Groundwater Technical Memorandum No. 3
2015 Laramie Master Plan, Level I – Appendix 430

TO: Wyoming Water Development Commission — Date: November 30, 2015
City of Laramie
WWC Engineering

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GROUNDWATER QUALITY, PROTECTION, AND MONITORING

This technical memorandum is the third of a series of four regarding the groundwater supply of the City of Laramie. This memorandum addresses specifically the water quality and City programs designed to protect and monitor the Casper Aquifer. References cited in this technical memorandum are listed in the "References" chapter of the main report.

I. Groundwater Quality Characteristics and Treatment

A groundwater source has five chemical characteristics that affect its use as a municipal water supply. First, the basic water chemistry defined by the pH and major cations/anions will determine the water's taste, reactivity to infrastructure (i.e. corrosive or incrusting), and general effect on human health. For example, high concentrations of total dissolved solids (i.e. the sum of cations and anions) or sulfate will affect taste and excessive amounts of sodium may cause hypertension. Second, trace metals such as arsenic and selenium at certain concentrations can cause acute or chronic health effects. Third, radionuclides such as uranium, gross alpha, and radium can cause acute or chronic health effects. Fourth, if the groundwater is in intimate contact with surface water or human/animal waste, the groundwater may have biological contaminants such as fecal coliform, giardia, and cryptosporidium and elevated concentrations of inorganic contaminants such as nitrate. Alternately, the groundwater may have a native population of bacteria (iron or sulfur-reducing) that can affect water taste and biofoul system infrastructure. Fifth, man-made volatile and semi-volatile compounds (e.g. herbicides, pesticides, and solvents) can seriously contaminate an aquifer at very low concentrations. In essence, there is a long list of chemical attributes required of a municipal-grade groundwater supply.

Table TM 3-1 lists Casper Aquifer water quality data from the City's municipal wells. The data define the general groundwater chemistry from the Casper as illustrated by major cations/anions, total dissolved solids, and selected parameters such as fluoride, iron, uranium, and radionuclides. These selected parameters are well below Maximum Contaminant Levels (MCLs) established by the Environmental Protection Agency (EPA) for a public water supply. What is equally important are the regulated parameters not listed in the table that are also well below (or non-detect) the drinking water MCL. For example, selenium, arsenic, volatile and semi-volatile compounds, and biological contaminants are either non-detect or at concentrations well below regulatory standards.

The major cation/anion chemistry of the Casper Aquifer produces water with a pleasant taste and appearance, and is not corrosive to water system infrastructure. The groundwater temperature is approximately 46.5º F; not too warm, not too cold. The groundwater is saturated with respect to calcium carbonate; and consequently, a layer of calcium carbonate forms on the interior of well casing and infrastructure piping which serves to reduce the corrosion of metal. There is no evidence of significant biofouling (i.e. iron bacteria) at the Pope, Turner, Spur, or Soldier supply wells after upwards of 78 years of service. The groundwater chemistry is conducive (i.e. no adverse chemical reactions) to blending with surface water in the storage tanks and distribution system.

Casper groundwater is classified as calcium-magnesium-bicarbonate type water. The one disagreeable aspect of the groundwater quality is that, due to the high combined calcium and magnesium concentrations, the water is very hard. Calcium carbonate deposits will form on household plumbing fixtures and water customers that prefer soft water for domestic use have in-house water softeners.

Casper Aquifer water quality is excellent for reasons associated with the hydrogeology, mineralogy, and Laramie's proximity to the recharge area. Primary reasons for the excellent water quality are listed below.

- Benign chemical reactions between infiltrated precipitation and the carbonate limestone and quartz-rich sandstone of the formation
- An active and short-path groundwater flow system between the recharge area on the west flank of the Laramie Range and the springs and wells (Spur, City, Pope, and Soldier) at the base of the range
- A low level of land-use development on the recharge area

A groundwater supply does not require treatment (e.g. chlorination, filtration, aeration, blending) unless an individual constituent exceeds an MCL established by the EPA. When a constituent in groundwater consistently exceeds an MCL, the groundwater will need to be treated to comply with drinking water standards. As water quality regulations have expanded and changed through the years, it is increasingly difficult for groundwater sources to comply with the MCLs for natural and man-made constituents. However, the Casper Aquifer in the vicinity of Laramie is a rare exception to this reality. The exceptional groundwater quality of the Casper Aquifer in the vicinity of Laramie and its current compliance with EPA drinking water standards is another characteristic that makes this a unique and valuable resource.

As a result of the outstanding groundwater quality and current drinking water regulations, the City is not required by the EPA to treat groundwater from the Casper Aquifer. However, per standard minimum water treatment for large municipal systems, the City chlorinates (i.e. disinfection) and fluoridates the groundwater at the Wye (Soldier and Pope wells), City Springs (Turner wells), and the Spur (Spur wells). The purpose of chlorination in this case is to maintain a residual concentration in the transmission and distribution system rather than to kill bacteria in the source water. Disinfection by-products generated by chlorination are not a problem because of the low concentration of total organic carbon in the groundwater.

Later in this memorandum there is a discussion of the nature and causes of elevated nitrate concentrations from county subdivisions along East Grand Avenue. This condition occurs southeast of the Turner Wellfield, beneath the county subdivisions, and has been documented by water sampling performed by the City (with additional data analyses by WWC Engineering, 2013) and by a recent water quality/hydrogeologic investigation by Hinckley Consulting and Wyoming Groundwater (2015). Although elevated nitrate concentrations on the order of 4 to 8 mg/l occur within City limits in an area contributory to the Turner Wellfield, the dilution of groundwater with elevated nitrate concentrations by groundwater with a much lower nitrate concentration produces a nitrate concentration in groundwater pumped from the Turner wells that is approximately 2 mg/l. The resulting concentration of 2 mg/l is significantly less than the MCL of 10 mg/l for nitrate.

II. Ground Water Under the Direct Influence of Surface Water

Every 3 to 5 years the EPA performs a sanitary survey that evaluates the water supply system including source, storage, distribution, and treatment infrastructure. The sanitary survey usually includes a field evaluation of whether the City's groundwater collection facilities at the Spur, Turner, Pope, and Soldier wellfields are potentially influenced by surface water. This evaluation is referred to as Groundwater Under the Direct Influence of Surface Water (GWUDISW) and the results of the evaluation have significant consequence regarding groundwater treatment. If the EPA designates a groundwater source as GWUDISW, then the source is considered to be surface water and must comply with the Surface Water Treatment Rule per the Safe Drinking Water Act. Groundwater designed as GWUDISW would have to be treated and disinfected to surface water standards, at considerable cost.

The sanitary survey performed in September 2012 provided relatively minor recommendations for facility maintenance and improvements, but no significant system deficiencies were identified. A GWUDISW evaluation was not performed during the 2012 sanitary survey. A sanitary survey and GWUDISW evaluation was performed in August 2015; however, as of this writing, the survey report from the EPA has not been submitted to the City.

GWUDISW Evaluation Process

EPA personnel inspect each wellfield using a field evaluation form that assigns a numerical score to each wellfield. The evaluation form is included as Attachment 1 and consists of four elements with point values that are combined for a total score.

- Type of subsurface water source (e.g. well, spring, or infiltration gallery)
- Historical microbiological contamination (e.g. documented violations)
- Hydrological features
- Structural features (e.g. well or springbox construction and conditions)

A total point score of greater than or equal to 40 indicates that the groundwater source may be GWUDISW and that additional assessment is needed. Additional assessment used by the EPA involves a water sampling program using Microscopic Particulate Analysis (MPA) to document the presence or absence of bio-indicators of surface water influence. Each MPA sample receives a score based on a consensus method (EPA, 1992), and a relative risk (i.e. low, moderate, or high) of surface water contamination is assigned to the sample. In general, if MPA samples indicate a high risk, the groundwater source will likely be designated GWUDISW; a moderate risk may require additional sampling, indicator parameters, and analysis; and low risk designates the source as not GWUDISW.

GWUDISW Study at Soldier Spring

In February 1995, based on the results of a sanitary survey and field evaluation, the EPA notified the City that the Soldier Spring source was GWUDISW. At that time, groundwater from Soldier Spring was obtained from a cistern that was surrounded by cottonwood trees and large root masses could be seen in the water column of the cistern. EPA's water quality concerns were based on facility construction inadequacies and the potential to compromise water quality. The City and EPA designed a groundwater sampling program to assess whether Soldier Spring was GWUDISW. As part of the approved sampling program, five monitoring wells were installed in the Casper Aquifer at Soldier Spring (see Figure TM 1-2). Water quality data were collected from November 1995 to June 1996, and consisted of MPA, total coliform, temperature, conductivity, and particle counts (Table TM 3-2). Based on the results, the City concluded that Soldier Spring was not GWUDISW (City of Laramie, 1996).

Regardless of the designation, the City recognized the problems associated with the cistern, and in 1998 the cistern was plugged and replaced with a production well, Soldier No. 1, located 450 feet west of the cistern.

Current and Future Assessment of GWUDISW at Municipal Wellfields

From 1996 to 2014, the EPA has relied on the Soldier Spring GWUDISW assessment and did not perform a GWUDISW assessment at the City wellfields during this time period. A GWUDISW assessment of the City wellfields was performed during the recent sanitary survey in August 2015. As the date of this writing, the August 2015 GWUDISW assessment has not been submitted to the City.

As a general indication of what to expect from a GWUDISW assessment by the EPA, the following is an estimate of the total point score at the City supply wells based on well construction, water collection facilities, and hydrological features.

- Spur wells: 15 points
- Turner wells: 15 points
- Pope wells: 15 points
- Soldier No. 1: 20 points

The point total is derived primarily from the fact that the Casper Aquifer is fractured (i.e. 15 points) and these points cannot be avoided. Soldier No. 1 may receive an additional 5 points because the top of the well screen is at 44 feet, slightly less than the no point cut-off of 50 feet of casing. These scores are much less than the 40 point threshold that would trigger further investigation of GWUDISW. However, due to the uncertain evolution of EPA's implementation of the GWUDISW concept and interpretation of field conditions, the City has no guarantee regarding how the wells and wellfields will be evaluated and designated in the future.

On a regional level, the Casper Aquifer is not GWUDISW. The recharge area does not have perennial streams or surface water reservoirs. In the recharge area, the Casper is a combination of water table, semi-confined, and confined aquifer conditions, and is not hydraulically connected to a shallow alluvial aquifer system. Livestock and native wildlife activity as it relates to a volume of fecal matter deposited on the recharge area is low. Although the Casper Aquifer has excellent recharge characteristics, this should not designate a groundwater source as GWUDISW. GWUDISW is not an issue in the area west of the recharge area where the Satanka Shale overlies and confines the Casper Aquifer.

GWUDISW Issues at City Springs and Soldier Spring

The opportunity for GWUDISW issues to arise is due to the wellfields being located near active springs. For example, the Turner No. 2 and Soldier No. 1 wells are located in the vicinity of City and Soldier springs, respectively. When these wells are pumped, the flow from the springs are reduced or eliminated. When the spring discharge is eliminated entirely by pumping, there is the opportunity for surface water to be drawn downward back into the aquifer and towards the pumping well.

At Soldier Spring, the Soldier No. 1 pump is rarely used and when the well is pumped at maximum capacity, the spring reportedly continues to flow. The continuous discharge of the spring during non-pumping and pumping operation of Soldier No. 1 indicates that a vertical upward flow of water from the aquifer to the surface is maintained. Groundwater discharged to the surface at the spring does not flow back into the aquifer and, consequently, GWUDISW issues at Soldier No. 1 are unlikely.

At City Springs, however, groundwater discharge occasionally occurs at the east end and low-lying areas of the enclosure (see Figure TM 1-4). Extended operation of either or both of the

Turner wells will eliminate groundwater discharge to the surface within the enclosure as indicated by the elimination of discharge from the pipe-springbox collection system outlet pipe (see Technical Memorandum No. 1). It is reasonable to infer that surface water in the enclosure area is occasionally being drawn downward back into the aquifer by the decline in head caused by pumping the Turner wells. This situation indicates both a potential risk to biological contamination and the future possibility of EPA requiring additional testing to evaluate GWUDISW at City Springs. As discussed in Technical Memorandum No. 4, Turner Wellfield operation and well improvements should be directed towards eliminating the surface discharge of groundwater within the City Springs enclosure.

MPA samples collected from the Turner wells in 1994 were classified as low risk of surface water contamination (Table TM 3-2). Regardless, it is recommended that the City periodically conduct additional analysis of groundwater samples from Turner No. 2 to evaluate the potential for biological contamination. Analyses may include, at a minimum, fecal coliform and MPA. These analyses will allow the City to respond to any water quality issues and may provide the data needed to support the contention that the Turner Wellfield is not GWUDISW.

GWUDISW Issues at Pope Springs

There are no ephemeral or intermittent surface water drainages in the immediate vicinity of the Pope wells, so it is unlikely that there are any GWUDISW issues with the Pope Wellfield. However, standing water occasionally occurs in the old reservoir (see Figure TM 1-3) located approximately 410 feet east of the Pope No. 4 well (Mike Lytle, pers. comm., 8/8/15). The occurrence and response of the water in the reservoir to pumping of the Pope wells may deserve further documentation and evaluation.

GWUDISW Summary

Based on the current GWUDISW evaluation process used by EPA, estimated total points, existing water quality data, and hydrogeology it is unlikely that the EPA will designate groundwater from the Spur, Pope, or Soldier wellfields as GWUDISW. The Turner Wellfield, however, may be vulnerable to a GWUDISW designation. The results of the August 2015 assessment will provide guidance regarding how the EPA is currently interpreting GWUDISW assessments.

A consideration in these types of assessments may be that the City has proactively developed a Casper Aquifer Protection Program and a Casper Aquifer Monitoring Program designed to ensure continued safe and high quality groundwater from the Casper Aquifer for use as a municipal water supply.

III. Casper Aquifer Protection Program

Much of the discussion to follow is drawn directly or summarized from the 2015 Laramie

Monitor Well Project Phase II report (Hinckley Consulting and Wyoming Groundwater, 2015) prepared for the City of Laramie. Readers are referred to that document for a detailed overview of the Casper Aquifer Protection Program.

History and Execution of Casper Aquifer Protection Efforts

The 1986 amendments to the Safe Drinking Water Act established the Wellhead Protection Program (WHPP) with the objective to prevent the contamination of groundwater resources that supply public drinking water. As part of a grant from the EPA, in 1993 the City began the WHPP process by delineating the wellhead protection area (WWC, 1993b). Following general EPA guidelines and supplemented by aquifer tests, the 1993 report focused on groundwater travel times to specific municipal supply wells or wellfields. The report focused strongly on the role of faults as avenues of enhanced permeability guiding groundwater to the natural discharge areas (i.e. springs) where municipal wells are located.

In the late 1990s, the focus of groundwater resource protection shifted from wellhead/wellfield protection to a more comprehensive view of the aquifer including recharge areas, groundwater flows, and identified/potential sources of contamination. A broad-based group of citizens and local hydrogeologists (i.e. technical review committee) began creation of a Casper Aquifer Protection Plan (CAPP), the first version of which was finalized in 2002.

The 2002 CAPP included theoretical calculations that suggested groundwater nitrate levels were likely to exceed the EPA Primary Drinking Water MCL of 10 mg/l in the oldest of the subdivisions along East Grand Avenue that still has individual septic systems (Plate I). However, there were no systematic measurements of groundwater quality from the aquifer available to directly address contamination concerns. Although there are many potential groundwater contaminants associated with septic systems, nitrate is the most common indicator due its ease of measurement and high concentration in septic system effluent relative to the low natural background nitrate concentration.

When the CAPP was updated in 2008 (Wittman Hydro Planning Associates, 2008) the Contaminant Management Plan section noted:

"To date, there has not been a systematic, aquifer-wide, long-term groundwater monitoring program to assess water quality in the Casper Aquifer." (p. 91)

and concluded:

"It is recommended that the City and County develop a program to routinely collect groundwater samples and water levels throughout the Casper Aquifer Protection Area to establish baseline water quality data and to evaluate changes in groundwater quality over time. The baseline data collected from this program should be used to set standards for quantifying contamination in the Casper Aquifer. A systematic monitoring program has a secondary benefit of increasing understanding of the Casper Aquifer. The City of Laramie should continue to evaluate water-quality at the City wells in the current manner of comparing current results to historical concentrations and initiating additional sampling when results show increased concentrations."

The 2008 CAPP identified specific locations for monitor well construction, and recommended that "establishing a routine groundwater monitoring program be one of the City of Laramie's highest priorities for implementation."

The 2008 CAPP was followed by implementing regulation: Section 15.08.040.A of the Laramie Unified Development Code. That ordinance includes the geographic extent of the Casper Aquifer Protection Overlay, the limitations on land use within that area, and a requirement for Site Specific Investigations (SSI) for proposed development within the protection area.

Although begun as a joint project between the City of Laramie and Albany County, the 2008 CAPP update was ultimately completed as a City-only document. Draft recommendations to bring sewer lines into the rural subdivisions along East Grand Avenue to eliminate the ongoing impact of individual septic systems on groundwater quality generated considerable alarm from some subdivision residents. Although those recommendations were subsequently dropped, the County embarked on its own update, producing a separate Albany County Casper Aquifer Protection Plan in 2011. Unless otherwise noted, the "CAPP" referred throughout these technical memoranda is the 2008 City of Laramie CAPP.

Only one of the three municipal wellfields is located within the City of Laramie and because almost the entirety of the Casper Aquifer recharge area is located outside city boundaries, Albany County regulations for aquifer protection are clearly the more important with respect to the city and county groundwater supply.

In a July 20, 2012, letter to the Albany County Commissioners, the City of Laramie expressed the concerns with the pending County regulations implementing the CAPP, highlighting the "major differences" between the City and County regulations to include the following.

- The County definition of the "development" triggering evaluation for aquifer protection is ambiguous.

- The west boundary of the County area subject to aquifer protection regulation is inaccurate, is contrary to the recommendation of the County Planning & Zoning Commission, does not included important wellhead locations, and is inconsistent with the City of Laramie 2008 CAPP.

- Specific scientific data from city wells are prohibited for use in future analyses of the west boundary of the aquifer protection zone.

- The County list of prohibited uses within the protection area is less restrictive than the City list of prohibited uses.

- The County provides opportunity for waiving setback requirements from vulnerable features.

- The County exempts from site specific investigations the “great majority” of the most important recharge area which is immediately east of the city wellfields.

None of the City’s concerns are addressed in the final County aquifer protection regulations (Albany County Zoning Resolution; August 7, 2012; Chapter V, Section 10).

In 2009, with limited re-sampling in 2010, the City collected samples from 115 domestic wells across the Casper Aquifer recharge area. These data were analyzed by WWC Engineering (2013), who concluded that in the Laramie Plains and Sherman Hills Subdivision areas (Plate I) (i.e. "Clusters" A and B) 100% and 45%, respectively, of the wells had been "impacted" by nitrate contamination, with 52% and 27% of those wells "significantly impacted" or "unsafe" (p. 8). They characterized the "risk to county residents" as "significant", but the "risk to city wells" as "low" (Laramie City Council presentation slides, July 13, 2010). A "statistically significant" trend of "slightly" increasing nitrate concentrations was cited for the Turner wells. However, it should be noted that even a very long-term projection of the trend of increasing nitrate in the Turner wells will fall well below the EPA MCL of 10 mg/l.

In 2009, the City and County jointly began an investigation of possible mitigation measures for the aquifer contamination that could result from a hazardous materials spill on Interstate 80 (I-80) where it traverses the recharge area in Telephone Canyon. The first report from the program (Trihydro, 2011) surveyed the vulnerability of the aquifer to this mode of contamination and outlined a series of potential monitoring, prevention, containment, and mitigation alternatives.

Since then, the City, County, and Wyoming Department of Transportation have been working in cooperation to implement portions of the 2011 recommendations. Traction-improvement and conditions-responsive signing and speed limits projects have been implemented to reduce the potential for spill-producing accidents on the interstate. Emergency response personnel and equipment capabilities have been reviewed with respect to an I-80 accident. (David Gertsch, Albany Co. Planner, pers. comm., 6/18/2015).

As of this writing, five monitor wells - two within the I-80 right-of-way near the mouth of Telephone Canyon and three between the mouth of the canyon and the Soldier-Pope wellfield - have been sited (Trihydro, 2015a). The City is taking the lead on securing the necessary access and funding to install those wells. A liner has been designed for a short section of the drainage within the I-80 right-of-way near the mouth of Telephone Canyon with the objective of preventing the infiltration of a contaminant spill at that location (Trihydro, 2015b). Funding in the amount of $1.4 million is being sought for that project. (David Gertsch, Albany Co. Planner, pers. comm., 6/18/2015)

In 2013, a study commissioned by the City of Laramie was completed investigating the feasibility of providing centralized sewer collection and wastewater treatment to the county subdivisions along East Grand Avenue (WWC Engineering, 2013). Various configurations were evaluated at a reconnaissance level. The least expensive configuration was a combination of on-site pre-treatment with centralized treatment of wastewater that would otherwise be individual leach field effluent.

In 2014, the City began a focused program of groundwater-quality monitoring in areas from which groundwater flows towards the municipal wellfields. This initial step addressed recharge to the Turner Wellfield and resulted in the construction, testing, and sampling of three permanent monitor wells (Triangle, North, and South wells; Plate I) and one temporary borehole. The results of that project are provided in the Phase II Report (Hinckley Consulting and Wyoming Groundwater, 2015) and include significant insights into the hydrogeology of the Casper Aquifer and the migration of elevated nitrate from the East Grand Avenue subdivisions toward the Turner Wellfield and to points west of the subdivisions.

Since the execution and enforcement of Laramie Enrolled Ordinance 1527 in 2008, approximately 53 site specific investigations (SSI) have been performed that address aquifer protection issues related to proposed development within the Casper Aquifer Protection Area. In some cases, the SSI's and subsequent technical reviews have generated additional information on the Casper Aquifer and insights into the process of aquifer protection using regulation.

The subsections to follow are aspects of the Casper Aquifer Protection Program that warrant recommendations for consideration by the City.

West Boundary of the Casper Aquifer Protection Area

The west boundary of the Casper Aquifer Protection Area attempts to include areas that have at less than 75 feet of Satanka Shale overlying the Casper Formation. As described in the 2002 CAPP, the technical review committee decided that the aquifer was vulnerable to contamination from surface sources if there is less than 75 feet of overlying Satanka Shale. The City and County versions of the CAPP now have distinctly different versions of the location of the west boundary. The County CAPP retains the initial (2002) mapping of the west boundary which has known delineation errors based on the criteria of 75 feet of undisturbed Satanka Shale. The City 2008 CAPP recognized several errors in the 2002 mapping and revised the west boundary westward to encompass a larger area to ensure compliance with the criteria of 75 feet of undisturbed Satanka Shale.

At this point, the aquifer-protection provisions of the city ordinance apply within the city boundary and the aquifer-protection provisions of the county resolution apply outside the city boundary. The Turner Wellfield is within the city boundary; however, the Spur, Soldier-Pope, and potential wellfields farther south remain vulnerable to the deficiencies in the west boundary delineation in the County CAPP. The City should work with the County to correct the obvious delineation errors of the west boundary in the vicinity of the City's Spur and Soldier-Pope wellfields. In a larger sense, the City and County should strive to establish overall consistency between the City and County CAPPs.

Casper Aquifer Protection Plan Update

The 2008 CAPP states that the CAPP should be revised or updated when new information is available concerning:

- Hydrologic characteristics of the Casper Aquifer
- Changes in water supply or pumping volumes
- Planning or development of new water supplies
- Changes in potential contaminant sources or the threat posed by potential contaminants
- New management strategies
- Contingency planning

It has been 7 years since the 2008 update and studies have been conducted that represent significant changes to our understanding of the Casper Aquifer, potential contaminant sources, protection area boundaries, and implementation of aquifer protection regulations. For example, these Level I Master Plan Groundwater Technical Memoranda provide substantial new information on the permeability distribution in the Casper Aquifer (e.g. horizontal fractures as dominant permeability features, hydrologic role of faults), the source and distribution of elevated nitrate in the Casper, and recommended strategies for aquifer/wellfield management, all of which may have significant aquifer protection implications. It is recommended that the City begin the process of updating all elements of the CAPP in 2016.

IV. Casper Aquifer Water Level and Water Quality Monitoring

Primary information about an aquifer is provided by the simple measurement of the water level in a well (i.e. head) and the collection/analysis of water samples for specific water quality parameters. Water level measurements at a point and over a larger area define head distributions that determine hydraulic gradients and groundwater flow patterns. Frequent or continuous head measurements define trends through time and allow analysis of the response of the aquifer to precipitation and stresses such as pumping. The response of head to natural and man-made hydraulic stresses is the basic tool for learning about aquifer recharge and behavior. The water quality of the aquifer determines the usability of the source for municipal purposes and whether the groundwater will need to be treated to meet drinking water standards. In many respects, head and water quality are barometers of the health of an aquifer.

In Technical Memoranda No. 2 the value of water level monitoring was demonstrated by the analysis of long-term patterns of precipitation (i.e. recharge) with intermediate and long-term water level records from monitor wells near the Spur Wellfield and southeast of the Turner Wellfield (i.e. Huntoon No. 1 and No. 2 wells). The analysis provided an important conclusion that annual water level fluctuations in the aquifer are a response to natural recharge and not to City groundwater production. This conclusion may modify how the City operates the Spur and Turner wellfields in the future.

The importance of water quality from the Casper Aquifer is more obvious to the public. Good quality water reduces/eliminates treatment costs and supports the health of the population and local economy. The proactive nature of the Casper Aquifer Protection Plan provides a means to consider current and proposed land use development in the context of reducing the potential for groundwater contamination. The CAPP is an important element in protecting water quality, but the actual verification of water quality conditions in the aquifer by way of water sampling and laboratory analysis is the bottom line.

The future management, development, and protection of the Casper Aquifer by the City should be guided, in part, by the interpretation of water level and water quality data. The Casper is a complex and critical water resource that merits long-term data collection efforts that continually improve our understanding of the aquifer.

Head Monitoring Efforts

Water level data are currently collected automatically at:

- five monitor wells in the vicinity of the Spur Wellfield
- Huntoon No. 1 and Huntoon No. 2
- municipal production wells at the Spur, Turner, Pope, and Soldier wellfields

There are numerous local wells completed in the Casper Aquifer that are not used for supply purposes but are owned or controlled by the City and could serve as water level monitor wells. The City is in the initial stages of developing a network of monitor wells suitable for the periodic measurement of water level. Recent efforts to develop a monitor well network include the installation of monitor wells at Imperial Heights Park (Hinckley Consulting and Wyoming Groundwater, 2015) and proposed monitor wells associated with the I-80 Telephone Canyon Casper Aquifer Protection Study (Trihydro, 2015a).

At a specific point in time and for specific purposes, the head in the Casper Aquifer has been measured and reported in numerous water supply studies as far back as 1947. The most notable and spatially comprehensive water level data collection efforts being Lundy (1978) and Taboga (2006). Past studies provide head data at a point in time, but do not provide the continuity of periodic measurements at the well over a long time period. The Huntoon No. 1 and Huntoon No. 2 monitor wells administered by the USGS and the Wyoming State Engineer's Office provide the most continuous record of water levels in the Casper in the vicinity of Laramie.

Water Quality Monitoring Efforts

As a public water supply, the City is required to routinely test for water quality parameters in compliance with the Safe Drinking Water Act and its amendments. This testing ensures that groundwater quality complies with drinking water standards. A Consumer Confidence Report is provided annually to the public that summarizes water quality data and water quality related issues. Water quality data generated from EPA regulatory compliance are from the municipal supply wells.

Water quality data are much more varied and complex than head measurements because of the large number of water quality parameters that can be analyzed, depending on the purpose of sampling. There are water quality data, of one type or another, scattered through City files/databases, buried within past water supply studies and UW thesis, and collected by private well owners. The most notable and spatially comprehensive water quality data collection/analysis efforts in the Casper are presented in theses by Lundy (1978), Toner (2000), and Younus (1992). Past studies provide water quality data at a point in time, but do not provide continuity of periodic measurements at the well over a long time period. The EPA compliance sampling data at the City municipal wells provide the most regular collection of water quality data over time for selected parameters.

Since 2001, as part of the Spur Wellfield use agreement, the City has been collecting selected inorganic water quality data annually from the Spur No. 1 and Spur No. 2 wells. These data are listed in the monthly report of aquifer impacts at the Spur Wellfield.

In 2009 and 2010, the City undertook a limited sampling program targeting the water quality in the Casper up-gradient from the municipal wells (City of Laramie, 2009 and 2010). That sampling program identified elevated concentrations of nitrate in areas underlying rural subdivisions that potentially contribute groundwater to the municipal supply wells at the Turner Wellfield. The sampling program was terminated after two rounds of sampling.

Casper Aquifer water quality data from wells not associated with the City wellfields are available from hydrogeologic studies conducted for the City at Simpson Springs (Weston Engineering, 2013a), the area southeast of the Turner Wellfield and at Imperial Heights Park (Hinckley Consulting and Wyoming Groundwater, 2015), and LaPrele Park (WWC, 1997b).

The 2015 Laramie Monitor Well Project (LMWP) represented by the Phase II report is the first step in a long-term, comprehensive, and routine water quality sampling program that goes beyond the routine sampling of the municipal supply wells. The 2015 LMWP focused on obtaining water quality data from the contributory area southeast of the Turner Wellfield. Similar monitor well installation and water quality sampling projects are anticipated for the Pope and Soldier wellfields.

Opportunities for Additional Water Level and Water Quality Monitoring

Over the course of numerous water supply studies, wells have been installed, identified, and/or been used for water level/water quality monitoring. Notable studies include Goodrich (1942), Lundy (1978), Taboga (2006), WWC (1993b), WWC (1995), WWC (1996a), WWC (1997a), WWC (1997b), WWC (1997c), and Weston Engineering (2013a). These studies can be reviewed to identify wells with the potential for inclusion in a monitor well network. The discussion to follow identifies wells and locations of particular relevance to the development of a monitor well network in the Casper.

At the Spur Wellfield, existing Spur monitor wells MW-7 and MW-9 are strategically located to obtain meaningful water quality data from upgradient subdivisions. Completion intervals of these wells should be reviewed. MW-7 is part of the current program of continuous water level monitoring, but is not routinely sampled for water quality.

There are five monitor wells on the City property that surrounds Soldier Spring and the Soldier No. 1 well (Plate I). Depending on the questions being asked, these wells may provide relevant water level and water quality data.

At the Pope Wellfield, the up-gradient monitor wells being pursued in association with the I-80 study (Trihydro, 2015a) are potential candidates for wellfield-related water quality monitoring. Because the Pope Wellfield and specifically the Pope No. 3 and Pope No. 4 wells are not used often (see Technical Memorandum No. 1) and there is not a spring at this location to control the head elevation, perhaps a Pope well could be designated as a well for water level monitoring (i.e. water level data is collected automatically by the SCADA system).

Although there are no immediate plans to develop municipal wells in the Simpson Springs area, the existing test and monitor wells completed at Simpson Springs (Weston Engineering, 2013a; Plate I) can be used to establish pre-development background water quality data in that area.

The City recently executed a memorandum of understanding with the Albany County campus of the Laramie County Community College (LCCC) to collect water samples twice a year from LCCC MW #1 located on the west edge of the campus property (Plate I).

The City is working towards establishing a memorandum of understanding between Albany County and the State Engineer's Office for the City to assume responsibility for water level and water quality monitoring at the Huntoon No. 1 and Huntoon No. 2 monitor wells.

The three monitor wells recently installed during LWMP project – Triangle, North, and South wells - are well-suited for inclusion in a monitor well network (Hinckley Consulting and Wyoming Groundwater, 2015). That project includes recommendations for the location of monitor well(s) designed to provide background (i.e. not impacted by human activities) water quality data.

Wells installed as part of the LaPrele Park prospect investigation (WWC, 1997b) and the LaPrele Park irrigation study (Wester-Wetstein, 2013) may be suitable for inclusion in a monitor well network. These wells include LAPCA-1, LaPRELE No. 1, and SHFCA-1 (Plate I).

Casper Aquifer Monitoring Document

The City has initiated development of a monitor well network in the Casper Aquifer as demonstrated by the installation of monitor wells southeast of the Turner Wellfield and the proposed installation of monitor wells in the Telephone Canyon and Pope Springs area. Water level and water quality data collection from a preliminary monitor well network is scheduled to begin in 2016. The designation of the monitor well network as "preliminary" is used herein because a comprehensive water level and water quality monitoring plan document has not yet been prepared by the City.

It is recommended that the City prepare a document that defines the objective(s) of the monitor well network, the location of existing and proposed monitor wells, water level measurement and groundwater sampling procedures, water quality analytes, sampling frequency/schedule, and the creation of water level and water quality databases that facilitate data presentation and interpretation. There may also be value in the City supporting a comprehensive tabulation of existing water level and water quality data that can be used to establish data trends through time and baseline (pre-development) values for selected water quality parameters.

List of Tables

List of Attachments

TECHNICAL MEMORANDUM NO. 3

TABLES

Table TM 3-1: Groundwater Quality of Casper Aquifer, Municipal Wells and Springs. 2015 Laramie Master Plan, Level I

											Other Key Parameters						
	Sample		Major Cations				Major Anions							TDS		Gross	Radium
Well	Year	pH	Ca	Mg	Na	K	HCO_3	Cl	SO_4	NO_3 as N	F	Fe	U	sum	Hardness	Alpha	226+228*
Spur No. 1	1997	8.0	52	16	2.6	<1.0	215	1.1	6.0	1.6	0.2	<0.05	0.002	300	196	<1.0	<1.0
Spur No. 2	1997	8.0	52	16	1.9	<1.0	216	<1.0	5.0	1.5	0.2	<0.05	0.001	298	196	<1.0	<1.0
Spur No. 1	2014	8.0	47	17	2.6	0.7	220	1.6	5.9	1.5	0.2	<0.02		301	187	2.8	-0.02
Spur No. 2	2014		48	17	2.3	0.7	220	1.4	5.3	1.4	0.2	<0.02		301	190	2.8	-0.02
City Springs	1973	7.8	52	17	2.1	0.9	233	1.8	6.6	1.4	0.2	0.03		320	200		
City Springs	2008	8.0	49	17	2.4	0.9	240	2.7	8.3	1.4	0.1	<0.02		326	192	2.7	0.1
Turner No. 1	1981	8.2	49	22	2.0	0.7	240	1.5	9.1	0.6	0.2	<0.1		327	213		
Turner No. 2	1981	8.3	35	20	2.0	0.2	210	1.4	6.6	0.2	0.2			276	170		
Turner No. 2	2014	7.5	53	17	2.9	0.9	240	4.0	11.0	2.0	0.1	<0.02	0.001	338	202		
Pope Wells	1973	8.2	54	13	2.1	0.7	222	1.8	5.8	1.6	0.2	0.04		306	188		
Pope No. 4	1981	8.2	51	19	2.0	0.2	230	1.8	0.0	0.8	0.2			308	205		
Soldier Spring	1973	7.9	50	16	3.7	0.9	220	1.8	8.2	1.7	0.7	0.04		308	191		
Solder No. 1	1997	8.1	58	17	1.9	<1.0	218	3.5	12.0	2.0	0.2	<0.05	<0.001	313	215	<1.0	<1.0
Soldier No. 1	2014	7.6	54	16	3.3	0.9	230	6.4	11.0	2.1	0.1	<0.02	0.001	331	201	1.8	0.4
MCL		*6.5 - 8.5*						*250*	*250*	**10**	**4.0**	*0.3*	**0.030**	*500*		**15**	**5**

Notes: Ca: Calcium; Mg: Magnesium; Na: Sodium; K: Potassium; HCO_3: Bicarbonate; Cl: Chloride; SO_4: Sulfate; NO_3: Nitrate; F: Fluoride; Fe: Iron; U: Uranium

TDS: Total Dissolved Solids

MCL: Maximum Contaminant Level as established by the EPA for drinking water standards.

Enforceable primary standards in **bold** type. Nonenforceable secondary standards in *italics*.

*: Radium 226 was not analyzed in most samples, but when analyzed it is non-detect.

Units: All units in mg/l with the following exceptions: pH in standard units, Hardness in mg/l $CaCO_3$; Gross Alpha and Radium in pCi/l

Table TM 3-2: Results of Microscopic Particulate Analysis (MPA) at City Wells. 2015 Laramie Master Plan, Level I
Data Source: WWC Engineering (2006)

Well ID	Sample Date	MPA Score	Risk*	Bioindicators Detected
Soldier Wellfield				
Soldier MW-1	11/5/1995	0	Low	ciliates
	1/7/1996	0	Low	pollen, ciliates
	3/27/1996	0	Low	pollen, ciliates, flagellates
	4/10/1996	0	Low	pollen, ciliates
	4/11/1996	0	Low	pollen, ciliates
	4/12/1996	0	Low	pollen
	4/14/1996	0	Low	pollen, ciliates
	4/16/1996	0	Low	ciliates
	5/19/1996	0	Low	pollen, ciliates
Solder MW-2	11/5/1995	0	Low	N.D.
	1/7/1996	0	Low	N.D.
	3/27/1996	0	Low	N.D.
	4/10/1996	0	Low	N.D.
	4/11/1996	0	Low	N.D.
	4/12/1996	0	Low	N.D.
	4/14/1996	0	Low	N.D.
	4/16/1996	0	Low	pollen
	5/19/1996	0	Low	N.D.
Soldier MW-3	11/12/1995	0	Low	N.D.
	1/15/1996	0	Low	N.D.
	5/26/1996	0	Low	ciliates
Soldier MW-4	11/12/1995	0	Low	N.D.
	1/15/1996	0	Low	N.D.
	3/27/1996	0	Low	N.D.
	4/10/1996	0	Low	N.D.
	4/11/1996	0	Low	N.D.
	4/12/1996	0	Low	N.D.
	4/14/1996	0	Low	N.D.
	4/16/1996	0	Low	N.D.
	5/19/1996	0	Low	N.D.
Soldier MW-5	11/12/1995	0	Low	pollen, ciliates
	1/15/1996	0	Low	flagellates
	5/26/1996	0	Low	pollen
Pope Wellfield				
Pope No. 1	7/6/1994	6	Low	diatoms, pollen, ciliates
	2/4/1996	1	Low	rotifers, pollen, flagellates
Pope No. 2	7/6/1994	6	Low	diatoms, pollen, ciliates
	2/5/1996	1	Low	rotifers, pollen
	5/26/1996	6	Low	diatoms, pollen
Pope No. 3	6/15/1994	15	Moderate	algae, diatoms, pollen
	2/4/1996	1	Low	rotifers, pollen
Pope No. 4	6/21/1994	0	Low	pollen
Turner Wellfield				
Turner No. 1	6/7/1994	0	Low	pollen
Turner No. 2	6/27/1994	0	Low	pollen

* : Risk of Surface Water Contamination: Score ≥ 20 = high risk   10 - 19 = moderate risk   ≤ 9 = low risk
N.D. = Not Detected

TECHNICAL MEMORANDUM NO. 3

ATTACHMENT 1

EPA FIELD EVALUATION FORM:
ASSESSMENT OF GROUNDWATER UNDER THE DIRECT INFLUENCE OF SURFACE WATER

Environmental Protection Agency, Region VIII
999 18th Street, Suite 300 (8P-W-MS)
Denver, Colorado 80202-2466

Assessment of Ground Water Under the Direct Influence of Surface Water (GWUDISW)
(GWUDISW is subject to the Surface Water Treatment Rule)

Public Water System Name: PWS#:

Well/Spring/Infiltration Gallery Name: County:

State Engineer's Office Ground Water Permit #:

Department of Environmental Quality Construction Permit #:

Date of Assessment: Analyst:

	Index Points	Score
A. TYPE OF SUBSURFACE WATER SOURCE (score one)		
Well, equal to or greater than 50 ft. deep *	0	
Well, less than 50 ft. deep*	5	
Spring	10	
Infiltration gallery, more than 2 ft. deep	10	
Infiltration gallery, ≤ 2 ft. deep	25	

*depth to first screen or perforation for groundwater entry

	Index Points	Score
B. HISTORICAL MICROBIOLOGICAL CONTAMINATION (score one)		
History or suspected outbreak of Giardia or other pathogenic organisms associated with surface water with current system configuration	50	
Record of total coliform acute MCL violations over last 3 years	30	
Record of total coliform monthly MCL violations over last 3 years		
One month	5	
Two months	10	
Three months	20	
Regulatory agency verifies complaints about turbidity or suspected waterborne disease	10	

GWUDISW ASSESSMENT, CONTINUED (PG. 2)

PWS ID#: DATE:

	Index Points	Score
C. HYDROLOGICAL FEATURES		
Distance between a surface water source and the groundwater collector (vertical well, spring box, or infiltration gallery)		
Over 200 ft.	0	
100-200 ft.	5	
Less than 100 ft.	10	
Well, spring, or infiltration gallery located on floodplain at approximate altitude of stream	20	
Surface runoff drains toward well, spring, or infiltration gallery	15	
Source aquifer that is alluvial material, cavernous, or fractured	15	
C: STRUCTURAL FEATURES		
WELLS (includes well collecting water from infiltration galleries)		
Uncased well	40	
Casing not properly sealed	15	
No watertight sanitary seal on well casing cap	15	
SPRING COLLECTION BOX (includes collection vaults collecting water from infiltration galleries)		
Deep-rooted vegetation (e.g. trees, shrubs) around springbox, providing conduit for surface water into spring water	15	
Springbox is not watertight, with watertight overlapping lid or cover	15	
Overflows or drains open to atmosphere or allow entrance of animals (unscreened)	15	
Marshy (standing water) around spring collection area	30	

TOTAL SCORE **:

** total score of ≥ 40 indicates further assessment is needed

COMMENTS: