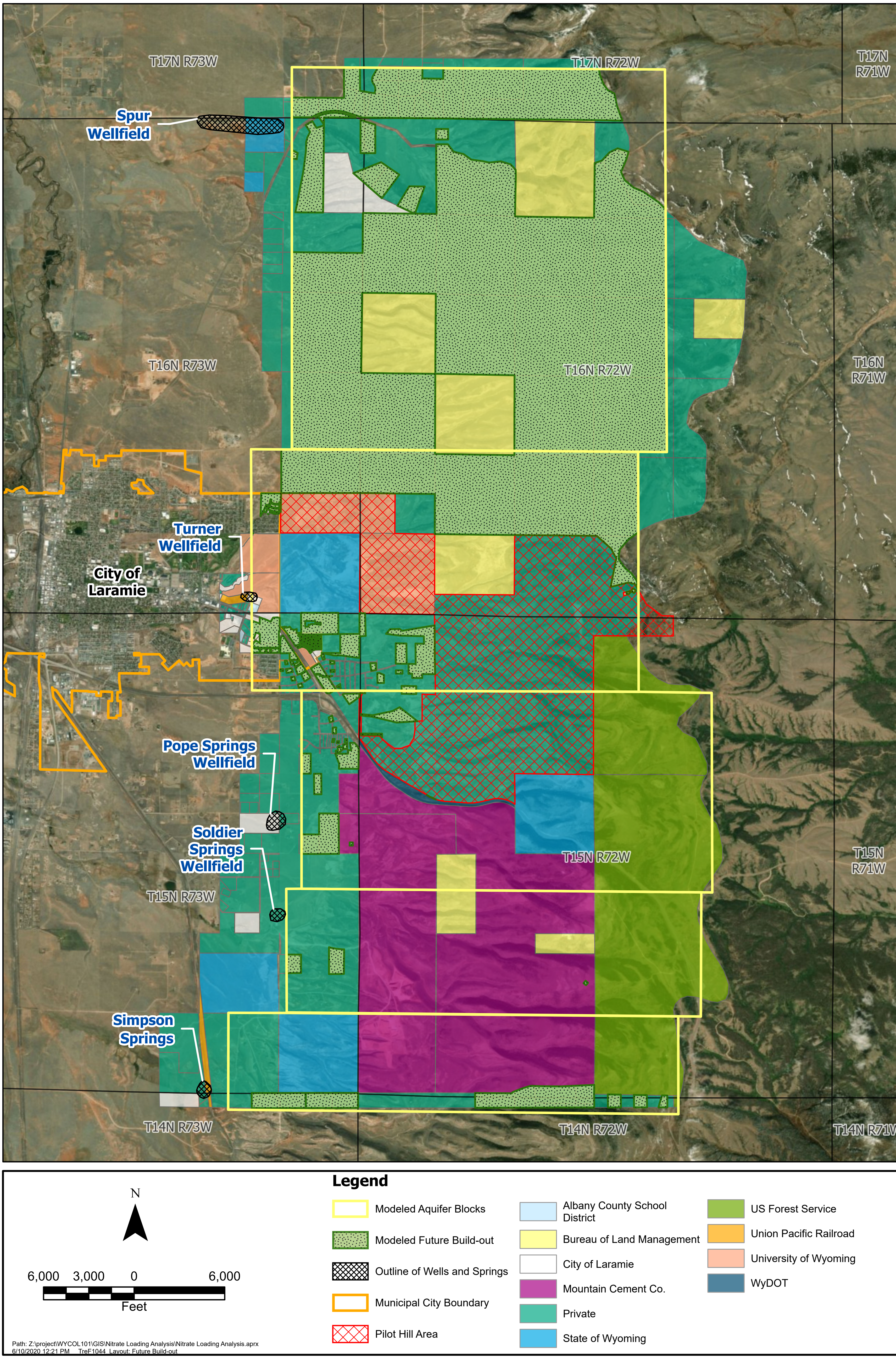
JUN 2020

Figure 4



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FUTURE BUILD-OUT		Figure 5

Appendix A

Water Quality Data

APPENDIX A1 – UPGRADIENT WELL DATA

WYOMING DEPARTMENT OF AGRICULTURE

ANALYTICAL SERVICES

1174 Snowy Range Road

Laramie, WY 82070 Phone: (307)-742-2984

Internet: http://wyagric.state.wy.us/aslab/aslab.htm E-mail: aslab@missc.state.wy.us

OFFICIAL ANALYTICAL REPORT

Water Supply **Development Series**

CBM Associates, Inc.
c/o Karl Toboga
820 Sheridan Ave.
Laramie, WY 82070

Phone No: 307-755-3489

Lab Number:	**64323**
Date Collected:	14-Mar-2007
Date Received:	16-Mar-2007
Date Completed:	28-Mar-2007
Purchase Order No:	
WDA Invoice No	**NA**
Amount Due:	$
Amount Paid:	$

Net 30 Days, Payable to: Wyoming Department of Agriculture

Sample ID:	City of Laramie - Bryant
Analysis:	Development Series

ANALYTE	UNITS	RESULT	ANALYTE	UNITS	RESULT
Cations			**Anions**		
Calcium	mg/L	62	Carbonate	mg/L	0
Magnesium	mg/L	5.5	Bicarbonate	mg/L	230
Sodium	mg/L	2.7	Chloride	mg/L	2.2
Potassium	mg/L	1.8	Fluoride	mg/L	0.1
Metals			Nitrate as N	mg/L	1.1
Copper	mg/L	0.003	Nitrite as N	mg/L	<0.05
Iron	mg/L	<0.020	Sulfate	mg/L	4.6
Lead	mg/L	<0.001	TDSbySummation	mg/L	200
Manganese	mg/L	<0.001			
Zinc	mg/L	0.012	T. Alk. as CaCO3	mg/L	190
Other Analytes			Hardness as CaCO3	mg/L	180
pH	pH Units	7.8	Corrosivity		0.21
Conductivity	umhos/cm	360			nonaggressive

Ref.	Analyte	Method	Units	Result
1				
2				
3				
4				

Prepared By: **mkw** RWH

I hereby certify that the above sample was analyzed by myself or my assistant.

Section Supervisor

State Chemist/Lab Manager

WYOMING DEPARTMENT OF AGRICULTURE
ANALYTICAL SERVICES
1174 Snowy Range Road
Laramie, WY 82070 Phone: (307)-742-2984
Internet: http://wyagric.state.wy.us/aslab/aslab.htm E-mail: aslab@missc.state.wy.us

OFFICIAL ANALYTICAL REPORT

Development Series

CBM Associates, Inc.
c/o Karl Toboga
920 Sheridan Ave.
Laramie, WY 82070

Phone No: 307-775-3489

Lab Number:	**64062**
Date Collected:	23-Feb-2007
Date Received:	23-Feb-2007
Date Completed:	20-Mar-2007
Purchase Order No:	
WDA Invoice No	**NA**
Amount Due:	**$**
Amount Paid:	**$**

Net 30 Days, Payable to: Wyoming Department of Agriculture

Sample ID:	City of Laramie - Klein Well WLC
Analysis:	Development Series

ANALYTE	UNITS	RESULT
Cations		
Calcium	mg/L	62
Magnesium	mg/L	16
Sodium	mg/L	2.6
Potassium	mg/L	0.7
Metals		
Copper	mg/L	0.471
Iron	mg/L	<0.020
Lead	mg/L	0.127
Manganese	mg/L	0.047
Zinc	mg/L	0.046
Other Analytes		
pH	pH Units	8.2
Conductivity	umhos/cm	420

ANALYTE	UNITS	RESULT
Anions		
Carbonate	mg/L	0
Bicarbonate	mg/L	260
Chloride	mg/L	3.5
Fluoride	mg/L	0.1
Nitrate as N	mg/L	3.0
Nitrite as N	mg/L	<0.05
Sulfate	mg/L	13
TDSbySummation	mg/L	240
T. Alk. as CaCO3	mg/L	210
Hardness as CaCO3	mg/L	220
Corrosivity		0.72
		non-aggressive

Ref.	Analyte	Method	Units	Result
	Acidified Sample (filtered; 0.45µm)			
1	Iron		mg/L	29
2	Zinc		mg/L	3.1
3				
4				

Prepared By: mkw RWH

I hereby certify that the above sample was analyzed by myself or my assistant.

Section Supervisor

State Chemist/Lab Manager

WYOMING DEPARTMENT OF AGRICULTURE
ANALYTICAL SERVICES
1174 Snowy Range Road
Laramie, WY 82070 Phone: (307)-742-2
Internet: http://wyagric.state.wy.us/aslab/aslab.htm E-mail: aslab@missc.state.w

OFFICIAL ANALYTICAL REPORT

Water Supply **Development Se**

CBM Associates, Inc.
c/o Karl Toboga
820 Sheridan Ave.
Laramie, WY 82070

Lab Number:	64
Date Collected:	22-Apr-2
Date Received:	25-Apr-2
Date Completed:	02-May-2
Purchase Order No:	
WDA Invoice No	
Amount Due:	$
Amount Paid:	$

Net 30 Days, Payable to: Wyoming Department of Agric

Phone No: 307-760-2328

Sample ID: City of Laramie - Mathis/Baker
Analysis: Development Series

ANALYTE	UNITS	RESULT	ANALYTE	UNITS	RESUL
Cations			**Anions**		
Calcium	mg/L	39	Carbonate	mg/L	0
Magnesium	mg/L	25	Bicarbonate	mg/L	260
Sodium	mg/L	3.8	Chloride	mg/L	2.1
Potassium	mg/L	1.0	Fluoride	mg/L	0.3
Metals			Nitrate as N	mg/L	1.4
Copper	mg/L	0.005	Nitrite as N	mg/L	<0.05
Iron	mg/L	<0.020	Sulfate	mg/L	5.7
Lead	mg/L	0.002	TDSbySummation	mg/L	210
Manganese	mg/L	<0.001			
Zinc	mg/L	0.014	T. Alk. as CaCO3	mg/L	210
Other Analytes			Hardness as CaCO3	mg/L	200
pH	pH Units	7.9	Corrosivity		0.39
Conductivity	umhos/cm	396			nonaggres

Ref.	Analyte	Method	Units	Result
1				
2				
3				
4				

Prepared By: mkw Kat 5/3/07

I hereby certify that the above sample was analyzed by myself or my assistant.

Mike Smith

WYOMING DEPARTMENT OF AGRICULTURE
ANALYTICAL SERVICES
1174 Snowy Range Road
Laramie, WY 82070 Phone: (307)-742-2984
Internet: http://wyagric.state.wy.us/aslab/aslab.htm E-mail: aslab@missc.state.wy.us

OFFICIAL ANALYTICAL REPORT

Water Supply **Development Series**

CBM Associates, Inc.
c/o Karl Taboga
920 E. Sheridan
Laramie, WY 82070

Phone No:
FAX No:

Lab Number:	**59688**
Date Collected:	29-Apr-2006
Date Received:	02-May-2006
Date Completed:	26-May-2006
Purchase Order No:	
WDA Invoice No	**NA**
Amount Due:	**$ NA**
Amount Paid:	$

Net 30 Days, Payable to: Wyoming Department of Agriculture

Sample ID:	**Peter Well**
Analysis:	Development Series

ANALYTE	UNITS	RESULT	ANALYTE	UNITS	RESULT
Cations			**Anions**		
Calcium	mg/L	54	Carbonate	mg/L	0
Magnesium	mg/L	15	Bicarbonate	mg/L	210
Sodium	mg/L	2.1	Chloride	mg/L	1.8
Potassium	mg/L	0.8	Fluoride	mg/L	0.3
Metals			Nitrate as N *	mg/L	1.4
Copper	mg/L	0.001	Nitrite as N *	mg/L	<0.05
Iron	mg/L	0.118	Sulfate	mg/L	9.1
Lead	mg/L	0.003	TDSbySummation	mg/L	190
Manganese	mg/L	0.005			
Zinc	mg/L	0.338	T. Alk. as CaCO3	mg/L	170
Other Analytes			Hardness as CaCO3	mg/L	200
pH	pH Units	7.9	Corrosivity		0.30
Conductivity	umhos/cm	360			nonaggressive

Ref.	Analyte	Method	Units	Result
1				
2				
3				
4				

*-Note: Sample received after the 48 hour maximum holding time for this analyte.

Prepared By: mkw

I hereby certify that the above sample was analyzed by myself or my assistant.

Section Supervisor

Kenneth L. McMillan, State Chemist/Lab Manager

APPENDIX A2 – DOWNGRADIENT WELL DATA

WYOMING DEPARTMENT OF AGRICULTURE
ANALYTICAL SERVICES
1174 Snowy Range Road
Laramie, WY 82070 Phone: (307)-742-2984
Internet: http://wyagric.state.wy.us/aslab/aslab.htm E-mail: aslab@missc.state.wy.us

OFFICIAL ANALYTICAL REPORT

Water Supply **Development Series**

CBM Associates, Inc.
c/o Karl Toboga
820 Sheridan Ave.
Laramie, WY 82070

Phone No: 307-760-2328

Lab Number:	**64422**
Date Collected:	27-Mar-2007
Date Received:	29-Mar-2007
Date Completed:	09-Apr-2007
Purchase Order No:	
WDA Invoice No	**NA**
Amount Due:	$
Amount Paid:	$

Net 30 Days, Payable to: Wyoming Department of Agriculture

Sample ID: City of Laramie - WOHL Well
Analysis: Development Series

ANALYTE	UNITS	RESULT
Cations		
Calcium	mg/L	50
Magnesium	mg/L	15
Sodium	mg/L	2.6
Potassium	mg/L	1.0
Metals		
Copper	mg/L	0.004
Iron	mg/L	<0.020
Lead	mg/L	<0.001
Manganese	mg/L	<0.001
Zinc	mg/L	0.032
Other Analytes		
pH	pH Units	7.9
Conductivity	umhos/cm	360

ANALYTE	UNITS	RESULT
Anions		
Carbonate	mg/L	0
Bicarbonate	mg/L	220
Chloride	mg/L	2.1
Fluoride	mg/L	0.2
Nitrate as N	mg/L	1.6
Nitrite as N	mg/L	<0.05
Sulfate	mg/L	9.1
TDSbySummation	mg/L	200
T. Alk. as CaCO3	mg/L	180
Hardness as CaCO3	mg/L	190
Corrosivity		0.31
		nonaggressive

Ref.	Analyte	Method	Units	Result
1				
2				
3				
4				

Prepared By: mkw RWH

I hereby certify that the above sample was analyzed by myself or my assistant.

Section Supervisor

State Chemist/Lab Manager

WYOMING DEPARTMENT OF AGRICULTURE
ANALYTICAL SERVICES
1174 Snowy Range Road
Laramie, WY 82070 Phone: (307)-742-2984
Internet: http://wyagric.state.wy.us/aslab/aslab.htm E-mail: aslab@missc.state.wy.us

OFFICIAL ANALYTICAL REPORT

Water Supply **Development Series**

CBM Associates, Inc.
c/o Karl Toboga
820 Sheridan Ave.
Laramie, WY 82070

Phone No: 307-755-3489

Lab Number:	**64324**
Date Collected:	16-Mar-2007
Date Received:	16-Mar-2007
Date Completed:	28-Mar-2007
Purchase Order No:	
WDA Invoice No	**NA**
Amount Due:	$
Amount Paid:	$

Net 30 Days, Payable to: Wyoming Department of Agriculture

Sample ID:	City of Laramie - Jensen Well
Analysis:	Development Series

ANALYTE	UNITS	RESULT	ANALYTE	UNITS	RESULT
Cations			**Anions**		
Calcium	mg/L	71	Carbonate	mg/L	0
Magnesium	mg/L	34	Bicarbonate	mg/L	350
Sodium	mg/L	9.4	Chloride	mg/L	7.9
Potassium	mg/L	1.9	Fluoride	mg/L	0.3
Metals			Nitrate as N	mg/L	1.6
Copper	mg/L	0.004	Nitrite as N	mg/L	<0.05
Iron	mg/L	<0.020	Sulfate	mg/L	25
Lead	mg/L	<0.001	TDSbySummation	mg/L	330
Manganese	mg/L	<0.001			
Zinc	mg/L	0.014	T. Alk. as CaCO3	mg/L	290
Other Analytes			Hardness as CaCO3	mg/L	320
pH	pH Units	7.7	Corrosivity		0.52
Conductivity	umhos/cm	580			nonaggressive

Ref.	Analyte	Method	Units	Result
1				
2				
3				
4				

Prepared By: mkw RWH

I hereby certify that the above sample was analyzed by myself or my assistant.

Section Supervisor

State Chemist/Lab Manager

```
#
# File created on 2020-05-29 17:13:09 EDT
#
# U.S. Geological Survey
#
# This file contains selected water-quality data for stations in the National Water
# Information System water-quality database.  Explanation of codes found in this file are
# followed by the retrieved data.
#
# The data you have secured from the USGS NWISWeb database may include data that have
# not received Director's approval and as such are provisional and subject to revision.
# The data are released on the condition that neither the USGS nor the United States
# Government may be held liable for any damages resulting from its authorized or
# unauthorized use.
#
# To view additional data-quality attributes, output the results using these options:
# one result per row, expanded attributes.  Additional precautions are at:
# https://help.waterdata.usgs.gov/tutorials/water-quality-data/help-using-the-water-quality-data-retrieval-system#Data_retrievals_precautions
#
#  agency_cd                - Agency Code
#  site_no                  - USGS site number
#  sample_dt                - Begin date
#  sample_tm                - Begin time
#  sample_end_dt            - End date
#  sample_end_tm            - End time
#  sample_start_time_datum_cd - Time datum
#  tm_datum_rlbty_cd        - Time datum reliability code
#  coll_ent_cd              - Agency Collecting Sample Code
#  medium_cd                - Sample Medium Code
#  tu_id                    - Taxonomic unit code
#  body_part_id             - Body part code
#  parm_cd                  - Parameter code
#  remark_cd                - Remark code
#  result_va                - Parameter value
#  val_qual_tx              - Result value qualifier code
#  meth_cd                  - Method code
#  dqi_cd                   - Data-quality indicator code
#  rpt_lev_va               - Reporting level
#  rpt_lev_cd               - Reporting level type
#  lab_std_va               - Lab standard deviation
#  anl_ent_cd               - Analyzing entity code
#
# The following parameters are included:
#  00010  - Temperature, water, degrees Celsius
#  00020  - Temperature, air, degrees Celsius
#  00025  - Barometric pressure, millimeters of mercury
#  00059  - Flow rate, instantaneous, gallons per minute
#  00095  - Specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees Celsius
#  00191  - Hydrogen ion, water, unfiltered, calculated, milligrams per liter
#  00300  - Dissolved oxygen, water, unfiltered, milligrams per liter
#  00301  - Dissolved oxygen, water, unfiltered, percent of saturation
#  00400  - pH, water, unfiltered, field, standard units
#  00405  - Carbon dioxide, water, unfiltered, milligrams per liter
#  00452  - Carbonate, water, filtered, inflection-point titration method (incremental titration method), field, milligrams per liter
#  00453  - Bicarbonate, water, filtered, inflection-point titration method (incremental titration method), field, milligrams per liter
#  00605  - Organic nitrogen, water, unfiltered, milligrams per liter as nitrogen
#  00610  - Ammonia (NH3 + NH4+), water, unfiltered, milligrams per liter as nitrogen
#  00615  - Nitrite, water, unfiltered, milligrams per liter as nitrogen
#  00620  - Nitrate, water, unfiltered, milligrams per liter as nitrogen
#  00650  - Phosphate, water, unfiltered, milligrams per liter as PO4
#  00681  - Organic carbon, water, filtered, milligrams per liter
#  00900  - Hardness, water, milligrams per liter as calcium carbonate
#  00904  - Noncarbonate hardness, water, filtered, field, milligrams per liter as calcium carbonate
#  00905  - Noncarbonate hardness, water, filtered, lab, milligrams per liter as calcium carbonate
#  00906  - Hardness, water, filtered, calculated, milligrams per liter as calcium carbonate
#  00915  - Calcium, water, filtered, milligrams per liter
#  00925  - Magnesium, water, filtered, milligrams per liter
#  00930  - Sodium, water, filtered, milligrams per liter
#  00931  - Sodium adsorption ratio (SAR), water, number
#  00935  - Potassium, water, filtered, milligrams per liter
#  00940  - Chloride, water, filtered, milligrams per liter
#  00945  - Sulfate, water, filtered, milligrams per liter
#  00950  - Fluoride, water, filtered, milligrams per liter
#  00955  - Silica, water, filtered, milligrams per liter as SiO2
#  00956  - Silica, water, unfiltered, milligrams per liter as SiO2
#  01000  - Arsenic, water, filtered, micrograms per liter
#  01002  - Arsenic, water, unfiltered, micrograms per liter
#  01005  - Barium, water, filtered, micrograms per liter
#  01007  - Barium, water, unfiltered, recoverable, micrograms per liter
#  01010  - Beryllium, water, filtered, micrograms per liter
#  01012  - Beryllium, water, unfiltered, recoverable, micrograms per liter
#  01020  - Boron, water, filtered, micrograms per liter
#  01022  - Boron, water, unfiltered, recoverable, micrograms per liter
#  01025  - Cadmium, water, filtered, micrograms per liter
#  01027  - Cadmium, water, unfiltered, micrograms per liter
#  01030  - Chromium, water, filtered, micrograms per liter
#  01034  - Chromium, water, unfiltered, recoverable, micrograms per liter
#  01035  - Cobalt, water, filtered, micrograms per liter
#  01037  - Cobalt, water, unfiltered, recoverable, micrograms per liter
#  01040  - Copper, water, filtered, micrograms per liter
#  01042  - Copper, water, unfiltered, recoverable, micrograms per liter
#  01045  - Iron, water, unfiltered, recoverable, micrograms per liter
#  01046  - Iron, water, filtered, micrograms per liter
#  01049  - Lead, water, filtered, micrograms per liter
#  01051  - Lead, water, unfiltered, recoverable, micrograms per liter
#  01055  - Manganese, water, unfiltered, recoverable, micrograms per liter
#  01056  - Manganese, water, filtered, micrograms per liter
#  01057  - Thallium, water, filtered, micrograms per liter
#  01059  - Thallium, water, unfiltered, micrograms per liter
#  01060  - Molybdenum, water, filtered, micrograms per liter
#  01062  - Molybdenum, water, unfiltered, recoverable, micrograms per liter
#  01065  - Nickel, water, filtered, micrograms per liter
#  01067  - Nickel, water, unfiltered, recoverable, micrograms per liter
#  01075  - Silver, water, filtered, micrograms per liter
#  01077  - Silver, water, unfiltered, recoverable, micrograms per liter
#  01080  - Strontium, water, filtered, micrograms per liter
#  01082  - Strontium, water, unfiltered, recoverable, micrograms per liter
#  01085  - Vanadium, water, filtered, micrograms per liter
#  01087  - Vanadium, water, unfiltered, micrograms per liter
#  01090  - Zinc, water, filtered, micrograms per liter
#  01092  - Zinc, water, unfiltered, recoverable, micrograms per liter
#  01095  - Antimony, water, filtered, micrograms per liter
#  01097  - Antimony, water, unfiltered, micrograms per liter
```

#
Description of sample_start_time_datum_cd:
MDT - Mountain Daylight Time
#
Description of tm_datum_rlbty_cd:
K - Known
#
Description of coll_ent_cd and anl_ent_cd:
USGS-WRD - U.S. Geological Survey-Water Resources Discipline
CO-TALDN - TestAmerica Labs - Denver, Arvada, CO
USEPA - U.S. Environmental Protection Agency
USGS-WRD - U.S. Geological Survey-Water Resources Discipline
USGSNWQL - USGS-National Water Quality Lab, Denver, CO
USGSSIVA - USGS-NRP, Stable Isotope Lab, Reston, VA
#
Description of medium_cd:
WG - Groundwater
#
Description of tu_id:
https://www.itis.gov/
#
Description of body_part_id:
#
Description of remark_cd:
< - less than
#
Description of val_qual_tx:
@ - holding time exceeded
b - value extrapolated at low end
c - see result comment
f - sample field preparation problem
k - counts outside acceptable range
#
Description of meth_cd:
ALGOR - Computation by NWIS algorithm
BAC18 - E coli, MI MF method
BAC52 - Total coliform, MI MF method
BAROM - Atmospheric pressure, barometer
CAL04 - Hardness, wf, by calculation
CDR08 - NO2+NO3, wu, auto Cd red (DODEC)
CL016 - Ammonia, wu, phenate colorimetry
CL104 - Ortho-PO4, wu,2-reagent ascorbic
GC164 - Dissolved gases, headspace GC
GCI01 - Nonhalogenated organics,wu,GCFID
GCI02 - GROs, wu, by GC/FID (EPA 8015B)
GCM25 - VOCs by capillary column GC/MS
GCM66 - VOC, wu, acidified, GCMS
GCM94 - VOCs, wu, GC/MS (DODEC,EPA8260B)
IC009 - Anions, IC, EPA 300.0
MEMBR - Diss oxygen, membrane electrode
MS007 - Deuterium/Protium, wu, MS
MS020 - Oxygen-18/16, wu, by MS
OX006 - DOC,0.45um cap,acid,persulfateIR
PLA17 - Elements,wu,ICP-AES(6010B,DODEC)
PLA18 - Elements, wf, ICP-AES (DODEC)
PLM28 - Elements, wu, ICP-MS (DODEC_01)
PLM39 - Elements, wf, ICP-MS (DODEC_02)
PLM42 - Elements, wf, ICP-MS (DODEC_04)
PLM57 - Elements, wu, ICP-MS (CO WSC)
PLM58 - Elements, wf, ICP-MS (CO WSC)
PROBE - pH, field, electrometric
ROE10 - ROE, wf, 180C, by weight (NWQL)
SC001 - Specific conductance sensor
THM01 - Temperature, water, thermistor
THM05 - Temperature, air, liq-in-glass
TS101 - HACH, sensor model 2100 P, NTRU
TT013 - Alkalinity, wf, field, increment
TT017 - Bicarbonate, wf, field, increm
TT019 - Carbonate, wf, field, increment
TT023 - Hydroxide, wf, field, increm
TT040 - Alkalinity, titr. pH 4.5 (NWQL)
#
Description of dqi_cd:
R - Reviewed and approved
S - Provisional
#
Description of rpt_lev_cd:
LT-MDL - Long term method detection level
MDL - Method detection limit
MRL - Minimum reporting level
#
Data for the following sites are included:
USGS 411638105314001 15-073-12dcc01
#

agency_cd	site_no	sample_dt	sample_tm	sample_en	sample_en	sample_st	tm_datum	coll_ent_c	medium_c	tu_id	body_part	parm_cd	remark_cd	result_va	val_qual_t	meth_cd	dqi_cd	rpt_lev_va	rpt_lev_cd	lab_std_va	anl_ent_cd
5s	15s	10d	5d	10d	5d	3s	1s	8s	3s	11s	11s	5s	1s	12s	5s	5s	1s	12s	6s	11s	8s
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			10		12.5		THM01	S				USGS-WRD
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			20		23		THM05	S				USGS-WRD
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			25		584		BAROM	S				USGS-WRD
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			59		4			S				USGS-WRD
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			95		389		SC001	S				USGS-WRD
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			191		0.00004		ALGOR	S				
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			300		8.2		MEMBR	S				USGS-WRD
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			301		101		ALGOR	S				
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			400		7.4		PROBE	S				USGS-WRD
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			405		14		ALGOR	S				
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			452		0		TT019	S				USGS-WRD
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			453		222		TT017	S				USGS-WRD
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			605	<	1.8		ALGOR	S				
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			610	<	0.03		CL016	R				USEPA
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			615	<	0.005		CDR08	R				USEPA
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			620		1.8		CDR08	R				USEPA
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			650		0.086		ALGOR	R				
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			681		0.59	b	OX006	R	0.23	LT-MDL		USGSNWQL
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			900		199		ALGOR	S				
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			904		16		ALGOR	S				
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			905		5		ALGOR	S				
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			906		200		CAL04	S				USEPA
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			915		51		PLA18	R				USEPA
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			925		17		PLA18	R				USEPA
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			930		3		PLA18	R				USEPA
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			931		0.09		ALGOR	R				
USGS	4.12E+14	8/5/2013	13:30			MDT	K	USGS-WRD	WG			935	<	1		PLA18	R				USEPA

USGS 411727105305901

```
#
# File created on 2020-05-29 17:10:03 EDT
#
# U.S. Geological Survey
#
# This file contains selected water-quality data for stations in the National Water
# Information System water-quality database.  Explanation of codes found in this file are
# followed by the retrieved data.
#
# The data you have secured from the USGS NWISWeb database may include data that have
# not received Director's approval and as such are provisional and subject to revision.
# The data are released on the condition that neither the USGS nor the United States
# Government may be held liable for any damages resulting from its authorized or
# unauthorized use.
#
# To view additional data-quality attributes, output the results using these options:
# one result per row, expanded attributes.  Additional precautions are at:
# https://help.waterdata.usgs.gov/tutorials/water-quality-data/help-using-the-water-quality-data-retrieval-system#Data_retrievals_precautions
#
#  agency_cd                - Agency Code
#  site_no                  - USGS site number
#  sample_dt                - Begin date
#  sample_tm                - Begin time
#  sample_end_dt            - End date
#  sample_end_tm            - End time
#  sample_start_time_datum_cd - Time datum
#  tm_datum_rlbty_cd        - Time datum reliability code
#  coll_ent_cd              - Agency Collecting Sample Code
#  medium_cd                - Sample Medium Code
#  tu_id                    - Taxonomic unit code
#  body_part_id             - Body part code
#  parm_cd                  - Parameter code
#  remark_cd                - Remark code
#  result_va                - Parameter value
#  val_qual_tx              - Result value qualifier code
#  meth_cd                  - Method code
#  dqi_cd                   - Data-quality indicator code
#  rpt_lev_va               - Reporting level
#  rpt_lev_cd               - Reporting level type
#  lab_std_va               - Lab standard deviation
#  anl_ent_cd               - Analyzing entity code
#
# The following parameters are included:
#  00010  - Temperature, water, degrees Celsius
#  00020  - Temperature, air, degrees Celsius
#  00025  - Barometric pressure, millimeters of mercury
#  00059  - Flow rate, instantaneous, gallons per minute
#  00095  - Specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees Celsius
#  00191  - Hydrogen ion, water, unfiltered, calculated, milligrams per liter
#  00300  - Dissolved oxygen, water, unfiltered, milligrams per liter
#  00301  - Dissolved oxygen, water, unfiltered, percent of saturation
#  00400  - pH, water, unfiltered, field, standard units
#  00405  - Carbon dioxide, water, unfiltered, milligrams per liter
#  00452  - Carbonate, water, filtered, inflection-point titration method (incremental titration method), field, milligrams per liter
#  00453  - Bicarbonate, water, filtered, inflection-point titration method (incremental titration method), field, milligrams per liter
#  00605  - Organic nitrogen, water, unfiltered, milligrams per liter as nitrogen
#  00610  - Ammonia (NH3 + NH4+), water, unfiltered, milligrams per liter as nitrogen
#  00615  - Nitrite, water, unfiltered, milligrams per liter as nitrogen
#  00620  - Nitrate, water, unfiltered, milligrams per liter as nitrogen
#  00650  - Phosphate, water, unfiltered, milligrams per liter as PO4
#  00681  - Organic carbon, water, filtered, milligrams per liter
#  00900  - Hardness, water, milligrams per liter as calcium carbonate
#  00904  - Noncarbonate hardness, water, filtered, field, milligrams per liter as calcium carbonate
#  00905  - Noncarbonate hardness, water, filtered, lab, milligrams per liter as calcium carbonate
#  00915  - Calcium, water, filtered, milligrams per liter
#  00925  - Magnesium, water, filtered, milligrams per liter
#  00930  - Sodium, water, filtered, milligrams per liter
#  00931  - Sodium adsorption ratio (SAR), water, number
#  00935  - Potassium, water, filtered, milligrams per liter
#  00940  - Chloride, water, filtered, milligrams per liter
#  00945  - Sulfate, water, filtered, milligrams per liter
#  00950  - Fluoride, water, filtered, milligrams per liter
#  00955  - Silica, water, filtered, milligrams per liter as SiO2
#  00956  - Silica, water, unfiltered, milligrams per liter as SiO2
#  01000  - Arsenic, water, filtered, micrograms per liter
#  01002  - Arsenic, water, unfiltered, micrograms per liter
#  01005  - Barium, water, filtered, micrograms per liter
#  01007  - Barium, water, unfiltered, recoverable, micrograms per liter
#  01010  - Beryllium, water, filtered, micrograms per liter
#  01012  - Beryllium, water, unfiltered, recoverable, micrograms per liter
#  01020  - Boron, water, filtered, micrograms per liter
#  01022  - Boron, water, unfiltered, recoverable, micrograms per liter
#  01025  - Cadmium, water, filtered, micrograms per liter
#  01027  - Cadmium, water, unfiltered, micrograms per liter
#  01030  - Chromium, water, filtered, micrograms per liter
#  01034  - Chromium, water, unfiltered, recoverable, micrograms per liter
#  01035  - Cobalt, water, filtered, micrograms per liter
#  01037  - Cobalt, water, unfiltered, recoverable, micrograms per liter
#  01040  - Copper, water, filtered, micrograms per liter
#  01042  - Copper, water, unfiltered, recoverable, micrograms per liter
#  01045  - Iron, water, unfiltered, recoverable, micrograms per liter
#  01046  - Iron, water, filtered, micrograms per liter
#  01049  - Lead, water, filtered, micrograms per liter
#  01051  - Lead, water, unfiltered, recoverable, micrograms per liter
#  01055  - Manganese, water, unfiltered, recoverable, micrograms per liter
#  01056  - Manganese, water, filtered, micrograms per liter
#  01057  - Thallium, water, filtered, micrograms per liter
#  01059  - Thallium, water, unfiltered, micrograms per liter
#  01060  - Molybdenum, water, filtered, micrograms per liter
#  01062  - Molybdenum, water, unfiltered, recoverable, micrograms per liter
#  01065  - Nickel, water, filtered, micrograms per liter
#  01067  - Nickel, water, unfiltered, recoverable, micrograms per liter
#  01075  - Silver, water, filtered, micrograms per liter
#  01077  - Silver, water, unfiltered, recoverable, micrograms per liter
#  01080  - Strontium, water, filtered, micrograms per liter
#  01082  - Strontium, water, unfiltered, recoverable, micrograms per liter
#  01085  - Vanadium, water, filtered, micrograms per liter
#  01087  - Vanadium, water, unfiltered, micrograms per liter
#  01090  - Zinc, water, filtered, micrograms per liter
#  01092  - Zinc, water, unfiltered, recoverable, micrograms per liter
#  01095  - Antimony, water, filtered, micrograms per liter
```

#
Description of sample_start_time_datum_cd:
MDT - Mountain Daylight Time
#
Description of tm_datum_rlbty_cd:
K - Known
#
Description of coll_ent_cd and anl_ent_cd:
USGS-WRD - U.S. Geological Survey-Water Resources Discipline
CO-TALDN - TestAmerica Labs - Denver, Arvada, CO
USEPA - U.S. Environmental Protection Agency
USGS-WRD - U.S. Geological Survey-Water Resources Discipline
USGSNWQL - USGS-National Water Quality Lab, Denver, CO
USGSSIVA - USGS-NRP, Stable Isotope Lab, Reston, VA
#
Description of medium_cd:
WG - Groundwater
#
Description of tu_id:
https://www.itis.gov/
#
Description of body_part_id:
#
Description of remark_cd:
< - less than
E - estimated
#
Description of val_qual_tx:
@ - holding time exceeded
b - value extrapolated at low end
c - see result comment
k - counts outside acceptable range
#
Description of meth_cd:
ALGOR - Computation by NWIS algorithm
BAC18 - E coli, MI MF method
BAC52 - Total coliform, MI MF method
BAROM - Atmospheric pressure, barometer
CDR08 - NO2+NO3, wu, auto Cd red (DODEC)
CL016 - Ammonia, wu, phenate colorimetry
CL104 - Ortho-PO4, wu,2-reagent ascorbic
GC164 - Dissolved gases, headspace GC
GCI01 - Nonhalogenated organics,wu,GCFID
GCI02 - GROs, wu, by GC/FID (EPA 8015B)
GCM25 - VOCs by capillary column GC/MS
GCM66 - VOC, wu, acidified, GCMS
GCM94 - VOCs, wu, GC/MS (DODEC,EPA8260B)
IC009 - Anions, IC, EPA 300.0
MEMBR - Diss oxygen, membrane electrode
MS007 - Deuterium/Protium, wu, MS
MS020 - Oxygen-18/16, wu, by MS
OX006 - DOC,0.45um cap,acid,persulfateIR
PLA17 - Elements,wu,ICP-AES(6010B,DODEC)
PLA18 - Elements, wf, ICP-AES (DODEC)
PLM28 - Elements, wu, ICP-MS (DODEC_01)
PLM39 - Elements, wf, ICP-MS (DODEC_02)
PLM42 - Elements, wf, ICP-MS (DODEC_04)
PLM57 - Elements, wu, ICP-MS (CO WSC)
PLM58 - Elements, wf, ICP-MS (CO WSC)
PROBE - pH, field, electrometric
ROE10 - ROE, wf, 180C, by weight (NWQL)
SC001 - Specific conductance sensor
THM01 - Temperature, water, thermistor
THM05 - Temperature, air, liq-in-glass
TS101 - HACH, sensor model 2100 P, NTRU
TT013 - Alkalinity, wf, field, increment
TT017 - Bicarbonate, wf, field, increm
TT019 - Carbonate, wf, field, increment
TT023 - Hydroxide, wf, field, increm
TT040 - Alkalinity, titr. pH 4.5 (NWQL)
#
Description of dqi_cd:
R - Reviewed and approved
S - Provisional
#
Description of rpt_lev_cd:
LT-MDL - Long term method detection level
MDL - Method detection limit
MRL - Minimum reporting level
#
Data for the following sites are included:
USGS 411727105305901 15-072-07bba01
#

agency_cd	site_no	sample_dt	sample_tm	sample_en	sample_en	sample_sta	tm_datum_	coll_ent_cc	medium_cc	tu_id	body_part_	parm_cd	remark_cd	result_va	val_qual_t	meth_cd	dqi_cd	rpt_lev_va	rpt_lev_cd	lab_std_va	anl_ent_cd
5s	15s	10d	5d	10d	5d	3s	1s	8s	3s	11s	11s	5s	1s	12s	5s	5s	1s	12s	6s	11s	8s
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			10		8.7		THM01	R				USGS-WRD
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			20		18		THM05	R				USGS-WRD
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			25		580		BAROM	R				USGS-WRD
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			59		8			R				USGS-WRD
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			95		391		SC001	R				USGS-WRD
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			191		0.00005		ALGOR	R				
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			300		7.8		MEMBR	R				USGS-WRD
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			301		89		ALGOR	R				
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			400		7.3		PROBE	R				USGS-WRD
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			405		21		ALGOR	R				
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			452		0		TT019	R				USGS-WRD
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			453		252		TT017	R				USGS-WRD
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			605	<	1.4		ALGOR	R				
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			610	<	0.05		CL016	R				USEPA
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			615	<	0.005		CDR08	R				USEPA
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			620		1.6		CDR08	S				USEPA
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			650		0.056		ALGOR	R				
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			681		0.6	b	OX006	R	0.23	LT-MDL		USGSNWQL
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			900		210		ALGOR	R				
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			904		2		ALGOR	R				
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			905		5		ALGOR	R				
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			915		60		PLA18	R				USEPA
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			925		15		PLA18	R				USEPA
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			930		1.7		PLA18	R				USEPA
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			931		0.05		ALGOR	R				
USGS	4.12E+14	9/11/2012	10:30			MDT	K	USGS-WRD	WG			935	<	1		PLA18	S				USEPA

#
File created on 2020-05-29 16:10:11 EDT
#
U.S. Geological Survey
#
This file contains selected water-quality data for stations in the National Water
Information System water-quality database. Explanation of codes found in this file are
followed by the retrieved data.
#
The data you have secured from the USGS NWISWeb database may include data that have
not received Director's approval and as such are provisional and subject to revision.
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#
To view additional data-quality attributes, output the results using these options:
one result per row, expanded attributes. Additional precautions are at:
https://help.waterdata.usgs.gov/tutorials/water-quality-data/help-using-the-water-quality-data-retrieval-system#Data_retrievals_precautions
#
agency_cd   - Agency Code
site_no   - USGS site number
sample_dt   - Begin date
sample_tm   - Begin time
sample_end_dt   - End date
sample_end_tm   - End time
sample_start_time_datum_cd - Time datum
tm_datum_rlbty_cd   - Time datum reliability code
coll_ent_cd   - Agency Collecting Sample Code
medium_cd   - Sample Medium Code
tu_id   - Taxonomic unit code
body_part_id   - Body part code
parm_cd   - Parameter code
remark_cd   - Remark code
result_va   - Parameter value
val_qual_tx   - Result value qualifier code
meth_cd   - Method code
dqi_cd   - Data-quality indicator code
rpt_lev_va   - Reporting level
rpt_lev_cd   - Reporting level type
lab_std_va   - Lab standard deviation
anl_ent_cd   - Analyzing entity code
#
The following parameters are included:
00010 - Temperature, water, degrees Celsius
00020 - Temperature, air, degrees Celsius
00059 - Flow rate, instantaneous, gallons per minute
00095 - Specific conductance, water, unfiltered, microsiemens per centimeter at 25 degrees Celsius
00191 - Hydrogen ion, water, unfiltered, calculated, milligrams per liter
00300 - Dissolved oxygen, water, unfiltered, milligrams per liter
00400 - pH, water, unfiltered, field, standard units
00405 - Carbon dioxide, water, unfiltered, milligrams per liter
00452 - Carbonate, water, filtered, inflection-point titration method (incremental titration method), field, milligrams per liter
00453 - Bicarbonate, water, filtered, inflection-point titration method (incremental titration method), field, milligrams per liter
00605 - Organic nitrogen, water, unfiltered, milligrams per liter as nitrogen
00610 - Ammonia (NH3 + NH4+), water, unfiltered, milligrams per liter as nitrogen
00615 - Nitrite, water, unfiltered, milligrams per liter as nitrogen
00620 - Nitrate, water, unfiltered, milligrams per liter as nitrogen
00650 - Phosphate, water, unfiltered, milligrams per liter as PO4
00681 - Organic carbon, water, filtered, milligrams per liter
00900 - Hardness, water, milligrams per liter as calcium carbonate
00904 - Noncarbonate hardness, water, filtered, field, milligrams per liter as calcium carbonate
00905 - Noncarbonate hardness, water, filtered, lab, milligrams per liter as calcium carbonate
00915 - Calcium, water, filtered, milligrams per liter
00925 - Magnesium, water, filtered, milligrams per liter
00930 - Sodium, water, filtered, milligrams per liter
00931 - Sodium adsorption ratio (SAR), water, number
00935 - Potassium, water, filtered, milligrams per liter
00940 - Chloride, water, filtered, milligrams per liter
00945 - Sulfate, water, filtered, milligrams per liter
00950 - Fluoride, water, filtered, milligrams per liter
00955 - Silica, water, filtered, milligrams per liter as SiO2
00956 - Silica, water, unfiltered, milligrams per liter as SiO2
01000 - Arsenic, water, filtered, micrograms per liter
01002 - Arsenic, water, unfiltered, micrograms per liter
01005 - Barium, water, filtered, micrograms per liter
01007 - Barium, water, unfiltered, recoverable, micrograms per liter
01010 - Beryllium, water, filtered, micrograms per liter
01012 - Beryllium, water, unfiltered, recoverable, micrograms per liter
01020 - Boron, water, filtered, micrograms per liter
01022 - Boron, water, unfiltered, recoverable, micrograms per liter
01025 - Cadmium, water, filtered, micrograms per liter
01027 - Cadmium, water, unfiltered, micrograms per liter
01030 - Chromium, water, filtered, micrograms per liter
01034 - Chromium, water, unfiltered, recoverable, micrograms per liter
01035 - Cobalt, water, filtered, micrograms per liter
01037 - Cobalt, water, unfiltered, recoverable, micrograms per liter
01040 - Copper, water, filtered, micrograms per liter
01042 - Copper, water, unfiltered, recoverable, micrograms per liter
01045 - Iron, water, unfiltered, recoverable, micrograms per liter
01046 - Iron, water, filtered, micrograms per liter
01049 - Lead, water, filtered, micrograms per liter
01051 - Lead, water, unfiltered, recoverable, micrograms per liter
01055 - Manganese, water, unfiltered, recoverable, micrograms per liter
01056 - Manganese, water, filtered, micrograms per liter
01057 - Thallium, water, filtered, micrograms per liter
01059 - Thallium, water, unfiltered, micrograms per liter
01060 - Molybdenum, water, filtered, micrograms per liter
01062 - Molybdenum, water, unfiltered, recoverable, micrograms per liter
01065 - Nickel, water, filtered, micrograms per liter
01067 - Nickel, water, unfiltered, recoverable, micrograms per liter
01075 - Silver, water, filtered, micrograms per liter
01077 - Silver, water, unfiltered, recoverable, micrograms per liter
01080 - Strontium, water, filtered, micrograms per liter
01082 - Strontium, water, unfiltered, recoverable, micrograms per liter
01085 - Vanadium, water, filtered, micrograms per liter
01087 - Vanadium, water, unfiltered, micrograms per liter
01090 - Zinc, water, filtered, micrograms per liter
01092 - Zinc, water, unfiltered, recoverable, micrograms per liter
01095 - Antimony, water, filtered, micrograms per liter
01097 - Antimony, water, unfiltered, micrograms per liter
01105 - Aluminum, water, unfiltered, recoverable, micrograms per liter

#
Description of dqi_cd:
R - Reviewed and approved
#
Description of rpt_lev_cd:
LT-MDL - Long term method detection level
MDL - Method detection limit
MRL - Minimum reporting level
SSLC - Sample-specific critical level
#
Data for the following sites are included:
USGS 412332105321201 16-073-01bbc01
#

agency_cd	site_no	sample_dt	sample_tm	sample_en	sample_en	sample_sta	tm_datum_	coll_ent_cc	medium_cc	tu_id	body_part_	parm_cd	remark_cd	result_va	val_qual_t	meth_cd	dqi_cd	rpt_lev_va	rpt_lev_cd	lab_std_va	anl_ent_cd
5s	15s	10d	5d	10d	5d	3s	1s	8s	3s	11s	11s	5s	1s	12s	5s	5s	1s	12s	6s	11s	8s
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			10		10.3		THM01	R				USGS-WRD
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			20		25.5		THM05	R				USGS-WRD
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			59		4			R				USGS-WRD
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			95		342		SC001	R				USGS-WRD
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			191		0.00004		ALGOR	R				
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			300		8.6		MEMBR	R				USGS-WRD
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			400		7.4		PROBE	R				USGS-WRD
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			405		13		ALGOR	R				
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			452		0		TT019	R				USGS-WRD
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			453		217		TT017	R				USGS-WRD
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			605	<	1.5		ALGOR	R				
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			610	<	0.05		CL016	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			615	<	0.005		CDR08	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			620		1.7		CDR08	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			650		0.06		ALGOR	R				
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			681		0.6	b	OX006	R	0.23	LT-MDL		USGSNWQL
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			900		183		ALGOR	R				
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			904		5		ALGOR	R				
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			905		5		ALGOR	R				
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			915		45		PLA18	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			925		17		PLA18	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			930		2.7		PLA18	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			931		0.09		ALGOR	R				
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			935	<	1		PLA18	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			940		1		IC009	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			945		5.7		IC009	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			950		0.2		IC009	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			955		9.2		PLA18	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			956		9.4		PLA17	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1000	<	4		PLM58	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1002	<	4		PLM28	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1005		130		PLA18	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1007		140		PLA17	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1010	<	1		PLA18	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1012	<	1		PLA17	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1020	<	100		PLA18	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1022	<	100		PLA17	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1025	<	0.2		PLM58	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1027	<	0.2		PLM28	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1030	<	5		PLA18	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1034	<	5		PLA17	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1035	<	2		PLA18	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1037	<	2		PLA17	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1040	<	5		PLA18	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1042	<	5		PLA17	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1045	<	100		PLA17	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1046	<	100		PLA18	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1049	<	1		PLM58	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1051	<	1		PLM57	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1055	<	2		PLA17	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1056	<	2		PLA18	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1057	<	0.3		PLM42	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1059	<	0.3		PLM28	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1060		5		PLA18	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1062	<	5		PLA17	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1065	<	4		PLA18	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1067	<	4		PLA17	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1075	<	0.5		PLM58	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1077	<	0.5		PLM57	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1080		170		PLA18	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1082		180		PLA17	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1085	<	10		PLA18	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1087	<	10		PLA17	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1090	<	50		PLA18	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1092	<	50		PLA17	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1095	<	1		PLM42	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1097	<	1		PLM28	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1105	<	100		PLA17	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1106	<	100		PLA18	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1145	<	1		PLM42	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			1147	<	1		PLM28	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			7000		5.3		LSC14	R	0.34	SSLC	0.45	USGSH3CA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			22703		2.1		PLM39	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			28011		2		PLM28	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			29801		179	@c	TT040	R	4.6	LT-MDL		USGSNWQL
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			30210		27.9		ALGOR	R				
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			30217	<	0.25		GCM25	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			32101	<	0.25		GCM25	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			32102	<	0.25		GCM25	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			32103	<	0.25		GCM25	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			32104	<	0.25		GCM25	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			32105	<	0.25		GCM25	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			32106	<	0.25		GCM25	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			34010	<	0.25		GCM25	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			34030	<	0.25		GCM25	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			34215	<	0.2		GCM25	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			34301	<	0.25		GCM25	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			34311	<	0.25		GCM25	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			34371	<	0.25		GCM25	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			34396	<	0.25		GCM66	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			34413	<	1		GCM25	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			34418	<	0.25		GCM25	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			34423	<	0.25		GCM25	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			34475	<	0.25		GCM25	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			34488	<	0.25		GCM25	R				USEPA
USGS	4.12E+14	8/28/2012	10:30			MDT	K	USGS-WRD	WG			34496	<	0.25		GCM25	R				USEPA

APPENDIX A3 – MEASURED WELL OR SPRING DATA

WYOMING DEPARTMENT OF AGRICULTURE
ANALYTICAL SERVICES

1174 Snowy Range Road, Laramie, WY 82070

Phone: (307) 742-2984

Internet: http://wyagric.state.wy.us/divisions/asl **E-mail: analytical.lab@wyo.gov**

Customer
City of Laramie
P.O. Box C
Laramie, WY 82073

Sample ID : AA27271
Date Collected : 06/25/2019 09:00
Date Received : 06/26/2019 12:27
Date Authorized : 07/02/2019
Sample Collector : DARREN PARKIN

Phone : 721-5280 | **Email** : dparkin@cityoflaramie.org

Official or Service : Official

Sample Description : SI-1

Temperature : 12.3 °C

Sample Comments:

Test Report

Analyte	Method	Units	Results	Comments	Date Completed
Nitrate (as N)	EPA 300.0	mg/L	2.37		07/02/2019
Nitrite (as N)	EPA 300.0	mg/L	< 0.20		07/02/2019

Analyte	Method	Units	Results	Comments	
Nitrate + Nitrite - N	Calculation	mg/L	2.37		

The results issued on this report only reflect the analysis of the sample submitted.
The laboratory will only maintain testing results for 7 years. Copies must be requested within 7 years of result date.
Sample received for testing was acceptable unless otherwise stated on report.

Authorized by: Laboratory Supervisor or Manager

7/3/2019 8:47

T JARVIS	07/02/2019
Authorizer	**Date**

Analytical Services Laboratory
1174 Snowy Range Road
Laramie, WY 82072
www.analytical.lab@wyo.gov
307-742-2984

Laboratory Sample Report

Lab Number: **AA30020** Received Date/Time: 02/19/2020 1:30 pm Received Temperature: 6.6°C

Customer Provided Information:

City of Laramie
P.O. Box C
Laramie, WY 82073
pumpswell@cityoflaramie.org

Collect Date/Time: 02/19/2020 9:10 am
Sample Description: Pope No. 2
Sample Collector: Bauman- Palm

Test Results:

Analysis	Result	Unit	EPA MCL[1] (mg/L)	Qualifier	Date Analyzed	Method
Alkalinity	187.8	mg/L			02/20/2020	SM2320 B
Bicarbonate	187.8	mg/L			02/20/2020	SM2320 B
Calcium	55.77	ppm			02/20/2020	WC.016
Carbonate	< 2.0	mg/L			02/20/2020	SM2320 B
Chloride	10.83	mg/L	250		02/20/2020	EPA 300.0
Conductivity	398.0	uS/cm			02/20/2020	SM2510 B
Fluoride	< 0.20	mg/L	4		02/20/2020	EPA 300.0
Magnesium	15.85	ppm			02/20/2020	WC.016
Nitrate (as N)	2.08	mg/L	10		02/20/2020	EPA 300.0
Nitrate + Nitrite - N	2.08	mg/L			02/26/2020	CALCULATION
Nitrite (as N)	< 0.20	mg/L	1		02/20/2020	EPA 300.0
pH	8.1		-		02/20/2020	SM4500-H+ B
Potassium	0.78	ppm			02/20/2020	WC.016
Sodium	3.58	ppm			02/20/2020	WC.016
Sulfate+	9.82	mg/L	250		02/20/2020	EPA 300.0
TDS by Summation	200	mg/L	500		02/27/2020	SM2540 C
Copper	< 0.010	ppm	1.3		02/26/2020	WC.004
Iron	< 0.079	ppm			02/20/2020	WC.016
Lead	< 0.005	ppm	0.015		02/26/2020	WC.004
Manganese	< 0.005	ppm			02/26/2020	WC.004
Zinc	< 0.005	ppm			02/26/2020	WC.004
Calcium Hardness	140	mg/L			02/20/2020	CALCULATION
Corrosivity··	0.54 Non-aggressive				02/27/2020	SM2330 B
Total Hardness	200	mg/L			02/27/2020	CALCULATION

Report Authorized By: Teresa Jarvis, Laboratory Manager

Report Date: 02/27/2020

Analytical Services Laboratory
1174 Snowy Range Road
Laramie, WY 82072
www.analytical.lab@wyo.gov
307-742-2984

Laboratory Sample Report

Lab Number: **AA30021** Received Date/Time: 02/19/2020 1:30 pm Received Temperature: 6.6°C

Customer Provided Information:

City of Laramie
P.O. Box C
Laramie, WY 82073
pumpswell@cityoflaramie.org

Collect Date/Time: 02/19/2020 11:30 am
Sample Description: Spur 1
Sample Collector: Bauman- Palm

Test Results:

Analysis	Result	Unit	EPA MCL[1] (mg/L)	Qualifier	Date Analyzed	Method
Alkalinity	174.2	mg/L			02/20/2020	SM2320 B
Bicarbonate	174.2	mg/L			02/20/2020	SM2320 B
Calcium	45.88	ppm			02/20/2020	WC.016
Carbonate	< 2.0	mg/L			02/20/2020	SM2320 B
Chloride	< 2.0	mg/L	250		02/20/2020	EPA 300.0
Conductivity	335.4	uS/cm			02/20/2020	SM2510 B
Fluoride	< 0.20	mg/L	4		02/20/2020	EPA 300.0
Magnesium	15.43	ppm			02/20/2020	WC.016
Nitrate (as N)	1.74	mg/L	10		02/20/2020	EPA 300.0
Nitrate + Nitrite - N	1.74	mg/L			02/26/2020	CALCULATION
Nitrite (as N)	< 0.20	mg/L	1		02/20/2020	EPA 300.0
pH	8.1		-		02/20/2020	SM4500-H+ B
Potassium	0.59	ppm		EST2	02/20/2020	WC.016
Sodium	2.30	ppm			02/20/2020	WC.016
Sulfate+	6.86	mg/L	250		02/20/2020	EPA 300.0
TDS by Summation	160	mg/L	500		02/27/2020	SM2540 C
Copper	< 0.010	ppm	1.3		02/26/2020	WC.004
Iron	< 0.079	ppm			02/20/2020	WC.016
Lead	< 0.005	ppm	0.015		02/26/2020	WC.004
Manganese	< 0.005	ppm			02/26/2020	WC.004
Zinc	< 0.005	ppm			02/26/2020	WC.004
Calcium Hardness	110	mg/L			02/20/2020	CALCULATION
Corrosivity··	0.45 Non-aggressive				02/27/2020	SM2330 B
Total Hardness	180	mg/L			02/27/2020	CALCULATION

Report Authorized By: Teresa Jarvis, Laboratory Manager

Report Date: 02/27/2020

Analytical Services Laboratory
1174 Snowy Range Road
Laramie, WY 82072
www.analytical.lab@wyo.gov
307-742-2984

Laboratory Sample Report

Lab Number: **AA30019** Received Date/Time: 02/19/2020 1:30 pm Received Temperature: 6.6°C

Customer Provided Information:

City of Laramie
P.O. Box C
Laramie, WY 82073
pumpswell@cityoflaramie.org

Collect Date/Time: 02/19/2020 8:45 am
Sample Description: Soldier Springs
Sample Collector: Bauman- Palm

Test Results:

Analysis	Result	Unit	EPA MCL[1] (mg/L)	Qualifier	Date Analyzed	Method
Alkalinity	180.3	mg/L			02/20/2020	SM2320 B
Bicarbonate	180.3	mg/L			02/20/2020	SM2320 B
Calcium	52.63	ppm			02/20/2020	WC.016
Carbonate	< 2.0	mg/L			02/20/2020	SM2320 B
Chloride	8.04	mg/L	250		02/20/2020	EPA 300.0
Conductivity	384.9	uS/cm			02/20/2020	SM2510 B
Fluoride	< 0.20	mg/L	4		02/20/2020	EPA 300.0
Magnesium	15.54	ppm			02/20/2020	WC.016
Nitrate (as N)	2.20	mg/L	10		02/20/2020	EPA 300.0
Nitrate + Nitrite - N	2.20	mg/L			02/26/2020	CALCULATION
Nitrite (as N)	< 0.20	mg/L	1		02/20/2020	EPA 300.0
pH	8.1		-		02/20/2020	SM4500-H+ B
Potassium	0.87	ppm			02/20/2020	WC.016
Sodium	3.44	ppm			02/20/2020	WC.016
Sulfate+	12.26	mg/L	250		02/20/2020	EPA 300.0
TDS by Summation	190	mg/L	500		02/27/2020	SM2540 C
Copper	< 0.010	ppm	1.3		02/26/2020	WC.004
Iron	< 0.079	ppm			02/20/2020	WC.016
Lead	< 0.005	ppm	0.015		02/26/2020	WC.004
Manganese	< 0.005	ppm			02/26/2020	WC.004
Zinc	< 0.005	ppm			02/26/2020	WC.004
Calcium Hardness	130	mg/L			02/20/2020	CALCULATION
Corrosivity··	0.50 Non-aggressive				02/27/2020	SM2330 B
Total Hardness	200	mg/L			02/27/2020	CALCULATION

Report Authorized By: Teresa Jarvis, Laboratory Manager

Report Date: 02/27/2020

Analytical Services Laboratory
1174 Snowy Range Road
Laramie, WY 82072
www.analytical.lab@wyo.gov
307-742-2984

Laboratory Sample Report

Lab Number: **AA30018** Received Date/Time: 02/19/2020 1:30 pm Received Temperature: 6.6°C

Customer Provided Information:

City of Laramie
P.O. Box C
Laramie, WY 82073
pumpswell@cityoflaramie.org

Collect Date/Time: 02/19/2020 8:15 am
Sample Description: Turner No. 2
Sample Collector: Bauman- Palm

Test Results:

Analysis	Result	Unit	EPA MCL[1] (mg/L)	Qualifier	Date Analyzed	Method
Alkalinity	189.5	mg/L			02/20/2020	SM2320 B
Bicarbonate	189.5	mg/L			02/20/2020	SM2320 B
Calcium	50.91	ppm			02/20/2020	WC.016
Carbonate	< 2.0	mg/L			02/20/2020	SM2320 B
Chloride	3.02	mg/L	250		02/20/2020	EPA 300.0
Conductivity	370.8	uS/cm			02/20/2020	SM2510 B
Fluoride	< 0.20	mg/L	4		02/20/2020	EPA 300.0
Magnesium	16.79	ppm			02/20/2020	WC.016
Nitrate (as N)	1.72	mg/L	10		02/20/2020	EPA 300.0
Nitrate + Nitrite - N	1.72	mg/L			02/26/2020	CALCULATION
Nitrite (as N)	< 0.20	mg/L	1		02/20/2020	EPA 300.0
pH	8.0		-		02/20/2020	SM4500-H+ B
Potassium	0.83	ppm			02/20/2020	WC.016
Sodium	2.39	ppm			02/20/2020	WC.016
Sulfate+	10.06	mg/L	250		02/20/2020	EPA 300.0
TDS by Summation	180	mg/L	500		02/27/2020	SM2540 C
Copper	< 0.010	ppm	1.3		02/26/2020	WC.004
Iron	< 0.079	ppm			02/20/2020	WC.016
Lead	< 0.005	ppm	0.015		02/26/2020	WC.004
Manganese	< 0.005	ppm			02/26/2020	WC.004
Zinc	< 0.005	ppm			02/26/2020	WC.004
Calcium Hardness	130	mg/L			02/20/2020	CALCULATION
Corrosivity··	0.41 Non-aggressive				02/27/2020	SM2330 B
Total Hardness	200	mg/L			02/27/2020	CALCULATION

Report Authorized By: Teresa Jarvis, Laboratory Manager

Report Date: 02/27/2020

Appendix B

Modeling Results

APPENDIX B1 – MODEL RESULTS

Cumulative Nitrate Loading Analysis - Wehrmann Model
Casper Aquifer Protection Overlay Zone
Current Build-out Scenario using 40 mg/L Nitrate Septic Effluent Concentration

Step 1: Calculate Vb (Volume of groundwater entering the leach field from up gradient area)

Block	Area (ft^2)	K (ft/day)	dh/dx (ft/ft)	Vb (gpd)
Spur	9141012	9.8	0.02554931	-
Turner	5721276	9.8	0.069246083	-
Pope	4716644	9.8	0.051308363	-
Soldier	2940560	9.8	0.056574419	-
Simpson	2292640	9.8	0.052475074	-

K is the hydraulic conductivity of the aquifer
i is the hydraulic gradient
A is the area of the upgradient area in square feet

Assumptions: Vb equals zero due to the fact the eastern edge of each aquifer block is set at the unsaturated edge of the Casper Formation.

Step 2: Enter Cb (ambient concentration of nitrate-nitrogen)

What is the ambient concentration of NO3- as N contained in the groundwater entering the leach field?

Block	Cb (mg/L)	Well Name
Spur	1.4	Mathis #1
Turner	1.4	Peter
Pope	3	Klein
Soldier	3	Klein
Simpson	1.1	Bryant

Assumptions: Based on water quality data provided by the city (included in Appendix A)

Step 3: Calculate V_i (volume of precipitation infiltrating beneath the leach field)

Block	Area (ft^2)	Vi (gpd)
Spur	643287800	1,538,015.9
Turner	415005700	992,223.7
Pope	368655500	881,406.5
Soldier	229200500	547,988.0
Simpson	191675804	458,271.5

Assumptions: 1. Area measured using GIS to calculating square foot of each modeled aquifer block
2. Precipitation into the aquifer assumed to be 1.4 in/year (Lundy 1978)

Step 4: Enter C_i (concentration of nitrate-nitrogen contained in the infiltrating precipitation)

What is the concentration of nitrate-nitrogen contained in the infiltrating precipitation?

Block	Ci (mg/L)	Well Name	
Spur	1.4	Mathis #1	
Turner	1.4	Peter	
Pope	2		Klein data replaced with City of Laramie well data (Pope #2).
Soldier	2		Klein data replaced with City of Laramie well data (Pope #2).
Simpson	1.1	Bryant	

Assumptions: Background nitrate concentrations based on water quality data provided by the City.

Step 5: Calculate V_s (volume of septic effluent introduced beneath the leach field)

Block	# of bedrooms or residents per lot	gpd/lot	# of lots	Vs (gpd)
Spur	2	280	45	12,600.0
Turner	2	280	199	55,720.0
Pope	2	280	235	65,800.0
Soldier	2	280	13	3,640.0
Simpson	2	280	22	6,160.0

Assumptions: 280 gpd/lot based on two bedrooms per DEQ Ch. 25 septic guidelines

Step 6: Enter C_s (concentration of nitrate-nitrogen contained in the septic effluent)

What is the concentration of NO3- as N contained in the septic effluent?

Block	Cs (mg/L)
Spur	40
Turner	40
Pope	40
Soldier	40
Simpson	40

Assumptions: Assumed septic effluent nitrate concentration of 40 mg/L per DEQ Ch. 23

Step 7: Calculate V_p (volume of groundwater pumped by wells beneath the leach field)

Block	gpd/Lot	# Lots	Lawn Irr. (acres)	Same Aquifer? Y=1; N=0	Vp (gpd)
Spur	390	45	0.5	1	-
Turner	390	199	0.5	1	-
Pope	390	235	0.5	1	-
Soldier	390	13	0.5	1	-
Simpson	390	22	0.5	1	-

Note: Vp > 0 only if pumping from same aquifer zone as Vs receptor aquifer zone; otherwise Vp = 0

Assumptions: Vp assumed to be zero or negligible due to assumed household water use only in this area.

Step 8: Enter C_p (concentration of nitrate-nitrogen contained in the pumped groundwater)

What is the concentration of nitrate-nitrogen contained in the pumped groundwater?

Block	Cp (mg/L)	Well name
Spur	1.7	USGS 412332105321201
Turner	1.6	USGS 411727105305901
Pope	1.8	USGS 411638105314001
Soldier	1.6	Jensen
Simpson	1.6	Wohl

Assumptions: Water quality data sourced from the City and USGS' National Water Information System

Step 9, Model Results: Diluted concentration of nitrate-nitrogen leaving the leach field.

Co = VbCb + ViCi + VsCs - VpCp / (Vb + Vi + Vs – Vp)

Block	Co (mg/L)
Spur	1.71
Turner	3.45
Pope	4.64
Soldier	2.25
Simpson	1.62

Cumulative Nitrate Loading Analysis - Wehrmann Model
Casper Aquifer Protection Overlay Zone
Current Build-out Scenario using 55 mg/L Nitrate Septic Effluent Concentration

Step 1: Calculate Vb (Volume of groundwater entering the leach field from up gradient area)

Block	Area (ft^2)	K (ft/day)	dh/dx (ft/ft)	Vb (gpd)
Spur	9141012	9.8	0.02554931	-
Turner	5721276	9.8	0.069246083	-
Pope	4716644	9.8	0.051308363	-
Soldier	2940560	9.8	0.056574419	-
Simpson	2292640	9.8	0.052475074	-

K is the hydraulic conductivity of the aquifer
i is the hydraulic gradient
A is the area of the upgradient area in square feet

Assumptions: Vb equals zero due to the fact the eastern edge of each aquifer block is set at the unsaturated edge of the Casper Formation.

Step 2: Enter Cb (ambient concentration of nitrate-nitrogen)

What is the ambient concentration of NO3- as N contained in the groundwater entering the leach field?

Block	Cb (mg/L)	Well Name
Spur	1.4	Mathis #1
Turner	1.4	Peter
Pope	3	Klein
Soldier	3	Klein
Simpson	1.1	Bryant

Assumptions: Based on water quality data provided by the city (included in Appendix A)

Step 3: Calculate V_i (volume of precipitation infiltrating beneath the leach field)

Block	Area (ft^2)	Vi (gpd)
Spur	643287800	1,538,015.9
Turner	415005700	992,223.7
Pope	368655500	881,406.5
Soldier	229200500	547,988.0
Simpson	191675804	458,271.5

Assumptions: 1. Area measured using GIS to calculating square foot of each modeled aquifer block
2. Precipitation into the aquifer assumed to be 1.4 in/year (Lundy 1978)

Step 4: Enter C_i (concentration of nitrate-nitrogen contained in the infiltrating precipitation)

What is the concentration of nitrate-nitrogen contained in the infiltrating precipitation?

Block	Ci (mg/L)	Well Name	
Spur	1.4	Mathis #1	
Turner	1.4	Peter	
Pope	2		Klein data replaced with City of Laramie well data (Pope #2).
Soldier	2		Klein data replaced with City of Laramie well data (Pope #2).
Simpson	1.1	Bryant	

Assumptions: Background nitrate concentrations based on water quality data provided by the City.

Step 5: Calculate V_s (volume of septic effluent introduced beneath the leach field)

Block	# of bedrooms or residents per lot	gpd/lot	# of lots	Vs (gpd)
Spur	2	280	45	12,600.0
Turner	2	280	199	55,720.0
Pope	2	280	235	65,800.0
Soldier	2	280	13	3,640.0
Simpson	2	280	22	6,160.0

Assumptions: 280 gpd/lot based on two bedrooms per DEQ Ch. 25 septic guidelines

Step 6: Enter C_s (concentration of nitrate-nitrogen contained in the septic effluent)

What is the concentration of NO3- as N contained in the septic effluent?

Block	Cs (mg/L)
Spur	55
Turner	55
Pope	55
Soldier	55
Simpson	55

Assumptions: Assumed nitrate effluent concentration of 55 mg/L per Wenck's consultant report to Albany County (2019).

Step 7: Calculate V_p (volume of groundwater pumped by wells beneath the leach field)

Block	gpd/Lot	# Lots	Lawn Irr. (acres)	Same Aquifer? Y=1; N=0	Vp (gpd)
Spur	390	45	0.5	1	-
Turner	390	199	0.5	1	-
Pope	390	235	0.5	1	-
Soldier	390	13	0.5	1	-
Simpson	390	22	0.5	1	-

Note: Vp > 0 only if pumping from same aquifer zone as Vs receptor aquifer zone; otherwise Vp = 0

Assumptions: Vp assumed to be zero or negligible due to assumed household water use only in this area.

Step 8: Enter C_p (concentration of nitrate-nitrogen contained in the pumped groundwater)

What is the concentration of nitrate-nitrogen contained in the pumped groundwater?

Block	Cp (mg/L)	Well name
Spur	1.7	USGS 412332105321201
Turner	1.6	USGS 411727105305901
Pope	1.8	USGS 411638105314001
Soldier	1.6	Jensen
Simpson	1.6	Wohl

Assumptions: Water quality data sourced from the City and USGS' National Water Information System

Step 9, Model Results: Diluted concentration of nitrate-nitrogen leaving the leach field.

Co = VbCb + ViCi + VsCs - VpCp / (Vb + Vi + Vs – Vp)

Block	Co (mg/L)
Spur	1.84
Turner	4.25
Pope	5.68
Soldier	2.35
Simpson	1.81

APPENDIX B2 – FUTURE BUILDOUT – AGRICULTURAL ZONING

Cumulative Nitrate Loading Analysis - Wehrmann Model
Casper Aquifer Protection Overlay Zone
Future Build-out Scenario -- Agricultural Zoning Designation using 40 mg/L Nitrate Septic Effluent Concentration

Step 1: Calculate Vb (Volume of groundwater entering the leach field from up gradient area)

Block	Area (ft^{2})	K (ft/day)	dh/dx (ft/ft)	Vb (gpd)
Spur	9141012	9.8	0.02554931	-
Turner	5721276	9.8	0.069246083	-
Pope	4716644	9.8	0.051308363	-
Soldier	2940560	9.8	0.056574419	-
Simpson	2292640	9.8	0.052475074	-

K is the hydraulic conductivity of the aquifer
i is the hydraulic gradient
A is the area of the upgradient area in square feet

Assumptions: Vb equals zero due to the fact the eastern edge of each aquifer block is set at the unsaturated edge of the Casper Formation.

Step 2: Enter Cb (ambient concentration of nitrate-nitrogen)

What is the ambient concentration of NO3- as N contained in the groundwater entering the leach field?

Block	Cb (mg/L)	Well Name
Spur	1.4	Mathis #1
Turner	1.4	Peter
Pope	3	Klein
Soldier	3	Klein
Simpson	1.1	Bryant

Assumptions: Based on water quality data provided by the city (included in Appendix A)

Step 3: Calculate V_i (volume of precipitation infiltrating beneath the leach field)

Block	Area (ft^2)	Vi (gpd)
Spur	643287800	1,538,015.9
Turner	415005700	992,223.7
Pope	368655500	881,406.5
Soldier	229200500	547,988.0
Simpson	191675804	458,271.5

Assumptions: 1. Area measured using GIS to calculating square foot of each modeled aquifer block
2. Precipitation into the aquifer assumed to be 1.4 in/year (Lundy 1978)

Step 4: Enter C_i (concentration of nitrate-nitrogen contained in the infiltrating precipitation)

What is the concentration of nitrate-nitrogen contained in the infiltrating precipitation?

Block	Ci (mg/L)	Well Name	
Spur	1.4	Mathis #1	
Turner	1.4	Peter	
Pope	2		Klein data replaced with City of Laramie well data (Pope #2).
Soldier	2		Klein data replaced with City of Laramie well data (Pope #2).
Simpson	1.1	Bryant	

Assumptions: Background nitrate concentrations based on water quality data provided by the City.

Step 5: Calculate V_s (volume of septic effluent introduced beneath the leach field)

Block	# of bedrooms or residents per lot	gpd/lot	# of lots	available land (acres)	# of future lots	Vs (gpd)
Spur	2	280	45	14043.46	401	124,947.7
Turner	2	280	199	11212.82	320	145,422.6
Pope	2	280	235	279.31	8	68,034.5
Soldier	2	280	13	80.27	2	4,282.2
Simpson	2	280	22	432.64	12	9,621.1

Assumptions: 1. 280 gpd/lot based on two bedrooms per DEQ Ch. 25 septic guidelines

2. Future lots determined by calculating amount of vacant private property and dividing by agricultural zoning designation (1 lot/35 acres)

Step 6: Enter C_s (concentration of nitrate-nitrogen contained in the septic effluent)

What is the concentration of NO3- as N contained in the septic effluent?

Block	Cs (mg/L)
Spur	40
Turner	40
Pope	40
Soldier	40
Simpson	40

Assumptions: Assumed septic effluent nitrate concentration of 40 mg/L per DEQ Ch. 23

Step 7: Calculate V_p (volume of groundwater pumped by wells beneath the leach field)

Block	gpd/Lot	# of lots	# of future lots	Lawn Irr. (acres)	Same Aquifer? Y=1; N=0	Vp (gpd)
Spur	390	45	401	0.5	1	-
Turner	390	199	320	0.5	1	-
Pope	390	235	8	0.5	1	-
Soldier	390	13	2	0.5	1	-
Simpson	390	22	12	0.5	1	-

Note: Vp > 0 only if pumping from same aquifer zone as Vs receptor aquifer zone; otherwise Vp = 0

Assumptions: Vp assumed to be neglible due to assumed household water use only.

Step 8: Enter C_p (concentration of nitrate-nitrogen contained in the pumped groundwater)

What is the concentration of nitrate-nitrogen contained in the pumped groundwater?

Block	Cp (mg/L)	Well name
Spur	1.7	USGS 412332105321201
Turner	1.6	USGS 411727105305901
Pope	1.8	USGS 411638105314001
Soldier	1.6	Jensen
Simpson	1.6	Wohl

Assumptions: Water quality data sourced from the City and USGS' National Water Information System

Step 9, Model Results: Diluted concentration of nitrate-nitrogen leaving the leach field.

Co = VbCb + ViCi + VsCs - VpCp / (Vb + Vi + Vs – Vp)

Block	Co (mg/L)
Spur	4.30
Turner	6.33
Pope	4.72
Soldier	2.29
Simpson	1.90

Cumulative Nitrate Loading Analysis - Wehrmann Model
Casper Aquifer Protection Overlay Zone
Future Build-out Scenario -- Agricultural Zoning Designation using 55 mg/L Nitrate Septic Effluent Concentration

Step 1: Calculate Vb (Volume of groundwater entering the leach field from up gradient area)

Block	Area (ft^2)	K (ft/day)	dh/dx (ft/ft)	Vb (gpd)
Spur	9141012	9.8	0.02554931	-
Turner	5721276	9.8	0.069246083	-
Pope	4716644	9.8	0.051308363	-
Soldier	2940560	9.8	0.056574419	-
Simpson	2292640	9.8	0.052475074	-

K is the hydraulic conductivity of the aquifer
i is the hydraulic gradient
A is the area of the upgradient area in square feet

Assumptions: Vb equals zero due to the fact the eastern edge of each aquifer block is set at the unsaturated edge of the Casper Formation.

Step 2: Enter Cb (ambient concentration of nitrate-nitrogen)

What is the ambient concentration of NO3- as N contained in the groundwater entering the leach field?

Block	Cb (mg/L)	Well Name
Spur	1.4	Mathis #1
Turner	1.4	Peter
Pope	3	Klein
Soldier	3	Klein
Simpson	1.1	Bryant

Assumptions: Based on water quality data provided by the city (included in Appendix A)

Step 3: Calculate V_i (volume of precipitation infiltrating beneath the leach field)

Block	Area (ft^2)	Vi (gpd)
Spur	643287800	1,538,015.9
Turner	415005700	992,223.7
Pope	368655500	881,406.5
Soldier	229200500	547,988.0
Simpson	191675804	458,271.5

Assumptions: 1. Area measured using GIS to calculating square foot of each modeled aquifer block
2. Precipitation into the aquifer assumed to be 1.4 in/year (Lundy 1978)

Step 4: Enter C_i (concentration of nitrate-nitrogen contained in the infiltrating precipitation)

What is the concentration of nitrate-nitrogen contained in the infiltrating precipitation?

Block	Ci (mg/L)	Well Name	
Spur	1.4	Mathis #1	
Turner	1.4	Peter	
Pope	2		Klein data replaced with City of Laramie well data (Pope #2).
Soldier	2		Klein data replaced with City of Laramie well data (Pope #2).
Simpson	1.1	Bryant	

Assumptions: Background nitrate concentrations based on water quality data provided by the City.

Step 5: Calculate V_s (volume of septic effluent introduced beneath the leach field)

Block	# of bedrooms or residents per lot	gpd/lot	# of lots	available land (acres)	# of future lots	Vs (gpd)
Spur	2	280	45	14043.46	401	124,947.7
Turner	2	280	199	11212.82	320	145,422.6
Pope	2	280	235	279.31	8	68,034.5
Soldier	2	280	13	80.27	2	4,282.2
Simpson	2	280	22	432.64	12	9,621.1

Assumptions: 1. 280 gpd/lot based on two bedrooms per DEQ Ch. 25 septic guidelines

2. Future lots determined by calculating amount of vacant private property and dividing by agricultural zoning designation (1 lot/35 acres)

Step 6: Enter C_s (concentration of nitrate-nitrogen contained in the septic effluent)

What is the concentration of NO3- as N contained in the septic effluent?

Block	Cs (mg/L)
Spur	55
Turner	55
Pope	55
Soldier	55
Simpson	55

Assumptions: Assumed septic effluent nitrate concentration of 55 mg/L per Wenck's consultant report to Albany County (2019)

Step 7: Calculate V_p (volume of groundwater pumped by wells beneath the leach field)

Block	gpd/Lot	# of lots	# of future lots	Lawn Irr. (acres)	Same Aquifer? Y=1; N=0	Vp (gpd)
Spur	390	45	401	0.5	1	-
Turner	390	199	320	0.5	1	-
Pope	390	235	8	0.5	1	-
Soldier	390	13	2	0.5	1	-
Simpson	390	22	12	0.5	1	-

Note: Vp > 0 only if pumping from same aquifer zone as Vs receptor aquifer zone; otherwise Vp = 0

Assumptions: Vp assumed to be neglible due to assumed household water use only.

Step 8: Enter C_p (concentration of nitrate-nitrogen contained in the pumped groundwater)

What is the concentration of nitrate-nitrogen contained in the pumped groundwater?

Block	Cp (mg/L)	Well name
Spur	1.7	USGS 412332105321201
Turner	1.6	USGS 411727105305901
Pope	1.8	USGS 411638105314001
Soldier	1.6	Jensen
Simpson	1.6	Wohl

Assumptions: Water quality data sourced from the City and USGS' National Water Information System

Step 9, Model Results: Diluted concentration of nitrate-nitrogen leaving the leach field.

Co = VbCb + ViCi + VsCs - VpCp / (Vb + Vi + Vs – Vp)

Block	Co (mg/L)
Spur	5.43
Turner	8.25
Pope	5.80
Soldier	2.41
Simpson	2.21

APPENDIX B3 – FUTURE BUILDOUT – RURAL RESIDENTIAL ZONING

Cumulative Nitrate Loading Analysis - Wehrmann Model
Casper Aquifer Protection Overlay Zone
Future Build-out Scenario -- Rural Residential Zoning Designation Using 40 mg/L Nitrate Septic Effluent Concentration

Step 1: Calculate Vb (Volume of groundwater entering the leach field from up gradient area)

Block	Area (ft^2)	K (ft/day)	dh/dx (ft/ft)	Vb (gpd)
Spur	9141012	9.8	0.02554931	-
Turner	5721276	9.8	0.069246083	-
Pope	4716644	9.8	0.051308363	-
Soldier	2940560	9.8	0.056574419	-
Simpson	2292640	9.8	0.052475074	-

K is the hydraulic conductivity of the aquifer
i is the hydraulic gradient
A is the area of the upgradient area in square feet

Assumptions: Vb equals zero due to the fact the eastern edge of each aquifer block is set at the unsaturated edge of the Casper Formation.

Step 2: Enter Cb (ambient concentration of nitrate-nitrogen)

What is the ambient concentration of NO3- as N contained in the groundwater entering the leach field?

Block	Cb (mg/L)	Well Name
Spur	1.4	Mathis #1
Turner	1.4	Peter
Pope	3	Klein
Soldier	3	Klein
Simpson	1.1	Bryant

Assumptions: Based on water quality data provided by the city (included in Appendix A)

Step 3: Calculate V_i (volume of precipitation infiltrating beneath the leach field)

Block	Area (ft^2)	Vi (gpd)
Spur	643287800	1,538,015.9
Turner	415005700	992,223.7
Pope	368655500	881,406.5
Soldier	229200500	547,988.0
Simpson	191675804	458,271.5

Assumptions: 1. Area measured using GIS to calculating square foot of each modeled aquifer block
2. Precipitation into the aquifer assumed to be 1.4 in/year (Lundy 1978)

Step 4: Enter C_i (concentration of nitrate-nitrogen contained in the infiltrating precipitation)

What is the concentration of nitrate-nitrogen contained in the infiltrating precipitation?

Block	Ci (mg/L)	Well Name	
Spur	1.4	Mathis #1	
Turner	1.4	Peter	
Pope	2		Klein data replaced with City of Laramie well data (Pope #2).
Soldier	2		Klein data replaced with City of Laramie well data (Pope #2).
Simpson	1.1	Bryant	

Assumptions: Background nitrate concentrations based on water quality data provided by the City.

Step 5: Calculate V_s (volume of septic effluent introduced beneath the leach field)

Block	# of bedrooms or residents per lot	gpd/lot	# of lots	available land (acres)	# of future lots	Vs (gpd)
Spur	2	280	45	14043.46	2809	799,033.8
Turner	2	280	199	11212.82	2243	683,638.1
Pope	2	280	235	279.31	56	81,441.2
Soldier	2	280	13	80.27	16	8,135.1
Simpson	2	280	22	432.64	87	30,387.6

Assumptions: 1. 280 gpd/lot based on two bedrooms per DEQ Ch. 25 septic guidelines

2. Future lots determined by calculating amount of vacant private property and dividing by rural residential zoning designation (1 lot/5 acres)

Step 6: Enter C_s (concentration of nitrate-nitrogen contained in the septic effluent)

What is the concentration of NO3- as N contained in the septic effluent?

Block	Cs (mg/L)
Spur	40
Turner	40
Pope	40
Soldier	40
Simpson	40

Assumptions: Assumed septic effluent nitrate concentration of 55 mg/L per Wenck's consultant report to Albany County (2019)

Step 7: Calculate V_p (volume of groundwater pumped by wells beneath the leach field)

Block	gpd/Lot	# of lots	# of future lots	Lawn Irr. (acres)	Same Aquifer? Y=1; N=0	Vp (gpd)
Spur	390	45	2809	0.5	1	-
Turner	390	199	2243	0.5	1	-
Pope	390	235	56	0.5	1	-
Soldier	390	13	16	0.5	1	-
Simpson	390	22	87	0.5	1	-

Note: Vp > 0 only if pumping from same aquifer zone as Vs receptor aquifer zone; otherwise Vp = 0

Assumptions: Vp assumed to be neglible due to assumed household water use only.

Step 8: Enter C_p (concentration of nitrate-nitrogen contained in the pumped groundwater)

What is the concentration of nitrate-nitrogen contained in the pumped groundwater?

Block	Cp (mg/L)	Well name
Spur	1.7	USGS 412332105321201
Turner	1.6	USGS 411727105305901
Pope	1.8	USGS 411638105314001
Soldier	1.6	Jensen
Simpson	1.6	Wohl

Assumptions: Water quality data sourced from the City and USGS' National Water Information System

Step 9, Model Results: Diluted concentration of nitrate-nitrogen leaving the leach field.

Co = VbCb + ViCi + VsCs - VpCp / (Vb + Vi + Vs – Vp)

Block	Co (mg/L)
Spur	14.60
Turner	17.15
Pope	5.21
Soldier	2.56
Simpson	3.52

Cumulative Nitrate Loading Analysis - Wehrmann Model
Casper Aquifer Protection Overlay Zone
Future Build-out Scenario -- Rural Residential Zoning Designation Using 55 mg/L Nitrate Septic Effluent Concentration

Step 1: Calculate Vb (Volume of groundwater entering the leach field from up gradient area)

Block	Area (ft^2)	K (ft/day)	dh/dx (ft/ft)	Vb (gpd)
Spur	9141012	9.8	0.02554931	-
Turner	5721276	9.8	0.069246083	-
Pope	4716644	9.8	0.051308363	-
Soldier	2940560	9.8	0.056574419	-
Simpson	2292640	9.8	0.052475074	-

K is the hydraulic conductivity of the aquifer
i is the hydraulic gradient
A is the area of the upgradient area in square feet

Assumptions: Vb equals zero due to the fact the eastern edge of each aquifer block is set at the unsaturated edge of the Casper Formation.

Step 2: Enter Cb (ambient concentration of nitrate-nitrogen)

What is the ambient concentration of NO3- as N contained in the groundwater entering the leach field?

Block	Cb (mg/L)	Well Name
Spur	1.4	Mathis #1
Turner	1.4	Peter
Pope	3	Klein
Soldier	3	Klein
Simpson	1.1	Bryant

Assumptions: Based on water quality data provided by the city (included in Appendix A)

Step 3: Calculate V_i (volume of precipitation infiltrating beneath the leach field)

Block	Area (ft^2)	Vi (gpd)
Spur	643287800	1,538,015.9
Turner	415005700	992,223.7
Pope	368655500	881,406.5
Soldier	229200500	547,988.0
Simpson	191675804	458,271.5

Assumptions: 1. Area measured using GIS to calculating square foot of each modeled aquifer block
2. Precipitation into the aquifer assumed to be 1.4 in/year (Lundy 1978)

Step 4: Enter C_i (concentration of nitrate-nitrogen contained in the infiltrating precipitation)

What is the concentration of nitrate-nitrogen contained in the infiltrating precipitation?

Block	Ci (mg/L)	Well Name	
Spur	1.4	Mathis #1	
Turner	1.4	Peter	
Pope	2		Klein data replaced with City of Laramie well data (Pope #2).
Soldier	2		Klein data replaced with City of Laramie well data (Pope #2).
Simpson	1.1	Bryant	

Assumptions: Background nitrate concentrations based on water quality data provided by the City.

Step 5: Calculate V_s (volume of septic effluent introduced beneath the leach field)

Block	# of bedrooms or residents per lot	gpd/lot	# of lots	available land (acres)	# of future lots	Vs (gpd)
Spur	2	280	45	14043.46	2809	799,033.8
Turner	2	280	199	11212.82	2243	683,638.1
Pope	2	280	235	279.31	56	81,441.2
Soldier	2	280	13	80.27	16	8,135.1
Simpson	2	280	22	432.64	87	30,387.6

Assumptions: 1. 280 gpd/lot based on two bedrooms per DEQ Ch. 25 septic guidelines

2. Future lots determined by calculating amount of vacant private property and dividing by rural residential zoning designation (1 lot/5 acres)

Step 6: Enter C_s (concentration of nitrate-nitrogen contained in the septic effluent)

What is the concentration of NO3- as N contained in the septic effluent?

Block	Cs (mg/L)
Spur	55
Turner	55
Pope	55
Soldier	55
Simpson	55

Assumptions: Assumed septic effluent nitrate concentration of 55 mg/L per Wenck's consultant report to Albany County (2019)

Step 7: Calculate V_p (volume of groundwater pumped by wells beneath the leach field)

Block	gpd/Lot	# of lots	# of future lots	Lawn Irr. (acres)	Same Aquifer? Y=1; N=0	Vp (gpd)
Spur	390	45	2809	0.5	1	-
Turner	390	199	2243	0.5	1	-
Pope	390	235	56	0.5	1	-
Soldier	390	13	16	0.5	1	-
Simpson	390	22	87	0.5	1	-

Note: Vp > 0 only if pumping from same aquifer zone as Vs receptor aquifer zone; otherwise Vp = 0

Assumptions: Vp assumed to be neglible due to assumed household water use only.

Step 8: Enter C_p (concentration of nitrate-nitrogen contained in the pumped groundwater)

What is the concentration of nitrate-nitrogen contained in the pumped groundwater?

Block	Cp (mg/L)	Well name
Spur	1.7	USGS 412332105321201
Turner	1.6	USGS 411727105305901
Pope	1.8	USGS 411638105314001
Soldier	1.6	Jensen
Simpson	1.6	Wohl

Assumptions: Water quality data sourced from the City and USGS' National Water Information System

Step 9, Model Results: Diluted concentration of nitrate-nitrogen leaving the leach field.

Co = VbCb + ViCi + VsCs - VpCp / (Vb + Vi + Vs – Vp)

Block	Co (mg/L)
Spur	19.73
Turner	23.27
Pope	6.48
Soldier	2.78
Simpson	4.45

APPENDIX B4 – FUTURE BUILDOUT – SMALL LOT RESIDENTIAL ZONING

Cumulative Nitrate Loading Analysis - Wehrmann Model
Casper Aquifer Protection Overlay Zone
Future Build-out Scenario -- Small Lot Residential Zoning Designation Using 40 mg/L Nitrate Septic Effluent Concentrat

Step 1: Calculate Vb (Volume of groundwater entering the leach field from up gradient area)

Block	Area (ft^{2})	K (ft/day)	dh/dx (ft/ft)	Vb (gpd)
Spur	9141012	9.8	0.02554931	-
Turner	5721276	9.8	0.069246083	-
Pope	4716644	9.8	0.051308363	-
Soldier	2940560	9.8	0.056574419	-
Simpson	2292640	9.8	0.052475074	-

K is the hydraulic conductivity of the aquifer
i is the hydraulic gradient
A is the area of the upgradient area in square feet

Assumptions: Vb equals zero due to the fact the eastern edge of each aquifer block is set at the unsaturated edge of the Casper Formation.

Step 2: Enter Cb (ambient concentration of nitrate-nitrogen)
What is the ambient concentration of NO3- as N contained in the groundwater entering the leach field?

Block	Cb (mg/L)	Well Name
Spur	1.4	Mathis #1
Turner	1.4	Peter
Pope	3	Klein
Soldier	3	Klein
Simpson	1.1	Bryant

Assumptions: Based on water quality data provided by the city (included in Appendix A)

Step 3: Calculate V_i (volume of precipitation infiltrating beneath the leach field)

Block	Area (ft^{2})	Vi (gpd)
Spur	643287800	1,538,015.9
Turner	415005700	992,223.7
Pope	368655500	881,406.5
Soldier	229200500	547,988.0
Simpson	191675804	458,271.5

Assumptions: 1. Area measured using GIS to calculating square foot of each modeled aquifer block
2. Precipitation into the aquifer assumed to be 1.4 in/year (Lundy 1978)

Step 4: Enter C_i (concentration of nitrate-nitrogen contained in the infiltrating precipitation)
What is the concentration of nitrate-nitrogen contained in the infiltrating precipitation?

Block	Ci (mg/L)		
Spur	1.4	Mathis #1	
Turner	1.4	Peter	
Pope	2		Klein data replaced with City of Laramie well data (Pope #2).
Soldier	2		Klein data replaced with City of Laramie well data (Pope #2).
Simpson	1.1	Bryant	

Assumptions: Background nitrate concentrations based on water quality data provided by the City.

Step 5: Calculate V_s (volume of septic effluent introduced beneath the leach field)

Block	# of bedrooms or residents per lot	gpd/lot	# of lots	available land (acres)	# of future lots	Vs (gpd)
Spur	2	280	45	14043.46	7022	1,978,684.4
Turner	2	280	199	11212.82	5606	1,625,515.3
Pope	2	280	235	279.31	140	104,903.1
Soldier	2	280	13	80.27	40	14,877.8
Simpson	2	280	22	432.64	216	66,728.9

Assumptions: 1. 280 gpd/lot based on two bedrooms per DEQ Ch. 25 septic guidelines
2. Future lots determined by calculating amount of vacant private property and dividing by urban residential zoning designation (1 lot/2 acres)

Step 6: Enter C_s (concentration of nitrate-nitrogen contained in the septic effluent)
What is the concentration of NO3- as N contained in the septic effluent?

Block	Cs (mg/L)
Spur	40
Turner	40
Pope	40
Soldier	40
Simpson	40

Assumptions: Assumed septic effluent nitrate concentration of 55 mg/L per Wenck's consultant report to Albany County (2019)

Step 7: Calculate V_p (volume of groundwater pumped by wells beneath the leach field)

Block	gpd/Lot	# of lots	# of future lots	Lawn Irr. (acres)	Same Aquifer? Y=1; N=0	Vp (gpd)
Spur	390	45	7022	0.5	1	-
Turner	390	199	5606	0.5	1	-
Pope	390	235	140	0.5	1	-
Soldier	390	13	40	0.5	1	-
Simpson	390	22	216	0.5	1	-

Note: Vp > 0 only if pumping from same aquifer zone as Vs receptor aquifer zone; otherwise Vp = 0

Assumptions: Vp assumed to be neglible due to assumed household water use only.

Step 8: Enter C_p (concentration of nitrate-nitrogen contained in the pumped groundwater)
What is the concentration of nitrate-nitrogen contained in the pumped groundwater?

Block	Cp (mg/L)	Well name
Spur	1.7	USGS 412332105321201
Turner	1.6	USGS 411727105305901
Pope	1.8	USGS 411638105314001
Soldier	1.6	Jensen
Simpson	1.6	Wohl

Assumptions: Water quality data sourced from the City and USGS' National Water Information System

Step 9, Model Results: Diluted concentration of nitrate-nitrogen leaving the leach field.
Co = VbCb + ViCi + VsCs - VpCp / (Vb + Vi + Vs – Vp)

Block	Co (mg/L)
Spur	23.12
Turner	25.37
Pope	6.04
Soldier	3.00
Simpson	6.04

Cumulative Nitrate Loading Analysis - Wehrmann Model
Casper Aquifer Protection Overlay Zone
Future Build-out Scenario -- Small Lot Residential Zoning Designation Using 55 mg/L Nitrate Septic Effluent Concentrat

Step 1: Calculate Vb (Volume of groundwater entering the leach field from up gradient area)

Block	Area (ft^2)	K (ft/day)	dh/dx (ft/ft)	Vb (gpd)
Spur	9141012	9.8	0.02554931	-
Turner	5721276	9.8	0.069246083	-
Pope	4716644	9.8	0.051308363	-
Soldier	2940560	9.8	0.056574419	-
Simpson	2292640	9.8	0.052475074	-

K is the hydraulic conductivity of the aquifer
i is the hydraulic gradient
A is the area of the upgradient area in square feet

Assumptions: Vb equals zero due to the fact the eastern edge of each aquifer block is set at the unsaturated edge of the Casper Formation.

Step 2: Enter Cb (ambient concentration of nitrate-nitrogen)

What is the ambient concentration of NO3- as N contained in the groundwater entering the leach field?

Block	Cb (mg/L)	Well Name
Spur	1.4	Mathis #1
Turner	1.4	Peter
Pope	3	Klein
Soldier	3	Klein
Simpson	1.1	Bryant

Assumptions: Based on water quality data provided by the city (included in Appendix A)

Step 3: Calculate V_i (volume of precipitation infiltrating beneath the leach field)

Block	Area (ft^2)	Vi (gpd)
Spur	643287800	1,538,015.9
Turner	415005700	992,223.7
Pope	368655500	881,406.5
Soldier	229200500	547,988.0
Simpson	191675804	458,271.5

Assumptions: 1. Area measured using GIS to calculating square foot of each modeled aquifer block
2. Precipitation into the aquifer assumed to be 1.4 in/year (Lundy 1978)

Step 4: Enter C_i (concentration of nitrate-nitrogen contained in the infiltrating precipitation)

What is the concentration of nitrate-nitrogen contained in the infiltrating precipitation?

Block	Ci (mg/L)		
Spur	1.4	Mathis #1	
Turner	1.4	Peter	
Pope	2		Klein data replaced with City of Laramie well data (Pope #2).
Soldier	2		Klein data replaced with City of Laramie well data (Pope #2).
Simpson	1.1	Bryant	

Assumptions: Background nitrate concentrations based on water quality data provided by the City.

Step 5: Calculate V_s (volume of septic effluent introduced beneath the leach field)

Block	# of bedrooms or residents per lot	gpd/lot	# of lots	available land (acres)	# of future lots	Vs (gpd)
Spur	2	280	45	14043.46	7022	1,978,684.4
Turner	2	280	199	11212.82	5606	1,625,515.3
Pope	2	280	235	279.31	140	104,903.1
Soldier	2	280	13	80.27	40	14,877.8
Simpson	2	280	22	432.64	216	66,728.9

Assumptions: 1. 280 gpd/lot based on two bedrooms per DEQ Ch. 25 septic guidelines

2. Future lots determined by calculating amount of vacant private property and dividing by urban residential zoning designation (1 lot/2 acres)

Step 6: Enter C_s (concentration of nitrate-nitrogen contained in the septic effluent)

What is the concentration of NO3- as N contained in the septic effluent?

Block	Cs (mg/L)
Spur	55
Turner	55
Pope	55
Soldier	55
Simpson	55

Assumptions: Assumed septic effluent nitrate concentration of 55 mg/L per Wenck's consultant report to Albany County (2019)

Step 7: Calculate V_p (volume of groundwater pumped by wells beneath the leach field)

Block	gpd/Lot	# of lots	# of future lots	Lawn Irr. (acres)	Same Aquifer? Y=1; N=0	Vp (gpd)
Spur	390	45	7022	0.5	1	-
Turner	390	199	5606	0.5	1	-
Pope	390	235	140	0.5	1	-
Soldier	390	13	40	0.5	1	-
Simpson	390	22	216	0.5	1	-

Note: Vp > 0 only if pumping from same aquifer zone as Vs receptor aquifer zone; otherwise Vp = 0

Assumptions: Vp assumed to be neglible due to assumed household water use only.

Step 8: Enter C_p (concentration of nitrate-nitrogen contained in the pumped groundwater)

What is the concentration of nitrate-nitrogen contained in the pumped groundwater?

Block	Cp (mg/L)	Well name
Spur	1.7	USGS 412332105321201
Turner	1.6	USGS 411727105305901
Pope	1.8	USGS 411638105314001
Soldier	1.6	Jensen
Simpson	1.6	Wohl

Assumptions: Water quality data sourced from the City and USGS' National Water Information System

Step 9, Model Results: Diluted concentration of nitrate-nitrogen leaving the leach field.

Co = VbCb + ViCi + VsCs - VpCp / (Vb + Vi + Vs – Vp)

Block	Co (mg/L)
Spur	31.56
Turner	34.68
Pope	7.64
Soldier	3.40
Simpson	7.95