TECHNICAL MEMORANDUM
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To:	Santa Cruz Water Department	Date:	October 18, 2019
Attention:	Isidro Rivera, P.E. Associate Civil Engineer	Project No:	15-0111
Copy to:			
From:	Robert C. Marks, P.G., C.Hg. Principal Hydrogeologist		
Subject:	Santa Cruz ASR Project – Phase 1 Feasibility Investigation; Task 1.4 - ASR Pilot Test Work Plan for Beltz 8 **DRAFT**		

INTRODUCTION

Presented in this TM is a detailed Work Plan for implementing an Aquifer Storage and Recovery (ASR) pilot test program at the Santa Cruz Water Department (SCWD) Beltz 8 well. Beltz 8 is located in the Santa Cruz Mid-County Groundwater Basin (MCGB) and is screened in the so-called A Unit of the Purisima Aquifer system. The location of the subject well is shown on **Figure 1** and an As-Built Schematic of the well is shown on **Figure 2**. The overall purpose of the Work Plan is to develop and present the information required to scope, budget, permit and implement an ASR pilot test program at Beltz 8. The Work Plan consists of the following main sections:

- Permitting Requirements
- Site Preparation Details
- ASR Pilot Test Program
- Sampling and Analysis Plan
- Preliminary Project Schedule

BACKGROUND

The SCWD is investigating the feasibility of an (ASR) project to meet projected shortfalls in City water supplies during extended droughts. The project would involve the diversion of “excess”[1] winter and spring flows from the San Lorenzo River (SLR) via the Tait Street and/or Felton Diversion facilities, which would be treated to potable standards at the Graham Hill Water Treatment Plant (GHWTP), then conveyed through the existing (and/or improved) water distribution system(s) to ASR wells located in the Santa Cruz Mid-County Groundwater Basin (MCGB) and/or the Santa Margarita Groundwater Basin (SMGB) for injection, storage and later recovery when needed.

[1] “Excess” flows are those flows that exceed SCWD demands and in-stream flow requirements and are within City water rights.

The SCWD's ASR Project is being implemented in phases, as follows:

- Phase 1 – Technical Feasibility Investigation
- Phase 2 – ASR Pilot Testing
- Phase 3 – Permanent Project Design, Permitting, and Implementation

The Phase 1 Technical Feasibility Investigation is near completion (groundwater modeling is ongoing) and Phase 2 ASR Pilot Testing has been successfully implemented at the existing Beltz 12 well (the test program was completed in July 2019). Based on the favorable results of both the Phase 1 Technical Feasibility Investigation and Phase 2 ASR Pilot Testing at Beltz 12, the SCWD desires to further advance the Phase 2 ASR Pilot Testing program to the existing Beltz 8 well.

The overall objective of the Phase 2 pilot testing is to field verify the findings developed from Phase 1 and empirically determine specific hydrogeologic and water quality factors that will allow a technical and economic viability assessment of ASR technology at the Beltz 8 well. If feasible, the data gathered may also be used to complete CEQA documentation for a full scale or permanent ASR project and provide design basis information for the permanent project.

PURPOSE

The primary purpose of the Beltz 8 ASR Pilot Test is to field demonstrate the potential application of ASR in the A Unit of the Purisima Aquifer system in the MCGB. The data will be used to assess both the economic and logistical viability of ASR and will provide the basis for the design, environmental planning, and permitting for a long-term full-scale ASR project. Primary issues to be investigated in the ASR pilot test include the following:

- Determination of well efficiency and specific capacity and injectivity
- Evaluation of injection well plugging rates (both active and residual)
- Determination of optimal rates, frequency, and duration of backflushing to maintain injection capacity
- Determination of long-term sustainable injection rates
- Determination of local aquifer response to injection at Beltz 8
- Monitor ion exchange and redox reactions
- Evaluate water-quality changes during aquifer storage and recovery pumping
- Monitor Disinfection Byproducts (DBPs) Trihalomethanes (THM) and Haloacetic Acid (HAA) ingrowth and degradation during aquifer storage
- Monitor recovery efficiencies (with particular emphasis on manganese concentrations)

FINDINGS

PERMITTING REQUIREMENTS

The State Water Resources Control Board (SWRCB) has adopted general waste discharge requirements for ASR projects that inject drinking water into groundwater (Order No. 2012-0010-DWQ or ASR General Order). The ASR General Order provides a consistent statewide regulatory framework for authorizing both pilot ASR testing and permanent ASR projects, and the Beltz 8 ASR Pilot Test will be permitted under the ASR General Order. Oversight of these regulations is done through the Regional Water Quality Control Boards (RWQCBs) and obtaining coverage under the General ASR Order requires the preparation and submission of a Notice of Intent (NOI) application package to the local RWQCB. The NOI package for the Beltz 8 ASR pilot test program will be modeled on the NOI submitted to the Central Coast RWQCB for the Beltz 12 ASR pilot test, and include the following components:

- NOI application fee
- Complete Form 200 (RWQCB general information form for Waste Discharge Requirements or NPDES Permit)
- Technical Report
- US EPA Underground Injection Control registration
- CEQA compliance documentation

The main body of the NOI package consists of the Technical Report, which would be based largely on the findings developed from the Phase 1 Investigation, including the ASR pilot test Work Plan presented herein. The Beltz 8 well will need to be registered as a Class V Injection Well[2] with the US EPA Underground Injection Control (UIC) Program. This registration is a straight-forward process done via the EPA's on-line UIC Inventory Form.

In addition, the ASR General Order allows that a pilot test may be exempt from provisions of the California Environmental Quality Act (CEQA) under CEQA Guidelines Section 15306, which exempts basic data collection that does not result in a serious or major disturbance to an environmental resource. Accordingly, the City should plan to file a Notice of Categorical Exemption (CE) from CEQA for the ASR pilot test under CEQA Guidelines Section 15306 (including the drilling on an on-site monitoring well).

SITE PREPARATION DETAILS

The Beltz 8 well facility will need some preparatory work performed in order to maximize the potential for a successful the ASR pilot test program, including the following activities:

- Installation of a proximate monitoring well;
- Rehabilitation of the Beltz 8 well, and;

[2] A Class V well is used to inject non-hazardous fluids underground.

- Installation of various temporary site improvements at the Beltz 8 facility.

Each of these activities are described in further detail in the following sections.

Monitoring Well

A proximate monitoring well that is located within the radius of injected water predicted to surround the subject well (i.e., within the injection "bubble") during the ASR pilot test well and that is completed in the same aquifer zones as the pilot test well is needed for monitoring of both water-level responses and water-quality interactions during the ASR pilot test program. Such a monitoring is particularly important for the following investigative issues:

- Monitoring or ion exchange and redox reactions;
- Evaluation of water-quality changes during aquifer storage and recovery pumping, and;
- Monitoring of DBPs ingrowth and degradation during aquifer storage.

The existing monitoring well at the Beltz 8 facility is a converted former production well (Beltz 6); however, the screened interval of this existing monitoring well only partially penetrates the aquifer that is screened by Well 8 and, therefore, would not provide adequately representative data for the test program goals. Accordingly, a new monitoring well will need to be drilled at the site prior to initiating the ASR pilot test program and having the following key parameters:

- Located within 80 feet of Beltz 8 (i.e., within the planned radius of injected water influence);
- Completed to a total depth of approximately 190 feet with screens placed between depths of approximately 100 to 180 feet (i.e., matching the Well 8 screened interval);
- Constructed of 2-inch-diameter (minimum) Schedule 40 PVC casing and machine-cut horizontal slot screen;
- Sealed to a depth of approximately 80 feet, and;
- Completed in a grade-level traffic-rated monitoring well vault.

The proposed MW location is shown on **Figure 3** (note: the proposed MW location shown is approximate and may change slightly depending on logistical considerations at the time of drilling but is anticipated to be within 25 feet of the shown location).

Well Rehabilitation

Beltz 8 was drilled in 1998. Following its construction, a constant-rate pumping test was performed, and the well was pumped at a rate of approximately 1,200 gallons per minute and it displayed a 24-hour specific capacity[3] of approximately 22.8 gpm per foot of drawdown (gpm/ft). It is our understanding that the well has not been rehabilitated since its construction, and the performance has declined significantly with the recent specific capacity at 9.8 gpm/ft[4]. This represents an approximate 60 percent decline in performance.

Performing an ASR pilot test at the well with its current performance would be limited in terms of the injection and extraction rates that could be achieved and would not be representative of the ASR capacity that the aquifer system at the site is capable of supporting; therefore, it is recommended that the well undergo formal rehabilitation to restore some of the lost performance and maximize the ASR capacity for the pilot test program. To be effective, the rehabilitation program should consist of both mechanical and chemical well rehabilitation techniques and consist of the following tasks:

1. Performance of pre-rehabilitation pumping test
2. Removal of the existing pump and appurtenances from the well
3. Pre-rehabilitation downhole video surveying
4. Nylon brushing the well screen
5. Bailing the well to bottom
6. Installation of temporary piping, valving and storage tanks to allow for solids settling and acid neutralization of the discharge water
7. Pre-chemical simultaneous air-lift pumping/zone swabbing of the well screen
8. Chemical treatment with combination of hydrochloric and glycolic acids
9. Periodic agitation by “dry” swabbing screen while chemicals remain in well for 48 hours
10. Post-chemical simultaneous air-lift pumping/zone swabbing of the well screen
11. Post-rehabilitation acceptance downhole video surveying
12. Installation of temporary pump and appurtenances (this pump will remain in the well for the ASR pilot test)
13. Well disinfection and flushing
14. Performance of post-rehabilitation pumping test

Project discharges would be routed to the nearest storm drain inlet and maintained in compliance with the existing Statewide NPDES Permit for Drinking Water System Discharges (Order WQ 2014-0194-DWQ, General Order No. CAG140001).

[3] Specific capacity is the ratio of discharge rate to drawdown, typically expressed in terms of gallons per minute per foot of drawdown (gpm/ft). The value is useful for tracking the performance of a given well over its service life and comparing performance between wells.
[4] Pueblo Water Resources, Inc., *Santa Cruz ASR Project – Phase 1 Feasibility Investigation, Task 1.2 Site-Specific Injection Capacity Analysis*, Technical Memorandum prepared for Santa Cruz Water Department, dated May 11, 2017.

It is noted that the Beltz 8 well has not been rehabilitated since its construction nearly 20 years ago and the performance has declined significantly (by approximately 60 percent). Formal well rehabilitation of municipal production wells is typically recommended to be performed every 5 years or when the performance (as measured by specific capacity) has declined by 25 percent from baseline, whichever occurs first. Given these conditions, it is unlikely that rehabilitation will be capable of restoring 100 percent of the lost performance and capacity at this stage of the well's service life. For planning purposes, therefore, it is assumed that rehabilitation will restore 50 percent of the lost capacity. This assumption has been utilized in estimating the injection and extraction capacities for the ASR pilot test program (discussed in a below section).

Site Improvements

Several temporary modifications will be necessary at the Beltz 8 site for implementation of the ASR pilot test, including the following:

- Removal of the existing 20 HP pump assembly and installation of a temporary 30 HP pump and injection drop tubes.
- Connection of temporary injection supply pipeline to the City's distribution system as the source of the injection water (injectate).
- Setup of backflush water and recovered test water pipelines
- Setup of connection to existing on-site reclaim tanks for backflush water solids settling and dichlorination prior to discharge to storm drain

A schematic of the preliminary piping plan is shown in **Figure 4**, which shows the locations of various valves, meters, sampling ports, pressure gauges, etc., in addition to the direction of flows during the recharge and pumping phases of the test program.

Based on the results of the revised site-specific injection capacity analysis for Beltz 8 incorporating an assumed improvement in well performance from well rehabilitation (as noted above), a nominal injection rate of **400 gpm** is recommended for planning purposes. For an injection rate of 400 gpm, a minimum backflush pumping capacity of 800 gpm will be required (i.e., twice the rate of injection) in order to limit well plugging during the test program (refer to the Task 1.2 – Site-Specific Injection Capacity Analysis TM for a discussion of backflushing requirements).

The existing 20 HP pump assembly in Beltz 8 is only rated for approximately 400 gpm @ 100 ft Total Dynamic Head (TDH). The test program will require a pump that is rated for 800 gpm @ 100 ft of TDH for backflushing of the well during the pilot test; therefore, a temporary pump assembly will need to be installed in Beltz 8 with the following general specifications:

1. Removal of the existing 20 HP pump assembly (and cleaned and inspected by the pump contractor).
2. Fabrication of special temporary wellhead seal plate.

3. Installation of temporary submersible pump (Grundfos 800S300-1 [30 HP], or approved equal) set to a depth of approximately 190 ft with a cooling shroud.
4. Installation of three (3) 2-in-dia Sch 40 PVC injection drop tubes. Injection drop tubes shall be F480 flush-threaded set to a depth approximately 80 ft. Special orifice caps for each tube will be provided by PWR for injection flow control.
5. Installation of two (2) 1-in-dia Sch 40 PVC water-level sounding tubes set to a depth of approximately 190 ft.

ASR PILOT TEST PROGRAM

ASR operations generally consist of three steps:

1. Injection of potable-quality drinking water into the aquifer;
2. Storage of the injected/recharged water within the aquifer, and;
3. Recovery of the stored water.

The ASR pilot test program for Beltz 8 presented herein is modeled on the program that was successfully implemented at Beltz 12 but modified for the Beltz 8 site-specific conditions. The structure of the ASR pilot test program includes numerous incremental steps of ASR operations to provide multiple checkpoints in the event that pilot operations deviate significantly from the predicted responses. The program will generally involve three repeated ASR cycles of operations and monitoring, each of larger volume and duration than the preceding cycle, so that if adverse conditions are encountered at any point, the program can be adjusted, if needed.

Summary of ASR Cycles

The ASR pilot test program generally consists of a 1-day hydraulic “pre-test” to establish injection system hydraulics, followed by three (3) repeated cycles of injection-storage-recovery, with each cycle of greater duration and volume. A robust dataset of aquifer response and water quality information will be developed, while minimizing the risk of adverse effects to the well or aquifer system. A summary of the planned ASR cycles is presented in **Table 1** below:

Table 1. Summary of ASR Cycles

ASR Cycle No.	Injection					Storage	Recovery				
	Period (days)	Rate (gpm)	Total Volume (mg)	Total Volume (af)	Radius (ft)	Period (days)	Period (days)	Rate (gpm)	Volume (mg)	Volume (af)	Discharge Location
1	1	400	0.58	1.77	18	2	1	700	1.01	3.09	Storm Drain
2	7	400	4.03	12.4	46	14	6	700	6.05	18.6	Storm Drain
3	30	400	17.3	53.0	96	60	30	400	17.3	53.0	Distribution

Total Active Duration (days): 151
Total Injection Volume (mg): 21.9
Total Recovery Volume (mg): 24.3

As shown, the amount of water injected during each ASR Cycle will vary from approximately 0.6 mg (1.8 af) to 17 mg (53 af), with aquifer storage periods ranging from 2 to 60 days before the water is recovered. Recovery volumes for Cycles 1 and 2 are approximately 150 percent of the previously injected water and will vary from approximately 1 mg (3.1 af) to 7 mg (22 af). The recovery volume for Cycle 3 will be the same as the injected volume (17 mg / 53 af) and will essentially mimic a permanent project typical ASR cycle.

Although no adverse reactions were predicted by the Task 1.3 Geochemical Interaction Analysis[5], it is planned to discharge recovered water during ASR Cycles 1 and 2 to the storm drain system to allow for the collection and analysis of water-quality data to ensure that no adverse reactions are occurring during aquifer storage that would affect the potability of recovered water. It is our understanding that the water-quality results from Cycles 1 and 2 will need to be provided to the local Department of Drinking Water (DDW) for their review and approval to pump Cycle 3 recovery flows into the SCWD distribution system.

Assuming no adverse reactions are observed during ASR Cycles 1 and 2, the temporary test pump and injection drop tubes will be removed from the well (following thorough backflushing of the well) and the permanent pump assembly reinstalled prior to the recovery period of Cycle 3, allowing the well to be operated under normal conditions (which includes manganese treatment prior to distribution). It is also noted that the recovery rate for ASR Cycle 3 is limited to 400 gpm (refer to **Table 1 above**), compared to 700 gpm (approximately 1 mgd) for Cycles 1 and 2. This is due to the capacity of the permanent pump and manganese treatment system at the Beltz 8 facility.

The primary test objectives for each ASR Cycle are summarized below:

<u>ASR Cycle 1</u>

- Establish short-term injection hydraulics
- Monitor short-term ion exchange reactions

[5] Assuming GHWTP water is maintained at pH of 7.6 or less to prevent calcite precipitation.

<u>ASR Cycle 2</u>

- Measure well plugging rates (active and residual)
- Evaluate backflushing efficacy
- Monitor longer-term ion exchange reactions
- Monitor redox reactions
- Evaluate water chemistry changes during storage
- Monitor recovery efficiency (the percentage of recharged water that is recovered during each cycle)
- Monitor DBPs during recovery
- Define volume of potential "buffer zone" around ASR well

<u>ASR Cycle 3</u>

- Evaluate longer-term well performance and plugging rates
- Monitor injected water quality stability during storage
- Monitor DBP ingrowth/degradation during storage
- Monitor recovered water for re-chlorination and DBP reformation
- Determine economic factors of permanent ASR operations

The total duration of the ASR pilot test program is anticipated to require approximately 6 months and is tentatively scheduled to begin in February 2019 (refer to the preliminary schedule presented in a following section).

Specific procedures for well injection and backflushing during the Beltz 8 ASR Pilot Test Program are outlined below:

Injection Procedures

1. Adjust valving to flush the potable system supply to the storm drain. Set de-chlorination equipment as needed.
2. Initiate system flow to storm drain to flush the distribution system of pipe scale/residue/particulates. Flushing rate should be at least 125 % of maximum ASR injection rate.
3. Perform Silt Density Index (SDI) test on flowing water stream. Record flush meter reading, time, and SDI value.
4. Repeat SDI test after 20-30 minutes. When two successive results of SDI < 3.0 are achieved, injection operations can be initiated.

5. Upon initiation of injection operations for the test program, perform a backflush 24 hours after commencement of injection to ensure material sloughed off system piping from flow reversals in the distribution system is backflushed out of the well.
6. Regularly monitor SDI. If SDI > 5.0, immediately stop injection operations, backflush the well, and flush the distribution system to waste until SDI < 3.0 is restored.

Backflushing Procedures

1. Record all meter readings and water levels.
2. Stop injection flow to well, being careful to avoid both water hammer to the distribution system (i.e., by closing valves to quickly) and prolonged negative pressure/cascading water conditions in the well as practical.
3. Record all meter readings and water levels.
4. Adjust valving to 'backflush position', routing well production to the on-site tanks.
5. Start well at backflush rate setpoint (800 gpm) and pump for 15 minutes. Measure and record Turbidity at 1, 2, 5, 10 and 15 minutes of elapsed pumping time. Observe visual water clarity and particulate content and note observations. Turn pump off, noting the minimum 'off-time' (restart delay) for the specific pump motor in service.
6. Repeat Step 5 a total of 3 times, or until the discharge water is visually clear and less than 10 NTU within 1 minute of pump start-up.
7. When static water level has stabilized (15-minute minimum), start pump and set flow to normal recovery rate (700 gpm for Cycles 1 and 2, and 400 gpm for Cycle 3). Record 10-minute pumping water level and flow rate, calculate and record 10-minute specific capacity.
8. Record all meter readings and water levels.
9. Adjust valving as needed to next ASR operation (e.g., return to injection, storage, or recovery mode).
10. Following sufficient storage period to allow for solids settling and de-chlorination to meet discharge requirements, drain clear water from tanks to storm drain and ready for next backflushing event.

SAMPLING AND ANALYSIS PLAN

During the Beltz 8 ASR Pilot Test Program, a variety of water-level and water-quality data are to be collected. Water levels in the aquifer system are to be monitored during all phases at the ASR pilot testing well (Beltz 8) as well as several existing, proximate monitoring wells owned by both SCWD and Soquel Creek Water District (SqCWD). In addition, periodic samples of the injected, stored, and recovered waters are to be collected from the Beltz 8 pilot test well and the to-be-constructed Beltz 8 monitoring well (discussed above) and analyzed for a variety of water-quality constituents. The purpose of the Sampling and Analysis Plan (SAP) described below is to identify the locations, sample collection frequency, and parameters to be monitored as part of the ASR pilot test project data collection program.

Project Wells

The Beltz 8 well facility is located in the western portion of the City's service area. Several proximate existing monitoring wells owned both by the SCWD and SqCWD will also be utilized as monitoring wells during the project. The locations of the project wells are shown on **Figure 5** and a summary of project well completion parameters are presented in **Table 2** below:

Groundwater Monitoring Equipment

The equipment required to perform the groundwater monitoring as prescribed in this SAP includes:

- Pressure Transducers/Data Loggers
- Electric Water-Level Sounder
- Sampling Pumps
- Field Water-Quality Monitoring Devices
- Flow-Thru Cell Device(s)
- Sample Containers
- Coolers and Ice

Beltz 8 will be equipped with a temporary 30 Hp electric submersible pump. Flow for all process streams will be measured using in-line rate and totalizing flow meters. Sampling ports on the well-head piping allow for the collection of grab samples during recharge and pumping operations. In addition, a submersible sampling pump (Grundfos Redi-Flo2) will be installed in the to-be-constructed on-site Beltz 8 monitoring well and utilized to collect periodic water-quality samples from the aquifer.

Field water-quality monitoring is to be performed using various instruments that allow for the field analysis of a variety of constituents, including but not limited to: chlorine residual, conductivity, dissolved oxygen, pH, temperature, redox/ORP, and Silt Density Index (SDI). The field water-quality monitoring devices are to be routinely calibrated as prescribed in the operating procedures manual for each device.

The pilot test well, as well as the monitoring wells listed in **Table 2**, will be instrumented with dedicated pressure/level transducers and dataloggers[6]. Reference-point elevations will be established by existing survey records for the wells. Static water-levels will be manually measured with an electric sounder on a monthly basis (minimum) and the transducers calibrated accordingly. The transducers are to be programmed with the reference static water-level and the appropriate data-collection intervals.

[6] Most of the project monitoring wells have existing water level transducers / dataloggers programmed on hourly data collection intervals, which will be maintained and utilized during the pilot test; Beltz 8 and the on-site monitoring well will have supplemental instrumentation installed by PWR and programmed with variable data collection intervals (i.e., depending on the phase of testing and particular well).

Table 2. Project Well Construction Summary

Well	Distance from Beltz 8 (ft)	Depth (ft bgs)	Dia (in)	Screen Intervals (ft bgs)	Tp Unit(s) Completed
Beltz 8	--	210	14	100 - 180	A
Beltz 8 MW	50	190	2	100 - 180	A
Beltz 4 MW	945				
shallow		90	2	50 - 80	A (upper?)
deep		135	2	115 - 125	A (lower?)
Beltz 10	1010	362	8	100 - 357	AA
Beltz 9	2120	230	14	110 - 200	A
30th Ave	2385				
shallow		240	2	200 - 240	A
medium		410	2	370 - 410	AA
deep		800	2.5	720 - 800	Tu
Pleasure Pt	2565				
shallow		140	2	110 - 130	A (upper)
medium		240	2	210 - 230	A (lower)
deep		355	2	325 - 345	AA (upper?)
Corcoran Lagoon	2740				
shallow		40	2	30 - 40	A (upper)
medium		100	2	80 - 100	A (lower)
deep		195	2	175 - 195	AA (upper?)
SC-1A*	3670	320	2.5	113 - 320	A
SC-22 *	3675				
shallow		240	2	150 - 230	A
medium		500	2	460 - 490	AA (upper)
deep		705	2	640 - 700	AA (lower)
SC-13*	3745	820	2	760 - 770	AA/A
Moran Lake	4025				
shallow		170	2	130 - 170	A (upper)
medium		225	2	205 - 225	A (lower)
deep		295	2	255 - 295	AA (upper?)
Soquel Pt	4190				
SP-3		130	2	110 - 130	A (upper)
SP-2		270	2	250 - 270	AA (lower)
SP-1		330	2	310 - 330	AA (upper?)

Notes:

Tp - Purisima Formation

* - SqCWD monitoring well

Purging and Sampling

During injection periods, samples of the recharge water will be collected directly at the Beltz 8 wellhead while active injection is occurring. During storage periods, the well will be periodically purged and sampled per the below Sampling Schedule. During recovery periods, the well pump will be operating, therefore sample purging is continuous and sustained.

The sampling pumps will be used to purge a volume equivalent to a minimum of three (3) casing volumes from each well prior to sampling. Purge water from the pilot well during backflushing and sampling is to be discharged to holding tanks on site (existing Reclaim tanks) for surge suppression and analysis prior to discharge to the on-site storm drain system. Water produced by the well during Cycles 1 and 2 recovery operations will also be discharged to the storm drain. The water-quality data collected during Cycles 1 and 2 are intended to demonstrate the potability of recovered water - assuming the results are favorable, Cycle 3 recovery operations will pump into the distribution system (i.e., to minimize “wasting” of water during the pilot test program).

During purging and prior to sampling, field water-quality parameters of temperature, pH and specific conductance are to be monitored. Stabilization of these water-quality parameters will indicate when collection of a representative sample is allowable.

Laboratory Program

A complete list of constituents and constituent “groups” to be monitored as part of the Beltz 8 ASR Pilot Test Project for injected, stored, and recovered waters is presented in **Table 3** below:

Table 3. Analytic Testing Program Constituent Summary

Parameter	Location of Analysis	Method	Unit	PQL	Field Parameters	Geo-chemical	Disinfection By-Products	Supple-mental
Group ID					**F-1**	**G-1**	**DBPs**	**S-1**
Field Parameters								
Cl Residual	on-site	Hach	mg/L	0.05	x			
Diss O2	on-site	Hach	mg/L	0.2	x			
EC	on-site	EPA 120.1	umho/cm	10	x			
ORP	on-site	USGS	mV	10	x			
pH	on-site	EPA 150.1	Std Units	0.01	x			
SDI	on-site		Std Units	0.01	x			
Temperature	on-site	SM 2550	°C	0.5	x			
Turbidity	on-site	Hach 2100Q	NTU	0.1	x			
General Mineral Analysis								
Alkalinity (Total)	Lab	SM2320B	mg/L	5		x		x
Ca	Lab	EPA 200.7	mg/L	0.03		x		x
Cl	Lab	EPA 300.0	mg/L	0.5		x		x
EC	Lab	EPA 120.1	umho/cm	10		x		x
F	Lab	EPA 300.0	mg/L	0.1		x		
Fe (Dissolved)	Lab	EPA 200.7	mg/L	0.05		x		x
Fe (Total)	Lab	EPA 200.8	mg/L	0.05		x		x
K	Lab	EPA 200.8	mg/L	1		x		x
MBAS	Lab	SM 5540C	mg/L	0.05		x		
Mg	Lab	EPA 200.8	mg/L	0.5		x		x
Mn (Dissolved)	Lab	EPA 200.7	mg/L	0.05		x		x
Mn (Total)	Lab	EPA 200.9	mg/L	0.05		x		x
Na	Lab	EPA 200.7	mg/L	0.05		x		x
NH3	Lab	EPA 350.1	mg/L	0.05		x		
NO2	Lab	EPA 300.0	mg/L	0.1		x		x
NO3 (as N)	Lab	EPA 300.0	mg/L	0.1		x		x
P (Total)	Lab		mg/L	0.001		x		
pH	Lab	EPA 150.1	Std Units	0.01		x		x
SiO2	Lab	EPA 370.1	mg/L	2		x		
SO4	Lab	EPA 300.0	mg/L	0.5		x		x
Sulfides (Total)	Lab	EPA 376.2	mg/L	0.1		x		
TDS	Lab	SM2540C	mg/L	5		x		x
TKN	Lab	EPA 351.2	mg/L	0.2		x		

Table 3. Analytic Testing Program Constituent Summary (con't)

Parameter	Location of Analysis	Method	Unit	PQL	Field Parameters	Geo-chemical	Disinfection By-Products	Supple-mental
Group ID					F-1	G-1	DBPs	S-1
Inorganic Trace Metals								
Ag	Lab	EPA 200.8	ug/L	10		x		
Al	Lab	EPA 200.8	ug/L	10		x		
As	Lab	EPA 200.8	ug/L	1		x		x
B	Lab	EPA 200.8	ug/L	50		x		
Ba	Lab	EPA 200.7	ug/L	1		x		
Be	Lab	EPA 200.8	ug/L	1		x		
Br	Lab	EPA 200.9	ug/L	100		x		x
Cd	Lab	EPA 200.8	ug/L	1		x		
Co	Lab	EPA 200.8	ug/L	1		x		
Cr	Lab	EPA 200.8	ug/L	10		x		
Cu	Lab	EPA 200.8	ug/L	5		x		
Hg	Lab	EPA 200.8	ug/L	0.025		x		x
I	Lab	EPA 200.8	ug/L	100		x		
Li	Lab	EPA 200.7	ug/L	1		x		
Mo	Lab	EPA 200.8	ug/L	5		x		
Ni	Lab	EPA 200.8	ug/L	1		x		
Pb	Lab	EPA 200.8	ug/L	1		x		
Sb	Lab	EPA 200.8	ug/L	1		x		
Se	Lab	EPA 200.8	ug/L	5		x		
Sr (Total)	Lab	EPA 200.7	ug/L	1		x		
Sr 86/Sr 87 (ratio)	Lab	EPA 200.8	ug/L	0.1 (ratio acuracy)		x		
Tl	Lab	EPA 200.8	ug/L	1		x		
U	Lab	EPA 200.8	ug/L	0.5		x		
V	Lab	EPA 200.8	ug/L	1		x		
Zn	Lab	EPA 200.8	ug/L	10		x		
Bio / Organics								
Coliform	Lab		CFU	<1		x		
HAA5's	Lab	EPA 552.2	ug/L	1			x	
HPCs	Lab	SM9215B	CFU	<1		x		
Organic Carbon (Dissolved)	Lab	SM5310B	mg/L	0.1			x	
Organic Carbon (Total)	Lab	SM5310B	mg/L	0.1			x	
TTHM's	Lab	EPA 502.2	ug/L	1			x	
Miscellaneous								
CH4	Lab	RSK-175	ug/L	5		x		
Gross Alpha	Lab	EPA 900.0	pCi/L			x		
Color	Lab	SM2120B	Color Units	3		x		
Hardness	Lab	SM2340B	mg/L	10		x		
Tu	Lab	EPA 180.1	NTU	0.1		x		
TSS	Lab	EPA 160.2	mg/L	1		x		

Notes:

F-1 parameters to be measured concurrently with collection of G-1, DBP and S-1 samples.

Sampling Schedule

The planned sample constituent group frequencies for each source for the injection, storage, and recovery periods for each ASR Cycle are summarized below.

Baseline. Prior to Cycle 1 injection, samples will be collected from Beltz 8 and the to-be-constructed on-site monitoring well (MW) and analyzed for F-1, G-1 and DBPs Group parameters to establish baseline conditions.

ASR Cycle 1. The sampling schedule for Cycle 1 is presented in **Table 4** below:

Table 4. Sampling Schedule – ASR Cycle 1

Analyte Group	Injection		Storage		Recovery	
	Injectate	MW	Beltz 8	MW	Beltz 8	MW
F-1	Once	--	@end	--	@ 25, 50, 75, 100, 125 & 150%	--
G-1	Once	--	@end	--	@ 50 and 100%	--
DBP	Once	--	@end	--	@ 100%	--
S-1	--	--	--	--	@ 25, 75, 125, & 150%	--

As shown, the full suite of parameters (F-1, G-1, and DBPs) will be collected of the injectate once during the 1-day injection period of Cycle 1. One sample of the stored water will be collected from Beltz 8 at the end of the 2-day storage period. During recovery pumping, G-1 samples will be collected at 50 and 100 **percent recovery of the injection volume**, supplemented with the shorter S-1 group at 25, 75, 125 and 150 percent. No samples are planned to be collected from the on-site monitoring well during Cycle 1 due to the limited volume of injection not anticipated to be sufficient to arrive at the well during the cycle.

ASR Cycle 2. The sampling schedule for Cycle 2 is presented in **Table 5** below:

Table 5. Sampling Schedule – ASR Cycle 2

Analyte Group	Injection		Storage		Recovery	
	Injectate	MW	Beltz 8	MW	Beltz 8	MW
F-1	Once	--	Weekly	@end	@ 0, 25, 50, 75, 100, 125 & 150%	@end
G-1	Once	--	Weekly	@end	@ 0, 50 and 100%	@end
DBP	Once	--	Weekly	@end	@ 0 & 100%	@end
S-1	--	--	--	--	@ 25, 75, 125, & 150%	--

As shown, the sampling schedule for Cycle 2 is similar in scope to Cycle 1 but expanded somewhat and also includes some limited sampling of the on-site monitoring well. During the 1-week injection period, again only one sample is needed. During the 2-week storage period, two samples will be collected from Beltz 8 and one sample collected from the on-site monitoring well at the end of the period. During recovery pumping, samples will be collected from Beltz 8 at similar percent recovery points as described above for Cycle 1, with one sample collected from the on-site monitoring well at the end of the period.

ASR Cycle 3. The sampling schedule for Cycle 3 is presented in **Table 6** below:

Table 6. Sampling Schedule – ASR Cycle 3

Analyte Group	Injection		Storage		Recovery	
	Injectate	MW	Beltz 8	MW	Beltz 8	MW
F-1	Weekly	Weekly	Weekly	Weekly	@0, 25, 50, 75, & 100%	Weekly
G-1	Once	Once	Once	Once	@ 0, 50 and 100%	@ 0, 50 and 100%
DBP	Weekly	Weekly	Weekly	Weekly	@0, 25, 50, 75, & 100%	Weekly
S-1	Weekly	Weekly	Weekly	Weekly	@ 25 & 75%	Weekly

As shown, the sampling schedule for Cycle 3 is the most intensive. This is due to both the extended duration and larger volumes of injection and recovery during Cycle 3. In particular, it is anticipated that the injected water will fully envelope the on-site monitoring well during the injection period; therefore, sampling at this monitoring well is more relevant during Cycle 3 than the previous cycles. During the 30-day injection period, weekly samples will be collected from both Beltz 8 and the monitoring well for the F-1, DBP and S-1 groups, with one sample of the full G-1 suite collected. A similar schedule is planned for the 60-day storage period. During the 30-day recovery period, samples will be collected from Beltz 8 at similar percent recovery levels as the previous cycles, with weekly samples collected from the on-site monitoring well.

PRELIMINARY PROJECT SCHEDULE

A preliminary schedule for the Beltz 8 ASR Pilot Test Program is presented in **Table 7** below:

Table 7. Preliminary Project Schedule

Task / Activity	Time Period	Duration (months)
CEQA and Permitting	Nov 2019 - Jan 2019	3
Monitoring Well Drilling	Jan 2020	0.75
Well Rehabilitation	Jan - Feb 2020	1
Site Preparation	Feb 2020	0.25
ASR Cycles	Mar 2020 - Aug 2020	6
Data Analysis and Reporting	Sep 2020 - Oct 2020	2
	Total:	**12**

As shown, the ASR cycles are planned to be implemented during the winter/spring of the 2020 water year when excess SLR flows are anticipated to be available (i.e., through the month of May 2020). There is an estimated 4 months of CEQA/permitting and site preparatory work (including monitoring well drilling and well rehabilitation) to be completed prior to implementing the test program; therefore, this work will need to be initiated no later than November 2019. Data analysis, reporting and project completion are anticipated by October of 2020, for a total project duration of approximately 1 year.

CLOSURE

This memorandum has been prepared exclusively for the City of Santa Cruz Water Department for the specific application to the City of Santa Cruz ASR Feasibility – Phase 1 Investigation. The findings and conclusions presented herein were prepared in accordance with generally accepted hydrogeologic practices. No other warranty, express or implied, is made.

FIGURES

October 2019
Project No. 15-0111

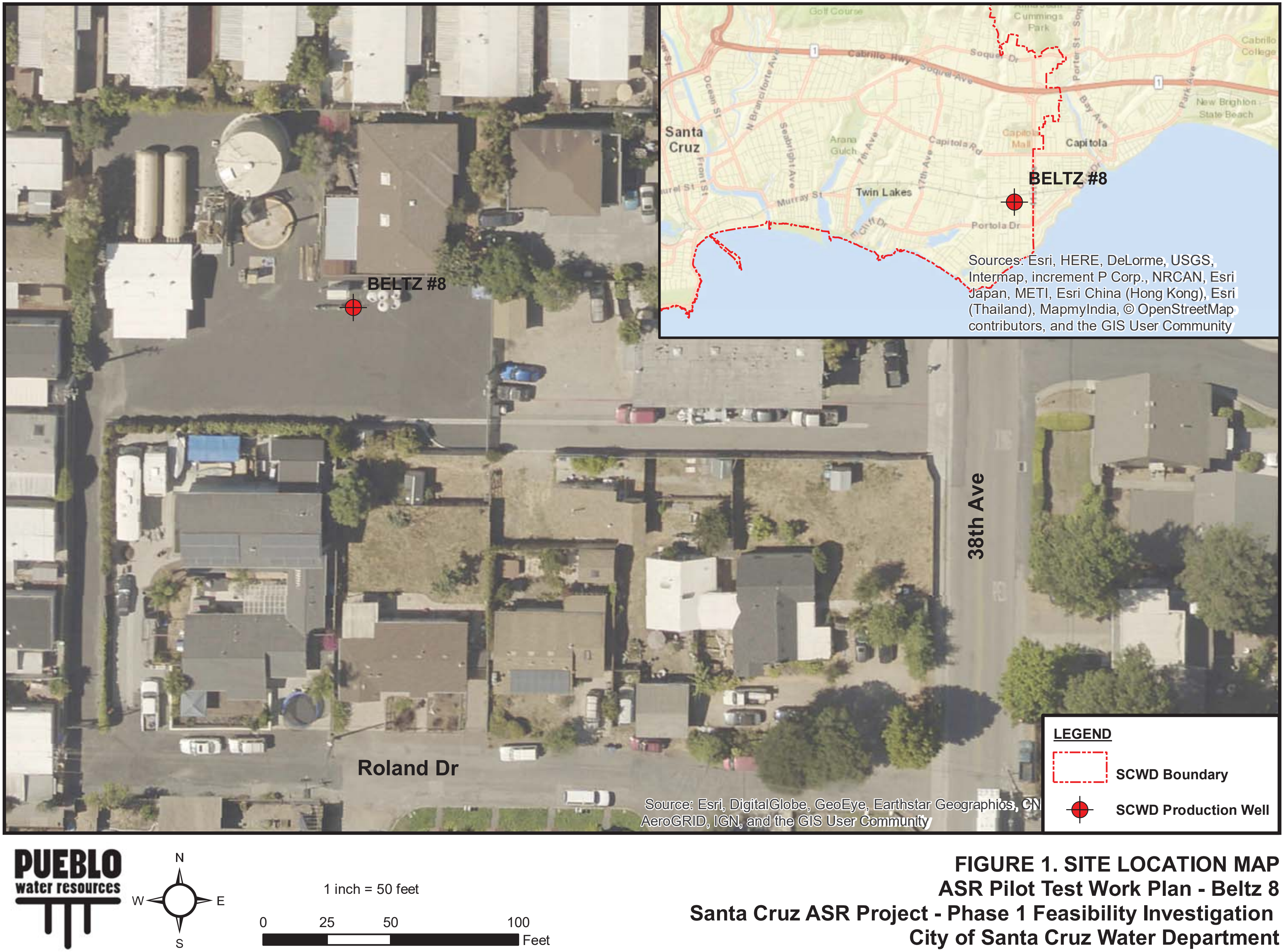


FIGURE 1. SITE LOCATION MAP
ASR Pilot Test Work Plan - Beltz 8
Santa Cruz ASR Project - Phase 1 Feasibility Investigation
City of Santa Cruz Water Department

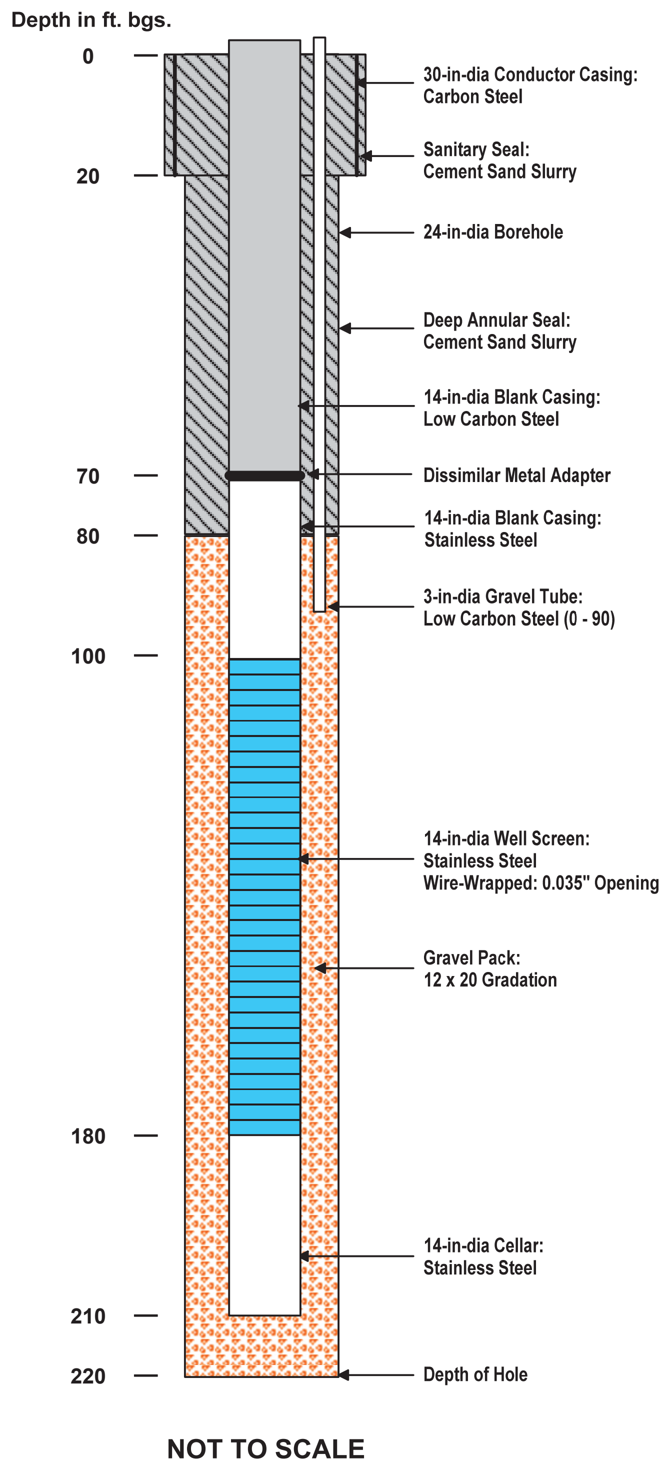
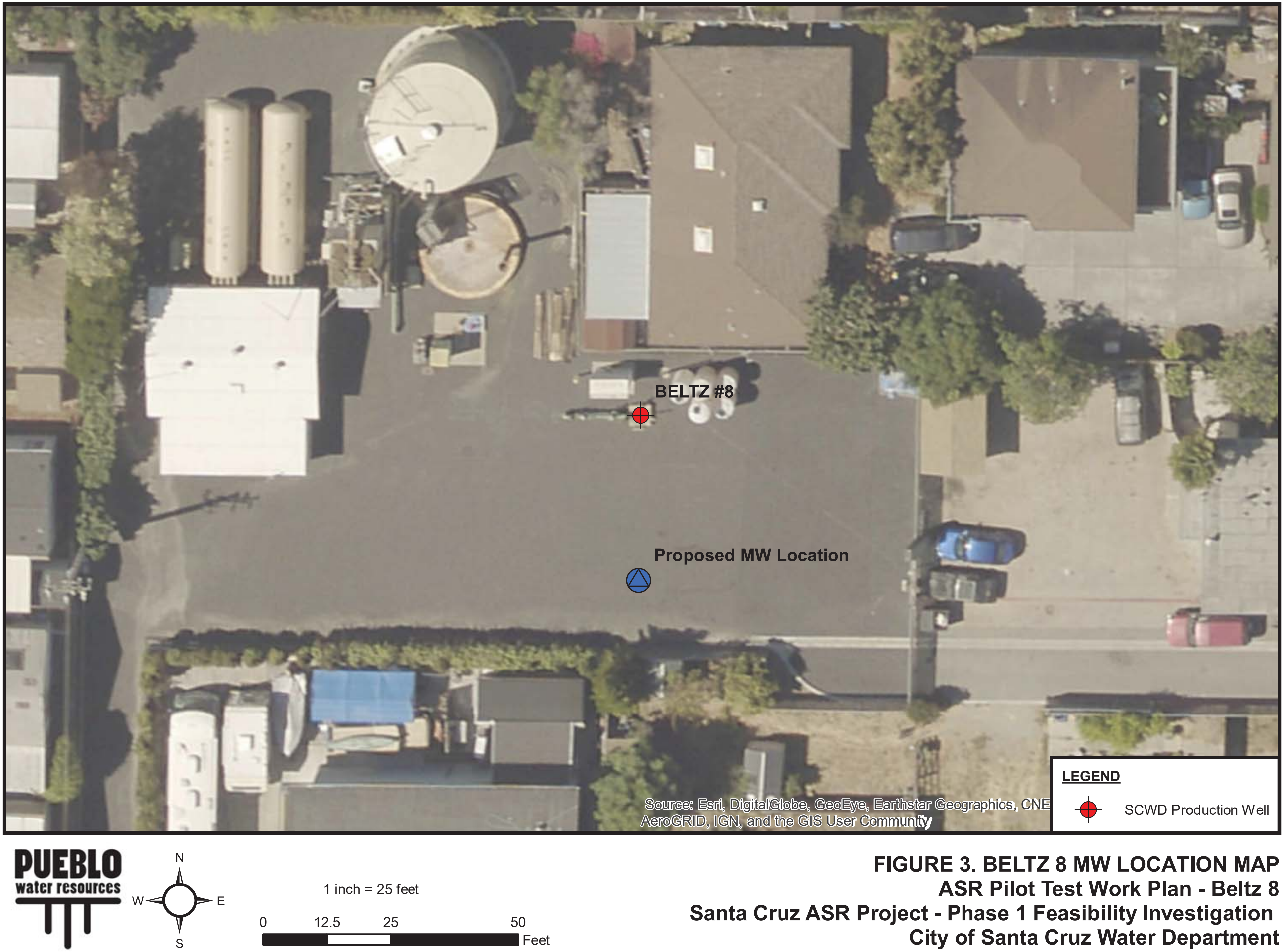


FIGURE 2. AS-BUILT WELL SCHEMATIC
ASR Pilot Test Work Plan - Beltz 8
Santa Cruz ASR Project - Phase 1 Feasibility Investigation
City of Santa Cruz Water Department

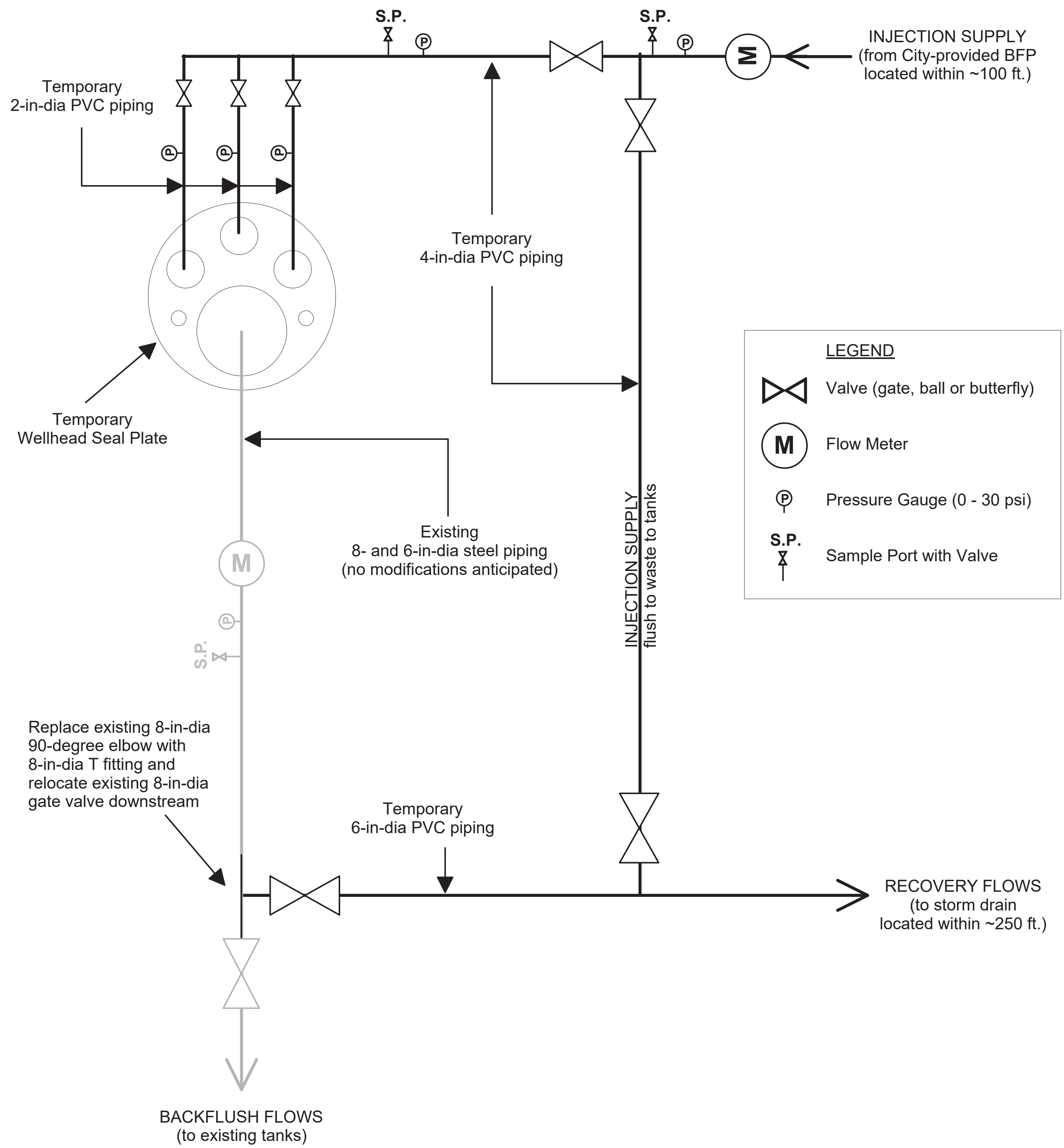
PUEBLO water resources

October 2019
Project No. 15-0111



PUEBLO water resources

FIGURE 3. BELTZ 8 MW LOCATION MAP
ASR Pilot Test Work Plan - Beltz 8
Santa Cruz ASR Project - Phase 1 Feasibility Investigation
City of Santa Cruz Water Department

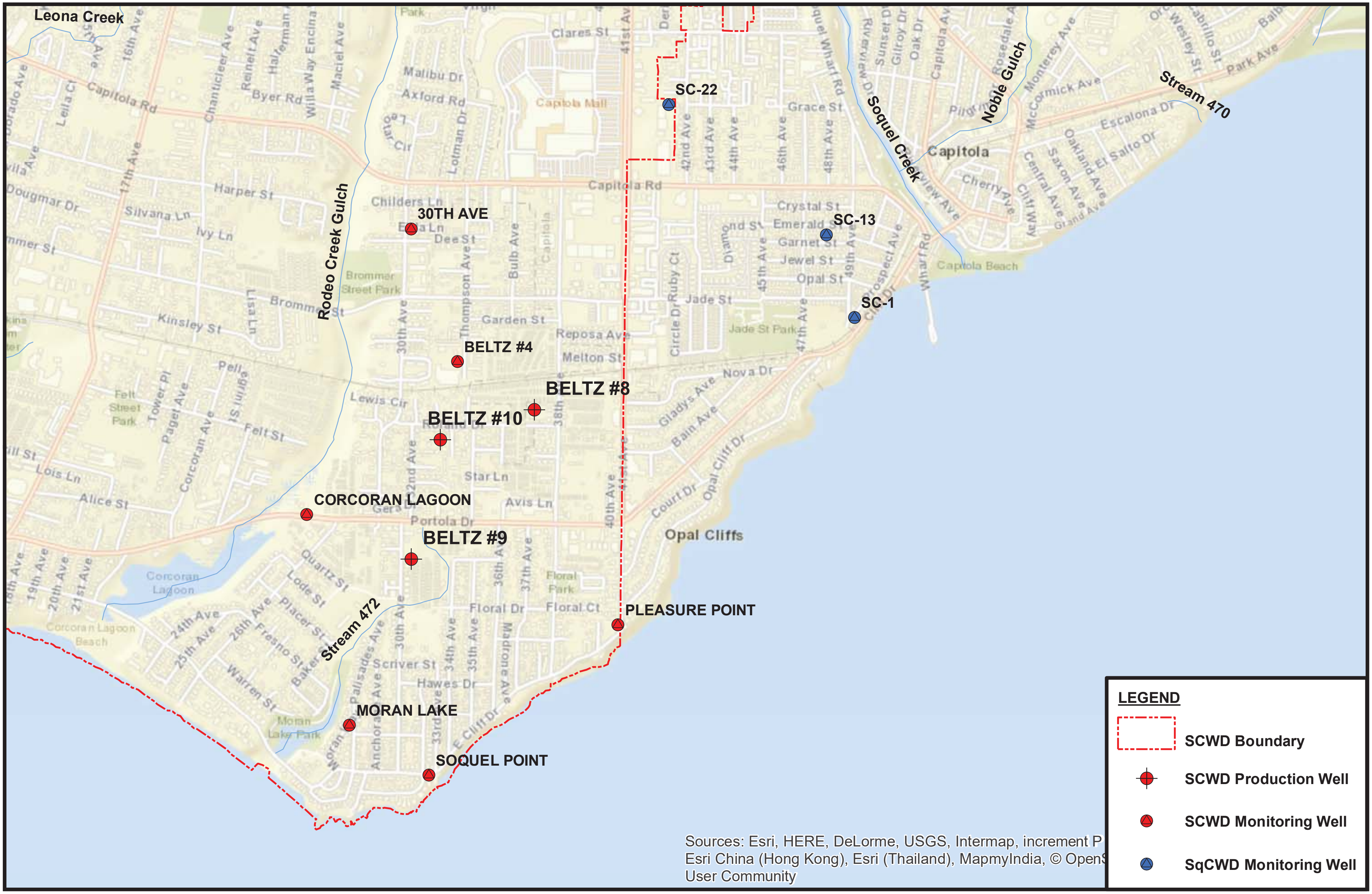


Note: existing piping is shown in grey and temorary piping is shown in **black**

FIGURE 4. PRELIMINARY PIPING SCHEMATIC
ASR Pilot Test Work Plan - Beltz 8
Santa Cruz ASR Project - Phase 1 Feasibility Investigation
City of Santa Cruz Water Department

PUEBLO water resources

October 2019
Project No. 15-0111



PUEBLO water resources

N W E S

1 inch = 1,500 feet

0 750 1,500 3,000 Feet

FIGURE 5. WELL LOCATION MAP
ASR Pilot Test Work Plan - Beltz 12
Santa Cruz ASR Project - Phase 1 Feasibility Investigation
City of Santa Cruz Water Department