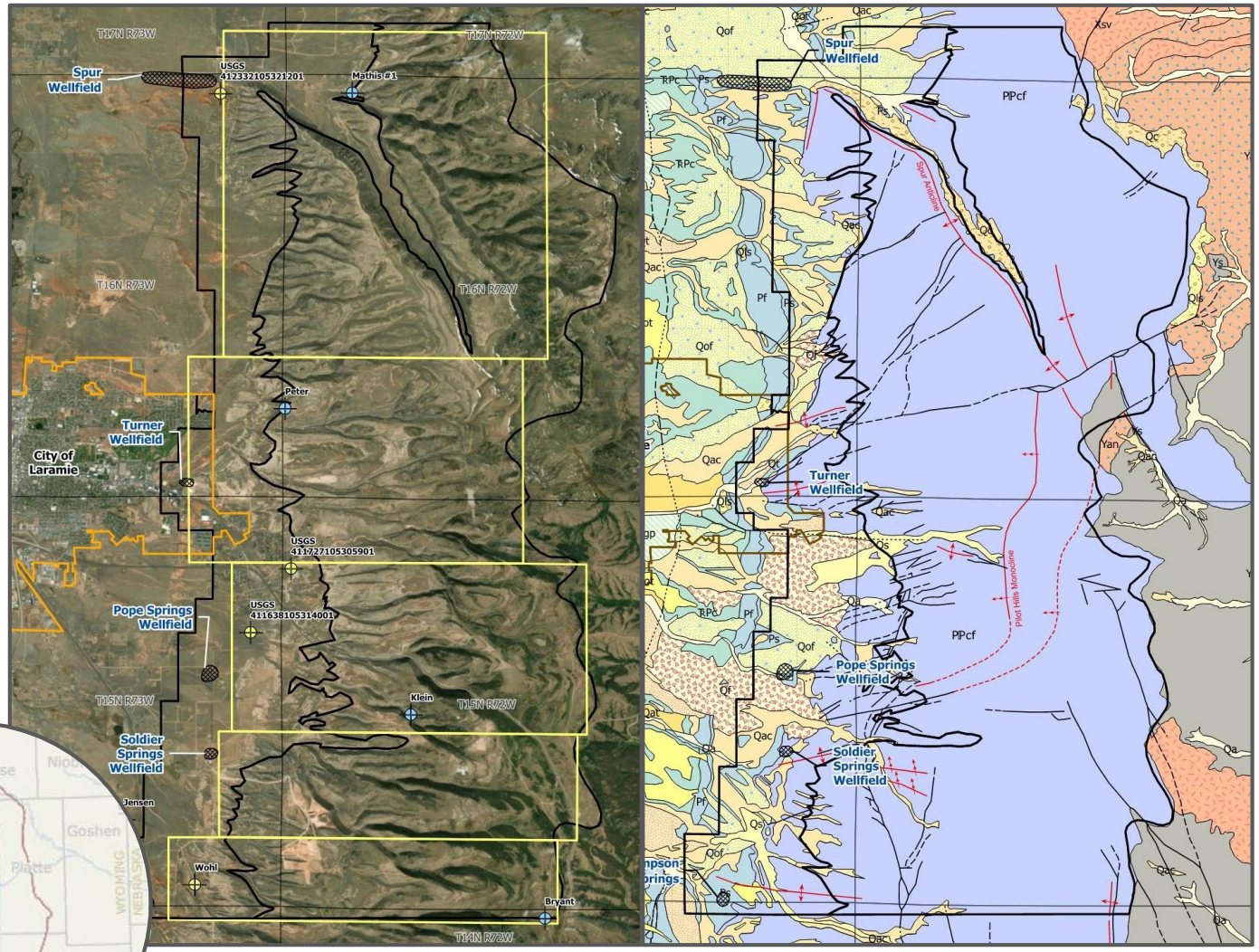
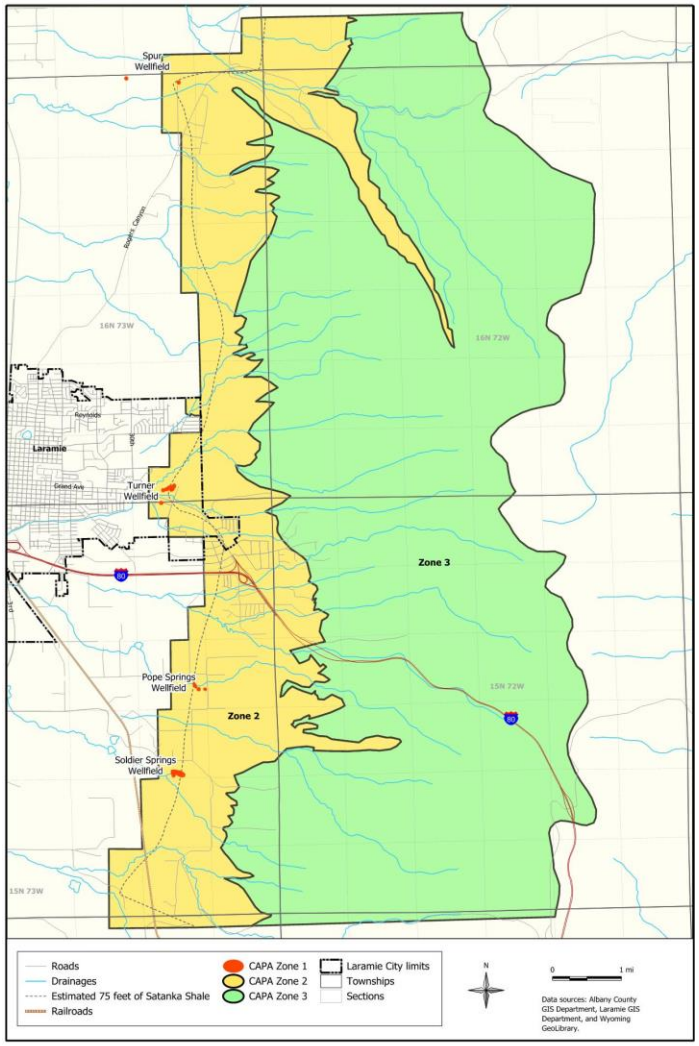


CASPER AQUIFER NITRATE LOADING STUDY
LARAMIE, WYOMING

WENCK

Nov 2020

PROJECT AREA



Attachment A. Casper Aquifer Protection Area (CAPA) boundaries and zones.

Casper Aquifer Protection Overlay Zone (APOZ)

- East of Laramie, extends eastwards to the crest of the Laramie Range
- Covers 6 miles north and 6 miles south of Laramie city limits
- 79 Square Miles

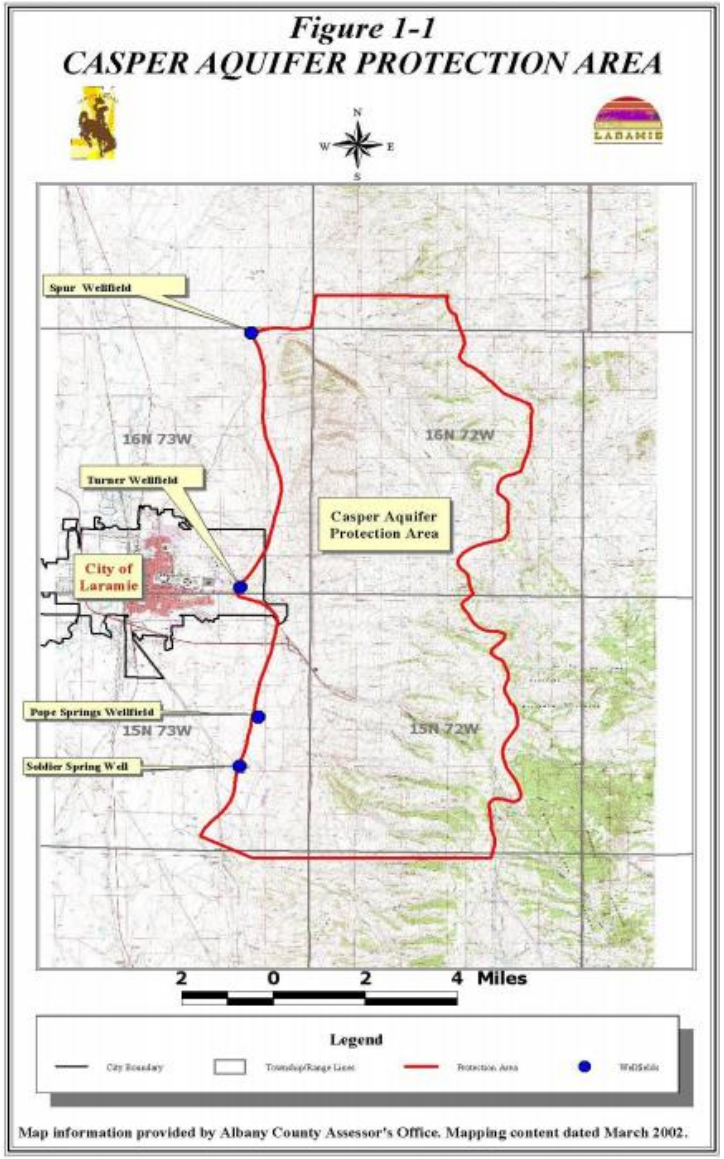
Positioned on top of the Casper Aquifer

- The Aquifer supplies approximately 50 to 60% of the City's water supply
- 100% of approximately 450 rural residences in Albany County

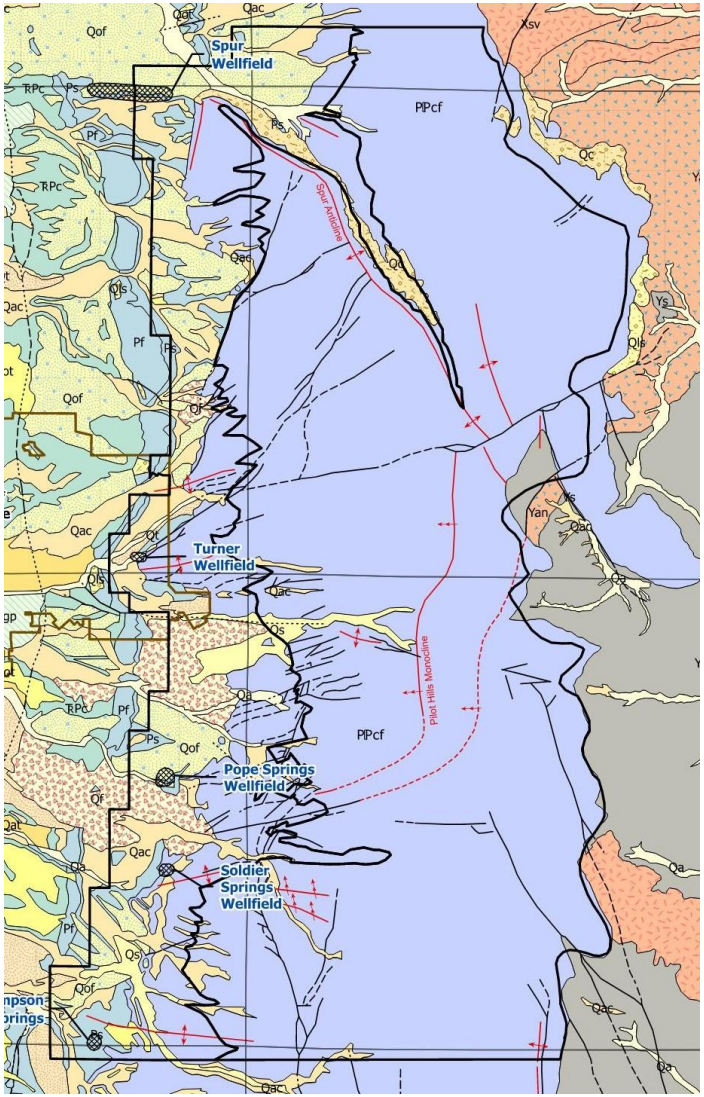
STUDY PURPOSE

The goal of this study was to investigate the potential nitrate loading effects due to both current and future development in the APOZ.

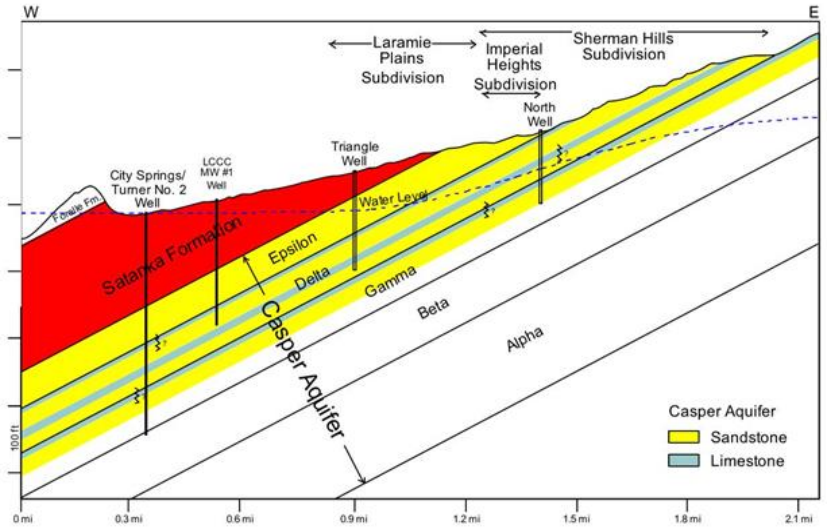
- What nitrate concentrations currently exist in groundwater within the APOZ?
- What nitrate concentrations could be anticipated in groundwater assuming several potential development scenarios?



GEOLOGIC SETTING



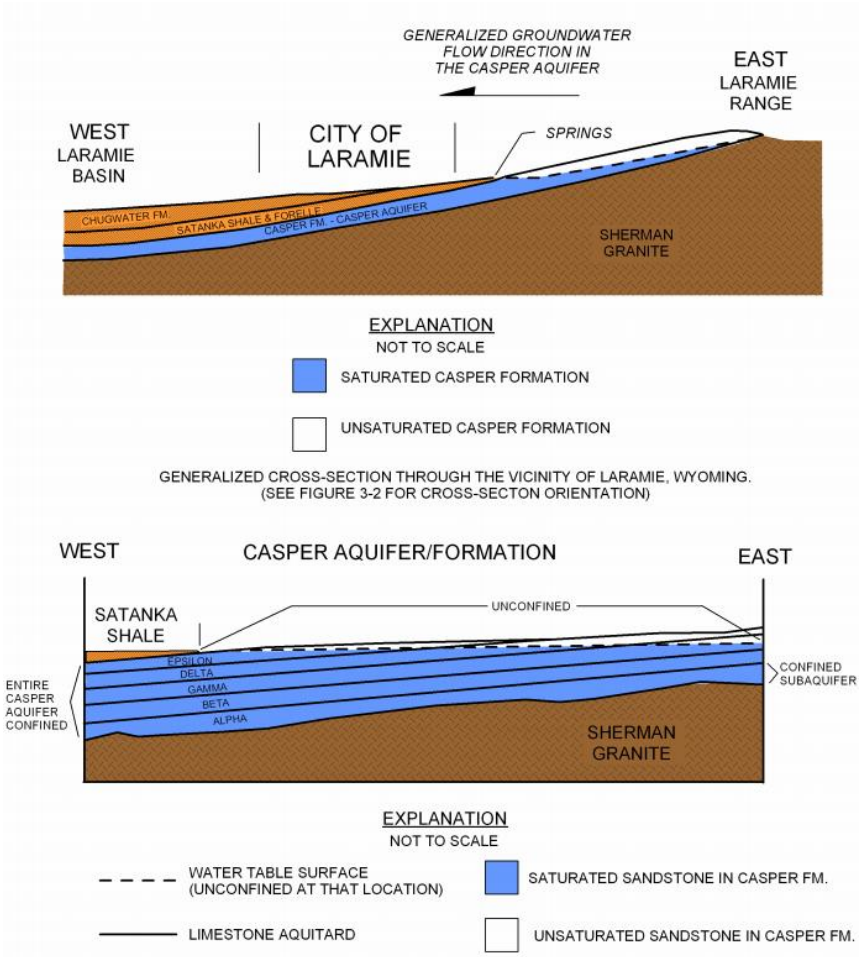
- APOZ located along the eastern margin of the Laramie Basin and western flank of the Laramie Range
- **<u>Casper Formation</u>** was deposited upon the **<u>Sherman Granite</u>**, uplifted during the Laramide Orogeny, and exposed through erosion
  - Approximately 750 feet of interbedded sandstones, limestones, and minor amounts of shale
  - 5 members of limestone and sandstone layers: Alpha, Beta, Gamma, Delta & Epsilon
- **<u>Satanka Shale</u>** unconformably overlies the Casper Formation



HYDROGEOLOGIC CONDITIONS

The Casper Aquifer is the primary source of potable water for the City's wells and springs

- The Casper Aquifer extends 21 miles south of the Colorado border and 50 miles north-northwest of Laramie
- Saturated thickness varies from zero feet along the Laramie Range to 712 feet immediately west of the Casper-Satanka contact
  - Confined by the overlying Satanka Shale and underlying Sherman Granite
- Groundwater flow occurs through porous sandstone or fractured sandstone and limestone
  - Groundwater flow is generally westward from the Laramie Range towards the Laramie Basin



WATER QUALITY MODELING

- Wenck completed a modeling study with no fieldwork to estimate nitrate loading under current and various development scenarios including cumulative impact
- Downgradient changes in nitrate concentrations were evaluated using the **Wehrmann Model**, a mass balance equation

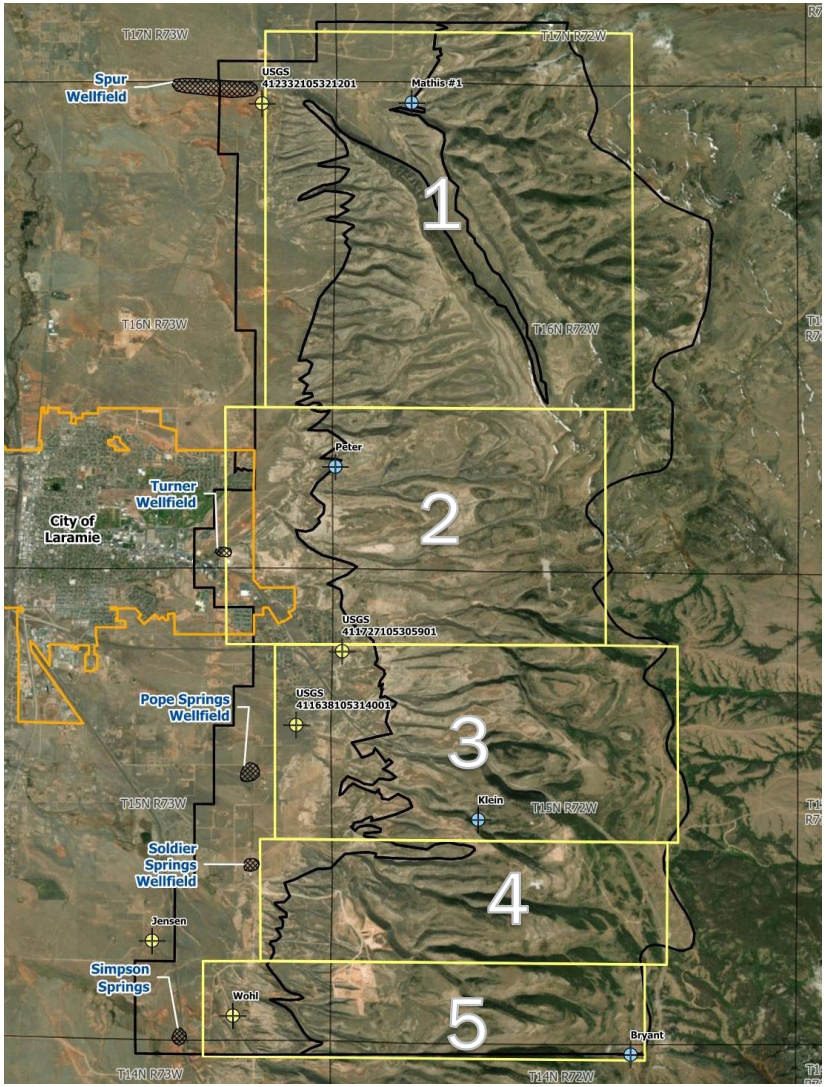
$$C_o = V_b C_b + V_i C_i + V_s C_s - V_p C_p / (V_b + V_i + V_s - V_p)$$

Where:

C_o = diluted concentration of NO_3^- as N leaving the subdivision
V_b = volume of ground water entering the subdivision from upgradient area
C_b = ambient concentration of NO_3^- as N contained in the ground water entering the subdivision
V_i = volume of precipitation infiltrating beneath the subdivision
C_i = concentration of NO_3^- as N contained in the infiltrating precipitation
V_s = volume of septic effluent introduced beneath the subdivision
C_s = concentration of NO_3^- as N contained in the septic effluent (assume 40 mg/L for conventional septic systems, and manufacturer specifications (mg/L) for enhanced treatment systems)
V_p = volume of ground water pumped by wells beneath the subdivision (use only if same aquifer as V_s)
C_p = concentration of nitrate-nitrogen contained in the pumped ground water

MODELED APOZ WELLFIELD AND SPRING BLOCKS

- The APOZ was separated into five modeled aquifer blocks
  - Each block corresponded to a wellfield or spring sourced by the Casper Aquifer which serves the City's water needs
  - Dividing the APOZ allowed for better local estimation of nitrate concentrations
- From the north end to the south, the five aquifer blocks correspond with the following features:
  - (1) Spur Wellfield, (2) Turner Wellfield, (3) Pope Springs Wellfield, (4) Soldier Springs Wellfield, and (5) Simpson Springs



CURRENT NITRATE CONCENTRATIONS

- Using the same five aquifer blocks, current nitrate concentrations were determined by analyzing water quality data from the City's wells and springs
- **Upgradient nitrate concentrations** were used to estimate ambient concentrations introduced through precipitation
- **Downgradient concentrations** were used to represent the concentration of nitrate contained in pumped groundwater

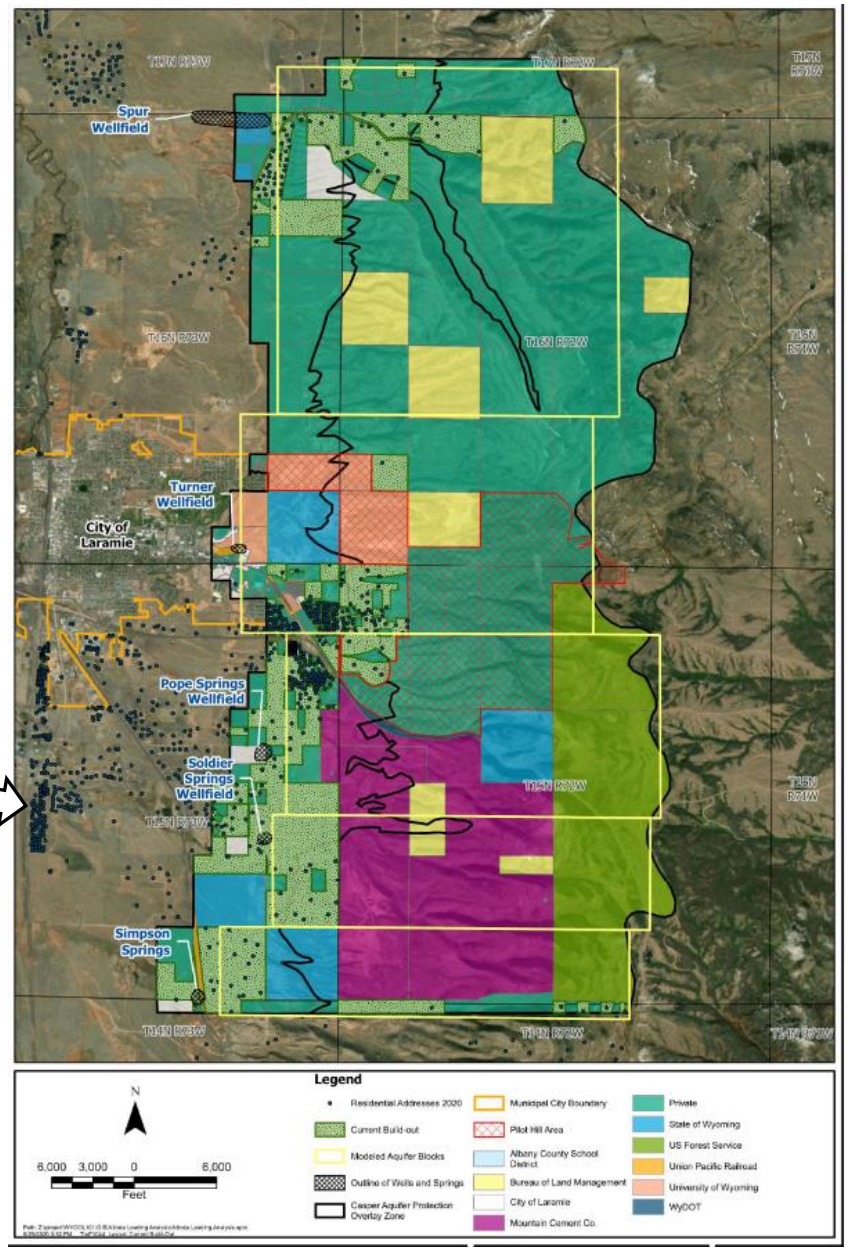
Table 1: Upgradient versus Downgradient Nitrate Concentrations

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.

CURRENT NITRATE CONCENTRATIONS

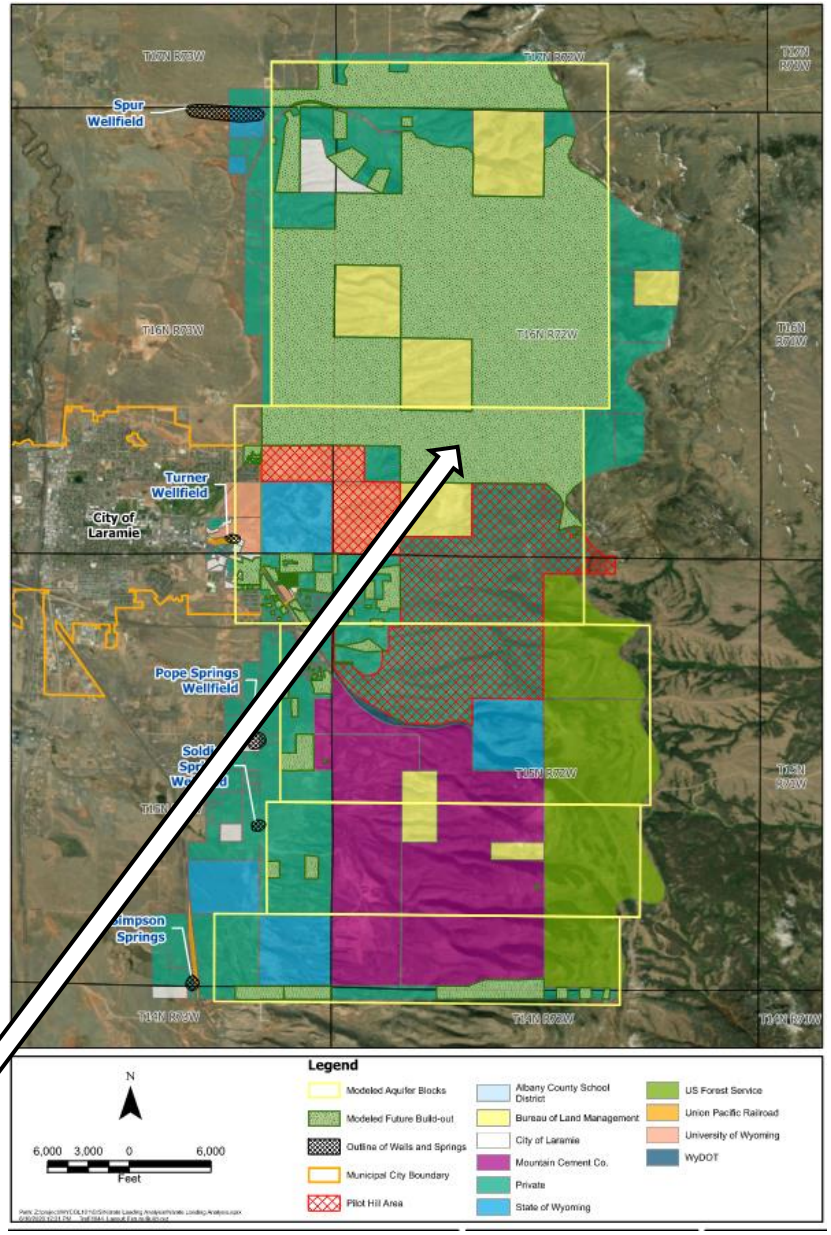
- **To determine the number of current lots, GIS was used to tally the number of registered addresses in the APOZ as of 2020**
- **Each dot corresponds with a registered address**



FUTURE BUILD-OUT SCENARIOS

- To estimate the number of lots available under future build-out scenarios, land was marked **developable or undevelopable** according to zoning designations
  - Land considered **undevelopable** was excluded from the model and included land owned by BLM, the City of Laramie, Mountain Cement Company, 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 also excluded

Developable land is marked in light green



FUTURE BUILD-OUT SCENARIOS

Three housing densities were evaluated:

Small Lot Residential Zoning	Rural Residential Zoning	Agricultural Zoning
2-acre lots	5-acre lots	35-acre lots

CURRENT VERSUS FUTURE BUILT-OUT LOT RESULTS

- The number of lots considered for current and future build-out scenarios, separated by modeled aquifer blocks is summarized in the table below:

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 the current build-out modeling efforts are compared against actual nitrate concentrations measured at the City's wellfields and springs

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.

WATER QUALITY MODELING RESULTS

- Wenck modeled three **future build-out scenarios** using Albany County Zoning Designations to estimate the potential cumulative nitrate loading affect to the Casper Aquifer
- Assumes all lots had been built upon and does not consider variations in growth

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.							

CONCLUSIONS

- Under **current build-out conditions**, nitrate concentrations in each of the five modeled aquifer blocks of the Casper Aquifer are anticipated to remain below 5 mg/L. Nitrate concentrations with no further buildout are anticipated to remain within US EPA MCL Drinking Water Standards.

- Modeling of current conditions yielded similar nitrate water quality concentrations as exhibited downgradient at the current wellfields.

- **Future built-out** modeling under agricultural zoning suggests that development of the APOZ under a 35-acre lot spacing would have a limited impact on the aquifer.

CONCLUSIONS

- **Future build-out** modeling scenarios indicate Pope Springs, Soldier Springs, and Simpson Springs aquifer blocks are likely to see nitrate concentrations rise, but remain below 10 mg/L due to limited developable land.

- Rural residential zoning and development of the Spur and Turner Wellfield blocks would result in elevated nitrate concentrations that exceed 10 mg/L.

- Both the Turner and Spur wellfields could be adversely impacted if small lot residential spacings were extended through the developable lands in these areas. Nitrate concentrations would be expected to exceed 10 mg/L.

WENCK

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