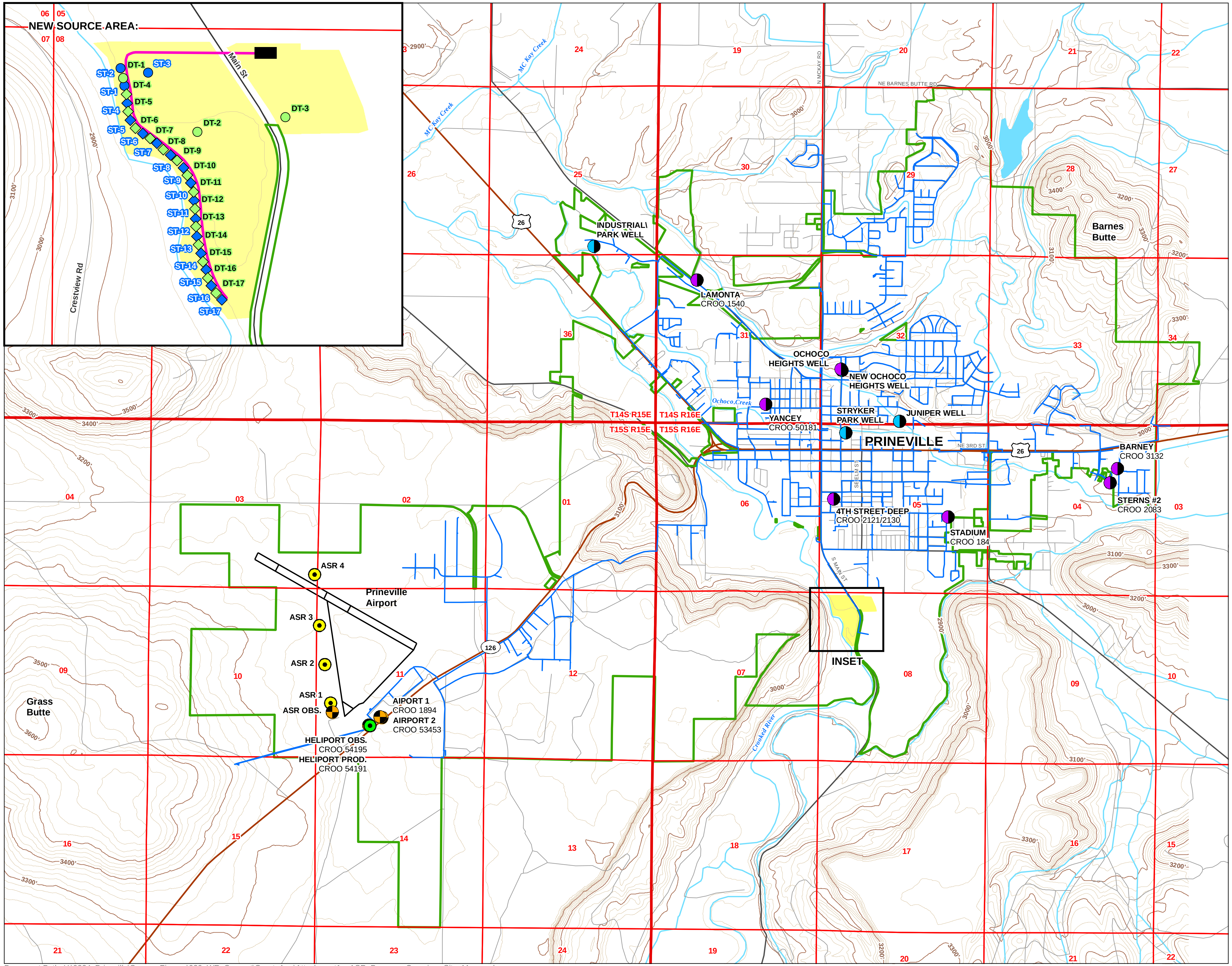
ATTACHMENT 1

Project Site Map

City of Prineville Water Grant Application



ATTACHMENT 1A

ASR Program Overview Site Map

Prineville, Oregon

LEGEND

- Existing City Well - Retrofitted for ASR
- Proposed ASR Well
- Exsting Source Water Well (POD)
- Proposed Valley Well
- ASR Observation Well

Future New City Source Wells (PODs)

- Existing Deep
- Existing Shallow
- Future Deep
- Future Shallow
- Waterline
- Proposed Water Line
- Proposed Water Treatment Plant

All Other Features

- New Alluvial Wellfield
- Prineville City Limit
- Highway
- Major Road
- Watercourse
- Waterbody

NOTES:

POD = Point of Diversion

N

0 1,500 3,000 4,500

Feet

Date: May 3, 2019

Data Sources: ESRI, USGS, DigiGlobe 2016

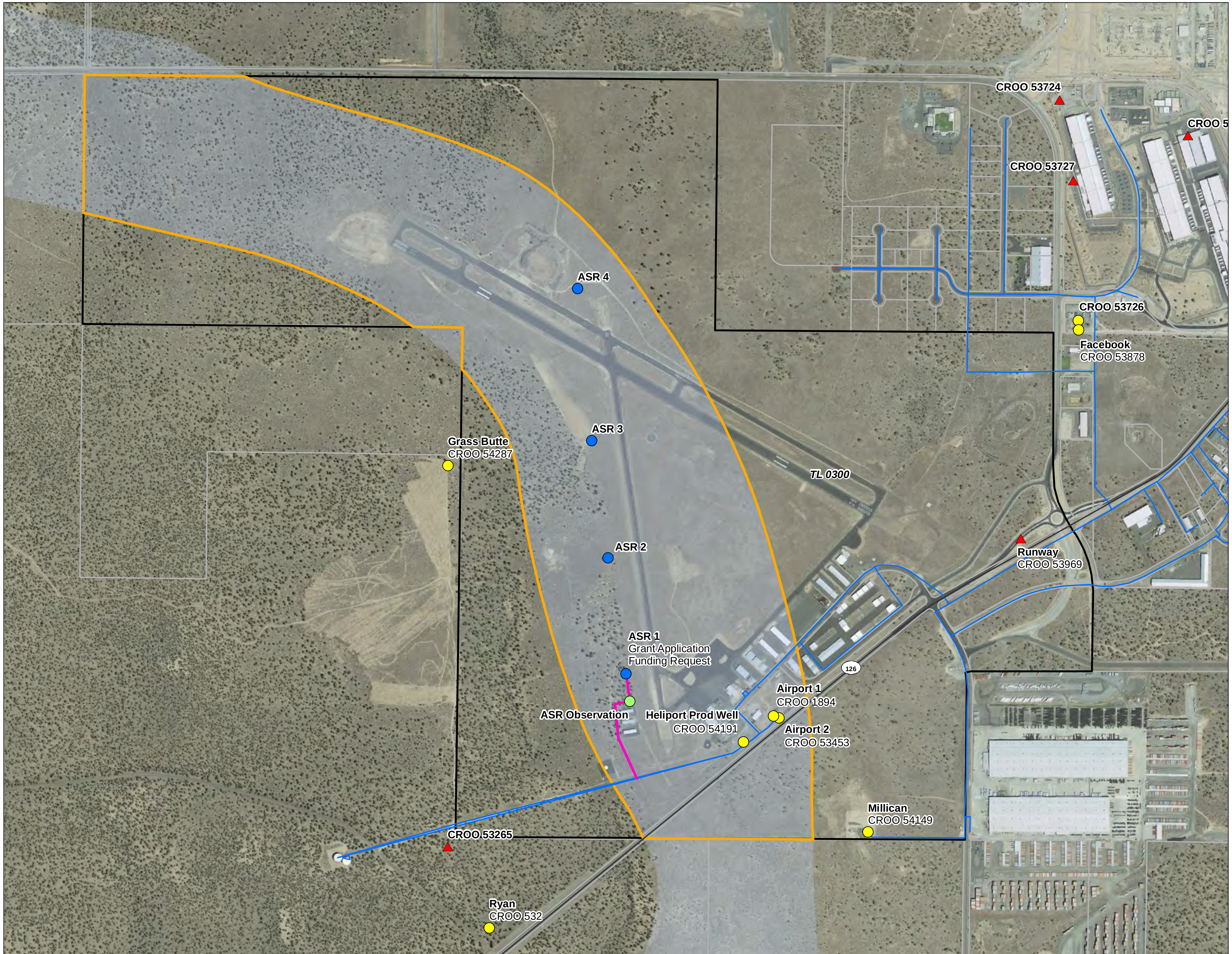
GSI Water Solutions, Inc.

Document Path: Y:\0224_Prineville\Source_Figures\029_WR_Support\Grant_App\Attachment1a_ASR_Program_Overview_Site_Map.mxd

ATTACHMENT 1B

ASR Program
Airport Area Site Map

Prineville, Oregon



LEGEND

- Abandoned Boring
- Existing Well
- Proposed ASR Observation Well
- Proposed ASR Program Well
- Waterline
- Proposed System Distribution Line (Grant Application Funding Request)
- Project Area Boundary
- Airport Property Boundary
- Estimated Location of Ancestral Crooked River Canyon
- Tax Lot

All Other Features

- Major Road

Project Locations (Latitude, Longitude):
ASR Observation: 44.280268, -120.905274
ASR 1: 44.281055, -120.905436 (Grant Application)
ASR 2: 44.284361, -120.906163
ASR 3: 44.287708, -120.906834
ASR 4: 44.292047, -120.907434

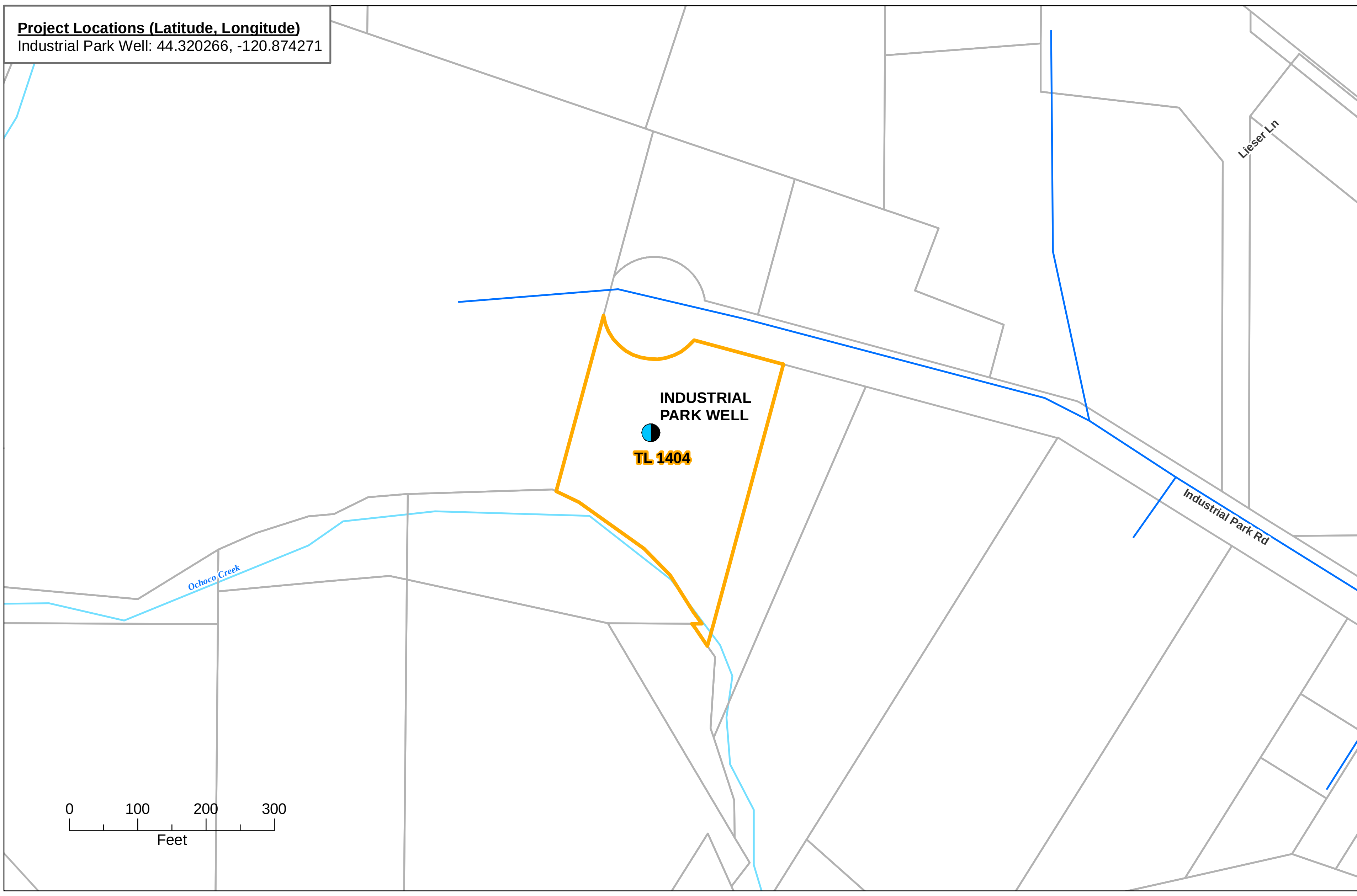
N

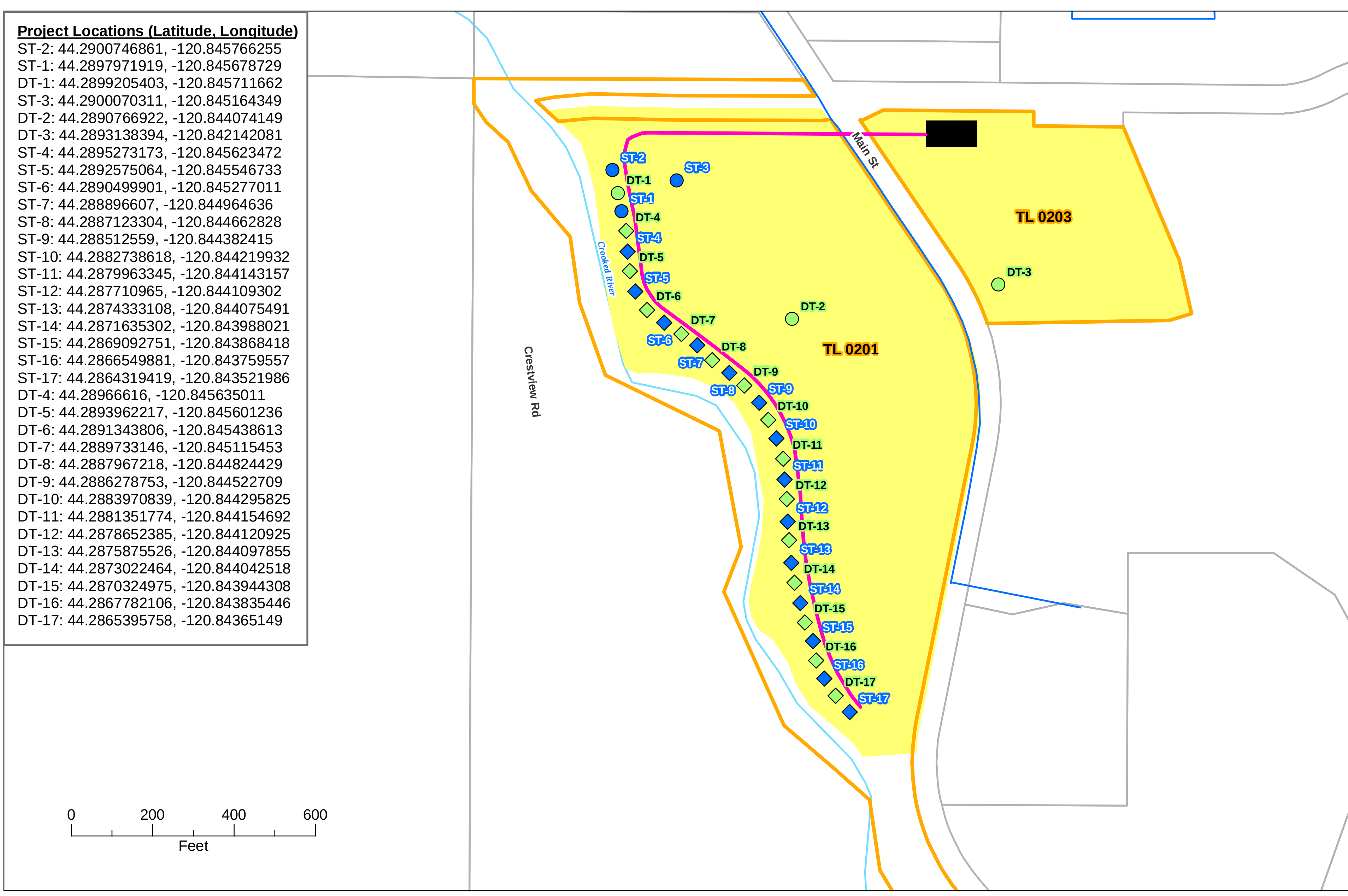
0 500 1,000 1,500
Feet

Date: May 2, 2019
Data Sources: GE 2018, ESRI

GSI Water Solutions, Inc.

Document Path: Y:\0224_Prineville\Source_Figures\029_WR_Support\Grant_App\Attachment1b_ASR_Program_Airport_Area_Site_Map.mxd





LEGEND

- Proposed Valley Well

Future New City Source Wells (PODs)

- Existing Deep
- Existing Shallow
- Propsoed Deep
- Proposed Shallow
- Waterline
- Proposed Water Line
- Proposed Water Treatment Plant
- Project Area Boundary
- New Alluvial Wellfield

All Other Features

- Tax Lot
- Watercourse
- Waterbody

ATTACHMENT 1C

ASR Program
Valley Floor Well Site Map

Prineville, Oregon

N

GSI Water Solutions, Inc.

Date: May 3, 2019
Data Sources: ESRI, USGS, City of Prineville, Crook Co.

Document Path: Y:\0224_Prineville\Source_Figures\029_WR_Support\Grant_App\Attachment1c_ASR_Program_Valley_Floor_Well_Site_Maps.mxd

LEGEND

- Existing Source Water Well (POD)
- Proposed Valley Well
- Waterline
- Project Area Boundary

All Other Features

- Tax Lot
- Watercourse
- Waterbody

ATTACHMENT 1D

ASR Program
Valley Floor Well Site Map

Prineville, Oregon

Project Locations (Latitude, Longitude)

Juniper Well: 44.305408, -120.837689
Stryker Park Well: 44.304407, -120.844117
Ochoco Heights Well: 44.309864, -120.844714
New Ochoco Heights Well: 44.309764, -120.844607

N

0 200 400 600
Feet

GSI Water Solutions, Inc.

Date: May 3, 2019
Data Sources: ESRI, USGS, City of Prineville, Crook Co.

Document Path: Y:\0224_Prineville\Source_Figures\029_WR_Support\Grant_App\Attachment1d_ASR_Program_Valley_Floor_Well_Site_Maps.mxd

ATTACHMENT 2

Property Access Authorization Form

City of Prineville Water Grant Application

OREGON
WATER RESOURCES DEPARTMENT

Water Project Grants and Loans

Landowner Agreement

Instructions to Applicants: Work with landowners to complete this form for all properties on which the proposed project would occur. Submit this completed form as part of your grant/loan application. For questions contact WRD_DL_waterprojects@oregon.gov.

Project and Applicant Information

Project Name: Prineville Airport Area Aquifer – ASR Project – ASR Well #2

Funding Applicant: City of Prineville

Co-Applicant (if applicable): -NA-i

Funding Applicant Contact Information:
Name: Eric Klann
Phone Number: 541-447-2357
Email Address: eklann@cityofprineville.com

Co-Applicant Contact Information:
Name: _____
Phone Number: _____
Email Address: _____

Landowner Information

Landowner(s) Name: Crook County

Landowner Authorized Representative: _____

Landowner Contact Information (or Authorized Representative)
Address: _____
_____
Phone Number: _____
Email Address: _____

Property Information

List each property owned by the above-mentioned Landowner on which the project would occur:

County	Tax map	Lot number
Crook	1515	0300

Landowner Acknowledgement

1. Crook County is/are the legal owner(s) (the Landowner) of the above described property (the Property).
2. I am authorized to act on behalf of the Landowner.
3. I am aware of and agree to the above-mentioned proposed project and grant permission for the Applicant, and the Applicant's agents, to conduct the following activities on the Property. (List activities below)

a. Install new ASR wells and conveyance system piping on the airport property
b.
c.
d.

a. I am aware that monitoring information related to the Project is a matter of public record.
b. I certify that the above-mentioned information is true and accurate, I am aware of and agree to the proposed work, and I am authorized to sign as the Landowner or Authorized Representative.

Signature of Landowner or Authorized Representative: Kelly Coffelt
Date: 4-23-19 Print Name: Kelly Coffelt
Airport Manager

OREGON WATER RESOURCES DEPARTMENT

Water Project Grants and Loans

Landowner Agreement

Instructions to Applicants: Work with landowners to complete this form for all properties on which the proposed project would occur. Submit this completed form as part of your grant/loan application. For questions contact WRD_DL_waterprojects@oregon.gov.

Project and Applicant Information

Project Name: Prineville Airport Area Aquifer – ASR Project – ASR Well #2

Funding Applicant: City of Prineville

Co-Applicant (if applicable): -NA-

Funding Applicant Contact Information:
Name: Eric Klann
Phone Number: 541-447-2357
Email Address: eklann@cityofprineville.com

Co-Applicant Contact Information:
Name:______
Phone Number: _____
Email Address: _____

Landowner Information

Landowner(s) Name: Crook County Park and Recreation

Landowner Authorized Representative: Duane Garner

Landowner Contact Information (or Authorized Representative)
Address: 296 S. Main St Prineville OR 97754
Phone Number: (541) 447-1209
Email Address: duane@ccprd.org

Property Information

List each property owned by the above-mentioned Landowner on which the project would occur:

County	Tax map	Lot number
Crook County	15S16E08	0000201

Landowner Acknowledgement

1. Crook County Park and Recreation is/are the legal owner(s) (the Landowner) of the above described property (the Property).
2. I am authorized to act on behalf of the Landowner.
3. I am aware of and agree to the above-mentioned proposed project and grant permission for the Applicant, and the Applicant's agents, to conduct the following activities on the Property. (List activities below)

a. Install City's new production wells and conveyance system piping
b.
c.
d.

a. I am aware that monitoring information related to the Project is a matter of public record.
b. I certify that the above-mentioned information is true and accurate, I am aware of and agree to the proposed work, and I am authorized to sign as the Landowner or Authorized Representative.

Signature of Landowner or Authorized Representative: Duane Garner

Date: 5/1/19 Print Name: Duane Garner

OREGON WATER RESOURCES DEPARTMENT

Water Project Grants and Loans

Landowner Agreement

Instructions to Applicants: Work with landowners to complete this form for all properties on which the proposed project would occur. Submit this completed form as part of your grant/loan application. For questions contact WRD_DL_waterprojects@oregon.gov.

Project and Applicant Information

Project Name: Prineville Airport Area Aquifer – ASR Project – ASR Well #2

Funding Applicant: City of Prineville

Co-Applicant (if applicable): -NA-

Funding Applicant Contact Information:
Name: Eric Klann
Phone Number: 541-447-2357
Email Address: eklann@cityofprineville.com

Co-Applicant Contact Information:
Name: ______
Phone Number: _____
Email Address: _____

Landowner Information

Landowner(s) Name: Crook County

Landowner Authorized Representative: County Judge Seth Crawford

Landowner Contact Information (or Authorized Representative)
Address: 300 NE 3RD PRINEVILLE, OR 97754
Phone Number: 541-447-6555
Email Address: SETH.CRAWFORD@co.crook.or.us

Property Information

List each property owned by the above-mentioned Landowner on which the project would occur:

County	Tax map	Lot number
Crook	15S16E08	0000203

Landowner Acknowledgement

1. Crook County is/are the legal owner(s) (the Landowner) of the above described property (the Property).
2. I am authorized to act on behalf of the Landowner.
3. I am aware of and agree to the above-mentioned proposed project and grant permission for the Applicant, and the Applicant's agents, to conduct the following activities on the Property. (List activities below)

a. Install City's new water treatment plant
b.
c.
d.

a. I am aware that monitoring information related to the Project is a matter of public record.
b. I certify that the above-mentioned information is true and accurate, I am aware of and agree to the proposed work, and I am authorized to sign as the Landowner or Authorized Representative.

Signature of Landowner or Authorized Representative: [signature]
Date: 5/1/19 Print Name: Seth Crawford

ATTACHMENT 3

Matching Fund Documentation

City of Prineville Water Grant Application

City of Prineville
Water Improvement - Water Repair and Maintenance (R&P) Capital Improvement Plan
Fiscal Years 2019 - 2023

Project Description	Current Year Construction Estimate	2019	2020	2021	2022	2023
Source						
ASR Project	$ 500,000	$ 500,000				
Storage						
Airport Industrial Park Utility Extension	$ 400,000	$ 220,000				
Total	$ 900,000	$ 720,000	$ -	$ -	$ -	$ -

This City of Prineville CIP budget line item documents the matching funds for the ASR project during FY 2018/2019.

Project Description

The aquifer storage and recovery (ASR) project is a method of water storage that uses the natural water storage capabilities of underground aquifers as a cost-effective, scalable and ecologically friendly water storage alternative to traditional storage options, such as above-ground reservoirs and short-term water supply storage tanks. An ASR system allows water to be appropriated and injected into the aquifer via wells during periods of cooler temperatures, higher streamflow and lower demands. The stored water can later be recovered and used during periods of hotter temperatures and higher demands, thereby reducing stress on native water sources. In addition, it also provides for a readily available "reservoir" of stored water for use in the event of drought or supply interruption. This project is funded by local data center interests.

Public Works Director Eric Klann speaks with Abbas Well Drilling as work is carried out for the ASR project.

City of Prineville Water SDC Capital Improvement Plan Fiscal Years 2020 - 2024						
Project Description	Current Year Construction Estimate	2020	2021	2022	2023	2024
Source						
Master Plan Update						
Storage						
Barnes Butte Tank #2 (1.0 mg steel)	$ 1,250,000				$ 1,250,000	
Fairgrounds Tank #2 (1.0 mg concrete)	$ 1,250,000					
Hudspeth Tank #1 (2.0 mg concrete)	$ 2,500,000					
Hospital Tank (1.5 MG Steel)	$ 2,000,000			$ 2,000,000		
Melrose Tank #1 (1.0 mg steel)	$ 1,000,000					
Transmission						
Elm Street Bridge 12" water main Extension (Ductile Iron)	$ 100,000	$ 100,000				
Combs Flat Transmission Main	$ 102,000					
Barnes Butte Transmission/Distribution Mains	$ 1,797,300					
Fairgrounds Transmission/Distribution Mains	$ 1,100,000					
Hudspeth Booster Pump Station #1	$ 350,000					
Hudspeth Booster Pump Station #2	$ 350,000					
Hudspeth Booster Pump Station #3	$ 350,000					
Hudspeth Transmission/Distribution Mains	$ 1,994,300					
Aquifer Storage and Recovery Project	$ 9,935,572	$ 6,954,900	$ 2,980,672			
NW Area Transmission/Distribution Mains	$ 2,781,900					$ 2,781,900
Total	$ 26,861,072	$ 7,054,900	$ 2,980,672	$ 2,000,000	$ 1,250,000	$ 2,781,900

This City of Prineville CIP budget line item documents the matching funds for the ASR project over the next 2 years. The City funded this budget line item when the contract was signed with in February 2019.

ATTACHMENT 4

ASR Feasibility Study

City of Prineville Water Grant Application

Prineville Airport Area Aquifer
Aquifer Storage and Recovery (ASR) Feasibility Study

City of Prineville

May 2018

Prepared by

GSI Water Solutions, Inc.

CASCADE GEOENGINEERING

JACOBS

The City of Prineville
Prineville Airport Area Aquifer
Aquifer Storage and Recovery (ASR)
Feasibility Study

Prepared For
City of Prineville

Prepared By
GSI Water Solutions, Inc.
147 SW Shevlin Hixon Drive
Bend, OR 97702

May 2018

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Appendices

Executive Summary

The City of Prineville is exploring options for developing resilient, sustainable, and cost-effective water sources to meet growing demands of its customers. The biggest challenge the City faces is meeting summertime peak day demands, which can be almost 3 times greater than average day demands. Aquifer storage and recovery (ASR) is a cost-effective water management tool that would allow the City to meet its growing peak day demands by taking advantage of the natural storage space found underground in geologic formations near the City.

An ASR system uses a well to inject water into the aquifer, where it is stored and later pumped back out for use. Water is collected during periods of cooler temperatures, higher streamflow, and lower demands. The stored water can later be recovered and used during periods of hotter temperatures and higher water demands—typically during the summer months—thereby easing peak demand stress on native water sources and reducing the need to build expensive water infrastructure (e.g. above-ground storage, etc.) in order to meet these short-duration peak demands. In addition, ASR programs can be used to counteract long-term impacts from climate change (such as reduced snowpack water volumes), and provides for a readily available underground reservoir of stored water for use in the event of drought or supply interruption.

This ASR feasibility study (FS) is part of the City's ongoing ASR assessment project for the airport area aquifer (Study Area) and evaluates:

- Hydrogeologic characteristic of the recharge aquifer
- Recharge rates and potential storage volumes
- Water quality compatibility between the source water and the target aquifer
- Potential loss of stored water to surface water or seepage

The findings of this FS indicate that implementing an ASR program appears to be feasible in the airport area's Upper Aquifer.

The highly productive Upper Aquifer, with its a deep water table, can take advantage of the natural storage capacity of the system resulting in the storage of millions of gallons of water that can be later recovered to meet summer peak day demands. Potential storage volume evaluation indicates that with a single well (the Heliport Production Well) volumes of up to 179 million gallons (MG) could be stored annually. If additional wells are installed, the Upper Aquifer may be capable of storing up to 870 MG annually.

The evaluation also indicates that there would be minimal potential for creating excessive groundwater level changes in nearby wells, and a large proportion of the recharged water (stored water) will remain in place and be available for recovery by the City's wells.

In summary, these geologic, hydrogeologic, and regulatory evaluations suggest favorable ASR feasibility in the Upper Aquifer. Based on the technical analysis presented in this feasibility study, GSI Water Solutions, Inc. (GSI), recommends proceeding with the next steps of the project: ASR permitting, design, and construction tasks; and ASR pilot testing.

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1 Introduction

The City of Prineville (City) has been has been proactively exploring opportunities to cost effectively meet the City's peak municipal water demand and increase the long-term resiliency of its water supply. Aquifer storage and recovery (ASR) is a water management tool that that the City can use to achieve these objectives. A City ASR system would store water in an airport area aquifer (Study Area) by artificially recharging the existing Heliport Production Well during periods of low water demand (typically winter). The stored water will be available for recovery and use during periods of high water demand (typically summer). The water sources for ASR are (1) a new alluvial wellfield on the south side of Prineville that the City is evaluating, and (2) the City's existing production wells in the Prineville Valley. Locations of the new alluvial wellfield, existing production wells in the Prineville Valley, the Heliport Production Well (ASR Well), and the Study Area are shown in Figure 1.

1.1 Purpose and Objectives

This ASR feasibility study (FS) is part of the City's ongoing ASR assessment project for the airport area aquifer. The purposes of this report are to (1) evaluate the feasibility of ASR in the Study Area, and (2) summarize key information required in an application for an ASR limited license from the Oregon Water Resources Department (OWRD). The report objectives include:

- Summarize the geology and hydrogeology of the Study Area, including the geologic and hydrogeologic units, aquifer properties (e.g., transmissivity), and aquifer characteristics (e.g., depth to groundwater).
- Assess the suitability of the Study Area for ASR based on performance of existing wells, aquifer properties, and aquifer characteristics.
- Estimate the volume of water that can be stored in the aquifers in the Study Area.
- Evaluate the potential for adverse impacts to other wells as a result of ASR (e.g., an unacceptable amount of water level buildup in other wells).
- Evaluate source water and native groundwater quality, including the geochemical compatibility between source water and native groundwater, and whether source water quality meets ASR standards.
- Evaluate groundwater and surface water conditions for basing recovery estimations.

1.2 ASR Feasibility Project Scope

ASR projects commonly are divided into three phases: Phase 1 - ASR Feasibility Study, Phase 2 - ASR Pilot Testing, and Phase 3 – Expansion and Full-Scale Operation. This report documents Phase 1 of ASR implementation, and is designed to provide the City with key information needed to:

- Identify potential fatal flaws to ASR development in the Study Area.

- Submit an ASR limited license application to OWRD.
- Identify factors determining the approximate water volume that the ASR system will store.
- Identify key uncertainties to address.

After receiving an ASR limited license from OWRD, the City intends to implement Phase 2 of ASR (i.e., ASR pilot testing) to test and demonstrate ASR feasibility in the Study Area.

The ASR FS for the Study Area is organized into the following sections:

Section 1 – Introduction.

Section 2 – Hydrogeologic Characterization. Review available information about the geology of the Study Area, including surficial geologic maps, geologic cross sections, publications from the U.S. Geological Survey (USGS), and reports by consultants. Based on the geologic information, characterize the hydrogeology of aquifers in the Study Area (including aquifer properties and aquifer characteristics) to provide the basis for evaluating ASR.

Section 3 – Source Water and Native Groundwater Quality and Compatibility. Evaluate source water and native groundwater quality data to understand whether the water quality meets ASR or drinking water regulatory standards, and to assess the potential for adverse chemical reactions to occur as a result of mixing source water and native groundwater in the aquifer.

Section 4 – Source Water Availability. Review the sources of water available to supply water for recharge, and assess the amount of water that may be available for recharge.

Section 5 – ASR Feasibility Evaluation. Evaluate the feasibility of ASR based on the hydraulic properties of the aquifer, performance of existing wells, depth to groundwater, likely volume of water that can be stored and recovered, potential adverse impacts to existing wells (e.g., unacceptable water level build-up), well construction issues, and compatibility between source water and native groundwater.

Section 6 – Permitting Requirements. Identify required permits for ASR, fatal flaws associated with obtaining the permits (if any), and the schedule for obtaining the permits.

Section 7 – Conclusions and Recommendations. Discuss conclusions of the ASR FS, and present recommendations for proceeding with the project.

2 Hydrogeologic Characterization

This section presents a hydrogeologic characterization of the Study Area, which is a required component and application for an ASR limited license[1]. The hydrogeologic characterization is based on previous geologic and hydrogeologic reports by GSI Water Solutions, Inc. (GSI), Newton Consultants, Inc.; Oregon Department of Geology and Mineral Industries (DOGAMI); OWRD; and USGS.

2.1 Physical Setting

The City is planning to implement ASR using an aquifer located in the Study Area, which is a plateau located southwest of Prineville as shown on Figure 1. The topographic relief in the Study Area ranges from approximately 3,260 feet above mean sea level (amsl) within the level areas surrounding the Prineville Airport to about 3,600 feet above amsl at the peak of Grass Butte and Meyers Butte, two volcanic vents at the edges of the plateau. The Crooked River Canyon, located in the valley to the east and north of the Study Area, ranges from 2,920 feet amsl upstream of the City to 2,820 feet amsl downstream of the City. The Study Area is arid, with an average annual rainfall of 9.89 inches per year based on climate data from 1897 to 2012 (WRCC, 2018).

Most of the Study Area is undeveloped, with the exception of rural homes, the Prineville Airport, Crook County Landfill, data centers, and industrial manufacturing warehouses. The risk of the aquifers in the Study Area being contaminated by surficial sources of contamination is relatively low because of the deep water table in the Study Area (more than 400 feet below ground surface [bgs]). The City can further minimize aquifer contamination risk by tracking the types of industrial activities in the Study Area and their potential for being a contaminant source to the drinking water aquifer.

2.2 Geology of the Study Area

The Study Area is located on the northeastern flank of a large topographic paleo-basin known as the Upper Deschutes Basin. Locally, the bottom and sides of the basin are composed of old, low permeability tuffs, ash deposits, and fine sedimentary rock (called basement rock in this report). The basin is filled by unconsolidated sediments and volcanic rock (called basin-fill deposits in this report).

A generalized geologic map of the Prineville area is provided in Figure 2. Cross sections showing the basement rock and basin-fill deposits are provided in Figure 3 (A to A') and Figure 4 (B to B'). The location of the cross section lines are shown in Figure 2. The following sections describe the significant geologic units and geologic structure in the Study Area.

---

[1] See Oregon Administrative Rule (OAR) 690-350-0020(3)(b)(C)

2.2.1 Geologic Units

Geologic units are packages of rock or soil that have distinctive features. The following sections describe the geologic units in the Study Area and adjacent valley from oldest to youngest.

Basement Rock

The basement rock is the low permeability material that is located below the regional groundwater system. Unlike other portions of the Deschutes Basin, in Prineville the basement rock is found at relatively shallow depths (as part of an old caldera structure) and rises to land surface on the eastern side of the Prineville Valley (the edge of the older Ochoco Mountains). From oldest to youngest, the basement rock is composed of the John Day Formation and Simtustus Formation.

John Day Formation

The John Day Formation is composed of volcanically derived fine-grained tuff, ignimbrite, and ash deposited between 22 and 39 million years ago. Local examples of the John Day Formation include the rock formations at Smith Rock State Park, the rocks that make up Powell and Barnes Buttes, and the Ochoco Mountains northeast of the City (see Figure 2). This formation is characterized by a very low-permeability resulting from weathering and alterations of the original deposits, and does not contain significant water production zones; therefore, it forms the hydrologic basement for the regional groundwater system (Gannett et al., 2001; Gannett and Lite, 2003).

Simtustus Formation

The Simtustus Formation is a local deposit of fine-grained, water-lain tuffs, sandstones, and mudstones deposited between 12 and 15 million years ago. The fine-grained fluvial sedimentary deposits of this formation generally do not contain significant water production zones; therefore, it is considered to be part of the deposits that form the hydrologic basement of the regional groundwater flow system (Smith, 1985).

Basin-Fill Deposits

Following a period erosional activity between 15 and 9 million years ago, the Upper Deschutes Basin near Prineville was filled with sedimentary, volcanic, and alluvial deposits. From oldest to youngest, the basin fill deposits include the Deschutes Formation and recent alluvial deposits.

Prineville Basalt Formation

The Prineville Basalt Formation consists of lava flows that originated from one or more vents near Prineville between 15.6 and 15.8 million years ago (Smith, 1985). The source vents are exposed near Bowman Dam (10 miles southeast of the City) and in the Crooked River Canyon south of the City (see Figure 2). The Prineville Basalt is found beneath the western portion of the Study Area. Although the Prineville Basalt has the ability to transmit groundwater (Gannett et al., 2001), it is generally found above the local and regional water tables within them Study Area and is unsaturated.

Deschutes Formation

Volcanic activity in the Deschutes Basin surged between approximately 4 and 9 million years ago, rapidly filling the basin with interlayered sedimentary and volcanic deposits collectively known as the Deschutes Formation (Sherrod et al., 2004). As shown on the geologic map (Figure 2) and cross sections (Figure 3 and Figure 4), the Deschutes Formation is the primary geologic unit above the basement rock in the Study Area. The basalts and sediments of the Deschutes Formation exhibit a complex nature and extent caused by erosion and filling of canyons over time, and formation of volcanic vents. As shown in Figure 3, the ancestral Crooked River flowed through the Study Area and appears to have eroded a deep canyon extending into the basement rock of the Simtustus and John Day Formations (called the ancestral canyon in this report). McKay Creek, originating in the Ochoco Mountains, also incised a canyon through the basement rock to reach the ancestral Crooked River. After the erosional period ended, the canyons began filling in with Deschutes Formation age lava flows and alluvial deposits. At some point during the early portion of the Deschutes Formation depositional period, one of the many local volcanic vents (such as Meyers Butte and Round Butte [located north of the Study Area]) plugged the northern end of the ancestral canyon with basalt, forcing the ancestral Crooked River to move northeast into its current location. Following the shift, the ancestral canyon subsequently was filled with younger Deschutes Formation sediments and lava flows.

Near the Heliport Production Well, which the City plans to use as the initial ASR well, the eastern and western edges of the ancestral canyon have been reasonably well defined. The eastern edge of the ancestral canyon is located on or near the Facebook property (about 1 mile northeast of the Heliport Production Well). Facebook owns one production well that is completed within the ancestral canyon. However, several exploratory borings drilled just east of that well were either dry or produced very little water, and encountered basement rock at much higher elevations, indicating that the exploratory borings were located outside of the ancestral canyon. The western edge of the ancestral canyon is located about ¾ mile southwest of the Heliport Production Well, based on the geologic deposits that were logged in the exploratory boring at the City's water tank.

Recent Alluvial (Quaternary) Deposits

Approximately 3 million years ago, changes in the regional tectonic forces began a significant amount of regional uplift, again creating a period of erosional activity that resulted in deep channels being incised into the basement rock beneath the current Prineville Valley. Following this erosional event, sedimentary deposits began refilling the deeply eroded channels. From about 1.6 million years ago until present day, three distinctive sedimentary units were deposited in these deeply eroded channels. As shown in Figure 3, from oldest to youngest, the sedimentary units are (Robinson and Price, 1963):

- Lower Sand and Gravel (QTs3)
- Fine-Grained Deposits (QTs2)
- Upper Sand and Gravel (QTs1), which include terrace deposits, landslide deposits, and recent alluvial system deposits.

The groundwater system in the Prineville Valley is found within these recent alluvial deposits. The QTs3 is relatively permeable[2] and is typically under artesian pressure. The QTs2 has a much lower permeability relative to the other alluvial deposits and likely acts as a confining to semi-confining layer to the QTs3. GSI interpreted the Upper Sand and Gravel, terrace deposits, landslide deposits, and recent alluvium overlying QTs2 to be a single geologic unit (QTs1), which is saturated to varying degrees depending on location. The recent alluvial deposits are located in the Prineville Valley and, therefore, are separate from the Study Area. However, the wells that will provide source water for ASR will appropriate water from these deposits (i.e., within the QTs3 and QTs1).

2.2.2 Geologic Structure

Geologic structures in the Study Area include faults and volcanic vents (i.e., Grass Butte and Meyers Butte). These structures are important to evaluating fatal flaws for ASR because faults can form barriers to the lateral and vertical movement of groundwater, and volcanic vents can locally reduce aquifer permeability.

Faults

Two faults have been identified in the northern portion of the Study Area near Meyers Butte (Ferns and McClaughry, 2006). These faults are northwest and northeast trending normal faults. The faults are located outside of the ancestral canyon and, therefore, are not likely to influence groundwater movement and ASR operations in the Study Area because the aquifers in the Study Area are located within the ancestral canyon and isolated from the effects of these faults.

Volcanic Vents

Grass Butte and Meyers Butte are two prominent volcanic vents in the Study Area. Meyers Butte formed 5.42 million years ago (McClaughry et al., 2009). Molten rock pushing up through the Deschutes Formation resulted in surface lava flows extending from the vents. The high temperature of the molten rock passing through the existing rock and sediments, combined with the associated hydrothermal alterations, could create a halo of reduced permeability near the vents and their feeder dikes. The volcanic eruptive centers are not located close to the proposed ASR well (i.e., the Heliport Production Well) and, therefore, are not likely to influence groundwater movement and ASR operations.

2.3 Hydrogeology of the Study Area

The aquifers within the Study Area occur in the ancestral canyon's deeper Deschutes Formation deposits; the Deschutes Formation outside of the ancestral canyon does not transmit significant quantities of groundwater and, therefore, is not included in this evaluation of hydrogeology in the Study Area.

[2] See Appendix A for transmissivity of the QTs3.

2.3.1 Hydrogeologic Units

A hydrogeologic unit is a package of rock or soil that, because of its porosity or permeability, has a distinct influence on the storage or movement of groundwater. Drilling data and long-term water level monitoring show that there are two hydrogeologic units in the ancestral canyon: the Lower Aquifer and the Upper Aquifer. Groundwater elevations in the Lower Aquifer are approximately 50 feet higher than groundwater elevations in the Upper Aquifer, indicating that the Upper Aquifer and Lower Aquifer are hydraulically separate aquifers. All large production wells (water production rates greater than 200 gallons per minute [gpm]) in the Study Area are located in these hydrogeologic units[3].

The Upper Aquifer and Lower Aquifer are shown in the Figure 3 and Figure 4 cross sections. The areal extents of the Lower Aquifer and Upper Aquifer are shown in Figure 5. The Lower Aquifer is stratigraphically below the Upper Aquifer.

Lower Aquifer

The Lower Aquifer is located at the base of the ancestral canyon and is composed of a fractured basalt near the Prineville Airport and a fine sand and gravel in the southern part of the Study Area (i.e., in well CROO 52461, located approximately 3 miles to the south). The fractured basalt contains moderate groundwater production capacity (existing wells yield up to 300 gpm) and is characterized by an elevated groundwater temperature (68 to 70 degrees Fahrenheit [°F])[4].

The Millican Well (CROO 53956), Runway Well (CROO 53969, now abandoned), Facebook Well (CROO 53878), and Linhares/Raasch domestic well (CROO 52461) are completed in the Lower Aquifer. The Lower Aquifer is confined, based on the low storage coefficients (1.7×10^{-4} and 5.7×10^{-7}) and static water levels above the top of the lithology that comprises the aquifer[5].

Upper Aquifer

The Upper Aquifer is a permeable coarse sand and gravel deposit that represents the ancestral Crooked River's alluvial channel deposits. The City's Airport 1 Well, Airport 2 Well, and Heliport Production Well are completed in a sequence of Upper Aquifer sand and coarse gravel deposits that is more than 100 feet thick. Two of the City's production wells in the Upper Aquifer produce up to 1,100 gpm.

The Upper Aquifer exhibits characteristics of confined and unconfined aquifers. Unconfined characteristics of the Upper Aquifer include the high storage coefficient (0.14 to 0.23). Confined characteristics of the Upper Aquifer include observations during drilling of the

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[3] Other wells drilled outside of the ancestral canyon are located in fine-grained, low-permeability alluvial or volcanic deposits. These wells either did not encounter groundwater or have minimal groundwater production capacity (generally on the order of a few to tens of gallons per minute is reported on well logs).

[4] The Heliport Production Well was drilled into the fractured basalt of the Lower Aquifer, and water levels in the borehole rose 50 feet and water temperature increased. Based on driller logs, the temperature of groundwater in the Facebook Well is 71°F, the temperature of groundwater in the Runway Well is 62°F, and the temperature of groundwater in the Millican Well is 61°F.

[5] See wells CROO 52461, CROO 53956, and CROO 53878.

Heliport Production Well (specifically, a water-bearing zone was encountered at 470 feet bgs and the static water level in the zone was 435 feet bgs, indicating that the water-bearing zone was under pressure). High-quality data collected during ASR cycle testing (e.g., high-resolution water level data from pumping and observation wells[6]) will be used to further evaluate whether the Upper Aquifer is confined or unconfined.

2.3.2 Groundwater Levels and Trends

Groundwater elevations in the Study Area range from 358 feet bgs[7] to 448 feet bgs[8]. This is an approximately 90 feet difference in elevation between the highest and lowest groundwater elevations.

Generally, groundwater levels in the Study Area have been declining over time. GSI (2016) summarized water level trends in the Lower Aquifer and Upper Aquifer for a 3-year period from 2012 to 2015, and found that water levels in the Lower Aquifer declined less than 1 foot per year[9], and water levels in the Upper Aquifer declined less than 3.5 feet per year[10]. These static water level declines are can be observed in Figure 6 (Heliport Production Well, Upper Aquifer) and Figure 7 (Millican Well, Lower Aquifer). The water level declines correlate to both a decrease in precipitation in the Study Area and an increase in annual groundwater production from the Upper Aquifer and Lower Aquifer. Central Oregon has experienced a drying trend since the 1950s, and more recently a drying trend in the Prineville Valley starting in 1998 correlates closely with the declining water levels in the Upper Aquifer (GSI, 2016). It is currently unclear to what extent these identified factors are contributing to the observed water level declines.

2.3.3 Aquifer Properties (Transmissivity, Hydraulic Conductivity, Storativity)

Aquifers are characterized by hydraulic properties, including transmissivity (which is the rate at which groundwater is transmitted through a unit width of an aquifer under a unit hydraulic gradient), hydraulic conductivity (which is the transmissivity divided by the aquifer thickness), and storativity (which is the volume of water an aquifer releases from, or takes into, storage per unit surface area of the aquifer per unit change in head). Because aquifer properties are scale-dependent (Bear, 1972), aquifer properties measured at the wellfield-scale and at the regional-scale in the Study Area are presented in this section.

Wellfield-Scale Aquifer Properties

The City completed a long-term pumping test at the Millican Well (completed in the Lower Aquifer) and Heliport Production Well (completed in the Upper Aquifer) during the summer of 2015. This testing was conducted as part of the City's long-term water level monitoring

[6] During the Heliport Production Well pumping test in 2015 (GSI, 2016), groundwater elevation in the Airport 2 Well was measured only daily. Higher-resolution measurements can be used to determine whether the Airport 2 Well exhibits a delayed response to Heliport Production Well pumping (which may be indicative of unconfined conditions) or a near-instantaneous response to Heliport Production Well pumping (which may be indicative of confined conditions).

[7] CROO 53361, the Houston Lake Road Well.

[8] CROO 532, the Ryan Well.

[9] Based on water level declines in the Runway Well (0.6 foot per year) and the Linhares-Raasch Well (0.73 foot per year).

[10] Based on water level declines in Airport 2 Well (3.4 feet per year).

program of the aquifers in the Study Area. The results of the water level study and pumping tests were used to refine the understanding of the two aquifers and develop aquifer properties for each unit. The results are summarized in the *Groundwater Hydrology of the Prineville Airport Area Aquifer System – 2016 Update Report,* (GSI, 2016)

During the summer 2015 pumping, the City monitored water levels in the each of the two pumping wells and several other nearby water wells. As the cone of depression during the pumping test extended outward from the pumping well, it encountered the edge of the ancestral canyon (negative boundary), which was observed in the water level datasets with an abrupt change in the slope. This negative boundary (i.e., increased rate of drawdown with time) was encountered during the tests, likely related to the fact that both the Lower and Upper Aquifers are situated in an ancestral canyon[11]. Wellfield-scale aquifer properties from the tests are summarized in Table 1, and all aquifer testing results are presented in Appendix A.

Regional-Scale Aquifer Properties

Regional-scale aquifer properties are from the numerical groundwater model of the Study Area. The transmissivity of the Upper Aquifer was determined by matching model-simulated conditions to observed conditions based on testing of the Heliport Production Well in 2011 (GSI, 2013). The transmissivity of the Lower Aquifer was determined by matching model-simulated drawdown and observed drawdown in the Runway Well and Linhares-Raasch Well during the 2015 Millican Well pumping test (GSI, 2016). Regional-scale aquifer properties from the tests are summarized in Table 1, and all aquifer testing results are presented in Appendix A.

2.3.4 Estimated Groundwater Flow Direction and Velocity

The groundwater flow directions in the Lower Aquifer and Upper Aquifer mimic the slope of the ancestral canyon, flowing from south to north-northwest. The average linear velocity of groundwater in the Lower Aquifer and Upper Aquifer was calculated using Darcy's Law:

$$v = \frac{K}{\eta_e} \nabla h \tag{1}$$

where:

v = average linear groundwater velocity (feet per day or ft/d),
K = hydraulic conductivity (ft/d),
η_e = effective porosity (dimensionless), and
∇h = the horizontal hydraulic gradient (feet per foot or ft/ft).

The following sections summarize the assumptions that were used to calculate the average linear groundwater velocity in the Upper Aquifer and Lower Aquifer.

[11] See Appendix C of GSI (2016)

Lower Aquifer

The average linear groundwater velocity in the Lower Aquifer was estimated based on the following assumptions:

- Hydraulic conductivity is 570 ft/d (Table 1).
- The horizontal hydraulic gradient is 0.00136 ft/ft under ambient (non-pumping) conditions (from the numerical groundwater model of the Prineville area documented by GSI [2016]).
- The effective porosity of the basalt is 0.08 (based on the specific yield of a “young basalt” on Heath [1983, page 9]).

Using Equation (1), the average linear groundwater velocity in the Lower Aquifer under ambient (non-pumping) conditions is about 9.7 ft/d (3,537 feet per year).

Upper Aquifer

The average linear groundwater velocity in the Upper Aquifer was estimated based on the following assumptions:

- Hydraulic conductivity is 100 ft/d (Table 1).
- The horizontal hydraulic gradient is 0.00255 ft/ft under ambient (non-pumping) conditions (from the numerical groundwater model of the Prineville area documented by GSI [2016]).
- The effective porosity of the coarse sand and gravel is 0.185 (based on the specific yield measured during the Heliport Production Well aquifer test, see Table 1).

Using Equation (1), the average linear groundwater velocity in the Upper Aquifer under ambient (non-pumping) conditions is about 1.4 ft/d (about 503 feet per year).

2.3.5 Specific Capacity

Pumping rate and drawdown measurements can be used to calculate a hydraulic parameter called specific capacity, which reflects well performance and aquifer transmissivity, and is used to evaluate the ASR potential of an aquifer. Specific capacity (*SC*) is calculated by dividing the pumping rate (*Q*) by the drawdown (*s*) as follows:

$$SC = \frac{Q}{s} \tag{2}$$

where:

SC = specific capacity in gallons per minute per foot of drawdown (gpm/ft)
Q = the pumping rate in gallons per minute (gpm)
s = the drawdown in the well in feet (ft) at that pumping rate

The higher the specific capacity, the more productive the well and the higher the aquifer transmissivity. Although specific capacity varies with pumping rate, duration of pumping, and well construction, it is still a reasonable approximation of the aquifer response that is anticipated from recharge and recovery during ASR.

Specific capacities in the Study Area are shown in Figure 8. GSI included specific capacity data in Figure 8 if there was measureable drawdown during the test (i.e., several well tests in the Study Area report no drawdown during the test, but the lack of drawdown is likely caused by the pumping rate not being sufficiently high). Specific capacities at wells completed in the Upper Aquifer are 15 to 60 gpm/ft of water level change; specific capacities in the Lower Aquifer range from 1.5 to 3.0 gpm/ft of water level change. Specific capacities of sediments outside of the ancestral canyon are generally less than 1 gpm/ft of water level change.

2.4 Relative ASR Potential of the Upper Aquifer and Lower Aquifer

Based on the lower specific capacity and transmissivity of wells completed within the Lower Aquifer[12], it appears likely that the storage potential of the Upper Aquifer is substantially higher than the Lower Aquifer, and that the sediments outside of the ancestral canyon have no potential for ASR. As such, the remainder of this evaluation is focused on the water quality characteristics and storage potential of the Upper Aquifer. Additional exploration of the Lower Aquifer may be warranted as a location for supplemental groundwater storage as ASR pilot testing proceeds. Specifically, it may be possible to develop future ASR capacity within the Lower Aquifer near ASR wells targeting the Upper Aquifer to vertically “stack” groundwater storage that could leverage ASR infrastructure investments.

[12] The specific capacity of the Millican Well (CROO 53956) is 3.1 gpm/ft (based on 110 feet of drawdown observed while pumping the well at 340 gpm for 120 hours); the specific capacity of the Facebook Well (CROO 53878) is 1.52 gpm/ft (based on 223 feet of drawdown while pumping the well at 340 gpm for 120 hours).

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3 Source Water and Native Groundwater Quality and Compatibility

This section presents an evaluation of source water and native groundwater quality and compatibility in the Upper Aquifer based on groundwater quality samples[13]. GSI evaluates groundwater quality by comparing the concentration of groundwater constituents to regulatory standards (i.e., maximum contaminant levels [MCLs] and secondary MCLs [SMCLs]), and evaluates groundwater compatibility using the geochemical speciation model PHREEQC completed by subcontractor S.S. Papdopulous & Associates Inc., (refer to summary memorandum in Appendix C).

In summary, based on the water quality data available and the geochemical mixing evaluation completed, there are no detrimental water quality changes predicted to be caused by operations of an ASR system and the planned water treatment of the new alluvial source water for manganese, iron, and ammonia will minimize any small amount of potential precipitates within the aquifer that might occur without treatment of the water.

3.1 Native Groundwater

A sample of native groundwater was collected from the Heliport Production Well on June 1, 2017, and submitted to the Neilson Research Corporation in Medford, Oregon, for analysis. The sample was analyzed for the constituents required by the ASR administrative rules under OAR 690-350-0020(3)(b)(F), for constituents required for design of a wastewater treatment plant, and for constituents required for a geochemical mixing analysis. The laboratory analytical results are presented in Table 2, and laboratory analytical reports are provided in Appendix B.

3.1.1 Water Quality

Native groundwater at the Heliport Production Well is of good quality. The concentration of total dissolved solids (TDS; 198 milligrams per liter [mg/L]), which is a measure of inorganic salt and organic matter content of the water, is sufficiently low to be considered “excellent” by the World Health Organization (WHO, 1996). The water is considered moderately hard (97.5 mg/L hardness) (WHO, 2011) and has an alkalinity of 147 mg/L. The pH is slightly basic (about 8 standard units), the water is aerobic (dissolved oxygen of 7.93 mg/L), and the temperature is relatively warm (20 degrees Celsius [°C]). The water has no color, no odor, and is non-corrosive (Langelier Index, an indicator of the degree of saturation of calcium carbonate in water, is a near neutral -0.05).

Constituent concentrations were below the applicable drinking water regulatory criteria in the native groundwater (i.e., MCLs and SMCLs). Therefore, the native groundwater at the Heliport Production Well is suitable for use as drinking water.

[13] Required by OAR 690-350-0020(3)(b)(D), OAR 690-350-0020(3)(b)(F), and OAR 690-350-0020(3)(b)(G).

3.1.2 Mineral Stability

The geochemical speciation model PHREEQC was used to assess the equilibrium state of the native groundwater with respect to common minerals associated with basalt aquifers. The analysis is used to evaluate whether the water is undersaturated, supersaturated, or at equilibrium with respect to particular minerals. The saturation index (SI) is a measure of the chemical driving force available for mineral precipitation or dissolution reactions. Undersaturation (SI < 0) indicates a tendency for a mineral to dissolve into the water, if present in the subsurface. Supersaturation (SI > 0) indicates a tendency for a mineral to precipitate out of the water. At equilibrium, the water would not tend to either dissolve or precipitate the mineral. An understanding of the equilibrium state of a natural water provides insight on the geochemical controls on water composition and possible changes to expect when recharge water and native groundwater are mixed. The calculated SI values for common rock-forming minerals in the native groundwater samples are summarized in Appendix C.

The native groundwater is supersaturated (i.e., tendency to precipitate rather than dissolve) with respect to dolomite (SI=1.1), quartz (SI=1.3), and chalcedony (SI=1.0). Supersaturation with respect to these minerals is not uncommon and does not necessarily indicate that precipitation is occurring. Although these minerals have positive SI values, it is unlikely that quartz and chalcedony will precipitate because the precipitation kinetics are extremely slow at ambient temperatures. In addition, the precursor to quartz is amorphous silica, which has negative SI values. It is also unlikely that dolomite will precipitate because its precipitation is kinetically inhibited because of the large nucleation energy required to form new minerals. (SI values required for nucleation range from 1.3 to 2.5).

3.2 Source Water

Source water for the ASR project will be taken from the City's municipal conveyance system on the north side of the City and will be piped to the Heliport Production Well. The water in the City's conveyance system will be some combination of the following waters:

- **Groundwater from existing alluvial wells in the Prineville Valley.** The City holds water rights and produces groundwater from several alluvial wells in the Prineville Valley. The wells are completed in the Lower Sand and Gravel (QTs3). Because some of the alluvial wells are not connected to the City distribution system or are considered an emergency back-up well (e.g., 4th Street Shallow Well), only six of the City's existing wells connected to the City's conveyance system will be used to provide source water for ASR. These six wells are shown in Figure 9. The City collected a sample of groundwater from these wells on November 8, 2017 (called the "City Conveyance System" sample in Table 2 because the sample was collected from the conveyance system on the north side of the City).
- **Groundwater from a new alluvial wellfield.** The City plans to install a new groundwater wellfield in alluvial sediments adjacent to the Crooked River on the south side of the City (see Figure 9). The wells will be completed in the Upper Sand and Gravel (QTs1).

The City identified a shallow water-bearing zone and a deeper water-bearing zone during the wellfield investigation. As a result, the City will install both shallow wells (total depth of up to 40 feet bgs), and deeper alluvial wells (total depths up to 80 feet bgs) as part of this new wellfield.

Shallow Aquifer Test. The City installed a shallow test well at the future wellfield site and collected samples of shallow groundwater on each day of a 5-day aquifer test (five samples total). Samples collected on the first day of the aquifer test (January 18, 2018) and the last day of the aquifer test (January 23, 2018) were analyzed for a full suite of analytes. Groundwater samples collected on Day 2, Day 3, and Day 4 of the aquifer test were analyzed for anions and cations for geochemical analysis purposes.

Deep Alluvial Aquifer Test. The City installed a well in the deeper zone and collected samples of deep groundwater on each day of a 5-day aquifer test (five samples total). Samples collected on the first day of the aquifer test (on January 24, 2018) and on the last day of the aquifer test (on January 29, 2018) were analyzed for a full suite of analytes. Groundwater samples collected on Day 2, Day 3, and Day 4 of the aquifer test were analyzed for anions and cations for geochemical analysis purposes.

All water samples were submitted to Box R Water Analysis Laboratory (Prineville, Oregon) for analysis, and were analyzed for the constituents required by the ASR administrative rules under OAR 690-350-0020(3)(b)(D), for constituents required for design of a wastewater treatment plant, and for constituents required for geochemical mixing analysis. The laboratory analytical results are presented in Table 2.

3.2.1 Water Quality

The following sections discuss the quality of groundwater from the existing alluvial wells, and shallow and deep test wells (i.e., new alluvial groundwater source). Laboratory analytical reports are provided in Appendix B.

Existing Alluvial Wells

Groundwater from the City's distribution system is of good quality. The TDS concentration (237 mg/L), which is a measure of inorganic salt and organic matter content of the water, is sufficiently low to be considered "excellent" by the World Health Organization (WHO, 1996). The water is considered moderately hard (114 mg/L hardness) (WHO, 2011) and has an alkalinity of 173 mg/L. The pH is neutral (about 7.6 standard units), the water is aerobic (dissolved oxygen of 7.58 mg/L), and the temperature is relatively cool (14°C). The color of the water (10 color units [CUs]) is below the U.S. Environmental Protection Agency (EPA) SMCL of 15 CUs, and the odor (4 threshold odor numbers [TONs]) is slightly above the EPA SMCL of 3 TONs. Because the Langelier Index is positive (0.14), the water is noncorrosive.

With the exception of odor, constituent concentrations were below the applicable ASR standards for source water (i.e., the SMCL or one half of the MCL). Odor slightly exceeds the SMCL; however, the water is still suitable for ASR because slight odor exceedances are unlikely to result in odor exceedances in recovered water, and are unlikely to impair the beneficial use of native groundwater in the Heliport Production Well.

New Alluvial Source — Shallow Zone

The water quality analysis for the new shallow alluvial groundwater zone evaluates the quality of the Day 5 sample because it is more representative of source water quality during ASR. The TDS concentration in the new shallow groundwater source (not detected) is sufficiently low to be considered "excellent" by the World Health Organization (WHO, 1996). The water is considered moderately hard (129 mg/L hardness) (WHO, 2011) and has an alkalinity of 231 mg/L. The pH is neutral (about 7.7 standard units), the water is aerobic (dissolved oxygen of 8.6 mg/L), and the temperature is relatively cool (12°C). The color of the water (14 CUs) is below the EPA SMCL of 15 CUs, and the odor (17 TONs) is above the EPA SMCL of 3 TONs. Because the Langelier Index is positive (0.40), the water is noncorrosive.

With the exception of odor, turbidity, iron (total), and manganese (total), constituent concentrations were below the applicable ASR standards for source water (i.e., the SMCL or one half of the MCL). Source water treatment will be used to reduce odor, turbidity, iron (total), and manganese (total) to below ASR standards before recharge.

Toluene was detected in the Day 1 sample at a concentration of 0.94 microgram/liter (µg/L), but was not detected in the Day 5 sample. The Day 1 toluene concentration is below the ASR standard of 500 µg/L, but any toluene in source water would not be allowed under Oregon Department of Environmental Quality's (DEQ) groundwater protection rules because toluene would impair the beneficial use of groundwater as drinking water[14]. The toluene detection in the Day 1 sample likely is related to test well drilling because toluene was not detected in the Day 5 sample. However, GSI recommends that the City collect additional groundwater quality samples during treatment system pilot testing and wellfield installation for confirmation.

New Alluvial Source — Deep Zone

The water quality analysis for the new deep alluvial groundwater zone evaluates the quality of the Day 5 sample because it is more representative of source water quality during ASR. The TDS concentration in groundwater from the deep test well (238 mg/L) is sufficiently low to be considered "excellent" by the World Health Organization (WHO, 1996). The water is considered soft (51 mg/L hardness) (WHO, 2011) and has an alkalinity of 164 mg/L. The pH is slightly basic (about 8.3 standard units), the water is anaerobic (dissolved oxygen of 0.53 mg/L), and the temperature is relatively cool (13°C). The color of the water (12 CUs) was below the EPA SMCL of 15 CUs, and the odor (4 TONs) was slightly above the EPA SMCL of 3 TONs. Because the Langelier Index is positive (0.39), the water is noncorrosive.

With the exception of odor, constituent concentrations were below the applicable ASR standards for source water (i.e., the SMCL or one half of the MCL). Source water treatment will be used to reduce odor and address the elevated ammonia (which occurs at a relatively high concentration of 6.8 mg/L and could convert to nitrate).

Toluene was detected in the Day 1 sample at a concentration of 0.10 µg/L, but was not detected in the Day 5 sample. The Day 1 toluene concentration is below the ASR standard of

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[14] OAR 340-040-0020

500 µg/L, but any toluene in source water would not be allowed under DEQ's groundwater protection rules because the toluene would impair the beneficial use of groundwater as drinking water[15]. The toluene detection in the Day 1 sample likely is related to test well drilling because toluene was not detected in the Day 5 sample. However, GSI recommends that the City collect additional groundwater quality samples during wellfield installation for confirmation.

3.2.2 Mineral Stability

PHREEQC was used to assess the equilibrium state of the existing alluvial wells, new shallow alluvial source, and new deep alluvial source with respect to common minerals associated with alluvial aquifers. The analysis is used to evaluate whether the water is undersaturated, supersaturated, or at equilibrium with respect to particular minerals. The saturation index (SI) is a measure of the chemical driving force available for mineral precipitation or dissolution reactions (see Section 3.1.2).

Existing Alluvial Wells

The groundwater from existing alluvial wells is supersaturated (i.e., tendency to precipitate rather than dissolve) with respect to dolomite (SI=0.5), quartz (SI=1.1), chalcedony (SI=0.8), pyrolusite (SI=8.1), bixbyite (SI=7.7), and hausmannite (SI=4.7). Supersaturation with respect to these minerals is not uncommon and does not necessarily indicate that precipitation is occurring. Although these minerals have positive SI values, it is unlikely that quartz and chalcedony will precipitate because the precipitation kinetics are extremely slow at ambient temperatures. In addition, the precursor to quartz is amorphous silica, which has negative SI values. It is also unlikely that dolomite will precipitate because its precipitation is kinetically inhibited because of the large nucleation energy required to form new minerals. (SI values required for nucleation range from 1.3 to 2.5). The high positive values of iron and manganese minerals pyrolusite, bixbyite, and hausmannite indicate a potential for mineral precipitation and/or biofouling by iron-related bacteria in the ASR well, and for manganese precipitation. However, the amount of precipitate is likely to be small, and will be unlikely to cause clogging in the ASR well.

New Alluvial Sources – Shallow and Deep Zones

The groundwater from the deep and shallow new alluvial sources exhibit similar saturation indices. Both new alluvial sources are supersaturated (i.e., tendency to precipitate rather than dissolve) with respect to dolomite (SI=0.8 to 1.2), quartz (SI=1.1 to 1.2), chalcedony (SI=0.8 to 0.9), amorphous iron hydroxide (SI=3.2 to 4.2), goethite (SI=5.7 to 6.7), pyrolusite (SI=9.1 to 9.2), bixbyite (SI=9.6 to 10.0), and hausmannite (SI=7.4 to 8.4). Supersaturation with respect to these minerals is not uncommon and does not necessarily indicate that precipitation is occurring. Although these minerals have positive SI values, it is unlikely that quartz and chalcedony will precipitate because the precipitation kinetics are extremely slow at ambient temperatures. In addition, the precursor to quartz is amorphous silica, which has negative SI values. It is also unlikely that dolomite will precipitate because its precipitation is

[15] OAR 340-040-0020

kinetically inhibited because of the large nucleation energy required to form new minerals (SI values required for nucleation range from 1.3 to 2.5). The high positive values of iron and manganese minerals amorphous iron hydroxide, goethite, pyrolusite, bixbyite, and hausmannite indicate a potential for mineral precipitation and/or biofouling by iron-related bacteria in the ASR well, and for manganese precipitation. However, the amount of precipitate is likely to be small, and will be unlikely to cause clogging in the ASR well. In addition, water from the new alluvial sources will be treated prior to recharge, which will reduce the concentrations of iron and manganese (see Section 4.2).

3.3 Comparison of Native Groundwater and Source Water

Stiff diagrams and Piper plots are provided in Figure 10 and Figure 11, respectively. The water quality data that were used to create these diagrams are provided in Table 2 and Table 3.

These diagrams illustrate the chemical signatures and water types in terms of dominant ions for native groundwater and the source waters, and are commonly used to graphically compare the chemistry of water samples. As can be seen from the shape and size of the polygon on the Stiff diagram (Figure 10), the new alluvial source waters (both shallow and deep) are significantly more mineralized than the native groundwater and source water from existing alluvial wells. In addition, the mineral content of the new alluvial source waters (both shallow and deep) throughout the 5-day aquifer test was relatively consistent. Based on the Piper plot (Figure 11), the native groundwater and City conveyance source water are a bicarbonate type water; the new alluvial sources are sodium-bicarbonate type waters.

3.4 Compatibility of Native Groundwater and Source Water

PHREEQC was used to assess the equilibrium state of a mixture of native groundwater and each alluvial source water with respect to common minerals associated with basalt and alluvial aquifers. The assessment considered multiple mixing ratios (e.g., 10 percent native groundwater and 90 percent alluvial source water, 20 percent native groundwater and 80 percent alluvial source water, etc.). A memorandum documenting the results is provided in Appendix C.

Most mixtures of native groundwater and source water are supersaturated with respect to quartz, chalcedony, dolomite, and iron, and manganese minerals (i.e., the SI values of the mixed water for these minerals are greater than zero). Therefore, these minerals have a tendency to precipitate (rather than dissolve) in the mixed water. Supersaturation with respect to these minerals is not uncommon and does not necessarily indicate that precipitation is occurring. It is unlikely that quartz and chalcedony will precipitate because the precipitation kinetics are extremely slow at ambient temperatures. In addition, the precursor to quartz is amorphous silica, which has negative SI values. It is also unlikely that dolomite will precipitate because its precipitation is kinetically inhibited because of the large nucleation energy required to form new minerals (SI values required for nucleation range from 1.3 to 2.5). The high positive values of iron and manganese minerals amorphous iron hydroxide, goethite, pyrolusite, bixbyite, and hausmannite indicate a potential for mineral precipitation and/or biofouling by iron-related bacteria in the ASR well, and for manganese precipitation. However, the amount of precipitate is likely to be small, and will be unlikely to cause clogging in the ASR well. In addition, water from the new alluvial sources will be treated prior to recharge, which will reduce the concentrations of these iron and manganese minerals (see Section 4.2).

3.5 Water Quality and Compatibility Summary

Based on the water quality data available and the geochemical mixing evaluation completed, there are no detrimental water quality changes predicted to be caused by operations of an ASR system. The planned water treatment of the new alluvial source water for manganese, iron, and ammonia will minimize any small amount of potential iron and manganese precipitates that might occur without treatment of the water.

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4 Source Water Availability

This section documents the availability of source water for ASR, which is a required component of an application for an ASR limited license[16]. In the context of an ASR limited license, source water availability means that the City has a water right to appropriate the source water, and that the amount of source water the City can appropriate exceeds water demand (i.e., the City has excess water that can be used for ASR). The City plans to use the following waters for ASR source water:

- Groundwater from the City's existing alluvial wells completed in the Lower Sand and Gravel (QTs3) of the Quaternary alluvial deposit in the Prineville Valley.
- Groundwater from a new shallow alluvial wellfield currently under development at the south end of the City. These wells are completed in the Upper Sand and Gravel (QTs1) deposits.

The City's existing alluvial wells may provide most if not all of the ASR source water for the initial cycles of ASR, while the new alluvial wellfield is being installed and connected to the City's distribution system during the next couple years. However, after the new wellfield is completed, the existing alluvial wells are expected to comprise a relatively minor component of ASR source water.

The availability of source water from existing alluvial wells is documented by identifying the water rights for the wells, and by comparing the current average production from the wells to the maximum potential production. The availability of source water from the new alluvial wellfield is based on the process to be undertaken by the City to obtain a groundwater right for the wells, and by providing an overview of the preliminary aquifer testing results from pilot wells that have been drilled to estimate the yield and water quality of the wellfield.

4.1 Existing Alluvial Wells

The City owns and operates multiple water supply wells in the Prineville Valley to meet the community's water demands, shown in Table 4. Because several of the existing wells are not connected to the City distribution system or are considered an emergency back-up well (e.g., 4th Street Shallow Well), only six of the City's existing wells connected to the City's conveyance system will be used to provide source water for ASR, shown in Figure 9.

4.1.1 Water Rights

The water right certificates and permits that authorize appropriation of groundwater from the six existing alluvial wells in the Prineville Valley are summarized in Table 4. These water rights add up to 2,167 gpm (see "Authorized Rate" in Table 4). However, the amount of actual water supply produced by the wells is less due to limited well capacity at this time (about 1,350 gpm, see "Maximum Production Rate" in Table 4).

16 See OAR-690-350-0020(3)(a)(F)

4.1.2 Water Availability for ASR – Existing Alluvial Wells

The estimated amount of source water that is available for ASR from the existing alluvial wells is shown in Table 5, and was estimated on the basis of the following assumptions:

- The maximum total production from the six alluvial wells is 1.94 million gallons per day (mgd) (see "Maximum Production Rate" in Table 5). The maximum total production is based on City-provided production rates for each well.
- A portion the water that is produced is not available for ASR because it is needed to meet current average municipal water demand during the recharge period (estimated from November through March). The City's total production from November through March (151 days) from the wells that are connected to the municipal conveyance system in water year 2017 was 139.6 million gallons (MG), which equates to an average municipal demand during the recharge period of 0.92 mgd (Table 5).
- The water available for ASR from the City's existing municipal wells is the average municipal demand (0.92 mgd) subtracted from the maximum production rate (1.94 mgd), or 1.02 mgd.

Assuming that the City recharges water into the ASR well for 151 days, and 1.02 mgd of source water are available, the City's existing alluvial wells can supply a total of 154 MG for ASR each year. The estimate does not change significantly if production data from the 2015 or 2016 water year are used[17]. However, the City's existing alluvial water source is from a highly confined aquifer in Prineville valley that displays large seasonal water level fluctuations associated with the annual water demand cycles. During the high stress summer months, water levels in the Prineville valley aquifer drop, but during the winter months recharge to the aquifer is higher than the City's demands, allowing the water levels in the system to return to static conditions. Long-term additional pumping stress on this aquifer during the winter recharge period would likely upset this use and recharge balance. Therefore, this feasibility study also evaluated and identified a location in a different Prineville valley aquifer adjacent to the Crooked River for the ASR project source water that would be impact neutral.

4.2 New Shallow Alluvial Wellfield Source

The City is in the process of evaluating and planning a new alluvial wellfield that will be a new municipal water source. The new wellfield is located adjacent to the Crooked River in the southern part of the City (Figure 9) and will connect to the existing City water conveyance system. The City's goal for this new wellfield is for production of up to 2,000 gpm.

[17] Using production data from the 2015 water year, GSI estimated that 159 MG of source water are available for recharge. Using production data from the 2016 water year, GSI estimated that 165 MG of source water are available for recharge.

4.2.1 Shallow Alluvial Aquifer Evaluation

Site Investigation

In 2017, the City began actively researching locations for a new groundwater source to provide municipal water supply. Between October 2017 and January 2018 the City drilled exploratory borings to assess the subsurface geology at the identified site and installed wells for testing the aquifer. Test wells and observation wells were designed and installed on the basis of the following hydrogeologic units identified during drilling. This investigation and subsequent evaluation and documentation was completed by subcontractor Cascade Geoengineering LLC (CGE), and the full report summarizing this work is found in Appendix E. Below is a summary of CGE's investigation and results.

Shallow Water-Bearing Sand and Gravel Unit

The shallow water-bearing Sand and Gravel Unit extends from about 15 to 40 feet bgs; the static water level in the unit is about 5 feet bgs. The well network in the unit consists of:

- One test well
- Two observation wells (about 90 feet and 130 feet, respectively, from the pumping well)
- One existing shallow irrigation well (CROO 2218, about 310 feet from the pumping well)

Below the shallow water-bearing zone is a 5-foot-thick fine-grained silty/clayey layer separating the shallow zone from the deep sand and gravel water-bearing zone present from approximately 45 to 80 feet bgs.

Deep Water-Bearing Sand and Gravel Unit

The deep water-bearing Sand and Gravel Unit extends from 45 to 80 feet bgs; the static water level in the unit is about 2.5 feet bgs. The well network in the unit consists of:

- One test well
- Two observation well (about 430 feet and 950 feet, respectively, from the pumping well)

The static water levels in both water-bearing zones were identified during drilling as slightly higher than the top of the unit where water was first encountered and also continued to show this condition after the wells were completed. Water levels above the top of a water-bearing zone indicate confined or semi-confined conditions. The locations of the test and observation wells are shown in Figure 12, and the well logs for each of the new wells are included in Appendix D.

Aquifer Testing

A step-drawdown test and 5-day aquifer test were conducted on each water-bearing zone, with water level monitoring equipment in all of the new shallow and deeper alluvial wells, the existing irrigation well, and two of the City's production wells (4th Street Shallow and Deep Wells) located approximately 3,400 feet north of the test wells. The following are specifics about of the 5-day aquifer test developed by CGE:

Shallow Zone Aquifer Test (zero to 40 feet bgs)

Start 10:00 a.m. 1/18/2018
Stop 10:30 a.m. 1/23/2018
Pumping Rate = 87 gpm

Deeper Zone Aquifer Test (45 to 80 feet bgs)

Start 10:05 a.m. 1/24/2018
Stop 10:45 a.m. 1/29/2018
Pumping Rate = 102 gpm

Plots of water level drawdown versus time in the pumping wells and observation wells are provided in Appendix E. A positive boundary was encountered in the pumping wells during the shallow zone and deep zone aquifer tests[18], indicating that the cone of depression from the pumping encountered a recharge source. When a single boundary is encountered during an aquifer test, aquifer properties before the boundary are called "early-time," and aquifer properties after the boundary are called "late time." Cascade Geoengineering, LLC, calculated both the early-time and late-time transmissivity and a transmissivity for each water-bearing zone by averaging the early-time and late-time transmissivities at the pumping wells. The transmissivities are provided in Table 6.

New Alluvial Wellfield

Based on the 5-day aquifer tests of the shallow and deep Sand and Gravel Units, CGE estimated individual wells can produce up to 100 gpm and, if spaced properly, will have minimal interference with one another when operating. Based on the aquifer testing results, the wellfield design concept, at full build out, includes 10 shallow wells drilled to a maximum of 40 feet deep, and 10 deeper wells drilled and screened from 80 to 140 feet deep. The preliminary layout of the wells is shown in Figure 13, and consists of a well spacing of 100 feet (for wells completed in the same zone). The water from the new wellfield will be piped to a central location where it will undergo an appropriate level of treatment and disinfection before being added to the City's conveyance system. The City anticipates completing construction of the wells in the wellfield in phases to allow the flexibility of adding more capacity to meet City demands as needed.

It is recommended that during the future wellfield design stage of the project a more detailed evaluation of the existing data and interference analysis, and the any additional data and analyses are used to develop the final wellfield spacing and configuration.

Water Treatment for New Alluvial Source – Wellfield

Based on the results of the 5-day pump test samples for both the shallow and deep wells, water treatment will be required for the manganese, ammonia, and odor. Treatment for manganese also will treat any elevated iron in the new source. Based on an equal number of shallow and deep wells, the blended water concentrations for manganese and ammonia are calculated in Table 7.

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[18] The boundary is not apparent at monitoring wells because drawdown at monitoring wells was plotted on arithmetic axes.

The blended manganese concentration is nearly twice the SMCL and the ammonia concentration would exert a free chlorine demand of nearly 50 mg/L if it were not removed. The processes that could be used for removing ammonia and manganese include:

- Aeration, biological filtration, chlorination, and manganese dioxide filtration
- Biological denitrification, aeration, chlorination, and manganese dioxide filtration
- Aeration, biological filtration, anion exchange, chlorination, and manganese dioxide filtration
- Clinoptilolite adsorption, chlorination, and manganese dioxide filtration
- Low pressure nanofiltration or RO membrane

An evaluation of these options will be provided in the basis of design report for the wellfield by JACOBS Consultancy. That document has been completed and supplied to the project team under a separate cover (Jacobs 2018).

In addition, it is recommended that treatment pilot testing is conducted on the new alluvial source to both confirm the high concentration of ammonia in the deep well, given that it is significantly higher than the Total Kjeldahl nitrogen level measured in the same sample, and refine the currently conservatively designed treatment system. It is anticipated that a pilot test will pump water from both wells for several weeks to better understand the aquifer water quality patterns over time and test the effectiveness of various treatment configurations.

4.2.2 Water Rights

The City is in the preliminary stages of developing an application for a groundwater permit authorizing the use of up to 2,000 gpm from the new wellfield for municipal use. As required by OWRD's Deschutes Basin Groundwater Mitigation Program, the City's new groundwater permit will require the submittal of groundwater mitigation credits prior to a permit being issued by OWRD. The City is in the process of establishing 5,100 mitigation credits from the U.S. Bureau of Reclamation's application S-55091 (the release of 5,100 acre-feet of stored water annually from Prineville Reservoir for downstream fish life and wildlife use). The City will use a portion of these new mitigation credits to secure the new groundwater permit from OWRD. Once the application is submitted, OWRD is expected to process the City's water rights application in 12 to 18 months.

4.2.3 Water Availability for ASR – New Alluvial Wellfield

Based on the drilling and testing investigations, the City's new wellfield is being designed for production of up to 2,000 gpm. The estimated amount of source water that is available for ASR recharge from the new wellfield source is estimated on the basis of following assumptions:

- The City's existing production capacity from the existing alluvial wells is capable of meeting the average municipal demand during the recharge period based on 2015 through 2017 water use data.

- The full production rate (up to 2,000 gpm) from the new wellfield during the recharge period (November 1 through March 31) is available for use as a source of water for ASR, further assuming the City obtains its 5,100 mitigation credits and OWRD approves the permit application for 2,000.

Assuming that the City recharges the ASR well for 151 days, and 2.88 mgd (2,000 gpm) of source water are available, the City's new wellfield source can supply a total of 435 MG for ASR recharge each year.

5 ASR Feasibility Evaluation

This section presents an evaluation of the feasibility of ASR in the Upper Aquifer. ASR feasibility in the Upper Aquifer is focused on using the Heliport Production Well as the ASR well, and considers the following key factors: aquifer properties, performance of existing wells, depth to groundwater, volume of water that can be stored, potential adverse impacts to nearby wells (i.e., unacceptable water level buildup), potential for movement of stored water (to streams or other wells), well construction considerations, and source and receiving water quality and compatibility. Based on those criteria, GSI determined the feasibility of ASR in the Upper Aquifer using the Heliport Production Well as the ASR well.

5.1 Transmissivity, Storage, and Boundaries

Transmissivity, storativity, and boundaries are important aquifer characteristics for assessing the feasibility of ASR at a particular location. Transmissivity indicates whether the aquifer can readily accept ASR source water. Storage and transmissivity indicate whether there will be a large increase or decrease in water levels in response to recharge or recovery. Boundary conditions may limit the volume of water than can be stored in an aquifer. Together these parameters are used to predict the effects of ASR recharge, and to predict water level buildup during recharge and subsequent drawdown during recovery of the ASR stored water. The following sections evaluate whether transmissivity, storage, and boundaries are favorable to ASR in the Upper Aquifer.

5.1.1 Transmissivity

The transmissivities in the Upper Aquifer range from 94,250 gpd/ft (regional-scale) to 40,000 gpd/ft (late-time, wellfield-scale) and are shown in Table 1. To evaluate ASR feasibility with respect to transmissivity both locally in the Heliport Production Well and regionally in the Upper Aquifer, GSI compared the transmissivity of the Upper Aquifer to the transmissivity of the only sedimentary aquifer in Oregon that hosts an ASR system (i.e., the Troutdale Sandstone Aquifer)[19]. The regional- and wellfield-scale transmissivity of the Upper Aquifer is an order of magnitude larger than the transmissivity in the Troutdale Sandstone Aquifer (GSI, 2006), which hosts wells capable of recharging at 550 gpm. Therefore, given the comparatively high transmissivity of the Upper Aquifer, it appears favorable to ASR at the Heliport Production Well (wellfield-scale) and throughout the Study Area (regional-scale).

5.1.2 Storage

Storage is the volume of water an aquifer releases from, or takes into, storage per unit surface area of the aquifer per unit change in head, and is called specific yield for unconfined aquifers and storativity for confined aquifers. The aquifer storage in the Upper Aquifer ranges from 0.02 (regional-scale) to 0.23 (late-time, wellfield-scale). The relatively high storage of the Upper Aquifer indicates that water level rise in response to recharge will be

[19] The Sunrise Water Authority, located southeast of Portland, Oregon, stores water in the Troutdale Sandstone Aquifer, which consists of unconsolidated to consolidated sands.

small in areal extent, which is favorable to ASR both throughout the Study Area (regional-scale) and at the Heliport Production Well (wellfield-scale).

5.1.3 Boundaries

Negative boundaries may indicate compartmentalization of an aquifer, potentially limiting the volume of water that can be stored in the aquifer. Aquifer tests conducted in 2015 at the Heliport Production Well indicated that negative boundaries are present in the Upper Aquifer (see Appendix C of GSI [2016]), which indicates potential compartmentalization of the aquifer. However, two lines of evidence indicate that any compartments are very large and, therefore, capable of storing a large volume of water. First, the boundaries were observed long after pumping started (about 12 days after pumping started in the Upper Aquifer). Second, there is no geologic evidence for the Upper Aquifer being characterized by small-scale compartments. Specifically, no faults or other barriers to groundwater flow are evident in the Upper Aquifer based on existing geologic maps of the Study Area (see Figure 2 and Figure 5).

Based on the areal extent of the Upper Aquifer shown in Figure 5, GSI estimated that the saturated volume of the Upper Aquifer is 4.9 billion cubic feet (about 37 billion gallons)[20]. This is an order-of-magnitude estimate of saturated aquifer volume, but indicates that the Upper Aquifer is large and, therefore, favorable to storing a large volume of water using ASR.

5.2 Well Performance

In locations where detailed aquifer testing is not available, aquifer favorability for ASR can be approximated using specific capacity tests documented on OWRD well logs (see Section 2.3.5 for an in-depth discussion of specific capacity). The higher the specific capacity, the more water that can be recharged into the well. Specific capacities in the Upper Aquifer are shown in Figure 8. Specific capacity data were included in Figure 8 if there was measureable drawdown during the test (i.e., several well tests in the Study Area reported no drawdown during the test, but the lack of drawdown is likely due to the pumping rate not being sufficiently high). Specific capacities at wells completed in the Upper Aquifer are 15 to 60 gpm/ft, and indicate that the Upper Aquifer is favorable to ASR.

5.3 Depth to Groundwater

Another characteristic used to asses ASR feasibility is the depth to groundwater within the Upper Aquifer. The primary purpose of assessing depth to groundwater is based on a preference to conduct ASR recharge without groundwater levels in the aquifer rising above the ground surface. If groundwater levels rise above ground surface, then recharge will occur under pressure. Although maintaining groundwater levels below ground surface during ASR recharge is not a necessity (many ASR projects around the world conduct recharge under pressure), recharge under pressure requires upgrades to seal the wellhead and increases the potential for inducing flowing conditions at nearby wells, and is therefore a less preferable

[20] Based on an aerial extent of 133,500,000 square feet, thickness of 132 feet porosity of 0.275 [midrange of a “sand and gravel, mixed” from Table 4.3 of Fetter (1994)].

option than maintaining groundwater levels below ground surface. Therefore, although not a critical feasibility element, depth to groundwater should be considered when siting ASR wells and evaluating ASR feasibility.

The deep groundwater table in the Upper Aquifer is favorable to ASR. At the Heliport Production Well, the groundwater table is at 435 feet bgs[21], and in the Upper Aquifer, the groundwater table ranges from 358 feet bgs[22] to 448 feet bgs[23]. The deep groundwater table, together with the high specific capacity of Upper Aquifer, indicates that large volumes of water could be recharged in the Study Area without raising the groundwater level at the ASR well above ground surface.

5.4 ASR Storage and Recovery Volumes

The volume of water that can be stored at an ASR well depends on several factors, including the length of time that water can be recharged into the well, the amount of source water that is available, the ASR well production rate, specific capacity, and available buildup in the aquifer. GSI's estimates of ASR annual storage and recovery volumes are based on the following assumptions:

- Recharge will be conducted with groundwater levels in the ASR well remaining below ground surface.
- Ninety-five percent of the stored water is available for recovery, which is the maximum percentage of stored water that OWRD will allow an applicant to initially recover under an ASR limited license. OWRD sets this percentage based on project specific information, so the recovery volume may be lower (or higher) than the assumed 95 percent used in this analysis.
- The City will recharge water continuously from November 1 through March 31 of each year.
- Recharge will occur at a rate that is approximately 75 percent of the maximum production rate during recovery, which is standard practice to ensure the ability to impart more energy during ASR recovery as a means to reduce the potential for long-term well clogging.

Based on the characteristics of the aquifers in the Study Area, the limiting factor for storage volume appears to be the maximum well production rate. Specifically, water could be recharged into the Upper Aquifer at several thousand gpm based only on source water availability[24] and well performance[25]. However, given that the recharge rate is recommended

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[21] See the driller log for CROO 54191. Measured on November 28, 2014.

[22] CROO 53361, the Houston Lake Road Well.

[23] CROO 532, the Ryan Well.

[24] As discussed in Section 4, the City's existing alluvial wells can provide about 154 MG of source water (708 gpm continuously for 151 days), and in addition, the City expects to develop a new groundwater right for up to 1,051 MG of source water (the City expects the new wells to produce 2,000 gpm; water produced from the new well will be used for municipal supply and ASR).

[25] Based on a 120-hour pumping test documented on the well log for the Heliport Production Well (CROO 54191), 26 feet of drawdown were observed at a pumping rate of 780 gpm, for a specific capacity of 30 gpm/ft. Assuming 415 feet of available headroom for water levels to rise in the well (a static depth to water of 435 feet and safety factor of 20 feet), water could be

to be no more than 75 percent of the maximum production rate (1,100 gpm at the Heliport Production Well), the maximum production rate becomes the limiting factor defining the maximum rate that water can be recharged into the Upper Aquifer. GSI developed planning-level estimates of the storage volume and recovery volume under a baseline condition using the existing Heliport Production Well configuration, and two additional scenarios that involved recharge at 2,000 gpm and 4,000 gpm using a series of hypothetical new wells. The following sections discuss the storage and recovery volumes in the Upper Aquifer under these three scenarios.

Baseline ASR Scenario

The baseline scenario includes implementing ASR using the Heliport Production Well's existing pumping rate. The Heliport Production Well produces 1,100 gpm under this scenario, based on the well yield during the summer of 2015 (GSI, 2016). Based on setting the maximum recharge rate to 75 percent of the Heliport Production Well's pumping rate of 1,100 gpm, the maximum recharge rate in the Heliport Production Well is 825 gpm. Assuming a recharge rate of 825 gpm and a recharge period of 151 days (November 1-March 31), **GSI estimates that 179 MG can be stored in the Upper Aquifer using the Heliport Production Well as the ASR well.** Because the City's ASR limited license potentially will authorize the City to recover up to a maximum of 95 percent of this volume, 170 MG of the water that is stored was assumed to be available for recovery. Storage and recovery volumes are summarized in Table 8.

This planning-level estimate of the storage capacity of the Heliport Production Well is based on historical operation of the well, and will need to be confirmed as a part of additional assessment work on the production well (i.e., potential down-hole video and bacteriological sampling), groundwater elevation analysis, and data obtained from the Cycle 1 pilot testing results.

Additional Upper Aquifer Storage Capacity Evaluation

Based on the results of the baseline ASR scenario, the Upper Aquifer likely has the capacity to store a significant volume of water because the depth to groundwater and specific capacity of the Upper Aquifer are high (indicating that water can be recharged at a high rate with relatively little buildup in the ASR well). Therefore, this study evaluated potential ASR programs that store water under two additional scenarios.

- **Scenario 1.** Recharge water into the Upper Aquifer at 2,000 gpm using a total of two ASR wells (i.e., the Heliport Production Well and one additional hypothetical well that is completed the same as Heliport Production Well and has the same local aquifer conditions). Each well recharges groundwater at 1,000 gpm and recovers stored water at 1,100 gpm. Although this scenario assumes recharge at a rate higher than the recommended 75 percent of recovery rate, it is conservative with regard to

recharged into the Heliport Production Well at a rate of several thousand gallons per minute (because the recharge rate is found by multiplying 415 feet of available headroom by 30 gpm/ft).

potential response to recharge and recovery (because the water is recharged using fewer wells), and was selected to simplify the modeling process.

- **Scenario 2.** Recharge water into the Upper Aquifer at 4,000 gpm using a total of five ASR wells (i.e., the Heliport Production Well and four additional hypothetical wells that are completed the same as Heliport Production Well and have the same local aquifer conditions). Each well recharges groundwater at 800 gpm and recovers stored water at 1,100 gpm.

Results of the additional Upper Aquifer storage capacity evaluation are summarized in Table 8. Neither scenario results in groundwater levels rising above ground surface (i.e., both scenarios are feasible from the perspectives of the Upper Aquifer's ability to accept the recharge without adverse effects to other wells). **Under Scenario 1, GSI estimates that 434 MG can be stored in the Upper Aquifer (a storage volume of 217 MG per well)**; 412 MG can be recovered assuming OWRD allows the City to recover 95 percent of the storage volume. **Under Scenario 2, GSI estimates that 870 MG can be stored in the Upper Aquifer (174 MG per well)**; 827 MG can be recovered assuming OWRD allows the City to recover 95 percent of the storage volume.

The additional Upper Aquifer storage capacity evaluation is a planning-level estimate of the storage capacity of the Upper Aquifer based on historical operation of the Heliport Production Well. These storage volumes will need to be confirmed following additional assessment work and data obtained from the Cycle 1 pilot testing results. An evaluation of the water level rise and drawdown under each of these three scenarios is described in Section 5.5.

Heliport Production Well Current Operations

Since the Heliport Production Well began operating in 2015, the well has produced groundwater at a rate of approximately 1,100 gpm. As shown in Figure 6, pumping at 1,100 gpm in 2016 and 2017 caused the water level in the Heliport Production Well to be drawn down into the upper portion of the 135-foot-long well screen. Although this is a complex topic with multiple potential sources for a declining pumping water level as has been observed, lowering the water level into the screen interval could lead to the following undesirable conditions:

- Increased oxygenation in both the water column and in the aquifer near the well can enhance biological activity in well and in the vicinity of the well. This may create water quality problems, screen clogging, and an accelerated decline in well performance.
- Potential for acceleration of encrustation build up.
- Cascading water and air-entrainment can increase pump wear and limit pumping system efficiency.
- Increased flow velocity in the remaining open area of the well screen could cause increased drawdown due to turbulent well losses if entrance velocities are significantly exceeded.

Exposing the well screen in an ASR well adds a layer of additional risk due to possible bacterial growth problems that needs to be properly monitored and addressed, if necessary. Experience has shown that sometimes these risks can quickly contribute to negatively impact the ASR program (declines in well production and recharge capacity). Because bacterial testing of ASR wells is a standard procedure in all ASR systems with wellhead retrofits, GSI recommends that this testing be completed on the Heliport Production Well prior to the well's startup and regular use in the spring of 2018. Following bacterial sampling testing and evaluation of the results, the project team will re-assess the final design of the ASR system retrofit plans.

In addition, it was noticed that there is a potential decline in the Heliport Production Well performance since beginning operation in 2015 for unknown reasons. ASR systems potentially can affect well performance in both a negative or positive manner. Regular evaluations and well maintenance practices can manage any potential issues resulting from well performance declines well screen exposure or other causes.

Because projections about ASR capabilities have been made from the existing dataset, the Heliport Production Well's performance will need to be carefully monitored through the pilot testing cycles to determine if well performance issues (declines) might impact the ASR program objectives.

5.5 Potential Impacts to Nearby Wells

ASR recharge and recovery will cause groundwater elevations in the Study Area to change, which has the potential to adversely impact other wells in the Study Area. Potential impacts to wells were evaluated by predicting groundwater level changes in the Study Area caused by ASR using two different approaches:

- A numerical groundwater model that simulates groundwater flow in the Prineville area (GSI, 2011; GSI, 2016)[26]
- An analytical equation derived from Cooper and Jacob (1946) and Jacob (1944)

The approaches provide different predictions of groundwater level changes because the numerical model is based on regional-scale aquifer properties and the analytical equation is based on wellfield-scale aquifer properties. Together, the numerical model and analytical equation help to bracket the potential range of groundwater level changes in response to ASR.

The numerical model simulated 10 years of ASR operation; GSI used the maximum drawdown and buildup observed during the 10-year simulation as the predicted water level change. The analytical equation simulated a recharge period and a recovery period; GSI used the buildup at the end of the recharge period (151 days of recharge) and drawdown at the end of the recovery period *and* pumping under the City's native groundwater right

[26] The USGS finite difference, block-centered groundwater flow code MODFLOW-2005.

through the end of October (May 1 through October 31; 184 days of pumping) for the predicted water level changes.

Water level predictions based on groundwater models and analytical equations do not account for the ASR well inefficiencies. Based on the 2015 summer pumping season aquifer evaluations, GSI estimated that the Heliport Production Well has an efficiency of 59 percent. The water level changes in the ASR well were adjusted for this well inefficiency to more accurately predict build up and drawdown in the ASR well. These calculations should be reassessed following collection and analysis of data from the Year 1 pilot testing program. The following sections present GSI's analysis of potential impacts to nearby wells under the baseline ASR scenario and the additional storage capacity evaluation scenarios.

Baseline ASR Scenario

The baseline ASR scenario is the same as described in Section 5.4 with the following additional assumptions:

- Aquifer properties in the numerical model are presented in Section 2 (see "Regional Scale" properties of the Upper and Lower Aquifer in Table 1).
- Aquifer properties in the analytical equation were determined on the basis of the late-time response of the Airport 2 Well during the Heliport Production Well pumping test (see "Wellfield Scale" properties for the Upper Aquifer in Table 1)[27]. Using late-time aquifer properties is conservative (because late-time transmissivity is lower than early-time transmissivity) and is representative of aquifer response to long-term pumping that will occur during ASR)[28].

Predicted water level changes in response to ASR in the Study Area are provided in Table 9. Wells completed in the Lower Aquifer are not shown in Table 9 because the numerical model predicted no water level change in the Lower Aquifer in response to ASR. The numerical groundwater model predicts smaller buildup and drawdown than the analytical equation, which is the result of higher transmissivities in the model. Note that the analytical equation cannot compute drawdowns of less than 9.53 feet during recharge and 12.7 feet during recovery due to assumptions that are required for use of the analytical equation[29].

The water level buildups in Table 9 do not indicate adverse impacts to nearby wells as a result of ASR recharge because the buildup does not exceed the ground surface within the Study Area (see Section 5.3). Therefore, the predicted water level buildups in the Study Area

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27 The properties of the Upper Aquifer in the analytical model (hydraulic conductivity and specific yield) are based on early-time drawdown and late-time recovery in the Airport 2 Well during the Heliport Production Well pumping test (early-time drawdown data and late-time recovery data reflect conditions near the well).

28 Because the analytical equation only estimates drawdown in a single aquifer, the Lower Aquifer properties are not variables in the equation.

29 The Cooper Jacob equation requires that the ratio $\frac{r^2S}{4Tt}$ is less than 0.01 (Freeze and Cherry, 1979). When this requirement is violated, the equation cannot accurately predict drawdown. During recharge, the ratio exceeds 0.01 when build-up is less than 9.53 feet (i.e., at a radius of 375 feet from the Heliport Production Well). During recovery, the ratio exceeds 0.01 when drawdown is less than 12.7 feet (i.e., at a radius of 413 feet from the Heliport Production Well).

are favorable to ASR. With the exception of the Heliport Production Well, the water level drawdowns in Table 9 are small (i.e., drawdowns in vicinity pumping wells are less than 10 percent of the thickness of the Upper Aquifer)[30]. Therefore, the predicted water level drawdowns in the Study Area are favorable to ASR.

Additional Storage Capacity Evaluation Scenarios

The additional storage capacity evaluation using the previously described Scenarios 1 (injection of 2,000 gpm) and Scenarios 2 (injection of 4,000 gpm) were conducted using only the numerical groundwater model because application of the analytical equation becomes more complex when more than one ASR well is used.

Predicted water level changes in response to ASR at the Heliport Production Well under the two additional storage scenarios (recharge rates at 2,000 and 4,000 gpm, respectively) are shown in Table 10. The water level buildups in Table 10 do not indicate adverse impacts to nearby wells as a result of ASR recharge because the buildup does not exceed the ground surface within the Study Area (see Section 5.3). Therefore, the predicted water level buildups in the Study Area are favorable to ASR. With the exception of the Heliport Production Well, the water level drawdowns in Table 10 are small (i.e., drawdowns in vicinity pumping wells are less than 10 percent of the thickness of the Upper Aquifer)[31]. Therefore, the predicted water level drawdowns in the Study Area are favorable to ASR.

5.6 Affected Area by ASR and Potential Movement of Stored Water

This section summarizes the area affected by ASR operations at the Heliport Production Well under the baseline ASR conditions and presents an evaluation of the net movement of the stored water within the aquifer. The area affected by the City's ASR well was estimated using the Theis equation to calculate the areal extent of buildup (mounding) in the Upper Aquifer as a result of recharge:

$$s = \frac{Q}{4\pi T} * W(u) \qquad u = \frac{r^2 S}{4Tt} \qquad (3)$$

s = mounding (feet)
Q = injection rate (ft3/day)
T = transmissivity (ft2/d)
t = time (days)
r = radial distance from the well with a mounding of s (feet)
S = storativity (dimensionless)

The areal extent of mounding (i.e., area affected by the ASR well) was defined as the portion of the Upper Aquifer that experiences more than 1.0 feet of water level rise during ASR cycle testing. Assuming T = 40,000 gpd/ft (5,347 ft2/day), Q= 825 gpm (158,812 ft3/day), t= 151 days, s = 1.0 feet, and S= 0.23, GSI calculated that the areal extent of mounding (i.e., the area

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[30] The thickness of the Upper Aquifer is 126 feet (see Table 1). The maximum drawdown at a pumping well is less than 11.6 feet and occurs in the Airport 1 and Airport 2 Wells.

[31] The thickness of the Upper Aquifer is 126 feet (see Table 1). The maximum drawdown at a pumping well is less than 1 foot and occurs in the Airport 1 and Airport 2 Wells.

affected by the injection from a single ASR well) is approximately 3,000 feet radially from the well. Because the Upper Aquifer is a narrow ancestral channel deposit with clear lateral boundaries, the ASR affected radius may encounter this boundary and affect the overall shape of the area of influence, but is not expected to propagate beyond that boundary.

Using the affected area distance, the net movement of the stored water during a yearly ASR cycle is presented below. Conceptually, there is a low potential for the stored water not to be recovered because the City plans to pump groundwater at a higher rate and for a longer duration (using the City's native groundwater rights) during recovery than during recharge. GSI verified this concept by estimating the distances that recharged water travels using the average linear groundwater velocity equation [Equation (1) in Section 2.3.4].

- **Recharge (825 gpm for 151 days).** During the 151-day recharge period, GSI estimated that recharged water should migrate no more than 351 feet downgradient from the ASR well[32].
- **Storage (30 days).** During the 30-day storage period, GSI estimated that stored water that is downgradient of the ASR well should migrate an additional 42 feet away from the ASR well[33].
- **Recovery (1,100 gpm for 183 days).** During the 183-day recovery period, GSI estimated that the stored water should migrate up to 525 feet back toward the ASR well[34].

The distance that water will migrate away from the ASR well during recharge and storage (351 feet during recharge plus an additional 42 feet during storage, for a total of 393 feet) is less than the distance that water will migrate back toward the ASR well during recovery (525 feet).

Based on this analysis, significant overall movement or loss of stored water is not anticipated.

5.7 Well Construction Considerations

The ASR well must meet current well construction standards in the OARs to be authorized by OWRD for ASR use, and must be able to be retrofit for ASR purposes. GSI reviewed the construction of the Heliport Production Well (as reported on well log CROO 54191) to evaluate whether well construction was favorable for use as an ASR well.

- **Well Seal.** The Heliport Production Well is sealed to a depth of 482 feet bgs with cement and bentonite, in between the 18-inch-diameter production casing and 22-inch-diameter borehole wall (i.e., 4-inch seal thickness). This meets the requirements of OAR 690-210-150.

[32] Based on a horizontal hydraulic gradient of 0.01273 during recharge [calculated using the Cooper Jacob equation, recharging at 825 gpm after 151 days, and using late-time transmissivity and storage (see Table 1)].

[33] Based on the ambient groundwater velocity in the Upper Aquifer of 1.4 ft/day (see Section 2.3.4).

[34] Based on a horizontal hydraulic gradient of 0.01573 during recovery [calculated using the Cooper Jacob equation, recharging at 1,100 gpm after 183 days, and using late-time transmissivity and storage (see Table 1)].

- **Well Casing.** The Heliport Production Well is cased to a depth of 482 feet bgs with 18-inch-diameter, 0.375-inch gauge steel welded casing, which meets the requirements of OAR 690-210-0190(3) for well casing.
- **Well Liner.** The Heliport Production Well is lined from 422 to 452 feet bgs and from 572 to 597 feet bgs with 16-inch-diameter, 0.375-inch gauge steel welded pipe, which meets the requirements of OAR-210-0290 for liner pipe.
- **Well Diameter.** The Heliport Production Well is constructed of 18-inch-diameter production casing and a 16-inch-diameter liner. These diameters should be sufficiently large to accommodate downhole flow control valves, pump, and polyvinyl chloride (PVC) drop tubes that are required to operate a 1,100-gpm ASR well.

In summary, the Heliport Production Well has a sufficiently large diameter to be retrofit as an ASR well, and meets current OAR water well construction standards. Therefore, the Heliport Production Well is suitable for ASR purposes.

5.8 Source and Receiving Water Quality and Compatibility

Most mixtures of native groundwater and source water are supersaturated with respect to quartz, chalcedony, dolomite, iron, and manganese minerals. Therefore, these minerals have a tendency to precipitate (rather than dissolve) in the mixed water. However, supersaturation with respect to these minerals is not uncommon and does not necessarily indicate that precipitation is occurring. It is unlikely that quartz and chalcedony will precipitate because the precipitation kinetics are extremely slow at ambient temperatures. In addition, the precursor to quartz is amorphous silica, which has negative SI values. It is also unlikely that dolomite will precipitate because its precipitation is kinetically inhibited due to the large nucleation energy required to form new minerals. The high positive values of iron and manganese minerals (amorphous iron hydroxide, goethite, pyrolusite, bixbyite, and hausmannite) indicate a potential for mineral precipitation and/or biofouling by iron-related bacteria in the ASR well, and for manganese precipitation. However, the amount of precipitate is likely to be small, and will be unlikely to cause clogging in the ASR well. In addition, water from the new alluvial sources will be treated before recharge, which will reduce the concentrations of these iron and manganese minerals (see Section 4.2). Therefore, source and receiving water quality and compatibility are favorable to ASR.

6 Permitting Requirements

This section presents a summary of the permits, licenses, and certifications that are required for the ASR project as conceptualized in March 2018. The objectives of the summary are to identify the permits that the state of Oregon requires, and describe the key elements of each permit. The ASR project will require source water rights from OWRD, a design review from the Oregon Health Authority (OHA), an underground injection control (UIC) authorization from DEQ, and an ASR limited license from OWRD. The need for other permits, licenses, or certifications beyond those described in this section may become apparent as the ASR project details are finalized.

6.1 Source Water Rights

OWRD requires that the City hold a water right to appropriate the source water that will be recharged into the ASR well. The following sections describe water rights permitting for the two source waters that the City will use: (1) groundwater from existing alluvial wells in the Prineville Valley and (2) groundwater from a new alluvial wellfield on the south side of the City.

6.1.1 Groundwater from Existing Alluvial Wells

The existing alluvial wells that will supply source water for the ASR project are shown in Table 4 and Figure 9. The City holds one water right permit and five water right certificates to appropriate water from the wells. The City does not need to obtain any new water rights, or make any modifications to the existing water rights to use groundwater from these existing alluvial wells for ASR source water.

6.1.2 Groundwater from the City's New Municipal Source

The City is developing a new municipal water source located in the southern part of the City, shown in Figure 9 and Figure 13. The City plans to develop groundwater from the shallow alluvial system through a wellfield consisting of up to 20 wells, which in combination will produce up to 2,000 gpm total. Use of the new source for municipal use and as an ASR source water requires a groundwater permit from OWRD (as previously discussed) and a design review from OHA.

6.2 Native Groundwater Right for the Upper Aquifer

The City plans to continue pumping native groundwater from the Heliport Production Well and recovering the stored water volume permitted under the ASR limited license. The City currently has water rights to appropriate up to 1,770 gpm of native groundwater from the City's existing groundwater wells in the plateau area under Permits G-17089 and G-17236.

6.3 OHA Design Review

OHA must review and approve wellhead modifications and any proposed new wells that will provide water for community water systems. The review process involves submittal of two plans: (1) a preliminary plan submitted to OHA prior to drilling the well, and (2) a final plan submitted to OHA after the well is drilled. Initially, the City plans to retrofit the Heliport Production Well to allow for ASR recharge. At a later date, the City may choose to install additional new ASR wells or possibly retrofit other existing wells for ASR. Design plans of the modifications to the existing Heliport Production Well will be submitted to OHA for plan review and approval prior to work on the wellhead. Construction of the new well can begin after OHA completes its preliminary review and issues an approval letter. OHA issues its final approval after well construction is complete. Future modifications or new wells also will follow OHA review requirements.

6.4 UIC Authorization

Because the Heliport Production Well will be used for the subsurface emplacement of fluids, it is classified as a UIC under the Safe Drinking Water Act (and is specifically classified as a Class V UIC). DEQ requires that UICs are authorized by rule or permit. ASR wells in Oregon are authorized by rule, and the City can meet this requirement by submitting an application for authorization by rule to DEQ.

6.5 ASR Limited License Application

To implement ASR, the City must apply for and obtain a limited license for ASR testing. The limited license authorizes the City to pilot test the ASR system, with the objectives of confirming ASR feasibility in Study Area aquifer and developing criteria for full-scale ASR operation and project size. Upon completion of pilot testing, the City can apply for an ASR permit, which contains a reduced set of testing and reporting requirements. The following bullets provide an overview of the information needed to apply for an ASR limited license:

- OWRD Limited License Application
- ASR Feasibility Study
    - Hydrogeologic characterization and impact to the proposed aquifer
    - Demonstrate access to source water
    - Analysis of water quality and compatibility (source water and native groundwater)
    - Evaluation of proposed recharge, storage, and recovery volumes
    - Evaluation of ASR feasibility

- ASR Pilot Testing Work Plan
    - Wellhead facility designs
    - Baseline and ASR monitoring plan
    - Water quality monitoring plan
    - Proposed pilot testing program
    - Pilot testing report outline

7 Conclusions and Recommendations

The findings from the hydrogeologic characterization, water quality compatibility analysis, and ASR feasibility evaluation indicate that ASR appears to be feasible in the Study Area's Upper Aquifer. The Heliport Production Well appears capable of storing up to 179 MG (95 percent of which may be available for recovery based on ASR regulatory requirements). If additional wells are installed, the Upper Aquifer may be capable of storing up to 870 MG (95 percent of which may be available for recovery). GSI's conclusions are based on a number of hydrogeologic factors including the following.

7.1 Conclusions

Aquifer Characteristics

Aquifer characteristics of Upper Aquifer are favorable for ASR. The Upper Aquifer has a transmissivity of at least 40,000 gpd/ft that supports highly productive wells with specific capacities ranging from about 16 to 60 gpm/ft. In addition, the depth to groundwater in the Upper Aquifer is more than 358 feet bgs, which can accommodate significant water level rise during recharge. This highly productive aquifer has a deep water table that allows high rates of recharge and recovery, and a large capacity for ASR storage with minimal potential for creating excessive groundwater level changes in other wells.

Recharge Rate, Pumping Rate, and Storage Volumes

Based on an initial assessment of ASR storage, a minimum of 179 MG of storage appears feasible in the Heliport Production Well and significantly more storage appears feasible with additional ASR wells. Further, the findings from the ASR recharge evaluation suggest that larger storage volumes and higher rates of recharge and recovery may be possible without negative impacts, such as groundwater levels exceeding ground surface during recharge or excessive aquifer drawdown during recovery.

Potential Loss of Stored Water

GSI's analysis indicates that recharged water is likely to be captured by the City's wells during ASR recovery. Therefore, losses of stored water to surface streams are not anticipated.

Permitting Issues

The City has evaluated the opportunity to obtain a water right for the new wellfield on the south side of the City, and has not found any fatal flaws. Preliminary development of the permit application is underway. While the new wellfield is being constructed and permitted, the City can use existing water rights for existing alluvial groundwater in the Prineville Valley to supply source water. No fatal flaws have been identified for obtaining an ASR limited license; however, the City will need to address (treat) source water quality in the new wellfield (i.e., high concentrations of manganese, iron, odor, and ammonia).

In summary, these geologic, hydrogeologic, and regulatory observations suggest favorable ASR feasibility within the Upper Aquifer.

7.2 Recommendations

Based on the technical analysis presented in the FS, GSI identified no fatal flaws for implementing ASR in the Upper Aquifer, and thus recommend proceeding forward with the next steps of the project: ASR permitting and pilot testing. The following is a summary of the tasks outlined in the ASR Implementation Plan document being prepared for the City; that summarizes the steps necessary to implement an ASR program using the Heliport Production Well.

- **Heliport Production Well Bacterial Sampling.** Bacteriological sampling is a common component of ASR well retrofits to evaluate, understand, and control bacterial populations in the well. Collect samples in the spring of 2018 prior to beginning use of the well for the season.
- **ASR Limited License Application.** As previously mentioned, the ASR pilot testing program is a required element of the ASR permitting process and it is designed to demonstrate ASR feasibility and to provide necessary pilot testing operational data. The next step of the project will be to prepare and file an ASR limited license application and ASR work plan with OWRD.
- **Groundwater Right Application.** A new groundwater permit will need to be obtained for the new alluvial wellfield.
- **Engineering Preliminary and Final Design and Construction.**
    - Wellhead Retrofit
    - Treatment Stream Pilot Testing
    - New Shallow Alluvial Source (Wellfield and Treatment System)

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Tables

Table 1. Study Area Aquifer Properties.

City of Prineville ASR Feasibility Study

Hydrogeologic Unit	Scale	Transmissivity, T (gpd/ft)	Aquifer Thickness, b (feet)	Hydraulic Conductivity, K (ft/day)	Storage, S (-)
Upper Aquifer	Wellfield - Scale [1]	75,400 (early-time) 40,000 (late-time)	126 [2]	80 (early-time) 42 (late-time)	0.14 (early-time) 0.23 (late-time)
	Regional - Scale [3]	94,250	126 [2]	100	0.2
Lower Aquifer	Wellfield - Scale [4]	54,400 (early-time) 31,000 (late-time)	50 [5]	145 (early-time) 83 (late-time)	5.7E-07 (early-time) 1.7E-04 (late-time)
	Regional - Scale [3]	85, 250	20 [6]	570	5.00E-05

Notes:

(1) Based on time-drawdown and time-recovery at the Airport 2 observation during the Heliport Production Well pumping test in 2015.

(2) Aquifer thickness at the Airport 2 Well

(3) Based on a hydraulic conductivity from the numerical groundwater model of the Prineville Area (GSI, 2016)

(4) Based on time-drawdown data at the Runway observation well during the Millican Well pumping test in 2015.

(5) Aquifer thickness at the Runway Well

(6) The thickness of the Lower Aquifer in the numerical groundwater model

gpd/ft = gallons per day per foot

ft/day = feet per day

Table 2. Water Quality Sampling - Source Water and Receiving Aquifer Results

City of Prineville - ASR Feasibility Study

	ASR Source Water Options									Receiving Aquifer			
	ASR Source Water Quality Standard	Criteria	Units	Crooked River 6/1/2017	City Conveyance System.¥ 11/8/17	Shallow AQ Test Day 1 Sample 1/18/18	Shallow AQ Test Day 5 Sample 1/23/19	Deep Aq Test Day 1 Sample 1/24/19	Deep Aq Test Day 5 Sample 1/29/19	Drinking Water Quality Standard	Criteria	Units	Heliport Well 6/1/2017 [1]
Field Parameters													
Chlorine	2	MCL	mg/L	**0.0**	--	--	--	--	--	4	MCL	mg/L	**0.08**
Specific Conductivity	--	--	uS/cm	**200**	**1463**	**687**	**1180**	**1903**	**1033**	--	--	uS/cm	**342**
Dissolved Oxygen	--	--	mg/L	**8.53**	**3.36**	**5.01**	**8.62**	**1.28**	**0.53**	--	--	mg/L	**7.93**
ORP	--	--	mV	--	**252**	**39.1**	**34.4**	**83.1**	**208.3**	--	--	mV	**272.6**
pH	6.5 - 8.5	SMCL	su	**7.58/7.35**	**7.58**	**8.03**	**7.66**	**8.32**	**8.32**	6.5 - 8.5	SMCL	su	**7.99/8.10**
Temperature	--	--	degC	**12**	**14.36**	**12.12**	**12.13**	**12.76**	**12.75**	--	--	degC	**20.04**
General Chemistry (GC)													
Alkalinity, Total as CaCO3	--	--	mg/L	**100**	**173**	**201**	**231**	**161**	**164**	--	--	mg/L	**147**
Ammonia	--	--	mg/L	0.15 U	**0.11**	**3.1**	**3.3**	**1.26**	**6.8**	--	--	mg/L	0.15 U
Ammonium	--	--	mg/L	0.5 U	**0.14**	**4**	**4.3**	**1.62**	--	--	--	mg/L	0.05 U
Bicarbonate	--	--	mg/L	**120**	**211**	**234**	**281**	**182**	**186**	--	--	mg/L	**176**
Biological Oxygen Demand (BOD5)	--	--	mg/L	**15.43**	2 UH		2 U	1 U	2 U	--	--	mg/L	**11.71**
Bromide	--	--	mg/L	0.5 U	0.5 U	0.1 U	**0.0717**	0.1 U	0.1 U	--	--	mg/L	0.5 U
Calcium	--	--	mg/L	**20.6**	**24.6**	**22.2**	**29**	**12**	**12**	--	--	mg/L	**20.6**
Carbon Dioxide, total	--	--	mg/L	**89**	**156**	**175**	**208**	**137**	**140**	--	--	mg/L	**134**
Carbon Dioxide, free	--	--	mg/L	**3**	**4**	**2**	**5**	1 U	1 U	--	--	mg/L	**2**
Carbonate, as CaCO3	--	--	mg/L	6 U	5 U	**5**	5 U	**7**	**7**	--	--	mg/L	6 U
Chloride	250	SMCL	mg/L	**2.69**	**7**	**7**	**10**	**6**	**5**	250	SMCL	mg/L	**9.47**
Cyanide	0.1	MCL	mg/L	0.003 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U	0.2	MCL	mg/L	0.003 U
Fluoride	1	MCL/SMCL	mg/L	**0.11**	**0.3**	**0.4**	**0.4**	**0.4**	**0.3**	2	MCL/SMCL	mg/L	**0.706**
Hardness, as CaCO3	250	SMCL	mg/L	**85.2**	**114**	**102**	**129**	**53**	**51**	250	--	mg/L	**97.5**
Magnesium	--	--	mg/L	**8.2**	**12.7**	**11.4**	**13.7**	**5.5**	**5.6**	--	--	mg/L	**11.2**
Nitrate + Nitrite	5	MCL	mg/L	**0.12**	**0.2** ER	0.01 U	0.01 U	0.01 U	**0.01**	10	MCL	mg/L	**0.841**
Nitrate as N	5	MCL	mg/L	**0.12**	**0.2** H	0.01 U	0.01 U	0.01 U	0.01 U	10	MCL	mg/L	0.05 U
Nitrite as N	0.5	MCL	mg/L	0.05 U	0.2 UER	0.01 U	0.01 U	0.01 U	0.01 U	1	MCL	mg/L	**0.841**
Ortho-phosphate	--	--	mg/L	**0.0632**	**0.11** H	**0.296**	**0.285**	**0.108**	**0.124**	--	--	mg/L	0.025 U
Potassium	--	--	mg/L	**2.41**	**3.3**	**4.6**	**4.7**	**1.9**	**2.3**	--	--	mg/L	**3.65**
Silica	--	--	mg/L	**41.5**	**45**	**49**	**51**	**37**	**35**	--	--	mg/L	**58.6**
Sodium	--	--	mg/L	**16.6**	**31.9**	**51.9**	**59.7**	**50.6**	**58**	--	--	mg/L	**38.3**
Sulfate	250	SMCL	mg/L	**4.79**	**11**	**15**	**39.4**	**7**	**7**	250	SMCL	mg/L	**10.7**
Sulfide	--	--	mg/L	0.04 U	--	0.04 U	**0.103**	0.05 U	**0.056**	--	--	mg/L	0.04 U
Sulfur	--	--	mg/L	**1.6**	**4.12**	**5.52**	**6.6**	**2.6**	**2.5**	--	--	mg/L	**3.4**
Total Dissolved Solids	500	SMCL	mg/L	**142**	**237**	**282**	7 U	**232**	**238**	500	SMCL	mg/L	**198**
Total Kjeldahl Nitrogen (TKN)	--	--	mg/L	0.625 U	**0.5**	**3.2**	**3.6**	**1.4**	**1.4**	--	--	mg/L	0.625 U
Organic Carbon (dissolved)	--	--	mg/L	**5.38**	**1.1**	**1.3**	**2.4**	**1**	**1.6**	--	--	mg/L	0.189 N
Total Organic Carbon (total)	--	--	mg/L	**5.66**	**0.9**	**1.2**	**2.1**	**0.9**	**1**	--	--	mg/L	0.163 N
Total Phosphorous	--	--	mg/L	**0.120**	**0.11**	**0.32**	**0.31**		**0.124**	--	--	mg/L	**0.0493**
Total Suspended Solids	--	--	mg/L	**7**	1 U	**4**	**8**	**9**	1 U	--	--	mg/L	0 J

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City of Prineville - ASR Feasibility Study

	ASR Source Water Options									Receiving Aquifer			
	ASR Source Water Quality Standard	Criteria	Units	Crooked River 6/1/2017	City Conveyance System.[¥] 11/8/17	Shallow AQ Test Day 1 Sample 1/18/18	Shallow AQ Test Day 5 Sample 1/23/19	Deep Aq Test Day 1 Sample 1/24/19	Deep Aq Test Day 5 Sample 1/29/19	Drinking Water Quality Standard	Criteria	Units	Heliport Well 6/1/2017 [1]
Turbidity†	0.5	MCL	NTU	**6.69** *	--	**0.66**	**0.69**	**5.05**	0.36 U	1	MCL	NTU	**0.330**
Metals													
Aluminum (total)	0.05 - 0.2	SMCL	mg/L	**0.640** *	0.001 U	**0.554**	**0.03**	**0.255**	**0.009**	0.05 - 0.2	SMCL	mg/L	0.0158 U
Aluminum (dissolved)	--	--	mg/L	**0.119** *	0.03 U	0.03 U	**0.332**	**0.21**	0.03 U			mg/L	**0.0108**
Antimony (total)	0.003	MCL	mg/L	0.002 U	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.006	MCL	mg/L	0.002 U
Antimony (dissolved)	--	--	mg/L	0.002 U	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U			mg/L	0.002 U
Arsenic (total)	0.005	MCL	mg/L	0.001 U	**0.003**	**0.001**	0.001 U	0.001 U	0.001 U	0.01	MCL	mg/L	**0.00219**
Arsenic (dissolved)	--	--	mg/L	0.001 U	**0.003**	**0.001**	0.001 U	0.001 U	0.001 U			mg/L	**0.00197**
Barium (total)	0.5	MML	mg/L	**0.0181**	**0.01**	**0.03**	0.035	**0.004**	**0.003**	1	MML	mg/L	**0.00563**
Barium (dissolved)	--	--	mg/L	**0.015**	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U			mg/L	**0.00519**
Beryllium (total)	0.002	MCL	mg/L	0.0002 U	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.004	MCL	mg/L	0.0002 U
Beryllium (dissolved)	--	--	mg/L	**0.0002**	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U			mg/L	**0.000216**
Cadmium (total)	0.0025	MCL	mg/L	0.0001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.005	MCL	mg/L	0.0001 U
Cadmium (dissolved)	--	--	mg/L	0.0001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U			mg/L	0.000103 U
Chromium (total)	0.025	MCL	mg/L	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.05	MCL	mg/L	**0.00177**
Chromium (dissolved)	--	--	mg/L	0.001 U	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U			mg/L	**0.00185**
Copper (total)	1	SMCL	mg/L	0.00245 U	**0.002**	**0.001**	0.001 U	0.001 U	0.001 U	1	SMCL	mg/L	**0.000811**
Copper (dissolved)	--	--	mg/L	**0.00203**	0.005 U	**0.009**	0.005 U	0.005 U	**0.018**			mg/L	0.0005 U
Iron (total)	0.3	SMCL	mg/L	**0.637** *	0.03 U	**0.79**	**0.46**	**0.27**	0.03 U	0.3	SMCL	mg/L	**0.0863**
Iron (dissolved)	--	--	mg/L	**0.104**	0.02 U	0.06 U	**0.18**	**0.29**	**0.02**			mg/L	0.162 U
Lead (total)	0.025	MML	mg/L	0.0001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.05	MML	mg/L	0.0001 U
Lead (dissolved)	--	--	mg/L	0.0001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U			mg/L	0.0001 U
Manganese (total)	0.05	SMCL	mg/L	**0.0459**	**0.025**	**0.097**	**0.161**	**0.033**	**0.030**	0.05	SMCL	mg/L	0.005 U
Manganese (dissolved)	--	--	mg/L	**0.0280**	**0.025**	**0.093**	**0.148**	**0.038**	**0.031**			mg/L	0.00515 U
Mercury (total)	0.001	MCL	mg/L	0.0002 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.0001 U	0.002	MCL	mg/L	0.0002 U
Mercury (dissolved)	--	--	mg/L	**0.0002**	0.0001 UH	0.00001 U	0.0001 U	0.0001 U	0.0001 U			mg/L	0.0002 U
Nickel (total)††	††	††	mg/L	**0.00108**	0.01 U	0.001 U	0.001 U	0.001 U	0.001 U	--	††	mg/L	0.0005 U
Nickel (dissolved)††	--	--	mg/L	**0.00104**	0.005 U	0.005 U	0.005 U	0.005 U	0.005 U			mg/L	0.0005 U
Selenium (total)	0.005	MML	mg/L	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.01	MML	mg/L	0.001 U
Selenium (dissolved)	--	--	mg/L	0.001 U	0.001 U	0.002 U	**0.002**	0.001 U	0.001 U			mg/L	0.001 U
Silver (total)	0.025	MML	mg/L	0.0001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.05	MML	mg/L	0.0001 U
Silver (dissolved)	--	--	mg/L	0.0001 U	0.0010 U	0.0010 U	0.0010 U	0.0010 U	0.0010 U			mg/L	0.0001 U
Thallium (total)	0.001	MCL	mg/L	0.0005 U	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.002	MCL	mg/L	0.0005 U
Thallium (dissolved)	--	--	mg/L	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U			mg/L	0.0005 U
Zinc (total)	5	SMCL	mg/L	0.0050 U	**0.009**	**0.011**	**0.008**	**0.003**	**0.002**	5	SMCL	mg/L	0.005 U
Zinc (dissolved)	--	--	mg/L	0.005 U	0.01 U	**0.02**	0.01 U	**0.01**	**0.01**			mg/L	0.005 U

Table 2. Water Quality Sampling - Source Water and Receiving Aquifer Results

City of Prineville - ASR Feasibility Study

	ASR Source Water Options									Receiving Aquifer			
	ASR Source Water Quality Standard	Criteria	Units	Crooked River 6/1/2017	City Conveyance System.[¥] 11/8/17	Shallow AQ Test Day 1 Sample 1/18/18	Shallow AQ Test Day 5 Sample 1/23/19	Deep Aq Test Day 1 Sample 1/24/19	Deep Aq Test Day 5 Sample 1/29/19	Drinking Water Quality Standard	Criteria	Units	Heliport Well 6/1/2017 [1]
Disinfection Byproducts (DBPs)[§]													
Chloroform	--	--	mg/L	0.0005 U	0.0005 U	0.5 U	0.0005 U	0.0005 U	0.0005 U	--	--	mg/L	0.0005 U
Bromoform	--	--	mg/L	0.0005 U	**0.00069**	0.0005 U	0.0005 U	0.0005 U	0.0005 U	--	--	mg/L	0.00069
Dibromochloromethane	--	--	mg/L	0.0005 U	**0.00094**	--	0.0005 U	--	0.0005 U	--	--	mg/L	0.00094
Bromodichloromethane	--	--	mg/L	0.0005 U	0.0005 U	--	0.0005 U	--	0.0005 U	--	--	mg/L	0.0005 U
Total Trihalomethanes (TTHM)	0.08	MCL	mg/L	0.0005 U	0.00163	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.08	MCL	mg/L	0.00163
Dibromoacetic Acid	--	--	mg/L	0.003 U	0.003 U	--	0.003 U	--	0.003 U	--	--	mg/L	0.003 U
Dichloroacetic Acid	--	--	mg/L	0.003 U	0.003 U	--	0.003 U	--	0.003 U	--	--	mg/L	0.003 U
Monobromoacetic Acid	--	--	mg/L	0.003 U	0.003 U	--	0.003 U	--	0.003 U	--	--	mg/L	0.003 U
Monochloroacetic Acid	--	--	mg/L	0.003 U	**0.00923** CF	--	0.003 U	--	0.003 U	--	--	mg/L	0.003 U
Trichloroacetic Acid	--	--	mg/L	0.003 U	0.003 U	--	0.003 U	--	0.003 U	--	--	mg/L	0.003 U
Total Haloacetic Acids (HAA-5)	0.06	MCL	mg/L	0.003 U	**0.00923**	--	0.003 U	--	0.003 U	0.06	MCL	mg/L	0.00923
Bromate	0.01	MCL	mg/L	0.005 U	--	*0.025* U	0.01 U	*0.025* U	0.005 U	0.01	MCL	mg/L	0.025 U,ER
Chlorite	1	MCL	mg/L	0.01 U	--	0.05 U	0.01 U	0.02 U	0.01 U	1	MCL	mg/L	0.01 U
Microbial													
Total Coliform	Absent	MCL	CFU	**> 2,419.6**	Absent	*1* U	*1* U	*1* U	*1* U	Absent	MCL	CFU	1 U
Fecal Coliform	Absent	MCL	MPN/100mL	**500** FC	NA	NA	NA	NA	NA	Absent	MCL	MPN/100mL	2 U,FC
E. Coli	Absent	MCL	CFU	**307.6**	Absent	*1* U	*1* U	*1* U	*1* U	Absent	MCL	CFU	1 U
Miscellaneous (Misc.)													
Color	15	SMCL	cu	**35** *	**10** H	**16** H	**14**	**13**	**12**	15	SMCL	cu	5 U
Corrosivity (Langelier Index)	noncorrosive	SMCL	none	**-0.59**	**0.14**	**0.59**	**0.4**	**0.37**	**0.39**	noncorrosive	SMCL	none	**-0.05**
Foaming Agents (MBAS)	0.5	SMCL	mg/L	0.04 U	*1* UH	*1* H	*1* H	*1* U	*1* UH	0.5	SMCL	mg/L	0.04 U
Odor	3	SMCL	ton	1 U	**4** H	**2**	**17** H	**12**	**4** H	3	SMCL	ton	1 U
SDWA Radionuclides (Rads)													
Gross Alpha	7.5	MML	pCi/L	0.9 U	**4.6**	**1.3** U	**2.5**	**1.3**	**0.08**	15	MML	pCi/L	0.3 U
Gross Beta ‡	25	MML	pCi/L	3.3 U	5 U	**2.6** U	**3.4**	**0.5**	**2.5**	50	MML	pCi/L	3.1 U
Radium 226	--	--	pCi/L	0.1 U	0.2 U	**0.2** U	**0.2**	**0.2**	**0.2**	--	--	pCi/L	**0.2**
Radium 228	--	--	pCi/L	**3.2**	0.6 U	**-0.2** U	**-0.3**	**0.5**	**-0.07**	--	--	pCi/L	**1.5**
Radium 226/228	2.5	MML	pCi/L	**3.3**	0.8 U	-0.09 U	**-0.1**	**0.7**	**0.09**	5	MML	pCi/L	**1.7**
Uranium	0.015	MCL	mg/L	0.0003 U	**0.0008**	0.0003	0.0003 U	0.0003 U	0.0003 U	0.03	MCL	mg/L	**0.0010**
Uranium activity	--	--	pCi/L	0.2 U	**5.4E-10**	**2.00E-10**	2.00E-10	2.00E-10 U	2.00E-10 U	--	--	pCi/L	**0.70**
Radon†††	--	--	pCi/L	-50 U	**580**	**177**	**73.8**	**618**	**377**	--	--	pCi/L	**251**
Synthetic Organic Compounds (SOCs)													
Regulated SOCs													
2,4,5-TP (Silvex)	0.005	MML	mg/L	0.005 U	0.0002 U	0.005 U	0.005 U	0.005 U	0.005 U	0.01	MML	mg/L	0.005 U
2,4-D	0.035	MCL	mg/L	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.001 U	0.07	MCL	mg/L	0.001 U
Alachlor (Lasso)	0.001	MCL	mg/L	0.0002 U	--	0.0004 U	0.0002 U	0.0004 U	0.0002 U	0.002	MCL	mg/L	0.0002 U
Aldicarb	--		mg/L	0.004 U	0.004 U	0.004 U	0.004 U	0.004 U	0.004 U				
Aaldicarb Sulfone	--		mg/L	0.004 U	0.004 U	0.004 U	0.004 U	0.004 U	0.004 U				

Table 2. Water Quality Sampling - Source Water and Receiving Aquifer Results

City of Prineville - ASR Feasibility Study

	ASR Source Water Options															Receiving Aquifer				
	ASR Source Water Quality Standard	Criteria	Units	Crooked River 6/1/2017		City Conveyance System.¥ 11/8/17		Shallow AQ Test Day 1 Sample 1/18/18		Shallow AQ Test Day 5 Sample 1/23/19		Deep Aq Test Day 1 Sample 1/24/19		Deep Aq Test Day 5 Sample 1/29/19		Drinking Water Quality Standard	Criteria	Units	Heliport Well 6/1/2017 [1]	
Aldicarb Sulfoxide	--		mg/L	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U					
Aldrin	0.00001	MCL	mg/L	0.00001	U	0.00001	U	0.00001	U	0.00001	U	0.00001	U	0.00001	U					
Atrazine	0.0015	MCL	mg/L	0.0003	U	--		0.0006	U	0.0003	U	0.0006	U	0.0003	U	0.003	MCL	mg/L	0.0003	U
Baygon	--		mg/L	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U					
Benzo(a)pyrene	0.0001	MCL	mg/L	0.00004	U	*0.01*	U	0.00006	U	0.00004	U	0.00008	U	0.00004	U	0.0002	MCL	mg/L	0.00004	U
BHC, gamma (Lindane)	0.0001	MCL	mg/L	0.00001	U	0.00005	U	0.00001	U	0.0001	U	0.00001	U	0.00001	U	0.0002	MCL	mg/L	0.00001	U
bis(2-Ethylhexl)adipate	--		mg/L	0.004	U	0.004	U	0.008	U	0.004	U	0.008	U	0.004	U					
bis(2-Ethylhexl)phthalate	--		mg/L	0.002	U	0.002	U	0.004	U	0.002	U	0.004	U	0.002	U					
Butachlor	--		mg/L	0.0003	U	0.0003	U	0.0006	U	0.0003	U	0.0006	U	0.0003	U					
Carbaryl	--		mg/L	0.004	U	--		0.004	U	0.004	U	0.004	U	0.004	U					
Carbofuran	0.02	MCL	mg/L	0.004	U	--		0.004	U	0.004	U	0.004	U	0.004	U	0.04	MCL	mg/L	0.004	U
Chlordane	0.001	MCL	mg/L	0.00025	U	0.0005	U	0.00025	U	0.00025	U	0.00025	U	0.00025	U	0.002	MCL	mg/L	0.00025	U
Dalapon	0.1	MCL	mg/L	0.005	U	0.0025	U	0.005	U	0.005	U	0.005	U	0.005	U	0.2	MCL	mg/L	0.005	U
Dieldrin	--	MCL	mg/l	0.00001	U	--		0.00001	U	0.00001	U	0.00001	U	0.00001	U					
Di(2-Ethylhexyl) Adipate	0.2	MCL	mg/L	0.004	U	--		0.008	U	0.004	U	0.008	U	0.004	U	0.4	MCL	mg/L	0.004	U
Di(2-Ethylhexyl) Phthalate	0.003	MCL	mg/L	0.002	U	*0.01*	U	*0.004*	U	*0.002*	U	*0.004*	U	*0.002*	U	0.006	MCL	mg/L	0.002	U
Dibromochloropropane (DBCP)	0.0001	MCL	mg/L	2.01E-05	U	--		0.0005	U	*0.001*	U	2.08E-05	U	2.06E-05	U	0.0002	MCL	mg/L	0.00002	U
Dicamba	--		mg/L	0.005	U	0.00025	U	0.0005	U	0.0005	U	0.005	U	0.005	U					
Dinoseb	0.0035	MCL	mg/L	0.0005	U	0.001	U	0.0005	U	0.0005	U	0.0005	U	0.005	U	0.007	MCL	mg/L	0.0005	U
Diquat	0.01	MCL	mg/L	0.002	U	0.0004	U	0.002	U	0.002	U	0.002	U	0.002	U	0.02	MCL	mg/L	0.002	U
Endothall	0.05	MCL	mg/L	0.01	U	0.008	U	0.01	U	0.01	U	0.01	U	0.01	U	0.1	MCL	mg/L	0.01	U
Endrin	0.0001	MML	mg/L	0.00001	U	0.00005	U	0.00001	U	0.00001	U	0.00001	U	0.00001	U	0.0002	MML	mg/L	0.00001	U
Ethylene Dibromide (EDB)	0.000025	MCL	mg/L	2.01E-05	U	*0.0005*	U	0.0000204	U	0.0000205	U	0.0000208	U	0.0000205	U	0.00005	MCL	mg/L	0.00002	U
Glyphosate	0.35	MCL	mg/L	0.05	U	0.005	U	0.05	U	0.05	U	0.06	U	0.05	U	0.7	MCL	mg/L	0.05	U
Heptachlor	0.0002	MCL	mg/L	0.0001	U	0.00005	U	0.00001	U	0.00001	U	0.00001	U	0.00001	U	0.0004	MCL	mg/L	0.0001	U
Heptachlor Epoxide	0.0001	MCL	mg/L	0.00001	U	0.00005	U	0.00001	U	0.00001	U	0.00001	U	0.00001	U	0.0002	MCL	mg/L	0.00001	U
Hexachlorobenzene (HCB)	0.0005	MCL	mg/L	0.0001	U	*0.01*	U	0.0002	U	0.0001	U	0.0002	U	0.0001	U	0.001	MCL	mg/L	0.0001	U
Hexachlorocyclopentadiene	0.025	MCL	mg/L	0.005	U	0.01	U	0.01	U	0.005	U	0.01	U	0.005	U	0.05	MCL	mg/L	0.005	U
Methomyl	--			0.004	U	--		0.004	U	0.004	U	0.004	U	0.004	U					
Methoxychlor	0.02	MCL, MML	mg/L	0.001	U	0.00005	U	0.0001	U	0.001	U	0.0001	U	0.0001	U	0.04	MCL, MML	mg/L	0.001	U
Metolachlor	--		mg/L	0.0004	U	--		0.0008	U	0.0004	U	0.0008	U	0.0004	U					
Metribuzin	--		mg/L	0.0004	U	--		0.0008	U	0.0004	U	0.0008	U	0.0004	U					
Oxamyl (Vydate)	0.1	MCL	mg/L	0.004	U	0.0004	U	0.004	U	0.004	U	0.004	U	0.004	U	0.2	MCL	mg/L	0.004	U
Pentachlorophenol	0.0005	MCL	mg/L	0.0001	U	*0.05*	U	0.0001	U	0.0001	U	0.0001	U	0.0001	U	0.001	MCL	mg/L	0.0001	U
Picloram	0.25	MCL	mg/L	0.006	U	0.0005	U	0.005	U	0.005	U	0.005	U	0.005	U	0.5	MCL	mg/L	0.006	U
Polychlorinated Biphenyls (PCBs)	0.00025	MCL	mg/L	0.00025	U	*0.0005*	U	0.00025	U	0.00025	U	0.00025	U	0.00025	U	0.0005	MCL	mg/L	0.00025	U
Simazine	0.002	MCL	mg/L	0.0004	U	--		0.0008	U	0.0004	U	0.0008	U	0.0004	U	0.004	MCL	mg/L	0.0004	U
Toxaphene	0.0015	MCL, MML	mg/L	0.0003	U	*0.005*	U	0.0003	U	0.0003	U	0.0003	U	0.0003	U	0.003	MCL, MML	mg/L	0.0003	U

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City of Prineville - ASR Feasibility Study

	ASR Source Water Options									Receiving Aquifer			
	ASR Source Water Quality Standard	Criteria	Units	Crooked River 6/1/2017	City Conveyance System.[¥] 11/8/17	Shallow AQ Test Day 1 Sample 1/18/18	Shallow AQ Test Day 5 Sample 1/23/19	Deep Aq Test Day 1 Sample 1/24/19	Deep Aq Test Day 5 Sample 1/29/19	Drinking Water Quality Standard	Criteria	Units	Heliport Well 6/1/2017 [1]
Volatile Organic Compounds (VOCs)													
Regulated VOCs													
1,1,1-Trichloroethane	0.1	MCL, MML	mg/L	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.2	MCL, MML	mg/L	0.005 U
1,1,2-Trichloroethane	0.0025	MCL	mg/L	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.005	MCL	mg/L	0.005 U
1,1-Dichloroethene	0.0035	MCL, MML	mg/L	0.005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.007	MCL, MML	mg/L	0.005 U
1,2,4-Trichlorobenzene	0.035	MCL	mg/L	0.005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.07	MCL	mg/L	0.005 U
1,2-Dichlorobenzene (o-dichlorobenzene)	0.3	MCL	mg/L	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.6	MCL	mg/L	0.005 U
1,2-Dichloroethane (EDC)	0.0025	MCL, MML	mg/L	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.005	MCL, MML	mg/L	0.005 U
1,2-Dichloropropane	0.0025	MCL	mg/L	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.005	MCL	mg/L	0.005 U
1,4-Dichlorobenzene (p-dichlorobenzene)	0.0375	MCL, MML	mg/L	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.075	MCL, MML	mg/L	0.005 U
Benzene	0.0025	MCL, MML	mg/L	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.005	MCL, MML	mg/L	0.005 U
Carbon Tetrachloride	0.0025	MCL, MML	mg/L	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.005	MCL, MML	mg/L	0.005 U
Chlorobenzene (Monochlorobenzene)	0.05	MCL	mg/L	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.1	MCL	mg/L	0.005 U
cis-1,2-Dichloroethene	0.035	MCL	mg/L	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.07	MCL	mg/L	0.005 U
Ethylbenzene	0.35	MCL	mg/L	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.7	MCL	mg/L	0.005 U
Methylene Chloride (Dichloromethane)	0.0025	MCL	mg/L	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.005	MCL	mg/L	0.005 U
Styrene	0.05	MCL	mg/L	0.0005 U	0.0005 U	0.94 U	0.0005 U	0.0005 U	0.0005 U	0.1	MCL	mg/L	0.005 U
Tetrachloroethene	0.0025	MCL, MML	mg/L	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.005	MCL, MML	mg/L	0.005 U
Toluene	0.5	MCL	mg/L	0.0005 U	0.0005 U	**0.00094**	0.0005 U	**0.001**	0.0005 U	1	MCL	mg/L	0.005 U
trans-1,2-Dichloroethene	0.05	MCL	mg/L	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.1	MCL	mg/L	0.005 U
Trichloroethene (TCE)	0.0025	MCL, MML	mg/L	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.005	MCL, MML	mg/L	0.005 U
Vinyl Chloride	0.001	MCL, MML	mg/L	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.002	MCL, MML	mg/L	*0.005* U
Xylenes, Total	5	MCL	mg/L	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	0.0005 U	10	MCL	mg/L	0.005 U

Table 2. Water Quality Sampling - Source Water and Receiving Aquifer Results

City of Prineville - ASR Feasibility Study

	ASR Source Water Options									Receiving Aquifer			
	ASR Source Water Quality Standard	Criteria	Units	Crooked River 6/1/2017	City Conveyance System.¥ 11/8/17	Shallow AQ Test Day 1 Sample 1/18/18	Shallow AQ Test Day 5 Sample 1/23/19	Deep Aq Test Day 1 Sample 1/24/19	Deep Aq Test Day 5 Sample 1/29/19	Drinking Water Quality Standard	Criteria	Units	Heliport Well 6/1/2017 [1]

Notes:

Analytes added by CH2M for Wastewater Treatment Plant Project review.

Bold = parameter detected

Red = Parameter concentration exceeds groundwater protection or drinking water quality standards, or is greater than one-half the MCL for source water anticipated for recharge

Italics = Laboratory detection level exceeded groundwater protection or drinking water quality standards

1 = ORP and Temperature readings were collected on 1/29/18

AL = Action Level

MCL = Maximum Contaminant Level

SMCL = Secondary Maximum Contaminant Level

MML = Maximum Measureable Level

† MCLs for turbidity are applicable to all public water systems using surface water sources or groundwater sources under the direct influence of surface water in whole or in part. Compliance with MCLs shall be calculated pursuant to OAR 333-061-0036(5).

†† MCL being re-evaluated by EPA.

††† USEPA proposed standard is 300 to 4,000 pCi/L, depending on State primacy.

‡ Gross beta MCL is 4 mrem/yr; however lab results presented in pCi/L so compared it to the MML standard.

¥ Additional parameters were evaluated but are not reported on this table. All parameters not reported in this table were not detected above the reporting limit established by the labaratory. For more details please refer to XXXXX.

§ DBPs results are from a sample that was collected

Units:

Units are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter are equivalent to parts per million.

MPN = most probable number

CU = color number

TON = threshold odor number

pCi/L = picocuries per liter

su = standard units

uS/cm = micro Siemens per centimeter

mV = millivolts

degC = degrees Celsius

Data Flags:

* = Value exceeds Maximum Contaminant Level or is outside the acceptable range.

ER = Elevated reporting limit due to matrix. Report limits (MDLs, MRLs & PQLs) are adjusted based on variations in sample preparation amounts, analytical dilutions, and percent solids, where applicable.

H = analysis performed past recommended holding time

FC = Fecal Coliforms: Sample(s) received past 40 CFR Part 136 specified holding time. Results reported as estimated values.

J = detected below quantification limits

N = The Dissolved Organic Carbon (DOC) is greater than the Total Organic Carbon (TOC). The acceptable RPD between samples analyzed in duplicate is <25%.
The relative percent difference (RPD) between the TOC and DOC in this sample is at 14.7%, which shows that the TOC is in the dissolved form of organic carbon.

U = Not detected at the minimum reporting limit

Table 3. Summary of Aquifer Test Common Anions and Cations Testing Results

City of Prineville ASR Feasibility Study

Day of Test		Time Since Test Started (days)	Time Since Test Started (minutes)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	SO_4 (mg/L)	CO_3 (mg/L)		HCO_3 as CACO3 (mg/L)	Nitrate+Nitrite as N (mg/L)	
Crooked River Sample *(baseline)*														
River Sample - 6/1/2017		*- NA -*	*- NA -*	20.6	8.2	16.6	2.41	2.69	4.79	6		120	0.02	U
Shallow Aquifer Test *(1/18/18 thru 1/23/18)*														
Day 1	1/19/18 12:30	1.10	1,590	32.0	16.0	65.0	5.0	11.0	18.0	5.0	U	298.0	0.01	U
Day 2	1/20/18 11:00	2.04	2,940	33.0	16.0	66.0	5.0	11.0	18.0	5.0	U	303.0	0.02	
Day 3	1/21/18 11:10	3.05	4,390	31.0	15.0	64.0	5.0	11.0	17.0	5.0	U	295.0	0.01	U
Day 4	1/22/18 11:20	4.06	5,840	30.0	15.0	64.0	5.0	10.0	16.0	5.0	U	287.0	0.01	U
Day 5	1/23/18 9:30	4.98	7,170	29.0	13.7	59.7	4.7	10.0	17.0	5.0	U	231.0	0.01	U
Deep Aquifer Test *(1/24/18 thru 1/29/18)*														
Day 1	1/25/18 12:45	1.11	1,605	13.0	6.0	54.0	2.0	6.0	6.0	6.0		203.0	0.01	U
Day 2	1/26/18 13:30	2.15	3,090	13.0	6.0	55.0	2.0	6.0	6.0	7.0		185.0	0.01	U
Day 3	1/27/18 11:00	3.04	4,380	13.0	6.0	55.0	2.0	6.0	7.0	6.0		186.0	0.01	U
Day 4	1/28/18 15:00	4.21	6,060	12.0	6.0	52.0	2.0	6.0	7.0	7.0		186.0	0.01	U
Day 5	1/29/18 7:30	4.90	7,050	12.0	5.6	58.0	2.3	5.0	7.0	7.0		186.0	0.01	

Notes

Day 1a - collected at initial test start up

Day 1b - collected at end of day 1 (i.e., 24 hours into test)

Table 4. City of Prineville Water Rights for Alluvial Wells in the Prineville Valley

City of Prineville ASR Feasibility Study

Well ID	OWRD ID [1]	Use	Water Rights [1]				Geologic Unit	Authorized Rate [1]		Maximum Production Rate [2]		Notes
			Application	Permit	Certificate	Transfers		(gpm)	(MGD)	(gpm)	(MGD)	
Water Sources Currently Connected to the Municipal Water Supply System - Valley Wells												
Lamonta	CROO 1540	MU	G 605	G 506	86337		QTs3	346	0.50	210	0.302	
Yancey	CROO 50181	MU	U 241	U 215	22839		QTs3	359	0.52	210	0.302	
Barney	CROO 3132	MU	G 6313	G 9154	83993	~~T9762~~	QTs3	700	1.01	340	0.490	
Stearns #2	CROO 2083	MU								210	0.302	
Stadium	CROO 184	MU	G 12344	G 11993	87714		QTs3	271	0.39	205	0.295	
		MU					QTs3	154	0.22			Extension application pending
4th Street Deep	CROO 2121 CROO 2133	MU	U 402	U 372	86889		QTs3	337	0.49	175	0.252	
4th Street Shallow *(Emergency Use only)*	CROO 2130	MU	U 396	U 370	88146		QTs1	135	0.19	*90*	*NA*	Currently not in use - emergency well
Total								2,167	3.12	1,350	1.94	
Water Sources NOT Connected to the Municipal Water Supply System												
Ochoco Heights	CROO 1577	MU	U 147	U 140	86558		QTs3	359	0.52			Currently not in use due to water quality and/or production issues
10th Street Well	CROO 1549	MU	U 140	U 133	15539		QTs3	45	0.06			Currently not in use due to water quality and/or production issues
Northridge A		GD	G-13280	G-13280				67	0.10			Not connected to City's Municipal Water Supply System
Clear Pine		FP, Pollution Abatement, I/M	G-13238	G-12541				1,791	2.58			Not connected to City's Municipal Water Supply System
Freight Depot		MU	G-605	G-506	89853	~~T 11026~~		148	0.21			Not connected to City's Municipal Water Supply System
Stearns #1		GD	G-3139	G-2919	57438			112	0.16			Currently not in use due to water quality and/or production issues

Notes:

(1) From Exhibit 2-18 of the City of Prineville Water Management and Conservation Plan (GSI, 2017b)

(2) City production capacity from valley wells excludes the 4th Street Shallow well because it is only used as an emergency source

Strikethrough indicates that the transfer changed the water right, and the water right was re-certified.

MU = Municipal Use

GD = Group Domestic

FP = Fire Protection

I/M = Industrial / Manufactoring

OWRD = Oregon Water Resources Department

gpm = gallons per minute

MGD = millions of gallons per day

QTs1 = Upper Sand and Gravel Geologic Unit

QTs3 = Lower Sand and Gravel Geologic Unit

Table 5. Estimated Source Water Availability from Existing Alluvial Wells in the Prineville Valley

City of Prineville ASR Feasibility Study

<table>
<tr><th>Well ID</th><th>OWRD ID [1]</th><th>Rate Authorized by Water Right [2] (MGD)</th><th>Maximum Production Rate [3] (MGD)</th><th>Average Municipal Demand During Recharge Period [4] (MGD)</th><th>Water Available for Recharge [5] (MGD)</th></tr>
<tr><td>Lamonta</td><td>CROO 1540</td><td>0.50</td><td>0.30</td><td rowspan="8">0.92</td><td rowspan="8">1.02</td></tr>
<tr><td>Yancey</td><td>CROO 50181</td><td>0.52</td><td>0.30</td></tr>
<tr><td>Barney</td><td>CROO 3132</td><td rowspan="2">1.01</td><td>0.49</td></tr>
<tr><td>Stearns #2</td><td>CROO 2083</td><td>0.30</td></tr>
<tr><td rowspan="2">Stadium</td><td rowspan="2">CROO 184</td><td>0.39</td><td rowspan="2">0.30</td></tr>
<tr><td>0.22</td></tr>
<tr><td rowspan="2">4th Street Deep</td><td>CROO 2121</td><td rowspan="2">0.49</td><td rowspan="2">0.25</td></tr>
<tr><td>CROO 2133</td></tr>
<tr><td colspan="2">Total</td><td>3.12</td><td>1.94</td><td>0.92</td><td>1.02</td></tr>
</table>

Notes:

(1) From Oregon Health Authority Drinking Water Data Online

(2) From Exhibit 2-18 of the City of Prineville Water Management and Conservation Plan (GSI, 2017b)

(3) Based on maximum well production rate, provided by the City

(4) Based on the maximum monthly production rate from November to March of the 2017 Water Year, from OWRD Water Use Reporting System (OWRD, 2018b)

(5) The water available for recharge is the average water demand during the recharge period subtracted from the maximum production rate

MGD = Million gallons per day

MG = Million gallons

Table 6. Preliminary Aquifer Properties for the New Wellfield.

City of Prineville ASR Feasibility Study

Hydrogeologic Unit	Well	Early-Time Transmissivity, T (gpd/ft)	Late-Time Transmissivity, T (gpd/ft)	Average Transmissivity, T (gpd/ft)
Shallow Zone (ST-1 Pumping Test)	ST-1 (pumping well)	8,957	12,540	10,748
Deep Zone (DT-1 Pumping Test)	DT-1 (pumping well)	4,072	9,953	7,012

Notes:

(1) Transmissivity is an average of early-time and late-time values.

gpd/ft = gallons per day per foot

Table 7. Blended Manganese and Ammonia Concentrations

City of Prineville ASR Feasibility Study

Parameter	Shallow Well Concentration (mg/L)	Deep Well Concentration (mg/L)	Blended Wells Concentration (mg/L)
Manganese, Dissolved	0.148	0.031	0.090
Ammonia as N, Dissolved	3.3	6.8	5.1

Notes:

mg/L = milligrams per liter

Table 8. Predicted ASR Storage and Recovery Volumes in the Upper Aquifer

City of Prineville ASR Feasibility Study

Scenario	Storage Volume [1] (MG)	Storage Volume Per Well [2] (MG)	Volume Available for Recovery [3] (MG)
Baseline Scenario - 825 gpm	179	179	170
Scenario 1 - 2,000 gpm	434	217	412
Scenario 2 - 4,000 gpm	870	174	827

Notes:

(1) Assumes recharge from November 1 through March 31.

(2) The baseline scenario uses one ASR well, Scenario 1 uses two ASR wells, and Scenario 2 uses five ASR wells.

(3) Assumes OWRD allows maximum recovery of 95% of stored water; it is possible that OWRD will choose a lower percentage, which will affect the availability of stored water for recovery.

gpm = gallons per minute

MG = million gallons

Table 9. Predicted Water Level Changes in Response to ASR
Upper Aquifer - Baseline Scenario Conditions
City of Prineville ASR Feasibility Study

ASR Scenario Evaluated

Recharge = 825 gpm from November through March (151 days) - 1 well (Heliport Production Well)

Storage = 30 days

Recovery = 1,100 gpm from May through October (183 days)

Numerical Model = ASR recharge/recovery program cycled for 10 years

Analytical Equation = ASR recharge/recovery program - 1 full year ASR cycle

OWRD Well Log ID	Well Name	Distance from Heliport Well (feet)	Water Level Buildup [1] (feet)		Water Level Drawdown [1] (feet)	
			Numerical Groundwater Model	Analytical Equation	Numerical Groundwater Model	Analytical Equation
Wells in the Upper Aquifer						
CROO 54191	Heliport Production Well[2]	- NA -	12.4	66.4	21.7	87.5
CROO 53965	Heliport Observation Well	35	6.9	20.0	12.8	26.0
CROO 1894	Airport 1 Well	428	5.8	<9.53	11.2	<12.7
CROO 53453	Airport 2 Well	440	5.9	<9.53	11.4	<12.7
CROO 53361	Houston Lake Road	10,775	0.0	<9.53	0.9	<12.7
Wells West of Channel						
CROO 532	Ryan Well	3,280	0.0	<9.53	1.9	<12.7
CROO 54287	Grass Butte Well	4,180	0.0	<9.53	1.9	<12.7
CROO 3200	Gravel Quarry	6,825	0.0	<9.53	0.2	<12.7
Wells East of Channel						
CROO 50311	Hollander Well	8,115	0.0	<9.53	0.0	<12.7
CROO 50990	County Landfill	8,875	0.0	<9.53	0.2	<12.7
CROO 50802	County Landfill	10,500	0.0	<9.53	0.2	<12.7

Notes

The Cooper Jacob equation requires that the ratio $\frac{r^2S}{4Tt}$ is less than 0.01 (Freeze and Cherry, 1979). When this requirement is violated, the equation cannot accurately predict drawdown. During recharge, the ratio exceeds 0.01 when drawdown is less than 9.53 feet (i.e., at a radius of 375 feet from the Heliport Production Well). During recovery, the ratio exceeds 0.01 when drawdown is less than 12.7 feet (i.e., at a radius of 413 feet from the Heliport Production Well).

(1) "<" indicates that exact mounding or drawdown could not be calculated because *u* was greater than 0.01.

(2) Well efficiency of 59% is incorporated into the build-up and drawdown estimates for the production well to more accurately estimate responses within the well, and and provide a conservative estimate of conditions for the ASR feasibility evaluation

Table 10. Predicted Water Level Changes in the Upper Aquifer--2,000 gpm and 4,000 gpm ASR Recharge Scenarios

City of Prineville ASR Feasibility Study

ASR Scenario 1

 # ASR Wells = 2 wells
Recharge = November through March (151 days)
Storage = 30 days
Recovery = May through October (183 days)

ASR Scenario 2

 # ASR Wells = 5 wells
Recharge = November through March (151 days)
Storage = 30 days
Recovery = May through October (183 days)

Numerical Model = ASR recharge/recovery program cycled for 10 years

OWRD Well Log ID	Well Name	Scenario 1 Inject at 2,000 GPM				Scenario 2 Inject at 4,000 GPM			
		Injection Rate (gpm)	Recovery Rate (gpm)	Max Buildup (feet)	Max Drawdown (feet)	Injection Rate (gpm)	Recovery Rate (gpm)	Max Buildup (feet)	Max Drawdown (feet)
Wells in the Upper Aquifer									
CROO 54191	Heliport Production Well[1]	1,000	1,100	17.3	19.1	800	933	13.6	17.0
- NA-	Hypothetical Heliport 2 Well	1,000	1,100	23.2	24.7	800	933	18.4	20.6
- NA-	Hypothetical Heliport 3 Well	*- NA-*	*- NA-*	*- NA-*	*- NA-*	800	933	11.7	13.9
- NA-	Hypothetical Heliport 4 Well	*- NA-*	*- NA-*	*- NA-*	*- NA-*	800	933	10.6	12.2
- NA-	Hypothetical Heliport 5 Well	*- NA-*	*- NA-*	*- NA-*	*- NA-*	800	933	15.7	16.2
CROO 53965	Heliport Observation Well	0.0	0.0	9.7	10.8	0.0	0.0	7.6	9.7
CROO 1894	Airport 1 Well	0.0	0.0	8.2	9.1	0.0	0.0	6.5	8.7
CROO 53453	Airport 2 Well	0.0	0.0	8.4	9.3	0.0	0.0	6.7	8.9
CROO 53361	Houston Lake Road	0.0	0.0	0.0	0.3	0.0	0.0	0.1	0.4
Wells West of Channel									
CROO 532	Ryan Well	0.0	0.0	0.1	0.5	0.0	0.0	0.0	0.8
CROO 54287	Grass Butte Well	0.0	0.0	0.1	0.7	0.0	0.0	0.0	1.2
CROO 3200	Gravel Quarry	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wells East of Channel									
CROO 50311	Hollander Well	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CROO 50990	County Landfill	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1
CROO 50802	County Landfill	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.1

Notes

(1) Well efficiency of 59% is incorported into the build-up and drawdown estimates for the production well to more accurately estimate responses within the well, and provide a conservative estimate of conditions for the ASR feasibility evaluation

Figures

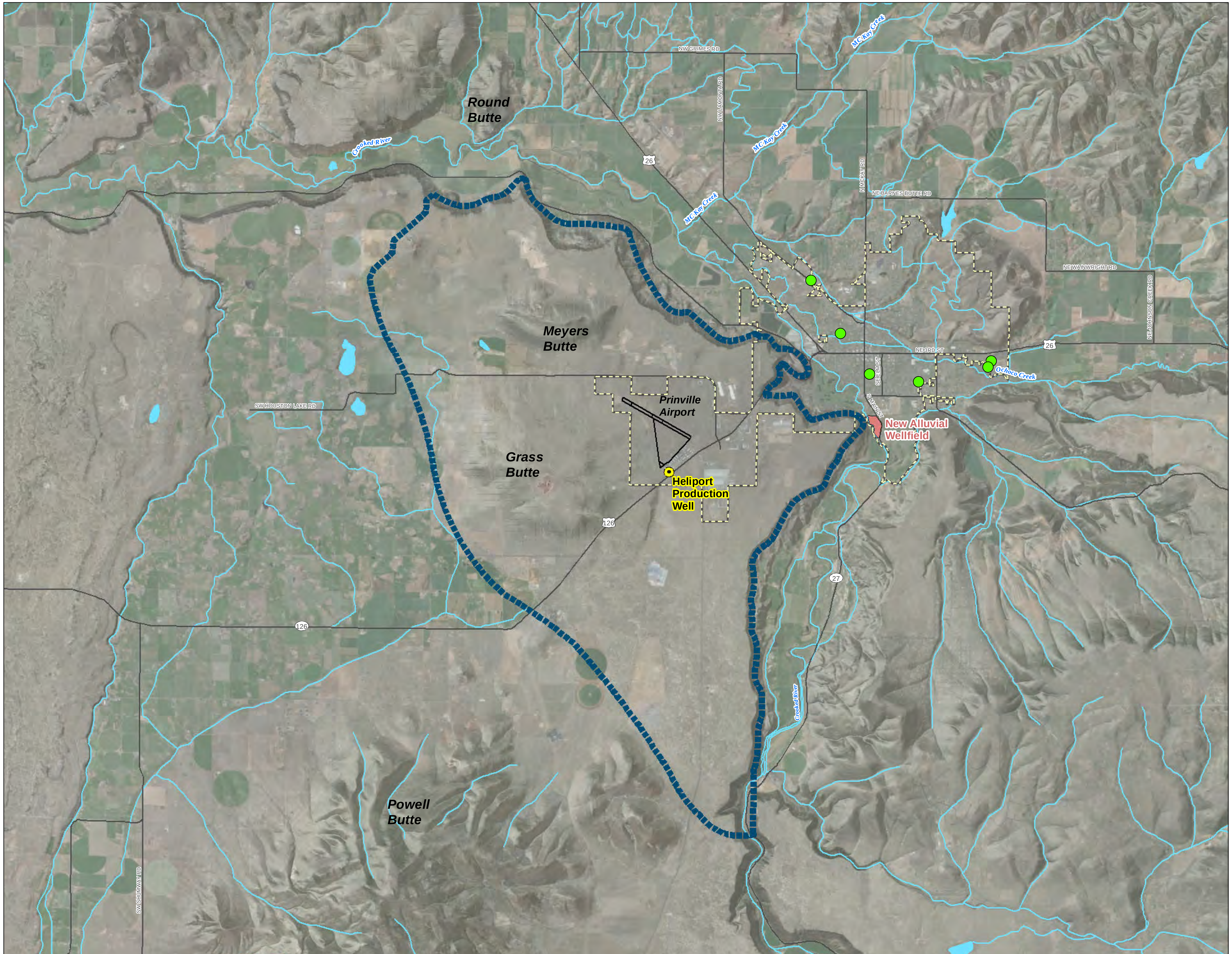

FIGURE 1

Study Area

Prineville ASR Feasibility Study

LEGEND

- Exsting Source Water Well
- ASR Well
- New Alluvial Wellfield
- ASR Study Area (Plateau)

All Other Features

- Prineville City Limit
- Roads
- Watercourse
- Waterbody

N

0 3,500 7,000 10,500
Feet

Date: March 14, 2018
Data Sources: ESRI, USGS, DigiGlobe 2016

GSI Water Solutions, Inc.

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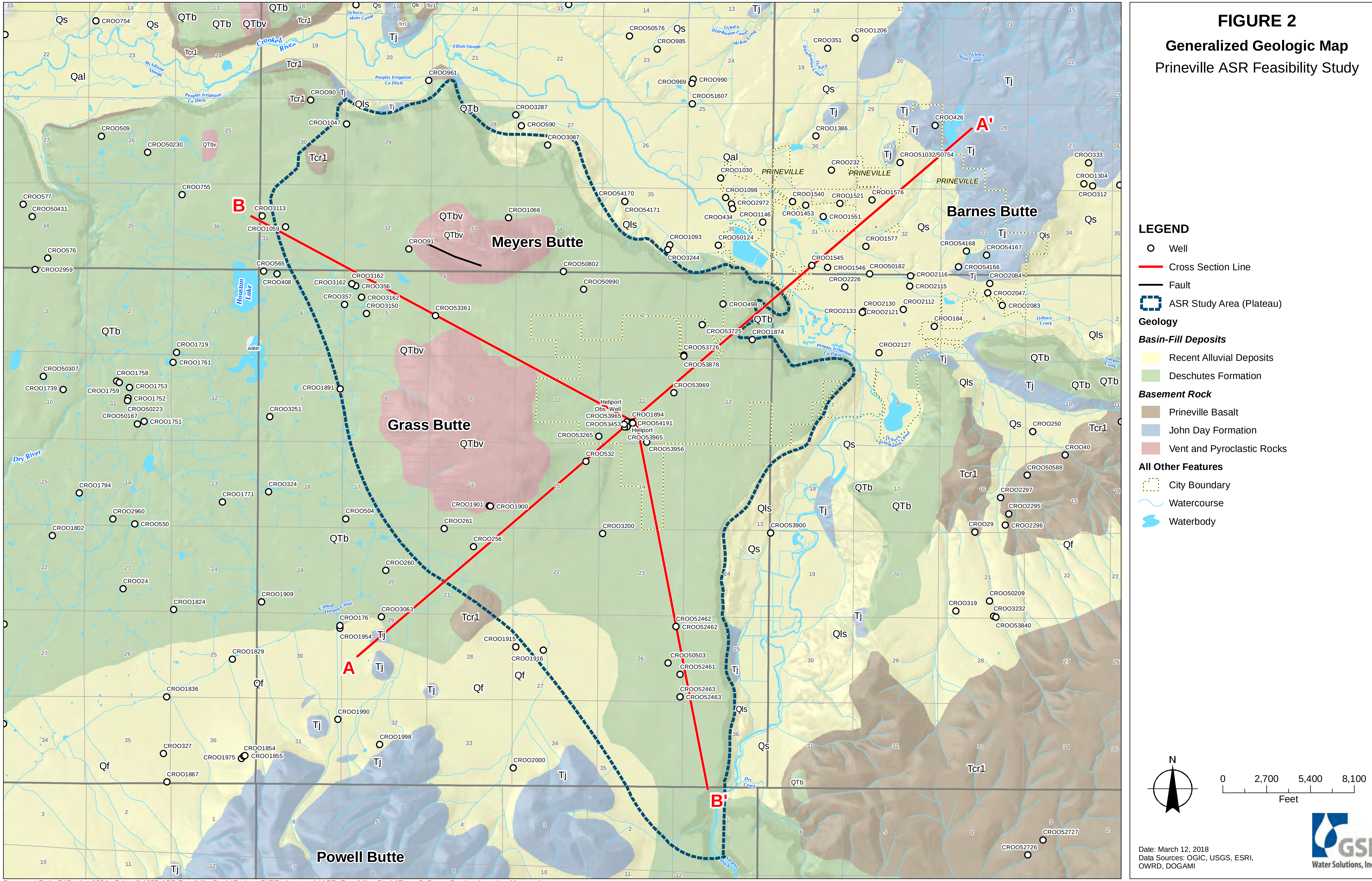

FIGURE 2

Generalized Geologic Map

Prineville ASR Feasibility Study

Date: March 12, 2018
Data Sources: OGIC, USGS, ESRI, OWRD, DOGAMI

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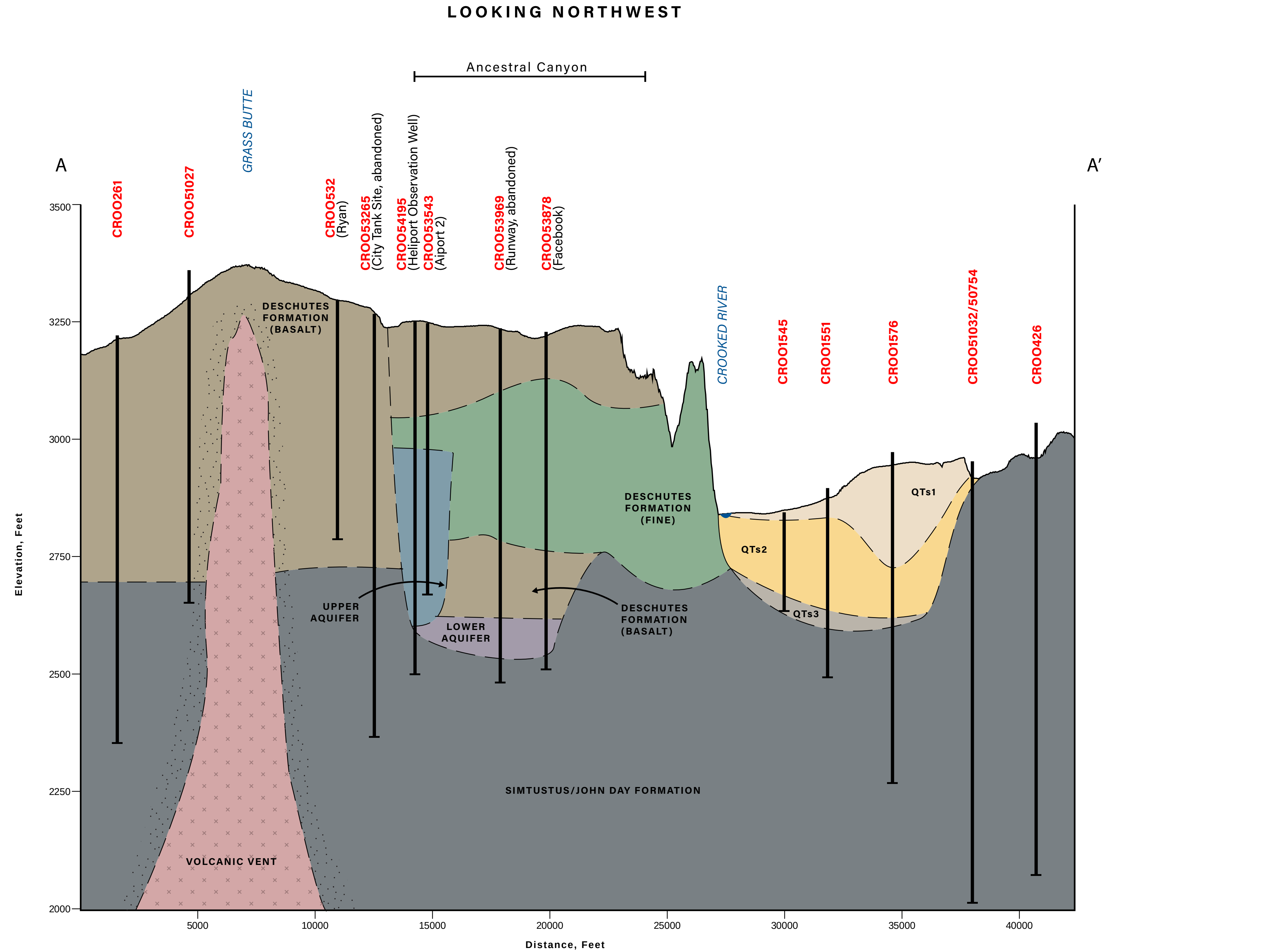

FIGURE 3

Cross Section A to A′

Prineville ASR Feasibility Study

LEGEND

Basin Fill Deposits

Recent Alluvial Deposits

- QTs1 - Upper Sand and Gravel
- QTs2 - Fine Grained Deposits (confining Unit)
- QTs3 - Lower Sand and Gravel

Deschutes Formation

- Deschutes Formation - Basalt
- Deschutes Formation - Fine Grained
- Deschutes Formation - Coarse Grained Sand and Gravel (Upper Aquifer)
- Fractured Basalt/Fine Sand and Gravel (Lower Aquifer)

Basement Rock

- Simtustus/John Day Formation
- Volcanic Vent

SCALE

250

0 5000

20X Vertical Exaggeration

Water Solutions, Inc.

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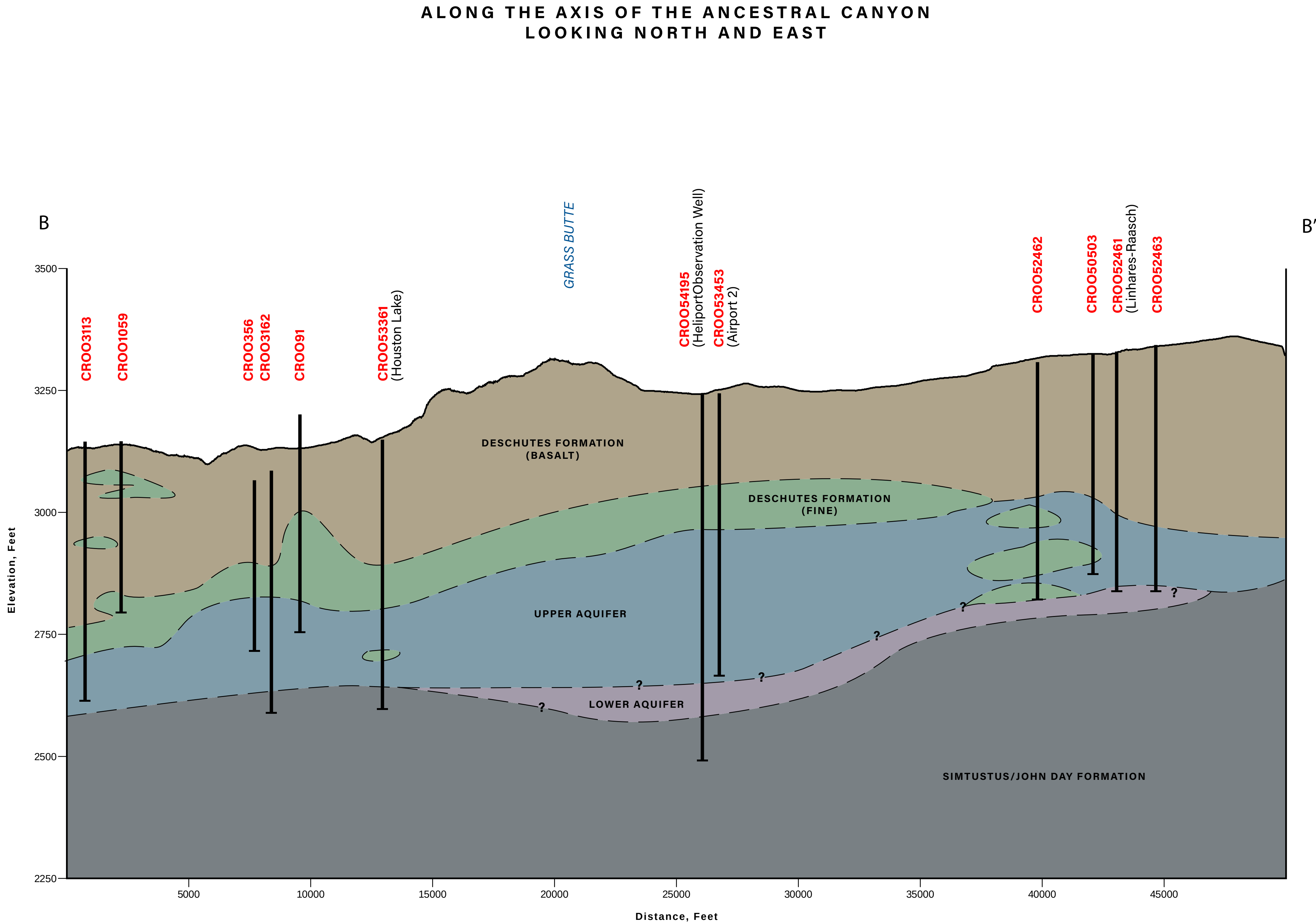


FIGURE 4

Cross Section B to B'

Prineville ASR Feasibility Study

LEGEND

Basin Fill Deposits

Deschutes Formation

- Deschutes Formation - Basalt
- Deschutes Formation - Fine Grained
- Deschutes Formation - Coarse Grained Sand and Gravel (Upper Aquifer)
- Fractured Basalt/Fine Sand and Gravel (Lower Aquifer)

Basement Rock

- Simtustus/John Day Formation

SCALE

250

0 5000

20X Vertical Exaggeration

GSI Water Solutions, Inc.

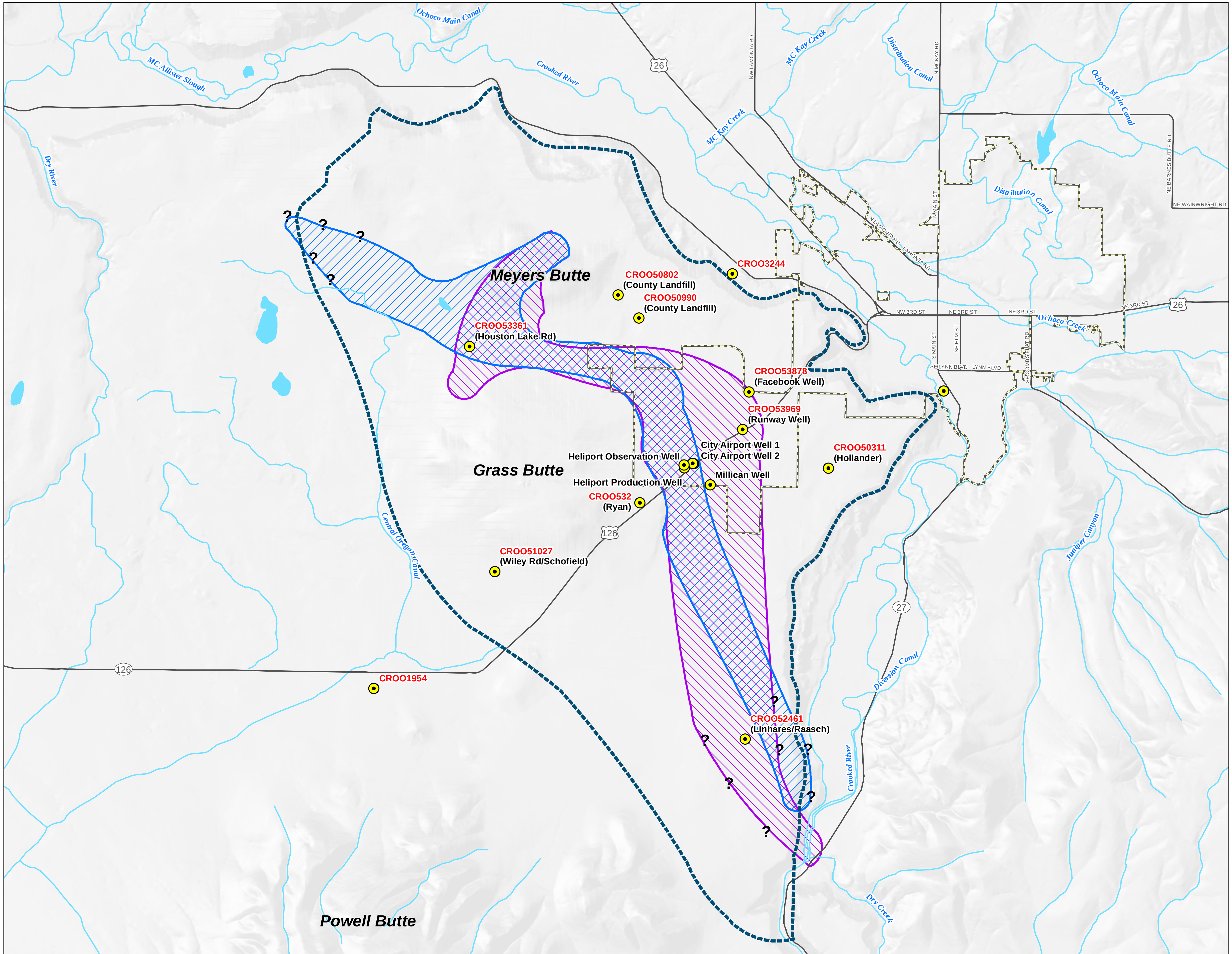


FIGURE 5

Estimated Areal Extent of the Upper Aquifer and Lower Aquifer

Prineville ASR Feasibility Study

LEGEND

- Well
- Upper Aquifer
- Lower Aquifer
- ASR Study Area (Plateau)

All Other Features

- Prineville City Limit
- Major Road
- Watercourse
- Waterbody

N

0 2,700 5,400 8,100
Feet

Date: August 1, 2016
Data Sources: ESRI, BLM, USGS

GSI Water Solutions, Inc.

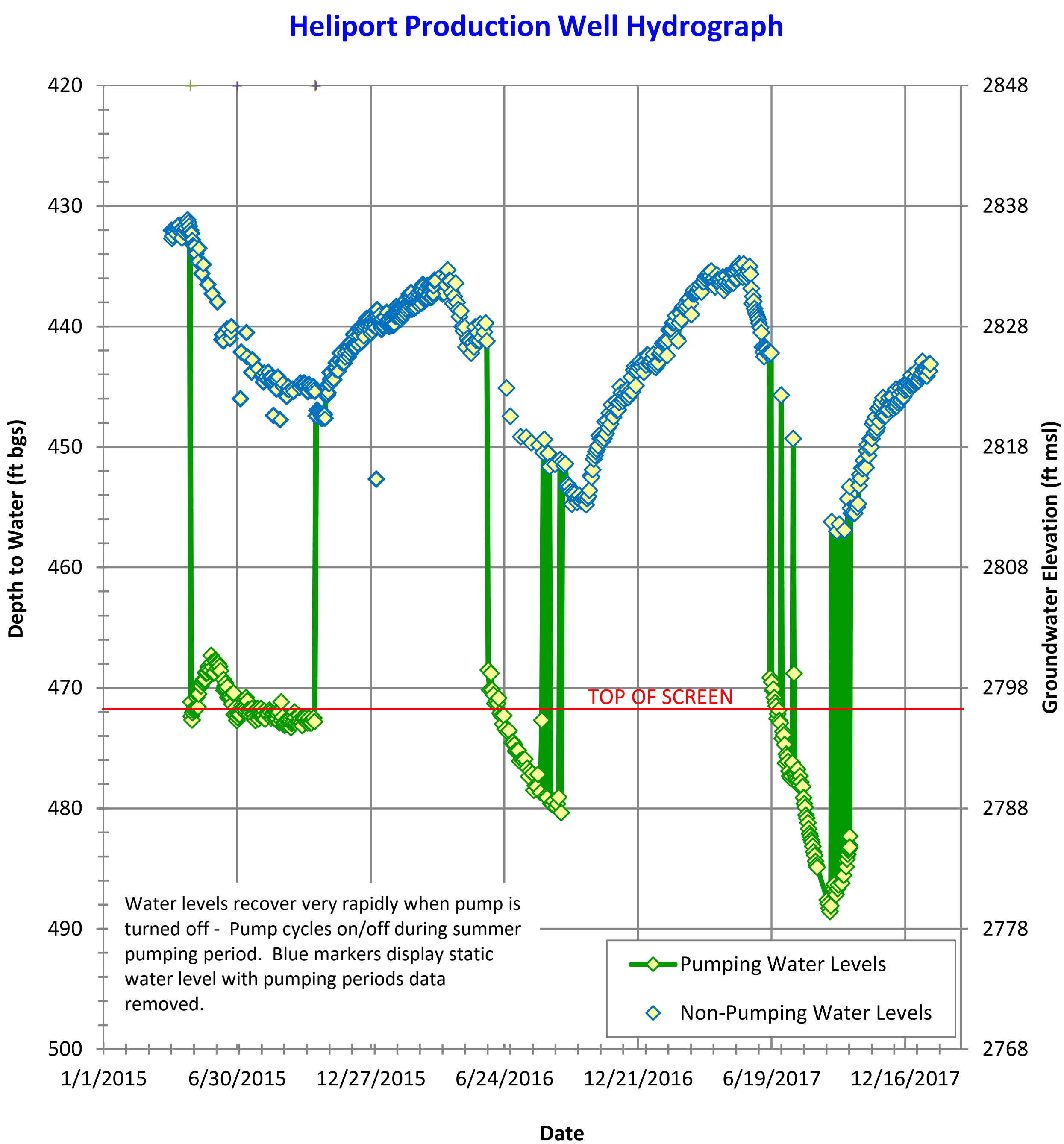
Document Path: P:\Portland\224 - Prineville\025-ASR Feasibility Study\Project_GIS\Project_mxds\ASR_Feasibility_Study\Figure5_Location_Aquifers.mxd

FIGURE 6

Heliport Production Well Hydrograph

OWRD Well Log # : **CROO 54191**

Location of well (T/R/S QQ): **T15S/R15E/S11 SE-SW**



GSI Water Solutions, Inc.

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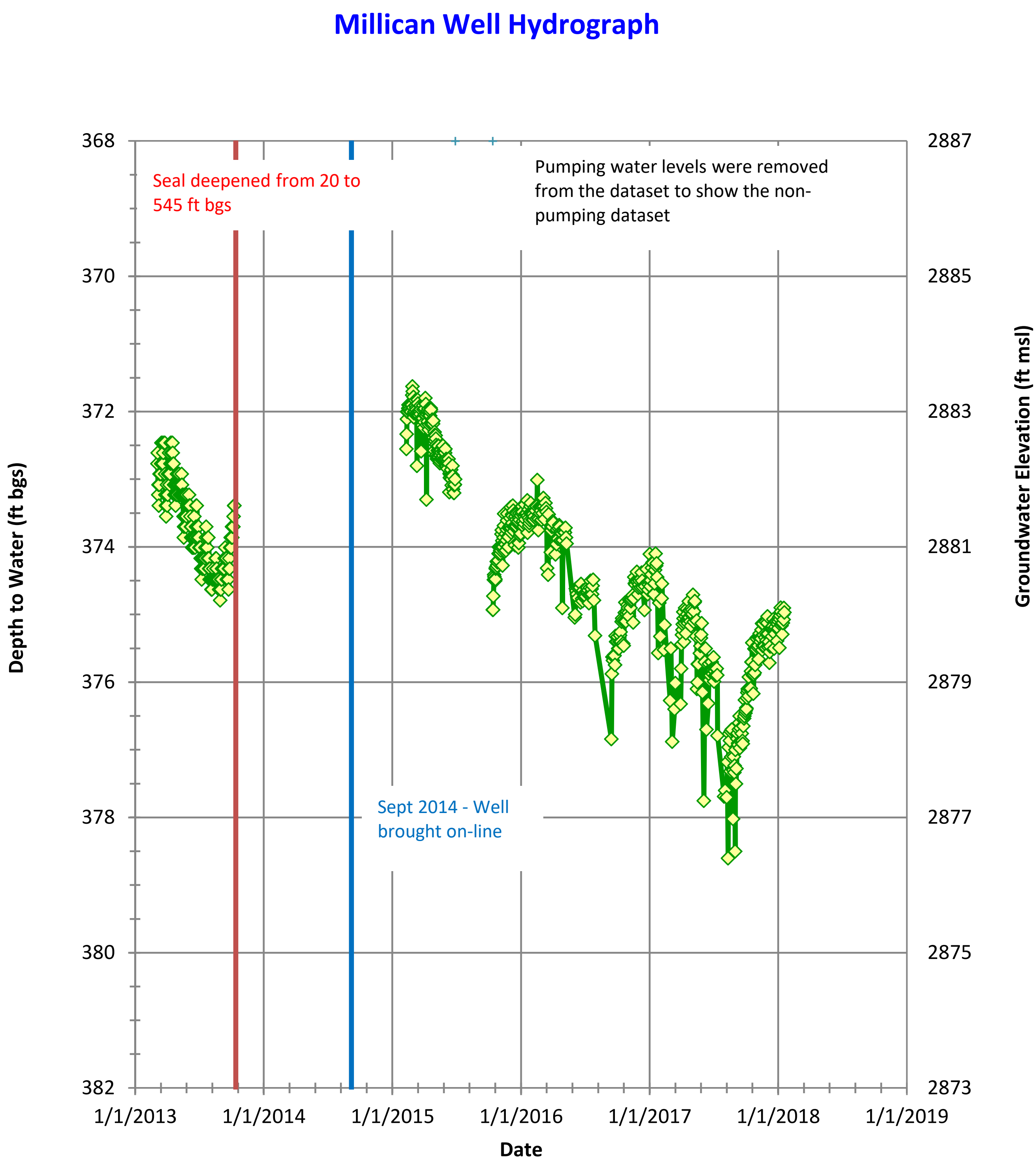
FIGURE 7
Millican Well Hydrograph

OWRD Well Log # : **CROO 53956**
Location of well (T/R/S QQ): **T15S/R15E/S11 SW - SE**



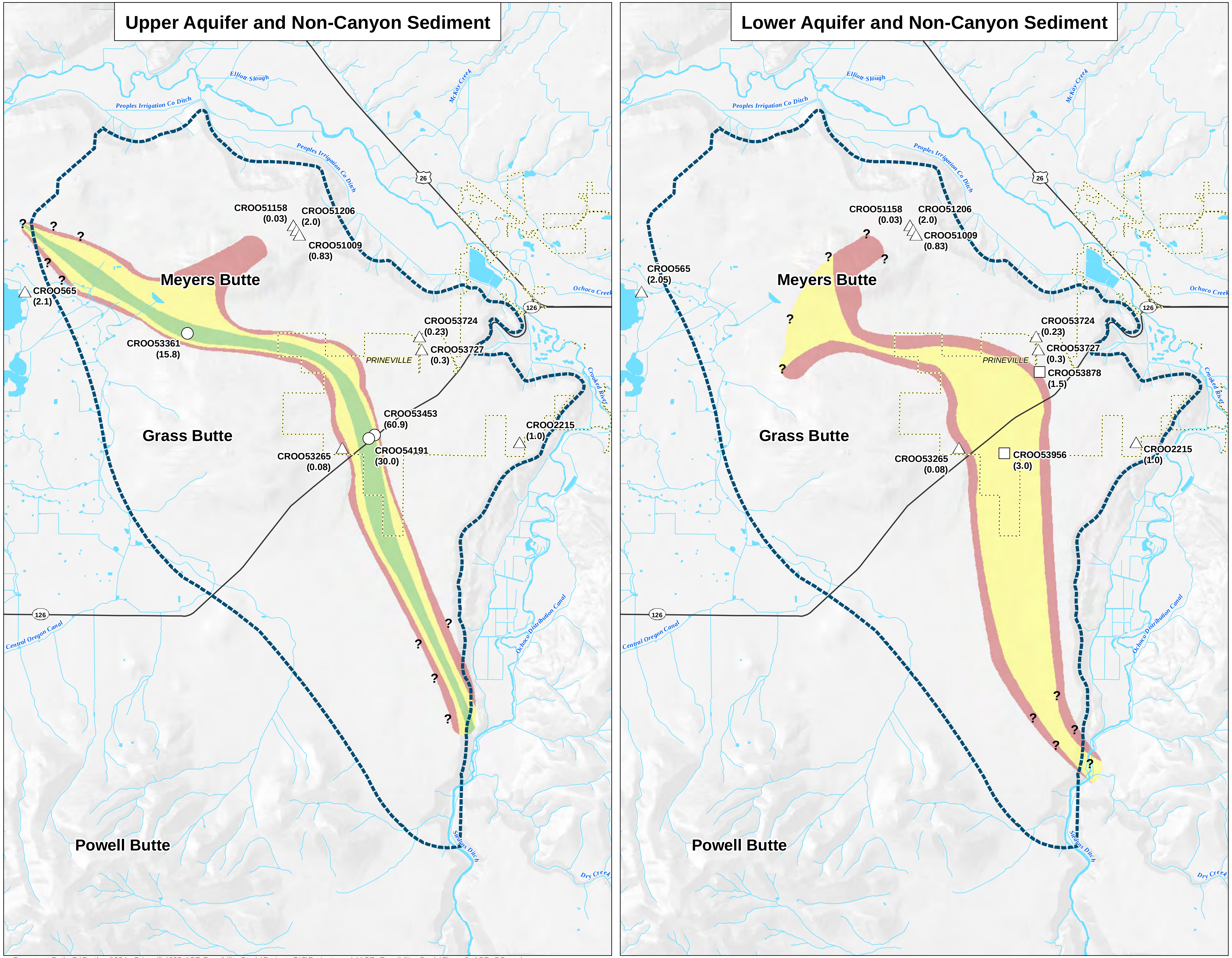


FIGURE 8

Specific Capacity in the Lower Aquifer and Upper Aquifer

Prineville ASR Feasibility Study

LEGEND

- Lower Aquifer
- Upper Aquifer
- Out of Channel
- ASR Study Area (Plateau)

Specific Capacity (gpm/ft)

- <1
- 1-10
- >10

All Other Features

- City Boundary
- Major Road
- Watercourse
- Waterbody

N

0 3,100 6,200 9,300
Feet

GSI Water Solutions, Inc.

Date: March 12, 2018
Data Sources: OGIC, USGS, ESRI, OWRD

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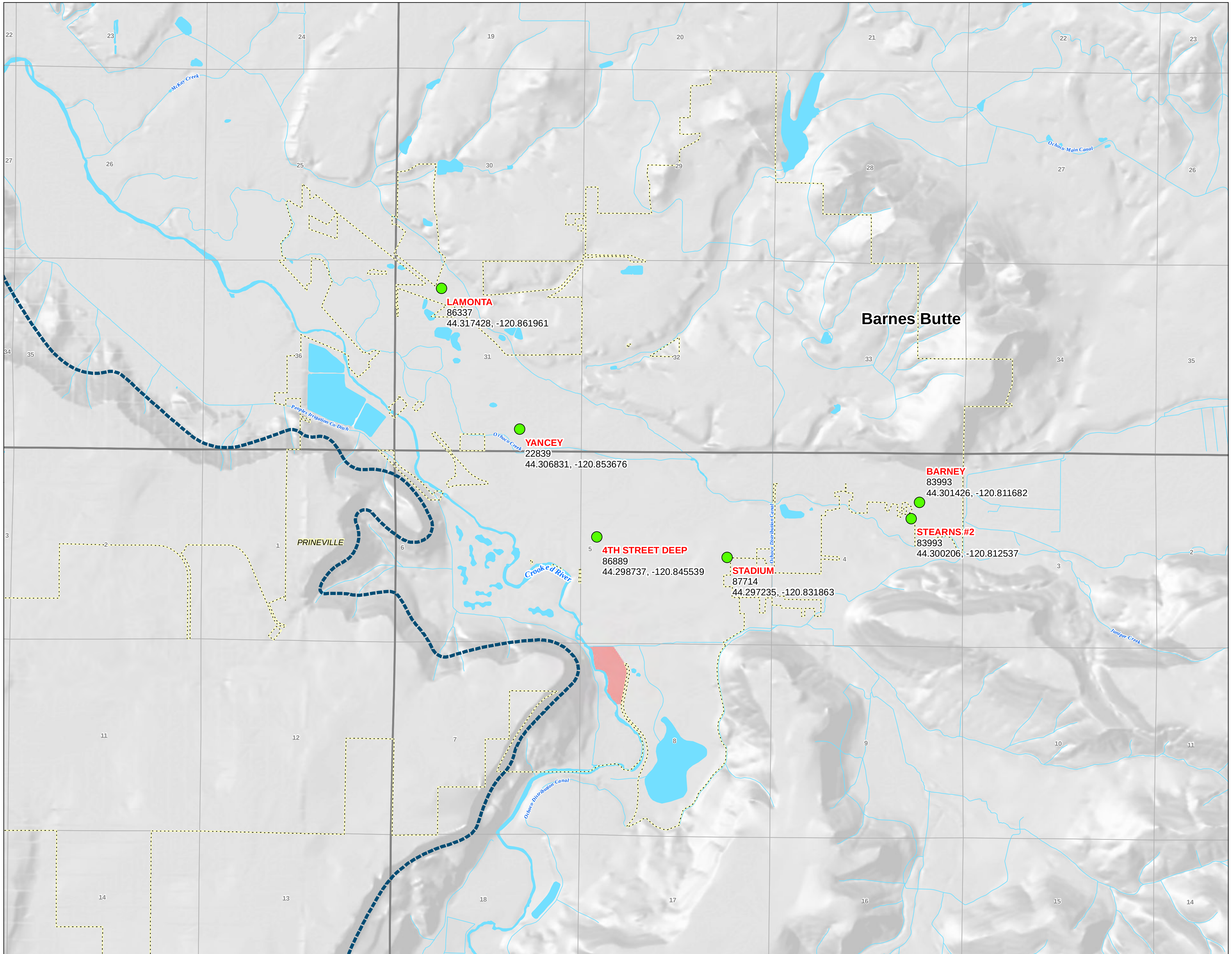

FIGURE 9

City of Prineville
Source Water Wells

Prineville ASR Feasibility Study

LEGEND

Existing Alluvial Source Water Well

Barney	*Well Name*
83993	*Water Right*
44.3, -120.8	*Latitude, Longitude*

New Alluvial Wellfield

ASR Study Area (Plateau)

All Other Features

City Boundary

Watercourse

Waterbody

N

0 0.25 0.5 0.75

Miles

Date: March 12, 2018

Data Sources: OGIC, USGS, ESRI, OWRD, DOGAMI

GSI Water Solutions, Inc.

Document Path: P:\Portland\224 - Prineville\025-ASR Feasibility Study\Project_GIS\Project_mxds\ASR_Feasibility_Study\Figure9_Source_Water_Wells.mxd

Figure 10. Stiff Diagrams - Prineville ASR Feasibility Study

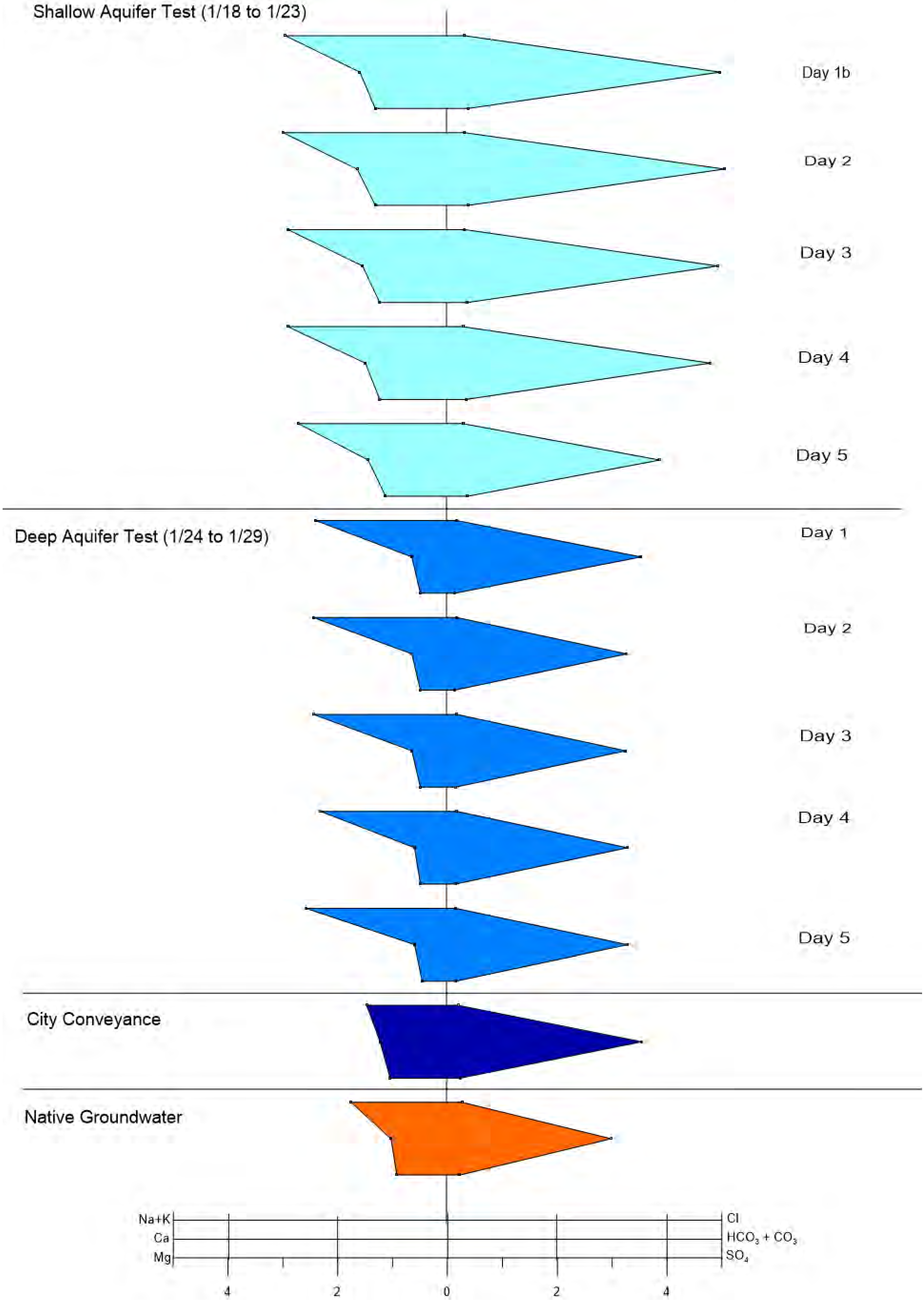

Figure 11. Piper Plots - Prineville ASR Feasibility Study

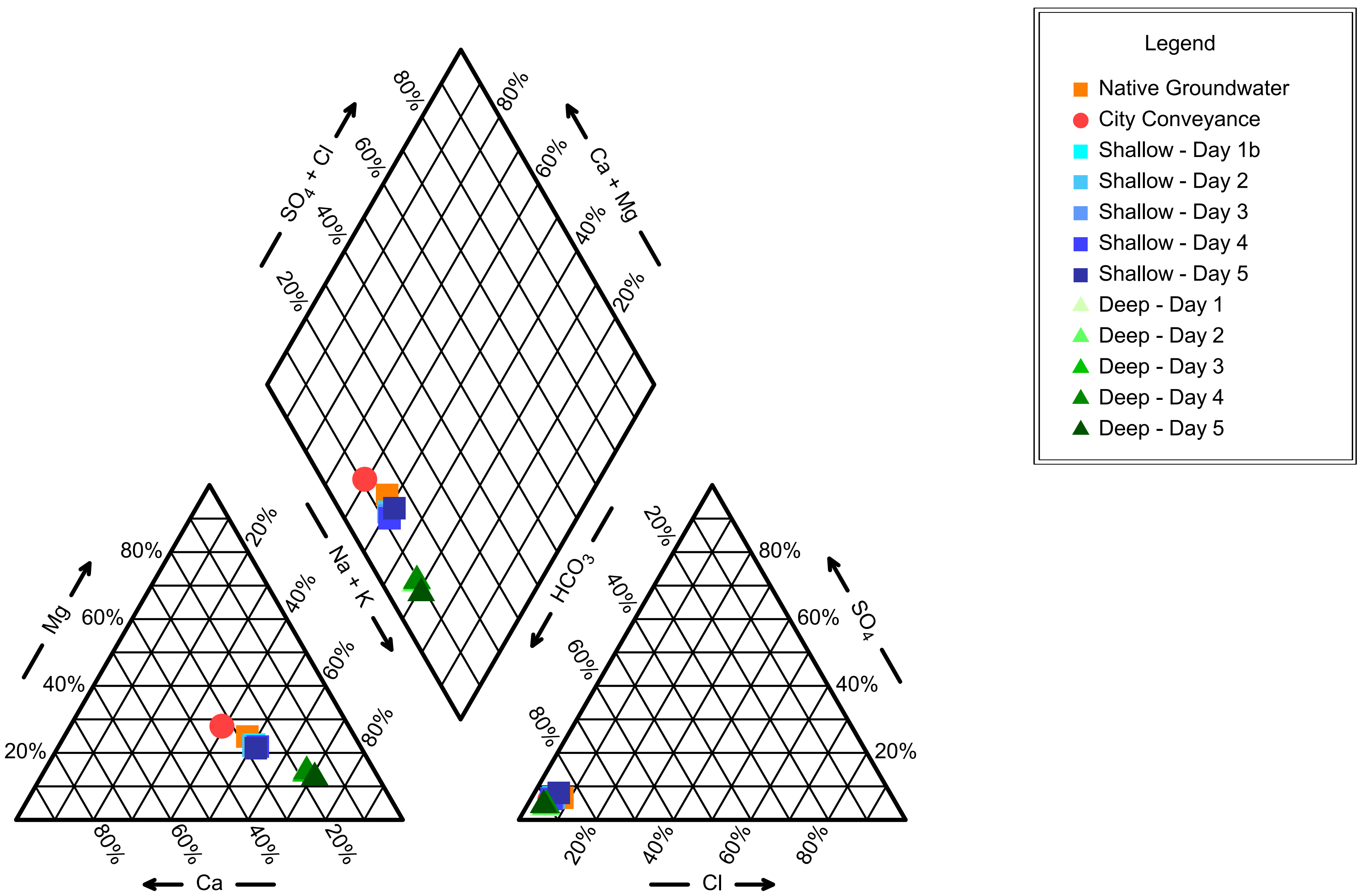

FIGURE 12

New Alluvial Source Investigation Test and Observation Well Network

Prineville ASR Feasibility Study

LEGEND

New Alluvial Wellfield

ASR Study Area (Plateau)

Test Wells

Deep Test Well

Shallow Test Well

Observation Wells

Deep Test Observation Well

Shallow Test Observation Well

All Other Features

City Boundary

Watercourse

Waterbody

N

0 100 200 300
Feet

Date: March 14, 2018
Data Sources: OGIC, USGS, ESRI, OWRD, DOGAMI

GSI Water Solutions, Inc.

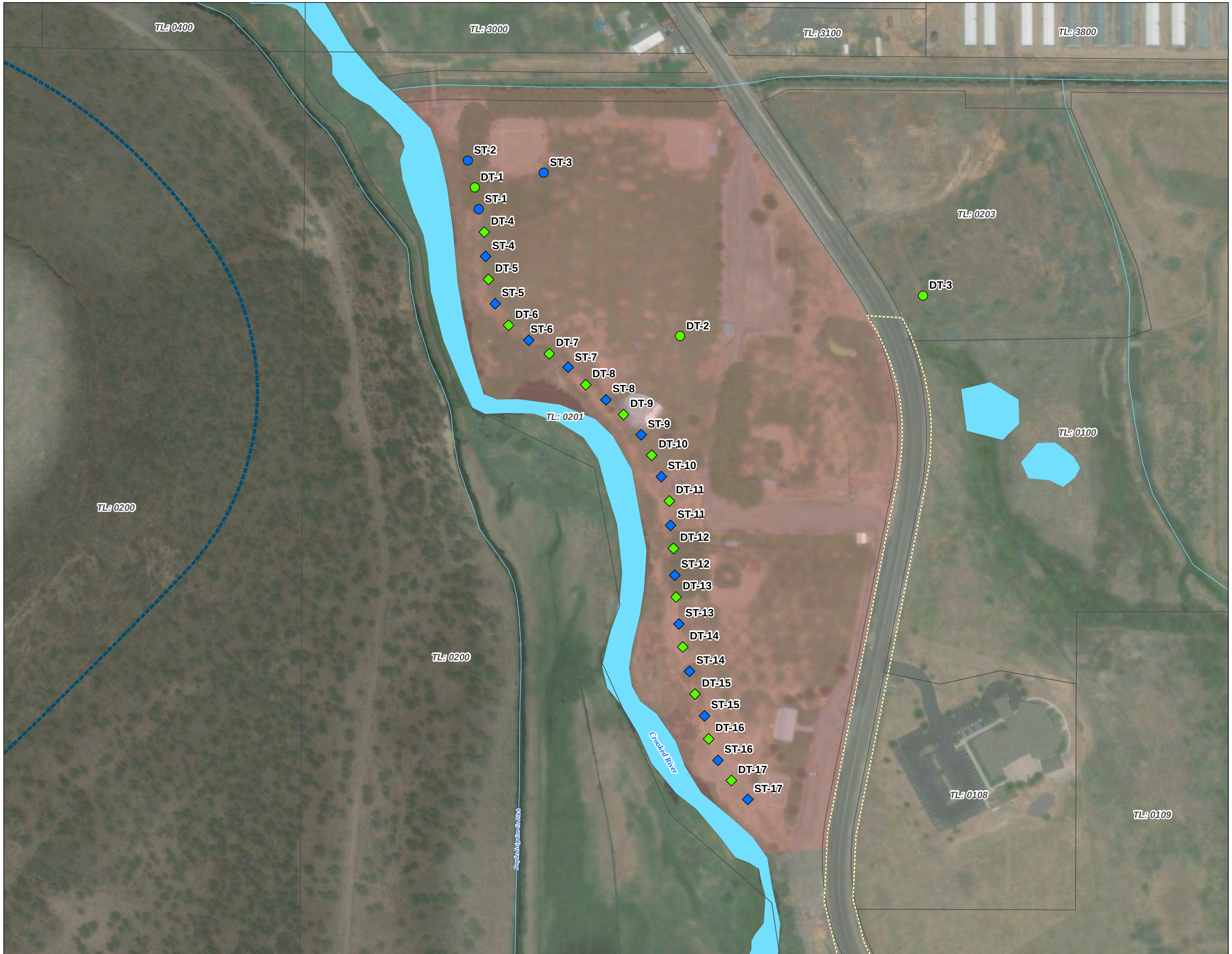

FIGURE 13

Proposed Source Water Well Locations – New Alluvial Wellfield

Prineville ASR Feasibility Study

LEGEND

- Existing Deep Test Well
- Existing Shallow Test Well
- Propsoed Deep Test Well
- Proposed Shallow Test Well
- ASR Study Area (Plateau)

All Other Features

- City Boundary
- Tax Lot
- Waterbody
- Watercourse
- New Alluvial Wellfield

N

0 100 200 300
Feet

Date: March 14, 2018
Data Sources: OGIC, USGS, ESRI, OWRD, DOGAMI

GSI Water Solutions, Inc.

Document Path: P:\Portland\224 - Prineville\025-ASR Feasibility Study\Project_GIS\Project_mxds\ASR_Feasibility_Study\Figure13_Proposed_SourceWells.mxd

Appendix A

Aquifer Hydraulic Properties

Appendix A. Aquifer Test Results.

City of Prineville ASR Feasibility Study

Hydrogeologic Unit	Well	Transmissivity, T (gpd/ft)	Aquifer Thickness, b (feet)	Hydraulic Conductivity, K (ft/day)	Storage, S (-)	Reference
QTs3	14/15-15Q1	7200	--	--	--	Robinson and Price (1963), Theis nonequilibrium and recovery
	14/15-22B1	7900	--	--	--	Robinson and Price (1963), Theis nonequilibrium and recovery
	14/15-36H1	11000	--	--	--	Robinson and Price (1963), Theis nonequilibrium and recovery
	14/16-31P1	9500	--	--	--	Robinson and Price (1963), Theis nonequilibrium and recovery
	14/16-31Q1	11000	--	--	--	Robinson and Price (1963), Theis nonequilibrium and recovery
	14/16-32N1	5500	--	--	--	Robinson and Price (1963), Theis nonequilibrium and recovery
Deschutes Formation - Upper Aquifer	Airport 2 Well (CROO 53453)	76,420	126	77	1.40E-01	GSI (2016), time-drawdown (early)
		31,560	126	33	2.30E-01	GSI (2016), time-drawdown (late)
	Airport 2 Well (CROO 53453)	74,460	126	79	--	GSI (2016), time-recovery (early)
		49,220	126	52	--	GSI (2016), time-recovery (late)
	Heliport Production Well (pw) (CROO 54191)	42,090	137	41	--	GSI (2016), time-recovery
Deschutes Formation - Lower Aquifer	Runway & Linhare Wells	35,380	50	94	7.02E-04	GSI (2016), distance-drawdown[2]
	Runway Well (CROO 53969)	54,420	50	145	5.70E-07	GSI (2016), time-drawdown (early)
		31,030	50	83	1.70E-04	GSI (2016), time-drawdown (late)
	Runway Well (CROO 53969)	78,610	50	210	--	GSI (2016), time-recovery
	Linhare Well (CROO 52461)	153,800	47	437	7.30E-05	GSI (2016), time-drawdown (early)
		59,960	47	171	5.40E-04	GSI (2016), time-drawdown (late)
	Linhare Well (CROO 52461)	228,200	47	649	--	GSI (2016), time-recovery (early)
		85,240	47	242	--	GSI (2016), time-recovery (late)
	Millican Well (pw) (CROO 53956)	18,620	54	46	--	GSI (2016), time-drawdown (early)
		64,320	54	159	--	GSI (2016), time-drawdown (late)
	Millican Well (pw) (CROO 53956)	67,380	54	167	--	GSI (2016), time-recovery

Notes:

(1) Average excludes estimates based on time-drawdown analysis at the pumping well

(2) Aquifer thickness for the distance-drawdown test is the average thickness at the Millican Well, Runway Well and Linhare Well

gpd/ft = gallons per day per foot   pw = pumping well   "--" = no value

ft/day = feet per day   S = storage (specific yield or storativity)

Laboratory reports included in the electronic version of this Report - No paper copies

Appendix B

Laboratory Analytical Reports

Appendix C

Geochemical Water Quality Mixing Evaluation

S.S. PAPADOPULOS & ASSOCIATES, INC.
Environmental & Water-Resource Consultants

Memorandum

Date: March 12, 2018

From: Brad Bessinger

To: Matt Kohlbecker, GSI Water Solutions, Inc.

Project: City of Prineville ASR Feasibility Study

Subject: **Water Quality Mixing Evaluation**

This memorandum summarizes an evaluation of water chemistry data for an Aquifer Storage and Recovery (ASR) system proposed by the City of Prineville, Oregon (the City). Included is an evaluation of potential changes in water quality caused by mixing native groundwater with the following ASR water sources:

- A new shallow groundwater well located near the Crooked River;
- A new deep groundwater well located near the Crooked River; and
- The City's municipal distribution system, which is fed by several shallow alluvial wells located throughout the City.

Also included in this memorandum is an assessment of mineral precipitation reactions that could potentially occur in the ASR system.

Methodology

A summary of water chemistry data for native groundwater from the Heliport Production Well and proposed injection water was provided in spreadsheet format by GSI Water Solutions (GSI) (Table 1). As shown in the table, concentrations of total dissolved solids (TDS) in both native and proposed injection water are relatively low, with no primary maximum contaminant level (MCL) exceedances for any constituent. By comparison, total iron and both dissolved and total manganese concentrations are higher than secondary MCLs analyzed for the new shallow groundwater well located near the Crooked River. Finally, secondary drinking water criteria for odor are exceeded in all proposed injection waters.

The USGS-supported geochemical model PHREEQC (Parkhurst and Appelo 1999) was used to calculate the effect of water mixing on (1) the concentrations of dissolved constituents in groundwater-injected water mixtures, and (2) mineral saturation indices[1] (SI). Model results were

[1] As concentrations of dissolved aqueous species that comprise a particular mineral increase, the tendency for that mineral to precipitate out of groundwater is enhanced. This tendency is defined mathematically by a value called the saturation index (SI), which is expressed on a logarithmic scale as the ratio of the concentration of ions in solution to the concentration required for mineral precipitation to occur. SI values greater than or equal to zero represent groundwater that is saturated or supersaturated (under these conditions, there is a thermodynamic driving force for

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WWW.SSPA.COM • E-MAIL: BBESSINGER@SSPA.COM

reported as a function of the percentage of alluvial source groundwater contained in the mixture (from 0 to 100%). A separate PHREEQC model simulation was conducted to evaluate the potential for trihalomethane formation in the ASR system.

Predicted Water Quality

Tables 2a through 2c compare model-predicted constituent concentrations in mixed groundwater to primary and secondary MCLs. The mixing of native groundwater with groundwater from the new shallow alluvial aquifer results in the exceedance of the secondary MCL for manganese when the percentage of injection water comprises more than 40% of the mixture (Table 2b). This exceedance is due to the presence of dissolved manganese in the alluvial groundwater. No other exceedances are predicted for any source water or constituent.

Predicted Mineral Saturation Indices

The saturation states of water mixtures with respect to selected minerals are summarized at the bottom of Tables 2a through 2c. Results include the following:

- Silica (SiO_2) Minerals: Groundwater is close to equilibrium with several silica polymorphs, including chalcedony and SiO_2(am) (SI values ± 1.0). Although quartz has the most-positive SI value, it is unlikely to precipitate. This is because quartz precipitation kinetics are extremely slow, and its precursor is SiO_2(am), has negative SI values. In summary, silica precipitation is not predicted.
- Carbonate Minerals: Native groundwater is close to equilibrium with calcite (SI = 0.0), which is consistent with it potentially-being present as a buffering mineral within the aquifer. Although dolomite is supersaturated (SI = 1.1), its precipitation is kinetically-inhibited and unlikely to occur[2]. As shown in Tables 2a and 2b, the use of municipal water or shallow groundwater results in a decrease in the saturation index of calcite. This implies that a small fraction of the calcite potentially-present in the aquifer could dissolve into recovered water. Although calcite re-precipitation is possible if CO_2(g) exsolution occurs within the ASR system, the model predicts that carbonate scale is unlikely ($SI_{calcite} < 0.6$ following exsolution of native groundwater).

mineral precipitation to occur). Conversely, values less than zero imply that a mineral is unstable, and if present in aquifer soils, will dissolve into groundwater.

[2] Although carbonate scale formation is possible, precipitation is inhibited by the large nucleation energy required to form new minerals. For example, SI values required for calcite nucleation and crystal growth range from 1.3 to 2.5 (Morse et al., 2007; Lebron and Suarez, 1996), which are higher than predicted by the model.

- Iron and Manganese Minerals: Iron oxyhydroxides (such as $Fe(OH)_3$(am) and goethite) are very insoluble ferric iron minerals that are known to precipitate in ASR and injection well systems (due to the oxidation/conversion of dissolved ferrous iron to ferric). As shown by the positive saturation indices for these minerals in Table 2, there is predicted to be a potential for mineral precipitation[3] and/or biofouling by Fe-related bacteria in the proposed ASR system when the injection water is from either the shallow or deep groundwater wells located near the Crooked River[4]. Also, there is predicted to be a potential for manganese to oxidize and precipitate (as shown in Table 2, the SI values for pyrolusite, bixbyite, and hausmannite are positive for all proposed mixing scenarios[5]).

  Although some iron and manganese oxyhydroxide precipitation is possible, the amount is likely to be small, based low concentrations of ferrous iron and manganese in the aquifer. Therefore, it is unlikely that these minerals will significantly affect injection well operations through clogging. Supporting evidence for a lack of clogging is provided in Table 3, which summarizes water quality from other regional ASR systems in basalt aquifers with similar iron and manganese concentrations, and no reported issues associated with mineral precipitation.

Total Trihalomethanes

Because residual chlorine is reported in native groundwater (0.08 mg/L; Table 1), a separate model simulation was conducted to evaluate the potential for the formation of trihalomethanes due to reactions with organic carbon. The initial concentration used in the simulations was 0.08 mg/L and additional trihalomethanes were formed via reaction between residual chlorine and the maximum-reported reactive organic carbon (2.1 mg/L). Also, the reaction rates used were those described in Clark et al. (1998a and 1998b). As shown in Figure 2, total trihalomethanes (TTHMs) are predicted

[3] Evidence that iron oxyhydroxide mineral precipitation is possible includes the following: 1) the occurrence of ferrous iron in groundwater (Table 1); 2) Eh-pH diagrams showing that the mineral $Fe(OH)_3$(am) is more-stable than dissolved iron (Fe^{+2}) (Figure 1; top diagram); and 3) positive saturation indices (SI) predicted for Fe(OH)3(am) and goethite during mixing (Tables 2b and 2c).

[4] Both wells reported detectable dissolved ferrous (Fe^{+2}) iron, which can be oxidized by dissolved oxygen and/or residual chlorine reported in the system.

[5] This result is predicated on the assumption that there was no oxygen introduced during sampling, which has the effect of increasing the stability of manganese oxide minerals relative to dissolved manganese (Mn^{+2}). It is important to note in this regard that even if the oxidation state of groundwater were assumed to be better-represented by ORP (or Eh), three of the groundwaters evaluated would still be near (or within) the stability field of manganese minerals (Figure 1, bottom Eh-pH diagram). Although the other groundwater sample (from the new shallow groundwater well near the Crooked River) is predicted to be within the stability field of Mn^{+2} (based on ORP/Eh), it could still oxidize and precipitate upon mixing with native groundwater (as indicated by the arrow in the figure, which shows the change in Eh-pH expected during mixing).

to increase initially, but then decay over time. Most-importantly, concentrations of TTHMs are predicted to be significantly-less than the MCL of 0.08 mg/L.

Conclusions and Recommendations

No detrimental water quality changes are predicted to be caused by operation of the ASR system; however, there is some potential for iron or manganese mineral precipitation to occur. The amount of precipitate formed would be small and could be mitigated by blending groundwater from new shallow well near the Crooked River, which has the highest dissolved manganese concentrations, with groundwater from the deep well and the City's municipal distribution system.

References

Clark, R.M. 1998a. Chlorine demand and TTHM formation kinetics: a second-order model. *J. Env. Eng.* 124: 16–24.

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Morse, J.W., R.S. Arvidson, and A. Lüttge. 2007. Calcium carbonate formation and dissolution. *Chem. Rev.* 107:342-381.

Parkhurst, D.L. and C.A.J. Appelo. 1999. User's guide to PHREEQC (Version 2)—A computer program for speciation, batch-reaction, one-dimensional transport, and inverse geochemical calculations. U.S. Geological Survey Water Resources Investigations Report 99-4259.

Table 1. Summary of Water Quality of Waters Used in Mixing Analysis

Type	Parameter	Units	Primary MCL	Secondary MCL	Native Groundwater	Municipal Distribution	New Shallow GW Well	New Deep GW Well
General	Conductivity	us/cm			342	1463	1180	1033
	Dissolved Oxygen	mg/L			7.93	3.36	8.62	0.53
	ORP	mV			272.6	252	34.4	208.3
	pH	unitless		6.5-8.5	7.99/8.10	7.58	7.66	8.32
	Temperature	degC			12	14.36	12.13	12.75
	Total Dissolved Solids	mg/L		500	198	237	319	238
Cations	Calcium	mg/L			20.6	24.6	29	12
	Magnesium	mg/L			11.2	12.7	13.7	5.6
	Potassium	mg/L			3.65	3.3	4.7	2.3
	Sodium	mg/L			38.3	31.9	59.7	58
Anions	Alkalinity, Total as CaCO3	mg/L			147	173	231	164
	Bicarbonate	mg/L			176	211	281	186
	Carbonate	mg/L			< 6	< 5	< 5	7
	Chloride	mg/L		250	9.47	7	10	5
	Sulfate	mg/L		250	10.7	11	17	7
Redox Species	Iron, Dissolved	mg/L		0.3	< 0.162	< 0.02	0.18	0.02
	Iron, Total	mg/L		0.3	0.0863	< 0.03	0.46	< 0.03
	Manganese, Dissolved	mg/L		0.05	< 0.00515	0.025	0.148	0.031
	Manganese, Total	mg/L		0.05	< 0.005	0.025	0.161	0.03
	Nitrate + Nitrite	mg/L			0.841	0.2	< 0.01	0.01
	Nitrate as N	mg/L	10		< 0.05	0.2	< 0.01	< 0.01
	Nitrite as N	mg/L	1		0.841	< 0.2	< 0.01	< 0.01
Metals	Aluminum	mg/L		0.05 to 2	0.0108	< 0.03	0.03	< 0.03
	Antimony	mg/L	0.006		< 0.002	< 0.001	< 0.001	< 0.001
	Arsenic	mg/L	0.01		0.00197	0.003	< 0.001	< 0.001
	Barium	mg/L	2		0.00519	< 0.05	< 0.05	< 0.05
	Beryllium	mg/L	0.004		0.000216	< 0.001	< 0.001	< 0.001
	Cadmium	mg/L	0.005		< 0.000103	< 0.001	< 0.001	< 0.001
	Chromium	mg/L	0.1		0.00185	< 0.005	< 0.005	< 0.005
	Copper	mg/L	1.3	1	< 0.0005	< 0.005	< 0.005	0.018
	Lead	mg/L	0.015		< 0.0001	< 0.001	< 0.001	< 0.001
	Mercury	mg/L	0.002		< 0.0002	< 0.0001	< 0.0001	< 0.0001
Metals	Nickel	mg/L			< 0.0005	< 0.005	< 0.005	< 0.005

Table 1. Summary of Water Quality of Waters Used in Mixing Analysis

Type	Parameter	Units	Primary MCL	Secondary MCL	Native Groundwater	Municipal Distribution	New Shallow GW Well	New Deep GW Well
	Selenium	mg/L	0.05		< 0.001	< 0.001	0.002	< 0.001
	Silver	mg/L		0.1	< 0.0001	< 0.001	< 0.001	< 0.001
	Thallium	mg/L	0.002		< 0.0005	< 0.0005	< 0.0005	< 0.0005
	Zinc	mg/L		5	< 0.005	< 0.01	< 0.01	0.01
Other Parameters	Color	c.u.		15	< 5	10	14	12
	Corrosivity	--		NC	-0.05	0.14	0.4	0.39
	Cyanide	mg/L	0.2		< 0.003	< 0.005	< 0.005	< 0.005
	Fluoride	mg/L	4	2	0.706	0.3	0.4	0.3
	Odor	ton		3	< 1	4	17	4
	Silica	mg/L			58.6	45	51	35
	Total Organic Carbon	mg/L			0.163	0.9	2.1	1
	Total Suspended Solids	mg/L			0	< 1	8	< 1
Disinfection Byproducts (DBPs)	Bromate	mg/L	0.01		< 0.025	--	< 0.01	< 0.005
	Bromodichloromethane	mg/L			< 0.0005	< 0.0005	< 0.0005	< 0.0005
	Bromoform	mg/L			< 0.0005	0.00069	< 0.0005	< 0.0005
	Chlorine	mg/L	4		0.08	--	--	--
	Chlorite	mg/L	1		< 0.01	--	< 0.01	< 0.01
	Chloroform	mg/L			< 0.0005	< 0.0005	< 0.0005	< 0.0005
	Dibromoacetic Acid (DBAA)	mg/L			< 0.003	< 0.003	< 0.003	< 0.003
	Dibromochloromethane	mg/L			< 0.005	0.00094	< 0.0005	< 0.0005
	Dichloroacetic Acid (DCAA)	mg/L			< 0.003	< 0.003	< 0.003	< 0.003
	Monobromoacetic Acid (MBAA)	mg/L			< 0.003	< 0.003	< 0.003	< 0.003
	Monochloroacetic Acid (MCAA)	mg/L			< 0.003	0.00923	< 0.003	< 0.003
	Total Haloacetic Acids	mg/L	0.06		< 0.003	0.00923	< 0.003	< 0.003
	Total Trihalomethanes	mg/L	0.08		< 0.0005	0.00163	< 0.0005	< 0.0005
	Trichloroacetic Acid (TCAA)	mg/L			< 0.003	< 0.003	< 0.003	< 0.003

Notes

- Unless otherwise notes, all values are the dissolved portion

-- = Not Tested

NC = Noncorrosive

Shading indicates exceedance of Water Quality Criteria

Table 2a. Summary of Mixing Calculations (Native Groundwater + Municipal Distribution System)

			Primary	Secondary	Municipal Distribution System										
Type	Parameter	Units	MCL	MCL	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
General	Dissolved Oxygen	mg/L			7.0	6.6	6.3	5.9	5.5	5.2	4.8	4.5	4.1	3.7	3.4
	Eh	mV			764	767	770	772	774	776	778	779	780	781	782
	pH	s.u.		6.5-8.5	8.1	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.6
	Temperature	degC			12.0	12.2	12.5	12.7	12.9	13.2	13.4	13.7	13.9	14.1	14.4
	Total Dissolved Solids	mg/L		500	198	202	206	210	214	218	221	225	229	233	237
Cations	Calcium	mg/L			20.6	21.0	21.4	21.8	22.2	22.6	23.0	23.4	23.8	24.2	24.6
	Magnesium	mg/L			11.2	11.4	11.5	11.7	11.8	12.0	12.1	12.3	12.4	12.6	12.7
	Potassium	mg/L			3.7	3.6	3.6	3.6	3.5	3.5	3.4	3.4	3.4	3.3	3.3
	Sodium	mg/L			38.3	37.7	37.0	36.4	35.8	35.1	34.5	33.8	33.2	32.6	31.9
Anions	Bicarbonate	mg/L			179.0	183.0	186.0	189.0	192.0	195.0	198.0	202.0	205.0	208.0	211.0
	Chloride	mg/L		250	9.5	9.2	9.0	8.7	8.5	8.2	8.0	7.7	7.5	7.3	7.0
	Sulfate	mg/L		250	10.7	10.7	10.8	10.8	10.8	10.9	10.9	10.9	10.9	11.0	11.0
Redox Species	Iron, Dissolved	mg/L		0.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Manganese, Dissolved	mg/L		0.05	ND	0.003	0.005	0.008	0.010	0.013	0.015	0.018	0.020	0.023	0.025
	Nitrate as N	mg/L	10		0.8	0.8	0.7	0.6	0.6	0.5	0.5	0.4	0.3	0.3	0.2
	Nitrite as N	mg/L	1		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Metals	Aluminum	mg/L		0.05 to 2	0.011	0.010	0.009	0.008	0.006	0.005	0.004	0.003	0.002	0.001	ND
	Antimony	mg/L	0.006		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Arsenic	mg/L	0.01		0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003
	Barium	mg/L	2		0.005	0.005	0.004	0.004	0.003	0.003	0.002	0.002	0.001	0.001	ND
	Beryllium	mg/L	0.004		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	ND
	Cadmium	mg/L	0.005		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Chromium	mg/L	0.1		0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	ND
	Copper	mg/L	1.3	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Lead	mg/L	0.015		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Mercury	mg/L	0.002		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Selenium	mg/L	0.05		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Silver	mg/L		0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Thallium	mg/L	0.002		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Zinc	mg/L		5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Other Parameters	Fluoride	mg/L	4	2	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.3	0.3
	Silica	mg/L			59	57	56	55	53	52	51	49	48	46	45
	Total Organic Carbon	mg/L			0.2	0.2	0.3	0.4	0.5	0.5	0.6	0.7	0.8	0.8	0.9
Disinfection Byproducts (DBPs)	Bromate	mg/L	0.01		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Chlorine	mg/L	4		0.08	0.07	0.06	0.06	0.05	0.04	0.03	0.02	0.02	0.01	ND
	Chlorite	mg/L	1		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total Haloacetic Acids	mg/L	0.06		ND	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
	Total Trihalomethanes	mg/L	0.08		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Saturation Index	Quartz	unitless			1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.1
	Chalcedony	unitless			1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.8
	SiO2(am)	unitless			-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
	Calcite	unitless			0.0	0.0	-0.1	-0.1	-0.2	-0.2	-0.2	-0.2	-0.3	-0.3	-0.3
	Dolomite	unitless			1.1	1.0	0.9	0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.5
	Gypsum	unitless			-3.0	-3.02	-3.01	-3.00	-3.00	-2.99	-2.98	-2.97	-2.96	-2.96	-2.95
	Siderite	unitless			-100	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0
	Fe(OH)3(am)	unitless			-100	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0
	Goethite	unitless			-100	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0	-100.0
	Pyrolusite	unitless			-100	8.0	8.2	8.2	8.3	8.3	8.2	8.2	8.2	8.2	8.1
	Bixbyite	unitless			-100	7.2	7.6	7.7	7.8	7.8	7.8	7.8	7.8	7.7	7.7
	Hausmannite	unitless			-100	3.9	4.4	4.7	4.8	4.8	4.8	4.8	4.8	4.7	4.7
	Rhodochrosite	unitless			-100	-2.1	-1.9	-1.7	-1.7	-1.6	-1.5	-1.5	-1.5	-1.4	-1.4

Notes

Shading indicates either (1) exceedance of Water Quality Criteria, or (2) Saturation Index value greater than 0.0

Table 2b. Summary of Mixing Calculations (Native Groundwater + New Shallow GW Well)

Type	Parameter	Units	Primary MCL	Secondary MCL	Municipal Distribution System 0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
General	Dissolved Oxygen	mg/L			7.0	7.1	7.3	7.5	7.6	7.8	8.0	8.1	8.3	8.5	8.6
	Eh	mV			764	768	771	774	777	779	781	783	784	786	787
	pH	s.u.		6.5-8.5	8.1	8.0	7.9	7.9	7.8	7.8	7.8	7.7	7.7	7.7	7.7
	Temperature	degC			12.0	12.0	12.0	12.0	12.1	12.1	12.1	12.1	12.1	12.1	12.1
	Total Dissolved Solids	mg/L		500	198	210	222	234	246	259	271	283	295	307	319
Cations	Calcium	mg/L			20.6	21.0	21.3	21.6	22.0	22.3	22.7	23.0	23.3	23.7	24.0
	Magnesium	mg/L			11.2	11.5	11.7	12.0	12.2	12.5	12.7	13.0	13.2	13.5	13.7
	Potassium	mg/L			3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7
	Sodium	mg/L			38.3	40.5	42.6	44.7	46.9	49.0	51.2	53.3	55.4	57.6	59.7
Anions	Bicarbonate	mg/L			179.0	190.0	200.0	210.0	220.0	231.0	241.0	251.0	262.0	272.0	282.0
	Chloride	mg/L		250	9.5	9.5	9.6	9.6	9.7	9.7	9.8	9.9	9.9	10.0	10.0
	Sulfate	mg/L		250	10.7	11.3	12.0	12.6	13.2	13.9	14.5	15.1	15.8	16.4	17.0
Redox Species	Iron, Dissolved	mg/L		0.3	ND	0.018	0.036	0.054	0.072	0.090	0.108	0.126	0.144	0.162	0.180
	Manganese, Dissolved	mg/L		0.05	ND	0.015	0.030	0.044	0.059	0.074	0.089	0.104	0.118	0.133	0.148
	Nitrate as N	mg/L	10		0.8	0.8	0.7	0.6	0.5	0.4	0.3	0.3	0.2	0.1	ND
	Nitrite as N	mg/L	1		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND
Metals	Aluminum	mg/L		0.05 to 2	0.011	0.013	0.015	0.017	0.019	0.020	0.022	0.024	0.026	0.028	0.030
	Antimony	mg/L	0.006		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Arsenic	mg/L	0.01		0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.000	0.000	ND
	Barium	mg/L	2		0.005	0.005	0.004	0.004	0.003	0.003	0.002	0.002	0.001	0.001	ND
	Beryllium	mg/L	0.004		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	ND
	Cadmium	mg/L	0.005		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Chromium	mg/L	0.1		0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	ND
	Copper	mg/L	1.3	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Lead	mg/L	0.015		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Mercury	mg/L	0.002		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Selenium	mg/L	0.05		ND	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002
	Silver	mg/L		0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Thallium	mg/L	0.002		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Zinc	mg/L		5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Other Parameters	Fluoride	mg/L	4	2	0.7	0.7	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.4	0.4
	Silica	mg/L			59	58	57	56	56	55	54	53	53	52	51
	Total Organic Carbon	mg/L			0.2	0.4	0.6	0.7	0.9	1.1	1.3	1.5	1.7	1.9	2.1
Disinfection Byproducts (DBPs)	Bromate	mg/L	0.01		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Chlorine	mg/L	4		0.08	0.07	0.06	0.06	0.05	0.04	0.03	0.02	0.02	0.01	ND
	Chlorite	mg/L	1		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total Haloacetic Acids	mg/L	0.06		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total Trihalomethanes	mg/L	0.08		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Saturation Index	Quartz	unitless			1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.2
	Chalcedony	unitless			1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.9
	SiO2(am)	unitless			-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2
	Calcite	unitless			0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2
	Dolomite	unitless			1.1	1.0	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.8
	Gypsum	unitless			-3.0	-3.00	-2.98	-2.95	-2.93	-2.91	-2.88	-2.86	-2.84	-2.82	-2.81
	Siderite	unitless			-100	-12.1	-11.8	-11.5	-11.4	-11.2	-11.1	-11.0	-10.9	-10.8	-10.8
	Fe(OH)3(am)	unitless			-100	3.3	3.6	3.7	3.9	3.9	4.0	4.1	4.1	4.1	4.2
	Goethite	unitless			-100	5.7	6.0	6.2	6.3	6.4	6.5	6.5	6.6	6.6	6.7
	Pyrolusite	unitless			-100	8.8	9.0	9.1	9.1	9.2	9.2	9.2	9.2	9.2	9.2
	Bixbyite	unitless			-100	8.8	9.1	9.3	9.4	9.5	9.5	9.5	9.5	9.6	9.6
	Hausmannite	unitless			-100	6.2	6.7	7.0	7.1	7.2	7.2	7.3	7.3	7.3	7.4
	Rhodochrosite	unitless			-100	-1.4	-1.1	-0.9	-0.8	-0.8	-0.7	-0.6	-0.6	-0.5	-0.5

Notes

Shading indicates either (1) exceedance of Water Quality Criteria, or (2) Saturation Index value greater than 0.0

Table 2c. Summary of Mixing Calculations (Native Groundwater + New Deep GW Well)

Type	Parameter	Units	Primary MCL	Secondary MCL	Municipal Distribution System										
					0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
General	Dissolved Oxygen	mg/L			7.0	6.3	5.7	5.0	4.4	3.8	3.1	2.5	1.8	1.2	0.5
	Eh	mV			764	762	759	757	755	752	749	746	742	738	731
	pH	s.u.		6.5-8.5	8.1	8.1	8.1	8.1	8.2	8.2	8.2	8.2	8.3	8.3	8.3
	Temperature	degC			12.0	12.1	12.2	12.2	12.3	12.4	12.5	12.5	12.6	12.7	12.8
	Total Dissolved Solids	mg/L		500	198	202	206	210	214	218	222	226	230	234	238
Cations	Calcium	mg/L			20.6	19.7	18.9	18.0	17.2	16.3	15.4	14.6	13.7	12.9	12.0
	Magnesium	mg/L			11.2	10.6	10.1	9.5	9.0	8.4	7.8	7.3	6.7	6.2	5.6
	Potassium	mg/L			3.7	3.5	3.4	3.3	3.1	3.0	2.8	2.7	2.6	2.4	2.3
	Sodium	mg/L			38.3	40.3	42.3	44.2	46.2	48.2	50.1	52.1	54.1	56.0	58.0
Anions	Bicarbonate	mg/L			179.0	182.0	184.0	186.0	188.0	190.0	192.0	194.0	196.0	198.0	200.0
	Chloride	mg/L		250	9.5	9.0	8.6	8.1	7.7	7.2	6.8	6.3	5.9	5.5	5.0
	Sulfate	mg/L		250	10.7	10.3	10.0	9.6	9.2	8.9	8.5	8.1	7.7	7.4	7.0
Redox Species	Iron, Dissolved	mg/L		0.3	ND	0.002	0.004	0.006	0.008	0.010	0.012	0.014	0.016	0.018	0.020
	Manganese, Dissolved	mg/L		0.05	ND	0.003	0.006	0.009	0.012	0.016	0.019	0.022	0.025	0.028	0.031
	Nitrate as N	mg/L	10		0.8	0.8	0.7	0.6	0.5	0.4	0.3	0.3	0.2	0.1	ND
	Nitrite as N	mg/L	1		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ND
Metals	Aluminum	mg/L		0.05 to 2	0.011	0.010	0.009	0.008	0.006	0.005	0.004	0.003	0.002	0.001	ND
	Antimony	mg/L	0.006		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Arsenic	mg/L	0.01		0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.000	0.000	ND
	Barium	mg/L	2		0.005	0.005	0.004	0.004	0.003	0.003	0.002	0.002	0.001	0.001	ND
	Beryllium	mg/L	0.004		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	ND
	Cadmium	mg/L	0.005		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Chromium	mg/L	0.1		0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	ND
	Copper	mg/L	1.3	1	ND	0.002	0.004	0.005	0.007	0.009	0.011	0.013	0.014	0.016	0.018
	Lead	mg/L	0.015		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Mercury	mg/L	0.002		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Selenium	mg/L	0.05		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Silver	mg/L		0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Thallium	mg/L	0.002		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Zinc	mg/L		5	ND	0.001	0.002	0.003	0.004	0.005	0.006	0.007	0.008	0.009	0.010
Other Parameters	Fluoride	mg/L	4	2	0.7	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.3	0.3
	Silica	mg/L			59	56	54	52	49	47	45	42	40	37	35
	Total Organic Carbon	mg/L			0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.8	0.9	1.0
Disinfection Byproducts (DBPs)	Bromate	mg/L	0.01		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Chlorine	mg/L	4		0.08	0.07	0.06	0.06	0.05	0.04	0.03	0.02	0.02	0.01	ND
	Chlorite	mg/L	1		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total Haloacetic Acids	mg/L	0.06		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Total Trihalomethanes	mg/L	0.08		ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Saturation Index	Quartz	unitless			1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.1
	Chalcedony	unitless			1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.8
	SiO2(am)	unitless			-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.2	-0.3	-0.3	-0.3	-0.3
	Calcite	unitless			0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	Dolomite	unitless			1.1	1.1	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.2	1.2
	Gypsum	unitless			-3.0	-3.06	-3.09	-3.13	-3.17	-3.20	-3.24	-3.29	-3.33	-3.38	-3.43
	Siderite	unitless			-100	-13.2	-12.9	-12.7	-12.6	-12.5	-12.5	-12.4	-12.4	-12.3	-12.2
	Fe(OH)3(am)	unitless			-100	2.3	2.6	2.8	2.9	3.0	3.0	3.1	3.1	3.2	3.2
	Goethite	unitless			-100	4.8	5.1	5.3	5.4	5.5	5.5	5.6	5.6	5.7	5.7
	Pyrolusite	unitless			-100	8.3	8.6	8.8	8.9	9.0	9.1	9.2	9.2	9.2	9.1
	Bixbyite	unitless			-100	7.7	8.4	8.8	9.1	9.4	9.6	9.8	9.9	10.0	10.0
	Hausmannite	unitless			-100	4.6	5.6	6.3	6.8	7.2	7.5	7.8	8.0	8.2	8.4
	Rhodochrosite	unitless			-100	-2.0	-1.7	-1.5	-1.3	-1.2	-1.1	-1.0	-0.9	-0.8	-0.8

Notes

Shading indicates either (1) exceedance of Water Quality Criteria, or (2) Saturation Index value greater than 0.0

Table 3.Water Quality Data for Select Columbia River Basalt Wells

Analyte	Unit	Regulatory Standard	Regulatory Criteria	City of Beaverton (Hanson Well) ASR 1 (WASH 8988)	City of Beaverton ASR No. 3 Pilot Well -- Start of Pump Test Day 10	City of Tigard ASR 1	City of Tigard ASR 2	Grabhorn Well	TVWD Miller Hill Road Well	Cornelius Test Well
Date Sampled				**7/14/1994**	**3/18/2004**	**11/29/2001**	**8/4/2004**	**5/15/2003**	**10/21/2011**	**1/20/2015**
Alkalinity	mg/L	250	SMCL	110	NT	109	139	135	100	140
Calcium	mg/L	None	None	36	58	25	26.1	23.4	15	31
Chloride	mg/L	250	SMCL	47.5	210	3.7	16	3.86	3.5	380
Total Hardness, as CaCO3	mg/L	250	SMCL	140	256	108	120	107	70	120
Bicarbonate (HCO3)	mg/L	None	None	110	NT	133	139	138	120	170
Potassium	mg/L	None	None	2.6	7.9	3	5.3	2.8	2.6	30
Magnesium	mg/L	None	None	19	27	11	13.7	11.9	7.7	10
Manganese Total	mg/L	0.05	SMCL	NT	0.085	0.0024	0.14	ND	0.021	0.14
Manganese Dissolved	mg/L	None	None	NT	NT	NT	0.14	0.01	ND	0.15
Iron Total	mg/L	0.3	SMCL	ND	0.12	ND	0.13	ND	0.18	0.15
Iron Dissolved	mg/L	None	None	NT	NT	NT	ND	NT	ND	0.16
Fluoride	mg/L	2	SMCL	ND	NT	0.09	ND	0.11	0.18	1.2
Sodium	mg/L	20	URC (advisory)	12.1	73	8.2	21.3	13.3	20	220
Nitrite as N	mg/L	1	MCL	0	NT	ND	ND	ND	ND	ND
Nitrate as N	mg/L	10	MML	0.56	NT	1.7	0.9	0.09	ND	ND
Silica	mg/L	None	None	NT	NT	NT	55.1	66.5	59	66
Sulfate	mg/L	250	URC, SMCL	ND	NT	4.3	ND	2.33	2.3	ND
Total Dissolved Solids	mg/L	500	SMCL	245	530	200	220	210	150	870
Total Organic Carbon	mg/L	None	None	0.7	NT	NT	ND	ND	ND	0.54
Total Suspended Solids	mg/L	None	None	ND	NT	NT	ND	NT	ND	ND
Field pH	Units	6 - 8.5	None	6.88	6.78	6.78	7.14	7.2	7.45	7.53
Field Temperature	Celsius	None	None	NT	15.7	11.7	15.2	14.4	15.7	19.7
Field Specific Conductance	umho/cm	None	None	377	902	NT	349	252	218	957
Field Dissolved Oxygen	mg/l	None	None	4.2	6.3	6.98	1.5	NT	1.86	0.39
Odor	TON	3	SMCL	NT	NT	NT	NT	ND	1	ND
Radon 222	pCi/l	300 or 4000	Proposed MCL	NT	NT	NT	NT	NT	330	460
Field Oxidation-Reduction Potential	mV	None	None	NT	NT	NT	NT	72.9	NT	-89.8

Footnotes:

Analytical data shown in shading exceed the applicable regulatory standard

ND = not detected

NT = not tested

SMCL = Secondary Maximum Contaminant Levels -- Federal Regulations

MCL = Maximum Contaminant Levels -- Federal Regulations

MML = Maximum Measurable Level -- Oregon Department of Environmental Quality

URC = Oregon Health Authority Unregulated Contaminants

mg/l = milligrams per liter

umhos/cm = micromhos per centimeter

Celsius (C = 5/9 (F - 32))

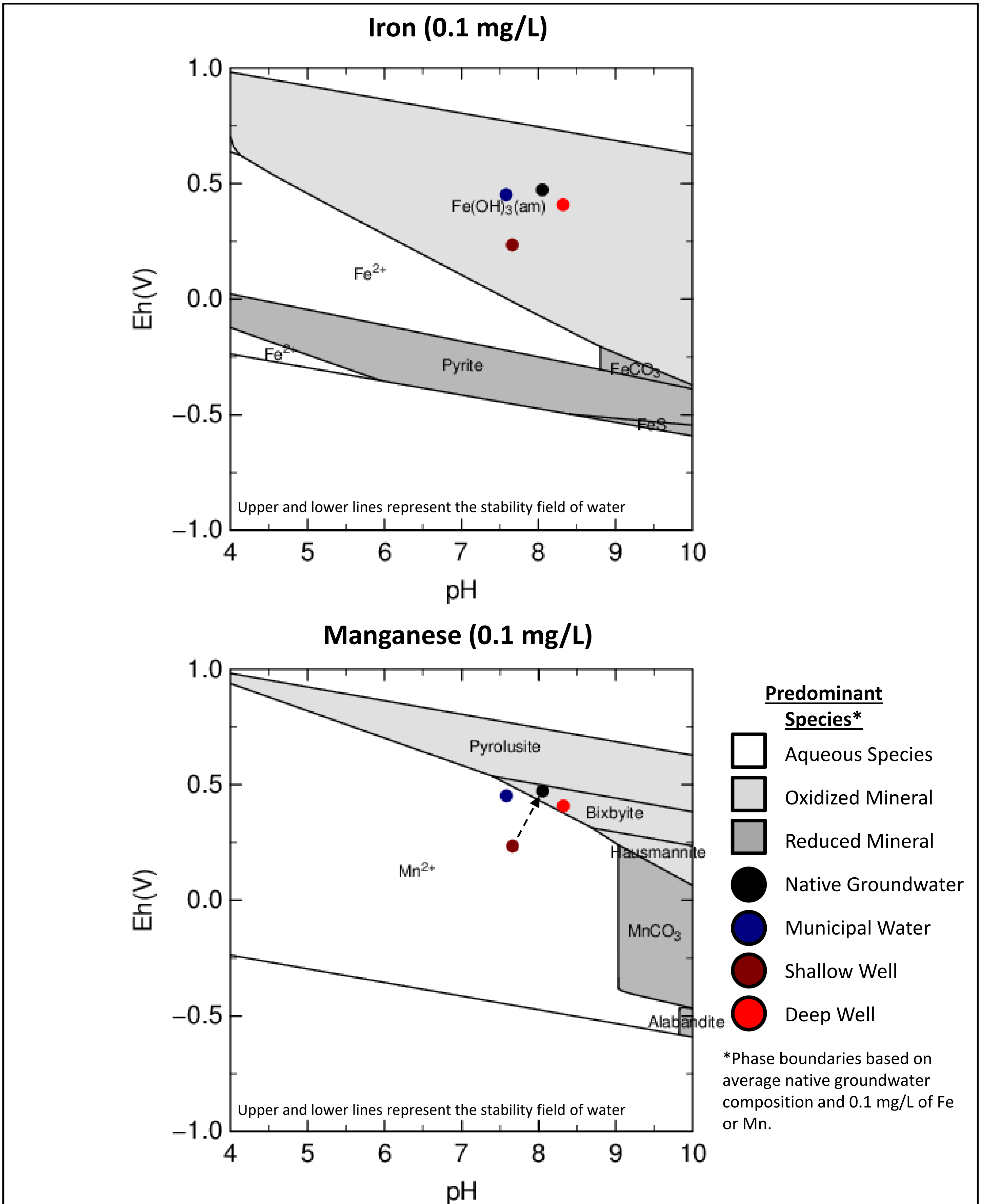
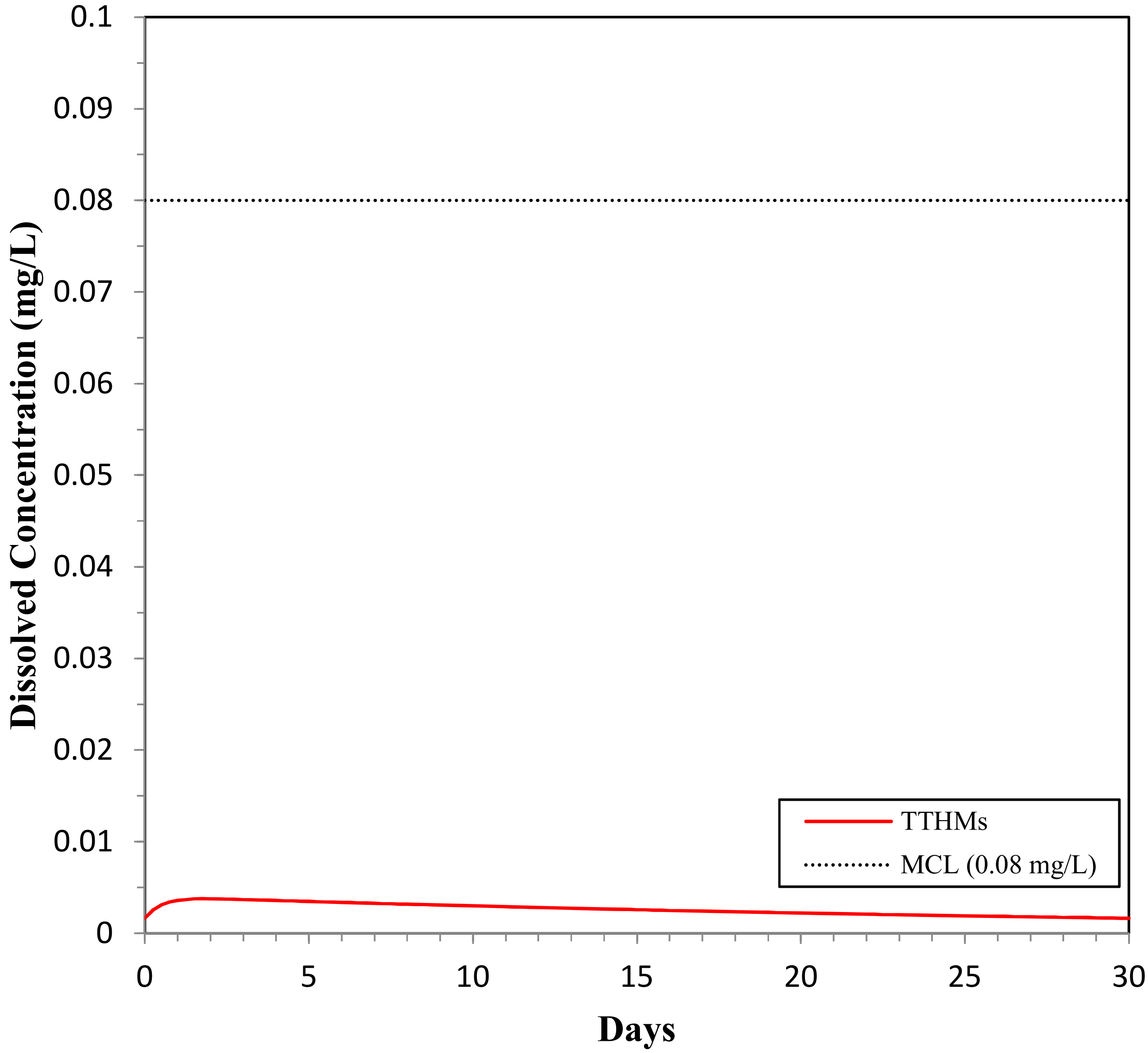


Figure 1. Eh-pH diagram for iron (*top*) and manganese (*bottom*) showing the stability fields of minerals and dissolved species.

Figure 2. Predicted Change in TTHMs Over Time



Appendix D

New Alluvial Water Source Investigation
OWRD Well Logs

STATE OF OREGON
WATER SUPPLY WELL REPORT
(as required by ORS 537.765 & OAR 690-205-0210)

CROO 54587

2/16/2018

WELL I.D. LABEL# L 127083
START CARD # 1037842
ORIGINAL LOG #

(1) LAND OWNER

Owner Well I.D. STW-1
First Name JIM Last Name NEWTON
Company CITY OF PRINEVILLE
Address 387 NE 3RD ST
City PRINEVILLE State OR Zip 97754

(2) TYPE OF WORK

[X] New Well [ ] Deepening [ ] Conversion
[ ] Alteration (complete 2a & 10) [ ] Abandonment(complete 5a)

(2a) PRE-ALTERATION

Casing:

Dia	+	From	To	Gauge	Stl	Plstc	Wld	Thrd

Seal:

Material	From	To	Amt	sacks/lbs

(3) DRILL METHOD

[ ] Rotary Air [ ] Rotary Mud [X] Cable [ ] Auger [ ] Cable Mud
[ ] Reverse Rotary [ ] Other

(4) PROPOSED USE

[ ] Domestic [ ] Irrigation [ ] Community
[ ] Industrial/ Commericial [ ] Livestock [ ] Dewatering
[ ] Thermal [ ] Injection [X] Other EXPLORITORY

(5) BORE HOLE CONSTRUCTION

Special Standard [ ] (Attach copy)
Depth of Completed Well 40.00 ft.

BORE HOLE

Dia	From	To
12	0	40

SEAL

Material	From	To	Amt	sacks/ lbs
Bentonite Chips	0	18	53	S
		Calculated	14	
		Calculated		

How was seal placed: Method [ ] A [ ] B [ ] C [ ] D [ ] E
[X] Other POURED DRY
Backfill placed from ft. to ft. Material
Filter pack from 18 ft. to 40 ft. Material SAND Size 8/12
Explosives used: [ ] Yes Type Amount

(5a) ABANDONMENT USING UNHYDRATED BENTONITE

Proposed Amount Actual Amount

(6) CASING/LINER

Casing	Liner	Dia	+	From	To	Gauge	Stl	Plstc	Wld	Thrd
(●)	( )	6	[X]	2	20	.250	(●)	( )	[X]	[ ]
( )	( )		[ ]				( )	( )	[ ]	[ ]
( )	( )		[ ]				( )	( )	[ ]	[ ]
( )	( )		[ ]				( )	( )	[ ]	[ ]
( )	( )		[ ]				( )	( )	[ ]	[ ]

Shoe [ ] Inside [X] Outside [ ] Other Location of shoe(s)
Temp casing [X] Yes Dia 12 From + [X] 1 To 40

(7) PERFORATIONS/SCREENS

Perforations Method
Screens Type JOHNSON Material STAINLESS

Perf/ Screen	Casing/ Liner	Screen Dia	From	To	Scrn/slot width	Slot length	# of slots	Tele/ pipe size
Screen	Casing	6	20	40	.05			

(8) WELL TESTS: Minimum testing time is 1 hour

( ) Pump (●) Bailer ( ) Air ( ) Flowing Artesian

Yield gal/min	Drawdown	Drill stem/Pump depth	Duration (hr)
100	26	38	120
25	5		4

Temperature 54 °F Lab analysis [ ] Yes By
Water quality concerns? [ ] Yes (describe below) TDS amount 111 ppm

From	To	Description	Amount	Units

(9) LOCATION OF WELL (legal description)

County CROOK Twp 15.00 S N/S Range 16.00 E E/W WM
Sec 8 NW 1/4 of the NW 1/4 Tax Lot 201
Tax Map Number Lot
Lat ° ' " or 44.28944444 DMS or DD
Long ° ' " or -120.84569444 DMS or DD
( ) Street address of well (●) Nearest address
WEST OF MAIN ST/CROOKED RIVER HWY CROOKED RIVER PARK (STW-1)

(10) STATIC WATER LEVEL

	Date	SWL(psi)	+	SWL(ft)
Existing Well / Pre-Alteration			[ ]	
Completed Well	1/9/2018		[ ]	11

Flowing Artesian? [ ] Dry Hole? [ ]

WATER BEARING ZONES Depth water was first found 14.00

SWL Date	From	To	Est Flow	SWL(psi)	+	SWL(ft)
10/24/2017	24	37	20		[ ]	12
					[ ]	
					[ ]	
					[ ]	
					[ ]	

(11) WELL LOG

Ground Elevation 2886.00

Material	From	To
CLAY GRAVEL	0	9
SILT GRAY CLAY	9	12
GRAVELS SAND GRAY	12	24
SILT SAND GRAY	24	32
CLAY SAND GRAY	32	37
CLAY GRAY	37	40

Date Started 10/24/2017 Completed 1/9/2018

(unbonded) Water Well Constructor Certification

I certify that the work I performed on the construction, deepening, alteration, or abandonment of this well is in compliance with Oregon water supply well construction standards. Materials used and information reported above are true to the best of my knowledge and belief.

License Number 758 Date 2/16/2018

Signed THOMAS R PECK (E-filed)

(bonded) Water Well Constructor Certification

I accept responsibility for the construction, deepening, alteration, or abandonment work performed on this well during the construction dates reported above. All work performed during this time is in compliance with Oregon water supply well construction standards. This report is true to the best of my knowledge and belief.

License Number 1720 Date 2/16/2018

Signed JACK ABBAS (E-filed)

Contact Info (optional)

WATER SUPPLY WELL REPORT - Map with location identified must be attached and shall include an approximate scale and north arrow

CROO 54587

2/16/2018

Map of Hole

STATE OF OREGON
WELL LOCATION MAP

This map is supplemental to the WATER SUPPLY WELL REPORT

Oregon Water Resources Department
725 Summer St NE, Salem OR 97301
(503)986-0900

LOCATION OF WELL

Latitude: 44.28944444 Datum: WGS84
Longitude: -120.84569444
Township/Range/Section/Quarter-Quarter Section:
WM 6S 2W 34 NWNW
Address of Well:
WEST OF MAIN ST/CROOKED RIVER HWY CROOKED RIVER PARK (STW-1)

Well Label: 127083

Printed: February 16, 2018

DISCLAIMER: This map is intended to represent the approximate location the well. It is not intended to be construed as survey accurate in any manner.

Provided by well constructor

STATE OF OREGON
WATER SUPPLY WELL REPORT
(as required by ORS 537.765 & OAR 690-205-0210)

CROO 54588

2/16/2018

WELL I.D. LABEL# L 129187
START CARD # 1037839
ORIGINAL LOG #

(1) LAND OWNER

Owner Well I.D. DTW-3
First Name JIM   Last Name NEWTON
Company CITY OF PRINEVILLE
Address 387 NE 3RD ST
City PRINEVILLE   State OR   Zip 97754

(2) TYPE OF WORK

☒ New Well ☐ Deepening ☐ Conversion
☐ Alteration (complete 2a & 10) ☐ Abandonment(complete 5a)

(2a) PRE-ALTERATION

	Dia	+	From	To	Gauge	Stl	Plstc	Wld	Thrd
Casing:									

	Material	From	To	Amt	sacks/lbs
Seal:					

(3) DRILL METHOD

☐ Rotary Air ☐ Rotary Mud ☒ Cable ☐ Auger ☐ Cable Mud
☐ Reverse Rotary ☐ Other

(4) PROPOSED USE

☐ Domestic ☐ Irrigation ☐ Community
☐ Industrial/ Commericial ☐ Livestock ☐ Dewatering
☐ Thermal ☐ Injection ☒ Other EXPLORITORY

(5) BORE HOLE CONSTRUCTION

Special Standard ☐ (Attach copy)
Depth of Completed Well 140.00 ft.

BORE HOLE

Dia	From	To
16	0	140

SEAL

Material	From	To	Amt	sacks/lbs
Bentonite Chips	0	7	28	S
		Calculated	10	
Cement	7	70	70	S
		Calculated	39	

How was seal placed: Method ☐ A ☐ B ☒ C ☐ D ☐ E
☒ Other POURED DRY
Backfill placed from ______ ft. to ______ ft. Material ______
Filter pack from 70 ft. to 140 ft. Material PEA GRAVI Size pea gravel
Explosives used: ☐ Yes Type ______ Amount ______

(5a) ABANDONMENT USING UNHYDRATED BENTONITE

Proposed Amount   Actual Amount

(6) CASING/LINER

Casing	Liner	Dia	+	From	To	Gauge	Stl	Plstc	Wld	Thrd
◉	○	8	☒	2	140	.250	◉	○	☒	☐
○	○		☐				○	○	☐	☐
○	○		☐				○	○	☐	☐
○	○		☐				○	○	☐	☐
○	○		☐				○	○	☐	☐

Shoe ☐ Inside ☒ Outside ☐ Other Location of shoe(s)
Temp casing ☒ Yes Dia 16 From + ☒ 1 To 140

(7) PERFORATIONS/SCREENS

Perforations Method MACHINE
Screens Type ______ Material ______

Perf/ Screen	Casing/ Liner	Screen Dia	From	To	Scrn/slot width	Slot length	# of slots	Tele/ pipe size
Perf	Casing	8	80	140	.125	3	1824	

(8) WELL TESTS: Minimum testing time is 1 hour

○ Pump ◉ Bailer ○ Air ○ Flowing Artesian

Yield gal/min	Drawdown	Drill stem/Pump depth	Duration (hr)
30	10		2

Temperature 54 °F Lab analysis ☐ Yes By ______
Water quality concerns? ☐ Yes (describe below) TDS amount 120 ppm

From	To	Description	Amount	Units

(9) LOCATION OF WELL (legal description)

County CROOK Twp 15.00 S N/S Range 16.00 E E/W WM
Sec 8 NW 1/4 of the NW 1/4 Tax Lot 203
Tax Map Number ______ Lot ______
Lat ___° ___' ___" or 44.28961111 DMS or DD
Long ___° ___' ___" or -120.84225000 DMS or DD
○ Street address of well ◉ Nearest address

EAST OF MAIN ST/CRROKED RIVER HWY \NCROOKED RIVER PARK (DTW-3)

(10) STATIC WATER LEVEL

	Date	SWL(psi)	+	SWL(ft)
Existing Well / Pre-Alteration			☐	
Completed Well	2/6/2018		☐	4

Flowing Artesian? ☐ Dry Hole? ☐

WATER BEARING ZONES   Depth water was first found 10.00

SWL Date	From	To	Est Flow	SWL(psi)	+	SWL(ft)
1/19/2018	10	25	20		☐	10
1/24/2018	70	112	20		☐	4
					☐	
					☐	
					☐	

(11) WELL LOG

Ground Elevation 2876.00

Material	From	To
CLAY SAND SILT	0	9
GRAVELS LARGE	9	25
SILT GRAY CLAY	25	70
SAND GRAY	70	112
SILTY GRAY SAND	112	140

Date Started 1/19/2018   Completed 2/6/2018

(unbonded) Water Well Constructor Certification

I certify that the work I performed on the construction, deepening, alteration, or abandonment of this well is in compliance with Oregon water supply well construction standards. Materials used and information reported above are true to the best of my knowledge and belief.

License Number ______ Date ______

Signed ______

(bonded) Water Well Constructor Certification

I accept responsibility for the construction, deepening, alteration, or abandonment work performed on this well during the construction dates reported above. All work performed during this time is in compliance with Oregon water supply well construction standards. This report is true to the best of my knowledge and belief.

License Number 1720   Date 2/16/2018

Signed JACK ABBAS (E-filed)

Contact Info (optional) ______

WATER SUPPLY WELL REPORT - Map with location identified must be attached and shall include an approximate scale and north arrow

CROO 54588

2/16/2018

Map of Hole

STATE OF OREGON
WELL LOCATION MAP
This map is supplemental to the WATER SUPPLY WELL REPORT

Oregon Water Resources Department
725 Summer St NE, Salem OR 97301
(503)986-0900

LOCATION OF WELL
Latitude: 44.28961111 Datum: WGS84
Longitude: -120.84225
Township/Range/Section/Quarter-Quarter Section:
WM 15S 16E 8 NWNW
Address of Well:
EAST OF MAIN ST/CRROKED RIVER HWY
CROOKED RIVER PARK (DTW-3)

Well Label: 129187

Printed: February 16, 2018

DISCLAIMER: This map is intended to represent the approximate location the well. It is not intended to be construed as survey accurate in any manner.

Provided by well constructor

STATE OF OREGON
WATER SUPPLY WELL REPORT
(as required by ORS 537.765 & OAR 690-205-0210)

CROO 54589

2/16/2018

WELL I.D. LABEL# L 127081
START CARD # 1037841
ORIGINAL LOG #

(1) LAND OWNER

Owner Well I.D. STW-2
First Name JIM Last Name NEWTON
Company CITY OF PRINEVILLE
Address 387 NE 3RD ST
City PRINEVILLE State OR Zip 97754

(2) TYPE OF WORK

[X] New Well [ ] Deepening [ ] Conversion
[ ] Alteration (complete 2a & 10) [ ] Abandonment(complete 5a)

(2a) PRE-ALTERATION

	Dia	+	From	To	Gauge	Stl	Plstc	Wld	Thrd
Casing:									

	Material	From	To	Amt	sacks/lbs
Seal:					

(3) DRILL METHOD

[ ] Rotary Air [ ] Rotary Mud [X] Cable [ ] Auger [ ] Cable Mud
[ ] Reverse Rotary [ ] Other

(4) PROPOSED USE

[ ] Domestic [ ] Irrigation [ ] Community
[ ] Industrial/ Commericial [ ] Livestock [ ] Dewatering
[ ] Thermal [ ] Injection [X] Other EXPLORITORY

(5) BORE HOLE CONSTRUCTION

Special Standard [ ] (Attach copy)
Depth of Completed Well 40.50 ft.

BORE HOLE Dia	From	To	SEAL Material	From	To	Amt	sacks/ lbs
12	0	40.5	Bentonite Chips	0	18	27	S
			Calculated			14	
			Calculated				

How was seal placed: Method [ ] A [ ] B [ ] C [ ] D [ ] E
[X] Other POURED DRY
Backfill placed from ft. to ft. Material
Filter pack from 18 ft. to 40.5 ft. Material PEA GRAVE Size 6/9
Explosives used: [ ] Yes Type Amount

(5a) ABANDONMENT USING UNHYDRATED BENTONITE

Proposed Amount Actual Amount

(6) CASING/LINER

Casing	Liner	Dia	+	From	To	Gauge	Stl	Plstc	Wld	Thrd

Shoe [ ] Inside [ ] Outside [ ] Other Location of shoe(s)
Temp casing [ ] Yes Dia From + [ ] To

(7) PERFORATIONS/SCREENS

Perforations Method MACHINE
Screens Type Material

Perf/ Screen	Casing/ Liner	Screen Dia	From	To	Scrn/slot width	Slot length	# of slots	Tele/ pipe size
Perf	Casing	6	20.5	40.5	.125	3	456	

(8) WELL TESTS: Minimum testing time is 1 hour

( ) Pump (•) Bailer ( ) Air ( ) Flowing Artesian

Yield gal/min	Drawdown	Drill stem/Pump depth	Duration (hr)
20	20		2

Temperature 54 °F Lab analysis [ ] Yes By
Water quality concerns? [ ] Yes (describe below) TDS amount 115 ppm

From	To	Description	Amount	Units

(9) LOCATION OF WELL (legal description)

County CROOK Twp 15.00 S N/S Range 16.00 E E/W WM
Sec 8 NW 1/4 of the NW 1/4 Tax Lot 201
Tax Map Number Lot
Lat ° ' " or 44.28969444 DMS or DD
Long ° ' " or -120.84572222 DMS or DD
( ) Street address of well (•) Nearest address

WEST OF MAIN ST/CROOKED RIVER HWY
CROOKED RIVER PARK (STW-2)

(10) STATIC WATER LEVEL

	Date	SWL(psi)	+	SWL(ft)
Existing Well / Pre-Alteration				
Completed Well	12/14/2017			8

Flowing Artesian? [ ] Dry Hole? [ ]

WATER BEARING ZONES Depth water was first found 10.00

SWL Date	From	To	Est Flow	SWL(psi)	+	SWL(ft)
10/31/2017	10	37	20			8

(11) WELL LOG

Ground Elevation 2864.00

Material	From	To
CLAY BROWN	0	10
GRAVELS SAND BROWN	10	12
GRAVELS SAND SILT GRAY	12	20
LARGE GRAVELS TIGHT	20	22
SILT GRAY SAND	22	35
SAND GRAVELS GRAY SMALL	35	37
CLAY SILT GRAY	37	40.5

Date Started 10/30/2017 Completed 12/14/2017

(unbonded) Water Well Constructor Certification

I certify that the work I performed on the construction, deepening, alteration, or abandonment of this well is in compliance with Oregon water supply well construction standards. Materials used and information reported above are true to the best of my knowledge and belief.

License Number 758 Date 2/16/2018

Signed THOMAS R PECK (E-filed)

(bonded) Water Well Constructor Certification

I accept responsibility for the construction, deepening, alteration, or abandonment work performed on this well during the construction dates reported above. All work performed during this time is in compliance with Oregon water supply well construction standards. This report is true to the best of my knowledge and belief.

License Number 1720 Date 2/16/2018

Signed JACK ABBAS (E-filed)

Contact Info (optional)

WATER SUPPLY WELL REPORT - Map with location identified must be attached and shall include an approximate scale and north arrow

CROO 54589

2/16/2018

Map of Hole

STATE OF OREGON
WELL LOCATION MAP

This map is supplemental to the WATER SUPPLY WELL REPORT

Oregon Water Resources Department
725 Summer St NE, Salem OR 97301
(503)986-0900

LOCATION OF WELL

Latitude: 44.28969444 Datum: WGS84
Longitude: -120.84572222
Township/Range/Section/Quarter-Quarter Section:
WM 15S 16E 8 NWNW
Address of Well:
WEST OF MAIN ST/CROOKED RIVER HWY CROOKED RIVER PARK (STW-2)

Well Label: 127081

Printed: February 16, 2018

DISCLAIMER: This map is intended to represent the approximate location the well. It is not intended to be construed as survey accurate in any manner.

Provided by well constructor

STATE OF OREGON
WATER SUPPLY WELL REPORT
(as required by ORS 537.765 & OAR 690-205-0210)

CROO 54591

2/18/2018

WELL I.D. LABEL# L 127080
START CARD # 1037844
ORIGINAL LOG #

(1) LAND OWNER

Owner Well I.D. STW-3
First Name JIM   Last Name NEWTON
Company CITY OF PRINEVILLE
Address 387 NE 3RD ST
City PRINEVILLE   State OR   Zip 97754

(2) TYPE OF WORK

[X] New Well [ ] Deepening [ ] Conversion
[ ] Alteration (complete 2a & 10) [ ] Abandonment(complete 5a)

(2a) PRE-ALTERATION

Casing: Dia | + | From | To | Gauge | Stl | Plstc | Wld | Thrd

Seal: Material | From | To | Amt | sacks/lbs

(3) DRILL METHOD

[ ] Rotary Air [ ] Rotary Mud [X] Cable [ ] Auger [ ] Cable Mud
[ ] Reverse Rotary [ ] Other

(4) PROPOSED USE

[ ] Domestic [ ] Irrigation [ ] Community
[ ] Industrial/ Commericial [ ] Livestock [ ] Dewatering
[ ] Thermal [ ] Injection [X] Other EXPLORITORY

(5) BORE HOLE CONSTRUCTION

Special Standard [ ] (Attach copy)
Depth of Completed Well 40.00 ft.

BORE HOLE Dia	From	To	SEAL Material	From	To	Amt	sacks/lbs
12	0	40	Bentonite Chips	0	18	47	S
			Calculated			14	
			Calculated				

How was seal placed: Method [ ] A [ ] B [ ] C [ ] D [ ] E
[X] Other POURED DRY
Backfill placed from ____ ft. to ____ ft. Material ____
Filter pack from 18 ft. to 40 ft. Material SAND Size 6/9
Explosives used: [ ] Yes Type ____ Amount ____

(5a) ABANDONMENT USING UNHYDRATED BENTONITE

Proposed Amount   Actual Amount

(6) CASING/LINER

Casing	Liner	Dia	+	From	To	Gauge	Stl	Plstc	Wld	Thrd
(●)	( )	6	[X]	2	40	.250	(●)	( )	[X]	[ ]
( )	( )		[ ]				( )	( )	[ ]	[ ]
( )	( )		[ ]				( )	( )	[ ]	[ ]
( )	( )		[ ]				( )	( )	[ ]	[ ]
( )	( )		[ ]				( )	( )	[ ]	[ ]

Shoe [ ] Inside [X] Outside [ ] Other   Location of shoe(s)
Temp casing [X] Yes Dia 12 From + [X] 1 To 40

(7) PERFORATIONS/SCREENS

Perforations Method MACHINE
Screens Type ____ Material ____

Perf/ Screen	Casing/ Liner	Screen Dia	From	To	Scrn/slot width	Slot length	# of slots	Tele/ pipe size
Perf	Casing	6	20	40	.125	3	456	

(8) WELL TESTS: Minimum testing time is 1 hour

( ) Pump (●) Bailer ( ) Air ( ) Flowing Artesian

Yield gal/min	Drawdown	Drill stem/Pump depth	Duration (hr)
20	10		2

Temperature 54 °F Lab analysis [ ] Yes By
Water quality concerns? [ ] Yes (describe below) TDS amount 111 ppm

From	To	Description	Amount	Units

(9) LOCATION OF WELL (legal description)

County CROOK Twp 15.00 S N/S Range 16.00 E E/W WM
Sec 8 NW 1/4 of the NW 1/4 Tax Lot 201
Tax Map Number ____ Lot ____
Lat ___° ___' ___" or 44.28969444 DMS or DD
Long ___° ___' ___" or -120.84525000 DMS or DD
( ) Street address of well (●) Nearest address
WEST OF MAIN ST/CROOKED RIVER HWY \NCROOKED RIVER PARK (STW-3) S SIDE OF NW BASEBALL FIELD

(10) STATIC WATER LEVEL

	Date	SWL(psi)	+	SWL(ft)
Existing Well / Pre-Alteration			[ ]	
Completed Well	12/12/2017		[ ]	11

Flowing Artesian? [ ] Dry Hole? [ ]

WATER BEARING ZONES   Depth water was first found 18.00

SWL Date	From	To	Est Flow	SWL(psi)	+	SWL(ft)
11/3/2017	18	25	20		[ ]	11
					[ ]	
					[ ]	
					[ ]	
					[ ]	

(11) WELL LOG

Ground Elevation 2868.00

Material	From	To
CLAY BROWN	0	12
GRAVELS LARGE	12	17
LARGE GRAVELS TIGHT	17	18.5
SAND GRAVELS GRAY	18.5	25
SILT SAND GRAY	25	40

Date Started 11/3/2017   Completed 12/12/2017

(unbonded) Water Well Constructor Certification

I certify that the work I performed on the construction, deepening, alteration, or abandonment of this well is in compliance with Oregon water supply well construction standards. Materials used and information reported above are true to the best of my knowledge and belief.

License Number 758   Date 2/16/2018

Signed THOMAS PECK (E-filed)

(bonded) Water Well Constructor Certification

I accept responsibility for the construction, deepening, alteration, or abandonment work performed on this well during the construction dates reported above. All work performed during this time is in compliance with Oregon water supply well construction standards. This report is true to the best of my knowledge and belief.

License Number 1720   Date 2/18/2018

Signed JACK ABBAS (E-filed)

Contact Info (optional)

WATER SUPPLY WELL REPORT - Map with location identified must be attached and shall include an approximate scale and north arrow

CROO 54591

2/18/2018

Map of Hole

STATE OF OREGON
WELL LOCATION MAP

This map is supplemental to the WATER SUPPLY WELL REPORT

Oregon Water Resources Department
725 Summer St NE, Salem OR 97301
(503)986-0900

LOCATION OF WELL

Latitude: 44.28969444 Datum: WGS84
Longitude: -120.84525
Township/Range/Section/Quarter-Quarter Section:
WM 6S 2W 34 NWNW
Address of Well:
WEST OF MAIN ST/CROOKED RIVER HWY
CROOKED RIVER PARK (STW-3) S SIDE OF NW BASEBALL FIELD

Well Label: 127080

Printed: February 17, 2018

DISCLAIMER: This map is intended to represent the approximate location the well. It is not intended to be construed as survey accurate in any manner.

Provided by well constructor

STATE OF OREGON
WATER SUPPLY WELL REPORT
(as required by ORS 537.765 & OAR 690-205-0210)

CROO 54592
2/18/2018

WELL I.D. LABEL# L 129186
START CARD # 1037840
ORIGINAL LOG #

(1) LAND OWNER
Owner Well I.D. DTW-2
First Name JIM Last Name NEWTON
Company CITY OF PRINEVILLE
Address 387 NE 3RD ST
City PRINEVILLE State OR Zip 97754

(2) TYPE OF WORK
☒ New Well ☐ Deepening ☐ Conversion
☐ Alteration (complete 2a & 10) ☐ Abandonment(complete 5a)

(2a) PRE-ALTERATION
	Dia	+	From	To	Gauge	Stl	Plstc	Wld	Thrd
Casing:									

	Material	From	To	Amt	sacks/lbs
Seal:					

(3) DRILL METHOD
☐ Rotary Air ☐ Rotary Mud ☒ Cable ☐ Auger ☐ Cable Mud
☐ Reverse Rotary ☐ Other

(4) PROPOSED USE
☐ Domestic ☐ Irrigation ☐ Community
☐ Industrial/ Commericial ☐ Livestock ☐ Dewatering
☐ Thermal ☐ Injection ☒ Other EXPLORITORY

(5) BORE HOLE CONSTRUCTION
Special Standard ☐ (Attach copy)
Depth of Completed Well 140.00 ft.

BORE HOLE

Dia	From	To
16	0	140

SEAL

Material	From	To	Amt	sacks/lbs
Bentonite Chips	0	7	14	S
		Calculated	10	
Cement	7	50	70	S
		Calculated	31	

How was seal placed: Method ☐ A ☐ B ☒ C ☐ D ☐ E
☒ Other POURED DRY
Backfill placed from ft. to ft. Material
Filter pack from 50 ft. to 140 ft. Material SAND Size 50 MESH
Explosives used: ☐ Yes Type Amount

(5a) ABANDONMENT USING UNHYDRATED BENTONITE
Proposed Amount Actual Amount

(6) CASING/LINER
Casing	Liner	Dia	+	From	To	Gauge	Stl	Plstc	Wld	Thrd
●	○	8	☒	2	60	.250	●	○	☒	☐
○	○		☐				○	○	☐	☐
○	○		☐				○	○	☐	☐
○	○		☐				○	○	☐	☐
○	○		☐				○	○	☐	☐

Shoe ☐ Inside ☒ Outside ☐ Other Location of shoe(s)
Temp casing ☒ Yes Dia 16 From + ☒ 1 To 140

(7) PERFORATIONS/SCREENS
Perforations Method
Screens Type JOHNSON Material STAINLESS

Perf/ Screen	Casing/ Screen Liner	Dia	From	To	Scrn/slot width	Slot length	# of slots	Tele/ pipe size
Screen	Casing	8	60	140	.008			

(8) WELL TESTS: Minimum testing time is 1 hour
○ Pump ● Bailer ○ Air ○ Flowing Artesian

Yield gal/min	Drawdown	Drill stem/Pump depth	Duration (hr)
20	25		2

Temperature 54 °F Lab analysis ☐ Yes By
Water quality concerns? ☐ Yes (describe below) TDS amount 118 ppm

From	To	Description	Amount	Units

(9) LOCATION OF WELL (legal description)
County CROOK Twp 15.00 S N/S Range 16.00 E E/W WM
Sec 8 NW 1/4 of the NW 1/4 Tax Lot 201
Tax Map Number Lot
Lat ° ' " or 44.28905556 DMS or DD
Long ° ' " or -120.84419444 DMS or DD
○ Street address of well ● Nearest address
WEST OF MAIN ST/CROOKED RIVER HWY
CROOKED RIVER PARK (DTW-2)

(10) STATIC WATER LEVEL
	Date	SWL(psi)	+	SWL(ft)
Existing Well / Pre-Alteration			☐	
Completed Well	1/17/2018		☐	4

Flowing Artesian? ☐ Dry Hole? ☐

WATER BEARING ZONES Depth water was first found 13.00

SWL Date	From	To	Est Flow	SWL(psi)	+	SWL(ft)
11/7/2017	13	22	20		☐	10
11/8/2017	32	133	20		☐	4
					☐	
					☐	
					☐	

(11) WELL LOG
Ground Elevation 2876.00

Material	From	To
FILL	0	2
CLAY SILT BROWN	2	6
CLAY SILT GRAY	6	13
GRAVELS	13	16
GRAVELS TIGHT LARGE	16	23
SILT CLAY GRAY	23	32
SAND FINE GRAY HEAVING	32	56
SAND TIGHT LOOSE LAYERS	56	133
CLAY GRAY	133	140

Date Started 11/17/2017 Completed 1/17/2018

(unbonded) Water Well Constructor Certification
I certify that the work I performed on the construction, deepening, alteration, or abandonment of this well is in compliance with Oregon water supply well construction standards. Materials used and information reported above are true to the best of my knowledge and belief.
License Number 758 Date 2/18/2018
Signed THOMAS PECK (E-filed)

(bonded) Water Well Constructor Certification
I accept responsibility for the construction, deepening, alteration, or abandonment work performed on this well during the construction dates reported above. All work performed during this time is in compliance with Oregon water supply well construction standards. This report is true to the best of my knowledge and belief.
License Number 1720 Date 2/18/2018
Signed JACK ABBAS (E-filed)
Contact Info (optional)

WATER SUPPLY WELL REPORT - Map with location identified must be attached and shall include an approximate scale and north arrow

CROO 54592

2/18/2018

Map of Hole

STATE OF OREGON
WELL LOCATION MAP

This map is supplemental to the WATER SUPPLY WELL REPORT

Oregon Water Resources Department
725 Summer St NE, Salem OR 97301
(503)986-0900

LOCATION OF WELL

Latitude: 44.28905556 Datum: WGS84

Longitude: -120.84419444

Township/Range/Section/Quarter-Quarter Section:
WM 15S 16E 8 NWNW

Address of Well:
WEST OF MAIN ST/CROOKED RIVER HWY
CROOKED RIVER PARK (DTW-2)

Well Label: 129186

Printed: February 18, 2018

DISCLAIMER: This map is intended to represent the approximate location the well. It is not intended to be construed as survey accurate in any manner.

Provided by well constructor

STATE OF OREGON
WATER SUPPLY WELL REPORT
(as required by ORS 537.765 & OAR 690-205-0210)

CROO 54593
2/19/2018

WELL I.D. LABEL# L 127082
START CARD # 1037843
ORIGINAL LOG #

(1) LAND OWNER

Owner Well I.D. DTW-1
First Name JIM Last Name NEWTON
Company CITY OF PRINEVILLE
Address 387 NE 3RD ST
City PRINEVILLE State OR Zip 97754

(2) TYPE OF WORK

[X] New Well [ ] Deepening [ ] Conversion
[ ] Alteration (complete 2a & 10) [ ] Abandonment(complete 5a)

(2a) PRE-ALTERATION

	Dia	+	From	To	Gauge	Stl	Plstc	Wld	Thrd
Casing:									

	Material	From	To	Amt	sacks/lbs
Seal:					

(3) DRILL METHOD

[ ] Rotary Air [ ] Rotary Mud [X] Cable [ ] Auger [ ] Cable Mud
[ ] Reverse Rotary [ ] Other

(4) PROPOSED USE

[ ] Domestic [ ] Irrigation [ ] Community
[ ] Industrial/ Commericial [ ] Livestock [ ] Dewatering
[ ] Thermal [ ] Injection [X] Other EXPLORITORY

(5) BORE HOLE CONSTRUCTION

Special Standard [ ] (Attach copy)
Depth of Completed Well 87.00 ft.

BORE HOLE

Dia	From	To
16	0	140

SEAL

Material	From	To	Amt	sacks/lbs
Bentonite Chips	0	4	7	S
		Calculated	6	
Cement	4	50	70	S
		Calculated	31	

How was seal placed: Method [ ] A [ ] B [X] C [ ] D [ ] E
[X] Other POURED DRY
Backfill placed from 87 ft. to 140 ft. Material PEA GRAVEL
Filter pack from 50 ft. to 87 ft. Material SAND Size 6/9
Explosives used: [ ] Yes Type Amount

(5a) ABANDONMENT USING UNHYDRATED BENTONITE

Proposed Amount Actual Amount

(6) CASING/LINER

Casing	Liner	Dia	+	From	To	Gauge	Stl	Plstc	Wld	Thrd
(●)	( )	8	[X]	2	52	.250	(●)	( )	[X]	[ ]
( )	( )		[ ]				( )	( )	[ ]	[ ]
( )	( )		[ ]				( )	( )	[ ]	[ ]
( )	( )		[ ]				( )	( )	[ ]	[ ]
( )	( )		[ ]				( )	( )	[ ]	[ ]

Shoe [ ] Inside [X] Outside [ ] Other Location of shoe(s)
Temp casing [X] Yes Dia 16 From + [X] 1 To 73

(7) PERFORATIONS/SCREENS

Perforations Method
Screens Type JOHNSON Material STAINLESS

Perf/ Screen	Casing/ Liner	Screen Dia	From	To	Scrn/slot width	Slot length	# of slots	Tele/ pipe size
Screen	Casing	8	52	87	.01			

(8) WELL TESTS: Minimum testing time is 1 hour

(●) Pump ( ) Bailer ( ) Air ( ) Flowing Artesian

Yield gal/min	Drawdown	Drill stem/Pump depth	Duration (hr)
20	20		2
103	54	80	120

Temperature 54 °F Lab analysis [ ] Yes By
Water quality concerns? [ ] Yes (describe below) TDS amount 572 mg/L

From	To	Description	Amount	Units

(9) LOCATION OF WELL (legal description)

County CROOK Twp 15.00 S N/S Range 16.00 E E/W WM
Sec 8 NW 1/4 of the NW 1/4 Tax Lot 201
Tax Map Number Lot
Lat ° ' " or 44.28950000 DMS or DD
Long ° ' " or -120.84572222 DMS or DD
( ) Street address of well (●) Nearest address

WEST OF MAIN ST/CROOKED RIVER HWY
CROOKED RIVER PARK (DTW-1)

(10) STATIC WATER LEVEL

	Date	SWL(psi)	+	SWL(ft)
Existing Well / Pre-Alteration			[ ]	
Completed Well	1/5/2018		[ ]	4.5

Flowing Artesian? [ ] Dry Hole? [ ]

WATER BEARING ZONES Depth water was first found 14.00

SWL Date	From	To	Est Flow	SWL(psi)	+	SWL(ft)
10/3/2017	14	27	20		[ ]	10
10/6/2017	42	58	20		[ ]	4.5
					[ ]	
					[ ]	
					[ ]	

(11) WELL LOG

Ground Elevation 2875.00

Material	From	To
TOP SOIL	0	1
CLAY BROWN	1	9
CLAY SAND	9	14
GRAVELS GRAY SILT COARS MEDIUM	14	27
CLAY SILT GRAVELS	27	38
SILT CLAY	38	42
GRAVELS SAND SILT	42	58
CLAY GRAY	58	88
CLAY GRAY ASH MIX	88	104
CLAY HARD GRAY	104	120
CLAY SOFT STICKY BROWN	120	140

Date Started 10/2/2017 Completed 1/5/2018

(unbonded) Water Well Constructor Certification

I certify that the work I performed on the construction, deepening, alteration, or abandonment of this well is in compliance with Oregon water supply well construction standards. Materials used and information reported above are true to the best of my knowledge and belief.

License Number 758 Date 2/16/2018
Signed THOMAS PECK (E-filed)

(bonded) Water Well Constructor Certification

I accept responsibility for the construction, deepening, alteration, or abandonment work performed on this well during the construction dates reported above. All work performed during this time is in compliance with Oregon water supply well construction standards. This report is true to the best of my knowledge and belief.

License Number 1720 Date 2/19/2018
Signed JACK ABBAS (E-filed)
Contact Info (optional)

WATER SUPPLY WELL REPORT - Map with location identified must be attached and shall include an approximate scale and north arrow

CROO 54593

2/19/2018

Map of Hole

STATE OF OREGON
WELL LOCATION MAP

This map is supplemental to the WATER SUPPLY WELL REPORT

Oregon Water Resources Department
725 Summer St NE, Salem OR 97301
(503)986-0900

LOCATION OF WELL

Latitude: 44.2895 Datum: WGS84
Longitude: -120.84572222
Township/Range/Section/Quarter-Quarter Section:
WM 6S 2W 34 NWNW
Address of Well:
WEST OF MAIN ST/CROOKED RIVER HWY
CROOKED RIVER HWY (DTW-1)

Well Label: 127082

Printed: February 18, 2018

DISCLAIMER: This map is intended to represent the approximate location the well. It is not intended to be construed as survey accurate in any manner.

Provided by well constructor

Appendix E

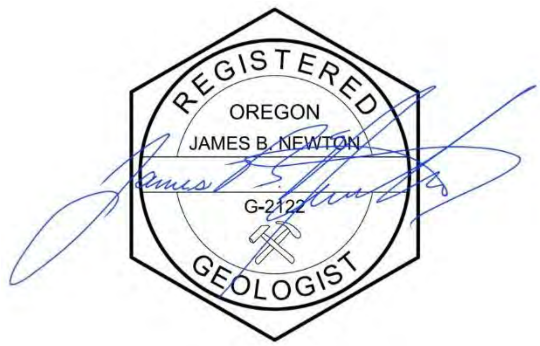
Aquifer Test Summary for the New Alluvial Wellfield

Technical Memorandum

CASCADE GEOENGINEERING

21145 Scottsdale DR, Bend, Oregon 97701
360-907-4162 newtonjim@hotmail.com

May 20, 2018



TO:
Bruce Brody-Heine, RG, CWRE
GSI Water Solutions

FROM:
Jim Newton, P.E., R.G., C.W.R.E.
Cascade Geoengineering, LLC

RE: SUMMARY OF GROUNDWATER SOURCE INVESTIGATION – CITY OF PRINEVILLE ASR FEASIBILITY; CROOK COUNTY, OREGON

This memorandum was prepared by Cascade Geoengineering, LLC (CGE) to assess potential new municipal water source for the City of Prineville Aquifer Storage and Recovery Project (Project) located in Prineville, Oregon. CGE specializes in water supply and water resources management. Accordingly, CGE has provided hydrogeologic services related to geologic investigation and has prepared Project source water test-well designs, and recommendations for installation and testing.

The City of Prineville (City) contracted with GSI Water Solutions (GSI) for work that includes overseeing the installation of 6 test wells used to investigate groundwater capacity on the identified Crooked River Park and adjacent Crook County Fairgrounds properties (Site), and the provision of preliminary results of short-duration pump tests. The locations of the test wells, the results of the well pump tests and the Project Vicinity Map (Figure 1) are attached to this memorandum.

INTRODUCTION

The Project consists of installation and testing of groundwater source wells located within the Site. These wells will serve to investigate the potential for production of up to 2,000 gallons per minute (gpm) of flow from within the Site, to be used by the City for injection into the airport area aquifer system near the Prineville Municipal Airport. The Airport is just over 1 mile west of the City of Prineville. (See Figure 1).

The purpose of this assessment is to provide a summary of the well installations and pump testing of two of these wells on the Site and to determine a reasonable course of action that may allow the City to achieve 2,000 gpm of source water for City and ASR use. The Site is shown on the attached Figure 2. Analysis logs of wells in the Site vicinity and boring test data indicates that groundwater exists in geologic strata underlying the Site. The findings also suggest that it is feasible to obtain groundwater from geologic strata beneath the Site for needs of the objectives of the Project.

SITE LOCATION

The Project area is approximately 33.06 acres located on the south end of the City of Prineville in section 8, township 15 south, range 16 east, Willamette Meridian. The Site currently consists of Crooked County Park (Park, 26.3 acres) and Crook County Fairground property (Fairgrounds, 6.76 acres) with the two properties separated by the Crooked River Highway. Prior to the onsite test well installations which inform this investigation, two shallow wells were sited within the Park, one of which was used for Park irrigation and the other was previously used for lavatory facilities. Additionally, the Fairgrounds site has two existing wells that were installed by the City in 2006 for exploratory purposes. The western border of the Park is bound by the Crooked River and to the north by the Juniper Canal (flood control canal). The area immediately east and south of the Fairgrounds is bordered by farm or grazing lands.

REGIONAL HYDROGEOLOGY

Source of Groundwater

The upper Deschutes River Basin covers about 4,500 square miles and extends between the headwaters of the Deschutes and Little Deschutes Rivers on the south to Lake Billy Chinook on the north. The High Cascade Mountain Range bounds the southwest and west sides of the basin. The Ochoco Mountain complex bounds the easterly side of the basin. The Crooked River comprises the eastern portion of the upper Deschutes River Basin and is a major tributary to the Deschutes River downstream from Prineville near Culver, Oregon.

The source of groundwater in the upper basin is precipitation and water from melting snow which infiltrates into the ground through permeable soil and rock. Downward infiltrating water ultimately comes to rest upon subsurface formations with low permeability which prevents or impedes continued downward movement. Accumulated groundwater moves under gravitational forces through permeable flow paths from high elevation recharge areas to low elevation discharge areas. Recharge areas are where the more significant amounts of precipitation and water from melted snow enter the ground to supply the groundwater system. Discharge areas are where the groundwater escapes the subsurface aquifer system through springs or through streambeds in canyons that have been down cut across the aquifers.

Recharge Areas

The principal groundwater recharge area is located in the higher elevations of the Cascade Mountain Range along the west boundary and the relatively high-elevation areas in the south and southeast parts of the upper basin. These areas receive substantial precipitation and snow pack. Local precipitation in high elevation areas near the west boundary of the upper basin can exceed 200 inches per year, mostly as snow during the winter. Annual precipitation rates drop toward the east to less than 10 inches per year in the central part of the upper basin near the City and the Project.

Discharge Areas

Groundwater discharge from the upper Deschutes Basin occurs primarily in Davis and Cultus Creeks, the Fall and Spring Rivers south of Bend, the Deschutes and Crooked Rivers north of Lower Bridge, and in Whychus Creek and the Metolius River. The incised canyons of the Deschutes and Crooked Rivers, and Whychus Creek are down-cut across aquifer zones in the lower-elevation part of the upper basin, resulting in groundwater discharge into the streams near Lake Billy Chinook. Of the major discharge areas, those in the Deschutes and Crooked Rivers near Lake Billy Chinook are nearest the Site, at distances of approximately 15 to 20 miles to the west-northwest. The Fall, Metolius, and Spring Rivers flow from large springs located at relatively high elevations in the upper basin.

Groundwater Conditions at the Site

Information on groundwater in the area of the Site was obtained from available well logs on file at the Oregon Water Resources Department (OWRD), U.S. Geological Survey published reports, and from previous CGE experience in the area. Well logs were obtained for an area extending up to 1 mile outside the Project boundaries in order to evaluate groundwater availability, geology, and potential well yield and to also consider potential for interference between Project wells and other offsite wells and water rights.

Well logs provide information on depths at which groundwater was first reported by the driller, static water levels in the wells after they were completed, types of geologic materials penetrated by the wells as described by the drillers, pump or well test results, and other well construction information.

PROJECT SITE TEST WELLS

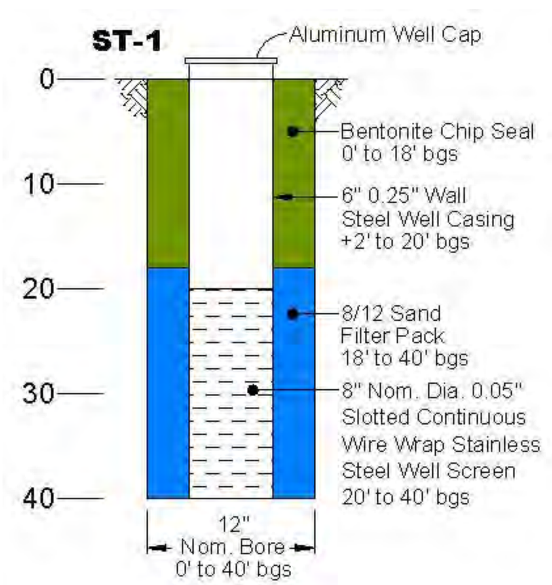
In an effort to investigate potential for groundwater development on the Site, CGE oversaw the installation of 6 test wells ranging in depth from 40 feet below ground surface (bgs) at boring location ST1, ST-2 and ST-3, and up to 140 feet bgs at borings DT-1, DT-2 and DT-3 (locations of Project test wells are shown on the attached Figure 3). Installation of these test wells provided critical Site-specific information on subsurface geologic conditions and potential for groundwater development at the Site for Project water needs. The test well DT-1 was installed first to understand the geologic deposits at the Site followed by completion of the three shallow test wells (ST-1, ST-2, ST-3) and other deep wells (DT-2, DT-2)Driller well logs for the installed test wells are included in the attached Appendix A.

Shallow Test Wells (ST-1, ST-2 and ST-3)

Test Well ST-1 is located in the northwestern corner of the Site at a surface elevation of approximately 2,869 feet MSL. ST-1 was installed to a depth of approximately 40 feet bgs, with water encountered at 14 feet bgs, as reported by the driller (driller log CROO 54587). The water-bearing zone at 14 feet bgs corresponded with an approximate transition in geology between a gray silty-clay layer and an underlying fine to coarse grained sand and gravel-cobble layer. Based on observations during drilling of the boring, water persisted to depth; however, at approximately 38.5 a significant increase in silt with trace clay was observed. The static water level recorded prior to each day of drilling by CGE was 8 feet bgs, corresponding to an approximate elevation of 2,861 feet MSL (subsequently, the driller log reflects a static water level of 11 feet bgs). The overall nominal boring diameter of ST-1 was 12 inches.

The boring was terminated when drilling encountered silt with clay, as similar material was encountered in DT-1 (Deep Test Well, as described below) and the very fine black sand with silt and clay appeared to be a confining layer, and it was not penetrated below 40 feet bgs. A detailed geologic log of ST-1 was developed from onsite geologic observations and samples collected by CGE during drilling and included in the attached Appendix B.

As ST-1 was determined to be a pumped test well, a 6 inch inside diameter stainless steel continuous wire wrap screen and sand pack was installed from a depth interval of 40 feet to 20 feet bgs, with the well seal being from 18 feet to ground surface. The screen slot size was calculated based on sieve analysis of representative fine-grained drill cutting samples and sized to 0.050-inch slot size with an 8/12 grit sand filter pack. A schematic diagram of the well completion of ST-1 is shown below:



Test Well ST-2 is located in the northwestern corner of the Site, approximately 100 feet north of ST-1, at an approximately surface elevation of 2,870 feet MSL. ST-2 was installed to a depth of approximately 40.5 feet bgs, encountering water at 10 feet bgs, with a reported static level during drilling and on the driller log of 8 ft bgs (driller log CROO-54589). The water producing zone of the aquifer was very similar to ST-1 and ST-3 (described below), being a fine to coarse grained sand and gravel-cobble layer. Based on observations during drilling, water persisted to depth; however, at depths below 37 feet bgs increases in silt and trace clays proved similar to encountered materials in ST-1 and DT-1, and drilling ceased at approximately 40 feet bgs. The overall nominal boring diameter of ST-2 was 12 inches.

As ST-2 was determined to primarily be a monitoring well for pumped test wells, ST-2 was completed with vertical machine perforated 6-inch nominal diameter steel casing (0.250-inch wall thickness). The perforations were 1/8-inch machined perforations with a 6/9 grit sand filter pack. A detailed geologic log of ST-2 was developed from onsite geologic observations and samples collected by CGE during drilling and included in the attached Appendix B.

Test Well ST-3 is located in the northwestern corner of the Site, approximately 200 feet east of ST-2 and 240 feet from ST-1, at an approximately surface elevation of 2,870 feet MSL. ST-3 was installed to a depth of approximately 40 feet bgs, encountering water at 18 feet bgs, with a reported static level during drilling and on the driller log of 11 ft bgs (driller log CROO-54591). The water producing zone of the aquifer was very similar to ST-1 and ST-2, being a fine to coarse grained sand and gravel-cobble layer. Based on observations during drilling, water persisted to depth; however, at depths nearing 40 feet bgs increases in silt and trace clays proved similar to encountered materials in ST-1 and DT-1(described below), and drilling ceased at approximately 40 feet bgs. The overall nominal boring diameter of ST-3 was 12 inches.

As ST-3 was determined to primarily be a monitoring well for pumped test wells, ST-3 was completed with vertical machine perforated 6-inch nominal diameter steel casing (0.250-inch wall thickness). The perforations were 1/8-inch machined perforations with a 6/9 grit sand filter pack. A detailed geologic log of ST-3 was developed from onsite geologic observations and samples collected by CGE during drilling and included in the attached Appendix B.

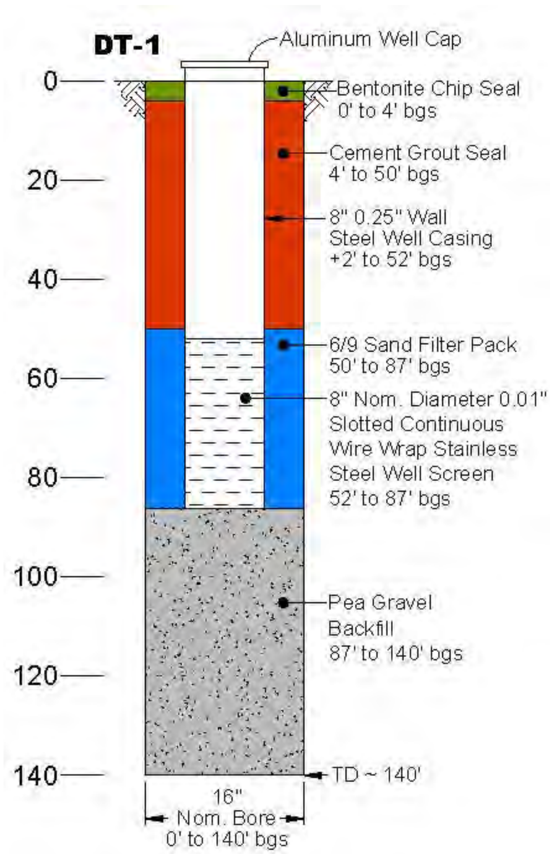
Deep Test Wells DT-1, DT-2 and DT-3

Test Well DT-1 is located in the northwestern corner of the Site at a surface elevation of approximately 2,870 feet MSL. DT-1 was drilled to a depth of approximately 140 feet bgs, however, because clay material non-water bearing water zones were encountered below 80 feet bgs, the well was backfilled from 140 feet to 80 feet bgs and completed at 80 feet bgs. DT-1 encountering first water at 14 feet bgs as reported by the driller (driller log CROO 54593), and below the silty clay a second water bearing zone was encountered at approximately 46 feet bgs. The water-bearing zone at 14 feet bgs was at an approximate transition in geology between a gray silty-clay layer and an underlying fine to coarse grained sand and gravel-cobble layer, the same water-bearing zone encountered in ST-1/2/3. The lower water-bearing zone encountered at 46 feet to 80 feet bgs was comprised of fine sands to course gravels-cobbles with silt and interbeds of clayey-silt and silty-clays with gravels to a depth of approximately 80 feet bgs; below 80 feet the boring encountered clays of light tan to bluish green clays. Based on observations during drilling of the boring, water persisted in the lower water-bearing zone from approximately 45 feet to 80 feet bgs.

The static water level recorded upon completion of the well (after sealing off the upper water-bearing zone) was approximately 4.5 feet bgs, corresponding to an approximate elevation of 2,865.5 feet MSL. The overall nominal boring diameter of DT-1 was 16 inches.

The boring was terminated when drilling reached 140 feet in depth, and because DT-1 was the first well drilled it served as the marker for encountered materials, providing relative comparison for each subsequent well installed. A detailed geologic log of DT-1 was developed from onsite geologic observations and samples collected by CGE during drilling and included in the attached Appendix B.

As DT-1 was determined to be a pumped test well, an 8-inch inside diameter stainless steel continuous wire wrap screen and sand pack was installed from a depth interval of 52 feet to 87 feet bgs, with the well seal being from 50 feet bgs to ground surface. The screen slot size was calculated based on sieve analysis of representative fine-grained drill cutting samples and sized to 0.010-inch slot size with an 6/9 grit sand filter pack. A schematic diagram of the well completion of DT-1 is shown below:

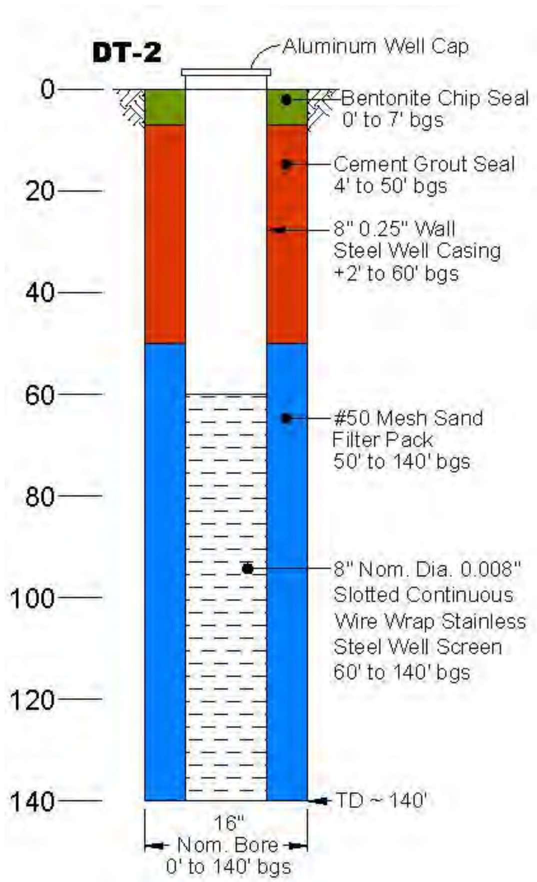


Test Well DT-2 is located in the northern center of the Site at a surface elevation of approximately 2,872 feet MSL. DT-2 was drilled to a depth of approximately 140 feet bgs, producing water continuously in the lower water-bearing zone from approximately 32 feet to 133 feet. The lower interval from 133 feet to 140 feet bgs likely produced water, however, the very fine silts with clay likely did not contribute appreciable amounts of water to the well bore. DT-2 encountered first water at 13 feet bgs as reported by the driller (driller log CROO 54592), and below the silty clay a second water bearing zone was encountered at approximately 32 feet bgs. The first water-bearing zone at 13 feet bgs was at an approximate transition in geology between a gray silty-clay layer and an underlying fine to coarse grained sand and gravel-cobble layer, likely the same water-bearing zone encountered in ST-1/2/3. The lower water-bearing zone encountered from 32 feet to 140 feet bgs was comprised of very fine black sands with silt and intervals of trace clay; below 133 feet the boring encountered a higher mix of clay with the very fine silts and sands. Based on observations during drilling of the boring, water persisted in the lower water-bearing zone from approximately 32 feet to 140 feet bgs.

The static water level recorded upon completion of the well (after sealing off the upper water-bearing zone) was approximately 4 feet bgs, corresponding to an approximate elevation of 2,868 feet MSL. The overall nominal boring diameter of DT-2 was 16 inches.

The boring was terminated when drilling reached 140 feet in depth, in anticipation that DT-2 may exhibit properties similar to the previous City exploratory wells CROO-53215/53355 that anecdotally reported a strong scent of sulfur. A detailed geologic log was developed from samples collected during drilling by CGE.

As DT-2 was determined by the City to potentially have future viability as a water source based on placement in the Site park, an 8-inch inside diameter stainless steel continuous wire wrap screen and sand pack was installed from a depth interval of 60 feet to 140 feet bgs, with the well seal being from 50 feet bgs to ground surface. The screen slot size was calculated based on sieve analysis of representative fine-grained drill cutting samples and sized to 0.008-inch slot size with a 50-grit sand filter pack. A schematic diagram of the well completion of DT-1 is shown below:



Test Well DT-3 is located on the east side of the Crooked River Highway portion of the Site at a surface elevation of approximately 2,872 feet MSL. DT-3 was drilled to a depth of approximately 140 feet bgs, producing water continuously in the lower water-bearing zone from approximately 70 feet to 112 feet. The lower interval from 112 feet to 140 feet bgs likely produced water, however, the very fine silts likely did not contribute appreciable amounts of water to the well bore. DT-3 encountered first water at 10 feet bgs as reported by the driller (driller log CROO 54588), and below the silty gray clay a second water bearing zone was encountered at approximately 70 feet bgs. The first water-bearing zone at 10 feet bgs was at an approximate transition in geology between a gray silty-sand layer and an underlying fine to coarse grained sand and gravel-cobble layer, likely the same water-bearing zone encountered in ST-1/2/3. The lower water-bearing zone encountered from 70 feet to 112 feet bgs was comprised of fine gray sands; below 112 feet the boring encountered a high mix of very fine silts and sands. Based on observations during drilling of the boring, water persisted in the lower water-bearing zone from approximately 70 feet to 140 feet bgs.

The static water level recorded upon completion of the well (after sealing off the upper water-bearing zone) was approximately 4 feet bgs, corresponding to an approximate elevation of 2,868 feet MSL. The overall nominal boring diameter of DT-3 was 16 inches.

The boring was terminated when drilling reached 140 feet in depth, in anticipation that DT-3 may exhibit properties similar to the previous City exploratory wells CROO-53215/53355 that anecdotally reported a strong scent of sulfur. The drillers well log is included in the attached Appendix A, however, based on pump testing of ST-1 and DT-2 being conducted concurrently to drilling of DT-3, a detailed well log was not prepared by CGE.

PUMP TESTING OF EXPLORATORY BORINGS

The completed test wells ST-1 and DT-1 were constructed with stainless steel wire wrap screens and sand filter packs appropriately sized to allow for test pumping of the wells while reducing the potential to develop sand or fine-grained material from entering the well bore. Each of the 5-day continuous constant rate pump tests performed on ST-1 and DT-1 were conducted using a 10-horsepower submersible well pump set near the bottom of the well screens to allow installation of a test pump which helps estimate potential water yield from each boring. Test pump water was piped through a digital totalizing flow meter and discharged to the ground approximately 500 feet south of each well respectively.

Flow rates for the 5-day pump test on each of the pump tested wells ST-1 and DT-1 were determined by conducting a step-drawdown pump test, where the flow rate began at a relatively low pumping rate of 50 gpm or less. Once water levels in the pumped well began to stabilize at each interval flow rate, the control valve was adjusted to allow for an incrementally higher flow rate. With each subsequent increase in flow rate during the step-drawdown test, the drawdown would increase; once the drawdown was not sustainable, the flow rate was adjusted to a previous lower flow rate until a relatively stable water pumping level was observed. This *stabilized pumping rate* was the target constant flow at which each respective well was operated for each 5-day pump test, respectively.

During each pump test, an automated water-level recorder, or pressure transducer, was installed in the pumped well and in nearby wells to monitor influence of the pump tested well on non-pumped wells. Pressure transducers recorded water levels before, during and after the pumping portion of the 5-day pump tests in all monitored wells. The period after pumping is described as the recovery portion of the well test.

Pump tests are described below.

ST-1 Pump Test

The pump test of test well ST-1 was conducted between January 18 and January 23 2018, using a 10-horsepower test pump set at approximately 32 feet bgs with an average pumping rate of approximately 86.8 gpm. For the duration of the 5-day pump test, the maximum observed drawdown was approximately 21.8 feet. The drawdown and recovery curves for the test are shown in Appendix C. The drawdown vs. time curve has a period around minute 150 where the water level began to sharply rise followed immediately by continuing, uninterrupted drawdown thereafter. During this short, sharp rise in drawdown, the discharge valve maintaining the flow rate was adjusted to maintain a consistent flow, causing a slight disruption in the flow rate and resulting in a temporary lower rate. As shown in the drawdown curve, once the flow rate was returned to the constant rate for the remainder of the 5 -day test, the drawdown remained relatively consistent.

Using the maximum drawdown of 21.8 feet recorded during the test of ST-1 and the average pumping rate of 86.8 gpm, an approximate specific capacity value is 3.98 gpm/ft of drawdown. Using this calculated specific capacity value, the nature of the drawdown observed in ST-1, and drawdown observed in surrounding non-pumped monitor wells during the 5-day test, the following aquifer parameters were calculated:

- T_2 = 8,957 gpd/ft or 1,197 ft^2/day
- T_3 = 12,540 gpd/ft or 1,676 ft^2/day
- An Average Transmissivity for ST-1; $T_{2\ \&\ 3}$ = 10,748 gpd/ft or 1,436 ft^2/day
- Estimated Storage Coefficient.) = 8.9 x 10^{-5}
- Calculated Hydraulic Coefficient (K) of $T_{2\ \&\ 3\ avg.}$ = 62.4 ft/day

The following non-pumped monitored wells were used to help calculate the above-listed aquifer parameters:

- The ST-2, ST-3, and DT-1 wells,
- The nearby existing Park Irrigation Well, and
- The City's 4th Street Shallow Well about 3200 feet to the north.

NOTE: These well yield calculations are consistent with methods described in *"Ground Water and Wells" 1975*.

DT-1 Pump Test

The pump test of test well DT-1 was conducted between January 18 and January 23 2018, using a 10-horsepower test pump set at approximately 75 feet bgs with an average pumping rate of approximately 101.8 gpm. For the duration of the 5-day pump test, the maximum observed drawdown was approximately 54.6 feet. The drawdown and recovery curves for the test are shown in Appendix C. As shown in the drawdown curve, the constant rate and the drawdown remained relatively consistent throughout the 5 -day test.

Using the maximum drawdown of 54.6 feet recorded during the test of DT-1 and the average pumping rate of 101.8 gpm, an approximate specific capacity value is 1.86 gpm/ft of drawdown. Using this calculated specific capacity value, the nature of the drawdown observed in DT-1, and drawdown observed in surrounding non-pumped monitored wells during the 5-day test, the following aquifer parameters were calculated:

- T_2 = 4,072 gpd/ft or 544 ft^2/day
- T_3 = 9,953 gpd/ft or 1,330 ft^2/day
- An Average Transmissivity for DT-1; $T_{2\ \&\ 3}$ = 7,011 gpd/ft or 937 ft^2/day
- Calculated Storage Coefficient (Avg $T_{2\ \&\ 3}$) = 3.95×10^{-4}
- Calculated Hydraulic Coefficient (K) of $T_{2\ \&\ 3\ avg.}$ = 26.7 ft/day

The following non-pumped monitored wells were also used to calculate aquifer parameters:

- The ST-2, ST-3, and DT-2 wells,
- The nearby existing Park Irrigation Well, and
- The City's 4th Street Shallow Well about 3200 feet to the north.

NOTE: These well yield calculations are consistent with methods described in *"Ground Water and Wells" 1975*.

FUTURE WELL PLACEMENT CONCEPT

Based on the testing completed on the Project test wells ST-1 and DT-1, there is capacity in the aquifer to develop multiple wells within the Park Site. Because the pumping of ST-1 and DT-1 had very limited observed drawdown in the monitored wells nearby each pumped well, there seems to be limited potential for well interference (interference being when the pumping of one well causes measurable drawdown in a nearby well in the same aquifer). Accordingly, there is the potential to install pumped wells in a series along the Crooked River. The following maximum drawdown was observed in each monitored well during pump testing of ST-1 and DT-1:

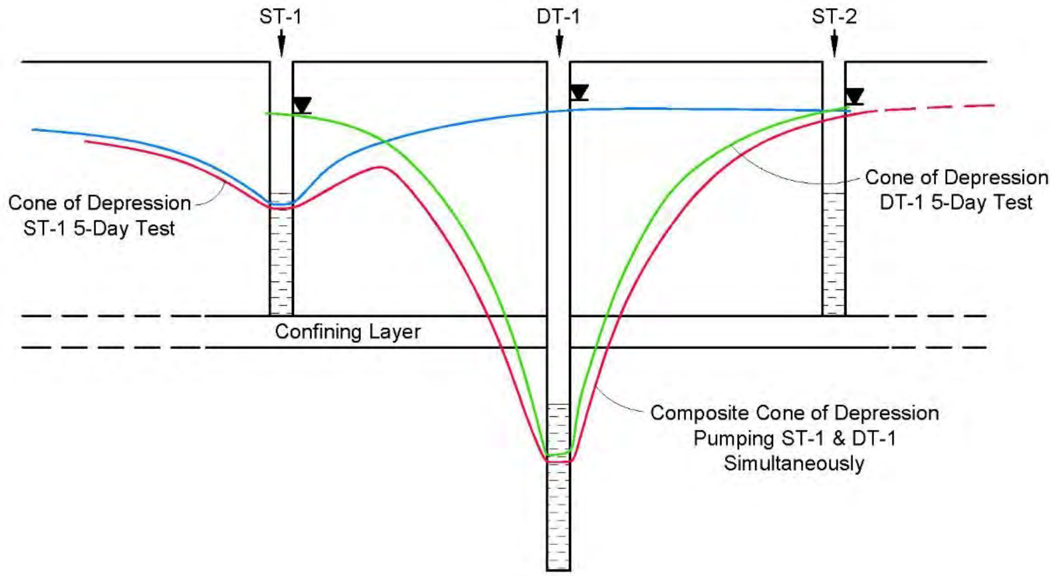
Pump Test of ST-1 – Observed Drawdown

- ST-2, located approximately 100 feet from ST-1, experienced 1.25 feet of maximum drawdown during the pump test;
- ST-3, located approximately 140 feet from ST-1, experienced 1.03 feet of maximum drawdown during the pump test;
- DT-1, located approximately 50 feet from ST-1, experienced 1.9 feet of maximum drawdown during the pump test;
- Park Irrigation Well, located approximately 320 feet from ST-1, experienced 0.37 feet of maximum drawdown during the pump test;
- City's 4th Street Shallow Well had no discernable effect, the water level in this well inclined approximately 0.18 feet during the testing of ST-1.

Pump Test of DT-1 – Observed Drawdown

- ST-2, located approximately 50 feet north of DT-1, experienced 0.69 feet of drawdown in the first 6.5 hours of testing DT-1, only to fluctuate up to only 0.27 feet of drawdown over the course of the 5-day pump test;
- ST-3, located approximately 115 feet from DT-1, experienced 0.38 feet of maximum drawdown during the pump test;
- DT-2, located approximately 430 feet from DT-1, experienced 0.47 feet of maximum drawdown during the pump test;
- Park Existing Irrigation Well, located approximately 270 feet from DT-1, experienced 1.23 feet of maximum drawdown during the pump test;
- City's 4th Street Deep Well had no discernable effect; the water level in this well inclined approximately 0.32 feet during the testing of DT-1.

Based on the minimal potential for pumping interference between properly spaced wells from others producing water from the same water-bearing zone, and the minimal communication between the shallow and deep water-bearing zones between ST-1 and DT-1 respectively, multiple wells may be installed at the Park Site. The below graphic illustrates the observed drawdown effect and potential pumping impacts from pumping ST-1 (shallow water-bearing zone) and DT-1 (deep water-bearing zone) and the cumulative effect on one another and on ST-2 (the nearby shallow water-bearing zone monitored well).



This minimal interference potential demonstrated by pumping wells in the same water-bearing zone, and the limited leakage interference of wells in the alternate water-bearing zone, (e.g. limited effect between ST-1 and DT-1 when pumped respectively) suggests that installation of new well locations at an alternating distance of 50 feet away would have little to no effect on overall well pumping capacities. The attached Figure 4 has been prepared to show the potential to install alternating shallow and deep wells along the western boundary of the Park Site along the eastern shore of the Crooked River, staying above the river bank. This figure illustrates the potential to install wells at a recurring shallow well-deep well-shallow well-deep well (and so on) fashion, with minimum separation distances of 50 feet between wells. Figure 4 further illustrates that up to 30 alternating deep-shallow well installations along the Site river bank may reasonably fit. However, based on the likely capacity of the wells during simultaneous production, a mix of only 10 shallow and 10 deep wells (20 wells total) may likely reach the Project combined production target of 2,000 gpm.

CONCLUSIONS

Groundwater is available beneath the Site and is contained in two water-bearing zones: a shallow zone with a depth range of approximately 15 feet to 40 feet, and a deep zone between approximately 45 feet and 80 feet. Initial testing and preliminary findings suggest it is possible to construct multiple production wells in the Park meet the City's production target of 2,000 gpm for the new municipal water source. However, additional considerations must be addressed to account for geologic variability in aquifer conditions, to refine estimates of water yield capacity relative to ultimate Project needs, and to plan and develop a water supply system.

The vertical geologic section revealed in the 6 well borings consists generally of interbedded sand and gravel sediments with a confining layer of silty clay (likely a leaky confining layer) overlaying a lower confining clay unit. Groundwater was encountered in the upper shallow-sediment unit which ranges in apparent thickness of around 27 to 28 feet. The lower sediment unit range in thickness of 35 feet to nearly 100 feet or more. Considering this general characteristic and discovery of groundwater in both materials beneath the Site, the potential groundwater source for the proposed Project may be developed from both the shallow and deep sand/gravel interbed units.

Findings during testing of ST-1 an DT-1 suggest that water-bearing units have a potentially leaky confined relationship. Production wells constructed to depths of approximately 40 feet bgs for the shallow water-bearing zone; and depths of between 80 and 140 feet for the deep water-bearing, indicate a groundwater source on the Site with potential to meet Project water supply objectives.

Initial pump test results suggest that it is possible for the City to develop a new municipal water source from multiple wells. Initial testing suggests that multiple wells at or near the western boundary of the Park site could produce in a range of 85 to 120 gpm per well. Pumping interference between wells is a possibility and based on the 5-day pump tests conducted on ST-1 and DT-1, placement of the alternating shallow and deep wells with minimum separation distances of 50 feet or more is recommended to reduce overall pumping interference potential.

RECOMMENDATIONS

1. Construct additional potential Project wells along the western boundary of the Park Site on the eastern bank of the Crooked River at minimum separation distance of 50 to each neighboring well, alternating between deep and shallow well installations. This would yield

a minimum separation distance of 100 feet between wells developing water from the same water-bearing zone.

2. Consider construction in 6-well increments, 3 shallow and 3 deep, and perform a monitored 5-day pump test to compare and confirm aquifer observed and calculated aquifer characteristics from testing of ST-1 and DT-1 contained herein. Analyze the well test results including specific capacity, drawdown characteristics and recovery characteristics. Analyze potential drawdown effects on the other borings on the site and evaluate the potential capacity of the new well sets.

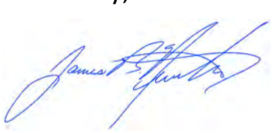
3. During installation of new wel6-well installation increments, it is recommended that a minimum of 1 of each shallow and deep well installation be logged with detailed geologic oversight to allow for comparison to current test wells ST-1/2/3, and DT-1/2. If significant deviation of observed geologic conditions exist in comparison to anticipated geology, further analysis may be warranted prior to installation of the next 6-well installation increment.

4. Depending on results of items 1 thru 3, continue to install new Project production wells considering the comparative results of the newly installed wells with calculated aquifer characteristics from testing of ST-1 and DT-1.

CLOSURE

If you have questions regarding this memorandum, please feel free to contact me at your convenience. I can be reached by email at newtonjim@hotmail.com, or by telephone at 360-9047-4162.

Sincerely,



Jim Newton, PE, RG, CWRE
Principal – Engineer-Geologist
Cascade Geoengineering, LLC

REFERENCES

Lite Jr., Kenneth E., Gannett, Marshall W., 2000, Framework for Regional, Coordinated Monitoring in the Middle and Upper Deschutes River Basin, Oregon: U.S. Geological Survey Open File Report 00-386.

Lite Jr., Kenneth E., Gannett, Marshall W., 2000, Ground-Water Hydrology of the Upper Deschutes River Basin, Oregon: U.S. Geological Survey Water-Resources Investigations Report 00-4162.

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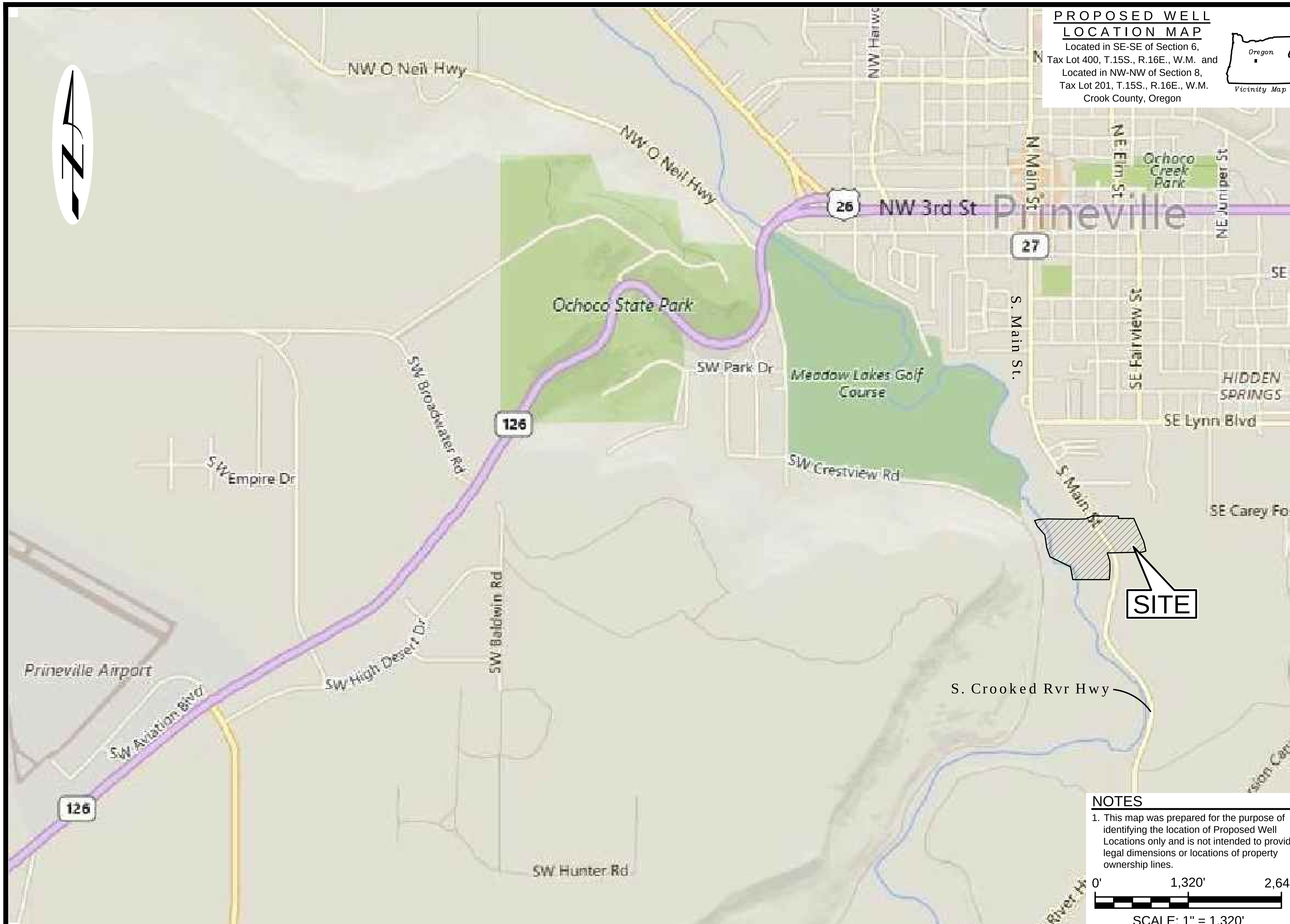
FIGURES



Vicinity Map

City of Prineville - ASR Project

Crook County, Oregon

FIGURE 1

PROJECT NO. CG-1002-104

DATE: APR 2018

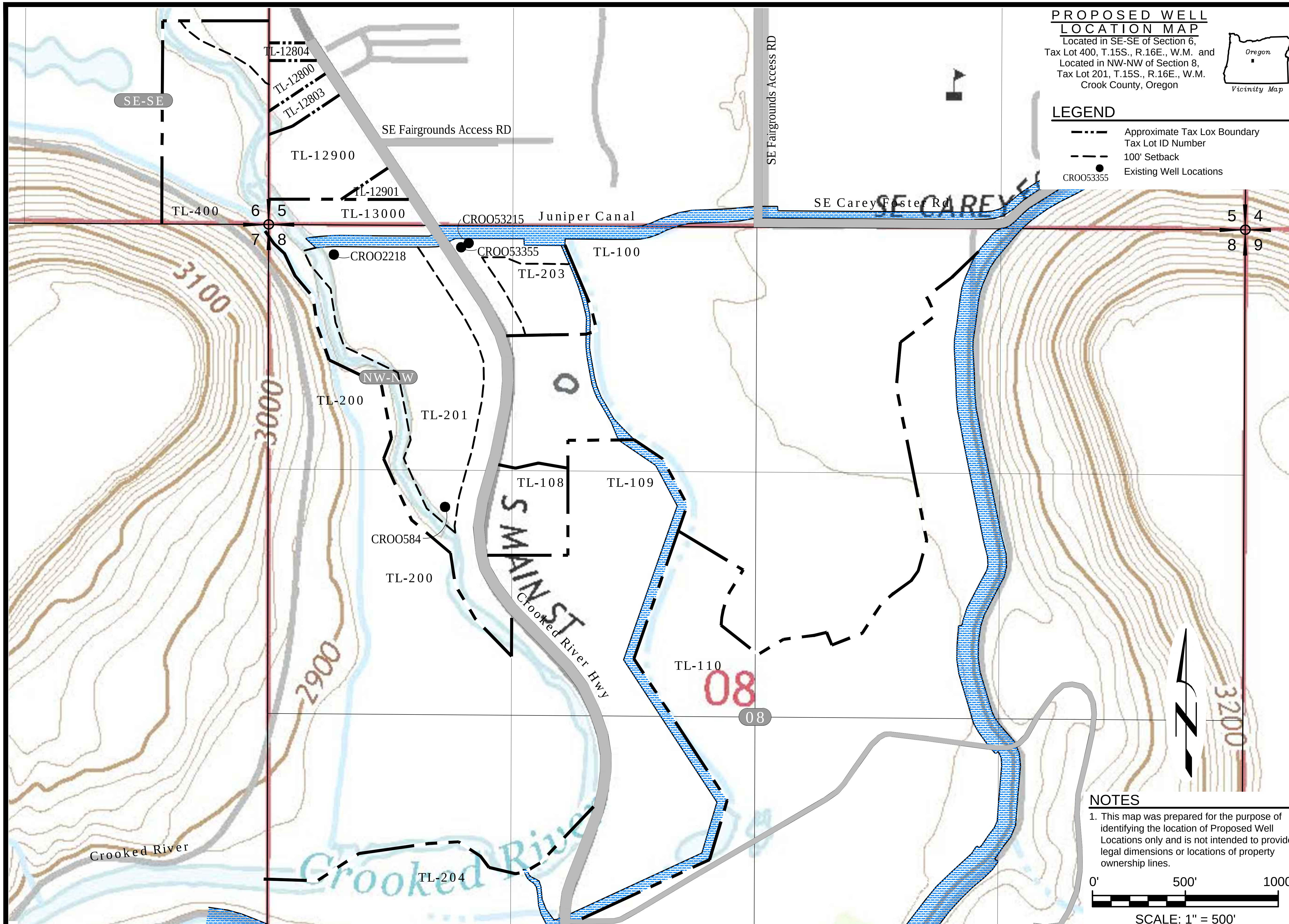
DRAWN BY: R2D

DESIGNED BY: J. Newton

CASCADE GEOENGINEERING

cascadegeoengineering.com

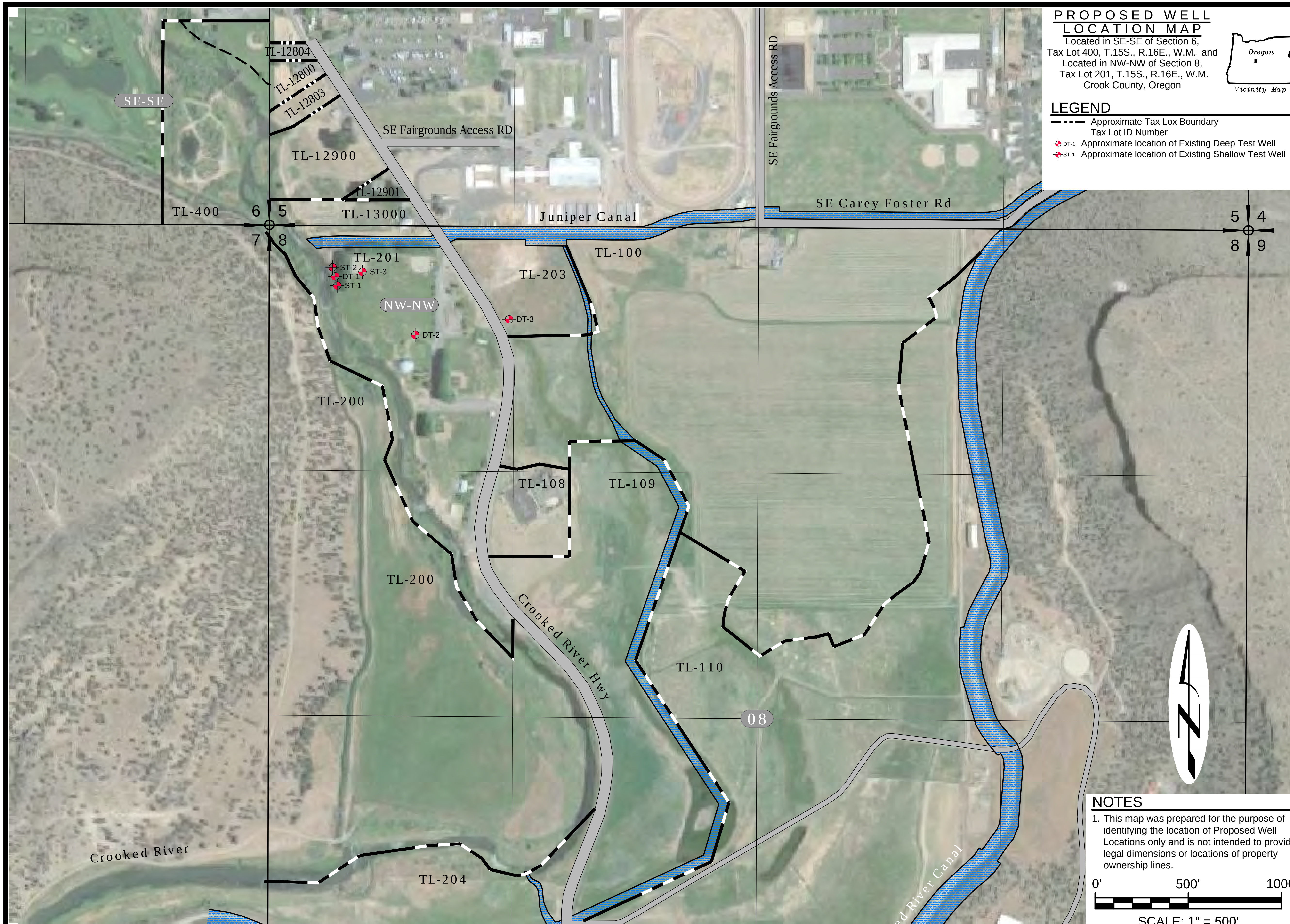
360.907.4162



Site - Existing Well Locations
City of Prineville - ASR Project
Crook County, Oregon

CASCADE GEOENGINEERING
cascadegeoengineering.com
360.907.4162

FIGURE	2
PROJECT NO.	CG-1002-104
DATE:	APR 2018
DRAWN BY:	R2D
DESIGNED BY:	J. Newton



PROPOSED WELL LOCATION MAP

Located in SE-SE of Section 6,
Tax Lot 400, T.15S., R.16E., W.M. and
Located in NW-NW of Section 8,
Tax Lot 201, T.15S., R.16E., W.M.
Crook County, Oregon

LEGEND

- Approximate Tax Lox Boundary
- Tax Lot ID Number
- DT-1 Approximate location of Existing Deep Test Well
- ST-1 Approximate location of Existing Shallow Test Well

NOTES

1. This map was prepared for the purpose of identifying the location of Proposed Well Locations only and is not intended to provide legal dimensions or locations of property ownership lines.

0' 500' 1000'

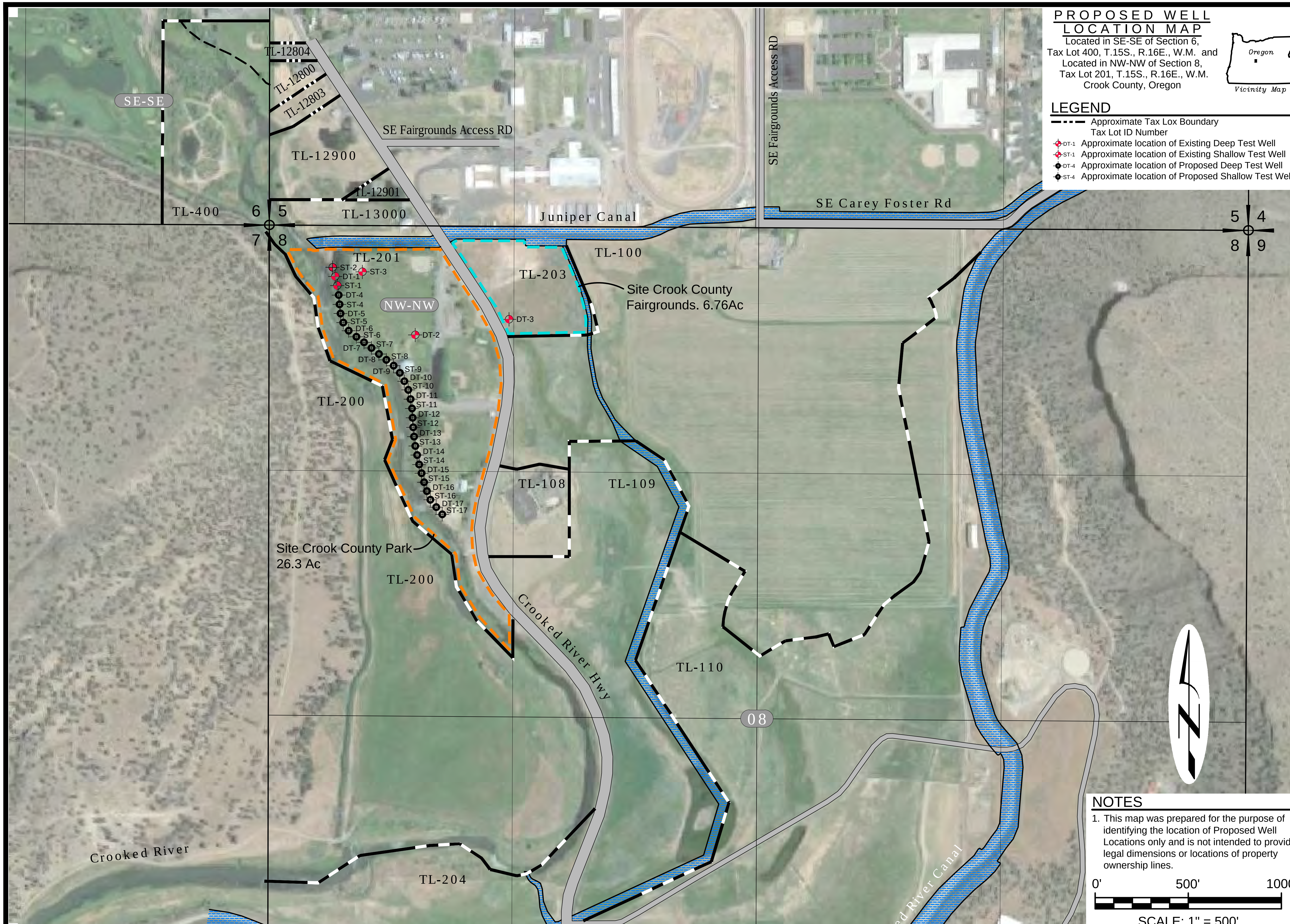
SCALE: 1" = 500'

ASR Test Well Locations

City of Prineville - ASR Project
Crook County, Oregon

CASCADE GEOENGINEERING
360.907.4162
cascadegeoengineering.com

FIGURE	3
PROJECT NO.	CG-1002-104
DATE:	APR 2018
DRAWN BY:	R2D
DESIGNED BY:	J. Newton



Proposed ASR Well Locations

City of Prineville - ASR Project
Crook County, Oregon

FIGURE 4

PROJECT NO. CG-1002-104

DATE: APR 2018

DRAWN BY: R2D

DESIGNED BY: J. Newton

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APPENDIX A

OWRD WELL LOGS

STATE OF OREGON
WATER SUPPLY WELL REPORT
(as required by ORS 537.765 & OAR 690-205-0210)

CROO 54587
2/16/2018

WELL I.D. LABEL# L 127083
START CARD # 1037842
ORIGINAL LOG #

(1) LAND OWNER

Owner Well I.D. STW-1
First Name JIM Last Name NEWTON
Company CITY OF PRINEVILLE
Address 387 NE 3RD ST
City PRINEVILLE State OR Zip 97754

(2) TYPE OF WORK

[X] New Well [ ] Deepening [ ] Conversion
[ ] Alteration (complete 2a & 10) [ ] Abandonment(complete 5a)

(2a) PRE-ALTERATION

Casing:

Dia	+	From	To	Gauge	Stl	Plstc	Wld	Thrd

Seal:

Material	From	To	Amt	sacks/lbs

(3) DRILL METHOD

[ ] Rotary Air [ ] Rotary Mud [X] Cable [ ] Auger [ ] Cable Mud
[ ] Reverse Rotary [ ] Other

(4) PROPOSED USE

[ ] Domestic [ ] Irrigation [ ] Community
[ ] Industrial/ Commericial [ ] Livestock [ ] Dewatering
[ ] Thermal [ ] Injection [X] Other EXPLORITORY

(5) BORE HOLE CONSTRUCTION

Special Standard [ ] (Attach copy)
Depth of Completed Well 40.00 ft.

BORE HOLE

Dia	From	To
12	0	40

SEAL

Material	From	To	Amt	sacks/lbs
Bentonite Chips	0	18	53	S
		Calculated	14	
		Calculated		

How was seal placed: Method [ ] A [ ] B [ ] C [ ] D [ ] E
[X] Other POURED DRY
Backfill placed from ft. to ft. Material
Filter pack from 18 ft. to 40 ft. Material SAND Size 8/12
Explosives used: [ ] Yes Type Amount

(5a) ABANDONMENT USING UNHYDRATED BENTONITE

Proposed Amount Actual Amount

(6) CASING/LINER

Casing	Liner	Dia	+	From	To	Gauge	Stl	Plstc	Wld	Thrd
(●)	( )	6	[X]	2	20	.250	(●)	( )	[X]	[ ]
( )	( )		[ ]				( )	( )	[ ]	[ ]
( )	( )		[ ]				( )	( )	[ ]	[ ]
( )	( )		[ ]				( )	( )	[ ]	[ ]
( )	( )		[ ]				( )	( )	[ ]	[ ]

Shoe [ ] Inside [X] Outside [ ] Other Location of shoe(s)
Temp casing [X] Yes Dia 12 From + [X] 1 To 40

(7) PERFORATIONS/SCREENS

Perforations Method
Screens Type JOHNSON Material STAINLESS

Perf/ Screen	Casing/ Liner	Screen Dia	From	To	Scrn/slot width	Slot length	# of slots	Tele/ pipe size
Screen	Casing	6	20	40	.05			

(8) WELL TESTS: Minimum testing time is 1 hour

( ) Pump (●) Bailer ( ) Air ( ) Flowing Artesian

Yield gal/min	Drawdown	Drill stem/Pump depth	Duration (hr)
100	26	38	120
25	5		4

Temperature 54 °F Lab analysis [ ] Yes By
Water quality concerns? [ ] Yes (describe below) TDS amount 111 ppm

From	To	Description	Amount	Units

(9) LOCATION OF WELL (legal description)

County CROOK Twp 15.00 S N/S Range 16.00 E E/W WM
Sec 8 NW 1/4 of the NW 1/4 Tax Lot 201
Tax Map Number Lot
Lat ° ' " or 44.28944444 DMS or DD
Long ° ' " or -120.84569444 DMS or DD
( ) Street address of well (●) Nearest address
WEST OF MAIN ST/CROOKED RIVER HWY CROOKED RIVER PARK (STW-1)

(10) STATIC WATER LEVEL

	Date	SWL(psi)	+	SWL(ft)
Existing Well / Pre-Alteration			[ ]	
Completed Well	1/9/2018		[ ]	11

Flowing Artesian? [ ] Dry Hole? [ ]

WATER BEARING ZONES Depth water was first found 14.00

SWL Date	From	To	Est Flow	SWL(psi)	+	SWL(ft)
10/24/2017	24	37	20		[ ]	12
					[ ]	
					[ ]	
					[ ]	
					[ ]	

(11) WELL LOG

Ground Elevation 2886.00

Material	From	To
CLAY GRAVEL	0	9
SILT GRAY CLAY	9	12
GRAVELS SAND GRAY	12	24
SILT SAND GRAY	24	32
CLAY SAND GRAY	32	37
CLAY GRAY	37	40

Date Started 10/24/2017 Completed 1/9/2018

(unbonded) Water Well Constructor Certification

I certify that the work I performed on the construction, deepening, alteration, or abandonment of this well is in compliance with Oregon water supply well construction standards. Materials used and information reported above are true to the best of my knowledge and belief.

License Number 758 Date 2/16/2018

Signed THOMAS R PECK (E-filed)

(bonded) Water Well Constructor Certification

I accept responsibility for the construction, deepening, alteration, or abandonment work performed on this well during the construction dates reported above. All work performed during this time is in compliance with Oregon water supply well construction standards. This report is true to the best of my knowledge and belief.

License Number 1720 Date 2/16/2018

Signed JACK ABBAS (E-filed)

Contact Info (optional)

WATER SUPPLY WELL REPORT - Map with location identified must be attached and shall include an approximate scale and north arrow

CROO 54587

2/16/2018

Map of Hole

STATE OF OREGON
WELL LOCATION MAP
This map is supplemental to the WATER SUPPLY WELL REPORT

Oregon Water Resources Department
725 Summer St NE, Salem OR 97301
(503)986-0900

LOCATION OF WELL
Latitude: 44.28944444 Datum: WGS84
Longitude: -120.84569444
Township/Range/Section/Quarter-Quarter Section:
WM 6S 2W 34 NWNW
Address of Well:
WEST OF MAIN ST/CROOKED RIVER HWY CROOKED RIVER PARK (STW-1)

Well Label: 127083

Printed: February 16, 2018

DISCLAIMER: This map is intended to represent the approximate location the well. It is not intended to be construed as survey accurate in any manner.

Provided by well constructor

STATE OF OREGON
WATER SUPPLY WELL REPORT
(as required by ORS 537.765 & OAR 690-205-0210)

CROO 54589
2/16/2018

WELL I.D. LABEL# L 127081
START CARD # 1037841
ORIGINAL LOG #

(1) LAND OWNER

Owner Well I.D. STW-2
First Name JIM Last Name NEWTON
Company CITY OF PRINEVILLE
Address 387 NE 3RD ST
City PRINEVILLE State OR Zip 97754

(2) TYPE OF WORK

[X] New Well [ ] Deepening [ ] Conversion
[ ] Alteration (complete 2a & 10) [ ] Abandonment(complete 5a)

(2a) PRE-ALTERATION

Casing:

Dia	+	From	To	Gauge	Stl	Plstc	Wld	Thrd

Seal:

Material	From	To	Amt	sacks/lbs

(3) DRILL METHOD

[ ] Rotary Air [ ] Rotary Mud [X] Cable [ ] Auger [ ] Cable Mud
[ ] Reverse Rotary [ ] Other

(4) PROPOSED USE

[ ] Domestic [ ] Irrigation [ ] Community
[ ] Industrial/ Commericial [ ] Livestock [ ] Dewatering
[ ] Thermal [ ] Injection [X] Other EXPLORITORY

(5) BORE HOLE CONSTRUCTION

Special Standard [ ] (Attach copy)
Depth of Completed Well 40.50 ft.

BORE HOLE

Dia	From	To
12	0	40.5

SEAL

Material	From	To	Amt	sacks/ lbs
Bentonite Chips	0	18	27	S
		Calculated	14	
		Calculated		

How was seal placed: Method [ ] A [ ] B [ ] C [ ] D [ ] E
[X] Other POURED DRY
Backfill placed from ft. to ft. Material
Filter pack from 18 ft. to 40.5 ft. Material PEA GRAVE Size 6/9
Explosives used: [ ] Yes Type Amount

(5a) ABANDONMENT USING UNHYDRATED BENTONITE

Proposed Amount Actual Amount

(6) CASING/LINER

Casing	Liner	Dia	+	From	To	Gauge	Stl	Plstc	Wld	Thrd

Shoe [ ] Inside [ ] Outside [ ] Other Location of shoe(s)
Temp casing [ ] Yes Dia From + [ ] To

(7) PERFORATIONS/SCREENS

Perforations Method MACHINE
Screens Type Material

Perf/ Screen	Casing/ Liner	Screen Dia	From	To	Scrn/slot width	Slot length	# of slots	Tele/ pipe size
Perf	Casing	6	20.5	40.5	.125	3	456	

(8) WELL TESTS: Minimum testing time is 1 hour

( ) Pump (•) Bailer ( ) Air ( ) Flowing Artesian

Yield gal/min	Drawdown	Drill stem/Pump depth	Duration (hr)
20	20		2

Temperature 54 °F Lab analysis [ ] Yes By
Water quality concerns? [ ] Yes (describe below) TDS amount 115 ppm

From	To	Description	Amount	Units

(9) LOCATION OF WELL (legal description)

County CROOK Twp 15.00 S N/S Range 16.00 E E/W WM
Sec 8 NW 1/4 of the NW 1/4 Tax Lot 201
Tax Map Number Lot
Lat ° ' " or 44.28969444 DMS or DD
Long ° ' " or -120.84572222 DMS or DD
( ) Street address of well (•) Nearest address

WEST OF MAIN ST/CROOKED RIVER HWY
CROOKED RIVER PARK (STW-2)

(10) STATIC WATER LEVEL

	Date	SWL(psi)	+	SWL(ft)
Existing Well / Pre-Alteration				
Completed Well	12/14/2017			8

Flowing Artesian? [ ] Dry Hole? [ ]

WATER BEARING ZONES Depth water was first found 10.00

SWL Date	From	To	Est Flow	SWL(psi)	+	SWL(ft)
10/31/2017	10	37	20			8

(11) WELL LOG

Ground Elevation 2864.00

Material	From	To
CLAY BROWN	0	10
GRAVELS SAND BROWN	10	12
GRAVELS SAND SILT GRAY	12	20
LARGE GRAVELS TIGHT	20	22
SILT GRAY SAND	22	35
SAND GRAVELS GRAY SMALL	35	37
CLAY SILT GRAY	37	40.5

Date Started 10/30/2017 Completed 12/14/2017

(unbonded) Water Well Constructor Certification

I certify that the work I performed on the construction, deepening, alteration, or abandonment of this well is in compliance with Oregon water supply well construction standards. Materials used and information reported above are true to the best of my knowledge and belief.

License Number 758 Date 2/16/2018

Signed THOMAS R PECK (E-filed)

(bonded) Water Well Constructor Certification

I accept responsibility for the construction, deepening, alteration, or abandonment work performed on this well during the construction dates reported above. All work performed during this time is in compliance with Oregon water supply well construction standards. This report is true to the best of my knowledge and belief.

License Number 1720 Date 2/16/2018

Signed JACK ABBAS (E-filed)

Contact Info (optional)

WATER SUPPLY WELL REPORT - Map with location identified must be attached and shall include an approximate scale and north arrow

CROO 54589

2/16/2018

Map of Hole

STATE OF OREGON
WELL LOCATION MAP
This map is supplemental to the WATER SUPPLY WELL REPORT

Oregon Water Resources Department
725 Summer St NE, Salem OR 97301
(503)986-0900

LOCATION OF WELL
Latitude: 44.28969444 Datum: WGS84
Longitude: -120.84572222
Township/Range/Section/Quarter-Quarter Section:
WM 15S 16E 8 NWNW
Address of Well:
WEST OF MAIN ST/CROOKED RIVER HWY CROOKED RIVER PARK (STW-2)

Well Label: 127081

Printed: February 16, 2018

DISCLAIMER: This map is intended to represent the approximate location the well. It is not intended to be construed as survey accurate in any manner.

Provided by well constructor

STATE OF OREGON
WATER SUPPLY WELL REPORT
(as required by ORS 537.765 & OAR 690-205-0210)

CROO 54591
2/18/2018

WELL I.D. LABEL# L 127080
START CARD # 1037844
ORIGINAL LOG #

(1) LAND OWNER

Owner Well I.D. STW-3
First Name JIM Last Name NEWTON
Company CITY OF PRINEVILLE
Address 387 NE 3RD ST
City PRINEVILLE State OR Zip 97754

(2) TYPE OF WORK

[X] New Well [ ] Deepening [ ] Conversion
[ ] Alteration (complete 2a & 10) [ ] Abandonment(complete 5a)

(2a) PRE-ALTERATION

	Dia	+	From	To	Gauge	Stl	Plstc	Wld	Thrd
Casing:									

	Material	From	To	Amt	sacks/lbs
Seal:					

(3) DRILL METHOD

[ ] Rotary Air [ ] Rotary Mud [X] Cable [ ] Auger [ ] Cable Mud
[ ] Reverse Rotary [ ] Other

(4) PROPOSED USE

[ ] Domestic [ ] Irrigation [ ] Community
[ ] Industrial/ Commericial [ ] Livestock [ ] Dewatering
[ ] Thermal [ ] Injection [X] Other EXPLORITORY

(5) BORE HOLE CONSTRUCTION

Special Standard [ ] (Attach copy)
Depth of Completed Well 40.00 ft.

BORE HOLE Dia	From	To	SEAL Material	From	To	Amt	sacks/ lbs
12	0	40	Bentonite Chips	0	18	47	S
			Calculated			14	
			Calculated				

How was seal placed: Method [ ] A [ ] B [ ] C [ ] D [ ] E
[X] Other POURED DRY
Backfill placed from ____ ft. to ____ ft. Material ____
Filter pack from 18 ft. to 40 ft. Material SAND Size 6/9
Explosives used: [ ] Yes Type ____ Amount ____

(5a) ABANDONMENT USING UNHYDRATED BENTONITE

Proposed Amount Actual Amount

(6) CASING/LINER

Casing	Liner	Dia	+	From	To	Gauge	Stl	Plstc	Wld	Thrd
(●)	( )	6	[X]	2	40	.250	(●)	( )	[X]	[ ]
( )	( )		[ ]				( )	( )	[ ]	[ ]
( )	( )		[ ]				( )	( )	[ ]	[ ]
( )	( )		[ ]				( )	( )	[ ]	[ ]
( )	( )		[ ]				( )	( )	[ ]	[ ]

Shoe [ ] Inside [X] Outside [ ] Other Location of shoe(s)
Temp casing [X] Yes Dia 12 From + [X] 1 To 40

(7) PERFORATIONS/SCREENS

Perforations Method MACHINE
Screens Type ____ Material ____

Perf/ Screen	Casing/ Liner	Screen Dia	From	To	Scrn/slot width	Slot length	# of slots	Tele/ pipe size
Perf	Casing	6	20	40	.125	3	456	

(8) WELL TESTS: Minimum testing time is 1 hour

( ) Pump (●) Bailer ( ) Air ( ) Flowing Artesian

Yield gal/min	Drawdown	Drill stem/Pump depth	Duration (hr)
20	10		2

Temperature 54 °F Lab analysis [ ] Yes By ____
Water quality concerns? [ ] Yes (describe below) TDS amount 111 ppm

From	To	Description	Amount	Units

(9) LOCATION OF WELL (legal description)

County CROOK Twp 15.00 S N/S Range 16.00 E E/W WM
Sec 8 NW 1/4 of the NW 1/4 Tax Lot 201
Tax Map Number ____ Lot ____
Lat ____° ____' ____" or 44.28969444 DMS or DD
Long ____° ____' ____" or -120.84525000 DMS or DD
( ) Street address of well (●) Nearest address

WEST OF MAIN ST/CROOKED RIVER HWY \NCROOKED RIVER PARK (STW-3) S SIDE OF NW BASEBALL FIELD

(10) STATIC WATER LEVEL

	Date	SWL(psi)	+	SWL(ft)
Existing Well / Pre-Alteration			[ ]	
Completed Well	12/12/2017		[ ]	11

Flowing Artesian? [ ] Dry Hole? [ ]

WATER BEARING ZONES Depth water was first found 18.00

SWL Date	From	To	Est Flow	SWL(psi)	+	SWL(ft)
11/3/2017	18	25	20		[ ]	11
					[ ]	
					[ ]	
					[ ]	
					[ ]	

(11) WELL LOG

Ground Elevation 2868.00

Material	From	To
CLAY BROWN	0	12
GRAVELS LARGE	12	17
LARGE GRAVELS TIGHT	17	18.5
SAND GRAVELS GRAY	18.5	25
SILT SAND GRAY	25	40

Date Started 11/3/2017 Completed 12/12/2017

(unbonded) Water Well Constructor Certification

I certify that the work I performed on the construction, deepening, alteration, or abandonment of this well is in compliance with Oregon water supply well construction standards. Materials used and information reported above are true to the best of my knowledge and belief.

License Number 758 Date 2/16/2018

Signed THOMAS PECK (E-filed)

(bonded) Water Well Constructor Certification

I accept responsibility for the construction, deepening, alteration, or abandonment work performed on this well during the construction dates reported above. All work performed during this time is in compliance with Oregon water supply well construction standards. This report is true to the best of my knowledge and belief.

License Number 1720 Date 2/18/2018

Signed JACK ABBAS (E-filed)

Contact Info (optional) ____

WATER SUPPLY WELL REPORT - Map with location identified must be attached and shall include an approximate scale and north arrow

CROO 54591

2/18/2018

Map of Hole

STATE OF OREGON
WELL LOCATION MAP

This map is supplemental to the WATER SUPPLY WELL REPORT

Oregon Water Resources Department
725 Summer St NE, Salem OR 97301
(503)986-0900

LOCATION OF WELL

Latitude: 44.28969444 Datum: WGS84
Longitude: -120.84525
Township/Range/Section/Quarter-Quarter Section:
WM 6S 2W 34 NWNW
Address of Well:
WEST OF MAIN ST/CROOKED RIVER HWY
CROOKED RIVER PARK (STW-3) S SIDE OF NW BASEBALL FIELD

Well Label: 127080

Printed: February 17, 2018

DISCLAIMER: This map is intended to represent the approximate location the well. It is not intended to be construed as survey accurate in any manner.

Provided by well constructor

STATE OF OREGON
WATER SUPPLY WELL REPORT
(as required by ORS 537.765 & OAR 690-205-0210)

CROO 54593

2/19/2018

WELL I.D. LABEL# L 127082
START CARD # 1037843
ORIGINAL LOG #

(1) LAND OWNER

Owner Well I.D. DTW-1
First Name JIM Last Name NEWTON
Company CITY OF PRINEVILLE
Address 387 NE 3RD ST
City PRINEVILLE State OR Zip 97754

(2) TYPE OF WORK

[X] New Well [ ] Deepening [ ] Conversion
[ ] Alteration (complete 2a & 10) [ ] Abandonment(complete 5a)

(2a) PRE-ALTERATION

Casing: Dia + From To Gauge Stl Plstc Wld Thrd
Seal: Material From To Amt sacks/lbs

(3) DRILL METHOD

[ ] Rotary Air [ ] Rotary Mud [X] Cable [ ] Auger [ ] Cable Mud
[ ] Reverse Rotary [ ] Other

(4) PROPOSED USE

[ ] Domestic [ ] Irrigation [ ] Community
[ ] Industrial/ Commericial [ ] Livestock [ ] Dewatering
[ ] Thermal [ ] Injection [X] Other EXPLORITORY

(5) BORE HOLE CONSTRUCTION

Special Standard [ ] (Attach copy)
Depth of Completed Well 87.00 ft.

BORE HOLE Dia	From	To	SEAL Material	From	To	Amt	sacks/lbs
16	0	140	Bentonite Chips	0	4	7	S
			Calculated			6	
			Cement	4	50	70	S
			Calculated			31	

How was seal placed: Method [ ] A [ ] B [X] C [ ] D [ ] E
[X] Other POURED DRY
Backfill placed from 87 ft. to 140 ft. Material PEA GRAVEL
Filter pack from 50 ft. to 87 ft. Material SAND Size 6/9
Explosives used: [ ] Yes Type Amount

(5a) ABANDONMENT USING UNHYDRATED BENTONITE

Proposed Amount Actual Amount

(6) CASING/LINER

Casing	Liner	Dia	+	From	To	Gauge	Stl	Plstc	Wld	Thrd
(●)	( )	8	[X]	2	52	.250	(●)	( )	[X]	[ ]

Shoe [ ] Inside [X] Outside [ ] Other Location of shoe(s)
Temp casing [X] Yes Dia 16 From + [X] 1 To 73

(7) PERFORATIONS/SCREENS

Perforations Method
Screens Type JOHNSON Material STAINLESS

Perf/ Screen	Casing/ Liner	Screen Dia	From	To	Scrn/slot width	Slot length	# of slots	Tele/ pipe size
Screen	Casing	8	52	87	.01			

(8) WELL TESTS: Minimum testing time is 1 hour

(●) Pump ( ) Bailer ( ) Air ( ) Flowing Artesian

Yield gal/min	Drawdown	Drill stem/Pump depth	Duration (hr)
20	20		2
103	54	80	120

Temperature 54 °F Lab analysis [ ] Yes By
Water quality concerns? [ ] Yes (describe below) TDS amount 572 mg/L

From	To	Description	Amount	Units

(9) LOCATION OF WELL (legal description)

County CROOK Twp 15.00 S N/S Range 16.00 E E/W WM
Sec 8 NW 1/4 of the NW 1/4 Tax Lot 201
Tax Map Number Lot
Lat ° ' " or 44.28950000 DMS or DD
Long ° ' " or -120.84572222 DMS or DD
( ) Street address of well (●) Nearest address

WEST OF MAIN ST/CROOKED RIVER HWY
CROOKED RIVER PARK (DTW-1)

(10) STATIC WATER LEVEL

	Date	SWL(psi)	+	SWL(ft)
Existing Well / Pre-Alteration				
Completed Well	1/5/2018			4.5

Flowing Artesian? [ ] Dry Hole? [ ]

WATER BEARING ZONES Depth water was first found 14.00

SWL Date	From	To	Est Flow	SWL(psi)	+	SWL(ft)
10/3/2017	14	27	20			10
10/6/2017	42	58	20			4.5

(11) WELL LOG

Ground Elevation 2875.00

Material	From	To
TOP SOIL	0	1
CLAY BROWN	1	9
CLAY SAND	9	14
GRAVELS GRAY SILT COARS MEDIUM	14	27
CLAY SILT GRAVELS	27	38
SILT CLAY	38	42
GRAVELS SAND SILT	42	58
CLAY GRAY	58	88
CLAY GRAY ASH MIX	88	104
CLAY HARD GRAY	104	120
CLAY SOFT STICKY BROWN	120	140

Date Started 10/2/2017 Completed 1/5/2018

(unbonded) Water Well Constructor Certification

I certify that the work I performed on the construction, deepening, alteration, or abandonment of this well is in compliance with Oregon water supply well construction standards. Materials used and information reported above are true to the best of my knowledge and belief.

License Number 758 Date 2/16/2018

Signed THOMAS PECK (E-filed)

(bonded) Water Well Constructor Certification

I accept responsibility for the construction, deepening, alteration, or abandonment work performed on this well during the construction dates reported above. All work performed during this time is in compliance with Oregon water supply well construction standards. This report is true to the best of my knowledge and belief.

License Number 1720 Date 2/19/2018

Signed JACK ABBAS (E-filed)

Contact Info (optional)

WATER SUPPLY WELL REPORT - Map with location identified must be attached and shall include an approximate scale and north arrow

CROO 54593

2/19/2018

Map of Hole

STATE OF OREGON
WELL LOCATION MAP
This map is supplemental to the WATER SUPPLY WELL REPORT

Oregon Water Resources Department
725 Summer St NE, Salem OR 97301
(503)986-0900

LOCATION OF WELL
Latitude: 44.2895 Datum: WGS84
Longitude: -120.84572222
Township/Range/Section/Quarter-Quarter Section:
WM 6S 2W 34 NWNW
Address of Well:
WEST OF MAIN ST/CROOKED RIVER HWY
CROOKED RIVER HWY (DTW-1)

Well Label: 127082

Printed: February 18, 2018

DISCLAIMER: This map is intended to represent the approximate location the well. It is not intended to be construed as survey accurate in any manner.

Provided by well constructor

STATE OF OREGON
WATER SUPPLY WELL REPORT
(as required by ORS 537.765 & OAR 690-205-0210)

CROO 54592
2/18/2018

WELL I.D. LABEL# L 129186
START CARD # 1037840
ORIGINAL LOG #

(1) LAND OWNER

Owner Well I.D. DTW-2
First Name JIM Last Name NEWTON
Company CITY OF PRINEVILLE
Address 387 NE 3RD ST
City PRINEVILLE State OR Zip 97754

(2) TYPE OF WORK

[X] New Well [ ] Deepening [ ] Conversion
[ ] Alteration (complete 2a & 10) [ ] Abandonment(complete 5a)

(2a) PRE-ALTERATION

	Dia	+	From	To	Gauge	Stl	Plstc	Wld	Thrd
Casing:									

	Material	From	To	Amt	sacks/lbs
Seal:					

(3) DRILL METHOD

[ ] Rotary Air [ ] Rotary Mud [X] Cable [ ] Auger [ ] Cable Mud
[ ] Reverse Rotary [ ] Other

(4) PROPOSED USE

[ ] Domestic [ ] Irrigation [ ] Community
[ ] Industrial/ Commericial [ ] Livestock [ ] Dewatering
[ ] Thermal [ ] Injection [X] Other EXPLORITORY

(5) BORE HOLE CONSTRUCTION

Special Standard [ ] (Attach copy)
Depth of Completed Well 140.00 ft.

BORE HOLE

Dia	From	To
16	0	140

SEAL

Material	From	To	Amt	sacks/lbs
Bentonite Chips	0	7	14	S
		Calculated	10	
Cement	7	50	70	S
		Calculated	31	

How was seal placed: Method [ ] A [ ] B [X] C [ ] D [ ] E
[X] Other POURED DRY
Backfill placed from ft. to ft. Material
Filter pack from 50 ft. to 140 ft. Material SAND Size 50 MESH
Explosives used: [ ] Yes Type Amount

(5a) ABANDONMENT USING UNHYDRATED BENTONITE

Proposed Amount Actual Amount

(6) CASING/LINER

Casing	Liner	Dia	+	From	To	Gauge	Stl	Plstc	Wld	Thrd
(●)	( )	8	[X]	2	60	.250	(●)	( )	[X]	[ ]
( )	( )		[ ]				( )	( )	[ ]	[ ]
( )	( )		[ ]				( )	( )	[ ]	[ ]
( )	( )		[ ]				( )	( )	[ ]	[ ]
( )	( )		[ ]				( )	( )	[ ]	[ ]

Shoe [ ] Inside [X] Outside [ ] Other Location of shoe(s)
Temp casing [X] Yes Dia 16 From + [X] 1 To 140

(7) PERFORATIONS/SCREENS

Perforations Method
Screens Type JOHNSON Material STAINLESS

Perf/ Screen	Casing/ Screen Liner	Dia	From	To	Scrn/slot width	Slot length	# of slots	Tele/ pipe size
Screen	Casing	8	60	140	.008			

(8) WELL TESTS: Minimum testing time is 1 hour

( ) Pump (●) Bailer ( ) Air ( ) Flowing Artesian

Yield gal/min	Drawdown	Drill stem/Pump depth	Duration (hr)
20	25		2

Temperature 54 °F Lab analysis [ ] Yes By
Water quality concerns? [ ] Yes (describe below) TDS amount 118 ppm

From	To	Description	Amount	Units

(9) LOCATION OF WELL (legal description)

County CROOK Twp 15.00 S N/S Range 16.00 E E/W WM
Sec 8 NW 1/4 of the NW 1/4 Tax Lot 201
Tax Map Number Lot
Lat ° ' " or 44.28905556 DMS or DD
Long ° ' " or -120.84419444 DMS or DD
( ) Street address of well (●) Nearest address

WEST OF MAIN ST/CROOKED RIVER HWY
CROOKED RIVER PARK (DTW-2)

(10) STATIC WATER LEVEL

	Date	SWL(psi)	+	SWL(ft)
Existing Well / Pre-Alteration			[ ]	
Completed Well	1/17/2018		[ ]	4

Flowing Artesian? [ ] Dry Hole? [ ]

WATER BEARING ZONES Depth water was first found 13.00

SWL Date	From	To	Est Flow	SWL(psi)	+	SWL(ft)
11/7/2017	13	22	20		[ ]	10
11/8/2017	32	133	20		[ ]	4
					[ ]	
					[ ]	
					[ ]	

(11) WELL LOG

Ground Elevation 2876.00

Material	From	To
FILL	0	2
CLAY SILT BROWN	2	6
CLAY SILT GRAY	6	13
GRAVELS	13	16
GRAVELS TIGHT LARGE	16	23
SILT CLAY GRAY	23	32
SAND FINE GRAY HEAVING	32	56
SAND TIGHT LOOSE LAYERS	56	133
CLAY GRAY	133	140

Date Started 11/17/2017 Completed 1/17/2018

(unbonded) Water Well Constructor Certification

I certify that the work I performed on the construction, deepening, alteration, or abandonment of this well is in compliance with Oregon water supply well construction standards. Materials used and information reported above are true to the best of my knowledge and belief.

License Number 758 Date 2/18/2018

Signed THOMAS PECK (E-filed)

(bonded) Water Well Constructor Certification

I accept responsibility for the construction, deepening, alteration, or abandonment work performed on this well during the construction dates reported above. All work performed during this time is in compliance with Oregon water supply well construction standards. This report is true to the best of my knowledge and belief.

License Number 1720 Date 2/18/2018

Signed JACK ABBAS (E-filed)

Contact Info (optional)

WATER SUPPLY WELL REPORT - Map with location identified must be attached and shall include an approximate scale and north arrow

CROO 54592

2/18/2018

Map of Hole

STATE OF OREGON
WELL LOCATION MAP

This map is supplemental to the WATER SUPPLY WELL REPORT

Oregon Water Resources Department
725 Summer St NE, Salem OR 97301
(503)986-0900

LOCATION OF WELL

Latitude: 44.28905556 Datum: WGS84
Longitude: -120.84419444
Township/Range/Section/Quarter-Quarter Section:
WM 15S 16E 8 NWNW
Address of Well:
WEST OF MAIN ST/CROOKED RIVER HWY
CROOKED RIVER PARK (DTW-2)

Well Label: 129186

Printed: February 18, 2018

DISCLAIMER: This map is intended to represent the approximate location the well. It is not intended to be construed as survey accurate in any manner.

Provided by well constructor

STATE OF OREGON
WATER SUPPLY WELL REPORT
(as required by ORS 537.765 & OAR 690-205-0210)

CROO 54588
2/16/2018

WELL I.D. LABEL# L 129187
START CARD # 1037839
ORIGINAL LOG #

(1) LAND OWNER

Owner Well I.D. DTW-3
First Name JIM Last Name NEWTON
Company CITY OF PRINEVILLE
Address 387 NE 3RD ST
City PRINEVILLE State OR Zip 97754

(2) TYPE OF WORK

[X] New Well [ ] Deepening [ ] Conversion
[ ] Alteration (complete 2a & 10) [ ] Abandonment(complete 5a)

(2a) PRE-ALTERATION

Casing: Dia | + | From | To | Gauge | Stl | Plstc | Wld | Thrd

Seal: Material | From | To | Amt | sacks/lbs

(3) DRILL METHOD

[ ] Rotary Air [ ] Rotary Mud [X] Cable [ ] Auger [ ] Cable Mud
[ ] Reverse Rotary [ ] Other

(4) PROPOSED USE

[ ] Domestic [ ] Irrigation [ ] Community
[ ] Industrial/ Commericial [ ] Livestock [ ] Dewatering
[ ] Thermal [ ] Injection [X] Other EXPLORITORY

(5) BORE HOLE CONSTRUCTION

Special Standard [ ] (Attach copy)
Depth of Completed Well 140.00 ft.

BORE HOLE

Dia	From	To
16	0	140

SEAL

Material	From	To	Amt	sacks/lbs
Bentonite Chips	0	7	28	S
		Calculated	10	
Cement	7	70	70	S
		Calculated	39	

How was seal placed: Method [ ] A [ ] B [X] C [ ] D [ ] E
[X] Other POURED DRY
Backfill placed from ___ ft. to ___ ft. Material
Filter pack from 70 ft. to 140 ft. Material PEA GRAVE Size pea gravel
Explosives used: [ ] Yes Type ___ Amount ___

(5a) ABANDONMENT USING UNHYDRATED BENTONITE

Proposed Amount Actual Amount

(6) CASING/LINER

Casing	Liner	Dia	+	From	To	Gauge	Stl	Plstc	Wld	Thrd
(•)	( )	8	[X]	2	140	.250	(•)	( )	[X]	[ ]

Shoe [ ] Inside [X] Outside [ ] Other Location of shoe(s)
Temp casing [X] Yes Dia 16 From + [X] 1 To 140

(7) PERFORATIONS/SCREENS

Perforations Method MACHINE
Screens Type ___ Material ___

Perf/ Screen	Casing/ Liner	Screen Dia	From	To	Scrn/slot width	Slot length	# of slots	Tele/ pipe size
Perf	Casing	8	80	140	.125	3	1824	

(8) WELL TESTS: Minimum testing time is 1 hour

( ) Pump (•) Bailer ( ) Air ( ) Flowing Artesian

Yield gal/min	Drawdown	Drill stem/Pump depth	Duration (hr)
30	10		2

Temperature 54 °F Lab analysis [ ] Yes By
Water quality concerns? [ ] Yes (describe below) TDS amount 120 ppm

From	To	Description	Amount	Units

(9) LOCATION OF WELL (legal description)

County CROOK Twp 15.00 S N/S Range 16.00 E E/W WM
Sec 8 NW 1/4 of the NW 1/4 Tax Lot 203
Tax Map Number ___ Lot ___
Lat ___°___'___" or 44.28961111 DMS or DD
Long ___°___'___" or -120.84225000 DMS or DD
( ) Street address of well (•) Nearest address

EAST OF MAIN ST/CRROKED RIVER HWY \NCROOKED RIVER PARK (DTW-3)

(10) STATIC WATER LEVEL

	Date	SWL(psi)	+	SWL(ft)
Existing Well / Pre-Alteration				
Completed Well	2/6/2018			4

Flowing Artesian? [ ] Dry Hole? [ ]

WATER BEARING ZONES Depth water was first found 10.00

SWL Date	From	To	Est Flow	SWL(psi)	+	SWL(ft)
1/19/2018	10	25	20			10
1/24/2018	70	112	20			4

(11) WELL LOG

Ground Elevation 2876.00

Material	From	To
CLAY SAND SILT	0	9
GRAVELS LARGE	9	25
SILT GRAY CLAY	25	70
SAND GRAY	70	112
SILTY GRAY SAND	112	140

Date Started 1/19/2018 Completed 2/6/2018

(unbonded) Water Well Constructor Certification

I certify that the work I performed on the construction, deepening, alteration, or abandonment of this well is in compliance with Oregon water supply well construction standards. Materials used and information reported above are true to the best of my knowledge and belief.

License Number ___ Date ___

Signed ___

(bonded) Water Well Constructor Certification

I accept responsibility for the construction, deepening, alteration, or abandonment work performed on this well during the construction dates reported above. All work performed during this time is in compliance with Oregon water supply well construction standards. This report is true to the best of my knowledge and belief.

License Number 1720 Date 2/16/2018

Signed JACK ABBAS (E-filed)

Contact Info (optional)

WATER SUPPLY WELL REPORT - Map with location identified must be attached and shall include an approximate scale and north arrow

CROO 54588

2/16/2018

Map of Hole

STATE OF OREGON
WELL LOCATION MAP
This map is supplemental to the WATER SUPPLY WELL REPORT

Oregon Water Resources Department
725 Summer St NE, Salem OR 97301
(503)986-0900

LOCATION OF WELL
Latitude: 44.28961111 Datum: WGS84
Longitude: -120.84225
Township/Range/Section/Quarter-Quarter Section:
WM 15S 16E 8 NWNW
Address of Well:
EAST OF MAIN ST/CRROKED RIVER HWY
CROOKED RIVER PARK (DTW-3)

Well Label: 129187

Printed: February 16, 2018

DISCLAIMER: This map is intended to represent the approximate location the well. It is not intended to be construed as survey accurate in any manner.

Provided by well constructor

APPENDIX B

CGE Detailed Well Boring Logs

CASCADE GEOENGINEERING
360.907.4162 cascadegeoengineering.com

PROJECT NUMBER	EXCAVATION DATE	TRENCH No.
CG1002-104	11/3/2017	ST-1

EXPLORATORY BORING LOG

SHEET 1 OF 1

PROJECT Prineville ASR Project LOCATION Crooked Rvr Fork, Prineville OR

ELEVATION 2870 Ft MSL TRENCHING CONTRACTOR Abbas Well & Drilling

TRENCHING METHOD AND EQUIPMENT Cable Tool Drilling - 12" Nominal

WATER LEVEL 4' bgs (Croo_54587) GEOLOGIST J. Newton

SAMPLE: INTERVAL DEPTH IN FEET	SAMPLE: NUMBER AND TYPE	USCS CLASSIFICATION SYMBOL	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS
0–9		OB		
9	ST1-1 (9')	SW-GW	Very dark brown silty-sand loam with fine gravels	First Water ~ 9' bgs
12	ST1-2(12')		Very dark greenish brown sand & gravel, well graded from fine sand to very coarse gravel of sub-round to smooth gravel up to ~ 80%	
15	ST1-3(15')		~70% gravels med-coarse & very coarse, ~30% med-coarse sands, gravels (30-40%) and cobbles of basalt, (~20%) with sands of basalt, hematite feldspar, quartz & misc.	
16	ST1-4(16')			
16.2	ST1-5(16'2)			
17	ST1-6(17')		Increase in sand to ~50%	
20				SWL 10/26 8'bgs
21	ST1-7(21')			
25–26	ST1-8 (25'-26')		Very fine to fine grained black sand with trace very coarse sands of rounded oblong basalt and silt - sand primarily block basalt (~90%)	
30	ST1-9(30')		Fine to medium gravels trace; rounded-oblong or flattened.	
32	ST1-10(32')		Very fine black sand free draining and un-lithified	
34	ST1-11(34')	SM-SW	90+% basalt with ash sands, very fine black sand with silt (~10-20% silt), rolls mildly to 1/8"; breaks and won't fold.	
38.5	ST1-12 (38.5') TD~38.5'	ML-CL	Very fine black sandy silt with trace clay, bit face sample was tight, had minor cohesion and relatively dry (humid).	Boring Completed 10/26/2017

SAMPLE TYPES: SPT = Standard Penetrometer Test Sample ___________" Dia.
B = Bag Sample ST = Shelby tube Sample SS = Split Spoon Sample SK = Sack Sample

NOTE: THE LOG OF SUBSURFACE CONDITIONS SHOWN HEREON APPLIES ONLY AT THE SPECIFIC BORING OR TRENCH LOCATION AND AT THE DATE INDICATED. IT IS NOT WARRANTED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND TIMES.

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PROJECT NUMBER	EXCAVATION DATE	TRENCH No.
CG1002-104	11/3/2017	ST-2

EXPLORATORY BORING LOG

SHEET 1 OF 1

PROJECT Prineville ASR Project LOCATION Crooked Rvr Fork, Prineville OR

ELEVATION 2870 Ft MSL TRENCHING CONTRACTOR Abbas Well & Drilling

TRENCHING METHOD AND EQUIPMENT Cable Tool Drilling - 12" Nominal

WATER LEVEL 8' bgs (Croo_54589) GEOLOGIST J. Newton

SAMPLE: INTERVAL DEPTH IN FEET	SAMPLE: NUMBER AND TYPE	USCS CLASSIFICATION SYMBOL	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS
0			Medium dark brown sand loam	
5		OB		
10	ST2-1 (9'-12')		Fine to medium grained medium brown in to sand and gravel, gravels are sub-round to sub-angular ~50/50, 90%) basalt and mixed mineralogy of ~10% feldspar and hematite.	15' @ 10/31 Startup SWL ~9' bgs
	ST2-2 (12'-15')		Color changes to medium gray with trace permice (?)	
15	ST2-3(16')	SW-GW		
20	ST2-4(19')		Sands and fine gravels intervals, includes trace white series sub-rounded, cobbles to ~120mm	SWL 11/1 12'bgs
	ST2-5(22')		Sands, fine-coarse ~8%, fine to medium gravels ~20%	
25			Fine sands	
		SW		
30	ST2-6(29')		Fine-coarse sands with fine-medium gravels	
	ST2-7(32')	SM-SW	Very fine black sand with silt	
35	ST2-8 (35'-36')	GW-SW	Very fine-medium sand with fine-medium sub-round oblong and flattened gravels (gravels ~40%)	
40	ST2-9 (39'-40') TD~40'		Very fine black silty-sand / sandy-silt with clay trace.	
		ML-CL		
45				
50				

SAMPLE TYPES: SPT = Standard Penetrometer Test Sample ___________" Dia.
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CASCADE GEOENGINEERING 360.907.4162 cascadegeoengineering.com	PROJECT NUMBER CG1002-104	EXCAVATION DATE 11/3/2017	TRENCH No. ST-3
	EXPLORATORY BORING LOG		SHEET 1 OF 1

PROJECT Prineville ASR Project LOCATION Crooked Rvr Fork, Prineville OR

ELEVATION 2870 Ft MSL TRENCHING CONTRACTOR Abbas Well & Drilling

TRENCHING METHOD AND EQUIPMENT Cable Tool Drilling - 12" Nominal

WATER LEVEL 11' bgs (Croo_54591) GEOLOGIST J. Newton

SAMPLE: INTERVAL DEPTH IN FEET	SAMPLE: NUMBER AND TYPE	USCS CLASSIFICATION SYMBOL	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS
0		OB		
5				
	ST3-1 (8')			
10				SWL 11'bgs
	ST3-2 (12'-15')	GW-SW	Fine to medium coarse sand and gravel, sands are mixed mineralogy of ~40% basalt, trace hematite. gravels are ~30% basalt; sub-round to oblong and flattened and sub-angular to smooth.	
15				
	ST3-3(16')		Cobbles included up to ~80mm sub-round and sub-smooth, cobbles ~10%	
	ST3-4(19')			
20				
	ST3-5(22')		Less gravels (~10-20%)	
	ST3-6(24')		Trace silt	
25				
	ST3-7(24')		No silt	
30			Very fine black sand with silt	
	ST3-8 (31.5')			
35		SM-SW		
	ST3-9(36')		Very fine silty-sand (black-very dark brown)	
	ST3-10 (40') TD~40' 11/6/2017		Very fine silty black sand with trace clay (clay provides very minimal cohesion to create saturated clods/clumps of materials retrieved from bailer	
40		ML-CL		
45				
50				

SAMPLE TYPES: SPT = Standard Penetrometer Test Sample ___________" Dia.
B = Bag Sample ST = Shelby tube Sample SS = Split Spoon Sample SK = Sack Sample

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PROJECT NUMBER	EXCAVATION DATE	TRENCH No.
CG1004-104	10/9/2017 - 10/23/2017	DT-1

EXPLORATORY BORING LOG

SHEET 1 OF 3

PROJECT Prineville ASR Project LOCATION Crooked Rvr Fork, Prineville OR
ELEVATION 2870 Ft MSL TRENCHING CONTRACTOR Abbas Well & Drilling
TRENCHING METHOD AND EQUIPMENT Cable Tool Drilling
WATER LEVEL First Water ~16' bgs GEOLOGIST J. Newton

SAMPLE: INTERVAL DEPTH IN FEET	SAMPLE: NUMBER AND TYPE	USCS CLASSIFICATION SYMBOL	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS
0–14	DT-1-1 0-5' Bag	OB	Grass Field Adjacent to Crooked River; Silt-Sand Loam, OMC, dk brown w/trace fine rooting below grass	
14–18	DT-1-2 14'-15'; DT-1-3 16'-18'	SW-GW	Med-coarse grained gravels with silty sand of v.fine sand, basalt sub-rounded - sub-spherical gravels	1st Ground Water 16'
18–21		SW-GW	Fine-med grained gravels with fine sand	DT-1-4 & previous samples were collected w/trip rampler; for DT-1-4 switched sand pump (plunger bailer style) & got good representative samples (with larger gravels)
21–24	DT-1-4 21'; DT-1-5 22'	SW-GW	Increased gravels to primarily 90% graves 15mm to 30mm in size of sub-round smooth gravels	Stiffer drilling & slower penetration rate
24–28	DT-1-6 24'; DT-1-7 25'-26'; DT-1-8 27'	SW-GW	Large gravels with fine to medium sub-round to elongated rock up to 50mm to 300mm (large gravels up to 50%, fine-med gravels ~50%)	DT-1-6 collected at bottom of 24' hole
28–38	DT-1-9 30'-33'; DT-1-10 34'-36'	SM-GW	Sample includes dark gray silty clay low to moderate plasticity w/v.fine to coarse gravels (gravels v.fine-med & coarse even split of ~50% of material, silty clays ~50% of materials); gravels are primarily basalt round to sub-spherical & oblong	
38–40	DT-1-11 38'-40'	SM-SW	Silty sand w/clay, v.fine-fine black sand w/v.dk grey clay-silt ~90% sand, 5% silt, 5% clay. Sand composed of black basalt (50%), hematite trace, feldspars (5%), misc.	(sample came from directly from bit face)
40–43	DT-1-12 41'	ML-CL	Silty sand v.dk. Gray low plastic clay	(sample from bit face & bailer material added to bag)
43–44	DT-1-13 43'	ML-CL	---samples included v.fine grained sub-angular gravels with clay	
44–45	DT-1-14 44'	SW	Dk grey-black v.fine-fine grained sand w/trace silt	(bailer sample)
45–50	DT-1-15 45'; DT-1-16 46'; DT-1-17 47'; DT-1-18 49'-50'	SW-GW	Compacted gravels w/sand	10/12 9:50 a.m. SWL prior to drilling 8'3" bgs

SAMPLE TYPES: SPT = Standard Penetrometer Test Sample ___________" Dia.
B = Bag Sample ST = Shelby tube Sample SS = Split Spoon Sample SK = Sack Sample

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PROJECT NUMBER: CG1004-104

EXCAVATION DATE: 10/9/2017 - 10/23/2017

TRENCH No. DT-1

EXPLORATORY BORING LOG

SHEET 2 OF 3

PROJECT: Prineville ASR Project
LOCATION: Crooked Rvr Fork, Prineville OR
ELEVATION: 2870 Ft MSL
TRENCHING CONTRACTOR: Abbas Well & Drilling
TRENCHING METHOD AND EQUIPMENT: Cable Tool Drilling
WATER LEVEL: First Water ~16' bgs
GEOLOGIST: J. Newton

SAMPLE: INTERVAL DEPTH IN FEET	SAMPLE: NUMBER AND TYPE	USCS CLASSIFICATION SYMBOL	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS
50–58	DT-1-19 52'-53'	SW-GW	Compacted gravels w/sand continued.	10/16 SWL 11' bgs
58–70	DT-1-20 58'; DT-1-21 59'-60'; DT-1-22 62'	SW-CL	Dark green silty plastic clay w/fine-med. Gravels & v. coarse sands (clays ~60%, sands & gravels ~40%; sands & gravels of angular to sub-angular)	10/17 SWL 12' bgs
70–74	DT-1-23 71'-74'	SW-GW	Fine sands - v. fine gravels in silty clay; med bluish green plastic clay; gravels are angular to sub-round of quartzite, basalt & mixed mineralogy	
74–77	DT-1-24 75'	SW-GW	---increase in fine gravels to ~40% sands-gravels	
77–79	DT-1-25 77'-79'	SW-GW	---reduced coarse sands & fine gravels ~20%-30% sands & gravels	
79–100	DT-1-26 82'-85'	ML-CL	Rock found in bailer head of pastel green silty claystone with trace coarse sands	85'; 10/18 SWL 13'2" bgs; 94'; 10/19 SWL 13' bgs

Depth scale (feet): 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 100

SAMPLE TYPES: SPT = Standard Penetrometer Test Sample ___________" Dia.
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PROJECT NUMBER	EXCAVATION DATE	TRENCH No.
CG1004-104	10/9/2017 - 10/23/2017	DT-1

EXPLORATORY BORING LOG

SHEET 3 OF 3

PROJECT Prineville ASR Project LOCATION Crooked Rvr Fork, Prineville OR

ELEVATION 2870 Ft MSL TRENCHING CONTRACTOR Abbas Well & Drilling

TRENCHING METHOD AND EQUIPMENT Cable Tool Drilling

WATER LEVEL First Water ~16' bgs GEOLOGIST J. Newton

SAMPLE: INTERVAL DEPTH IN FEET	SAMPLE: NUMBER AND TYPE	USCS CLASSIFICATION SYMBOL	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS
100		ML-CL	Rock found in bailer head of pastel green silty claystone with trace coarse sands continued.	
102–118	DT-1-27 104'; DT-1-28 110'; DT-1-29 113'	ML-CL	Pastel green silty/claystone w/black ash, sticky	107'; SWL 13' bgs 10/20; Sample from drill bit head
~117–119		ML-CL	Pastel green silty clay/claystone w/lt.-yellowish brown silty clay & trace of v.fine gravels /v.couarse sands of basalt grains	
119–125	DT-1-30 119'; DT-1-31 120'; DT-1-32 122'; DT-1-33 124'	ML-CL	---slight increase in v.coarse sands up to ~5%-8% basalt sands; clay is lt-yellowish greenish-lt. brown; ---trace of med. Gravels in silty-claystone	124'; Monday morning 10/23 SWL 8' bgs
125–140	DT-1-34 127'; DT-1-35 128'; DT-1-36 TD~140'	ML-CL	Lt-yellowish brown silty clay/claystone with gravels; clay is sticky, v.coarse sands - v.fine gravels ~5%	
145				
150				

SAMPLE TYPES: SPT = Standard Penetrometer Test Sample ___________" Dia.
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PROJECT NUMBER	EXCAVATION DATE	TRENCH No.
CG1002-104	11/17/2017	DT-2

EXPLORATORY BORING LOG

SHEET 1 OF 3

PROJECT Prineville ASR Project LOCATION Crooked Rvr Fork, Prineville OR

ELEVATION 2872 Ft MSL TRENCHING CONTRACTOR Abbas Well & Drilling

TRENCHING METHOD AND EQUIPMENT Cable Tool Drilling

WATER LEVEL 4' bgs (Croo_54592) GEOLOGIST J. Newton

SAMPLE: INTERVAL DEPTH IN FEET	SAMPLE: NUMBER AND TYPE	USCS CLASSIFICATION SYMBOL	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS
0–12		OB		
12		SW-GW	Loose sand and gravels, fine ~ very coarse sands with gravels with mixed mineralogy of sub-round smooth gravels. (basalt~40%, hematite trace, feldspar, quartzite trace)	SWL 11/13 11' bgs (Sampled with trip sampler, no coarse materials)
16			Tight sands and gravels	
18	DT-2-2 (18')			
30	DT-2-3 (30')		Very fine silty - black-brown/green sand with trace of clay, sand appears to be fine dark green-black basalt grains.	
32–36	DT-2-4 (32'-36')			
35–50		SM-SW		
40	DT-2-5 (40')		Very fine black sand; mineralogy appears ~90% basalt olivine grains with trace cinder/hermitite, feldspar, quartz/quartzite.	
45	DT-2-6 (45')			
49–50	DT-2-7 (49'-50')		Bailer pulled up lightly, littlefield sandstone of same makeup sand encountered.	

SAMPLE TYPES: SPT = Standard Penetrometer Test Sample ___________" Dia.
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PROJECT NUMBER	EXCAVATION DATE	TRENCH No.
CG1002-104	11/17/2017	DT-2

EXPLORATORY BORING LOG

SHEET 2 OF 3

PROJECT: Prineville ASR Project
LOCATION: Crooked Rvr Fork, Prineville OR
ELEVATION: 2872 Ft MSL
TRENCHING CONTRACTOR: Abbas Well & Drilling
TRENCHING METHOD AND EQUIPMENT: Cable Tool Drilling
WATER LEVEL: 4' bgs (Croo_54592)
GEOLOGIST: J. Newton

SAMPLE: INTERVAL DEPTH IN FEET	SAMPLE: NUMBER AND TYPE	USCS CLASSIFICATION SYMBOL	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS
50	DT-2-8 (51') 2 bgs	SM-SW		
55	DT-2-9 (56')		Very dark brown-black with fine silty-sand with possible trace clay and minor cohesive (clods)	
60				
65	DT-2-10 (64')			
70				
75				
80				
85	DT-2-11 (85')			
90				
95	DT-2-12 (95')			
100				

SAMPLE TYPES: SPT = Standard Penetrometer Test Sample ___________" Dia.
B = Bag Sample ST = Shelby tube Sample SS = Split Spoon Sample SK = Sack Sample

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PROJECT NUMBER	EXCAVATION DATE	TRENCH No.
CG1002-104	11/17/2017	DT-2

EXPLORATORY BORING LOG

SHEET 3 OF 3

PROJECT Prineville ASR Project LOCATION Crooked Rvr Fork, Prineville OR

ELEVATION 2872 Ft MSL TRENCHING CONTRACTOR Abbas Well & Drilling

TRENCHING METHOD AND EQUIPMENT Cable Tool Drilling

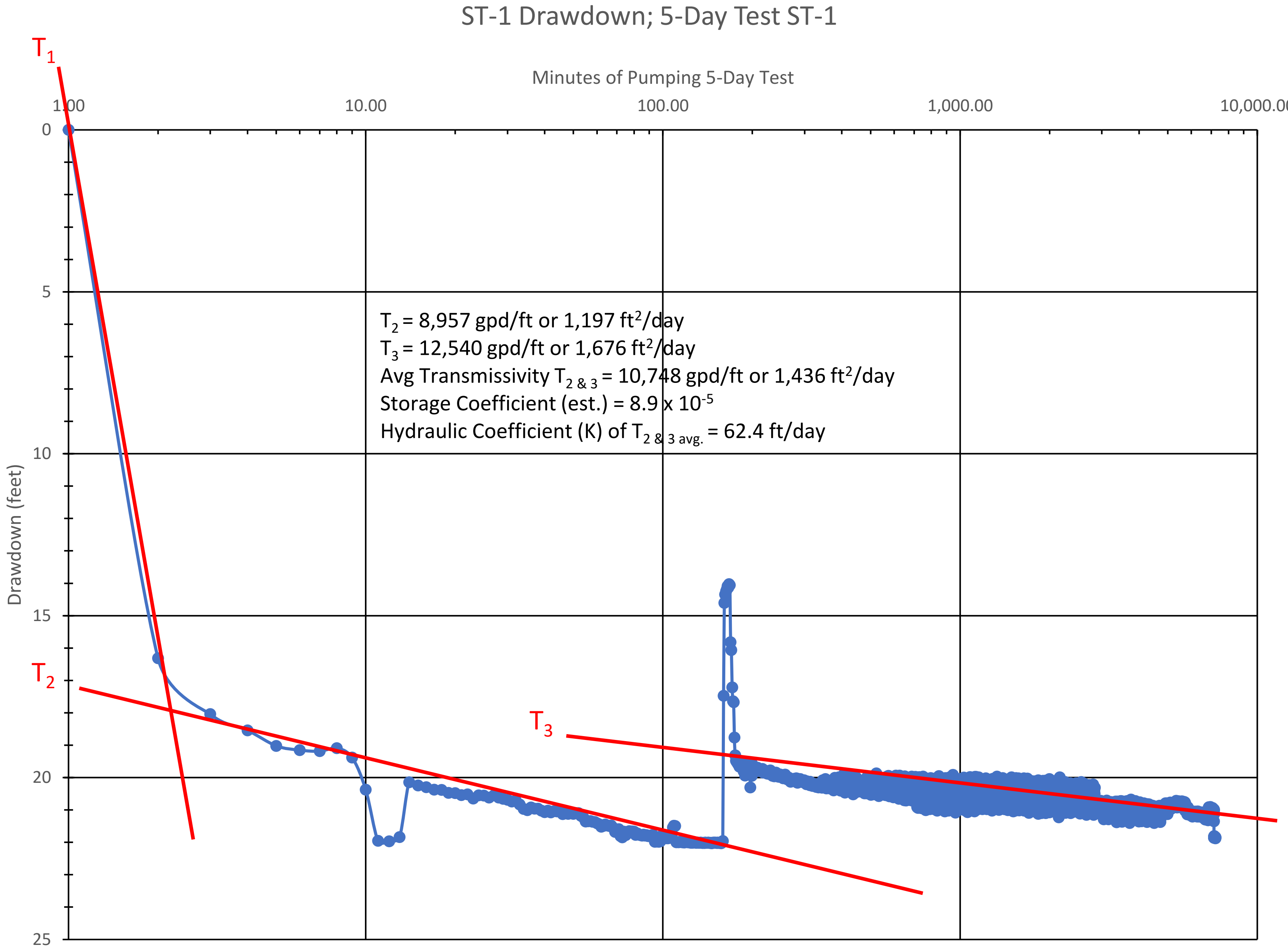
WATER LEVEL 4' bgs (Croo_54592) GEOLOGIST J. Newton

SAMPLE: INTERVAL DEPTH IN FEET	SAMPLE: NUMBER AND TYPE	USCS CLASSIFICATION SYMBOL	SOIL DESCRIPTION: SOIL NAME, COLOR, MOISTURE CONTENT, RELATIVE DENSITY OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY	COMMENTS
100	DT-2-13 (105')			
105				
110		SM-SW		
115	DT-2-14 (115')		Very fine dark with brownish (silt) black silty sand (black, very fine)	Noticeable sulfur (rotten egg) smell when sand pump discharges to catchment. Silts and sand settle quickly.
120				
125				
130				
135				
140				
145				
150				

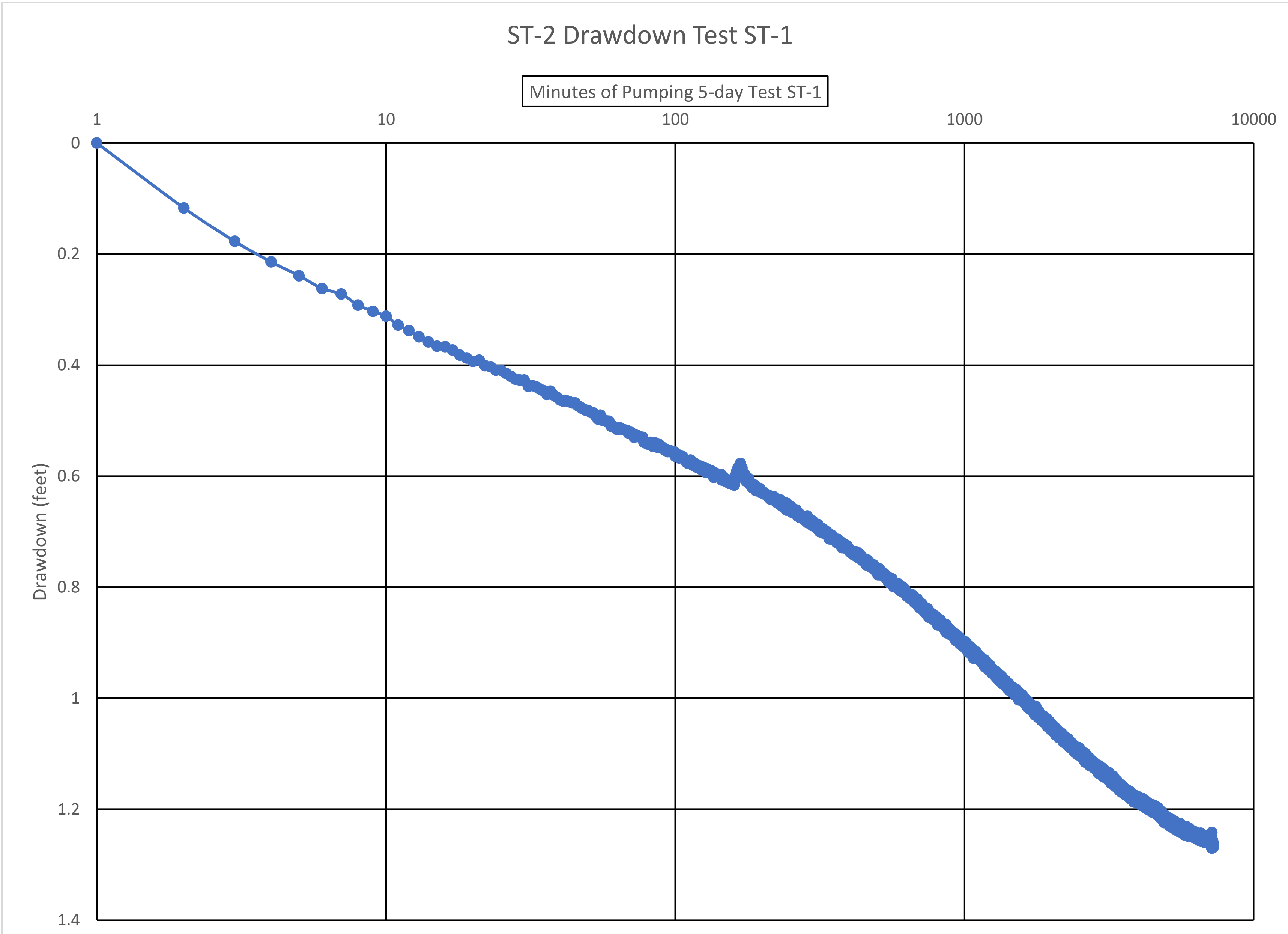
SAMPLE TYPES: SPT = Standard Penetrometer Test Sample ___________" Dia.
B = Bag Sample ST = Shelby tube Sample SS = Split Spoon Sample SK = Sack Sample

APPENDIX C

WELL TEST GRAPHS



CASCADE GEOENGINEERING



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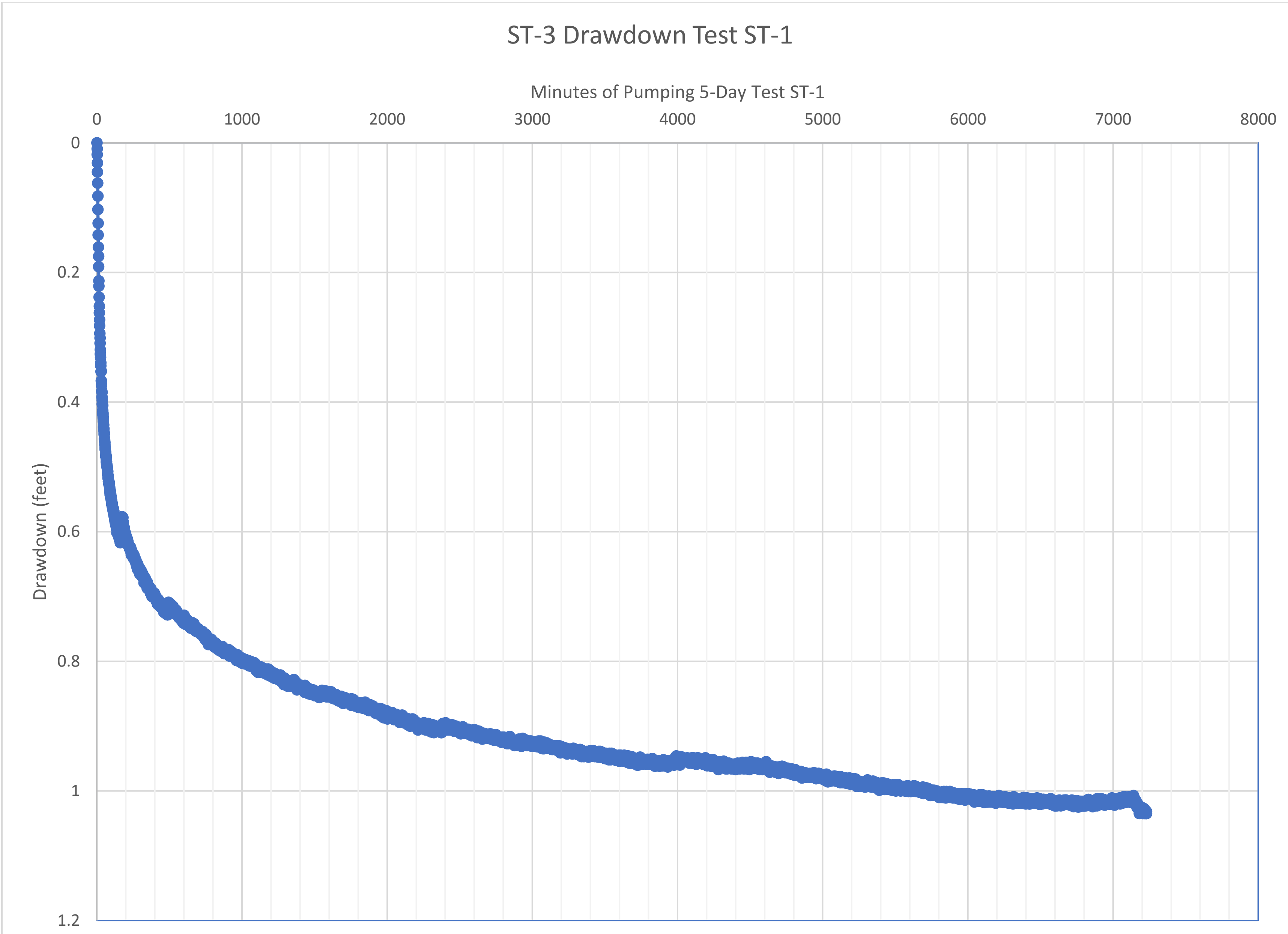

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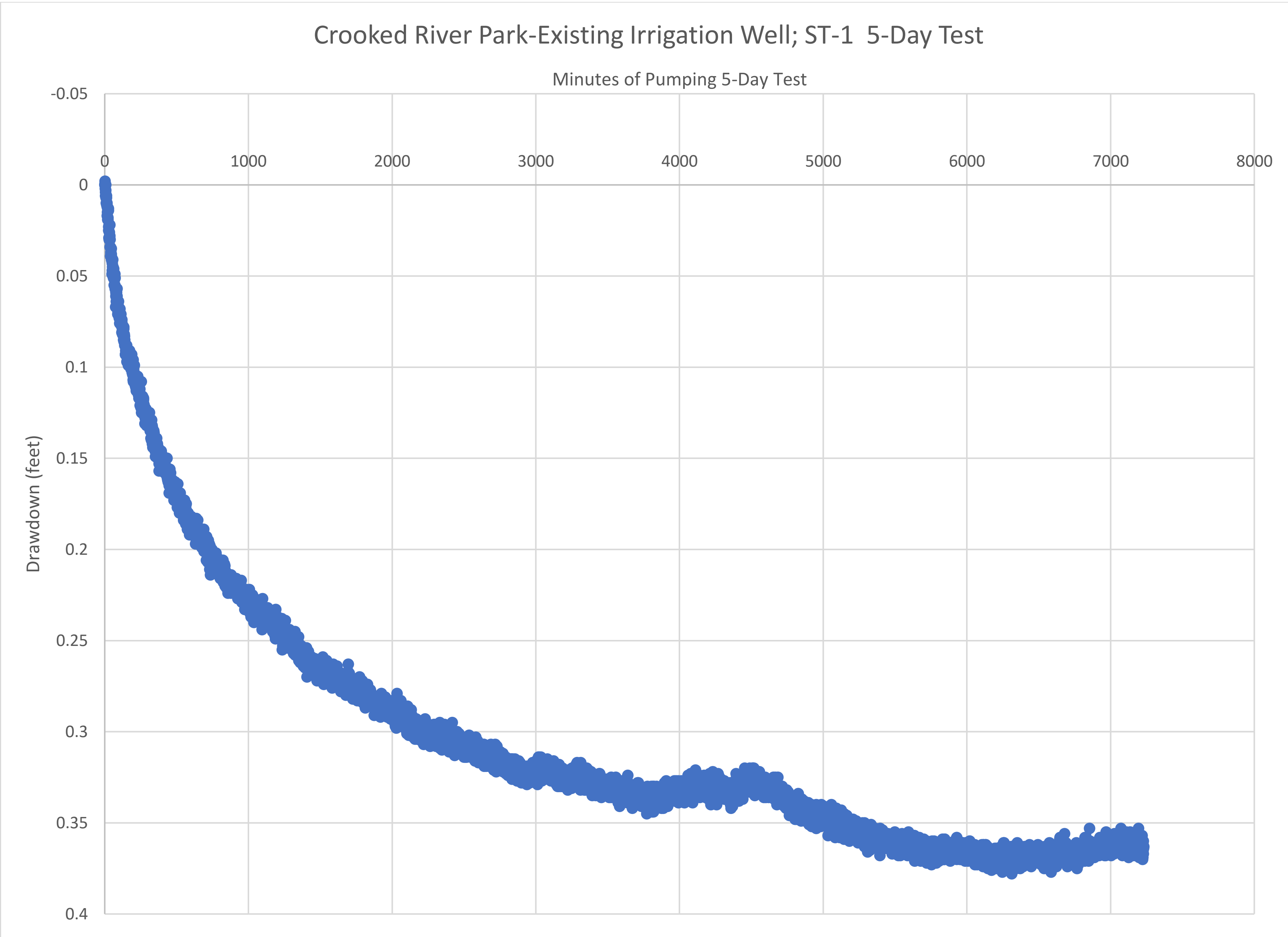

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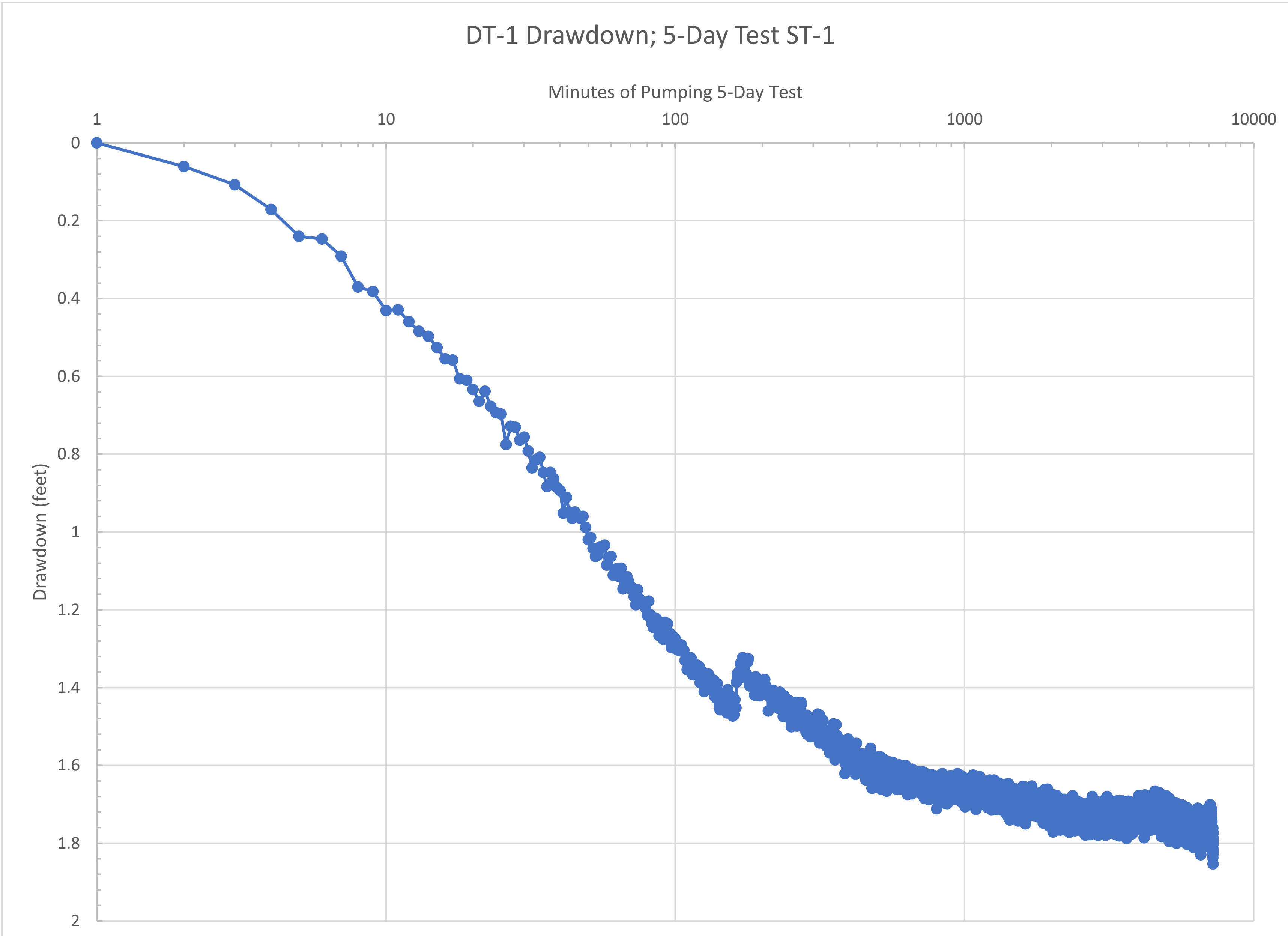
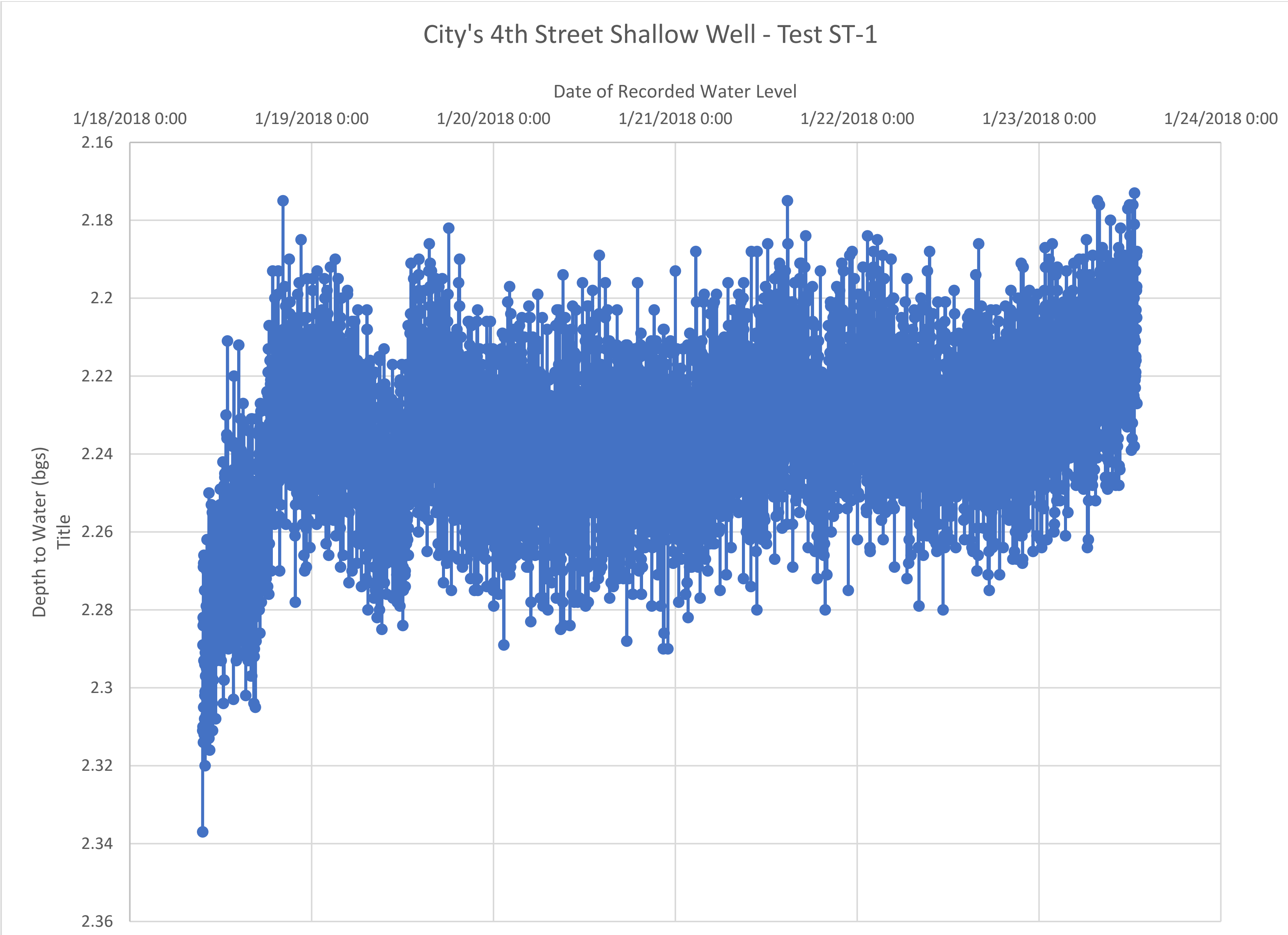

DT-1 Drawdown; 5-Day Test ST-1
Minutes of Pumping 5-Day Test
1
10
100
1000
10000
Drawdown (feet)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2



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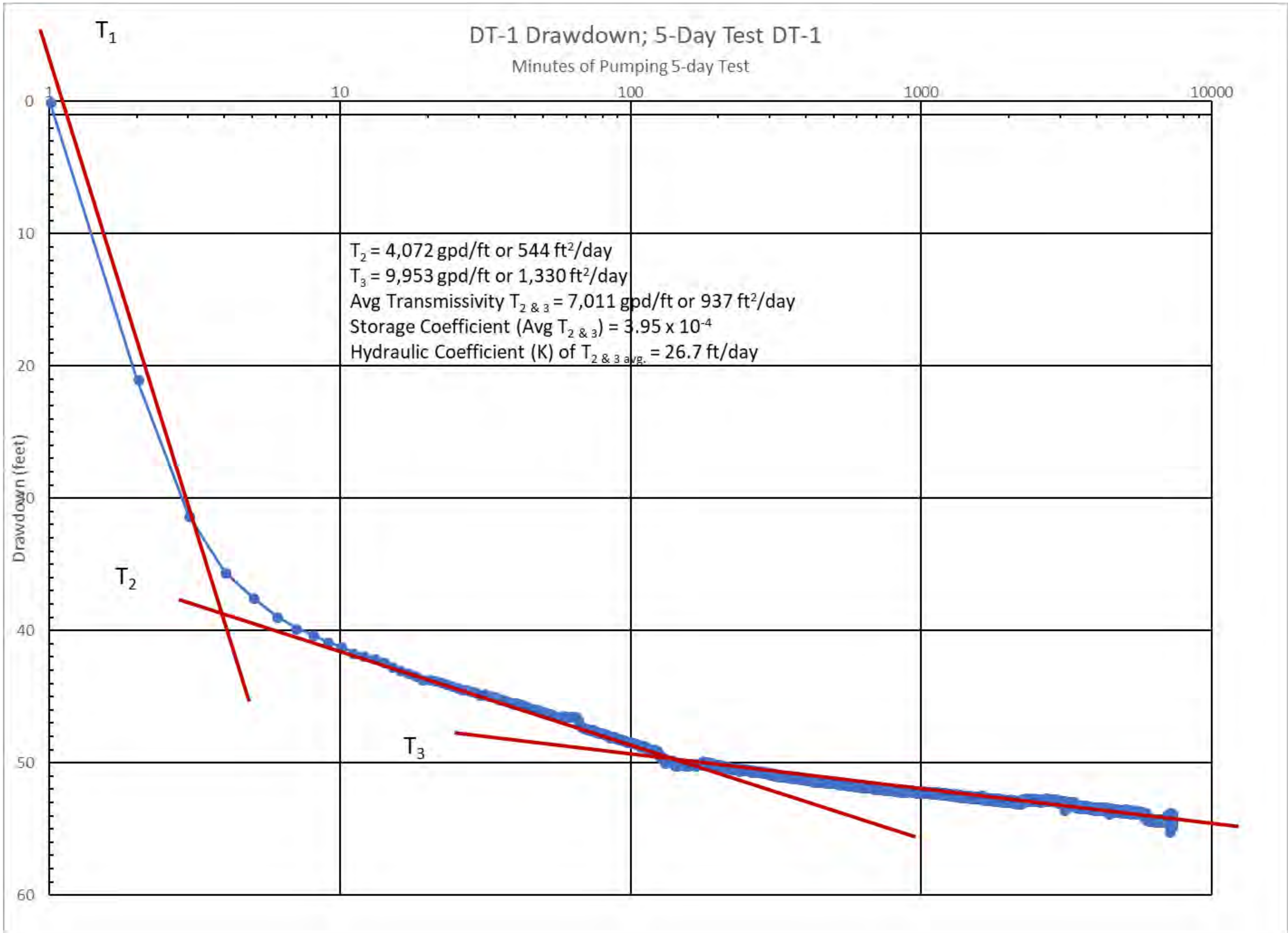

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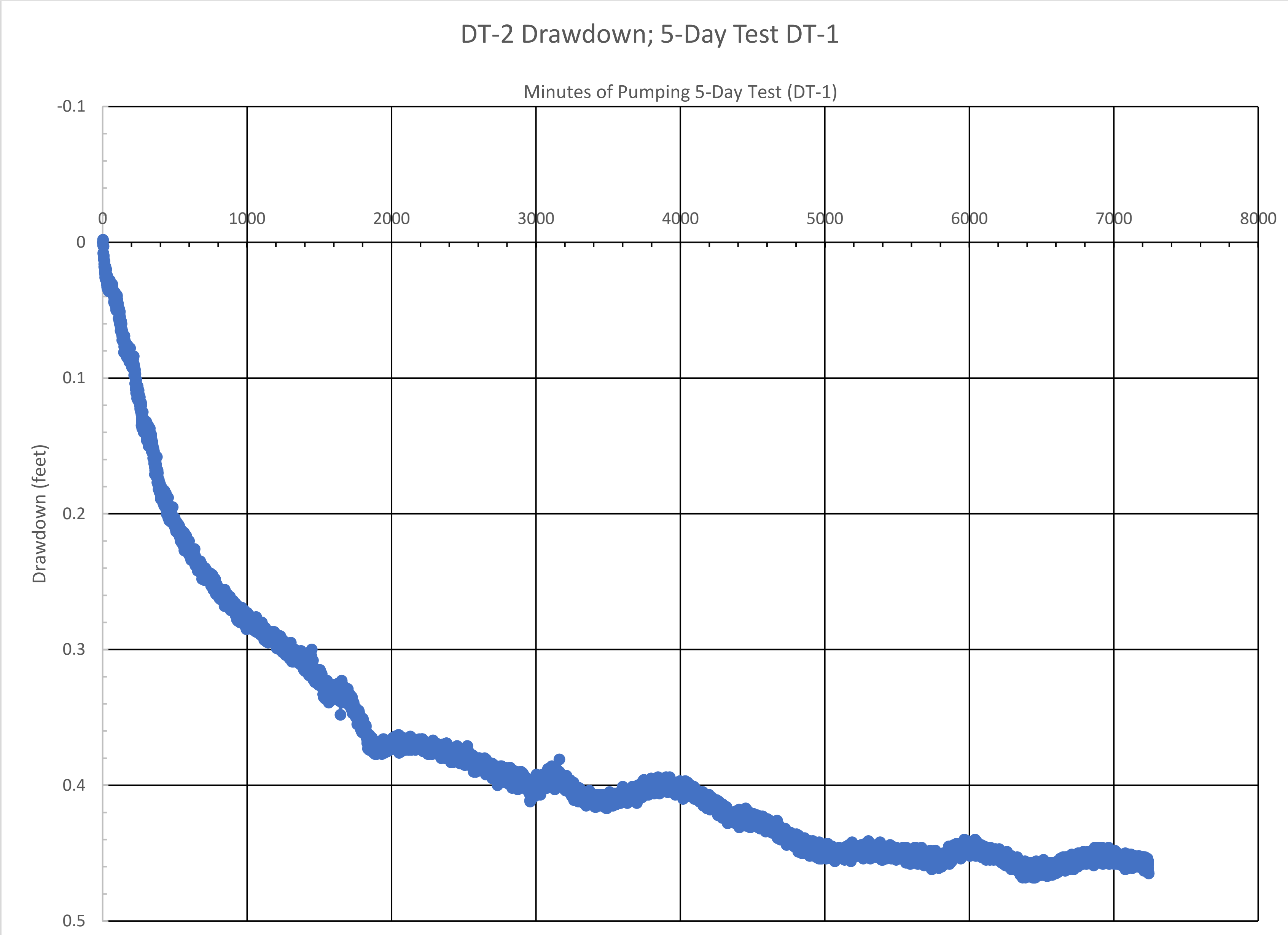

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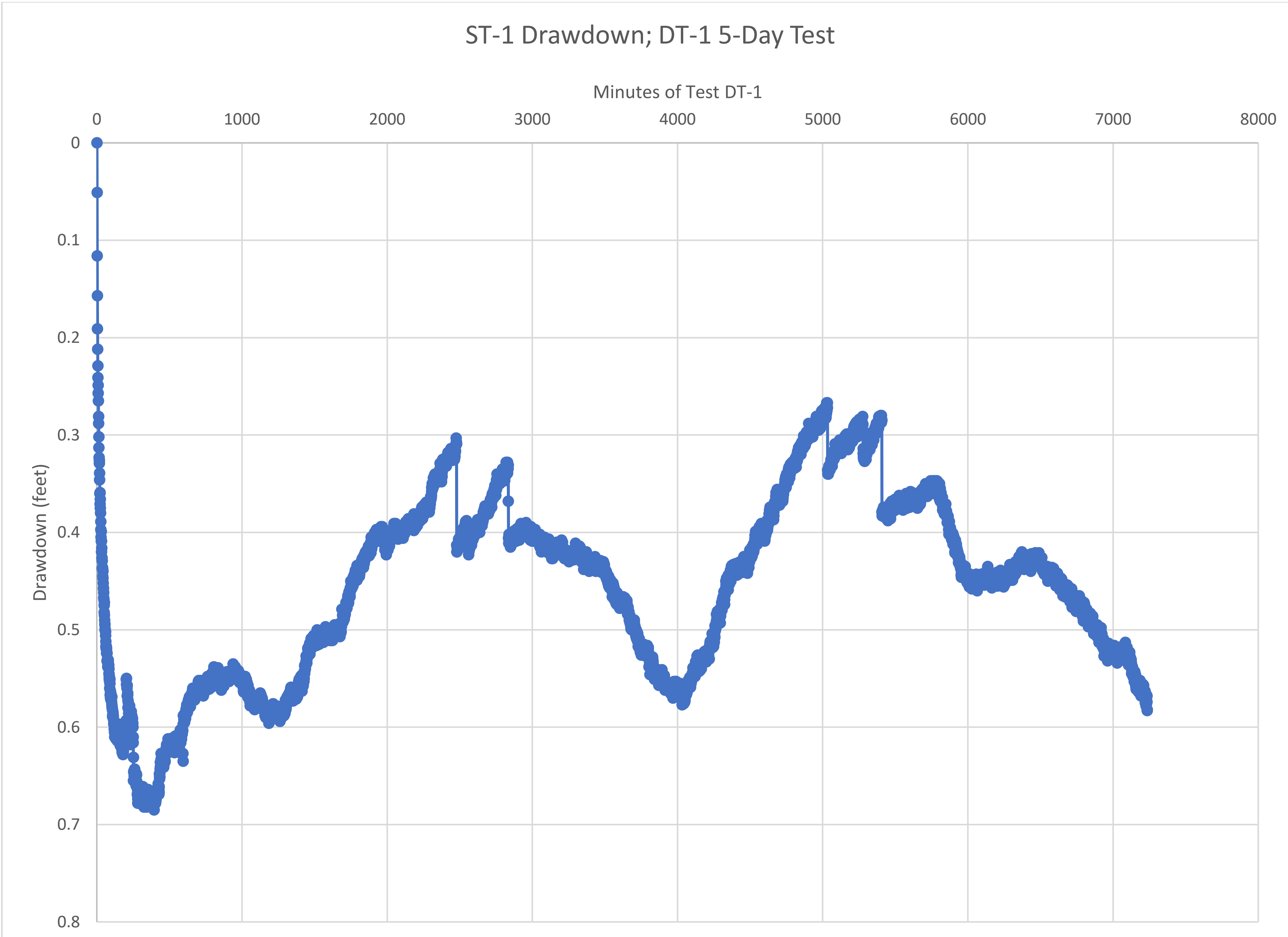

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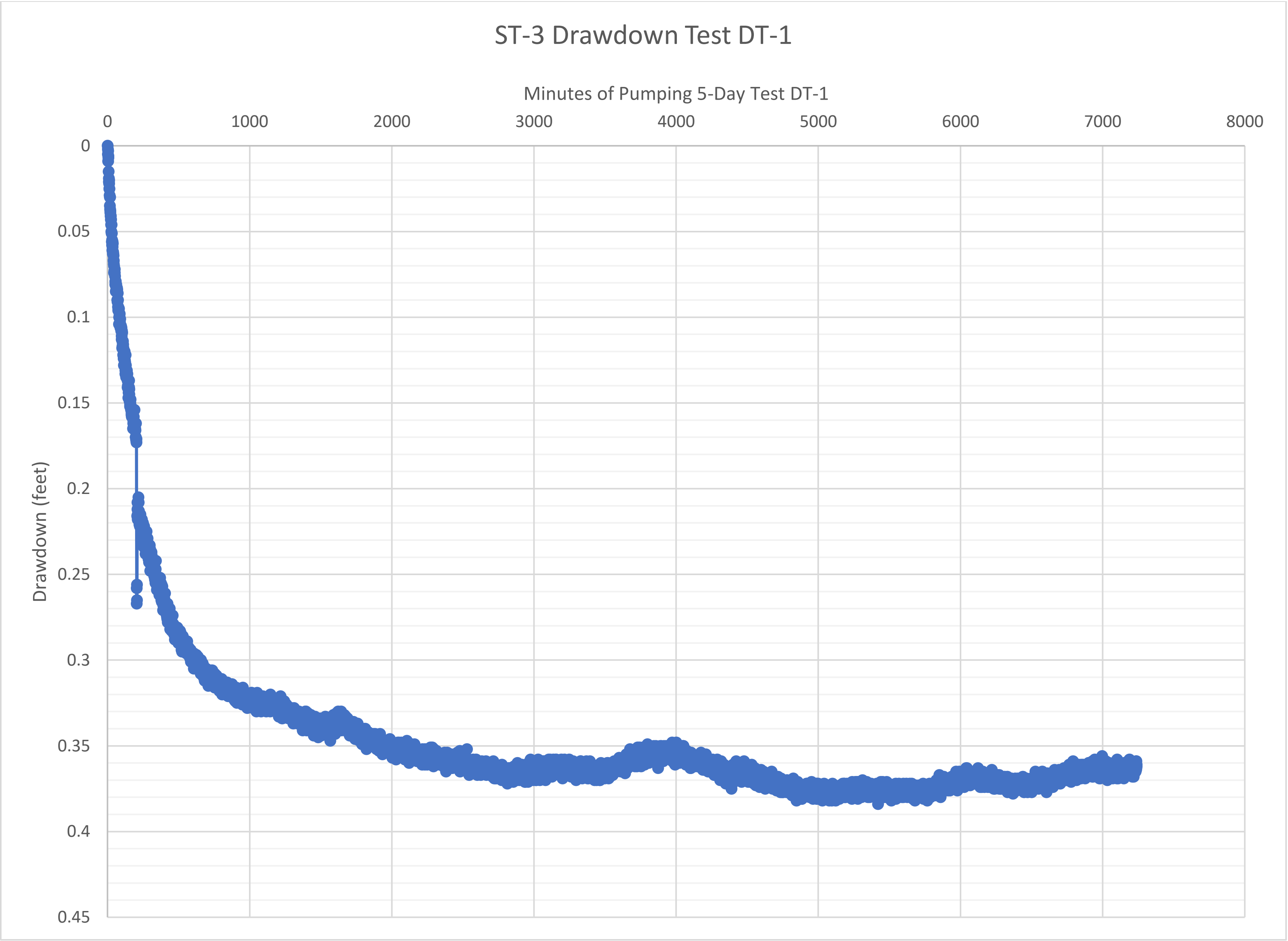
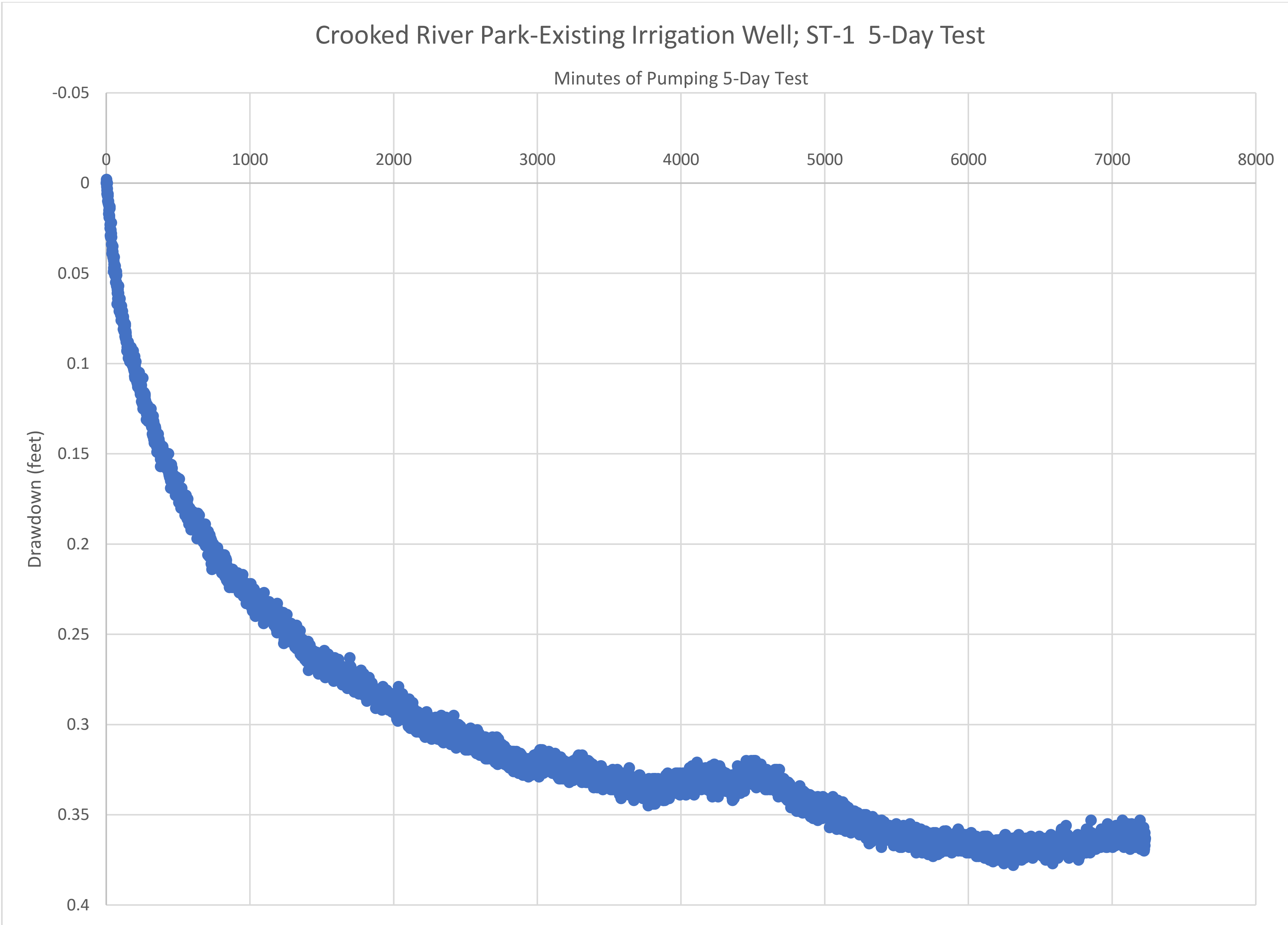
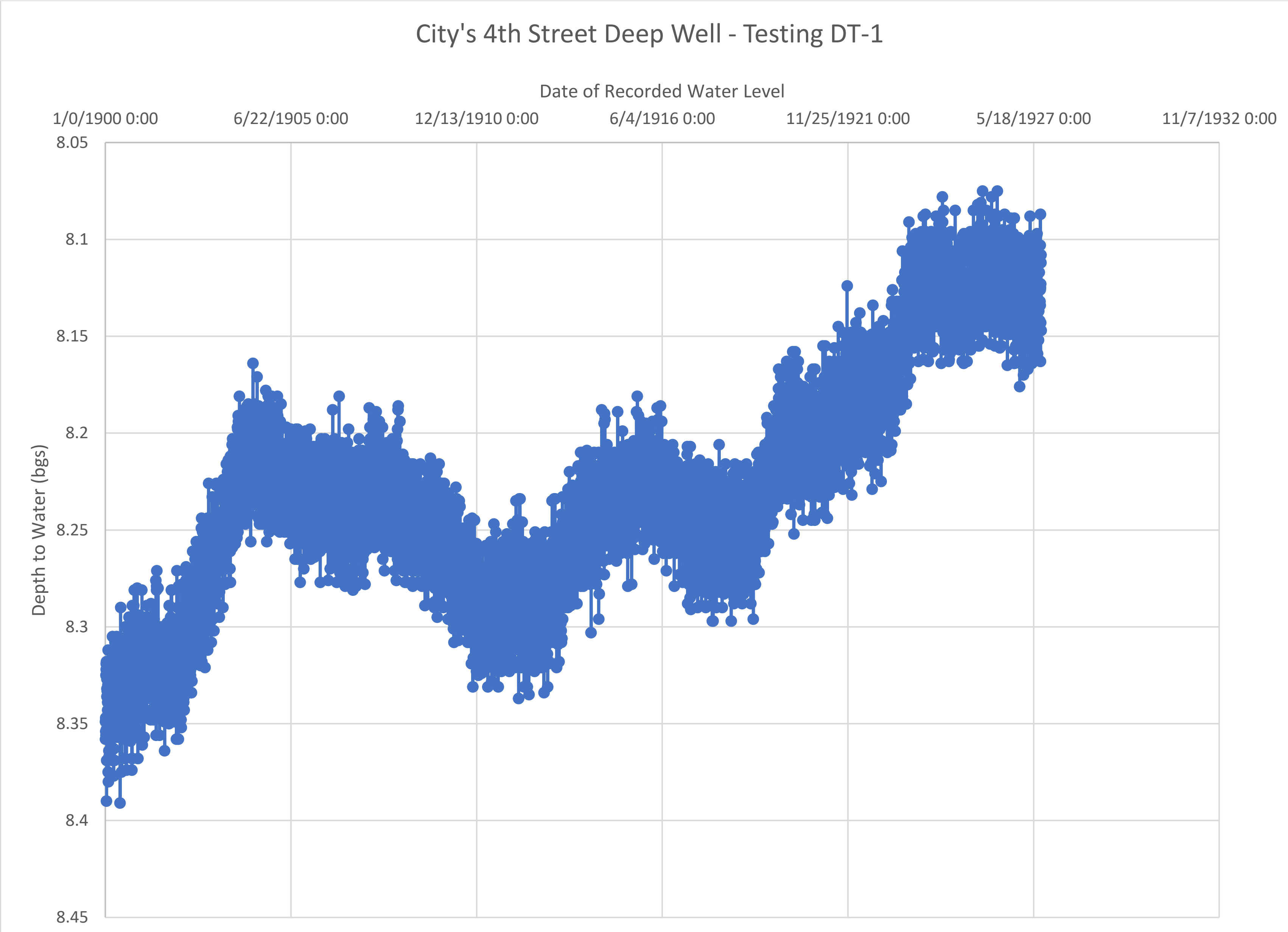


CASCADE GEOENGINEERING



Crooked River Park-Existing Irrigation Well; ST-1 5-Day Test
Minutes of Pumping 5-Day Test
Drawdown (feet)
-0.05
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0
1000
2000
3000
4000
5000
6000
7000
8000



CASCADE GEOENGINEERING

ATTACHMENT 5

Letters of Support

City of Prineville Water Grant Application

Oregon

Central Oregon Regional Solutions Center
1011 SW Emkay Dr., Suite 108
Bend, OR 97702

April 8, 2019

Grant Program Coordinator
Oregon Water Resources Department
725 Summer Street NE, Suite A
Salem, OR 97301

Dear Grant Program Coordinator,

Please accept this letter of support on behalf of the Central Oregon Regional Solutions Advisory Committee ("advisory committee") for the City of Prineville's application to receive funding for their Aquifer Storage and Recovery (ASR) System.

The advisory committee is comprised of local government, private sector, higher education and philanthropic leaders; our purposes are to identify community and economic development priorities for the region and look for opportunities to leverage resources to complete priority projects. One of the highest priorities identified by the advisory committee for Central Oregon is water availability, conservation and restoration.

We applaud the city for their innovative partnership to create a resilient, cost-effective and sustainable water supply solution to meet growing community demands. This project will prepare the city for the impacts of climate change, including reduced snowpack and stream flows, and will provide a source of stored water for use in the event of drought.

The City will use the ASR system as a water management tool to meet peak demands by taking advantage of the natural storage space found in geologic formations underground. The move to an ASR system is in response to dramatic seasonal differences in the community's current water supply needs -- less than 1 million gallons per day in the winter versus more than 4 million gallons per day in the summer.

We believe that funding for this important project is critical to the City of Prineville's long-term sustainability and respectfully ask for your consideration of the City of Prineville's application for funding through your grant program.

Sincerely,

Mike Hollern, Convener
Central Oregon Regional Solutions Committee

CENTRAL OREGON CITIES ORGANIZATION
BEND, CULVER, LA PINE, MADRAS, MAUPIN
METOLIUS, PRINEVILLE, REDMOND, SISTERS

March 11, 2019

Grant Program Coordinator
Oregon Water Resources Department
725 Summer Street NE, Suite A
Salem, OR 97301

Dear Grant Program Coordinator,

Please accept this letter of support for the City of Prineville's application to receive funding for their Aquifer Storage and Recovery (ASR) System. We applaud the City of Prineville and Apple in their innovative partnership to create a resilient, cost-effective and sustainable water supply solution to meet growing community demands.

Prineville's ASR system is expected to mitigate the long-term impacts of climate change, including reduced snowpack and stream flows, and provides for a readily available underground reservoir of stored water for use in the event of drought.

The City will use the ASR system as a water management tool that allows it to meet peak demands by taking advantage of the natural storage space found in geologic formations underground. The move to an ASR system is in response to dramatic seasonal differences in the community's current water supply needs -- less than 1 million gallons per day in the winter versus more than 4 million gallons per day in the summer.

The ASR system is just one of several initiatives the City of Prineville is undertaking to counter the effects of climate change and drought. We believe that funding for this important project is critical to the City of Prineville's long-term sustainment.

We respectfully ask for your consideration of the City of Prineville's application for funding through your grant program.

Sincerely,

George Endicott

George Endicott, COCO Chair
Mayor of Redmond

DESCHUTES RIVER
CONSERVANCY

April 15, 2019

Grant Program Coordinator
Oregon Water Resources Department
725 Summer Street NE, Suite A
Salem, OR 97301

Dear Grant Program Coordinator:

The purpose of this letter is to express support for the City of Prineville's proposed Aquifer Storage and Recovery Project. The Deschutes River Conservancy's mission is to restore streamflow and water quality in the Deschutes Basin, using collaborative consensus-based approaches.

The DRC understands that the City is proposing to pump out of existing and proposed alluvial wells near the Crooked River during the time period between November 1 and March 31; that the City plans to store that water in an Aquifer Storage and Recovery project in an airport area aquifer west of the City; and that the City could then recover this water to meet demands in periods of high demand in the summer. The DRC recognizes that this approach has the potential to decrease impacts of new groundwater development to surface water resources during low summer flow periods when both water quantity and quality issues could be of greater concern.

The DRC supports the City's efforts to meet future municipal and industrial demands in innovative ways that minimize impacts to surface water resources. The DRC understands that the City's new wells will require mitigation under the Deschutes Basin Groundwater Mitigation Program, and that this mitigation will be fulfilled using State of Oregon Permit S-55091 and subsequent Certificate 94149, which authorizes the Bureau of Reclamation to use 5,100 acre-feet of stored water in Prineville Reservoir, with the identified uses of flow augmentation for wildlife and fish life, and to establish mitigation credits under the Deschutes Groundwater Mitigation Program for the City of Prineville (via state mitigation application MP-222). The DRC understands, as indicated in Certificate 94149, that this water will be protected instream in the Crooked River, from Bowman Dam downstream to Lake Billy Chinook.

Thank you for the opportunity to review and comment.

Sincerely,

Ron Nelson

Ron Nelson
Executive Director

CRWC
CROOKED RIVER WATERSHED COUNCIL

498 SE Lynn Blvd.
Prineville, Oregon 97754

Phone: (541) 447-8567 **Fax**: (541) 416-2115

contact@crwc.info
www.crookedriver.deschutesriver.org

April 16, 2019

Letter of Support

We are writing to offer full support the City of Prineville's Aquifer Storage & Recovery Project (ASR). The council promotes watershed health, function, and natural processes as key tenets of our mission statement.

Established in 1994, the Council and its conservation partners have implemented over 75 projects to meet our mission statement, including several with the City of Prineville. Most recently, the council worked directly with city staff and leadership to complete a wetland and floodplain habitat project along the lower Crooked River. This innovative project represents the ongoing commitment by the city to work with others, and to pursue projects that both satisfy basic community needs like wastewater infrastructure, while remaining open to additional project elements that provide for improvements in natural resources.

The ASR project meets most all of these same principles and we are pleased to offer our full support. The project will provide a higher level of protection to surface waters, especially in summer months when demand on water increases significantly. By recharging a natural confined aquifer during water surplus periods and drawing this resource down during higher demand periods allows natural surface waters to remain at their highest volumes for a given year during the hottest months. This approach will mitigate what would have otherwise been a drafting of surface waters to meet city needs during the time it would have the largest negative impact. By avoiding this impact and essentially moving and reserving surplus when available, reduces the potential higher water temperatures in the Crooked River system.

It is fortunate that the City of Prineville have this option available. In many other jurisdictions and areas within Oregon, this option is not available due to lack of natural confined aquifers with the right characteristics for both storage (recharge) and recovery. Our organization supports this approach to both wisely use and provide protection for natural resource like water. The long term benefits from this particular project cannot be overstated. Water sustainability and resilient watersheds are of utmost importance in Oregon, and in particular on the East side of the State where this resource is more naturally limited.

Sincerely,

Chris M. Gannon
Director- Crooked River Watershed Council

Brooks Resources Corporation

April 22, 2019

Mr. Steve Forrester
City Manager
City of Prineville
887 NE Third Street
Prineville, OR 97754

Dear Steve:

Please accept this letter of support from Brooks Resources Corporation for the City of Prineville's application to receive funding for their Aquifer Storage and Recovery (ASR) System.

In addition, the Central Oregon Regional Solutions Advisory Committee, comprised of local government, private sector, higher education and philanthropic leaders, unanimously supported the Prineville application. I am the Convener of the Central Oregon Regional Solutions Advisory Committee. The Regional Solutions Advisory Team, all State of Oregon employees, under Annette Liebe, did not take a position on the application.

We applaud the City for their innovative partnership to create a resilient, cost-effective and sustainable water supply solution to meet growing community demands. This project will prepare the City for the impacts of climate change, including reduced snowpack and stream flows, and will provide a source of stored water for use in the event of drought.

The City will use the ASR system as a water management tool to meet peak demands by taking advantage of the natural storage space founds in geologic formations underground. The move to an ASR system is in response to dramatic seasonal differences in the community's current water supply needs – less than 1 million gallons per day in winter versus 4 million gallons per day in the summer.

We believe that funding for this important project is critical to the City of Prineville's long-term sustainability and respectfully ask for your consideration of the City of Prineville's application for funding through your grant program.

Sincerely,

Mike Hollern, Chairman
Brooks Resources Corporation

409 NW Franklin Avenue Bend, Oregon 97703 541.382.1662 Fax 541.385.3285 www.brooksresources.com

April 5, 2019

Grant Program Coordinator
Oregon Water Resources Department
725 Summer Street NE, Suite A
Salem, OR 97301

RE: SUPPORT FOR THE CITY OF PRINEVILLE'S PROPOSED AQUIFER STORAGE AND RECOVERY PROJECT

Dear Grant Program Coordinator,

Please accept this letter of support from the Coalition for the Deschutes for the City of Prineville's application to receive funding for their Aquifer Storage and Recovery (ASR) System. The Coalition fully supports the City of Prineville and Apple in their joint effort to create a robust, effective and environmentally friendly water supply solution.

The mission of the Coalition for the Deschutes is to restore the Deschutes River to a healthy ecological condition. Fish, families, and farms are all beneficiaries of irrigation modernization projects and other water conservation measures such at the ASR System.

We are a river advocacy group that works in partnership with and supports the work of irrigation districts, cities and other conservation groups in Central Oregon so that we can have:

- A healthy, restored Deschutes River
- Thriving farms and sustainable agriculture
- Robust and vibrant communities

The Coalition is an originator and signatory to the Shared Vision for the Deschutes (https://coalitionforthedeschutes.org/shared-vision-for-the-deschutes-river/). We feel that the ASR project contributes to the goals of the Shared Vision by reducing potential demand on instream sources of water.

Thank you for considering the City of Prineville's application for grant funding.

Sincerely,

Gail Snyder
Executive Director
Coalition for the Deschutes

Mike Taylor
Board President
Coalition for the Deschutes

cc. Mike Kasberger

To: Grant Program Coordinator

Oregon Water Resources Department

725 Summer Street NE, Suite A

Salem, OR 97301

I am writing in support of the City of Prineville's Aquifer Storage and Recovery (ASR) project and hope that OWRD will fund their request.

The project will store water in a contained aquifer in times of abundance. That water will then be used to augment wells during periods of less water availability. Matching water supply and demand across seasonal variability is critical to the economic health of Prineville and its residents. The ASR project does this without diverting additional surface water from the Crooked River. That's important because the Crooked is subject to seasonally extreme high and low flows. Those extreme variations not only damage the riparian ecosystem and native redound trout, but they also impede reintroduction of threatened and endangered steelhead and Chinook salmon. The Prineville ASR project will benefit both the city and the river. Ongoing monitoring of the ASR project by the City of Prineville, DEQ, and OWRD will insure against negative, unintended consequences.

The ASR project is a creative way to meet water supply challenges for both Prineville and the Crooked River. OWRD support for the project is both important and appropriate, and you are urged to fund it as requested.

Respectfully,

Jeff Wieland

Conservation Chair, Sunriver Anglers

541-280-3237

Crook County

300 NE 3rd Street • Prineville, Oregon 97754
(541) 447-6555 • (541) 416-3891

April 23, 2019

Mike Kasberger, Assistant City Engineer
387 NE 3rd St.
Prineville, OR 97754

Dear Mr. Kasberger,

Thank you for sharing the information on the City of Prineville's Aquifer Storage and Recovery project. This project provides the City with a unique opportunity to develop a sustainable and cost-effective water source for the growing demands of the city and its residents. As coordinator of the Crook County Natural Resource Policy, I support this effort by the City to capture water during periods of higher streamflow and lower demand by other beneficial uses of the water and then to be able to use it during periods of the summer when higher water demands on a limited resource are occurring.

One of the benefits of aquifer storage that is of particular interest to me was the value that aquifer storage and recovery provides in limited water years or as we refer to them as drought years. Precipitation in central Oregon and specifically in the Crooked River Watershed is highly variable from year to year. The ability to create additional storage of high flows during the late winter and early spring months results in better water management and delivery throughout the entire year.

The City of Prineville has done its homework. Successful aquifer storage relies on a suitable aquifer. The City has completed an extensive feasibility study which concluded that the ASR project will be able to take advantage of the airport area aquifer. With the storage capability of this aquifer, the impact and long term sustainability of this project will be significant.

In closing, this is a great project for the City and its residents. As coordinator of the County's Natural Resource Policy, I commend this project and the City's effort to have found a way to meet the growing needs of the City and yet, do it in a way that will have no impact on the other uses and benefits that the Crooked River provides.

Sincerely,

Tim Deboodt, Coordinator
Crook County Natural Resource Policy

CROOK COUNTY HEALTH DEPARTMENT
"A Healthy and Safe Future for the People of Crook County"
375 NW Beaver St., Suite 100 Prineville, OR 97754
Telephone: (541) 447-5165 Fax (541) 447-3093

April 23, 2019

Grant Program Coordinator
Oregon Water Resources Department
725 Summer Street, NE, Suite A
Salem, OR 97301

Dear Grant Program Coordinator,

I am writing on behalf of Crook County Health Department to express support for the City of Prineville's application to receive funding for their Aquifer Storage and Recovery (ASR) System. We applaud the City of Prineville and Apple in their innovative partnership to create a resilient, cost-effective and sustainable water supply solution to meet growing community demands.

Prineville's ASR system is expected to mitigate the long-term impacts of climate change, including reduced snowpack and stream flows, and provides for a readily available underground reservoir of stored water for use in the event of drought.

The City will use the ASR system as a water management tool that allows it to meet peak demands by taking advantage of the natural storage space found in geologic formations underground. The move to an ASR system is in response to dramatic seasonal differences in the community's water supply needs – less than 1 million gallons per day in the winter versus more than 4 million gallons per day in the summer.

Crook County Public Health is proud of this and other initiatives that the City of Prineville is undertaking to counter the effects of climate change and drought. We believe that funding for this important project is critical to the City of Prineville's long term sustainment.

Thank you for your consideration of this project.

Sincerely,

Muriel DeLaVergne-Brown, RN, MPH
Crook County Public Health Director

Grant Program Coordinator
Oregon Water Resources Department
725 Summer Street NE, Suite A
Salem, OR 97301

April 2, 2019

SUBJECT: CITY OF PRINEVILLE AQUIFER STORAGE AND RECHARGE PROJECT

Dear Grant Program Coordinator:

The Deschutes Redbands Chapter of Trout Unlimited enthusiastically supports the City of Prineville's Aquifer Storage and Recovery (ASR) project.

With this project, Prineville is creating a mechanism for efficient matching of water supply and demand. Using surface water rights gained through the Crooked River Jobs and Security Act as mitigation, the city obtained ground water rights for this project. The ASR then creates an efficient system allowing groundwater supply, which is available at a low rate continuously, to be shaped for use to economically meet peak demand. This is always a challenge for municipalities. Prineville fortuitously found the geology needed for the storage component of the project just west of the City.

For Trout Unlimited this is a win-win. Our mission is to restore cold water fisheries. The Crooked River below Prineville Reservoir is subject to damaging low flows during drought periods. The instream water created by the City's use of surface water rights for mitigation to obtain groundwater rights has proven to be invaluable for management of these natural fluctuations in instream flows. Given the rapid population growth of Central Oregon, meeting municipal water demands while also restoring instream flows in our rivers is a major challenge. It is gratifying that creative projects such as the ASR can be found to meet this challenge for both cities and streams.

Sincerely,

Shaun Pigott

M Tripp

Shaun Pigott
President

Michael Tripp M.D.
Advocacy Chair

ATTACHMENT 6

Permits, Certificates & Limited License

City of Prineville Water Grant Application

ASR Source Water - Permits and Certificate

STATE OF OREGON

COUNTY OF CROOK

PERMIT TO APPROPRIATE THE PUBLIC WATERS

THIS PERMIT IS HEREBY ISSUED TO

CITY OF PRINEVILLE
387 NE 3RD ST
PRINEVILLE, OR 97754

The specific limits and conditions of the use are listed below.

APPLICATION FILE NUMBER: G-18662

SOURCE OF WATER: 25 WELLS IN CROOKED RIVER BASIN

PURPOSE OR USE: MUNICIPAL USE

MAXIMUM RATE: 4.46 CUBIC FEET PER SECOND

PERIOD OF USE: JANUARY 1 THROUGH DECEMBER 31

DATE OF PRIORITY: APRIL 25, 2018

WELL LOCATION:

POA	POA Name	Twp	Rng	Mer	Sec	Q-Q	Measured Distances
1	D1 (CROO 54593)	15 S	16 E	WM	8	NW NW	422 FEET SOUTH AND 400 FEET EAST FROM NW CORNER, SECTION 8
2	S1 (CROO 54587)	15 S	16 E	WM	8	NW NW	471 FEET SOUTH AND 406 FEET EAST FROM NW CORNER, SECTION 8
3	D2 (CROO 54592)	15 S	16 E	WM	8	NW NW	585 FEET SOUTH AND 793 FEET EAST FROM NW CORNER, SECTION 8
4	D3	15 S	16 E	WM	8	NW NW	516 FEET SOUTH AND 438 FEET EAST FROM NW CORNER, SECTION 8
5	S2	15 S	16 E	WM	8	NW NW	561 FEET SOUTH AND 466 FEET EAST FROM NW CORNER, SECTION 8
6	D4	15 S	16 E	WM	8	NW NW	601 FEET SOUTH AND 509 FEET EAST FROM NW CORNER, SECTION 8
7	S3	15 S	16 E	WM	8	NW NW	621 FEET SOUTH AND 564 FEET EAST FROM NW CORNER, SECTION 8
8	D5	15 S	16 E	WM	8	NW NW	657 FEET SOUTH AND 611 FEET EAST FROM NW CORNER, SECTION 8
9	S4	15 S	16 E	WM	8	NW NW	694 FEET SOUTH AND 654 FEET EAST FROM NW CORNER, SECTION 8
10	D6	15 S	16 E	WM	8	NW NW	717 FEET SOUTH AND 700 FEET EAST FROM NW CORNER, SECTION 8
11	S5	15 S	16 E	WM	8	NW NW	789 FEET SOUTH AND 731 FEET EAST FROM NW CORNER, SECTION 8
12	D7	15 S	16 E	WM	8	NW NW	840 FEET SOUTH AND 759 FEET EAST FROM NW CORNER, SECTION 8

POA	POA Name	Twp	Rng	Mer	Sec	Q-Q	Measured Distances
13	S6	15 S	16 E	WM	8	NW NW	888 FEET SOUTH AND 784 FEET EAST FROM NW CORNER, SECTION 8
14	D8	15 S	16 E	WM	8	NW NW	952 FEET SOUTH AND 799 FEET EAST FROM NW CORNER, SECTION 8
15	S7	15 S	16 E	WM	8	NW NW	1004 FEET SOUTH AND 809 FEET EAST FROM NW CORNER, SECTION 8
16	D9	15 S	16 E	WM	8	NW NW	1061 FEET SOUTH AND 815 FEET EAST FROM NW CORNER, SECTION 8
17	S8	15 S	16 E	WM	8	NW NW	1116 FEET SOUTH AND 808 FEET EAST FROM NW CORNER, SECTION 8
18	D10	15 S	16 E	WM	8	NW NW	1179 FEET SOUTH AND 796 FEET EAST FROM NW CORNER, SECTION 8
19	S9	15 S	16 E	WM	8	NW NW	1232 FEET SOUTH AND 800 FEET EAST FROM NW CORNER, SECTION 8
20	D11	15 S	16 E	WM	8	NW NW	1267 FEET SOUTH AND 836 FEET EAST FROM NW CORNER, SECTION 8
21	S10	15 S	16 E	WM	8	NW NW	1320 FEET SOUTH AND 869 FEET EAST FROM NW CORNER, SECTION 8
22	D12	15 S	16 E	WM	8	SW NW	1372 FEET SOUTH AND 879 FEET EAST FROM NW CORNER, SECTION 8
23	S11	15 S	16 E	WM	8	SW NW	1420 FEET SOUTH AND 896 FEET EAST FROM NW CORNER, SECTION 8
24	D13	15 S	16 E	WM	8	SW NW	1479 FEET SOUTH AND 909 FEET EAST FROM NW CORNER, SECTION 8
25	S12	15 S	16 E	WM	8	SW NW	1527 FEET SOUTH AND 949 FEET EAST FROM NW CORNER, SECTION 8

THE PLACE OF USE IS LOCATED AS FOLLOWS:
Within the City of Prineville Service Boundary

1. **Measurement Devices, and Recording/Reporting of Annual Water Use Conditions:**

   A. Before water use may begin under this permit, the permittee shall install a totalizing flow meter at each point of appropriation. The permittee shall maintain the device in good working order.

   B. The permittee shall allow the watermaster access to the device; provided however, where any device is located within a private structure, the watermaster shall request access upon reasonable notice.

   C. The permittee shall keep a complete record of the volume of water used each month, and shall submit an annual report which includes the recorded water-use measurements to the Department annually, or more frequently as may be required by the Director. Further, the Director may require the permittee to report general water-use information, including the place and nature of use of water under the permit.

   D. The Director may provide an opportunity for the permittee to submit alternative measuring and reporting procedures for review and approval.

2. **Annual Measurement Condition:**

The Department requires the water user to obtain, from a qualified individual (see below), and report annual static water levels from one dedicated deep well and one dedicated shallow well. The static water level shall be measured in the month of March. Reports shall be submitted to the Department within 30 days of measurement.

The permittee shall report an initial March static water-level measurement once well construction is complete and annual measurements thereafter. Annual measurements are required whether or not the well is used. The first annual measurement will establish a reference level against which future measurements will be compared. However, the Director may establish the reference level based on an analysis of other water-level data. The Director may require the user to obtain and report additional water levels each year if more data are needed to evaluate the aquifer system.

All measurements shall be made by a certified water rights examiner, registered professional geologist, registered professional engineer, licensed well constructor or pump installer licensed by the Construction Contractors Board. Measurements shall be submitted on forms provided by, or specified by, the Department. Measurements shall be made with equipment that is accurate to at least the standards specified in OAR 690-217-0045. The Department requires the individual performing the measurement to:

A. Associate each measurement with an owner's well name or number and a Department well log ID; and

B. Report water levels to at least the nearest tenth of a foot as depth-to-water below ground surface; and

C. Specify the method of measurement; and

D. Certify the accuracy of all measurements and calculations reported to the Department.

The water user shall discontinue use of, or reduce the rate or volume of withdrawal from, the well(s) if any of the following events occur:

A. Annual water-level measurements reveal an average water-level decline of three or more feet per year for five consecutive years; or

B. Annual water-level measurements reveal a water-level decline of 15 or more feet in fewer than five consecutive years; or

C. Annual water-level measurements reveal a water-level decline of 25 or more feet; or

D. Hydraulic interference leads to a decline of 25 or more feet in any neighboring well with senior priority.

The period of restricted use shall continue until the water level rises above the decline level which triggered the action or the Department determines, based on the permittee's and/or the Department's data and analysis, that no action is necessary because the aquifer in question can sustain the observed declines without adversely impacting the resource or causing substantial interference with senior water rights. The water user shall not allow excessive decline, as defined in Commission rules, to occur within the aquifer as a result of use under this permit. If more than one well is involved, the water user may submit an alternative measurement and reporting plan for review and approval by the Department.

3. **Dedicated Measuring Tube Condition:**

Wells with pumps shall be equipped with a minimum 3/4-inch diameter, unobstructed, dedicated measuring tube pursuant to figure 200-5 in OAR 690-200. If a pump has been installed prior to the issuance of this permit, and if static water levels and pumping levels can be measured using an electrical tape, then the installation of the measuring tube can be delayed until such time that water levels cannot be measured or the pump is repaired or replaced.

4. **Well Identification Tag Condition:**

Prior to using water from any well listed on this permit, the permittee shall ensure that the well has been assigned an OWRD Well Identification Number (Well ID tag), which shall be permanently attached to the well. The Well ID shall be used as a reference in any correspondence regarding the well, including any reports of water use, water level, or pump test data.

5. **Groundwater Mitigation Conditions:**

a. Mitigation Obligation: 1292.0 AF of mitigation water in the Crooked River Zone of Impact (located anywhere in the Crooked River Basin above river mile 13.8).

b. Mitigation Source: Mitigation Credits or a Mitigation Project, in accordance with the incremental development plan on file with the Department, meeting the requirements of OAR Chapter 690, Division 505 (Deschutes Ground Water Mitigation Rules) and OAR Chapter 690, Division 522.

c. The permittee shall provide mitigation during each stage of development under the permit, as described in the Incremental Development Mitigation Plan on file with the Department, and in accordance with the standards of the Deschutes Ground Water Mitigation Rules, OAR Chapter 690, Division 505 and Division 522.

d. The permittee shall not increase the rate or amount of water diverted, as described in the incremental development mitigation plan, prior to increasing the corresponding mitigation.

e. The permittee shall seek and receive Department approval prior to changing the Incremental Mitigation Development Plan and related mitigation obligation for each stage of permit development.

f. The permittee shall report to the Department the progress of implementing the Incremental Mitigation Development Plan and related mitigation no later than April 1 of each year. The annual report shall include the annual volume of water used, the source and amount of mitigation, and any offset used for that period. This annual notification is not necessary if the permittee has completed development and submitted a Claim of Beneficial Use to the Department.

g. Mitigation water must be legally protected instream in the Crooked River Zone of Impact (located anywhere in the Crooked River Basin above river mile 13.8) for the life of the permit and subsequent certificate(s). Regulation of the use and/or cancellation of the permit, or subsequent certificate(s) will occur if the required mitigation is not maintained.

h. The permittee shall provide additional mitigation if the Department determines that average annual consumptive use of the subject appropriation has increased beyond the originally mitigated amount.

i. If mitigation is from a secondary right for stored water from a storage project not owned or operated by the permittee, the use of water under this right is subject to the maintenance and terms and conditions of a valid contract or satisfactory replacement, with the owner/operator of the storage project, a copy of which must be on file in the records of the Water Resources Department.

j. Failure to comply with these mitigation conditions shall result in the Department regulating the groundwater permit, or subsequent certificate(s), proposing to deny any permit extension application for the groundwater permit, and proposing to cancel the groundwater permit, or subsequent certificate(s).

k. All water use and mitigation accounting, including the incremental development plan and the annual report required in paragraph f, may be reported on a water year basis.

6. **Scenic Waterway Condition:**

Use of water under authority of this permit may be regulated if analysis of data available after the permit is issued discloses that the appropriation will measurably reduce the surface-water flows necessary to maintain the free-flowing character of a scenic waterway in quantities necessary for recreation, fish and wildlife in effect as of the priority date of the right, or as those quantities may be reduced subsequently. However, the use of groundwater allowed under the terms of this permit will not be subject to regulation for Scenic Waterway flows, provided the mitigation required is maintained.

STANDARD CONDITIONS

1. Failure to comply with any of the provisions of this permit may result in action including, but not limited to, restrictions on the use, civil penalties, or cancellation of the permit.

2. If the number, location, source, or construction of any well deviates from that proposed in the permit application or required by permit conditions, this permit may be subject to cancellation, unless the Department authorizes the change in writing.

3. If substantial interference with surface water or a senior water right occurs due to withdrawal of water from any well listed on this permit, then use of water from the well(s) shall be discontinued or reduced and/or the schedule of withdrawal shall be regulated until or unless the Department approves or implements an alternative administrative action to mitigate the interference. The Department encourages junior and senior appropriators to jointly develop plans to mitigate interferences.

4. The well(s) shall be constructed and maintained in accordance with the General Standards for the Construction and Maintenance of Water Supply Wells in Oregon. The works shall be equipped with a usable access port adequate to determine water-level elevation in the well at all times.

5. Where two or more water users agree among themselves as to the manner of rotation in the use of water and such agreement is placed in writing and filed by such water users with the watermaster, and such rotation system does not infringe upon such prior rights of any water user not a party to such rotation plan, the watermaster shall distribute the water according to such agreement.

6. Prior to receiving a certificate of water right, the permit holder shall submit to the Water Resources Department the results of a pump test meeting the Department's standards for each point of appropriation (well), unless an exemption has been obtained in writing under OAR 690-217. The Director may require water-level or pump-test data every ten years thereafter.

7. This permit is for the beneficial use of water without waste. The water user is advised that new regulations may require the use of best practical technologies or conservation practices to achieve this end.

8. By law, the land use associated with this water use must be in compliance with statewide land-use goals and any local acknowledged land-use plan.

9. Construction of the wells shall begin within twenty years of the date of permit issuance. The deadline to begin construction may not be extended. This permit is subject to cancellation proceedings if the construction deadline to begin is missed.

10. Complete application of the water shall be made within twenty years of the date of permit issuance. If beneficial use of permitted water has not been made before this date, the permittee may submit an application for extension of time, which may be approved based upon the merit of the application.

11. Within one year after complete application of water to the proposed use, the permittee shall submit a claim of beneficial use, which includes a map and report, prepared by a Certified Water Rights Examiner.

Issued December 26th, 2018

Dwight French
Water Right Services Division Administrator, for
Thomas M. Byler, Director
Oregon Water Resources Department

STATE OF OREGON

COUNTY OF CROOK

CERTIFICATE OF WATER RIGHT

THIS CERTIFICATE ISSUED TO

CITY OF PRINEVILLE
387 NE THIRD STREET
PRINEVILLE, OR 97754

confirms the right to use the waters of LaMONTA WELL in the OCHOCO CREEK BASIN for MUNICIPAL USES.

This right was perfected under Permit G-506. The date of priority is APRIL 5, 1957. The amount of water to which this right is entitled is limited to an amount actually used beneficially, and shall not exceed 0.77 CUBIC FOOT PER SECOND or its equivalent in case of rotation, measured at the well.

The well is located as follows:

Twp	Rng	Mer	Sec	Q-Q	Measured Distances
14 S	16 E	WM	31	NW NW	SOUTH 58 DEGREES 13 MINUTES EAST, 1447 FEET FROM NW CORNER OF SECTION 31

The use shall conform to such reasonable rotation system as may be ordered by the proper state officer.

A description of the place of use to which this right is appurtenant is as follows:

MUNICIPAL USES					
Twp	Rng	Mer	Sec	Q-Q	GLot
14 S	16 E	WM	31	NE SE	
14 S	16 E	WM	31	NW SE	
14 S	16 E	WM	31	SW SE	
14 S	16 E	WM	31	SE SE	
14 S	16 E	WM	32	NE SW	
14 S	16 E	WM	32	NW SW	
14 S	16 E	WM	32	SW SW	
14 S	16 E	WM	32	SE SW	
15 S	16 E	WM	5	NW NE	2
15 S	16 E	WM	5	SW NE	
15 S	16 E	WM	5	NE NW	3
15 S	16 E	WM	5	NW NW	4
15 S	16 E	WM	6	NE NE	1
15 S	16 E	WM	6	NW NE	2
15 S	16 E	WM	6	SE NE	

This certificate describes that portion of the water right confirmed by Certificate 29097, State Record of Water Right Certificates, NOT modified by the provisions of an order of the Water Resources Director entered JUN 0 7 2010, approving Transfer Application T-11026.

The issuance of this superseding certificate does not confirm the status of the water right in regard to the provisions of ORS 540.610 pertaining to forfeiture or abandonment.

The right to the use of the water for the above purpose is restricted to beneficial use on the lands or place of use described.

WITNESS the signature of the Water Resources Director, affixed June 7, 2010.

Phillip C. Ward, Director

 Recorded in State Record of Water Right Certificates numbered 86337.

STATE OF OREGON

COUNTY OF CROOK

CERTIFICATE OF WATER RIGHT

This Is to Certify, That PACIFIC POWER & LIGHT CO.

of Public Service Bldg., Portland 4, State of Oregon, has made proof to the satisfaction of the STATE ENGINEER of Oregon, of a right to the use of the waters of a well a tributary of for the purpose of municipal supply under Permit No. U-215 of the State Engineer, and that said right to the use of said waters has been perfected in accordance with the laws of Oregon; that the priority of the right hereby confirmed dates from June 17, 1947;

that the amount of water to which such right is entitled and hereby confirmed, for the purposes aforesaid, is limited to an amount actually beneficially used for said purposes, and shall not exceed 0.8 cubic foot per second

or its equivalent in case of rotation, measured at the point of diversion from the stream. The point of diversion is located in the SW¼SE¼, Section 31, Township 14 South, Range 16 East, W. M.

The amount of water used for irrigation, together with the amount secured under any other right existing for the same lands, shall be limited to - - - - - - - of one cubic foot per second per acre,

and shall conform to such reasonable rotation system as may be ordered by the proper state officer.

A description of the place of use under the right hereby confirmed, and to which such right is appurtenant, is as follows:

SW¼SE¼
NW¼SE¼
NE¼SE¼
SE¼SE¼
Section 31
SW¼SW¼
NW¼SW¼
NE¼SW¼
SE¼SW¼
Section 32
Township 14 South, Range 16 East, W. M.

SW¼NW¼
NW¼NW¼
NE¼NW¼
SE¼NW¼
SW¼NE¼
NW¼NE¼
Section 5
NW¼NE¼
NE¼NE¼
SE¼NE¼
Section 6
Township 15 South, Range 16 East, W. M.

The right to the use of the water for the purposes aforesaid is restricted to the lands or place of use herein described.

WITNESS the signature of the State Engineer, affixed

this 12th day of July, 57.

LEWIS A. STANLEY
State Engineer

Recorded in State Record of Water Right Certificates, Volume 16, page 22839.

STATE OF OREGON

COUNTY OF CROOK

CERTIFICATE OF WATER RIGHT

THIS CERTIFICATE ISSUED TO

CITY OF PRINEVILLE
387 NE 3RD STREET
PRINEVILLE, OREGON, 97754

confirms the right to use of the waters of STEARNS WELL #2 and BARNEY WELL in the OCHOCO CREEK BASIN for MUNICIPAL USE.

The right has been perfected under Permit G-9154. The date of priority is OCTOBER 5, 1973. The right is limited to 1.56 CUBIC FEET PER SECOND (CFS), IN ANY COMBINATION FROM THE TWO WELLS, AND IS FURTHER LIMITED TO A MAXIMUM OF 1.02 CFS FROM STEARNS WELL #2 OR 1.02 CFS FROM BARNEY WELL, or its equivalent in case of rotation, measured at the well(s).

The wells are located as follows:

<u>ORIGINAL WELL</u>

STEARNS WELL #2: SW ¼ NE ¼, SECTION 4, T15S, R16E, W.M.; 1810.2 FEET SOUTH & 1151.5 FEET EAST FROM N 1/4 CORNER OF SECTION 4.

<u>ADDITIONAL WELL</u>

BARNEY WELL: NE ¼ NE ¼, SECTION 4, T15S, R16E, W.M.; 1315 FEET SOUTH & 1370 FEET EAST FROM N 1/4 CORNER OF SECTION 4.

The right shall conform to such reasonable rotation system as may be ordered by the proper state officer.

This is a final order in other than a contested case. This order is subject to judicial review under ORS 183.484. Any petition for judicial review must be filed within the 60 day time period specified by ORS 183.484(2). Pursuant to ORS 536.075 and OAR 137-004-0080 you may either petition for judicial review or petition the Director for reconsideration of this order. A petition for reconsideration may be granted or denied by the Director, and if no action is taken within 60 days following the date the petition was filed, the petition shall be deemed denied.

T-9762.RA

Certificate Number 83993

A description of the place of use under the right, and to which such right is appurtenant, is as follows:

1/4 1/4	SECTION	TOWNSHIP	RANGE, W.M.
SW NE	31	14 S	16 E
NE NW	31	14 S	16 E
NW NW	31	14 S	16 E
SE NW	31	14 S	16 E
SE SW	31	14 S	16 E
NE SE	31	14 S	16 E
NW SE	31	14 S	16 E
SW SE	31	14 S	16 E
SE SE	31	14 S	16 E
SW NW	32	14 S	16 E
NE SW	32	14 S	16 E
NW SW	32	14 S	16 E
SW SW	32	14 S	16 E
SE SW	32	14 S	16 E
NW SE	32	14 S	16 E
SW SE	32	14 S	16 E
NW NW	3	15 S	16 E
NW NE	4	15 S	16 E
SW NE	4	15 S	16 E
NE NW	4	15 S	16 E
NW NW	4	15 S	16 E
SW NW	4	15 S	16 E
NE NE	5	15 S	16 E
NW NE	5	15 S	16 E
SW NE	5	15 S	16 E
SE NE	5	15 S	16 E
NE NW	5	15 S	16 E
NW NW	5	15 S	16 E
SW NW	5	15 S	16 E
SE NW	5	15 S	16 E
NE SW	5	15 S	16 E
NW SW	5	15 S	16 E
NW SE	5	15 S	16 E
NE NE	6	15 S	16 E
NW NE	6	15 S	16 E
SE NE	6	15 S	16 E
NE NW	6	15 S	16 E
SE NW	6	15 S	16 E
NE SE	6	15 S	16 E

The water user shall maintain the meter or measuring device in good working order.

This certificate is issued to confirm an ADDITIONAL POINT OF APPROPRIATION approved by an order of the Water Resources Director entered NOVEMBER 22, 2004, and supersedes Certificate 57443, State Record of Water Right Certificates.

The quantity of water diverted at the additional point of appropriation, together with that diverted at the original point of appropriation, shall not exceed the quantity of water lawfully available at the original point of appropriation.

Water shall be acquired from the same aquifer (water source) as the original point of appropriation.

Water may be applied to lands which are not specifically described above, provided the holder of this right complies with ORS 540.510(3).

Issued MAR 21 2008

Phillip C. Ward, Director
Water Resources Department

Recorded in State Record of Water Right Certificates numbered 83993.

T-9762.RA

STATE OF OREGON

COUNTY OF CROOK

CERTIFICATE OF WATER RIGHT

THIS CERTIFICATE ISSUED TO

CITY OF PRINEVILLE
387 NE THIRD ST
PRINEVILLE, OR 97754

confirms the right to use the waters of STADIUM WELL in the Ochoco Creek Basin for MUNICIPAL USE.

This right was perfected under Permit G-11993. The date of priority is DECEMBER 14, 1990. The amount of water to which this right is entitled is limited to an amount actually used beneficially, and shall not exceed 0.604 CUBIC FOOT PER SECOND or its equivalent in case of rotation, measured at the well.

The well is located as follows:

Twp	Rng	Mer	Sec	Q-Q	Measured Distances
15 S	16 E	WM	5	NE SE	2122 FEET NORTH & 461 FEET WEST FROM SE CORNER, SECTION 5

The period of allowed use is year round.

A description of the place of use is as follows:

Twp	Rng	Mer	Sec	Q-Q
14 S	16 E	WM	31	NE NE
14 S	16 E	WM	31	NW NE
14 S	16 E	WM	31	SW NE
14 S	16 E	WM	31	SE NE
14 S	16 E	WM	31	NE NW
14 S	16 E	WM	31	NW NW
14 S	16 E	WM	31	SW NW
14 S	16 E	WM	31	SE NW
14 S	16 E	WM	31	NE SW
14 S	16 E	WM	31	NW SW
14 S	16 E	WM	31	SW SW
14 S	16 E	WM	31	SE SW
14 S	16 E	WM	31	NE SE
14 S	16 E	WM	31	NW SE

NOTICE OF RIGHT TO PETITION FOR RECONSIDERATION OR JUDICIAL REVIEW

This is an order in other than a contested case. This order is subject to judicial review under ORS 183.484 and ORS 536.075. Any petition for judicial review must be filed within the 60 day time period specified by ORS 183.484(2). Pursuant to ORS 183.484, ORS 536.075 and OAR 137-004-0080, you may petition for judicial review and petition the Director for reconsideration of this order. A petition for reconsideration may be granted or denied by the Director, and if no action is taken within 60 days following the date the petition was filed, the petition shall be deemed denied. In addition, under ORS 537.260 any person with an application, permit or water right certificate subsequent in priority may jointly or severally contest the issuance of the certificate within three months after issuance of the certificate.

Twp	Rng	Mer	Sec	Q-Q
14 S	16 E	WM	31	SW SE
14 S	16 E	WM	31	SE SE
14 S	16 E	WM	32	NE NE
14 S	16 E	WM	32	NW NE
14 S	16 E	WM	32	SW NE
14 S	16 E	WM	32	SE NE
14 S	16 E	WM	32	NE NW
14 S	16 E	WM	32	NW NW
14 S	16 E	WM	32	SW NW
14 S	16 E	WM	32	SE NW
14 S	16 E	WM	32	NE SW
14 S	16 E	WM	32	NW SW
14 S	16 E	WM	32	SW SW
14 S	16 E	WM	32	SE SW
14 S	16 E	WM	32	NE SE
14 S	16 E	WM	32	NW SE
14 S	16 E	WM	32	SW SE
14 S	16 E	WM	32	SE SE
14 S	16 E	WM	33	NE NE
14 S	16 E	WM	33	NW NE
14 S	16 E	WM	33	SW NE
14 S	16 E	WM	33	SE NE
14 S	16 E	WM	33	NE NW
14 S	16 E	WM	33	NW NW
14 S	16 E	WM	33	SW NW
14 S	16 E	WM	33	SE NW
14 S	16 E	WM	33	NE SW
14 S	16 E	WM	33	NW SW
14 S	16 E	WM	33	SW SW
14 S	16 E	WM	33	SE SW
14 S	16 E	WM	33	NE SE
14 S	16 E	WM	33	NW SE
14 S	16 E	WM	33	SW SE
14 S	16 E	WM	33	SE SE
15 S	16 E	WM	4	NE NE
15 S	16 E	WM	4	NW NE
15 S	16 E	WM	4	SW NE
15 S	16 E	WM	4	SE NE
15 S	16 E	WM	4	NE NW
15 S	16 E	WM	4	NW NW
15 S	16 E	WM	4	SW NW
15 S	16 E	WM	4	SE NW
15 S	16 E	WM	4	NE SW
15 S	16 E	WM	4	NW SW
15 S	16 E	WM	4	SW SW
15 S	16 E	WM	4	SE SW
15 S	16 E	WM	4	NE SE
15 S	16 E	WM	4	NW SE
15 S	16 E	WM	4	SW SE
15 S	16 E	WM	4	SE SE
15 S	16 E	WM	5	NE NE

Twp	Rng	Mer	Sec	Q-Q
15 S	16 E	WM	5	NW NE
15 S	16 E	WM	5	SW NE
15 S	16 E	WM	5	SE NE
15 S	16 E	WM	5	NE NW
15 S	16 E	WM	5	NW NW
15 S	16 E	WM	5	SW NW
15 S	16 E	WM	5	SE NW
15 S	16 E	WM	5	NE SW
15 S	16 E	WM	5	NW SW
15 S	16 E	WM	5	SW SW
15 S	16 E	WM	5	SE SW
15 S	16 E	WM	5	NE SE
15 S	16 E	WM	5	NW SE
15 S	16 E	WM	5	SW SE
15 S	16 E	WM	5	SE SE
15 S	16 E	WM	6	NE NE
15 S	16 E	WM	6	NW NE
15 S	16 E	WM	6	SW NE
15 S	16 E	WM	6	SE NE
15 S	16 E	WM	6	NE NW
15 S	16 E	WM	6	NW NW
15 S	16 E	WM	6	SW NW
15 S	16 E	WM	6	SE NW
15 S	16 E	WM	6	NE SW
15 S	16 E	WM	6	NW SW
15 S	16 E	WM	6	SW SW
15 S	16 E	WM	6	SE SW
15 S	16 E	WM	6	NE SE
15 S	16 E	WM	6	NW SE
15 S	16 E	WM	6	SW SE
15 S	16 E	WM	6	SE SE

The well shall be maintained in accordance with the General Standards for the Construction and Maintenance of Water Wells in Oregon. The works shall be equipped with a usable access port, and may also include an air line and pressure gauge adequate to determine water level elevation at all times.

The Director may require water level or pump test results every ten years.

If substantial interference with a senior water right occurs due to withdrawal of water from any well listed on this right, then use of water from the well(s) shall be discontinued or reduced and/or the schedule of withdrawal shall be regulated until or unless the Department approves or implements an alternative administrative action to mitigate the interference. The Department encourages junior and senior appropriators to jointly develop plans to mitigate interferences.

Failure to comply with any of the provisions of this right may result in action including, but not limited to, restrictions on the use, civil penalties, or cancellation of the right.

This right is for the beneficial use of water without waste. The water user is advised that new regulations may require the use of best practical technologies or conservation practices to achieve this end.

By law, the land use associated with this water use must be in compliance with statewide land-use goals and any local acknowledged land-use plan.

The right to the use of the water for the above purpose is restricted to beneficial use on the lands or place of use described; however, water may be applied to lands which are not specifically described above, provided the holder of this right complies with ORS 540.510(3).

This certificate is issued for a partial perfection of Permit G-11993 as described in OAR 690-320-0040 and by an order of the Water Resources Director entered AUG 03 2012, at Volume 88, Page 247.

The use of water shall be limited when it interferes with any prior surface or ground water rights.

Issued AUG 03 2012.

Dwight W. French
Water Right Services Administrator, for
Phillip C. Ward, Director
Water Resources Department

STATE OF OREGON

COUNTY OF CROOK

CERTIFICATE OF WATER RIGHT

THIS CERTIFICATE ISSUED TO

CITY OF PRINEVILLE
387 NE THIRD STREET
PRINEVILLE, OREGON 97754

confirms the right to use the waters of a WELL, for MUNICIPAL USE.

This right was perfected under Permit U-372. The date of priority is DECEMBER 8, 1950. The amount of water to which this right is entitled is limited to an amount actually used beneficially, and shall not exceed 0.75 CUBIC FOOT PER SECOND, or its equivalent in case of rotation, measured at the point of diversion.

The point of appropriation is located as follows:

TWP	RNG	MER	SEC	Q - Q	MEASURED DISTAMCES
15 S	16 E	WM	5	SW NW	375 FEET NORTH AND 370 FEET EAST FROM W ¼ CORNER OF SECTION 5

A description of the place of use to which this right is appurtenant is as follows:

TWP	RNG	MER	SEC	Q - Q
14 S	16 E	WM	31	NE SE
14 S	16 E	WM	31	NW SE
14 S	16 E	WM	31	SW SE
14 S	16 E	WM	31	SE SE
14 S	16 E	WM	32	NE SW
14 S	16 E	WM	32	NW SW
14 S	16 E	WM	32	SW SW
14 S	16 E	WM	32	SE SW
14 S	16 E	WM	32	NW SE
14 S	16 E	WM	32	SW SE
15 S	16 E	WM	5	NW NE
15 S	16 E	WM	5	SW NE
15 S	16 E	WM	5	NE NW
15 S	16 E	WM	5	NW NW
15 S	16 E	WM	5	SW NW
15 S	16 E	WM	5	SE NW
15 S	16 E	WM	6	NE NE
15 S	16 E	WM	6	NW NE
15 S	16 E	WM	6	SE NE

This certificate describes that portion of the water right confirmed by Certificate 22868, State Record of Water Right Certificates, NOT modified by the provisions of an order of the Water Resources Director entered March 11, 2011, and recorded at Special Order Volume 81, pages 757 to 759, canceling a portion of the water right. This certificate supersedes Certificate 22868.

The issuance of this superseding certificate does not confirm the status of the water right in regard to the provisions of ORS 540.610 pertaining to forfeiture or abandonment.

WITNESS the signature of the Water Resources Director, affixed MAR 1 1 2011.

Dwight French for
PHILLIP C. WARD, DIRECTOR

STATE OF OREGON

COUNTY OF CROOK

CERTIFICATE OF WATER RIGHT

THIS CERTIFICATE ISSUED TO

CITY OF PRINEVILLE
387 NE THIRD STREET
PRINEVILLE, OREGON 97754

confirms the right to use the waters of a WELL (OCHOCO HEIGHTS WELL NO.1), for MUNICIPAL USE.

This right was perfected under Permit U-140. The date of priority is MAY 20, 1942. The amount of water to which this right is entitled is limited to an amount actually used beneficially, and shall not exceed 0.8 CUBIC FOOT PER SECOND, or its equivalent in case of rotation, measured at the point of diversion.

The point of appropriation is located as follows:

TWP	RNG	MER	SEC	Q - Q
14 S	16 E	WM	32	NW SW

A description of the place of use to which this right is appurtenant is as follows:

TWP	RNG	MER	SEC	Q - Q
14 S	16 E	WM	31	SE
14 S	16 E	WM	32	SW
15 S	16 E	WM	5	NW
15 S	16 E	WM	5	NE SW
15 S	16 E	WM	5	NW SW
15 S	16 E	WM	6	NE NE
15 S	16 E	WM	6	NW NE
15 S	16 E	WM	6	SE NE

This certificate describes that portion of the water right confirmed by Certificate 75223, State Record of Water Right Certificates, NOT modified by the provisions of an order of the Water Resources Director entered SEP 14 2010, and recorded at Special Order Volume 81, pages 796 to 798, canceling a portion of the water right. This certificate supersedes Certificate 75223.

The issuance of this superseding certificate does not confirm the status of the water right in regard to the provisions of ORS 540.610 pertaining to forfeiture or abandonment.

WITNESS the signature of the Water Resources Director, affixed Sept. 14, 2010.

[signature] for
Phillip C. Ward, Director

Recorded in State Record of Water Right Certificates numbered 86558.

c75223-part cancel-rr.GLN

STATE OF OREGON

COUNTIES OF CROOK, DESCHUTES, AND JEFFERSON

CERTIFICATE OF WATER RIGHT

THIS CERTIFICATE ISSUED TO

U.S. BUREAU OF RECLAMATION
1917 MARSH RD
YAKIMA WA 98901

confirms the right to the use of water perfected under the terms of Permit S-55091. The amount of water used to which this right is entitled is limited to the amount used beneficially, and shall not exceed the amount specified, or its equivalent in the case of rotation, measured at the point of diversion from the source. The specific limits and conditions of the use are listed below.

APPLICATION FILE NUMBER: S-88402

SOURCE OF WATER: PRINEVILLE RESERVOIR, CONSTRUCTED UNDER PERMIT R-2223, A TRIBUTARY OF CROOKED RIVER

PURPOSE OR USE: FLOW AUGMENTATION FOR WILDLIFE AND FISH LIFE; AND TO ESTABLISH MITIGATION CREDITS UNDER THE DESCHUTES GROUND WATER MITIGATION PROGRAM FOR THE CITY OF PRINEVILLE

MAXIMUM VOLUME: 5100.0 ACRE-FEET EACH YEAR

PERIOD OF USE: OCTOBER 1 THROUGH SEPTEMBER 30

DATE OF PRIORITY: MARCH 10, 2017

POINT OF DIVERSION LOCATION:

Twp	Rng	Mer	Sec	Q-Q	Measured Distances
17 S	16 E	WM	11	SW NW	BOWMAN DAM - 2350 FEET SOUTH AND 650 FEET EAST FROM NW CORNER, SECTION 11

THE PLACE OF USE IS LOCATED AS FOLLOWS:

IN THE CROOKED RIVER, FROM BOWMAN DAM DOWNSTREAM TO LAKE BILLY CHINOOK

NOTICE OF RIGHT TO PETITION FOR RECONSIDERATION OR JUDICIAL REVIEW

This is an order in other than a contested case. This order is subject to judicial review under ORS 183.484 and ORS 536.075. Any petition for judicial review must be filed within the 60-day time period specified by ORS 183.484(2). Pursuant to ORS 183.484, ORS 536.075 and OAR 137-004-0080, you may petition for judicial review and petition the Director for reconsideration of this order. A petition for reconsideration may be granted or denied by the Director, and if no action is taken within 60 days following the date the petition was filed, the petition shall be deemed denied. In addition, under ORS 537.260 any person with an application, permit or water right certificate subsequent in priority may jointly or severally contest the issuance of the certificate within three months after issuance of the certificate.

Measurement Devices, and Recording/Reporting of Annual Water Conditions:

A. The water user shall maintain, in good working order, a suitable measuring device at each point of diversion.

B. The water user shall allow the watermaster access to the device; provided however, where any device is located within a private structure, the watermaster shall request access upon reasonable notice.

C. The water user shall keep a complete record of the volume of water diverted each month, and shall submit a report which includes water-use measurements to the Department annually, or more frequently as may be required by the Director. Further, the Director may require the water user to report general water-use information, including the place and nature of use of water under the right.

D. The Director may provide an opportunity for the water user to submit alternative measuring and reporting procedures for review and approval.

Mitigation Credit Conditions:

1. Issuance of this right awards 5100.0 mitigation credits to mitigation-credit project MP-222; the credits are assigned to the City of Prineville. These mitigation credits may be used to satisfy a mitigation obligation of a groundwater permit or certificate held by the City of Prineville in the General and/or Crooked River Zones of Impact.

2. The 5100.0 mitigation credits awarded under MP-222 may be used only by the City of Prineville, and cannot be conveyed to any other person or mitigation bank.

3. By January 1 of each calendar year, the U.S. Bureau of Reclamation (BOR) must provide notice to OWRD of how much water will be released from storage under this right during the following year. In the event that an annual volume of less than 5100.0 AF will be released for mitigation use by the City of Prineville under this right, the number of mitigation credits available that year will be reduced proportionally. The Department and BOR may jointly agree to an alternate forecasting schedule.

4. The BOR shall, in writing, notify the watermaster of the dates and volumes that water will be released from storage under this water right.

Failure to comply with any of the provisions of this right may result in action including, but not limited to, restrictions on the use, civil penalties, or cancellation of the right.

Where two or more water users agree among themselves as to the manner of rotation in the use of water and such agreement is placed in writing and filed by such water users with the watermaster, and such rotation system does not infringe upon such prior rights of any water user not a party to such rotation plan, the watermaster shall distribute the water according to such agreement.

The use may be restricted if the quality of the source stream or downstream waters decreases to the point that those waters no longer meet existing state or federal water quality standards due to reduced flows.

This right is for the beneficial use of water without waste. The water user is advised that new regulations may require the use of best practical technologies or conservation practices to achieve this end.

By law, the land use associated with this water use must be in compliance with statewide land-use goals and any local acknowledged land-use plan.

The use of water allowed herein may be made only at times when sufficient water is available to satisfy all prior rights, including prior rights for maintaining instream flows.

The right to the use of the water for the above purpose is restricted to beneficial use on the place of use described.

Issued NOV 28 2018.

Dwight French
Water Right Services Division Administrator, for
Thomas M. Byler, Director
Oregon Water Resources Department

ASR Limited License and UIC Authorization

BEFORE THE WATER RESOURCES DEPARTMENT
OF THE STATE OF OREGON

In the Matter of Aquifer Storage and Recovery) (ASR) Limited License Application #026,) CROOK County	FINAL ORDER APPROVING ASR TESTING

AUTHORITY

Oregon Revised Statute (ORS) 537.534 and Oregon Administrative Rule (OAR) 690-350-0020 establish the process by which an application for ASR testing under an ASR limited license may be submitted and approved. OAR 690-350-0010 describes general provisions for ASR under Oregon law.

BACKGROUND

On October 16, 2018, the Water Resources Department (Department) received an application for ASR Limited License #026 from the City of Prineville. The Department determined the application was incomplete on December 4, 2018. The application was resubmitted on December 21, 2018 and determined complete on January 18, 2019.

FINDINGS OF FACT

1. On October 16, 2018, the City of Prineville submitted an application for ASR Limited License #026. After re-submission, the Department determined it was complete on January 18, 2019.
2. The Department provided public notice of the application in the Department's weekly public notice on January 22, 2019. A 30-day comment period followed.
3. The Department sought comments and recommendations from the Oregon Department of Environmental Quality (DEQ) and the Oregon Health Authority's Drinking Water Services (OHA) related to water quality standards. Comments were received from DEQ and OHA supporting the issuance of ASR LL #026, and the license is conditioned accordingly.
4. The Department reviewed the groundwater information included with the application and found it met the application requirements as described in OAR 690-350-0020(3).
5. The Department reviewed the ASR application and testing plan. The authorization of ASR LL #026 is conditioned accordingly.
6. The Department evaluated the application and comments and determined:
    a. The proposed ASR testing will not impair or be detrimental to the public interest;
    b. The proposed ASR testing will produce information that will adequately describe the water quality and quantity response in the aquifer and at nearby wells and springs due to ASR activities; and
    c. The proposed testing will not expand the use under an existing water right.

APPEAL RIGHTS

This is an order in other than a contested case. This order is subject to judicial review under ORS 183.484. Any petition for judicial review must be filed within the 60-day time period specified by ORS 183.484(2). Pursuant to ORS 536.075 and OAR 137-004-0080, you may petition for judicial review or petition the Director for reconsideration of this order. A petition for reconsideration may be granted or denied by the Director, and if no action is taken within 60 days following the date the petition was filed, the petition shall be deemed denied.

7. The Department evaluated the application and comments and determined that the proposed use is consistent with ORS 537.534 and OAR 690-350-0020.

CONCLUSIONS OF LAW

The request to issue ASR Limited License #026 to allow ASR testing for five years is consistent with the requirements of ORS 537.534 and OAR 690-350-0020.

ORDER

Now, THEREFORE, it is ORDERED, ASR Limited License #026 shall be valid for five years from issuance of this Final Order, pursuant to ORS 537.534 and OAR 690-350-0020(5).

Except as modified by other provisions of this license, the licensee is authorized to pursue the project schedule, monitoring, and other features noted in the accepted ASR testing plan. The plan may be modified and approved pursuant to condition (3)(A). The project schedule in the ASR testing plan may be reasonably adjusted by the licensee to reflect the license issuance date or other delays. Features of the testing plan are provided in the application documents entitled:

GSI Water Solutions, Inc. (October 2018). Prineville Airport Area Aquifer Storage and Recovery (ASR) Limited License Application and Pilot Test Work Plan.

GSI Water Solutions, Inc. (December 21, 2018). Response to Completeness Review of ASR LL #026 Application: City of Prineville.

ASR testing must provide data and analysis that address the following:

- The appropriate target storage volume
- Loss of stored ASR water and natural water by virtue of ASR activities
- Water quality changes due to ASR activities
- Well construction sufficiency for ASR purposes
- Water level response in the ASR wells, aquifer, springs and nearby wells
- Accounting of ASR inputs, withdrawals, and storage
- Water quality testing needs
- Well hydraulics at the ASR wells

The licensee may divert up to 3,000 gallons per minute (gpm) from wells in the Ochoco Creek Basin. The diversion rate shall not exceed the total diversion rate authorized for each source.

Source/ Certificate	Point of Diversion
One well/ Certificate 86337	CROO 1540/ Lamonta: SOUTH 58 DEGREES 13 MINUTES EAST, 1447 FEET FROM NW CORNER, SECTION 31, T14S/R16E,W.M.
One well/ Certificate 22839	CROO 50181/Yancey: 1070 FEET NORTH, 1370 FEET EAST AND 55 DEGREES AND 0 MINUTES EAST FROM S¼ CORNER, SECTION 31, T14S/R16E, W.M.

Two wells/ Certificate 83993	CROO 3132/Barney Well: 1315 FEET SOUTH AND 1370 FEET EAST FROM N ¼ CORNER, SECTION 4, T15S/R16E, W.M. CROO 2083/Stearns #2: 1810.2 FEET SOUTH AND 1151.5 FEET EAST FROM N ¼ CORNER, SECTION 4, T15S/R16E, W.M.
One well/ Certificate 87714	CROO 184/Stadium Well: 2122 FEET NORTH AND 461 FEET WEST FROM SE CORNER, SECTION 5, T15S/R16E, W.M.
One well/ Certificate 86889	CROO 2121: 375 FEET NORTH AND 370 FEET EAST FROM W ¼ CORNER, SECTION 5, T15S/R16E , W.M.
Up to 25 wells/Permit G-18154	Wells located within Section 8, T15S/R16E, W.M. : CROO 54593/D-1: 422 FEET SOUTH AND 400 FEET EAST FROM NW CORNER CROO 54587/S-1: 471 FEET SOUTH AND 406 FEET EAST FROM NW CORNER CROO 54592/D-2: 585 FEET SOUTH AND 793 FEET EAST FROM NW CORNER POD 4/D-3: 516 FEET SOUTH AND 438 FEET EAST FROM NW CORNER POD 5/S-2: 561 FEET SOUTH AND 466 FEET EAST FROM NW CORNER POD 6/D-4: 601 FEET SOUTH AND 509 FEET EAST FROM NW CORNER POD 7/S-3: 621 FEET SOUTH AND 564 FEET EAST FROM NW CORNER POD 8/D-5: 657 FEET SOUTH AND 611 FEET EAST FROM NW CORNER POD 9/S-4: 694 FEET SOUTH AND 654 FEET EAST FROM NW CORNER POD 10/D-6: 717 FEET SOUTH AND 700 FEET EAST FROM NW CORNER POD 11/S-5: 789 FEET SOUTH AND 731 FEET EAST FROM NW CORNER POD 12/D-7: 840 FEET SOUTH AND 759 FEET EAST FROM NW CORNER POD 13/S-6: 888 FEET SOUTH AND 784 FEET EAST FROM NW CORNER POD 14/D-8: 952 FEET SOUTH AND 799 FEET EAST FROM NW CORNER POD 15/S-7: 1004 FEET SOUTH AND 809 FEET EAST FROM NW CORNER POD 16/D-9: 1061 FEET SOUTH AND 815 FEET EAST FROM NW CORNER POD 17/S-8: 1116 FEET SOUTH AND 808 FEET EAST FROM NW CORNER POD 18/D-10: 1179 FEET SOUTH AND 796 FEET EAST FROM NW CORNER POD 19/S-9: 1232 FEET SOUTH AND 800 FEET EAST FROM NW CORNER

Up to 25 wells/Permit G-18154	POD 20/D-11: 1267 FEET SOUTH AND 836 FEET EAST FROM NW CORNER POD 21/S-10: 1320 FEET SOUTH AND 869 FEET EAST FROM NW CORNER POD 22/D-12: 1372 FEET SOUTH AND 879 FEET EAST FROM NW CORNER POD 23/S-11: 1420 FEET SOUTH AND 896 FEET EAST FROM NW CORNER POD 24/D-13: 1479 FEET SOUTH AND 909 FEET EAST FROM NW CORNER POD 25/S-12: 1527 FEET SOUTH AND 949 FEET EAST FROM NW CORNER
Certificate 86558/ T-13030	CROO 1577/Ochoco Heights Well 1: 1711 FEET NORTH AND 650 FEET EAST FROM SE CORNER SECTION 32, T14S/R16E, W.M. The following 4 proposed POAs are pending approval of T-13030: NEW OCHOCO HEIGHTS WELL/ NOT YET DRILLED: 1677 FEET NORTH AND 680 FEET EAST FROM SW CORNER SECTION 32, T14S/R16E, W.M. INDUSTRIAL PARK WELL/NOT YET DRILLED: 298 FEET NORTH AND 1908 FEET WEST FROM NW CORNER SECTION 31, T14S/R15E, W.M. STRYKER PARK WELL/NOT YET DRILLED: 277 FEET SOUTH AND 812 FEET EAST FROM SW CORNER SECTION 32, T15S/R16E, W.M. JUNIPER WELL/NOT YET DRILLED: 97 FEET NORTH AND 2493 FEET EAST FROM SW CORNER SECTION 32, T14S/R16E, W.M.

The licensee may store up to 870 million gallons in an aquifer within the Deschutes Formation. With the approval of individual ASR well testing plans, up to five wells may be authorized. The maximum injection rate is 1,100 gallons per minute (gpm) per well. The maximum recovery rate is 1,400 gpm per well at the same five wells. The maximum storage duration is five years under this license.

Five ASR wells may be authorized at the following locations:

Well Name	Well Log ID	Well Location
ASR 1-Heliport Production Well	CROO 54191	1070 FEET NORTH AND 1710 FEET EAST FROM THE SW CORNER OF SECTION 11, T15S/R15E
ASR 2	(not yet drilled)	1691 FEET NORTH AND 462 FEET EAST FROM THE SW CORNER OF SECTION 11, T15S/R15E
ASR 3	(not yet drilled)	2569 FEET NORTH AND 327 FEET EAST FROM THE SW CORNER OF SECTION 11, T15S/R15E
ASR 4	(not yet drilled)	1141 FEET SOUTH AND 83 FEET EAST FROM THE NW CORNER OF SECTION 11, T15S/R15E

Well Name	Well Log ID	Well Location
ASR 5	(not yet drilled)	442 FEET NORTH AND 86 FEET WEST FROM THE SE CORNER OF SECTION 3, T15S/R15E

The ASR testing project shall be operated according to the following conditions, pursuant to OAR 690-350-0020(5). Failure to comply with any of the provisions of this license may result in action including, but not limited to, revocation of the license.

1) **Notice Prior to Injection and Recovery**. The licensee shall give notice, in writing, to the watermaster not less than 15 days in advance of either initiating any injection under the license or recovering stored water. The injection notice shall include the license number, the location of the injection source water diversion, the quantity of water to be diverted from that source, the time of injection, and the place of injection. The recovery notice shall include the license number, the location of the recovery well(s), the time of recovery, and the quantity of water to be recovered.

2) **Record of Use**. The licensee shall maintain a record of injection and recovery, including the total number of hours and times of injection and recovery and the total metered quantity injected and recovered. The record of use may be reviewed by Department staff upon request.

3) **Modification/Revocation**. The Department shall notify the licensee in writing and allow the licensee to respond when considering the following actions:

(A) The Director may modify the ASR license for any of the following reasons:

(i) to reflect changes in Oregon Health Authority Drinking Water Services (OHA) and Oregon Department of Environmental Quality (DEQ) water quality or treatment standards;

(ii) to address needed technological changes as requested by DEQ or OHA to minimize constituents regulated under OAR 333-61-030 (ORS 448.131 and 448.273) or OAR 340-40 (ORS 468B.165);

(iii) to address a written request from the applicant for minor adjustments to the authorization in the license.

(B) The Director may revoke, suspend or modify the ASR license for any of the following reasons:

(i) to prevent or mitigate injury to other water rights, instream water rights, minimum perennial streamflows or aquifer water quality;

(ii) to address any other unintended, injurious effects of the ASR activity; or

(iii) failure to maintain compliance with all conditions of this license.

(C) The Department may offer an additional public comment opportunity consistent with the notice and comment provisions of OAR 690-350-020 prior to modifying the license.

4) **Priority/Protection**. This license does not receive a priority date and is not protected under ORS 540.045. The diversion of water for this ASR testing retains the priority date and protection of the source water rights.

5) **Compliance with Other Laws**. The injection of acceptable water into the aquifer as well as its storage and recovery under this license shall comply with all applicable local, state or federal laws. This shall include, but not be limited to, compliance with the Oregon Department of Environmental Quality's Underground Injection Control registration program as authorized under the Safe Drinking Water Act (40 CFR 144.26). Also, all pilot test discharges to waterways must be covered by a DEQ National Pollution Discharge Elimination System (NPDES) permit.

6) **Detailed Testing Plans**. The licensee shall submit a detailed testing plan for each injection well as the project develops. The plan shall include, but is not limited to, water quality and water level monitoring activities, precise well locations and well construction information. The plan shall be sealed and signed by a professional(s), registered or allowed under Oregon law, to practice geology. The licensee shall obtain the Department's approval of a detailed plan before injection testing at any well may begin. The Department may approve, condition or reject a plan. As the project installs new ASR wells, the Department will evaluate the water level monitoring plan's adequacy to describe the project's impact to the aquifer. If the Department determines the monitoring network is insufficient at that time, identification or installation of a dedicated observation well of similar depth and construction to the ASR well(s) will be required before approval of further testing.

7) **Well Construction.** Injection and recovery wells shall be continuously cased and continuously sealed into a competent layer directly above the target aquifer. The wells shall meet applicable well construction standards (e.g., OAR 690-200 and OAR 690-210). Following well drilling to total depth, the wells shall be thoroughly developed to remove cuttings and drilling fluids. The licensee or their agent shall consult with a Department Hydrogeologist and the Department's Well Construction and Compliance Section before well completion to obtain approval of the proposed final casing and seal depth. The wells shall be designed to limit the irretrievable loss of injected water to unsaturated zones.

8) **Cuttings**. During drilling of new project wells, the licensee shall collect cuttings at a minimum of 10 foot intervals and at major formation changes. The licensee shall provide a split of the cuttings to the Department.

9) **Well Tag Condition for Licensee Wells.** Prior to testing, the licensee shall ensure that their wells have been assigned a Department Well Identification Number (Well ID Number). A tag showing the Well ID Number shall be permanently attached to the well. If a well does not have a Well ID Number, the licensee shall apply for one from the Department and attach it to the well.

10) **Water Quality Conditions and Limits**.

(A) The licensee shall minimize, to the extent technically feasible, practical and cost-effective, the concentration of constituents in the injection source water that are not naturally present in the aquifer;

(B) Except as otherwise provided in (C) of this condition, if the injection source water contains constituents regulated under OAR 333-61-030 (ORS 448.131 and 448.273) or OAR 340-40 (ORS 468B.165) that are detected at greater than 50 percent of the established levels (MCLs or MMLs in the cited rules), the licensee shall employ technically feasible, practical and cost-effective methods to minimize concentrations of such constituents in the injection source water;

(C) Constituents that have a secondary contaminant level or constituents that are associated with disinfection of the injection source water may be injected into the aquifer according to the standards established under OAR 333-61-030 (ORS 448.131 and 448.273);

(D) The Department may, based upon valid scientific data, further limit certain constituents in the injection source water if the Department finds that those constituents will interfere with or pose a threat to the maintenance of the water resources of the state for present or future beneficial uses; and,

(E) If during the course of ASR testing, a constituent regulated under OAR 333-61-030 (ORS 448.131 and 448.273) or OAR 340-40 (ORS 468B.165) is detected above the 50 percent level prescribed in condition (10)(B), the licensee shall immediately stop injection activities upon receipt of lab data and notify the Department within five days. Injection may recommence after constituent levels return to acceptable levels pursuant to (B) or (C) of this condition.

11) **Water Quality Monitoring.** The licensee shall sample and analyze injection, receiving and recovered water as described in the currently approved testing plan.

12) **Water Level Monitoring.**
(A) The licensee shall monitor water levels in wells in the manner described in the currently approved testing plan.

(C) Transducer data shall be verified with quarterly manual measurements if an e-tape can be lowered past obstructions to the water level. In the event a pump is pulled, or in the case of a newly drilled project well, the well shall be equipped with an unobstructed, dedicated measuring tube pursuant to Figure 200-5 in OAR 690-200.

13) **Recovery.** The amount of stored water available for recovery is based on the following factors:
(A) Available stored water is determined on a well-by-well basis.

(B) The following two-step accounting method applies to each annual cycle:

(i.) The licensee may recover up to 95 percent of the quantity injected during the same water year.

(ii.) At the end of each water year, 95 percent of the storage account balance is carried over to the next year. The storage account balance consists of the sum of water not recovered within the water year and water carried over from previous testing cycles.

(D) Any water withdrawn from an ASR well identified in this license shall first be debited against the quantity available in the aquifer by virtue of ASR storage. When the ASR storage is depleted at an ASR well, any water withdrawn from an ASR well shall be considered a draft of natural groundwater, thereby requiring separate or additional authorization. At no time does this license authorize withdrawal of more water than was credited by injection.

(C) The availability of stored water is a running account that is subject to determination at any time.

14) **Use of Recovered Water**. The licensee shall use recovered water for the purposes described in the appropriate source water authorization.

15) **Annual Reporting.**
(A) Except as otherwise noted, the licensee shall provide the Department a written report of the results of ASR testing for the previous water year by February 15th. The first report shall be due in 2020 and include results from water year 2019. Annual reports shall be sealed and signed by a professional(s) registered or allowed, under Oregon law, to practice geology. The report shall:

- Include the data collected during the water year
- Analyze those data to show the ASR project impacts on the aquifer
- Evaluate loss of stored ASR water and natural water by virtue of ASR activities
- Indicate the testing and development progress made under the terms of the license
- Account for the injection of stored water, withdrawals of stored and natural water, and the storage account balance at the ASR well(s)

(B) The licensee shall provide the following to the Department:

(i) Submission of any and all hydrogeologic data collected and reports developed for the project, including, but not limited to, cuttings analysis, video logs, geophysical logs, aquifer tests, and step tests.

(ii) Submission of digital water level data for all ASR wells and any other wells measured in conjunction with the project (in a Department specified format), including annual report data.

(iii) Submission of annual reports with locations and elevations for all project wells (actual locations of built wells and proposed locations for proposed wells) and locations and elevations for all non-project wells that have been used for collecting water levels or other data pertinent to the project (in a Department specified format).

(iv) Notification in the annual report of any changes in well construction.

(v) Associating all project well data with the Department Well Identification Number (Well ID Number), the Department Well Log ID, if available, and the project Well Name.

16) **Protection for Existing Users**. In the event of conflicts with existing appropriators, the licensee shall conduct all testing to mitigate the injurious effects. In addition, the licensee shall cooperate with the efforts of the Department to protect existing water rights and the water quality of existing users that rely upon the receiving aquifer and the injection source water.

17) **Other Measures**. The licensee shall take additional measures, as appropriate, to address ASR-related issues such as landslide activation, seepage, streamflow increases, interference with nearby wells, aquifer storage limitations, and water quality protection. Further, the licensee shall notify the Department upon resolution of such issues. The licensee shall resolve these issues prior to submittal of an ASR permit application.

18) **Access.** The licensee shall allow reasonable access to ASR facilities to the watermaster and other state officials with an oversight role in this ASR project.

19) **Carryover Storage**. At the end of testing under this license, the licensee shall provide an accounting to the Department of the residual stored water based on the methods of determination given in this license. The Department shall consider this residual for carryover to a permanent ASR permit based on information which discloses the aquifer's ability to retain stored water.

20) **License Renewal**. The license may be renewed if the licensee demonstrates to the Director's satisfaction that further testing is necessary and that the licensee complied with the terms and conditions of the license.

Dated at Salem, Oregon on April 24, 2019.

Dwight French
Water Rights Services Division Administrator
for Thomas M. Byler, Director
Water Resources Department

This order was produced by Jen Woody. If you have questions about the Department or any of its programs please contact our Customer Service Group at 503-986-0801 or 503-986-0810. Address all other correspondence to: Groundwater Section, Oregon Water Resources Department, 725 Summer St NE, Suite A, Salem OR 97301-1266, Fax: 503-986-0902.

Bruce Brody-Heine

Subject: FW: UIC Authorization: #15746/Prineville ASR, 4735 SW Airport Road, Prineville OR 97754

From: ROBINSON Dory [mailto:Dory.ROBINSON@state.or.us]
Sent: Thursday, October 25, 2018 8:50 AM
To: Matt Kohlbecker <mkohlbecker@gsiws.com>; 'eklann@cityofprineville.com' <eklann@cityofprineville.com>
Cc: SANDOZ Derek <Derek.SANDOZ@state.or.us>; RICHERSON Phil <Phil.Richerson@state.or.us>
Subject: UIC Authorization: #15746/Prineville ASR, 4735 SW Airport Road, Prineville OR 97754

Dear Eric Klann and Matt Kohlbecker,

This email confirms that the aquifer storage and recovery underground injection control (UIC) system at Prineville ASR, 4735 SW Airport Road, Prineville OR 97754 has met the requirements for authorization by rule, and is "rule authorized" by the Department of Environmental Quality. The UIC system has been assigned facility ID number 15716. Specifically, the following UICs are rule-authorized:

Applicant UIC ID	DEQ UIC ID
ASR-1	15746-01

If ownership of this property is transferred in the future, you must fill out the "Name Change and/or Transfer of Registration and Authorization" form, available online at: http://www.deq.state.or.us/wq/uic/forms.htm

Please feel free to call or email with questions,

Dory Robinson
Northwest Region Water Quality Permit Coordinator
Oregon Department of Environmental Quality
700 NE Multnomah St. Suite 600 | Portland, OR | 97232
P: 503-229-5623 | F: 503-229-5787
Pronouns:Her, She

DEQ
State of Oregon
Department of Environmental Quality