Chromium-6 Treatment and Compliance Study for Coachella and Indio Water Authorities August 2015

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Project Number: 20038-000

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Definitions

ABBREVIATION	DEFINITION	ABBREVIATION	DEFINITION
AACE	American Association of Cost Engineering	HPC	Heterotrophic Plate Count
ADD	Average Daily Demand	HRL	Health Reference Level
AFY	Acre-Feet per year	HWL	High water line
AWWA	American Water Works Association	ID-1	Improvement District-1
BAT	Best Available Technology	IDM	ID Modeling
BV	Bed volumes	IRIS	Integrated Risk Information System
CCL3	Third Contaminant Candidate List	IWA	Indio Water Authority
CCL4	Fourth Contaminant Candidate List	IXTP	Ion exchange treatment process
CCPP	Calcium Carbonate Precipitation Potential	LRAA	Locational Running Annual Average
CEQA	California Environmental Quality Act	LSI	Langelier Saturation Index
CMAR	Construction Manager at Risk	MCC	Motor Control Center
Cr6	Hexavalent chromium	MCL	Maximum Contaminant Level
CRRF	Central Resin Regeneration Facility	MDD	Maximum Daily Demand
CRW	Colorado River Water	MG	Million gallons
CVC	Coachella Valley Canal	MGD	Million gallons per day
CVRWMG	Coachella Valley Regional Water Management Group	MIB	1-methylisoborneol
CVWD	Coachella Valley Water District	NDEA	n-nitrosodiethylamine
CWA	Coachella Water Authority	NDMA	n-nitrosodimethylamine
DBCP	Dibromochloropropane	NDPA	n-nitrosodipropylamine
DDW	Division of Drinking Water	NL	Notification Level
DI	Ductile Iron	NOM	Natural organic matter
DU	Dwelling Unit	NTP	National Toxicology Program
EBCT	Electron-beam computed tomography	NTU	nephelometric turbidity units
EDR	electrodialysis reversal	O&M	Operations and Maintenance
FBR	Fluidized bed reactor	OEHHA	Office of Environmental Health Hazard Assessment
FTE	Full Time Equivalent	OSG	On-site generated
FXB	Fixed or packed bed reactor	PHD	Peak Hour Demand
GAC	Granulated activated carbon	PHG	Public Health Goal
GAMA	Geotracker Groundwater Ambient Monitoring and Assessment	PLC	Programmable logic controller
GPD	Gallons per day	Ppb	Parts per billion
GPM	Gallons per minute	PSV	Pressure sustaining valves
gpm	Gallons per minute	PRV	Pressure reducing valves
GW	Groundwater	PVC	Polyvinyl Chloride
HAA	Haloacetic acids	QSA	Quantification Settlement Agreement
HAL	Health Advisory Level	RCF	Reduction coagulation filtration

ABBREVIATION	DEFINITION	ABBREVIATION	DEFINITION
RCMF	Reduction coagulation microfiltration	TENORM	Technologically Enhanced Naturally Occurring Radioactive Material
RCRA	Resource Conservation and Recovery Act	THM	Trihalomethanes
RD3	Preliminary Regulatory Determinations for Contaminants on the Third Drinking Water Contaminant Candidate List	TOC	Total organic carbon
regen	Regeneration	TTHM	Total Trihalomethanes
RO	Reverse Osmosis	TTLC	Total Threshold Limit Concentration
SBA	Strong base anion exchange	UCMR3	Unregulated Contaminant Monitoring Rule
SCADA	Supervisory control and data acquisition	USEPA	U.S. Environmental Protection Agency
STLC	Soluble Threshold Limit Concentration	VOC	Volatile Organic Compound
SWRCB-DDW	California State Water Resources Control Board Division of Drinking Water	WBA	Weak base anion exchange
SWTP	Surface Water Treatment Plant	WQTS	Water Quality and Treatment Services (Company)
TDS	Total dissolved solids (inorganic content)	WRP	Water Reclamation Plants

Executive Summary

The State of California released a new maximum contaminant level (MCL) for hexavalent chromium (Cr6) in drinking water, effective July 1, 2014. Numerous Coachella Water Authority (CWA) and Indio Water Authority (IWA) groundwater wells have historically had Cr6 concentrations above the new MCL and exceeded the levels when sampled for compliance with the regulation. The CWA/IWA Cr6 Compliance Study evaluated treatment options to identify the most reliable and cost effective treatment solution for Cr6 compliance. The most viable Best Available Technologies (BATs) listed by the State of California were examined to develop cost estimates and identify potential future risks in selection of different options. This Study Report outlines the plan for compliance and provides a roadmap for the next phase: design and construction of the selected treatment facilities.

Study Approach

The Study used a systematic approach to develop the compliance strategy including the following steps that were followed with CWA and IWA:

1. **Define goals** – Cr6 treatment targets (Cr6 of 2 µg/L in the treated effluent and 6 µg/L in the final blend) dictated the need for and size of treatment facilities. (Note that the target less than the MCL is a conservative approach to provide a buffer in case concentrations fluctuate in the groundwater or treated water).
2. **Evaluate decision criteria** – operability and treatment system robustness were evaluated in addition to capital and operational costs.
3. **Identify impacted wells** – based on Cr6 or other goals, wells that require treatment were identified and grouped into three Tiers for prioritization (Tier 1 with Cr6 > 10.4 µg/L; Tier 2 with 8 µg/L < Cr6 < 10.4 µg/L; and Tier 3 with Cr6 < 8 µg/L).
4. **Site treatment facilities** – based on geographical location and water quality, treatment facilities were sited for individual wells or wells were clustered together for treatment at a plant.
5. **Select treatment technologies** –water quality and decision criteria including equipment cost estimates were used to select a technology for each treatment site.
6. **Summarize costs** – estimates of total project capital, operations and maintenance, and lifecycle costs were developed for the selected treatment sites.
7. **Establish timetable** for treatment – next steps to design and construct treatment facilities were outlined based on the current and future water demands.

A scenario-based approach that considered varying levels of groundwater treatment for current and future water demands was used. These scenarios were evaluated in terms of cost, operational complexity, implementation complexity, and other water quality benefits, to site and select the technologies at each required treatment facility. Finally, conceptual designs and overall project costs were prepared for the primary treatment components of the selected facilities. Three scenarios were included in the evaluation.

Coachella Water Authority Compliance Study

Treatment Assessment for CWA -

Scenario A – Existing Systems (Baseline Using Only Low Cr6 or Currently Treated Wells). Scenario A defines the current baseline for existing conditions. CWA has 6 wells above the Cr6 MCL (no available well capacity below the MCL) and is out of compliance.

Scenario B - Achieve Compliance (Current Demands). Scenario B outlines the improvements needed to achieve compliance. For CWA, treatment on five wells is needed.

Scenario C – Full System Utilization (Future Demands). Scenario C assesses the projected future demands CWA system. This scenario includes fully utilizing existing wells by adding treatment and identifying if new wells are needed.

In addition to the scenarios evaluated above, emergency interconnections for joint CWA and IWA Systems were also discussed. These interconnections could be used to provide system redundancy and provide a reliable water supply in the event of an emergency or treatment system failure.

Study Findings for CWA -

Current and Future Supply and Demands. With all existing wells utilized, CWA system capacity is 17.6 MGD (15.6 MGD is Well 11 is taken offline), relative to a current MDD of 12.9 MGD and a future MDD of 20.9 MGD. At 2,000 gpm per well, CWA will require 7 additional new wells to meet the anticipated future demand that is projected in the Water System Master Plan. Future wells could be sited in the vicinity of the Well 12 or Well 18 reservoirs to allow for potential benefits that might be achieved with blending and operational flexibility.

Treatment Approach. Technologies identified as feasible for CWA included ion exchange (strong base anion exchange, SBA or weak base anion exchange, WBA) or reduction/coagulation/microfiltration (RCMF) with recycle of backwash water. RCF without recycle, RCMF without recycle, or reverse osmosis (RO) create much more water loss during treatment (3% for RCF, 5% for RCMF, and 15-25% for RO) compared with ion exchange (<0.05%).

SBA was estimated as the least costly Cr6 treatment technology for CWA wells. Lifecycle costs were similar across SBA options (i.e., containerized SBA or SBA with onsite brine treatment), with the wells with higher sulfate (and associated greater regeneration frequency), being most sensitive to the brine management assumptions. RCMF with recycle was not recommended over ion exchange due to the larger footprint, operational complexity, and capital costs.

With multiple options for implementing ion exchange including different SBA configurations, it is recommended as a next step that CWA consider preferences in system operational complexity, equipment longevity, and residuals waste generation, which were identified as the primary risks to the agencies in selection of a specific system confirmation for long term operations. Details of each, and potential risks for different approaches, are provided in this report.

Multiple options for clustering wells to blend or treat at common facilities were evaluated. Analysis showed that cost savings from treatment economies of scale were not sufficient to justify clustering of most wells. An example is provided that assessed clustering CWA's Wells 17 and 19 or IWA's Well U and CWA's Wells 17 and 19 together for treatment. Opportunities for clustering include clustering of future CWA wells. A summary of treatment system recommendations is depicted in **Figure 1** and **Figure 2**.

Cost Estimates. Estimated treatment costs (accuracy range of -30% to 50%) for CWA wells are summarized in **Table 2**. A range of SBA options (including containerized SBA and SBA with onsite brine treatment) are presented. Cr6 treatment facilities for existing wells to meet current demands are estimated to cost approximately $14M to $19M (up to $29M given planning level cost range accuracy) in capital with annual system O&M costs ranging from $1.4M to $1.5M.

Next Steps. The next step is for CWA to use the analysis presented in this Study report to inform key planning decisions and to begin the grant funding application process. This Study report lays the groundwork for the Proposition 1 grant application process and by working with the State, a timeline for funding options can be established.

In parallel to exploring grant funding options, it is recommended that CWA move forward with preliminary design. During this process, design and cost assumptions can be refined. For example, a key component of the preliminary design is to assess the impact of Cr6 treatment on system hydraulics. It is recommended to perform hydraulic modeling to assess treatment system headloss impacts on well hydraulics, to confirm the impact of pipelines for clustered treatment facilities (for future CWA wells), and to further simulate the use of interconnections. It is also recommended that brine management options be further explored in advance of or as part of the preliminary design process.

It is recommended that CWA remain open to multiple SBA options, by having bid packages be prepared to allow for both containerized SBA and traditional SBA treatment approaches.

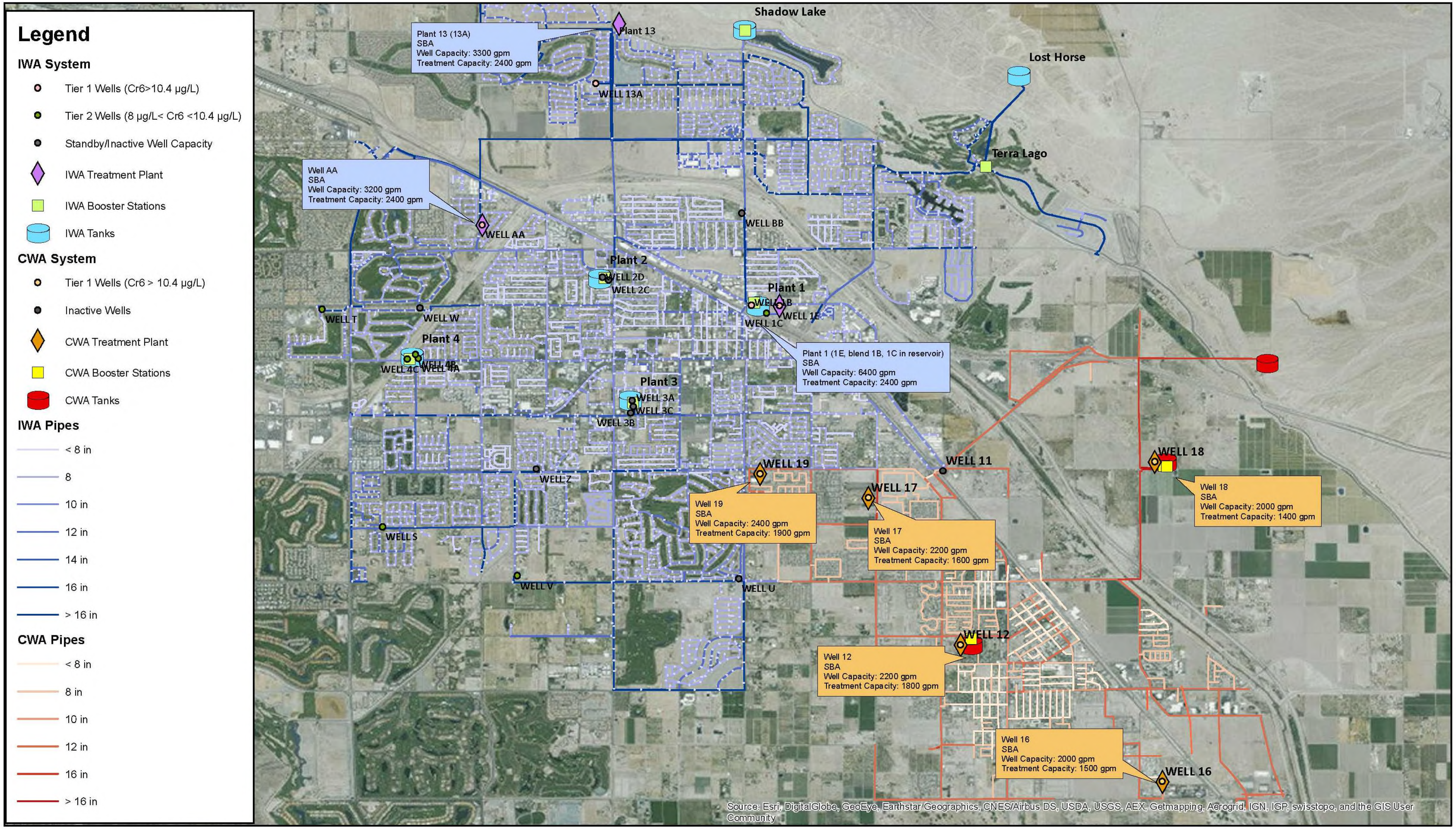

Figure 1. Scenario B - Cr6 Treatment Facilities for CWA and IWA Systems Current Demands

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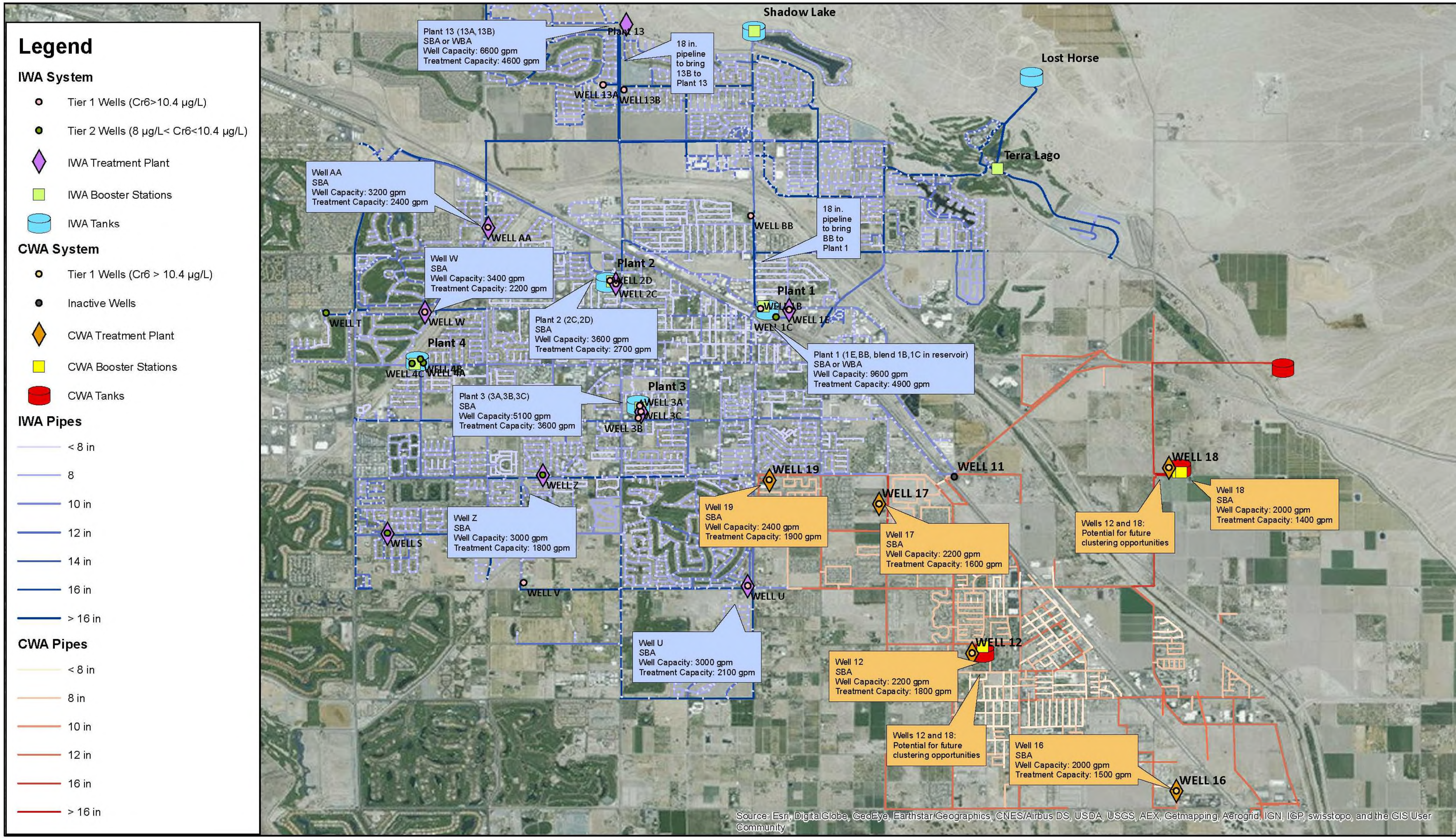

Figure 2. Scenario C - Cr6 Treatment Facilities for CWA and IWA Systems Future Demands

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Table 1. Summary of Treatment Costs for CWA Cr6 Facilities

	CWA	
Demand		
Average Day Demand	20.9 MGD	
Max. Day Demand	35.6 MGD	
Active with Treatment – Tier 1 (Cr6 > 10.4 µg/L)		
Wells	12, 16, 17, 18, 19	
Well Capacity	15.6 MGD	
Treatment Capacity[1]	12.1 MGD	
Active with Treatment – Tier 2 (8 < Cr6 < 10.4 µg/L)		
Wells	-	
Well Capacity	-	
Treatment Capacity[2]	-	
Standby/Inactive		
Wells	11	
Well Capacity	2.02 MGD	
TOTAL Active Well Capacity (Cr6 < 10.4 µg/L)	15.6 MGD	
SBA Option	Containerized SBA	SBA with Onsite Brine Treatment
Total Project Capital Costs Point Estimate ($M)	$14M	$19M
Total Project Capital Costs Accuracy Range (-30% to +50%, $M)	$10M to $21M	$14M to $29M
Annual O&M Costs ($M/Year)	$1.4M	$1.5M
Annualized Costs ($M/Year)[2]	$2.2M to $3.1M	$2.6M to $3.8M
NPV ($M)[2]	$28M to $39M	$33M to $48M

Planning Level Cost Estimates consistent with AACE Class 5, with an accuracy range of -30% to +50%.
[1] Treatment capacity is less than well capacity because partial stream treatment can be implemented.
[2]Amortized over 20 years at a rate of 5%.

Indio Water Authority Compliance Study

Treatment Assessment for IWA -

Scenario A – Existing Systems (Baseline Using Only Low Cr6 or Currently Treated Wells). Scenario A defines the current baseline for existing conditions. In this scenario, IWA has 7 wells below the Cr6 MCL and 3 wells with treatment (13 other wells are inactive), and is in compliance.

Scenario B - Achieve Compliance (Current Demands). Scenario B outlines the improvements needed to achieve compliance. For IWA, the 7 wells below the MCL and 3 additional wells with treatment are enough to satisfy current demands and stay in compliance. For additional capacity Well 1B can be added at Plant 1 without the need for additional treatment.

Scenario C – Full System Utilization (Future Demands). Scenario C assesses the projected future demands. This scenario includes fully utilizing existing wells by adding treatment and identifying if new wells are needed.

In addition to the scenarios evaluated above, emergency interconnections for joint CWA and IWA Systems were also discussed. These interconnections could be used to provide system redundancy and provide a reliable water supply in the event of an emergency or treatment system failure.

Study Findings for IWA -

Current and Future Supply and Demands. With all existing wells utilized and Well 13B equipped, IWA system capacity is 77.5 MGD, relative to a current maximum day demand (MDD) of 28 MGD and a future MDD of 40.8 MGD.

Treatment Approach. Technologies identified as feasible for IWA included ion exchange (strong base anion exchange, SBA or weak base anion exchange, WBA) or reduction/coagulation/microfiltration (RCMF) with recycle of backwash water. RCF without recycle, RCMF without recycle, or reverse osmosis (RO) create much more water loss during treatment (3% for RCF, 5% for RCMF, and 15-25% for RO) compared with ion exchange (<0.05%). Details of each, and potential risks for different approaches, are provided in this report. As additional technologies are developed in the future, it would be beneficial to both agencies to evaluate any new applications of best available technologies as they become available on the market.

SBA was estimated as the least costly Cr6 treatment technology for IWA wells. Two IWA sites with higher sulfate concentrations were identified as potential candidates for WBA that may be a slightly higher cost, but offer IWA operational simplicity for these sites with more brine production. Additionally, this would provide treatment diversification in the system. Costs were similar across SBA options (i.e., containerized SBA or SBA with onsite brine treatment), with the wells with higher sulfate (and associated greater regeneration frequency), being most sensitive to the brine management assumptions. RCMF with recycle was not recommended over ion exchange due to the larger footprint, operational complexity, and capital costs.

With multiple options for implementing ion exchange including different SBA configurations and WBA, it is recommended as a next step that IWA consider preferences in system operational complexity, equipment longevity, and residuals waste generation, which were identified as the primary risks to the agencies in selection of a specific system confirmation for long term operations.

IWA recently installed three containerized SBA treatment systems for Cr6 treatment. In the near term, it is recommended that IWA keep the Containerized SBA treatment equipment at Well 1E and blend with 1B and 1C in the Plant 1 reservoir to increase system capacity. The 2400 gpm Containerized SBA units at Wells 1E and 13A could be moved to other individual well sites (U, W) to accommodate the design and construction of larger treatment facilities in the future (SBA or WBA), or supplemented with additional capacity (Containerized SBA).

Multiple options for clustering wells to blend or treat at common facilities were evaluated. Analysis showed that cost savings from treatment economies of scale were not sufficient to justify clustering of most wells. An example is provided that assessed clustering Well U and CWA's Wells 17 and 19 together for treatment. Opportunities for clustering to provide cost savings and operational flexibility include clustered treatment of Well BB and 1E at Plant 1 (blending the treated effluent with 1C and 1B in the Plant 1 reservoir. A summary of treatment system recommendations is depicted in **Figure 1** and **Figure 2**.

Cost Estimates. Estimated treatment costs (accuracy range of -30% to 50%) for IWA wells are summarized in **Table 2**. For IWA's current facilities, including the three new Cr6 treatment facilities, are able to meet current system demand. Additional flexibility can be attained by blending Well 1B at Plant 1, and utilizing Well 1E treatment more. To meet future demands, costs of fully utilizing existing wells were estimated to be approximately $35 to $44M (up to $66M given planning level cost range accuracy) in capital with annual system O&M costs ranging from $2.9M to $3.1M. This cost is inclusive of all Cr6 facilities needed, including $7M spent in treating the three wells.

Next Steps. The next step is for IWA to use the analysis presented in this Study report to inform key planning decisions and to begin the grant funding application process. This Study report lays the groundwork for the Proposition 1 grant application process and by working with the State, a timeline for funding options can be established. It is also recommended that brine management options be further explored. IWA has three active Cr6 treatment facilities that present the opportunity to characterize brine composition, to conduct pilot testing of various brine treatment techniques, and to explore further various hazardous and non-hazardous disposal options that may be available.

It is recommended that IWA remain open to multiple SBA options, by having future bid packages be prepared to allow for both containerized SBA and traditional SBA treatment approaches. As the cost of treatment at wells with higher sulfate (and associated greater regeneration frequency) are most sensitive to the brine management assumptions, it is also recommended that WBA vendors be invited to bid at these higher sulfate sites (i.e. Plant 1 and Plant 13) so that the most economical and operationally preferable solution can be implemented for the long-term.

Table 2. Summary of Treatment Costs for IWA Cr6 Facilities

	IWA	
Demand		
Average Day Demand	27.2 MGD	
Max. Day Demand	40.8 MGD	
Active with Treatment – Tier 1 (Cr6 > 10.4 μg/L)		
Wells	Plant 1 (treat 1E, BB blend with 1B, 1C), Plant 2 (2C, 2D), Plant 3 (3A, 3B, 3C), Plant 13 (13A, 13B), AA, U, W, Z	
Well Capacity	52.3 MGD	
Treatment Capacity[1]	35.0 MGD	
Active with Treatment – Tier 2 (8 < Cr6 < 10.4 μg/L)		
Wells	1C, 4A, 4B, 4C, S, T, V	
Well Capacity	25.2 MGD	
Treatment Capacity[1]	12.4 MGD	
Standby/Inactive		
Wells	-	
Well Capacity	-	
TOTAL Active Well Capacity (Cr6 < 10.4 μg/L)	77.5	
SBA Option	Containerized SBA	SBA with Onsite Brine Treatment
Total Project Capital Costs Point Estimate ($M)	$35M	$44M
Total Project Capital Costs Accuracy Range (-30% to +50%, $M)	$25M to $52M	$31M to $66M
Annual O&M Costs ($M/Year)	$3.1M	$2.9M
Annualized Costs ($M/Year)[2]	$5.1M to $7.3M	$5.4M to $8.2M
NPV ($M)[2]	$64M to $91M	$67M to $102M

Planning Level Cost Estimates consistent with AACE Class 5, with an accuracy range of -30% to +50%.
[1] Treatment capacity is less than well capacity because partial stream treatment can be implemented.
[2] Amortized over 20 years at a rate of 5%.

Introduction and Objectives

In July 2014, the California State Water Resources Control Board Division of Drinking Water (SWRCB-DDW) set a new Cr6 MCL of 10 µg/L. Cr6 occurs naturally in the Coachella Valley and up to twenty of IWA's operating wells and CWA's six operating wells will not meet the new MCL. Working together, CWA and IWA engaged Hazen and Sawyer to conduct a study to recommend an efficient and cost effective approach for complying with the Cr6 MCL. The study aimed to analyze the costs and benefits of removing Cr6 (and other co-occurring constituents where applicable), and to develop a compliance strategy and timetable for design and construction of recommended treatment facilities. The cost to complete the study was shared between CWA and IWA and a Memorandum of Understanding (MOU) was approved by their respective boards. This report section provides background for the project, including a discussion of the Cr6 regulation, overview of CWA and IWA systems, and description of the Study approach.

1.1 Cr6 Regulatory Timeline

Chromium is a naturally occurring element found in rock (serpentinite), soil, and groundwater. It is the 11th most common element found in the Earth's crust. Chromium is commonly present in the environment in primarily two forms—Cr3 and Cr6. While Cr3 is an essential nutrient for humans, Cr6 is extremely mobile and soluble and is a probable human carcinogen. Cr6 can be found naturally in the environment, but it can also occur as an industrial byproduct in manufacturing processes for stainless steel, chrome plating, dyes, pigments, leather tanning, and wood preserving. Cr6 occurs naturally across the Coachella Valley, due to erosion of local sediments.

In the past few years, the toxicology of Cr6 was re-evaluated in a National Toxicology Program (NTP) study.[1] Based primarily on this study, the U.S. Environmental Protection Agency (USEPA) released its draft assessment of Cr6 toxicology for public comment in September 2010. The document identified Cr6 as a likely human carcinogen through ingestion, and proposed a reference dose of 0.0009 mg/kg/day, which was much lower than the current reference dose of 0.003 mg/kg/day for total chromium. However, significant public comments were received and an external peer review panel recommended that the USEPA consider the results of peer-reviewed toxicology research prior to reissuing the IRIS Cr6 assessment. Cr6 and total Cr were part of the third Unregulated Contaminant Monitoring Rule (UCMR3), which together with the toxicology assessment will set the stage for a potential future federal Cr6 MCL or lowering of the current total Cr MCL of 100 µg/L.

The State of California has a lower MCL of 50 µg/L for total chromium. In addition, in July 2014 the California State Water Resources Control Board Division of Drinking Water (SWRCB-DDW) set a new Cr6 MCL of 10 µg/L. As determined by SWRCB-DDW, the MCL was set as close as feasible from a cost and

[1] National Toxicology Program, 2008. Toxicology and Carcinogenesis Studies of Sodium Dichromate Dihydrate (CAS No. 7789-12-0) in F344/N Rats and B6C3F1 Mice (Drinking Water Studies). National Institutes of Health (NIH) Publication No. 08-5887.

technology feasibility perspective to the CA Office of Environmental Health Hazard Assessment (OEHHA)'s Public Health Goal (PHG) of 0.020 µg/L.

The Cr6 MCL is 0.010 mg/L (10 µg/L), with compliance calculated on the running annual average of four quarterly samples taken from a point-of-entry into the system. Based on the listed MCL and number of significant figures, 10.4 µg/L is considered in compliance and 10.5 µg/L, which would be 11 when rounded up, is out of compliance.

In addition to the Cr6 MCL, California Governor Jerry Brown released an Executive Order on April 1, 2015 calling for a decrease in potable urban water use in response to record drought. The State Water Control Board, under this directive, issued a Proposed Regulatory Framework that calls for a 35% decrease by CWA and IWA. A focal point of this project was identifying options for achieving compliance with the Cr6 regulation while minimizing wasted water, which is reflective of this water saving strategy.

1.2 Coachella Water Authority (CWA)

The City of Coachella was incorporated in 1946 and encompasses approximately 32 square miles in Riverside County. It is bordered by the City of Indio to the northwest and unincorporated areas of Riverside County to the north, south and east. CWA manages the maintenance, operation and treatment of water distribution and wastewater collection. The mission of these divisions is to deliver value to customers and communities by providing safe, reliable, economical and environmentally sustainable water services and to protect public health and the environment by providing effective and efficient wastewater collection, maintenance and treatment of sanitary waste water.[2]

The CWA water system includes:

- 6 groundwater wells with a total capacity of approximately 17.6 MGD
- 2 of the 6 wells pump water to ground storage reservoirs
- 4 of the 6 wells pump supply the distribution system directly
- Three additional inactive wells (Wells 7, 9, 10) are out of service due to maintenance issues and have been reclassified as monitoring wells.
- 3 storage reservoirs with a total storage capacity of 10.1 MG
- 120 miles of pipeline ranging 4 to 24 inches in diameter
- A distribution system consisting of two pressure zones: the Low Zone (90 ft HGL) and the High Zone (150 ft HGL)

Currently, 6 CWA wells are in operation and used to meet seasonal water demands (17.6 MGD pumping capacity) and all 6 wells have Cr6 concentrations above 10.4 µg/L and are out of compliance. The wells pump directly into the Low Zone distribution system with the exception of Well 12, which pumps into the 3.6 MG Low Zone Reservoir and Well 18. Additionally, Well 18 pumps into the 5 MG High Zone reservoir. Both Well 12 and Well 18 are controlled by tank water levels. Well 11 normally discharges to the Low Zone, but can discharge to the High Zone at a reduced output with manual pipeline valving changes. Moreover, the 5 MG High Zone reservoir has two booster stations, one supplies the Low Zone and the other supplies the High Zone. Additional system capacity and production information is presented in Appendix C.

[2] City of Coachella, Utilities Department What We Do. "coachella.org"

1.3 Indio Water Authority (IWA)

The Indio Water Authority was formed as a Joint Powers Authority in 2000 to deliver water to the City of Indio. Its mission is to provide the City's residents, visitors and businesses with safe and reliable water, while ensuring the long-term viability of the City's water services for its users. As one of the fastest growing municipal utilities in the Coachella Valley, IWA is committed to maintaining a sustainable water supply for its residential and commercial customers.[3]

IWA's service area includes approximately 38 square miles. Groundwater is delivered to customers through a pressurized distribution system supplied by 20 active wells and 6 pumping plants. IWA also has emergency Interconnection connections in place with Coachella Valley Water District (CVWD).

The IWA water system includes:

- 20 groundwater wells with a total capacity of 72.7 MGD
- 11 of the 20 wells pump water to ground storage reservoirs at four water production plants
- 9 of the 20 wells supply the distribution system directly
- Two additional inactive wells (Wells X and Y) are out of service due to high fluoride levels
- 7 storage reservoirs with a total storage capacity of 18.75 MG
- 326 miles of pipeline ranging 2 to 24 inches in diameter
- A distribution system consisting of one large main pressure zone and two small high zones

Historically, a combination of all 20 IWA wells were used to meet seasonal water demands. Currently, 7 of the 20 wells are in operation (25.2 MGD pumping capacity). The other 13 wells were placed in standby mode because they produce water exceeding the Cr6 MCL. In summer 2015, IWA will commission Cr6 treatment facilities at 3 of the 13 standby wells, increasing the available well supply to 39.2 MGD while remaining in compliance with the Cr6 regulation. The study, design, construction, and commissioning of these Cr6 treatment facilities were conducted in parallel to this Compliance Study Project (described further in Section 1.5). **Figure 3** shows the comprehensive distribution system and well sites for CWA and IWA.

[3] Indio Water Authority, Mission Statement. "indiowater.org"

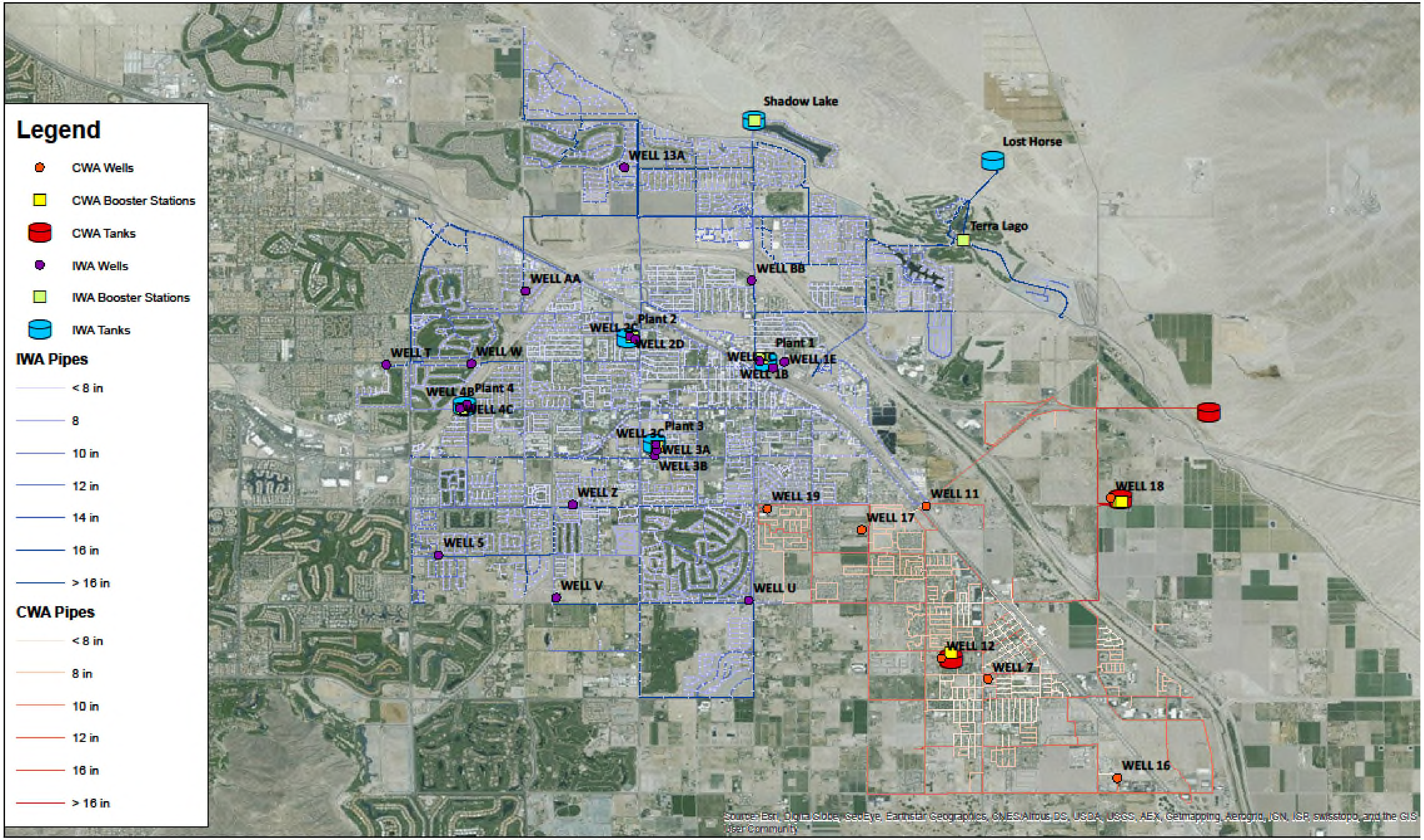

Figure 3. CWA and IWA Systems

1.4 Chromium-6 Compliance Study Project Overview

The Cr6 Compliance Study analyzed the costs and benefits of removing Cr6 (and other co-occurring constituents where applicable) and developed a compliance strategy and timetable for design and construction of recommended treatment facilities. The Study used a systematic approach to develop the compliance strategy including the following steps:

- **Define goals** – Cr6 treatment targets dictated the need for and size of treatment facilities.
- **Evaluate decision criteria** – operability and treatment system robustness were evaluated in addition to capital and operational costs.
- **Identify impacted wells** – based on Cr6 or other goals, wells that require treatment were identified.
- **Site treatment facilities** – based on geographical location and water quality, treatment facilities were sited for individual wells or wells were clustered together for treatment at a plant.
- **Select treatment technologies** –water quality and decision criteria were used to select a technology for each treatment site.
- **Summarize costs** – estimates of capital, operations and maintenance, and lifecycle costs were developed for the selected treatment sites.
- **Establish timetable** for treatment – next steps to design and construct treatment facilities were outlined based on the current and future water demands.

A scenario-based approach that considered varying levels of groundwater treatment for current and future water demands was used. These scenarios were evaluated simultaneously in terms of cost, operational complexity, implementation complexity, and other water quality benefits, to site and select the technologies at each required treatment facility. Finally, conceptual designs and overall project costs were prepared for the primary treatment components of the selected facilities.

1.5 Cr6 Treatment Facilities at IWA Wells 13A, AA and IE

Prior to the completion of this Compliance Study Report, IWA Staff identified three wells- 1E, AA, and 13A; which, with treatment could meet the Cr6 MCL and produce sufficient water to enable IWA to meet peak summer water demands in 2015. To meet these demands, treatment for these wells needed to be planned, designed, permitted, installed, and operational by July 2015. To do this, IWA contracted Hazen and Sawyer to perform a separate evaluation of treatment options for these wells (Appendix A).

IWA selected a containerized treatment approach (ion exchange equipment housed in metal shipping containers) for these wells with treatment equipment purchased from IonexSG. Working with the equipment supplier IonexSG, the contractor Borden Excavating, and Hazen and Sawyer for engineering and construction management services, IWA brought Wells 1E, AA, and 13A online in July 2015 with Cr6 concentrations that meet the Cr6 MCL.

The evaluation, design, and construction of the Cr6 treatment facilities for IWA Wells 1E, AA, and 13A were conducted in parallel with this Cr6 Compliance Study Project. Information and lessons learned from that effort informed the Study evaluation, allowed for refinement of design assumptions and cost estimates, and were incorporated into this Study report. Completion of this report was purposefully delayed to include this information.

1.6 Report Organization

This report is organized into ten chapters that capture the Study findings, detailing the approach used to evaluate and recommend treatment options and outlining the timetable for implementation:

- **Executive Summary** – a brief summary highlighting key findings and recommendations.
- **Chapter 1 Introduction and Objectives** – background information on the Cr6 rule, CWA and IWA systems, and overview of the project approach.
- **Chapter 2 System Supply and Demand** – analysis of existing CWA and IWA infrastructure capacity, operating trends, and current and future water demands and supply.
- **Chapter 3 Water Quality** – summary of available water quality information for groundwater and surface water supplies.
- **Chapter 4 Treatment Options** – description of best available groundwater treatment technologies for Cr6 and other constituents, non-treatment options, and surface water treatment approaches.
- **Chapter 5 Scenario Analysis** – details of the approach to scenario development and findings of scenario evaluation, including treatment equipment design and cost estimates, technology selection, and operational and distribution system evaluations.
- **Chapter 6 Cost Summary** – estimated project costs for recommended treatment facilities.
- **Chapter 7 SBA System Operations Comparison** – quantification of the impact of analysis assumptions and qualitative discussion of potential risks.
- **Chapter 8 Implementation Timetable** – timetable plan outlining next steps to plan for, design, and construct recommended projects.
- **Chapter 9 Summary and Conclusions** – wrap up summary of the evaluation and findings.
- **Chapter 10 Recommendations** – compiled list of recommendations.

System Supply and Demand

2.1 Groundwater Well Supply Capacity

Currently, CWA and IWA water demands are met from metered groundwater wells, 6 CWA wells and 20 IWA wells, respectively. The total well production capacity for the CWA system is 17.6 MGD and 72.7 MGD for the IWA system. **Table 3** and **Figure 4** summarize available information for CWA and IWA wells, including the well design capacity and the pumping capacity based on recent pump test records (if available). For the purposes of this Cr6 Study, the greater of the design or pumping capacity was rounded to the nearest 100 gpm for sizing and costing of treatment facilities.

Six CWA wells are currently active and above the Cr6 MCL. There are plans to decommission CWA Well 11 in the future and increase utilization of Well 16 to accommodate this loss in capacity. There are no plans to rehabilitate or bring back online CWA wells 7, 9, or 10. These wells have been designated as monitoring wells.

Seven of the 20 IWA wells are currently in operation (25.2 MGD), and three additional wells (1E, AA, 13A) will be brought online in July 2015 for a total available capacity of 39.2 MGD. The other 10 IWA wells were placed in standby because they produce water exceeding the Cr6 MCL. IWA Wells X and Y are inactive due to fluoride concentrations and well 13B is currently inactive, but is planned to be brought online in the future.

Table 3. CWA and IWA Well Status and Pumping Capacity

CWA					IWA				
ID	**Status**	**Design Capacity (gpm)**	**Pumping Capacity (gpm)**	**Selected Capacity for Cr6 Study (gpm)** [1]	**ID**	**Status**	**Design Capacity (gpm)**	**Pumping Capacity (gpm)**	**Selected Capacity for Cr6 Study (gpm)**[1]
Well 11	Active	1200	1371	1400	WELL 1B	Standby	2000	1939	2000
Well 12	Active	2000	2114	2200	WELL 1C	Standby	1150	1172	1200
Well 16	Active	2000	1848	2000	WELL 1E	Standby	3200	3179	3200
Well 17	Active	2200	2138	2200	WELL 2C	Standby	1100	1176	1200
Well 18	Active	2000	1965	2000	WELL 2D	Standby	2300	2359	2400
Well 19	Active	2000	2323	2400	WELL 3A	Standby	1350	1439	1500
Well 7	Inactive				WELL 3B	Standby	1450	1821	1900
Well 9	Inactive				WELL 3C	Standby	1550	1624	1700
Well 10	Inactive				WELL 4A	Active	2500	2513	2600
					WELL 4B	Active	2000	2050	2100
					WELL 4C	Active	2500	2474	2500
					WELL S	Active	2700	2770	2800
					WELL T	Active	2900	2933	3000
					WELL U	Standby	3000	3000	3000
					WELL V	Active	3300	3000	3300
					WELL W	Standby	3200	3329	3400
					WELL Z	Standby	3000	3000	3000
					WELL AA	Standby	3150	3200	3200
					WELL BB	Standby	3200	3200	3200
					WELL 13A	Standby	3000	3292	3300
					WELL 13B	Not equipped	3000	1939	3300
					WELL X	Inactive - fluoride	3000	1172	2000
					WELL Y	Inactive - fluoride	3000	3179	1200
Total CWA System Well Capacity, MGD				17.6	Total IWA System Well Capacity, MGD				72.7
Total CWA Active Well Capacity, MGD				17.6	Total IWA Active Well Capacity, MGD				25.2 (39.2)[2]

[1]Greater of the design or pumping capacity rounded to the nearest 100 gpm.
[2]Increased capacity with treatment at IWA Wells 1E, AA and 13A.

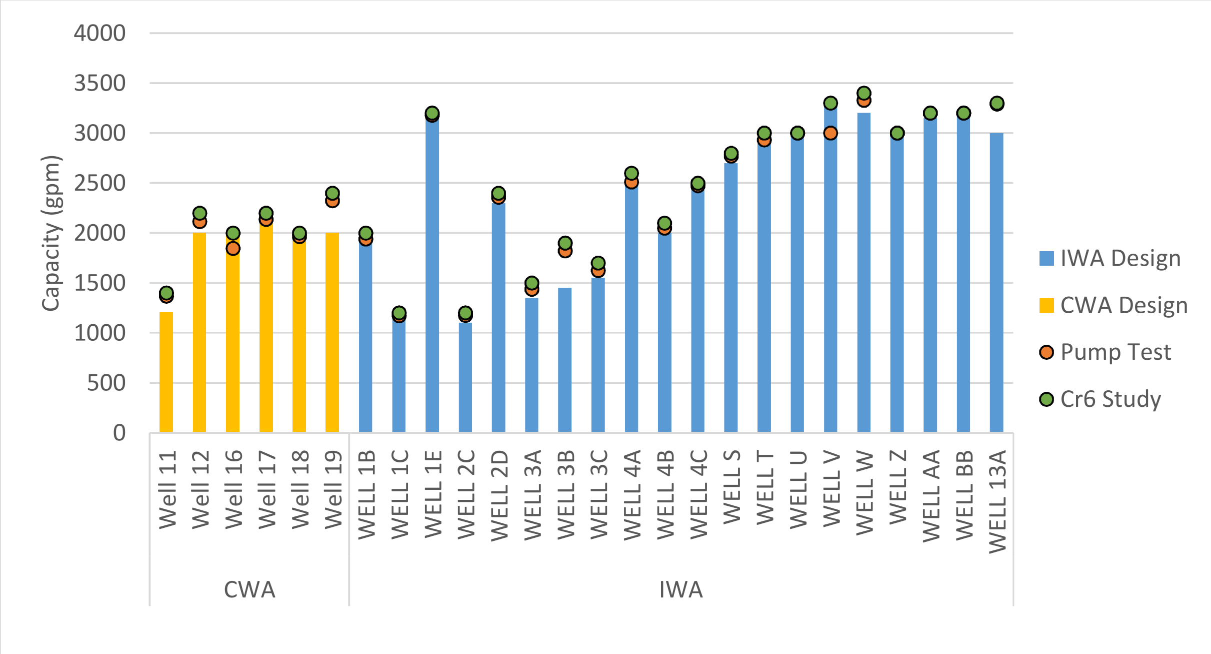

Figure 4. CWA and IWA Well Capacities

2.2 Historical Well Production Trends

CWA and IWA total well production vary seasonally, with peak production typically occurring in June. On average from 2010 to 2013, total well production ranged from 5.6 to 9.3 MGD and 12 to 26 MGD for CWA and IWA, respectively (**Figure 5**). Historical well production trends reflect the seasonal water demand peaks, which dictate the required treatment capacity to meet maximum daily demands.

Annual average well utilization (percentage of the average annual well production relative to the well design capacity) varies by well, but averaged 27 percent and 40 percent across the systems in 2013 for CWA and IWA wells, respectively. In the future, this well utilization strategy will change to account for planned future operations and to optimize Cr6 treatment costs. For CWA, the future well production trends include removing Well 11 from service and increased utilization of Well 16. For IWA, the utilization of better quality wells (the 7 wells that are in currently compliance with Cr6 less than 10.4 ppb) will be increased to approximately 80% and wells requiring Cr6 treatment will be relied on approximately 30% of the time to manage seasonal peaks. The long-term impact of this high of utilization should be examined further. **Figure 6** presents the annual average production by well (in 2013) against the well design capacity and also includes the planned future utilization strategy used in this Cr6 Study analysis. Well utilization information was used to estimate annual operations and maintenance and lifecycle costs.

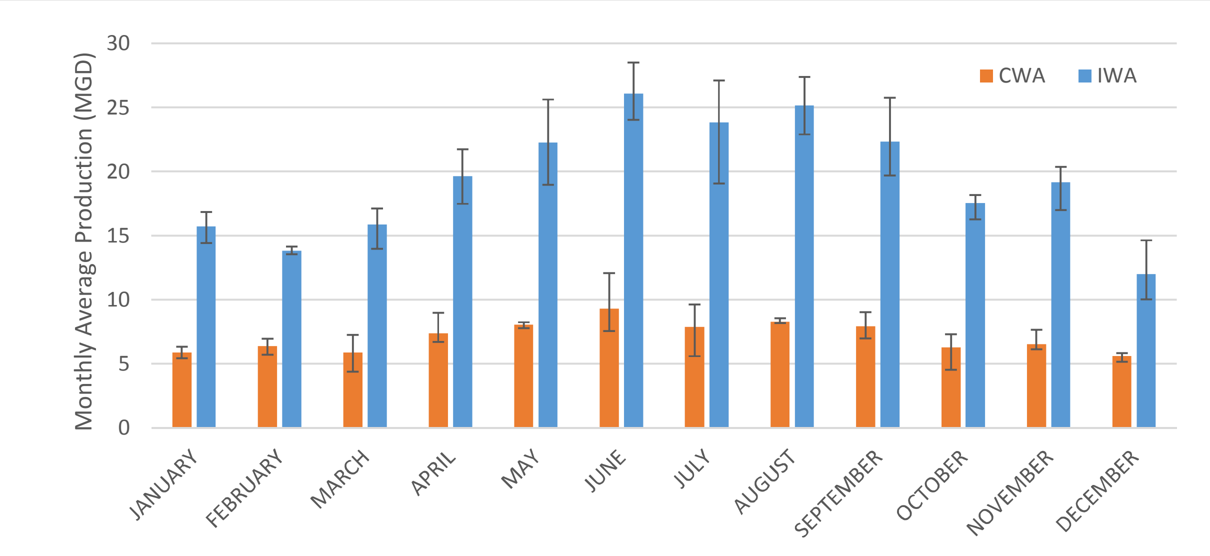

Figure 5. CWA and IWA Monthly Average Well Production

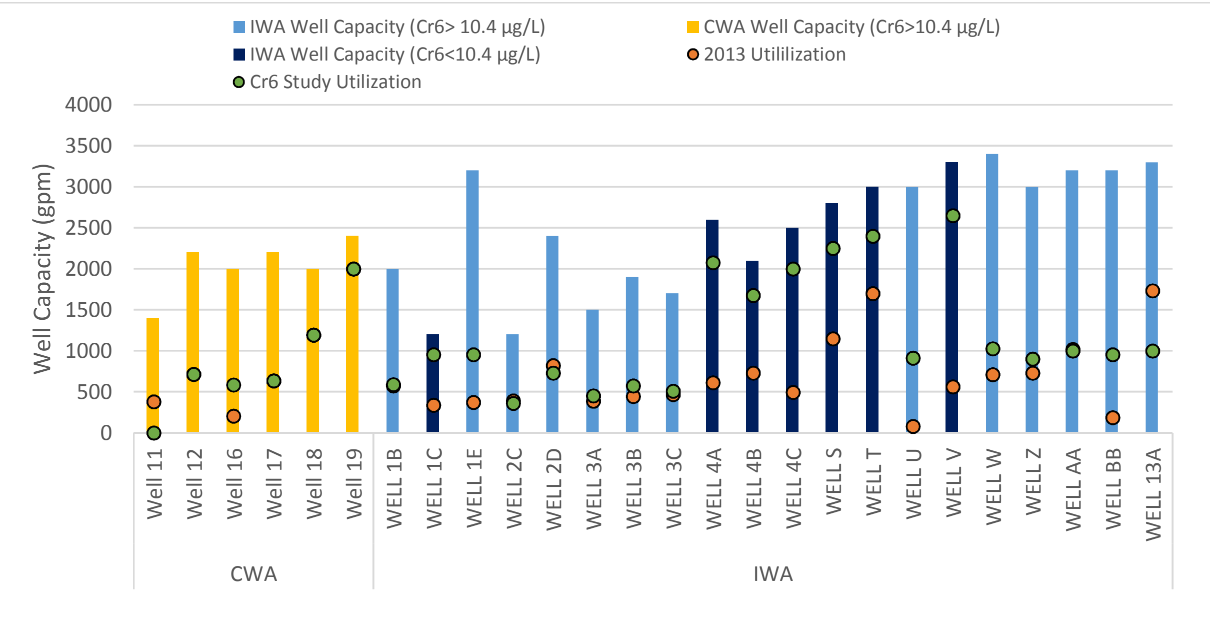

Figure 6. Annual Average Well Utilization

2.3 Storage Reservoirs, Booster Pumps, and Pipelines

There are three storage reservoirs (1.5 MG, 3.6 MG, and 5.0 MG) in the CWA system for a total existing capacity of 10.1 MGD (**Table 4**). The 3.6 MG is located at Well 12 and is equipped with a pressure relief valve to relieve excess system pressure in the low pressure zone. The 5.0 MG reservoir is located at Well 18, and includes two booster stations so that either the low or high pressure zone can be supplied by Well 18. The 1.5 MG reservoir establishes the hydraulic gradient for the high zone and maintains supply and pressure through gravity. The supply for the 1.5 MG reservoir is Well 18, although Well 11 was configured to have the ability to supply the reservoir during high demand periods if necessary. The total pumping capacity for the CWA system is 29 MGD (**Table 5**). There are approximately 120 miles of pipelines in the CWA system ranges in size from 4 to 24 inches. The majority (80 percent) of these pipes are asbestos cement (AC); however, some are PVC, DI, and steel.

Table 4. CWA Storage Reservoirs

Reservoir Name	Capacity (MG)	Pressure Zone	Bottom Elevation (ft)	HWL (ft)	Tank Height (ft)	Inside Diameter (ft)
High Zone	1.5	High	115.5	146	32	90.5
Low Zone	3.6	Low	-75	-49	26	158
Avenue 48	5	Low/High	-57.5	-29	28.5	175

Source: 2015 CWA Master Plan Update Report

Table 5. CWA Booster Stations

Facility	Number of Pumps	Capacity (gpm)	Capacity (MGD)
Reservoir at Well 12	3	3500	5.0
Reservoir at Well 18- Low	2	440	0.6
Reservoir at Well 18- High	2	4000	5.8
Well Pumps	Well 11	1400	2.0
	Well 12	2200	3.2
	Well 16	2000	2.9
	Well 17	2200	3.2
	Well 18	2000	2.9
	Well 19	2400	3.5
		TOTAL	29.0

Source: 2015 CWA Master Plan Update Report.

There are seven storage reservoirs in the IWA system totaling 18.75 MG in capacity **(Table 6**). Five of these reservoirs are located at various production plants. Recent modifications at these reservoirs included the addition of a flow control/pressure sustaining valves to allow the reservoirs to fill with system water at the Plant 2, Plant 3, and Plant 4 reservoirs as those wells are currently in standby. At Plant 1, the Palo Verde reservoir is filled with water from Well 1C and from the treatment system for Well 1E. Reservoirs at Shadow Lake and Terra Lago are connected to the distribution system and are filled using system water. These reservoirs are equipped with their own booster stations. Well pumps at individual IWA Wells S, T, U, V, W, Z, AA, BB, and 13A supply the distribution system directly. The total pumping capacity for the IWA system is 89.7 MGD, and firm capacity (largest pump out of service) is 71.1 MGD (**Table 7**). There are approximately 326 miles of IWA pipelines ranging in size from 2 to 24 inches. Most of the pipes are made of ductile iron (DI) or polyvinyl chloride (PVC); however there are some asbestos, concrete, cast iron, or steel materials.

Table 6. IWA Storage Reservoirs

Name	Plant	Type	Dimensions (feet)	Total Height (feet)	Total Volume (MG)
Palo Verde	#1	Rectangular Concrete	210 by 145	22	5
Dominguez	#2	Circular Steel	125	22	2
Reservoir 3	#3	Circular Steel	125	22	2
Reservoir 3A	#3	Circular Steel	126	27	2.5
Reservoir 4	#4	Circular Steel	125	22	2
Shadow Lake	Shadow Lake	Circular Steel	40	24	0.25
Lost Horse	Terra Lago	Circular Steel	180	27	5

Source: Updated from the 2012 IWA Master Plan Update Report

Table 7. IWA Booster Stations

Facility		Capacity (gpm)	Head (feet)	VFD Capable?	Target HGL (feet)	Total Capacity (MGD)	Firm Capacity (MGD)
Plant 1	Pump 1	2078	190.6	Yes	175	9	6
	Pump 2	2078	190.6	Yes	175		
	Pump 3	2093	191.7	Yes	175		
Plant 2	Pump 1	1979	165	Yes	179	6.3	2.8
	Pump 2	2830	164	Yes	179		
Plant 3	Pump 1	3157	180.2	Yes	180	13.9	9.2
	Pump 2	3290	170.9	Yes	180		
	Pump 3	3232	175.6	Yes	180		
Plant 4	Pump 1	966	134	No	-	10.3	7.3
	Pump 2	2078	135.1	No	-		
	Pump 3	2050	132.8	No	-		
	Pump 4	2038	135.1	No	-		
Shadow Lake	Pump 1	235	146.7	No	-	2.5	0.6
	Pump 2	209	146.7	No	-		
	Pump 3	1317	114.3	No	-		
Terra Lago	Pump 1	348	152	No	-	6.4	4.6
	Pump 2	348	152	No	-		
	Pump 3	1250	180	No	-		
	Pump 4	1250	180	No	-		
	Pump 5	1250	180	No	-		
Well Pumps	Well S	2800	334.7	No	-	4	4
	Well T	3000	365	No	-	4.3	4.3
	Well U	3000	325.3	Yes	169	4.3	4.3
	Well V	3300	340.3	No	-	4.8	4.8
	Well W	3400	311	No	-	4.9	4.9
	Well Z	3000	341.6	Yes	176	4.3	4.3
	Well AA	3200	346.8	Yes	186	4.6	4.6
	Well BB	3200	378.2	Yes	174	4.6	4.6
	Well 13A	3300	520.4	Yes	178	4.8	4.8
					TOTAL	89.7	71.1

Source: Updated from the 2012 IWA Master Plan Update Report.

2.4 Alternative Water Supply

CWA and IWA have established goals to limit groundwater pumping in the future to and 8,400 AFY[4] and 20,000 AFY[5]. Alternative sources of supply to groundwater such as surface water and recycled water are being considered by both agencies. While CWA and IWA do not have direct rights to surface water, the use of Colorado River water was considered as part of the overall Cr6 MCL compliance strategy and to meet future domestic water supply demands. Coachella Valley Water District (CVWD) operates and maintains the Coachella Canal, which delivers Colorado River water. The possibility of purchasing this source of water was investigated. As of 2010, CVWD received 368,000 AFY of Colorado River deliveries under the Quantification Settlement Agreement (QSA). CVWD's allocation will increase to 459,000 AFY by 2026[6].

The benefits of surface water treatment include increasing the reliability of CWA and IWA water supply, reducing groundwater overdraft, and potentially reducing Cr6 treatment costs if groundwater and surface water blending is employed. Initial evaluations for a potential Surface Water Treatment Plant (SWTP) have already been considered in the past, with a 14 MGD SWTP for IWA and a 10 MGD (with future expansions) for CWA referenced in agency master plans. This Study initially considered surface water treatment as a potential component of the Cr6 compliance strategy; however, based on projected SWTP costs (discussed further in Section 4.2) compared to the cost of Cr6 groundwater treatment, CWA and IWA decided to remove surface water from the evaluation. Thus, as it was no longer considered a cost-effective component of the Cr6 compliance strategy, a detailed analysis of treatment options (potential SWTP site locations, recommended treatment trains, and blending scheme) are not included in this Study report. A combination of direct use and/or recharge of surface water, recycled water, as well as conservation will all be components of a future strategy to meet water demands; however, in the context of this Cr6 analysis, cost estimates included individual well treatment and clustered well treatment options to meet both current and future water demands.

2.5 Current and Future Water Demands

Current unit water demands as reflected in the most recent CWA and IWA Master Plans are summarized in **Table 8**. These plans included additional unit demand conservation goals of 5 and 10 percent, for CWA and IWA, respectively.

To project future demands, peaking factors were applied to the Average Day Demand (ADD). The Maximum Day Demand (MDD) is used to size water supply systems, pump stations, and treatment facilities. The Peak Hour Demand (PHD) is used to size distribution and storage facilities. The MDD and PHD used in this Cr6 Study analysis are summarized in **Table 9**. These peaking factors are consistent with 2013 well production data and factors used in the Agency master plan reports.

Table 10 summarizes projected future demands as depicted in the Agency Water Master Plans.

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[4] CVRWMG Regional Management Plan, 2010
[5] IWA Water Master Plan, 2012
[6] MWH. 2012. Coachella Valley Water Management Plan 2010 Update

Table 8. CWA and IWA Existing Unit Water Demand from Agency Master Plans

Demand Category	CWA	IWA
Single Family Residential	600 gpd/DU	700 gpd/dwelling unit (DU)
Multi-family Residential	400 gpd/DU	500 gpd/DU
Commercial/Industrial	1300 gpd/acre	2,700 gpd/acre
Restaurants	1300 gpd/acre	4,000 gpd/acre
Park Irrigation	1300 gpd/acre	4,000 gpd/acre

Table 9. Peaking Factors

Parameter		CWA	IWA
Demands (2013)	Average Day	7.1 MGD	19.4 MGD
	Max Day	12.9 MGD	28.0 MGD
Peaking Factors	MDD/ADD	1.7[1]	1.5
	PHD/ADD	2.8	2.5

[1]Note that although the 2013 MDD/ADD peaking factor was 1.8, historically, this value was closer 1.7, and 1.7 continues to be used for facility planning.

Table 10. CWA and IWA Current and Future Demand Summary

Demand Factor	CWA[7]					IWA[8]				
	2013[1]	2015	2020	2025	2030	2013[1]	2015	2020	2025	2030
ADD	6.3	8.0	12.3	16.6	20.9	19.4	18.7	21.4	24.6	27.2
MDD	12.9	13.7	21.0	28.3	35.6	28.0	28.1	32.1	36.9	40.8

[1] 2013 ADD and MDD from well production records. 2015 to 2030 projections from Agency Water Master Plan Reports.

[7] CWA 2015 Water Master Plan Update
[8] IWA 2012 Water Master Plan Update

Figure 7 summarizes CWA supply and projected future demands. CWA supply is shown in solid bars. All wells are greater than 10.4 µg/L and will require treatment. Although alternative future water supplies (direct or indirect use of surface water or recycled water) have been discussed, there are no referenced data on potential capacity of these sources and thus this bar is not shown on the figure. For the purposes of this Study, it was assumed that future demand will be met with the installation of additional groundwater wells. The CWA demands (ADD and MDD) are shown as dashed lines. Similar to IWA projected future demands, a conservation boundary and its accompanying range were included to show a 35% reduction of peak demand through conservation, as mandated by the state of California[9] (applied in addition to the 20% reduction from the Water Conservation Act of 2009 (SBX7-7) that was already incorporated into the future demand projections).

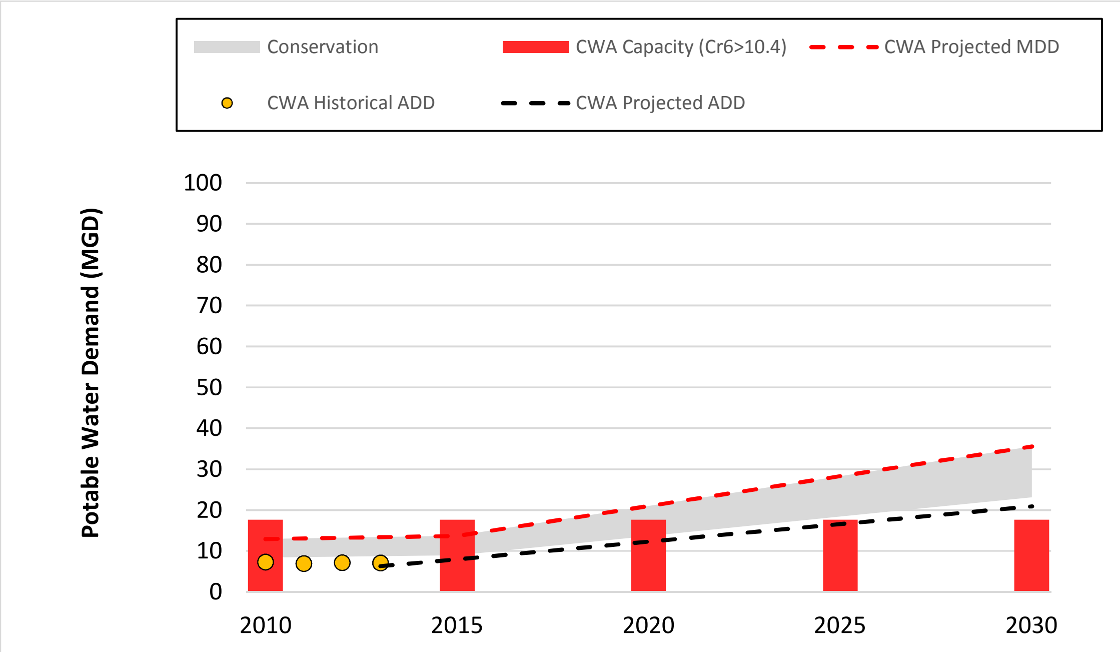

Figure 7 CWA Supply and Demand Summary

[9] California governor Jerry Brown released an executive order on April 1, 2015, that would decrease potable urban water use in response to record drought. The State Water Control Board, under this directive, issued a Proposed Regulatory Framework that calls for the stated 35% decrease by both CWA and IWA.

Figure 8 summarizes IWA supply and projected future demands. IWA supply is shown on the figure as stacked bars separated by the wells that with Cr6 greater than or less than 10.4 µg/L, and also alternative sources (direct or indirect use of surface water or recycled water). The IWA demand (ADD and MDD) are shown as dashed lines. A conservation boundary and its accompanying conservation range were included to show a 35% reduction of peaked demand through conservation efforts, mandated by the state of California . This reduction is applied in addition to the 20% reduction from the Water Conservation Act of 2009 (SBX7-7) that has already been incorporated into the projected demand trajectories. The scope of this Study includes achieving Cr6 compliance while minimizing wasted water. Thus, the range shows that demand could decrease from the upper limit due to conservation, however, for a conservative evaluation of compliance planning, the reduced demand from conservation efforts will not be considered. The groundwater goal accounts for the 20,000 acre-foot groundwater pumping restriction goal, self-imposed by IWA.

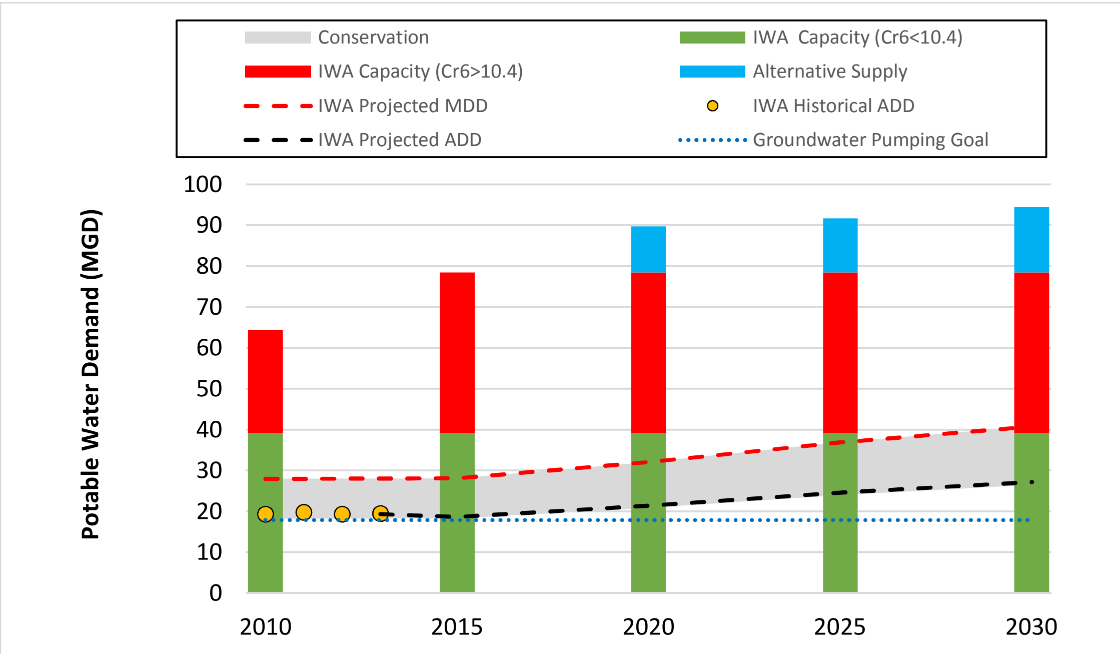

Figure 8 IWA Supply and Demand Summary

Figure 9 summarizes the combined CWA and IWA demands against the current CWA and IWA supplies that are currently less than 10.4 µg/L. The difference between the dashed combined system demand and the supply bars must be met through additional Cr6 groundwater treatment or alternative sources of supply (discussed further in **Section 5.12**).

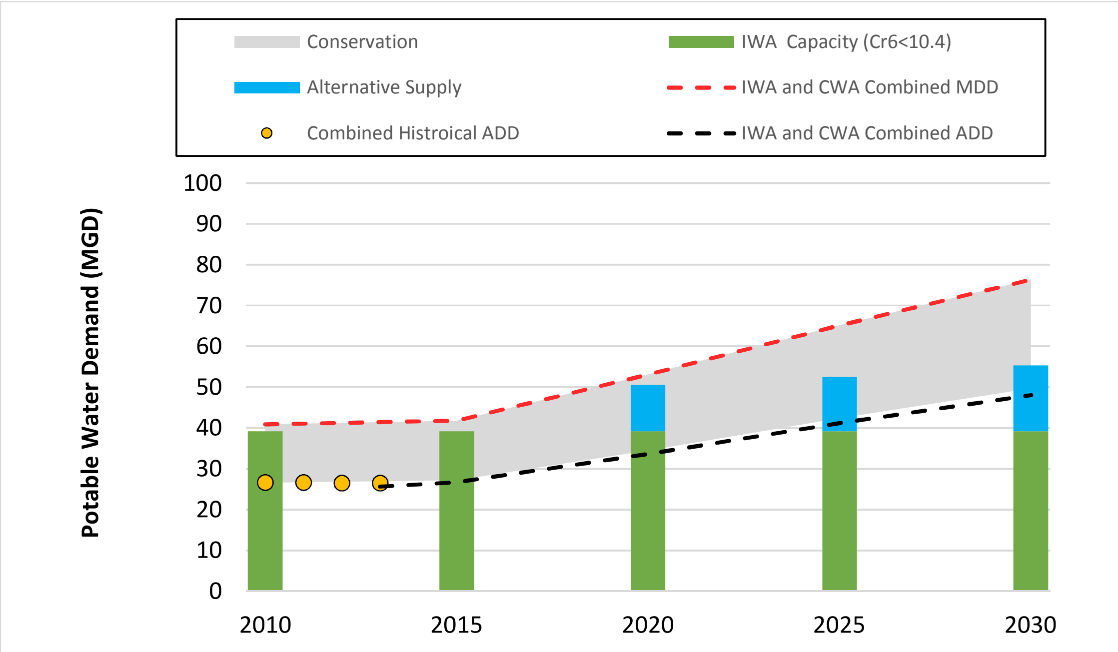

Figure 9. Combined CWA and IWA Supply and Demand Summary

Water Quality

Historical water quality information was reviewed to define treatment requirements, select applicable treatment technologies, and evaluate parameters that affect operational costs. Available groundwater well data were compiled to create a water quality database for analysis (Appendix B). The database utilized pivot-tables and pivot-figures for trending analysis. To account for data variability and to provide a level of conservatism in facility design, the maximum water quality concentrations were used for evaluation and design.

3.1 Groundwater

Overall, CWA and IWA existing groundwater well supply can be considered a high quality drinking water source characterized by low turbidity, low TOC, moderate alkalinity, and low dissolved solids content. Drinking water produced from the existing groundwater supply is generally aesthetically pleasing to customers. This analysis focused on Cr6 and co-occurring constituents such as arsenic, nitrate, total dissolved solids (TDS), and volatile organic compounds (VOCs) that could impact treatment decisions. Treatment decisions in relation to potential future regulations for emerging constituents (1,4-dioxane, antimony, cobalt, chlorate, molybdenum, nitrosamines, perchlorate, selenium, strontium, vanadium) are also discussed.

3.1.1 Cr6 and Total Cr

Cr6 and total Cr data were used to identify the wells impacted by the Cr6 MCL and to observe the trends for Cr variability over time. A Cr6 treatment trigger (the concentration at which treatment was determined to be necessary) of 10.4 µg/L was established by CWA and IWA to identify impacted wells. Wells with historical maximum concentrations less than 10.4 µg/L were planned to be grandfathered and left untreated. For the purposes of this analysis, impacted wells were categorized into three Tiers:

- **Tier 1 (Cr6 > 10.4 µg/L)** – current treatment required.
- **Tier 2 (8 µg/L < Cr6 < 10.4 µg/L)** – no current treatment required, costs estimates included for future contingency planning.
- **Tier 3 (Cr6 < 8 µg/L)** – no current treatment required and no plans for future treatment.

Apparent differences in Cr6 and total Cr data (i.e. Cr6 concentration greater than total Cr) can be attributed to the accuracy of the different analytical methods. Cr6 is analyzed using EPA method 218.6 (reporting limit of 0.050 µg/L), while total Cr is typically analyzed using EPA 200.8 (reporting limit 1.0 µg/L).

Figure 10 and **Figure 11** present historical trends for an example CWA and IWA well. Historical figures for all wells are presented in Appendix B. Generally, there was no trend of increasing Cr6 concentrations over time. Although there are some fluctuations in Cr concentrations, there were no prominent outliers in the data, supporting the use of the maximum concentration (as opposed to 90th percentile) for design criteria.

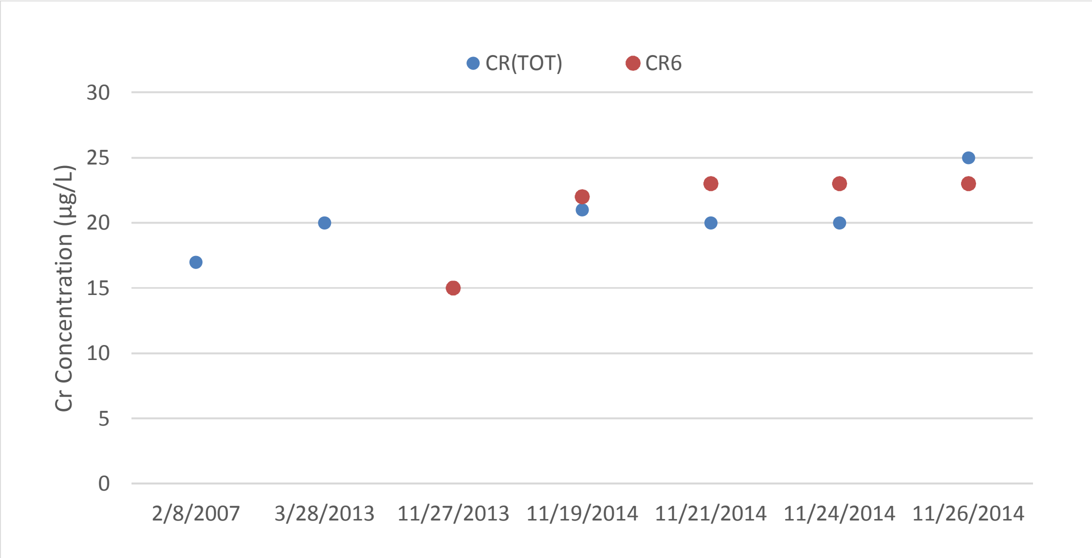

Figure 10. CWA (Well 12) Historical Chromium Concentrations

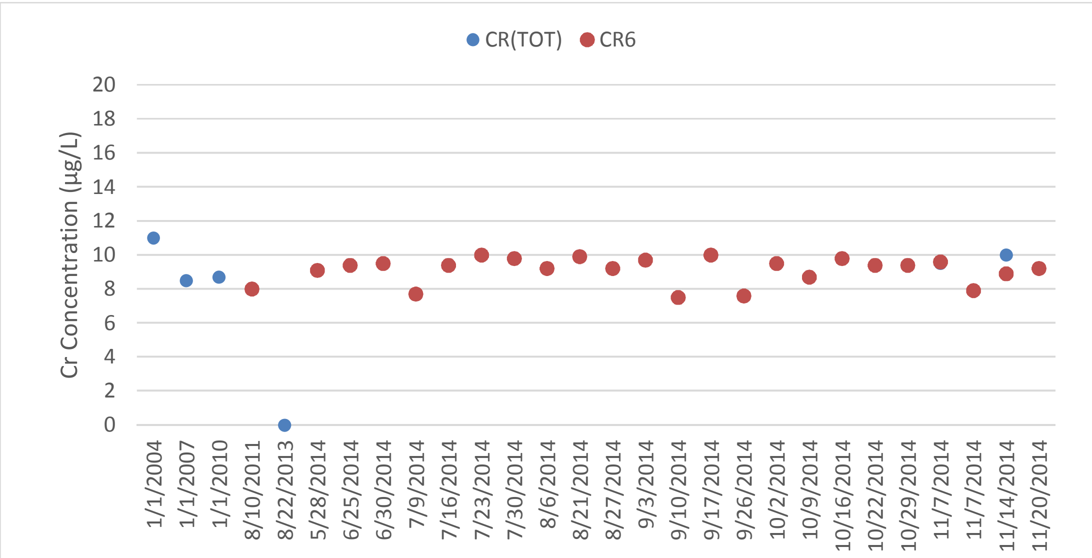

Figure 11. IWA (Well 1E) Historical Chromium Concentrations

Maximum and 90th percentile Cr6 concentrations for CWA wells are presented in **Figure 12**. All six CWA wells are Tier 1 wells requiring treatment based on these maximum values. Similarly, **Figure 13** shows the maximum and 90th percentile concentration values for all IWA wells. Again, there are minimal discrepancies between the maximum and 90th percentile data supporting the use of the maximum concentration as design criteria. IWA maximum Cr6 concentrations ranged from 8.5 to 20.0 µg/L with 13 Tier 1 wells, 7 Tier 2 well, and no Tier 3 wells. **Figure 14** shows a map of CWA and IWA well locations and their respective Cr6 concentrations.

Figure 12. CWA Cr6 Concentrations

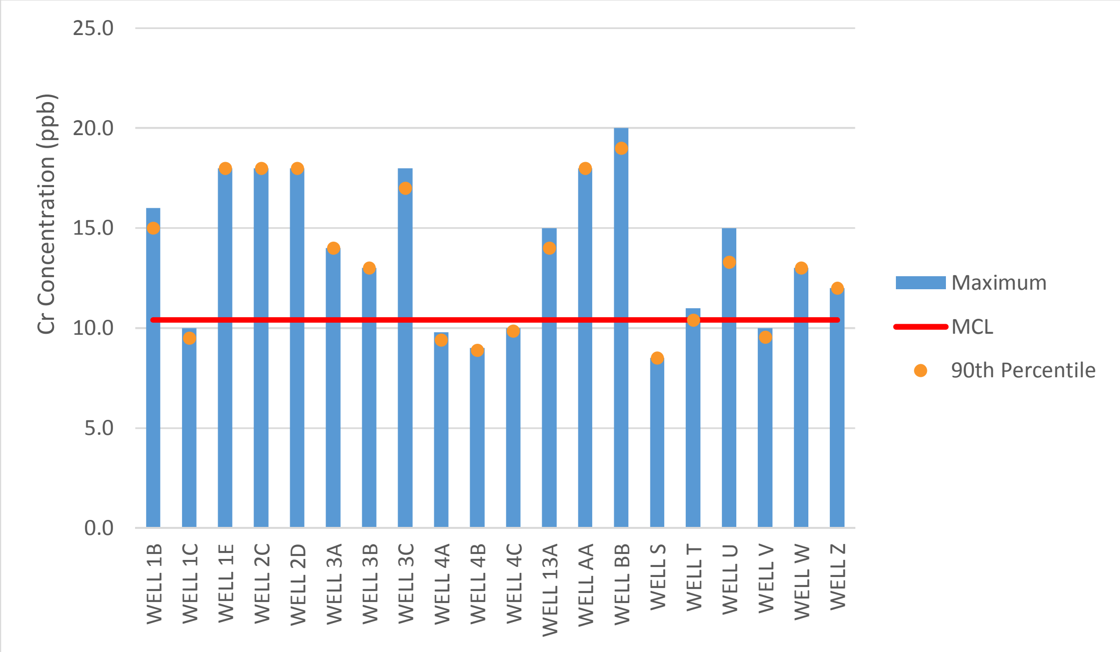

Figure 13. IWA Cr6 Concentrations

Figure 14. CWA and IWA Cr6 Concentrations

A summary of individual well data including the design capacity (established in Chapter 2), the design Cr6 concentration, and the possible treatment system bypass fraction is presented in **Table 11**. The bypass fraction is calculated as the percentage of the design flow that can be bypassed around treatment while maintaining final blended treatment goals. For all technologies, a bypass flow was assumed that blends treated water with untreated groundwater for cost effective design. A Cr6 treatment goal of 2 µg/L in Cr6 treatment system effluent and 6 µg/L in the final blend with bypass were the design criteria for this sizing capital facilities in this analysis. Note that the target less than the MCL is a conservative approach to provide a buffer in case concentrations fluctuate in the groundwater or treated water. In operation, these goals can be adjusted to maintain a treated water concentration below the Cr6 MCL.

Table 11. Cr6 Study Design Criteria Summary – Cr6 Concentration

	ID	Design Flow (gpm)	Design Cr6 Concentration (µg/L)	Bypass Fraction
CWA	WELL 11	1400	18.0	25%
	WELL 12	2200	23.0	18%
	WELL 16	2000	17.0	25%
	WELL 17	2200	23.0	27%
	WELL 18	2000	14.0	30%
	WELL 19	2400	21.0	21%
IWA	Plant 1	6400	18.3	24%
	Plant 2	3600	18.0	25%
	Plant 3	5100	15.0	29%
	Plant 4	7200	9.6	81%
	WELL 13A	3300	15.0	30%
	WELL AA	3200	18.0	25%
	WELL BB	3200	20.0	22%
	WELL S	2800	8.5	82%
	WELL T	3000	11.0	27%
	WELL U	3000	15.0	40%
	WELL V	3300	10.0	52%
	WELL W	3400	13.0	35%
	WELL Z	3000	12.0	40%

3.1.2 Wells with Co-occurring Regulated Constituents of Concern

Co-occurring constituents in groundwater can affect treatment selection and operations. For example, sloughing of nitrate (i.e., chromatographic peaking) can occur with strong base anion exchange for Cr6 removal. Solutions exist for minimizing impacts from nitrate peaking and would require incorporation of safeguards into the design, such as blending of multiple treatment vessels and/or online nitrate monitoring to discharge water in excess of the MCL to waste. Potential constituents of concern that were evaluated in this study included nitrate, TDS, arsenic, and VOCs.

Nitrate. Many of CWA and IWA's wells have low nitrate (less than 10 mg/L as NO_3^-) compared with the MCL of 45 mg/L as NO_3^-. A few IWA wells have concentrations in the 8 to 29 mg/L as NO_3^- range (Plant 4, Well S, Well V), although these wells currently have Cr6 concentrations less than the MCL. While none of these wells require nitrate treatment, nitrate concentrations should be a concern when strong base anion (SBA) exchange resin is considered for Cr6 treatment. Nitrate is removed by SBA resin for a short amount of treatment time (usually less than 500 bed volumes (BVs)) compared with Cr6, which has a higher selectivity (typically 5,000 to 20,000 BVs for most CWA and IWA wells). Once nitrate is at capacity on the resin ion exchange sites, chromatographic peaking can occur that results in release of nitrate at concentrations two to four times higher than the influent concentration.

Examples of mitigation strategies include use of online nitrate monitoring with the ability to discharge water with nitrate above the MCL, or use of multiple vessels in parallel to minimize peaking effects. In general, few of CWA and IWA's active wells will be impacted by the additional need for nitrate monitoring or parallel vessel design. To provide a conservative assumption in this analysis, wells exceeding 10 mg/L NO_3^- may need design features to mitigate potential chromatographic peaking; however, no Tier I CWA or IWA wells that require treatment (have Cr6 concentrations about the MCL) have nitrate levels exceeding this threshold.

TDS. TDS ranges from 190 to 410 mg/L in CWA wells and 180 to 380 mg/L in IWA wells, all below the recommended secondary MCL for TDS of 500 mg/L and the upper limit of 1,000 mg/ for consumer acceptance. Groundwater replenishment with Colorado River water may increase the TDS of groundwater over time. No CWA or IWA wells are in the vicinity of influence of current groundwater replenishment facilities.

Arsenic. Three CWA wells (16, 17, 18) have detectable levels of arsenic ranging from 2.1 to 3.3 µg/L, but well below the MCL of 10 µg/L. IWA wells have no detectable arsenic concentrations (> 2 µg/L). Arsenic is removed by SBA resin (usually less than 3,000 BVs) compared with Cr6, which has a higher selectivity (5,000 to 20,000 in CWA and IWA wells). Similar to nitrate, arsenic chromatographic peaking can occur that results in release of arsenic at levels higher than the influent concentration.

VOCs. VOC data for CWA wells were not available for review. There are no IWA wells with detectable VOC concentrations.

3.1.3 Emerging Constituents

The ability of Cr6 treatment options to remove emerging constituents was evaluated, to address the potential for selection of an approach that offers the most flexibility and cost savings for future as well as current compliance.

On the federal level, the Safe Drinking Water Act (SDWA) has several upcoming major regulatory actions that may impact which constituents are regulated in the future, including the preliminary regulatory determinations (RD3) from the third Contaminant Candidate List (CCL3), the draft fourth Contaminant Candidate List (CCL4) that was issued in February 2015, and the Six-Year Review in 2016. Additional pending regulations include the perchlorate draft rule and a draft rule adding eight additional carcinogenic VOCs to the existing VOC regulations.

The preliminary RD3 was released by EPA in October 2014 and included negative determinations for four constituents but only one positive determination, which was for strontium. EPA will issue its final RD3 in 2015. If the agency makes a final determination to regulate strontium, EPA will begin the process to propose an NPDWR. The draft CCL4 was issued in February 2015. Changes from CCL3 to CCL4 included the addition of manganese and nonylphenol; the removal perchlorate (EPA made a positive regulatory determination in 2011); and the removal of the five constituents with preliminary regulatory determinations pending publication of the final RD3. Nitrosamines and chlorate are opined by American Water Works Association (AWWA) to likely be included in the third Six-Year Review. Nitrosamine regulation is uncertain due to high source contribution from food.

In California, several additional constituents have had Public Health Goals (PHGs) decreased and Notification Levels established. A brief description of data for each constituent, is provided below. Data from the Geotracker Groundwater Ambient Monitoring and Assessment (GAMA) database was reviewed and plotted for Coachella Valley area wells to provide a broader picture of concentrations in the valley than provided by CWA and IWA production wells. Following subsections describe the potential treatability of emerging constituents.

Strontium. Due to its potential role in decreasing bone density, especially in sensitive life stages such as early childhood, strontium has a health advisory level (HAL) of 1.5 mg/L or 1,500 µg/L. In California, strontium currently has no public health goal, notification level (NL), or MCL. It is unclear at what level strontium would be regulated. CWA well strontium concentrations ranged from 230 to 390 µg/L and IWA well strontium concentrations ranged from non-detect to 640 µg/L (all below the HAL). The GAMA database reported strontium detected in 69 wells, with two wells above the HAL. By comparison, Colorado River water is observed at approximately 1,000 to 1,200 µg/L.

Chlorate. The EPA published a health reference level (HRL) of 210 µg/L for chlorate, though this has been widely criticized due to the EPA's assumption that only 20% of chlorate exposure is attributable to drinking water. The recent draft RD3 (October 2014) included a statement from the EPA regarding the uncertainty around total dietary exposure, indicating that any MCL could be significantly different from the HRL. Chlorate has a notification level (NL) of 800 µg/L in California and has a World Health Organization guideline value of 700 µg/L. No chlorate data were available from CWA, IWA, or the GAMA database.

The predominant source of chlorate in finished drinking water is through the use of chlorine dioxide, bulk hypochlorite, and on-site generated (OSG) hypochlorite. Several mechanisms for controlling chlorate formation in bulk hypochlorite have been identified, including minimizing storage time, diluting stored solutions with softened water, maintaining stored bulk hypochlorite pH between 11 and 13, and/or cooling bulk hypochlorite during warmer months. Alternatively, use of calcium hypochlorite can minimize by-product formation and avoid safety concerns for gaseous chlorine.

Nitrosamines. Nitrosamines do not have a federal HAL or reference level. Three nitrosamines (n-nitrosodiethylamine: NDEA, n-nitrosodimethylamine: NDMA, and n-nitrosodipropylamine: NDPA) have NLs in California of 10 ng/L. NDMA has a PHG of 3 ng/L in California. No nitrosamines are currently regulated with a MCL in California, but do require customer notification if the NL is exceeded. Nitrosamine data were not available for CWA and IWA wells and all the wells tested and reported in the GAMA database have non-detect NDMA (< 5 ng/L). Based on the available results from the GAMA database and the use of free chlorine as the disinfectant at CWA and IWA, nitrosamines do not appear to be a concern at this time.

1,4-Dioxane. 1,4-dioxane has a NL of 1 µg/L in California. No 1,4-dioxane data were available for CWA wells and IWA well 1,4-dioxane concentrations were non-detect. The GAMA database also reported non-detect concentrations for 1,4-dioxane in all supply wells tested in the Coachella Valley (a total of 9 wells); however multiple detection limits were provided (unknown, 6, 13 and 35 µg/L). Based on the available results from IWA and the GAMA database, 1,4-dioxane does not appear to be a concern at this time.

Antimony. Antimony is regulated with a federal and California MCL of 6 µg/L, and has a California Public Health Goal (PHG) of 0.7 µg/L. Since the method detection limit (6 µg/L) has been higher than the PHG, it is unclear how many wells would likely be impacted by a new regulatory limit if imposed at the PHG. For IWA wells, all antimony concentrations are non-detect. There were no data available for CWA wells. According to the GAMA database, antimony was non-detect in 63 wells (multiple detection limits of unknown and 6 µg/L), detected and below 0.7 µg/L in 3 wells, and detected between 0.7 µg/L and 6 µg/L in 2 wells. Based on the available results from IWA and the GAMA database, antimony does not appear to be a concern at this time.

Molybdenum. Molybdenum has a HAL of 40 µg/L with no MCL, NL, or PHG in California. There were no molybdenum data available for CWA wells. Detectable concentrations in IWA wells range from 4.4 to 21 µg/L (below the HAL). The GAMA database reported monitoring results for 39 wells. Molybdenum was detected in 38 wells, including two wells with molybdenum above 40 µg/L. Based on the available results from IWA and the GAMA database, molybdenum does not appear to be a concern for CWA or IWA at this time.

Perchlorate. Perchlorate is currently regulated at 6 µg/L MCL in California, with no federal limit. A lower PHG was announced in 2015 in California decreasing the concentration from 6 µg/L to 1 µg/L, which might trigger a lower regulatory level in the future. There were no perchlorate data available for CWA and IWA wells. The GAMA database reported non-detect perchlorate concentrations in 82 wells (a range of different method detection limits were used in these tests, from 0.5 to 6 µg/L). Perchlorate was detected below 1 µg/L in 9 wells, ranging from 1 to 6 µg/L in 10 wells, and above 6 µg/L in 9 wells. Due to the method detection limit higher than 1 µg/L, it is unclear how many wells would likely be affected by a new regulatory limit.

Perchlorate is also introduced into drinking water via sodium hypochlorite solutions. While perchlorate is formed during the electrolysis of OSG hypochlorite, recent research[10] indicated that OSG systems are

[10] Stanford, B. D., Pisarenko, A.N., Snyder, S.A., and Gordon, G. 2011. Perchlorate, bromate and chlorate in hypochlorite solutions: Guidelines for utilities. *Journal AWWA*, 103:6.

not likely to be significant contributors of the perchlorate burden in drinking water plants. However, bulk hypochlorite can be a significant source of perchlorate for water utilities. The same management practices described for chlorate also apply to perchlorate.

Selenium. Selenium has a current federal and California MCL of 50 µg/L and a California PHG of 30 µg/L. There were no selenium data available for CWA wells. For IWA wells, selenium concentrations were non-detect. The GAMA database reported non-detect selenium levels in 64 wells (many method detection limits from unknown, 0.08 to 10 µg/L). It was detected in 43 wells, all of which contained selenium below 30 µg/L. Based on the available results from IWA and the GAMA database, selenium does not appear to be a concern at this time.

Vanadium. Vanadium has a NL of 50 µg/L in California and an EPA reference level of 21 µg/L. CWA well vanadium concentrations ranged from 16 to 28 µg/L and IWA well strontium concentrations ranged from non-detect to 30 µg/L (all below the NL). The GAMA database reported vanadium non-detect in 9 wells (< 3 µg/L), below 21 µg/L in 77 wells, above 21 and below 50 µg/L in 7 wells and above 50 µg/L in 2 wells. Vanadium is not a concern for CWA and IWA if regulated at the current California NL.

3.2 Surface Water

Colorado River water is being used by a significant number of metropolitan areas including Las Vegas, Nevada, Phoenix and Tucson Arizona, and throughout Southern California including San Diego. More than 25 million people are supplied with water from the Colorado River in the lower basin of the river. The water is typically transported by open channel canals or in aqueducts from the river to the point of storage and distribution prior to treatment. For the Coachella Valley, Colorado River water is conveyed from the Imperial Dam approximately 160 miles through the All American Canal to the Coachella Canal. Both water quality data from the Colorado River and the Coachella Canal were summarized in this study.

Raw water quality for the Colorado River (at two locations: Lake Havasu and above Imperial Dam) and the Coachella Canal (at Avenue 52) have been summarized in the Indio Water Authority Posse Park Surface Water Treatment Facility Conceptual Design Report and the CVWD Phase 1 and Phase 2 Reports: Surface Water Treatment Process Evaluation. Pertinent water quality data important for plant design are presented in **Table 12**.

In general, the supply can be characterized as a variable turbidity supply with moderate levels of TOC and elevated TDS. The water has variable turbidity caused from silts and other silica based particles, and depending on the location where water is withdrawn can have varying levels of algae, organic matter and in some cases iron and manganese. The water tends to be high in hardness and alkalinity, making it a challenging water to treat with conventional softening or enhanced coagulation. Although not shown in the table, the supply is also subject to periodic taste and odor events due to algae.

Treatment of Colorado River water is required to address typical constituents of concern that are common for most surface water treatment plants throughout the United States including: pathogens, particles (turbidity), natural organic matter (NOM - normally measured as dissolved organic carbon (DOC) or total organic carbon (TOC)), algae, taste and odor, Cr6 (from groundwater blending at the SWTP), and TDS.

Table 12. Historical Raw Water Quality Data for Colorado River and Coachella Canal

Parameter	**Average**[1]	**Range**[2]
Turbidity (NTU)	4.4	0.4-38
TOC (mg/L)	3.1	2.6-3.4
pH	8.1	6.8 – 8.9
Alkalinity (mg $CaCO_3$/L)	146	101 – 189
Hardness (mg $CaCO_3$/L)	343	135 – 433
Iron (mg/L)	0.35[≠] (historical) 0.04 for total Fe, 0.01 for dissolved Fe (2008 pilot testing)	0.01– 1.3 (historical) 0.02 – 0.08 for total Fe, 0.00 – 0.02 for dissolved Fe (2008 pilot testing)
Manganese (mg/L)	0.013 (historical) 0.048 for total Mn, 0.024 for dissolved Mn (2008 pilot testing)	<0.001 – 0.040 (historical) 0.025 – 0.121 for total Mn, 0.000 – 0.080 for dissolved Mn
TDS (mg/L)	780	585 – 1,077

[1]Malcom Pirnie 2008. [2]Black and Veatch, 2010.

Treatment Options

4.1 Groundwater

This section discusses available groundwater treatment options to bring CWA and IWA into compliance with the Cr6 MCL. As discussed in Chapter 3, the Cr6 concentration that triggers a well into requiring treatment was selected by CWA and IWA to be 10.4 μg/L. The treated water Cr6 concentration goal of 6 μg/L allows for fluctuations in raw water quality and analytical variation. Treatment facilities were designed (and costs estimated) to meet this goal.

Three technologies are listed by DDW as Best Available Technologies (BAT) for Cr6 removal from drinking water, including:

- Ion exchange (Strong base anion exchange (SBA) or weak base anion exchange (WBA)),
- Coagulation filtration with reduction (also called reduction coagulation filtration, RCF, or reduction coagulation microfiltration, RCMF), and
- Reverse osmosis (RO).

In addition, there are several other technologies emerging for Cr6 compliance options, including biological reactors and adsorptive media. Both approaches are relatively new for Cr6 removal and less mature compared to WBA, SBA and RCF. Neither is a BAT technology for Cr6 and would require conditional approval from DDW and likely pilot testing. Overall, biological treatment and adsorptive media do not appear to offer advantages over WBA, SBA, or RCF for Cr6 treatment alone and were removed from consideration in this analysis.

Each of the BAT technologies were investigated to assess effectiveness, waste residuals, and ability to address variability, as discussed in the sections that follow.

4.1.1 Weak-base Anion Exchange

With anion exchange, water passes through a resin bed and Cr6 is removed by exchanging with other negatively charged inert ions (chloride) attached to the bed. Other ions with similar charge in the water can also compete with Cr6 and exhaust the resin bed more quickly. A variety of different resin materials are available for Cr6 removal.

Figure 15 illustrates a schematic of the WBA treatment process. Particles are removed from the groundwater using bag filters to minimize pressure drop in the resin bed and minimize the need for backwashing. WBA resins work most effectively for Cr6 removal at a pH of 6.0. At a higher pH, Cr6 is still removed but the resin capacity is less and Cr6 breakthrough occurs earlier. pH adjustment can be accomplished using carbon dioxide (CO_2) or acid (sulfuric or hydrochloric). Alkalinity and pH primarily determine the CO_2 or acid dose necessary, with higher pH and alkalinity requiring more CO_2 or acid. Chemical expenses for pH adjustment were included in the O&M cost estimates.

The mechanism with which WBA works is to remove Cr6 from the water and convert it into Cr3 on the resin surface. With continuing operation of the resin, Cr6 concentrations in the treated water slowly increase as the resin capacity for Cr6 is used. WBA resin is replaced rather than regenerated, when the target goal is exceeded.

Three WBA resins have been identified as having a high capacity for Cr6. These resins can operate for more than one year before they require replacement. By comparison, SBA resins typically require replacement or regeneration every few weeks to months. A cost-effective configuration for WBA resin includes trains of two vessels in series (lead/lag). Aeration or caustic are used downstream of the WBA resin to raise the pH of treated water to avoid corrosive water quality conditions in the distribution system.

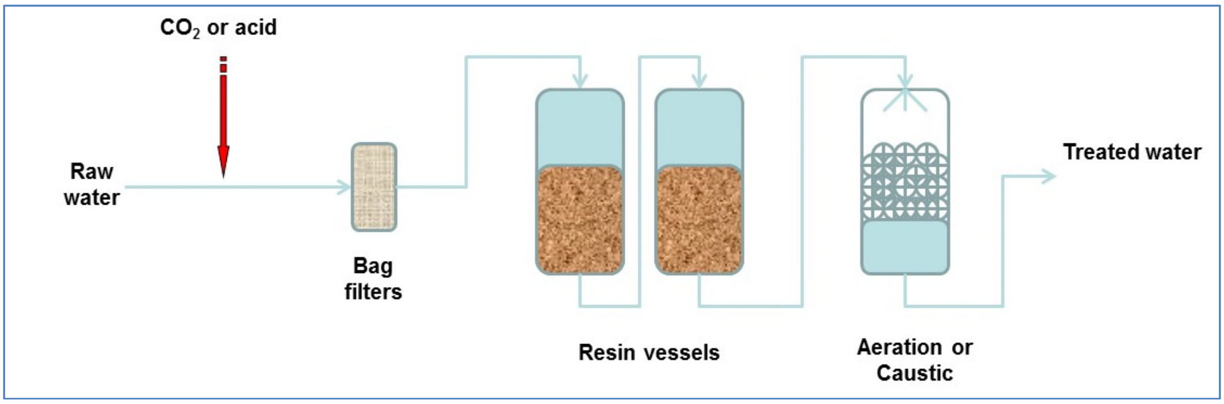

Figure 15. Schematic of Unit Processes in the WBA Treatment Process

WBA has been tested at bench, pilot, and demonstration-scale (425-gpm) for Cr6 removal. All studies have confirmed the effectiveness of the three WBA resins for removing Cr6 to below 10 µg/L. Resin capacity and operation has been shown to vary somewhat for different water qualities, but the lead/lag configuration is effective in minimizing differences in resin performance. Testing has shown that pH 6.0 is effective for Cr6 removal, and that a lower pH of 5.5 was not improved.[11] In addition, Cr3 leaching at a pH lower than 5.5 is a concern, as is excessive CO_2 or acid use.[12]

Residuals generated by the WBA process include spent resin, flush water generated at resin replacement, backwash wastewater (although backwash is not expected unless the well is a sand/silt producer and bag filters are ineffective). Spent resin is expected to be a non-RCRA hazardous waste due to a high chromium concentration above the California Total Threshold Limit Concentration (TTLC) and

[11] Najm, I., Brown, N.P., Seo, E., Gallagher, B., Gramith, K., Blute, N., Wu, X., Yoo, M., Liang, S., Maceiko, S., Kader, S., and Lowry, J. 2014. Impact of Water Quality on Hexavalent Chromium Removal Efficiency and Cost. Water Research Foundation.

[12] McGuire et al. 2007. Hexavalent Chromium Removal Using Anion Exchange and Reduction with Coagulation and Filtration. Awwa Research Foundation.

Technologically Enhanced Naturally Occurring Radioactive Material (TENORM), as experienced at Glendale. Thus, the spent resin needs to be disposed of to a non-RCRA hazardous waste landfill if disposed in California. These resin disposal costs are included in O&M cost estimates.

Flush water and backwash water are expected to be non-hazardous, which can be discharged to a sewer, blow off location, or trucked offsite without treatment. For WBA, this water loss is predicted to be less than 0.01% of the treated water flow.

An issue that has been observed for one WBA resin (Dow PWA7) is initial formaldehyde leaching above the 100 µg/L California notification level when fresh resin was installed at Glendale. Dow since revised their resin preconditioning procedure, which was tested and found to be effective in a pilot study to control formaldehyde leaching at Glendale. Two other resins (Purolite S106 and ResinTech SIR-700) have been found to not leach formaldehyde.

Table 13 summarizes the advantages and disadvantages that are associated with using WBA.

Table 13. Summary of WBA Considerations

Advantages	Disadvantages
• High capacity for Cr6 (more than a year of operation before resin changeout) • Ease of operation	• Resin disposal • pH adjustment • Requires booster pumps unless degasification membranes are used

4.1.2 Strong-base Anion Exchange

Figure 16 illustrates a schematic of the SBA treatment process. Particles are removed from the groundwater using bag filters (strainers), which minimizes pressure drop through the resin bed and the need for backwashing. Strong base anion exchange resin is used to remove Cr6 from the water. Cr6 in the treated water gradually increases over time as the resin capacity for Cr6 is filled. Other ions with similar charge in the water can also compete with Cr6 and exhaust the resin bed more quickly. Resin capacity can range between 2,800 BVs to more than 12,000 BVs (approximately one to four weeks of operation with full utilization) primarily depending on sulfate concentration. SBA is regenerated with a salt (brine) solution or replaced when the treated Cr6 concentration reaches the treatment target level. Regeneration involves elution of the Cr6 off the resin into the brine, in the process restoring capacity of the resin for additional Cr6 removal.

Residuals from SBA include spent brine and rinse wastewater, including slow rinse and fast rinse. Spent brine disposal is often the greatest challenge for SBA applications due to its high chromium and TDS concentrations. Brine is hazardous waste in California unless chromium (and possibly other constituents) is precipitated, in which case the brine can become non-hazardous and the precipitates are often hazardous. Brine management options are discussed in more detail in **Chapter 7.** Prior to regeneration, a backwash step is sometimes applied to ensure even distribution of resin before brine is added. The final step requires a rinse to remove any residual brine from the resin bed.

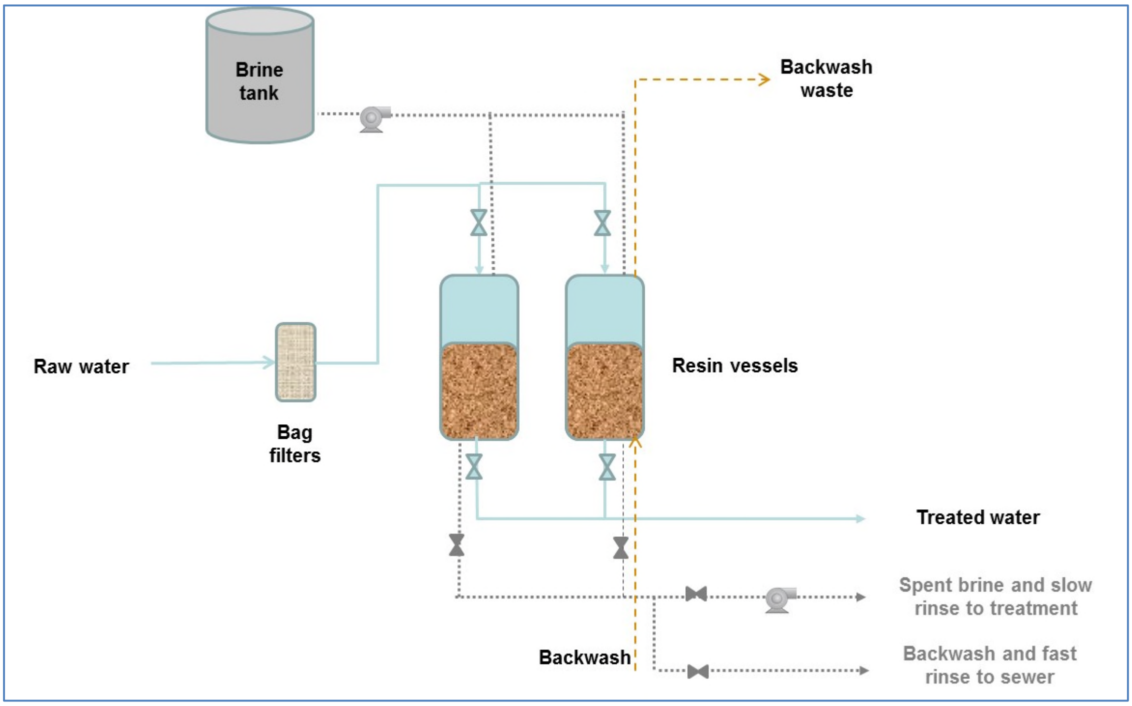

Figure 16. Schematic of Unit Processes in the SBA Treatment Process

The primary constituent impacting Cr6 resin capacity by SBA is sulfate. **Figure 17** shows the correlation between sulfate and resin bed volumes for breakthrough to 2 µg/L. The figure reflects data reported in the literature for various SBA resins and water qualities, as well as recent pilot testing conducted at IWA wells using Purolite A600E/9149 by Ionex SG. Overall, the number of resin bed volumes of water treated decreases dramatically with increases in sulfate concentration. For sulfate of 20 mg/L, the estimated number of bed volumes to reach 2 µg/L is approximately 16,100. For sulfate of 50 mg/L, the estimated number of bed volumes is approximately 5,800.

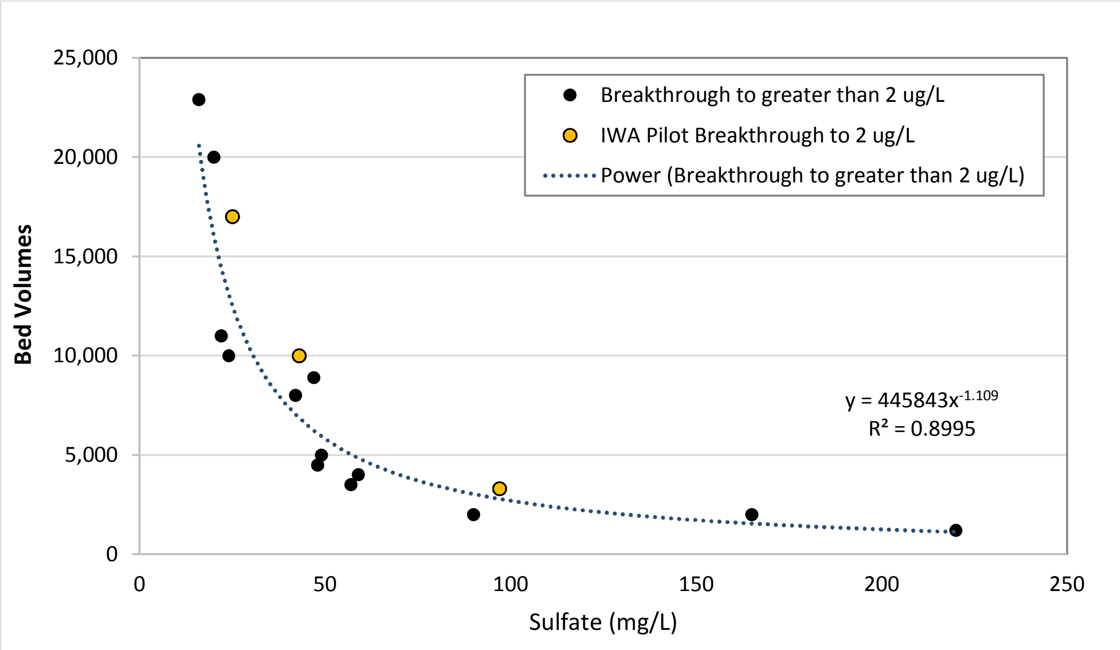

Figure 17. Correlation of SBA Bed Volumes with Sulfate Concentration
Data Sources: IWA Pilot Testing (Ionex SG), Glendale pilot testing (WRF 4423), CVWD pilot testing (WRF 4449), Bench testing at 8 utilities (WRF 4450)

SBA resin is not sensitive to the pH of the water for effective Cr6 removal (unlike WBA resin), which eliminates the need for pre-treatment pH adjustment. However, post-treatment pH adjustment may be necessary, especially when the treated water quality is corrosive toward piping materials. Calcium carbonate precipitate potential (CCPP) below 4 mg/L as $CaCO_3$ or Langelier Saturation Index (LSI) below zero can be used as indicators of water corrosivity. Alkalinity is removed by the resin during a short period in each resin service cycle after regeneration, which results in reduced pH in treated water. Treated water alkalinity and pH typically returns to the raw water concentration in a day.[13] If multiple vessels are operational in parallel or water is bypassed around treatment with final blending, sudden

[13] Clifford, D., Lin, C.C., Horng, L.L. and Boegel, J. 1987. Nitrate removal from drinking water in Glendale, Arizona. EPA/600/S2-86/107.

changes in alkalinity and pH can be minimized. This was also observed during the start-up of IWA SBA facilities at wells AA, 1E, and 13A.

SBA has been tested extensively from bench- to full-scale for Cr6 removal. All studies showed SBA can remove Cr6 effectively and consistently to below 10 µg/L, although the resin life before regeneration varied for raw water qualities, resin products and test conditions with sulfate having a primary adverse effect on resin capacity for Cr6.

Spent brine has been reported to be a non-RCRA hazardous waste due to the high Cr6 concentrations. Spent brine can be either disposed as a non-RCRA hazardous waste or can be treated to remove Cr6 before disposal as a non-hazardous waste. Strategies to minimize residual volumes include regeneration optimization, segmented regeneration, and brine recycle with or without treatment. For SBA with brine recycle, water loss is less than 0.01% of the treated water flow. **Table 14** summarizes the advantages and disadvantages that are associated with using SBA.

Table 14. Summary of SBA Considerations

Advantages	Disadvantages
• More history of applications in drinking water treatment (i.e. for other constituents including arsenic, nitrate, and perchlorate) • No pH adjustment needed for pre-treatment	• Runtimes dependent on background water quality (especially sulfate) • Regeneration waste brine handling and disposal

4.1.3 Reduction Coagulation Filtration/Microfiltration

The RCF process involves reduction of Cr6 to Cr3 using ferrous iron, followed by coagulation of Cr3 with iron hydroxides, and filtration to remove the Cr-associated particles. **Figure 18** illustrates a schematic of the RCF treatment process. Components in the RCF process include ferrous iron addition, a reduction tank that provides time for ferrous iron to reduce Cr6 to Cr3 and coagulate, hypochlorite (or air) addition to oxidize remaining ferrous to ferric, polymer addition to a rapid mixing tank to enhance floc formation (if granular filters), granular media filtration or microfiltration (without polymer) and potentially backwash recovery.

Studies have shown that the reduction step converts Cr6 to Cr3, leaving less than 1 µg/L of Cr6 in the water. The ferrous iron is converted to ferric iron (iron hydroxide), with which Cr6 co-precipitates or adsorbs. The particles then are removed from the water by granular media filtration or microfiltration. Testing indicates that granular media filters can reliably remove total Cr to below 5 µg/L, while microfiltration can remove total Cr to below 1 µg/L. The use of granular media filters is called “RCF”, and with microfiltration is called as “RCMF”.

Residuals from the RCF process include filter backwash waste water (3 to 5 percent for RCF and up to 1 percent for RCMF) that contains Cr3. This backwash water may be directly discharged to the sewer if permitted by the sewer agency. Backwash water can also be recycled if solids are removed. Dewatered solids are likely classified as non-RCRA, California hazardous waste due to total Cr concentration above the California TTLC, but below the federal TCLP limit. For the RCMF process, chemical cleaning and clean-in-place solutions will also require disposal.

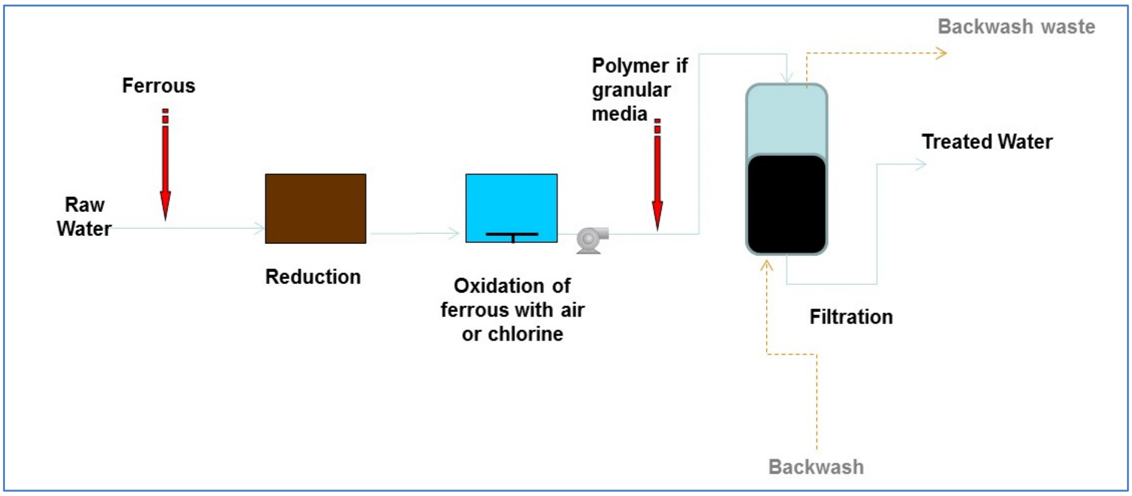

Figure 18. Schematic of Unit Processes in the RCF Treatment Process

RCF has been tested at demonstration scale at Glendale for three years, which showed effective removal of Cr6 to below 1 µg/L and total Cr to below 5 µg/L for a 100 gpm treatment system. Bench-scale testing by CVWD and a pilot study by WQTS confirmed similar or improved RCF effectiveness. The primary factors impacting effectiveness of reduction included ferrous iron dose and reduction time. The RCMF process has also been pilot tested at Glendale and CVWD, with the studies showing improved total Cr removal for RCMF compared to RCF. In general, RCF and RCMF processes are not as affected by raw water quality compared with the other BATs.

Table 15 summarizes the advantages and disadvantages that are associated with using RCF/RCMF. Based on the higher water loss and resulting sewer discharge volumes associated with the RCF process, as well as lower performance for Cr6 removal compared to RCMF, RCF was removed from further consideration in this analysis. The RCMF process that incorporates recycle to lower the water loss to less than 1 percent was included in the scenario analysis and cost evaluation for further consideration. The RCMF technology with recycle was recently tested for another (confidential) client and found to be successful. No published literature is available on the effectiveness of the process with recycle; piloting may be required by DDW.

Table 15. Summary of RCF/RCMF Considerations

Advantages	Disadvantages
• Microfiltration increases chromium removal over granular media filters • Less susceptible to water quality changes • Chlorination produces less footprint than aeration for residual ferrous oxidation • No pH adjustment typically needed • Filter backwash water can possibly be discharged to sewer, eliminating hazardous waste residuals	• Aeration or chlorine addition is needed • Relatively complex system, larger footprint • Not resilient to flow rates above design flow rate • Chlorination may require tighter controls than aeration to minimize Cr3 reoxidation • Residuals are generated if filter backwash water is settled • Greater quality of residuals compared to SBA or WBA

4.1.4 Reverse Osmosis

Figure 19 illustrates a schematic of the Reverse Osmosis (RO) treatment process. Constituents are removed using RO by applying pressure to force water through the membranes while retaining the constituents on the other side of the membranes. Pre-treatment may be necessary to enhance removal efficiency and/or help control membrane fouling, and post-treatment or blending is needed to stabilize the effluent with respect to corrosion in the distribution system. A benefit of RO is the ability to simultaneously remove multiple constituents, such as nitrate, sulfate and chloride.

Residuals from the RO process are primarily comprised of membrane reject concentrate (brine), which typically for groundwater systems accounts for 15 to 25 percent of the total feed flow. This concentrate waste results in a significant water loss and wastewater for disposal. **Table 16** summarizes the advantages and disadvantages that are associated with using RO. Based on the significant water loss associated with RO relative to the other technology options for Cr6, RO was removed from further consideration in this analysis.

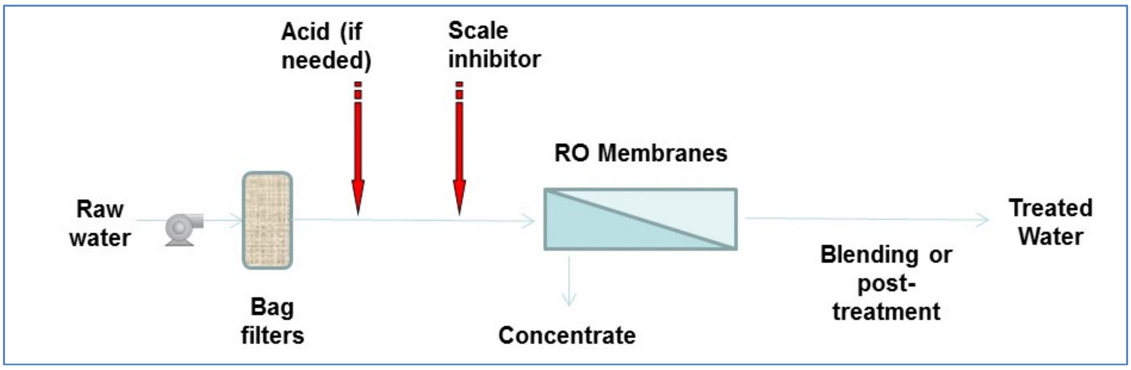

Figure 19. Schematic of Unit Processes in the RO Treatment Process

Table 16. Summary of RO Considerations

Advantages	Disadvantages
• Capable of simultaneously removing other constituents such as nitrate, sulfate and chloride	• Pre- and post-treatment may be necessary • Residual results in significant water loss and wastewater for disposal

4.1.5 Water Quality Constituents that Affect Cr6 Treatment

Water quality constituents that strongly impact select Cr6 treatment options were evaluated in this study, including:

- **pH and alkalinity** – dictate the required acid or CO_2 dose for WBA
- **Uranium** – affects residuals waste characteristics and disposal costs for WBA and SBA brine
- **Nitrate** – may require additional safeguards to avoid chromatographic peaking for SBA
- **Sulfate** – affects the regeneration frequency for SBA, a key driver for SBA costs

Water quality monitoring results for these constituents were used in this Study to provide a water quality-specific assessment of treatment options and costs for each well. The water quality database summarizing these and other constituents is provided in Appendix B.

4.1.6 Residuals Handling and Waste Disposal Options

Opportunities to minimize the cost of residuals handling and waste disposal considered in this Study included:

- SBA
  - Recycling of rinse water during regeneration process to minimize waste brine.
  - Disposal of hazardous waste brine versus treatment of hazardous brine (resulting in non-hazardous brine disposal and hazardous solids disposal).

    - Participation in the CVWD planned central resin regeneration facility (CRRF) either by sending resin for regeneration or hazardous brine for treatment.
- WBA
    - Pre-treatment of resin to minimize flush water.
- RCMF
    - Recycle of backwash water to the head of the treatment plant.

A central resin regeneration facility is being now being designed by CVWD to consolidate regeneration operations for the numerous SBA wells sites into one location. CVWD has indicated to CWA and IWA the willingness to develop regional solutions where practical. CWA and IWA participation in the CRRF could potentially include trucking spent SBA resin to the CRRF for regeneration or sending hazardous brine to the CRRF for treatment and disposal. The availability of this option and associated cost to CWA and IWA could not be speculated for this Study; however, by comparing the most cost effective technology to this approach, limitations of viability could be inferred.

4.1.7 Non-Treatment and Blending Options

Blending options were first considered as a means of compliance for wells that had sufficiently low Cr6 concentrations and nearby well(s) with low Cr6 to make blending a possible strategy. The advantage of blending is that treatment would be supplanted by pipeline installation; long-term O&M costs would be lower. For both CWA and IWA, there were no opportunities to avoid treatment altogether by blending wells. However, with treatment, some blending opportunities were identified to reduce overall treatment costs.

4.1.8 Clustered Groundwater Treatment Facilities

The potential for combining wells for clustered treatment was evaluated and compared with individual wellhead treatment. **Table 17** provides a listing of primary advantages and disadvantages of each approach. The next step was to provide a cost comparison of treatment approaches. Potential economies of scale were evaluated to determine whether clustering wells for treatment can overcome additional costs associated with pipelines. This evaluation was completed and costs presented as part of the scenario analysis.

Table 17. Comparison of Clustered vs. Wellhead Treatment

	Clustered Treatment	**Wellhead Treatment**
Advantages	• Fewer sites to construct and service • Potential economies of scale for the cost of capital treatment facilities	• Treatment can fit on existing sites • Faster implementation due to fewer pipelines and no land acquisition • Potentially simpler onsite operations
Disadvantages	• Pipelines to join wells • Land acquisition may be required	• More sites to construct and service

4.2 Surface Water

4.2.1 Evaluation and Planning

Construction of a SWTP to treat Colorado River Water and use it as a drinking water source to augment and replenish groundwater supplies has been evaluated by CWA and IWA as part of other long-term master planning efforts, and by CVWD in separate efforts. In the context of this Study, a SWTP (in addition to or in lieu of groundwater Cr6 treatment plants) was considered as a potential part of the strategy to achieve Cr6 compliance. The feasibility of using of this source to meet increasing demand, conserve groundwater, and avoid Cr6 groundwater treatment was considered.

For this option, Colorado River Water would be purchased from CVWD. Water from the Colorado River is delivered to Southern California via the All American Canal and to the Coachella Valley via the Coachella Canal. CVWD is the sole shareholder of Colorado River Water rights in the Coachella Valley. Locations and potential future capacities for a SWTP that CWA and IWA have evaluated as part of past planning efforts are depicted in **Figure 20**.

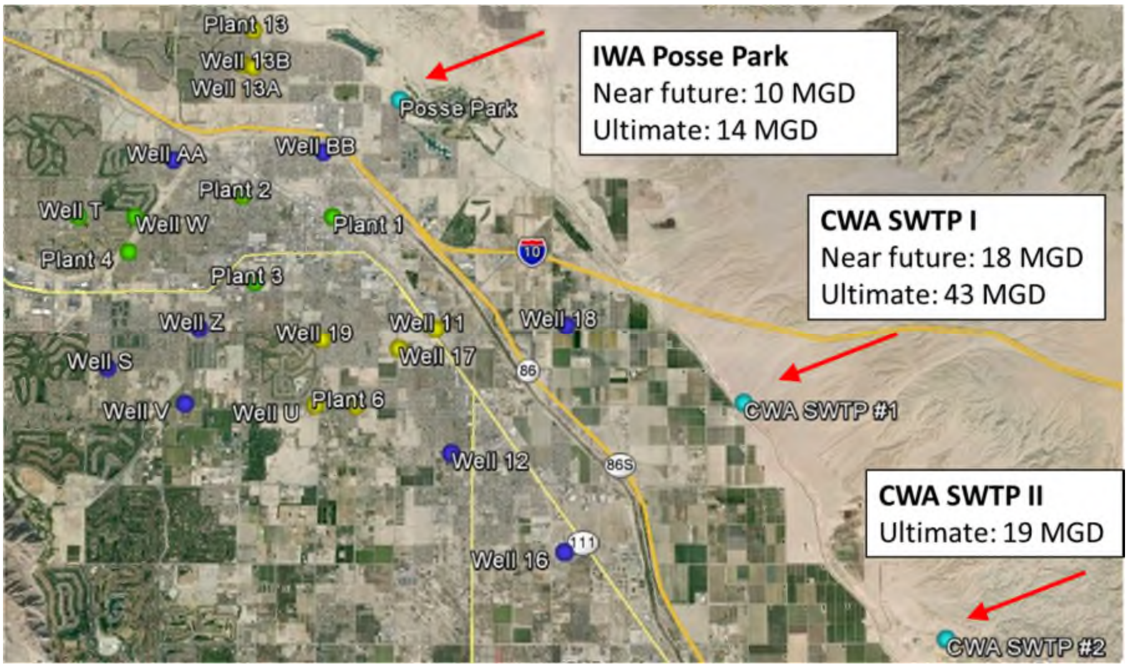

Figure 20. Potential SWTP Locations

4.2.2 Treatment

The design and operation of surface water treatment plants is commonly based on removal of turbidity and natural organic matter (NOM).

For the Coachella Valley, other constituents of importance in surface water treatment design include algae as algal blooms are known to occur on canals off of the Colorado River, taste and odor that arises primarily from algae, and Cr6 if the facility is designed to treat groundwater in addition to surface water.

Without targeted treatment or blending with existing groundwater, drinking water produced from the SWTP would be expected on average to have hardness approximately three times greater, and TDS approximately four times greater, than existing CWA and IWA drinking water. Technologies for hardness and TDS reduction, such as reverse osmosis, are available. Blending strategies can also be used to dilute TDS in the water served to customers. Opportunities for blending groundwater and surface water together were investigated, to decrease TDS concentrations in surface water through blending with lower TDS groundwater. Use of this blending approach will result in cost savings by avoiding reverse osmosis treatment while delivering lower TDS water that is likely to be more acceptable to customers.

Figure 21 provides a process flow diagram for an example surface water treatment plant for the Coachella Canal. A surface water plant would blend groundwater and surface water to reduce TDS to an acceptable level. A portion of the groundwater stream would require treatment to remove Cr6 to keep the Cr6 level in the final blended water below the desired maximum.

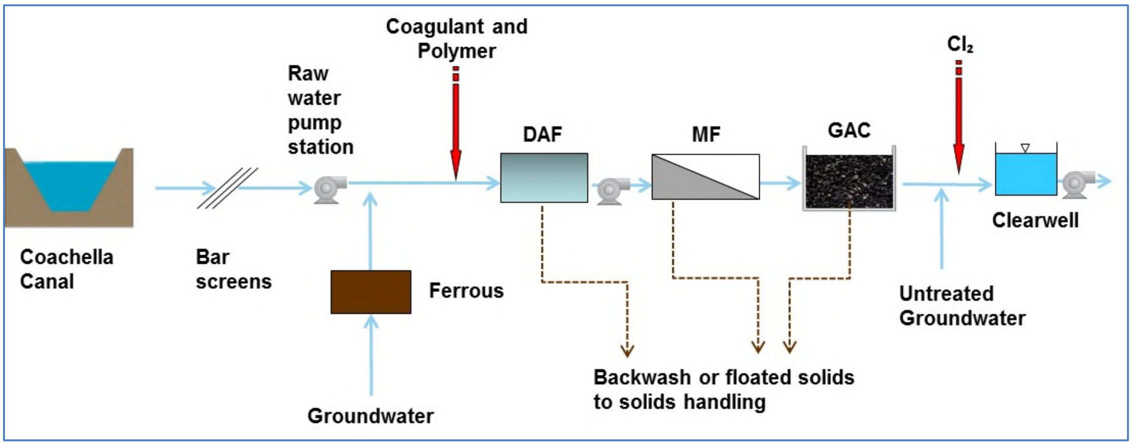

Figure 21. Process Flow Diagram for Surface Water Treatment

In the rapid mixing chamber, the combined influent would be dosed with a coagulant chemical. The influent would then flow to a dissolved air flotation (DAF) unit. The DAF unit will separate coagulated materials from the flow. These coagulated materials would be removed in an overflow stream, which would flow to the floated solids tanks, and from there to the solids handling unit. DAF was selected for this analysis for its smaller footprint, lower cost, and ability to effectively treat algae.

The treated flow from the DAF would enter an intake header for the membrane treatment unit. Flows from the header would be pumped through the membrane intake strainers and then through the membrane treatment units. Membrane filtration was selected for this analysis because it is proven to be a better barrier for removing chromium-associated particles, thus requiring less filtration by enabling more bypass or blending.

In this analysis, backwash water from the membrane units was identified as a treatment process using lamella clarifiers. The settled solids from the clarifiers will flow by gravity to the solids handling facility. The clarified overflow from the lamella separators will return to the influent chamber.

From the membrane units the treated water will flow to the GAC contact basins. GAC in the basins will remove organic compounds from the water eliminating unpleasant tastes and odors, and allow CWA and IWA to remain on free chlorine secondary disinfection while minimizing disinfection by-product formation.

From the GAC water would flow by gravity to the chlorine contact basin/clearwell. At this point, treated water would mix with groundwater that has bypassed the treatment process. Water entering the contact basins will be dosed with chlorine for disinfection. From the clearwell, the water would enter the distribution pump station and be pumped to service. As the water is pumped to service, it will be dosed with sodium hydroxide to adjust the final pH if necessary.

Solids handling processes would also be included in the surface water treatment plant, such as the use of centrifuges. Dewatered solids would be discharged into a truck or bin for removal from site.

4.2.3 Cost

Based on the treatment processes for a SWTP described above, the cost of surface water treatment is on the order of $600 to $800 /acre-foot, approximately double the estimated cost of Cr6 groundwater treatment. For this reason CWA and IWA decided that a detailed surface water treatment scenario evaluation should not be analyzed in this Study due to a lack of feasibility in the near term as a compliance strategy. Although a SWTP for Colorado River Water was removed from consideration in the Cr6 Study, it may be a source that can be considered for future demand.

Scenario Analysis

A scenario-based approach that considered varying levels of groundwater treatment for current and future water demands was used to evaluate Cr6 Compliance options while minimizing treatment costs. This section presents the results of the scenario analysis.

5.1 Approach

Scenarios that build a compliance strategy for CWA and IWA wells were developed by beginning with the existing systems and adding needed wells based on demand. The scenarios capture the current system baseline, adding enough treatment for compliance and to meet current demands, and a future bookend with full utilization of all wells in both systems. Strategies to reduce treatment costs through blending or clustered treatment were also analyzed within these options.

5.2 Scenarios

Scenario A – Existing Systems (Baseline Using Only Low Cr6 or Currently Treated Wells)
Scenario A defines the current baseline for existing conditions in both systems. In this scenario, IWA has 7 wells below the Cr6 MCL and 3 wells with treatment (13 other wells are inactive), and is in compliance. CWA has 6 wells above the Cr6 MCL (no available well capacity below the MCL) and is out of compliance.

Scenario B - Achieve Compliance (Current Demands)
Scenario B outlines the improvements needed to achieve compliance. For IWA, the 7 wells below the MCL and 3 additional wells with treatment are enough to satisfy current demands and stay in compliance (no additional treatment redundancy). For CWA, treatment on five wells is needed.

Scenario C – Full System Utilization (Future Demands)
Scenario C assesses the projected future demands of the CWA and IWA systems. This scenario includes fully utilizing existing wells by adding treatment (providing treatment redundancy) and identifying if new wells are needed. The emergency IWA/CWA Interconnections remain in place for potential future use.

In addition to the scenarios evaluated above, emergency Interconnections for CWA and IWA Systems were also discussed. These Interconnections could be used to provide additional system redundancy and provide a reliable water supply in the event of an emergency or treatment system failure.

5.3 Blending Opportunities

Opportunities to blend wells and reduce the need for treatment were evaluated. For CWA, all existing wells were above the Cr6 MCL, require treatment, and there were no nearby inactive wells for potential blending. For IWA, the following treatment and blending alternatives identified by IWA and were evaluated:

Plant 1 – Treatment of 1E, blending with 1B and 1C in the reservoir
This treatment and blending approach would avoid treatment of Well 1B. One system constraint would be that if Well 1B is on, Well 1E must be operated simultaneously to achieve a blend in the reservoir of Cr < 10.4 µg/L. Blending with Well 1C reduces the required treatment size.

Plant 1 – Treatment of 1E and BB, blending with 1B and 1C in the reservoir
This treatment and blending approach brings Well BB water to Plant 1 for combined treatment with Well 1E potentially economizing the treatment cost compared with treatment of Well 1E and Well BB individually. Larger treatment facilities would allow flexibility of operating either Well 1E or Well BB or both simultaneously. Treatment on Well 1B would be avoided. If Well 1B is on, either Well 1E or BB must be operated simultaneously to achieve a blend in the reservoir of Cr < 10.4 µg/L. Blending with Well 1C reduces the required treatment size.

Plant 1 – Treatment of 1B, 1E, and BB, blending with 1C in the reservoir
This treatment and blending option brings Well BB water to Plant 1 for combined treatment with Well 1B and 1E potentially economizing the treatment cost compared with treatment of 1B, 1E, and BB individually. Larger treatment facilities would allow flexibility of operating either 1B, 1E, BB or all simultaneously. Blending with 1C reduces the required treatment size.

Well W – Treatment of Well W, blending with Well T
This treatment and blending approach may be considered if Well T is greater than the Cr6 MCL in the future and requires action. Blending would be accomplished at Well W in the treated water pipeline prior to entering the distribution system. This approach would avoid treatment at Well T.

Treatment costs for each of these blending alternatives were evaluated and compared within the scenario analysis.

5.4 Clustered Treatment Opportunities

Wells impacted by the Cr6 MCL were identified on a satellite map and available drawings and schematics were reviewed to assess the available footprint for possible treatment systems. Where possible, wells in close proximity with available space were grouped together for clustered treatment where the pipeline cost would be less than the cost of separate individual treatment systems. It was considered that a clustered treatment facility could be constructed for existing wells and possibly expanded for new wells in the future. The following alternatives for clustered treatment facilities were identified by CWA and IWA to include in the scenario analysis:

IWA Well U and CWA Wells 17, 19

- Three configurations considered: Individual treatment at Wells U, 17, and 19; Individual treatment at U and clustered treatment for Wells 17 and 19; and clustered treatment for Wells U, 17, 19
- Land available for the treatment site at near Ave 50 and Jackson Street.
- Treatment facility could be expanded to accommodate future wells.
- Well 11 is in the vicinity, but CWA plans to inactivate this well in near future.

IWA Wells 1B, 1C, 1E, and BB (as described in blending opportunities above)

- Three configurations considered: Individual treatment of Well 1E at the Plant 1 site, blending with Wells 1B and 1C in the reservoir; Clustered treatment of Wells 1E and BB, blending with Wells 1B and 1C in the reservoir; and Clustered treatment of Wells 1B, 1E, and BB, blending with Well 1C in the reservoir.

IWA Wells 13A and 13B

- Expansion of treatment at the Plant 13 site (currently treating Well 13A) was considered to accommodate flows from Well 13B.

Treatment cluster assumptions were made for cost estimating conceptual planning purposes. Hydraulic assessment should be performed in preliminary design to determine the hydraulic impact of transferring treated water within the distribution system to meet system demands.

5.5 Cost Model Development

The basis for cost estimates are discussed in this section. Cost estimates were developed WBA, SBA, and RCMF to enable comparison. In the case of SBA, three options with different cost implications were also evaluated, including:

- SBA with on-site regeneration and brine treatment
- Containerized SBA with onsite brine treatment and hazardous brine disposal
- SBA with participation in a Central Resin Regeneration Facility (CRRF)

For all technologies, a bypass flow was assumed that blends treated water with untreated groundwater for cost effective design. A Cr6 treatment goal of 2 µg/L in Cr6 treatment system effluent and 6 µg/L in the blend with bypass was assumed in this analysis. In operation, these goals can be adjusted to maintain a treated water concentration below the Cr6 MCL.

Capital costs were generated using Hazen and Sawyer cost models, which are based on costs estimated for a range of water system sizes (100, 500, 2,000 and 7,000 gpm). The key assumptions include:

- Capital costs are AACE Class 5 Estimate, with an accuracy range of -30% to +50%.
- Capital costs were based on design capacity of the treatment facility.
- Cr6 treatment design capacity was determined based on the well capacity provided by CWA and IWA using a bypass approach.
- Product water storage was not included.
- Chlorination for disinfection was not included. It was confirmed with DDW that groundwater treatment does not result in mandatory contact time (CT) requirements.
- Annualized capital cost is based on an interest rate of 5% and 20 years.

A two-step approach was used for the scenario cost evaluation. The capital cost of treatment equipment, operations and maintenance costs, and resulting annualized lifecycle combination of these costs were initially used to compare and select technologies for each scenario (Section 5.9). Based on the selections, total project costs were then summarized using the cost factors and engineering factors.

O&M costs were estimated based on the following assumptions:

- O&M costs are AACE Class 5 Estimates, with an accuracy range of -30% to +50%.
- O&M costs include media replacements (such as resins), labor, chemicals, residuals, electricity, lab and field analysis, and equipment maintenance.
- O&M costs do not include electricity for existing well pumping.
- Booster pumping was included to compensate the pressure loss through the Cr6 treatment processes.
- Unit prices for chemicals, residuals disposal, labor and electricity are summarized in **Table 18**.

Table 18. Unit Prices for Chemicals, Residuals Disposal, Labor and Electricity

Item (Unit)	Unit Price	Source
Electricity ($/kWh)	$0.14	Cost reviewed and agreed by CWA
CO_2 unit price ($/lb)	$0.07	Average cost at City of Glendale for WBA
Spent WBA resin disposal ($/cf)	$342	Average cost at City of Glendale for WBA
Sewer discharge ($/hcf)	$0.67	CVWD charge for business starting July 2015
Sewer quarterly fee ($/EDU/month)	$38	CVWD charge for business starting July 2015. One EDU is 121 hcf/year.
Labor annual salary ($/yr)	$105,000	Cost reviewed and agreed by CWA and IWA
Salt ($/ton, including shipping)	$136	Cost provided by CVWD
Ferrous Sulfate ($/gal)	$2.50	Brenntag quote
Ferric Chloride and Ferrous Sulfate Blend ($/gal)	$9.93	Cost provided by CVWD
Polymer ($/gal)	$30	Cost provided by CVWD
Clarified brine disposal for SBA with on-site regen ($/kgal)	$300	Cost provided by CVWD
Hazardous brine disposal for SBA with on-site regen ($/gal)	$1.12	IonexSG agreement with Phibrotech. Evoqua's quote for hazardous brine is $2.30/gal.
Non-RCRA hazardous solids disposal ($/lb)	$1.61	Cost at City of Glendale for non-RCRA hazardous waste
SBA resin unit price ($/cf)	$188	Purolite's quote for A600E/9149, with extra 15% for tax and freight and $15/cf for resin installation. Evoqua's quote for Dow SAR resin is $150.
SBA spent resin disposal ($/cf)	$15	Evoqua's quote for non-hazardous, including disposal for incineration and transportation.
WBA resin unit price ($/cf)	$329	Evoqua's quote for SIR700, including resin rinsing and installation. Purolite's budgetary quote for S106 was $265/cf plus $10K for turnkey installation.
Spent WBA resin disposal ($/cf)	$342	Average cost at City of Glendale for WBA

5.6 Design Assumptions

The key assumptions used for estimating WBA treatment system costs include:

- WBA process includes bag filters for particle removal, pH adjustment using carbon dioxide (CO_2), ion exchange vessels in a lead/lag configuration, and post pH adjustment using aeration.
- CO_2 was assumed to achieve a pH target of 6.0. CO_2 dose was estimated using the RTW model.
- For aeration, anti-scalant (polyphosphate) at a dose of 1 mg/L was included to minimize calcium carbonate precipitation in the aerator (actual dose TBD based on water quality and manufacturer recommendations in design). No aeration off-gas treatment was included.
- WBA resin life was assumed to be 367,600 BVs for the lead bed when the lag bed effluent achieves 2 µg/L. The bed volume estimate reflects the maximum number of BVs tested in the WBA pilot at CVWD, at which the Cr(VI) concentration in the treated water was between 4 and 5 µg/L in a single bed; therefore, this estimated resin life is a conservative assumption.
- 6 BVs of water were assumed for resin flushing during resin change-out. Wastewater was assumed to be temporarily stored in baker tank(s) and disposed of as non-hazardous waste.
- Spent WBA was assumed as non-RCRA hazardous waste and TENORM (after blending with adsorbent) that can be disposed to US Ecology's landfill in Idaho (the same landfill that City of Glendale used for their spent WBA resin).
- The required labor was assumed to be 0.4 to 1.3 FTE depending on treatment production rate.

The key assumptions used for estimating RCMF treatment system costs include:

- RCMF treatment consists of ferrous sulfate addition, reduction tank (5-minute contact time), chlorination for residual ferrous iron oxidation (not to achieve disinfection residual), and microfiltration.
- Wastewater was assumed to account for 5% of the total production flow.
- MF membrane life was assumed to be 10 years. O&M cost includes replacement cost for 10% of the membranes every year.
- Wastewater was assumed to be treated and recycled to reduce the overall process waste to less than 1%.
- Cr6 treatment target was assumed to be 2 µg/L for RCMF based on findings of total chromium removal by this process.
- The required labor was assumed to be 1.3 to 2.6 FTE depending on treatment production rate.

The key assumptions used for estimating SBA with onsite brine treatment system costs include:

- SBA process includes bag filters for particle removal, ion exchange vessels in a parallel configuration, resin regeneration and spent brine treatment process. Each system includes a minimum of 2 vessels plus a standby/regen vessel.

- A caustic soda feed system was not included for wells with raw water calcium carbonate precipitation potential (CCPP) below zero. It is recommended that this be evaluated on a site-specific basis during preliminary design.
- SBA resin life was assumed to be 4 years.
- Resin regeneration frequency is based on maximum historical sulfate concentration in raw water and a function of BVs versus sulfate as discussed in the SBA section. Raw water Cr6 concentration was assumed to have no significant effect on resin operational life.
- Resin regeneration procedure consists of regen (12% brine, 4 BVs total comprised of 3 BVs to be recycled and 1 BV to waste), slow rinse (1 BVs, all 1 BV to be recycled) and fast rinse (3 BVs all to waste). The procedure needs to be validated and potentially optimized for different water qualities.
- Spent brine and slow rinse waste need to be treated before disposal. Backwash and fast rinse waste are non-hazardous and contain low TDS and can be disposed to sewer without treatment. Recycle of fast rinse waste may be feasible.
- Spent brine treatment was based on a 7:1 iron-to-Cr6 ratio, which is effective at CVWD's IXTPs. This iron dose is expected to be more than needed for Cr6 spent brine treatment. Reduced iron dose is expected to generate cost savings and the optimal iron dose should be identified through additional testing.
- Treated brine was assumed to be non-hazardous but with high TDS, which would be hauled off-site for disposal.
- Dewatered solids are non-RCRA hazardous waste due to chromium concentration. The dewatered solid quantity was estimated using mass balance, assuming all chromium and iron are settled and removed as dewatered solids. Moisture content was assumed 80%, based on results observed at Glendale for dewatered solids.
- For SBA with onsite brine treatment, the required labor was assumed to be 1.3 FTE to 2.6 FTE depending on treatment production rate.

The key assumptions used for estimating Containerized SBA treatment system costs include:

- SBA process includes bag filters for particle removal, multiple ion exchange vessels housed in multiple containers operated in a parallel configuration, resin regeneration and spent brine treatment process. Each system includes a minimum of 4 vessels per container.
- A caustic soda feed system was not included for wells with raw water calcium carbonate precipitation potential (CCPP) below zero. It is recommended that this be evaluated on a site-specific basis during preliminary design.
- SBA resin life was assumed to be 4 years.
- Resin regeneration frequency is based on maximum historical sulfate concentration in raw water and a function of BVs versus sulfate as discussed in the SBA section. Raw water Cr6 concentration was assumed to have no significant effect on resin operational life. Blending of multiple vessel effluents was accounted for, allowing for a lower regeneration frequency relative to SBA with onsite brine treatment.

- Resin regeneration procedure consists of regen (12% brine, 3 BVs total comprised of 1.5 BVs to be recycled and 1.5 BVs to waste), slow rinse (0.8 BV, all 0.8 BV to be recycled) and no fast rinse. The procedure needs to be validated and potentially optimized for different water qualities.
- Spent brine and slow rinse waste (if not recycled for the next regeneration) were hauled for disposal as hazardous waste at a cost.
- For Containerized SBA, labor costs were estimated as similar to SBA with onsite brine treatment, the required labor was assumed to be 1.3 to 2.6 FTE depending on treatment production rate.

The key assumptions used for estimating SBA with participation in the CRRF costs include:

- SBA process at well sites includes bag filters for particle removal, ion exchange vessels in a parallel configuration. Each system includes 2 vessels. Each vessels holds 600 cf resin to maximize resin volume per transportation for central regeneration.
- A caustic soda feed system was not included for wells with raw water calcium carbonate precipitation potential (CCPP) below zero. It is recommended that this be evaluated on a site-specific basis during preliminary design.
- SBA resin life was assumed to be 4 years.
- All SBA resin regeneration was assumed to take place at the CRRF.
- Resin regeneration frequency is based on maximum historical sulfate concentration in raw water and a function of BVs versus sulfate as discussed in the SBA section. Raw water Cr6 concentration was assumed to have no significant effect on resin operational life.
- Resin regeneration costs at the CRRF could not be estimated; however, a comparison of the potential unit cost for regeneration versus on-site regeneration that makes this option viable was discussed.

The key assumptions for estimating land, building and pipeline costs include:

- Land costs were not required for the scenarios evaluated. A CWA owned parcel of land was assessed for the potential clustered treatment facility and IWA clustered facilities were located at existing IWA sites.
- Building costs and shade structures for sites were not included and need to be assessed on a case-by case basis during preliminary design.
- Pipeline costs were estimated for clustered treatment facilities to connect raw water from all wells to the treatment site and treated/blended water to the existing distribution system. The unit cost for pipelines was assumed $10 per feet per inch diameter.

5.7 Technology and Scenario Selection Factors

This evaluation reviewed the viable treatment technologies to select the best treatment option for CWA and IWA for multiple criteria, including: treatment robustness of the technology, the complexity of operations and maintenance, the amount of water loss from the treatment process, waste disposal and handling generated from the treatment process (if applicable), the ability to treat other constituents, footprint requirements, and the annualized cost. Each of these criteria are discussed throughout this Study report where applicable. More specifically, each of these criteria were defined with multiple components:

- **Treatment Robustness** - Reliability to meet treated water Cr6 goal, ability to handle fluctuations in water quality or changes in the treatment goal without significant operational changes, manageable impacts from interfering constituents or chromatographic peaking
- **O&M Complexity** - Chemical feed system requirements, the need for constant monitoring, multiple components requiring frequent maintenance, frequency of chemical deliveries, level and number of operations staff required for the system
- **Water Loss** - Water loss associated from process
- **Residuals Handling** - Disposal options for liquid waste (sewer, hauling) and frequency of trucking requirements for liquid and solid waste disposal
- **Removal of Other Constituents**- technology removes co-occurring constituents that require treatment
- **Footprint** - Treatment plant footprint and land requirement
- **Annualized Cost** - Equipment, engineering, construction, and O&M

5.8 Scenario Evaluation Findings and Selections

This section presents the findings of the scenario analysis, which are presented as capital and annualized costs for comparison. Technologies included in the analysis were WBA, SBA, and RCMF with recycle. From this analysis, the most cost effective of the feasible BATs assessed can be selected. Note that RCF without recycle and RO were not moved forward to the cost evaluation due to higher water losses compared with ion exchange and RCMF with recycle. If applicable, costs for clustering and blending alternatives are presented.

If SBA was the least cost technology, various options for SBA were examined, including SBA with onsite brine treatment, Containerized SBA (without brine treatment), and participation in a regional CRRF. Error bars are included to represent the sensitivity of cost to key assumptions, including:

- SBA with onsite brine treatment – these costs include the treatment of SBA hazardous brine to render non-hazardous brine for hauling and hazardous solids for disposal. There are currently no operating facilities for the treatment of SBA brine from Cr6 treatment facilities and these processes may require optimization for effectiveness. The error bars here represent a range of brine treatment costs for each location.
- SBA with centralized regen – these costs include equipment for the SBA vessels only, and a range of operating costs should CWA and IWA decide to participate in a regional CRRF for resin regeneration. A cost estimate of $20 to $30 per cubic foot of resin regenerated was assumed for comparison based on approximate O&M costs for resin regeneration and brine treatment (exclusive of costs of equipment use at the facility and additional brine treatment that may be needed beyond chromium). This estimate requires significant refinement as a CRRF in the Coachella Valley is only in the preliminary design stage of development and a Cost of Service Study will need to be performed by CVWD.

- Containerized SBA – these costs do not include onsite brine treatment, instead they involve hauling the hazardous brine directly to a disposal facility. Regeneration steps that result in non-hazardous brine or rinse water are recycled in subsequent regenerations. The assumed steps in this regeneration process could be refined to further reduce waste brine generation in the future (e.g. Ionex SG sulfate return process pending DDW approval). The error bars represent hazardous brine disposal quotes ranging from $1.12 (Phibrotech) to $2.30 per gallon (Evoqua).

Scenario A – Existing Systems (Baseline Using Only Low Cr6 or Currently Treated Wells)
This scenario serves to establish a baseline for the existing CWA and IWA systems without treatment. In this scenario, IWA has 7 wells online with raw water Cr6 concentrations less than 10.4 µg/L (Wells 1C, 4A, 4B, 4C, S, T, V) and just completed installation and start-up of containerized SBA treatment at 3 additional wells (1E, 13A, AA). IWA Wells 1B, 2C, 2D, 3A, 3B, 3C, U, W, Z, and BB are inactive/standby.

CWA has 6 wells in service (11, 12, 16, 17, 18, and 19), all of which exceed the Cr6 MCL. No options are available to allow CWA to continue using these wells and be in compliance with the MCL.

For the purposes evaluating this scenario for IWA, cost models were applied to the three IWA wells with treatment, and those costs compared with IWA's recent construction costs to determine if Containerized SBA is the best long-term option for those wells or whether those treatment systems should be moved to other sites so that a different technology could be applied. In Scenario A, this includes 2,400 gpm of treatment and an average utilization rate of 30%. In subsequent scenarios, treatment is expanded at these locations to accommodate additional wells and/or blending.

Figure 22 and **Figure 23** present the capital equipment cost and the annualized lifecycle (annualized lifecycle cost equals the capital cost annualized over 20 years at 5% plus the annual O&M) costs for WBA, SBA, and RCMF at the three IWA wells with Cr6 treatment. Note that this lifecycle cost reflects equipment and operating costs only for comparison purposes. Total capital costs (including installation, site work, etc.) for the selected technology are presented in **Chapter 6**.

It was found that despite the higher sulfate concentrations at 13A (97 mg/L), SBA was the estimated to be the most cost effective technology. However, Plant 1 and Plant 13 will yield much higher brine volumes compared with the other sites (discussed further in **Section 5.9**) and may be a candidate for WBA if operational simplicity at the site and diversification of treatment approaches is desired by IWA. As discussed earlier, RCMF with recycle offers a potential solution but would require additional testing for confirmation since the only study of this is not publicly disclosed. RCMF is also higher in capital cost, is considered to be more operationally complex than WBA, and would require a larger footprint.

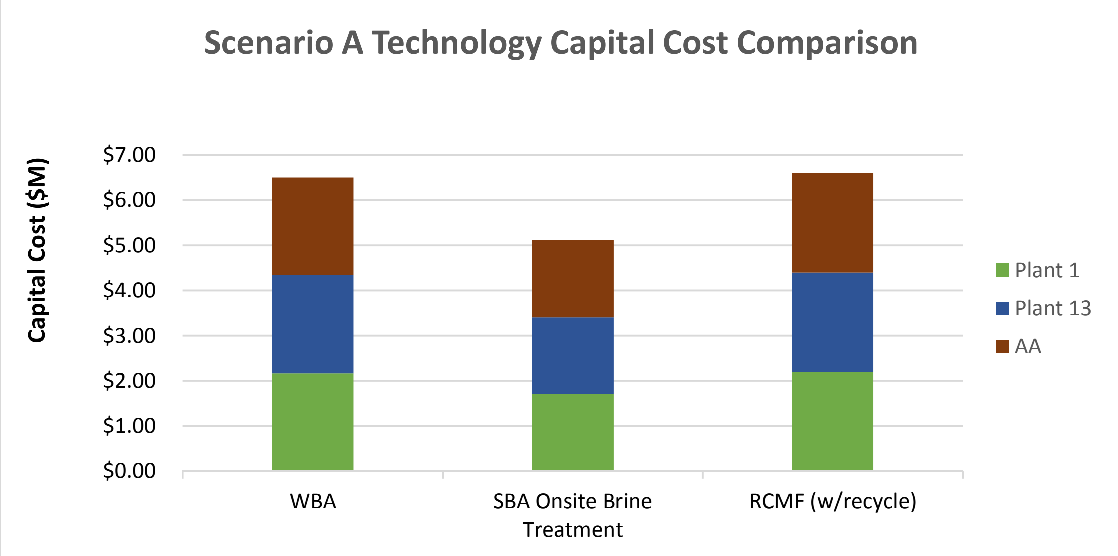

Figure 22. Scenario A Technology Capital Cost Comparison

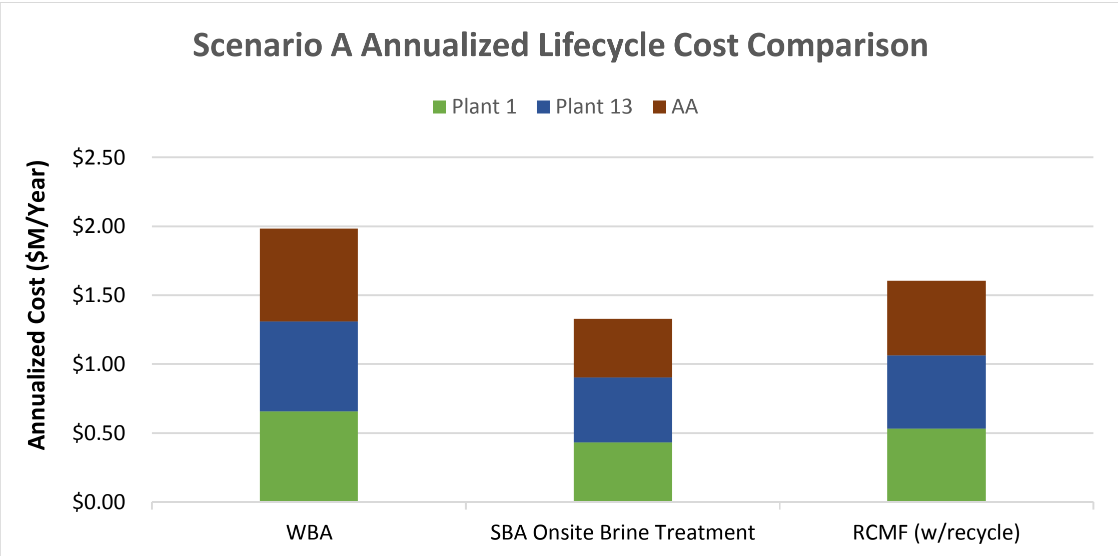

Figure 23. Scenario A Technology Annualized Lifecycle Cost Comparison

Figure 24 and **Figure 25** present the range of capital and annual O&M costs for different SBA implementation strategies. The CRRF option offers a significant capital cost savings as regeneration and brine treatment equipment are not required for this option; however, operational costs for this option are difficult to estimate (presented here based on a hypothetical range of unit costs) until CVWD completes the CRRF design and performs a Cost of Service Study. Generally, on an annualized basis there were similar costs across SBA options, supporting IWA's decision to move forward quickly with Containerized SBA. In terms of long-term applicability of Containerized compared with other SBA options, future brine management options and risk must be examined. **Table 19** presents a summary of these selections and associated system capacities.

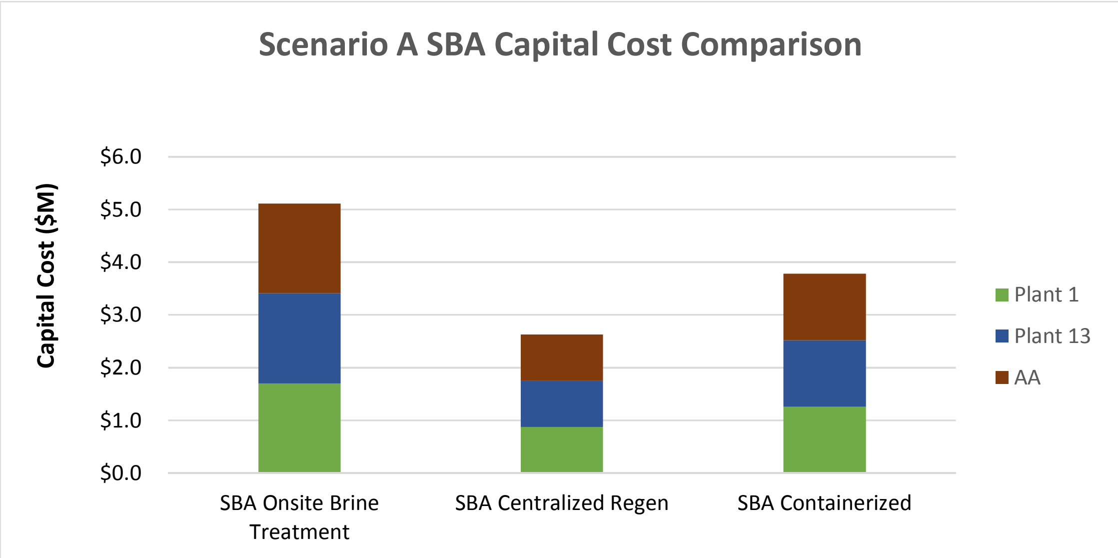

Figure 24. Scenario A SBA Capital Cost Comparison

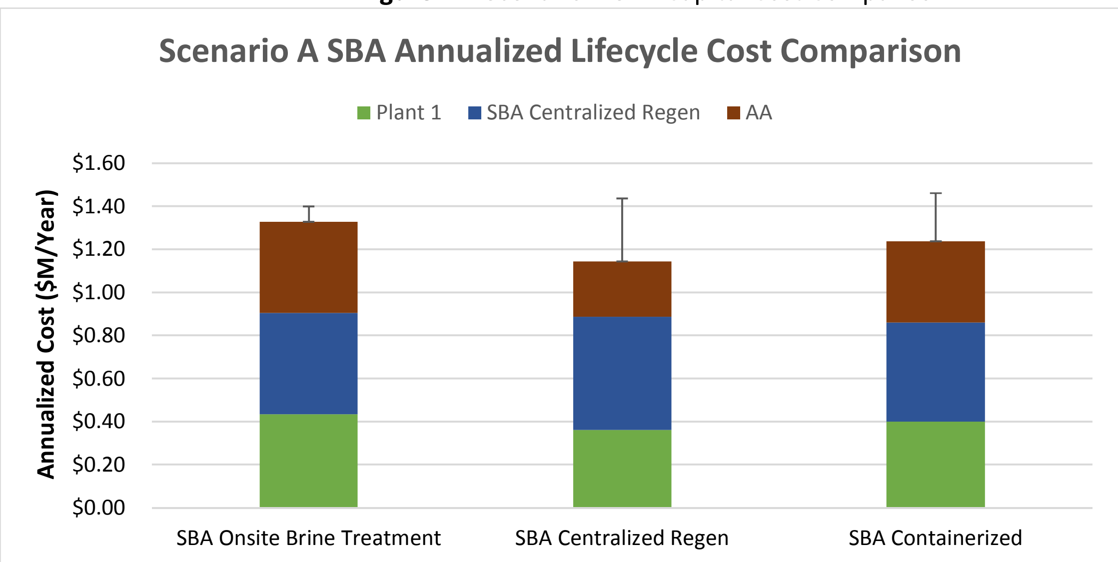

Figure 25. Scenario A SBA Annual O&M Cost Comparison

Table 19. Scenario A Treatment Technology Selection

Scenario A – Existing Systems			
CWA			
Demand	**ADD**	**MDD**	
	6.3 MGD	12.9 MGD	
	Production Capacity	**Treatment Capacity**	**Treatment Technology**
Active Well Capacity (Cr6 > 10.4)			
11, 12, 16, 17, 18, 19	17.6 MGD	-	-
Standby/Inactive Well Capacity	-		
IWA			
Demand	**ADD**	**MDD**	
	19.4 MGD	28.0 MGD	
	Production Capacity	**Treatment Capacity**	**Treatment Technology**
Active Well Capacity (Cr6 < 10.4)			
1C, 4A, 4B, 4C, S, T, V	25.2 MGD	-	-
Active Wells with Treatment	14 MGD	10.4 MGD	SBA
1E	3200 gpm	2400 gpm	SBA
13A	3300 gpm	2400 gpm	SBA
AA	3200 gpm	2400 gpm	SBA
TOTAL Active Well Capacity	39.2 MGD		
Standby/Inactive Well Capacity (Cr6 > 10.4)			
1B, Plant 2, Plant 3, U, W, Z, BB	33.6 MGD	-	-

In conclusion, the findings of the Scenario A Technology Cost Comparison include:

- CWA wells in operation are currently out of compliance.
- SBA was estimated as the least costly Cr6 treatment technology for IWA wells.
- Different SBA options are available that are similar in life cycle cost.

Scenario B – Achieve Compliance (Current Demands)
This scenario outlines the improvements needed to achieve compliance with the Cr6 MCL and meet current peak demands. For CWA, inactivation of one well (Well 11) is planned, and treatment on the remaining five wells is needed to achieve compliance with the Cr6 MCL. There are no opportunities to blend in lieu of treatment; however, an alternative that was identified by CWA and IWA as a possibility was assessed for a clustered treatment facility for CWA Wells 17 and 19 or 17, 19, and IWA well U.

For IWA, the 7 wells below the MCL and 3 additional wells with newly installed Cr6 treatment are enough to satisfy current demands and stay in compliance. However, there is an opportunity to increase system capacity through blending, without installing additional treatment. In this case, Well 1C and the treated effluent from Well 1E can be combined in the Plant 1 reservoir with Well 1B and Cr6 concentrations less than 10.4 µg/L can be achieved. To do this, treatment of Well 1E must be operated continuously, so 100% utilization of this well was assessed.

Figure 26 and **Figure 27** present the capital and annualized lifecycle costs for WBA, SBA, and RCMF in Scenario B. It was found that SBA was estimated to be the least costly Cr6 treatment technology. As mentioned previously, Plant 1 and Plant 13 may be a candidate for WBA despite the higher cost if operational simplicity at the site and diversification of treatment approaches is desired by IWA. **Figure 28** and **Figure 29** present the range of capital and annualized lifecycle costs for different SBA implementation options. Again the CRRF options offers significant potential for capital cost savings. On an annualized basis, there are similar costs across options, with the wells with higher sulfate (and associated greater regeneration frequency), being most sensitive to the brine management assumptions (represented by the error bars on the figure).

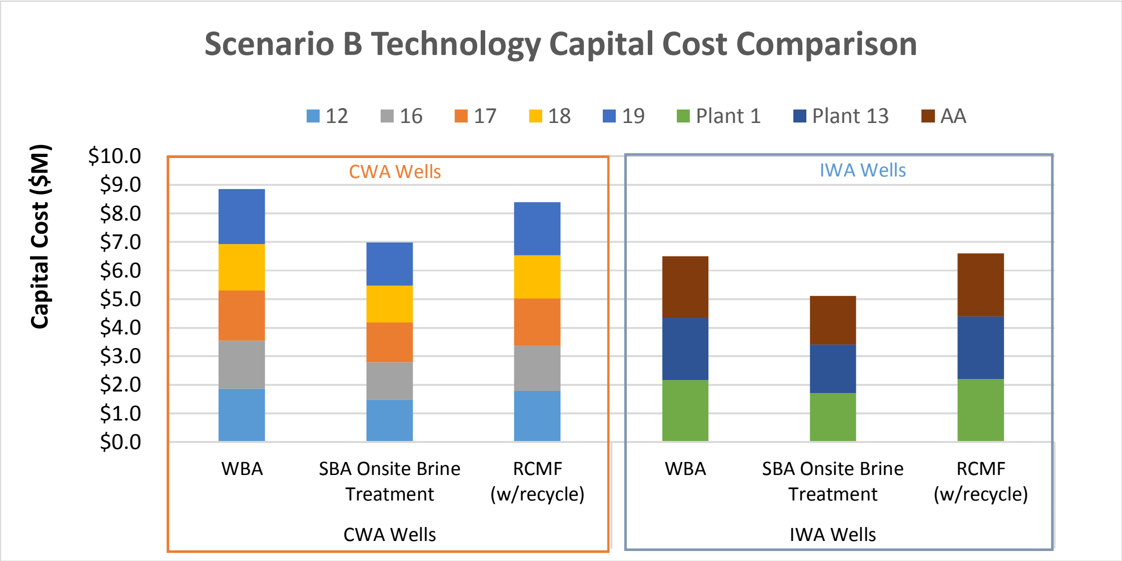

Figure 26. Scenario B Technology Capital Cost Comparison

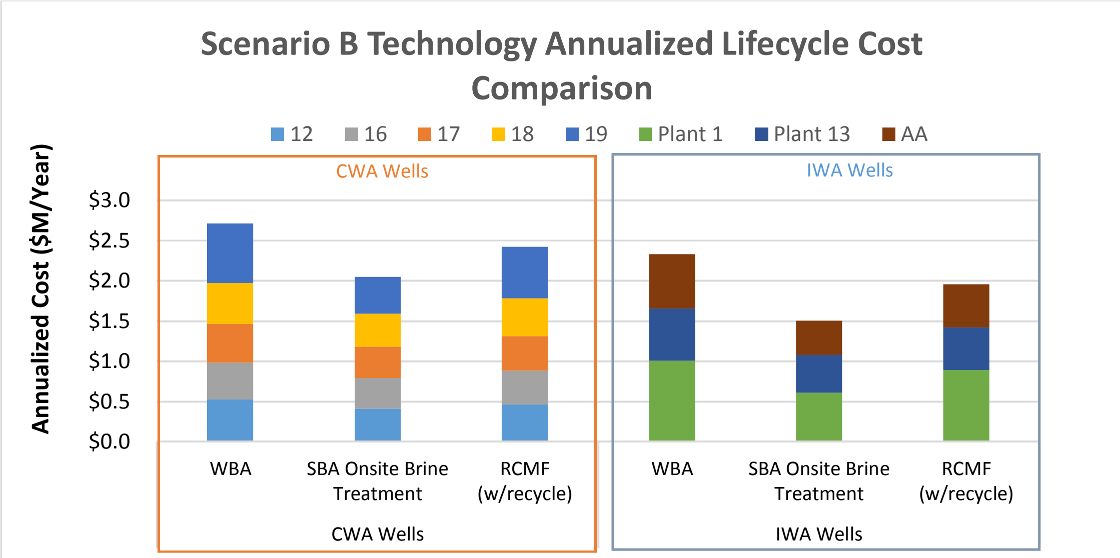

Figure 27. Scenario B Technology Annualized Lifecycle Cost Comparison

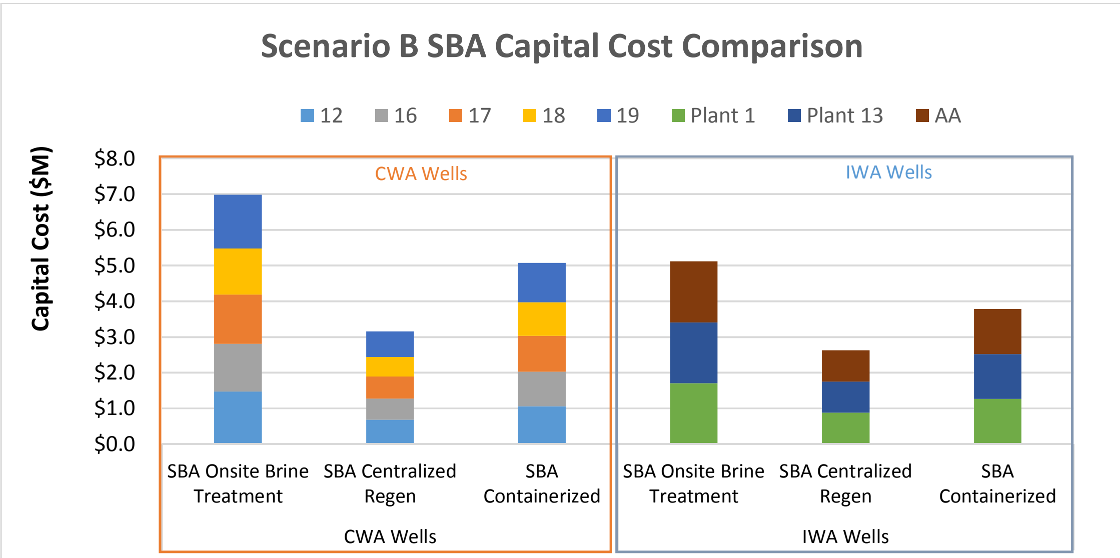

Figure 28. Scenario B SBA Capital Cost Comparison

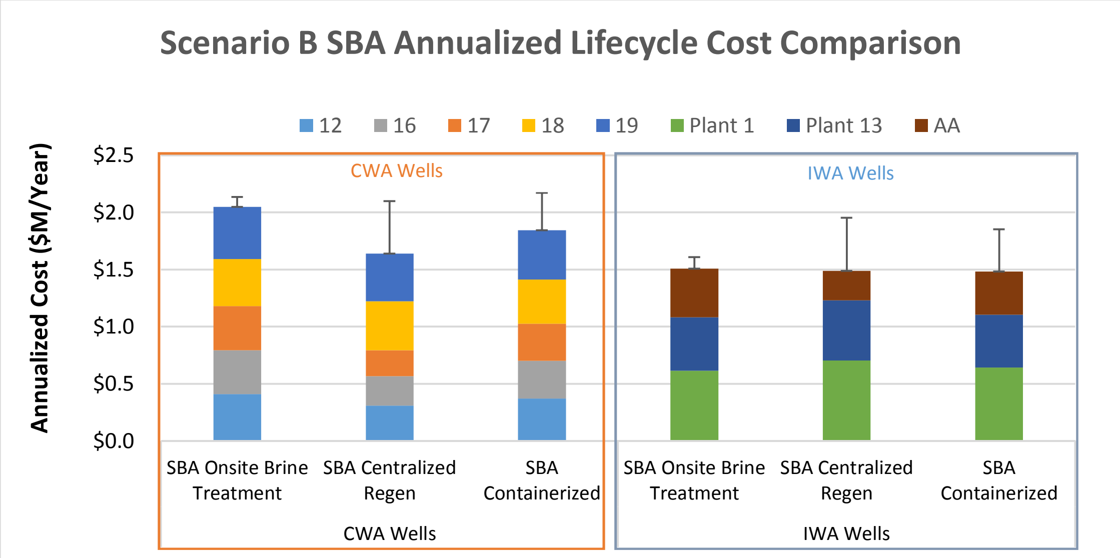

Figure 29. Scenario B SBA Annualized Lifecycle Cost Comparison

Figure 30 presents the lifecycle costs for cluster options of Wells 17, 19, and U. In this case, the cost of pipelines to bring the wells together at a common location for treatment did not significantly offset the estimated capital and O&M costs for combined treatment. If additional wells are planned to be sited at this location in the future, this cost advantage could be increased, but to allow for project phasing and flexibility, clustered treatment is not recommended at this time. **Table 20** summarizes these findings and presents the associated CWA and IWA system capacities.

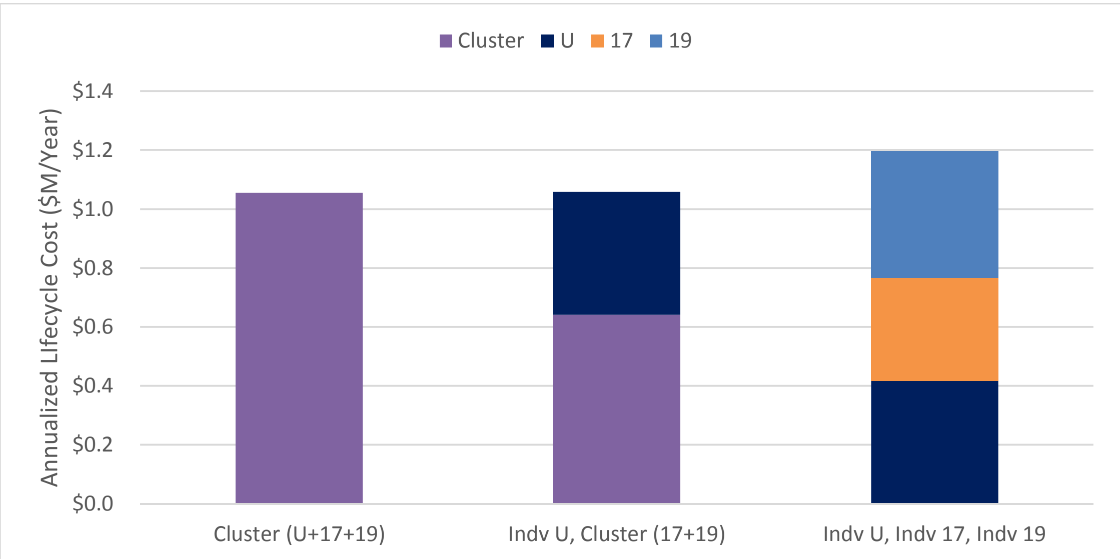

Figure 30. Scenario B Clustering Alternatives for Wells 17, 19, and U

Table 20. Scenario B Treatment Technology Selection

Scenario B – Achieve Compliance (Current Demands)			
CWA			
Demand	**ADD**	**MDD**	
	6.3 MGD	12.9 MGD	
	Production Capacity	**Treatment Capacity**	**Treatment Technology**
Active Well Capacity (Cr6 < 10.4)			
No Active Wells without Treatment			
Active Wells with Treatment	15.6 MGD	12.1 MGD	
12	2200 gpm	1800 gpm	SBA
16	2000 gpm	1500 gpm	SBA
17	2200 gpm	1600 gpm	SBA
18	2000 gpm	1400 gpm	SBA
19	2400 gpm	1900 gpm	SBA
Standby/Inactive Well Capacity			
11	2.02 MGD		
IWA			
Demand	**ADD**	**MDD**	
	19.4 MGD	28.0 MGD	
	Production Capacity	**Treatment Capacity**	**Treatment Technology**
Active Well Capacity (Cr6 < 10.4)			
1C, 4A, 4B, 4C, S, T, V	25.2 MGD	-	-
Active Wells with Treatment	16.8 MGD	10.4 MGD	SBA
1B	2000 gpm	-	Blend
1E	3200 gpm	2400 gpm	SBA
13A	3300 gpm	2400 gpm	SBA
AA	3200 gpm	2400 gpm	SBA
TOTAL Active Well Capacity	42.0 MGD		
Standby/Inactive Well Capacity (Cr6 > 10.4)			
Plant 2, Plant 3, U, W, Z, BB	30.7 MGD	-	-

In conclusion, the findings of the Scenario B Technology Cost Comparison include:

- SBA was estimated as the least costly Cr6 treatment technology for CWA and IWA wells.
- There was not enough cost savings to justify clustering 17 and 19 or U, 17, and 19 together for treatment.

- In the near term to meet current demands, it is recommended that IWA keep the Containerized SBA treatment equipment at Well 1E and blend with 1B and 1C in the Plant 1 reservoir to increase system capacity.

Scenario C – Full System Utilization (Future Demands)
This scenario assessed projected future demands of the CWA and IWA systems, included fully utilizing existing wells by adding treatment, and identified if new wells were needed. For this scenario, several treatment/blending alternatives were considered for IWA including:

- Plant 1 – Treatment of Wells 1E and BB, blending with Wells 1B and 1C in the reservoir.
- Plant 1 – Treatment of Wells 1B, 1E, and BB, blending with Well 1C in the reservoir.
- Well W – Treatment of Well W, blending with Well T

Figure 31 and **Figure 32** present the capital and annualized lifecycle costs for WBA, SBA, and RCMF. Across all CWA and IWA wells, SBA was estimated to be the least costly Cr6 treatment technology. **Figure 33** and **Figure 34** present the range of capital and annualized lifecycle costs for different SBA implementation strategies. Similar to the other scenarios, it was found that there are similar costs for the SBA options.

Figure 35 presents the annualized lifecycle costs for treatment/blending alternatives at Plant 1. In this scenario, bringing Well BB to Plant 1 offers several advantages. Larger treatment facilities allow flexibility of operating either Well 1E or BB or both simultaneously, while still blending with Wells 1B and 1C in the reservoir. By blending with Well 1B in the reservoir instead of including Well 1B in the treatment plant, the higher sulfate at Well 1B (average of 108 mg/L) does not increase the cost of treatment. Although there is not a significant reduction in treatment cost associated with clustering Well BB for treatment at Plant 1, the operational flexibility gained from this approach warrants seriously considering this alternative. As this option requires additional treatment capacity at Plant 1, it is recommended that during the preliminary design phase the option to expand the current Containerized SBA facility be compared to the cost to move the existing 2400 gpm Containerized SBA units to another individual wellhead treatment site allowing for construction of new larger facilities that take advantage of additional economies of scale to be assessed. Also, the performance of the current facilities can be used to refine and assess operations and lifecycle costs to evaluate whether brine management challenges warrant the consideration of WBA.

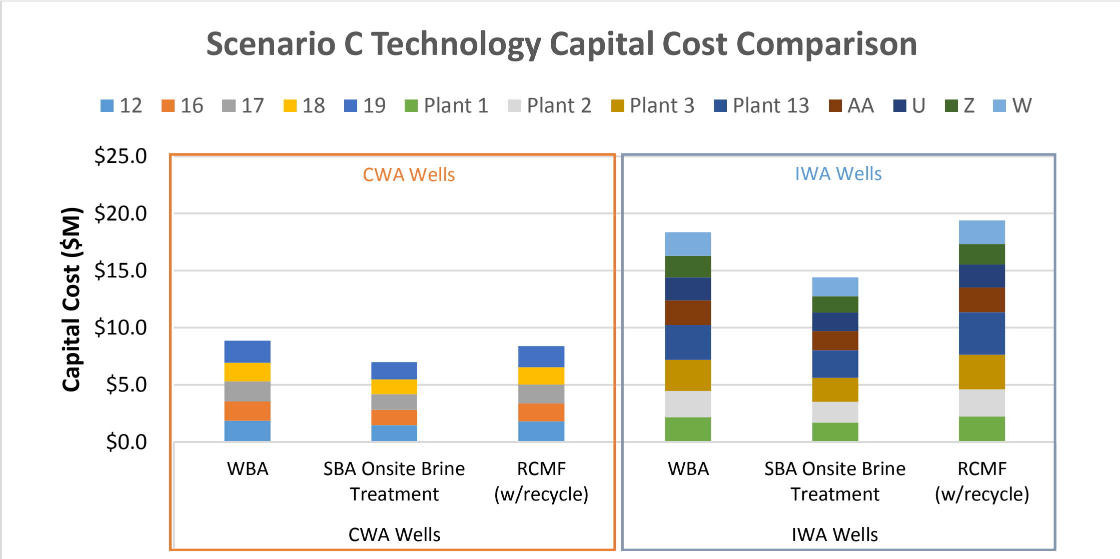

Figure 31. Scenario C Technology Capital Cost Comparison

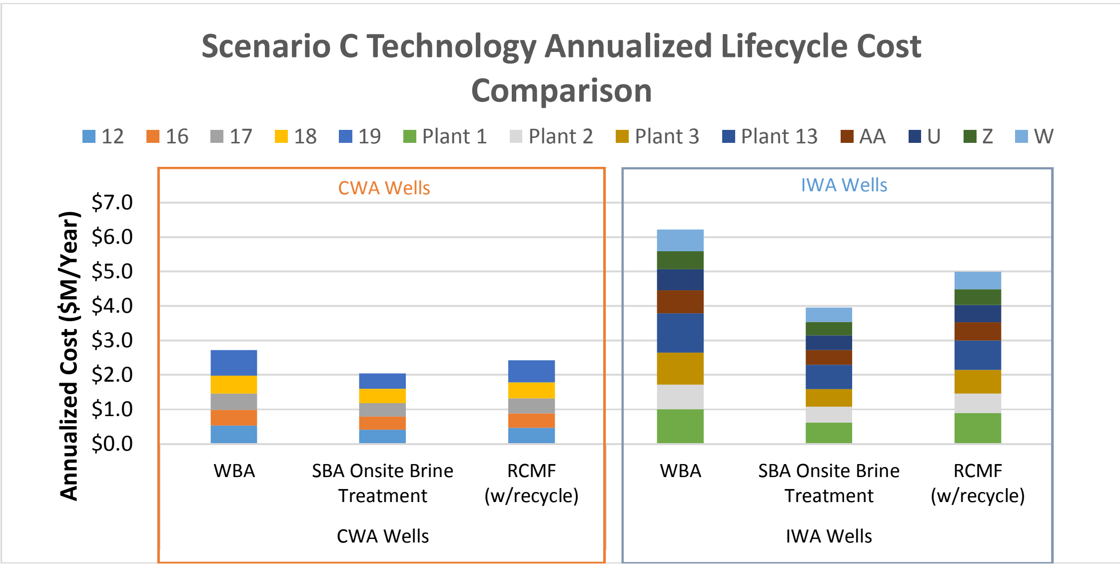

Figure 32. Scenario C Technology Annualized Lifecycle Cost Comparison

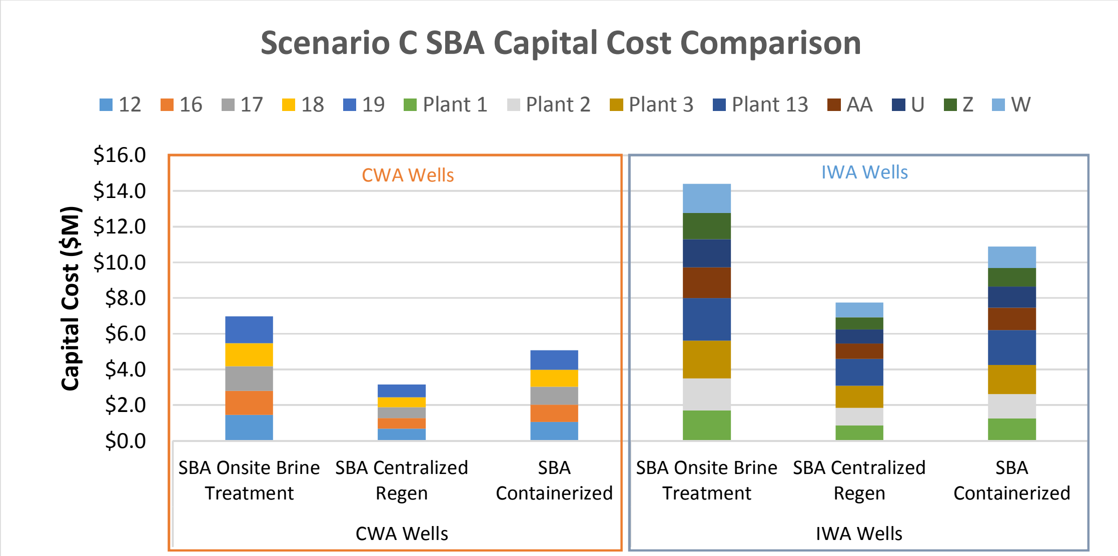

Figure 33. CWA Scenario C SBA Capital Cost Comparison

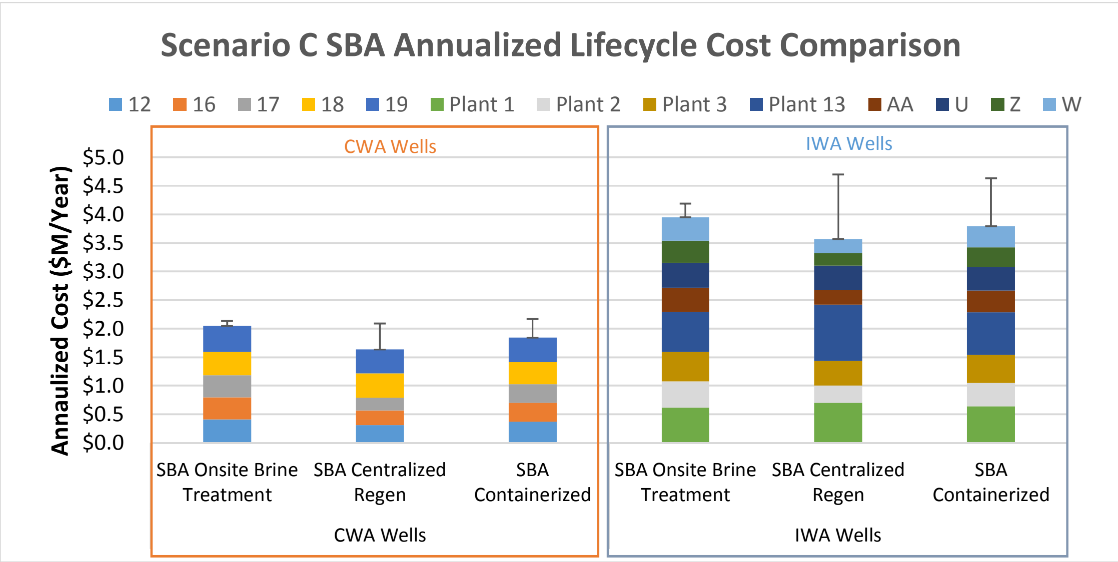

Figure 34. Scenario C SBA Annualized Lifecycle Cost Comparison

At Plant 13, this evaluation estimated treatment costs for equipping Well 13B and adding a pipeline installed to bring the water to the Plant 13 location (similar water quality and capacity to 13A was assumed). Similar to 1E, it is recommended that moving the existing 2400 gpm Containerized SBA units to another individual wellhead treatment site be considered. Based on actual operations experience with Containerized SBA at Plant 13, refined operating and lifecycle costs of larger facilities can be evaluated. **Table 21** summarizes these findings and presents the associated CWA and IWA system capacities.

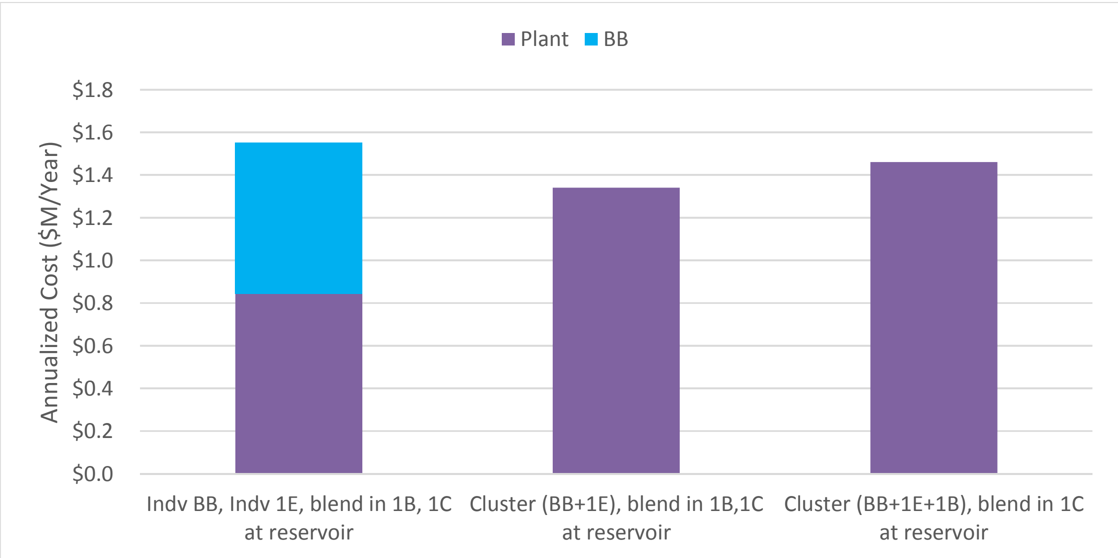

Figure 35. Scenario C Clustering/Blending Alternatives for Wells 1B, 1C, 1E, and BB

Table 21. Scenario C Treatment Technology Selection

Scenario C – Full System Utilization (Future Demands)			
CWA			
Demand	**ADD**	**MDD**	
	20.9 MGD	35.6 MGD	
	Production Capacity	**Treatment Capacity**	**Treatment Technology**
Active Well Capacity (Cr6 < 10.4)			
No Active Wells without Treatment			
Active Wells with Treatment	15.6 MGD	12.1 MGD	
12	2200 gpm	1800 gpm	SBA
16	2000 gpm	1500 gpm	SBA
17	2200 gpm	1600 gpm	SBA
18	2000 gpm	1400 gpm	SBA
19	2400 gpm	1900 gpm	SBA
Standby/Inactive Well Capacity			
11	2.02 MGD		
IWA			
Demand	**ADD**	**MDD**	
	27.2 MGD	40.8 MGD	
	Production Capacity	**Treatment Capacity**	**Treatment Technology**
Active Well Capacity (Cr6 < 10.4)			
1C, 4A, 4B, 4C, S, T, V	25.2 MGD	-	-
Active Wells with Treatment	52.3 MGD	35.0 MGD	SBA
1B	2000 gpm	-	Blend
1E + BB	6400 gpm	4900 gpm	SBA or WBA
Plant 2 (2C, 2D)	3600 gpm	2700 gpm	SBA
Plant 3 (3A, 3B, 3C)	5100 gpm	3600 gpm	SBA
Plant 13 (13A, 13B)	6600 gpm	4600 gpm	SBA or WBA
AA	3200 gpm	2400 gpm	SBA
U	3000 gpm	2100 gpm	SBA
W	3400 gpm	2200 gpm	SBA
Z	3000 gpm	1800 gpm	SBA
TOTAL Active Well Capacity	77.5 MGD		
Standby/Inactive Well Capacity (Cr6 > 10.4)	-		

In conclusion, the findings of the Scenario C Technology Cost Comparison include:

- SBA was estimated as the least costly Cr6 treatment technology for CWA and IWA wells. WBA may be operationally advantageous at Plant 1 and Plant 13 due to the large projected brine volumes, despite the higher cost.
- There are similar costs for different SBA options, with the wells with higher sulfate (and associated greater regeneration frequency), being most sensitive to the brine management assumptions. Long-term applicability of Containerized SBA should be assessed with future plant expansions to examine opportunities for cost savings and identify any associated brine management risks.
- Clustered treatment of Wells BB and 1E at Plant 1, blending the treated effluent with Wells 1C and 1B in the Plant 1 reservoir offers operational flexibility and cost savings.
- The 2,400 gpm Containerized SBA units at Wells 1E and 13A could be moved to other individual well sites (U, W, Z) to accommodate the design and construction of larger treatment facilities.
- With all existing wells utilized and Well 13B equipped, IWA system capacity is 77.5 MGD, relative to a maximum day demand of 40.8 MGD.
- With all existing wells utilized, CWA system capacity is 15.6 MGD, relative to a maximum day demand of 20.9 MGD. At 2,000 gpm per well, CWA will require 7 additional new wells to meet this future demand.

5.9 System Operation Evaluation

System operations including regeneration frequency, residuals waste generation, chemical consumption, and energy requirements were evaluated for all treatment technologies to develop cost estimates. **Table 22** summarizes operational components for the SBA treatment options. The range represents the varying operation and performance of Containerized SBA versus Traditional SBA with onsite brine treatment. These differences are discussed further in **Chapter 7**.

Based on average production rates, IWA wells generate on average 3,800 gallons of waste brine a month (one truck per month) that must be hauled as a hazardous waste or treated on-site and hauled as a non-hazardous waste. Plant 1 and Plant 13 at IWA are an exception. Due to the higher sulfate levels and more frequent regeneration requirements at these sites, approximately 21,000 gallons of waste brine (one truck per week) are produced. If during the peak summer months, Plant 1 and Plant 13 are increased to 100% utilization, the waste brine produced increases to approximately 34,000 and 64,000 gallons (two to four trucks per week). CWA wells at average production rates will produce an average of 4,820 gallons of waste brine per month (one truck per month).

Table 22. SBA System Operations

Well	Treatment Capacity (gpm)	Average Production Rate (gpm)	Waste Brine Produced (gallons per month)[1]	Rinse Water[2] (gallons per month)	Salt Consumption (tons/week)
Plant 1 (1E, BB)	4900	3150	21,200-22,700	56,700	2.4-2.6
Plant 2 (2C, 2D)	2700	820	2,800-3,100	7,000	0.3-0.4
Plant 3 (3A, 3B, 3C)	3600	1070	5,600	14,000	0.6
Plant 13 (13A, 13B)	4600	1390	17,000-21,900	54,600	1.9-2.5
AA	2400	750	2,700-2,900	6,600	0.3
U	2100	630	6,300-7,500	18,700	0.7-0.9
W	2200	660	2,700-2,800	6,600	0.3
Z	1800	540	1,700-1,900	4,100	0.2
12	1800	580	4,000-4,300	10,700	0.5
16	1500	430	3,100-3,400	8,300	0.3-0.4
17	1800	520	2,500-2,600	6,300	0.3
18	1400	800	6,900-8,000	20,000	0.8-0.9
19	1900	1580	6,500-6,900	16,300	0.7-0.8

[1]Range represents waste brine produced for SBA with onsite brine treatment (hauled as non-hazardous brine after treatment) and Containerized SBA (hauled as hazardous waste).
[2]The rinse waste stream is produced by SBA with onsite brine treatment final fast rinse. Containerized SBA does not incorporate a final fast rinse. Opportunities to reduce or recycle this stream can be tested, otherwise this stream is non-hazardous and can be disposed of to the sewer.

There are many components that contribute to the overall O&M cost of an SBA system. For the purposes of discussion, a breakdown of O&M for an example 2,000 gpm SBA with onsite brine treatment system (18 µg/L Cr6, 45 mg/L sulfate) is shown in **Figure 36** below. The annual estimate for this example totals $290k and includes labor (1.3 FTE), maintenance (1% of installed equipment cost), chemicals (salt for regenerations), residuals (includes disposal of treated non-hazardous brine and hazardous solids), replacements (4 year resin life replacement cost annualized), electricity to accommodate treatment system headloss, and sampling requirements.

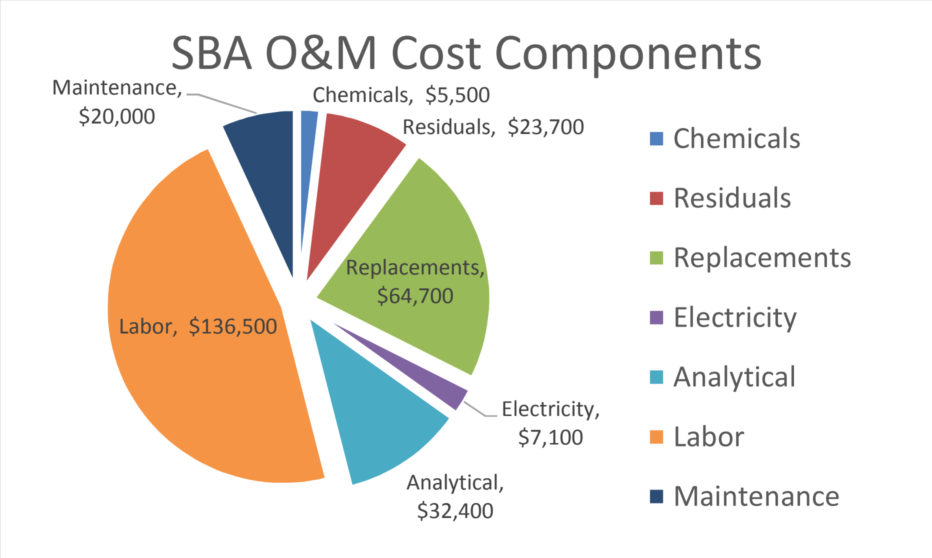

Figure 36. O&M Example for 2,000 gpm SBA with Onsite Brine Treatment System

5.10 Distribution & Storage Analysis

Three components were assessed in this evaluation regarding changes in CWA and IWA distribution system and storage, including:

- Pipelines for clustered treatment facilities
- Treatment system headloss impacts on well hydraulics
- Simulation of emergency IWA/CWA Interconnections

Pipelines for clustering alternatives were estimated based on the geographical location of well sites and estimated length from satellite maps. Pipelines were sized to accommodate design flows for wells using a velocity of less than 5 ft/sec. For CWA, clustered facilities in the near-term were not recommended. For IWA, the recommended alternative of bringing Well BB to Plant 1 for treatment, approximately 1.75 miles of 18 in diameter pipeline will be required. For bringing Well 13B to Plant 13 approximately 0.9 miles of 18 in pipe. Treatment at the well sites assumed no loss in well capacity and that additional bowls will be added and motors potentially upsized to accommodate any treatment system headloss. A headloss of 15 to 30 psi could result in a 10 to 20 percent reduction in well capacity if well modifications are not included. It is recommended that these assumptions be refined with subsequent modeling performed as part of the preliminary design process.

5.11 Facilities Schematics

Figure 37 and **Figure 38** below summarizes the recommended treatment facilities for CWA and IWA. Appendix D includes conceptual layouts of SBA options for each treatment site to demonstrate that there is sufficient space available for treatment. Detailed schematics for the selected SBA option should be developed as part of the preliminary design effort.

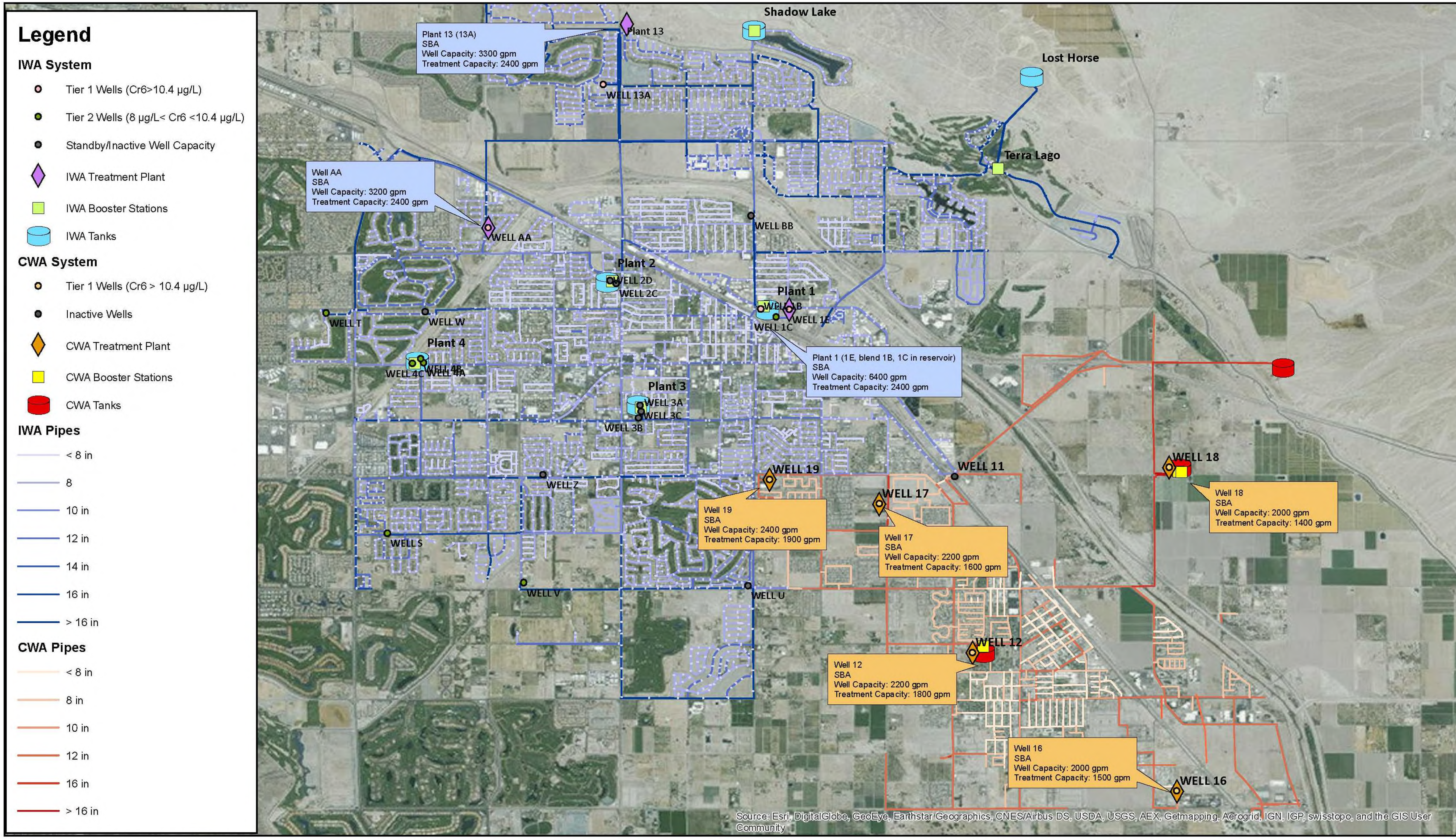

Figure 37. Scenario B - Cr6 Treatment Facilities for CWA and IWA Systems Current Demands

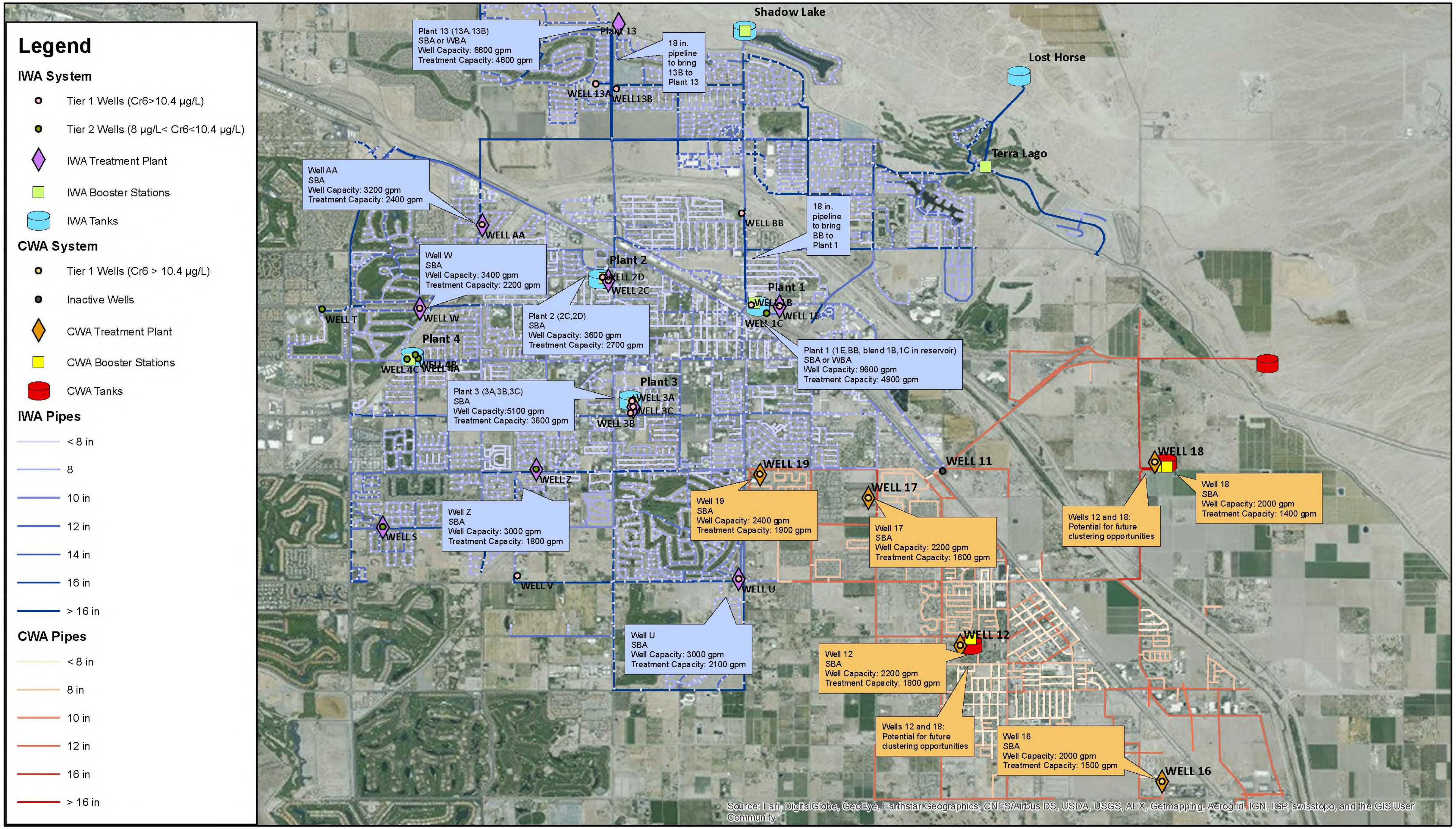

Figure 38. Scenario C - Cr6 Treatment Facilities for CWA and IWA Systems Future Demands

5.12 Emergency System Interconnections

In addition to the scenarios evaluated above, emergency interconnections for CWA and IWA Systems were also discussed. These interconnections could be used to provide system redundancy and provide a reliable water supply in the event of an emergency or treatment system failure. Interconnections between IWA, CWA, and CVWD agencies should be considered. For the purposes of discussion in this Study, this section presents information for one potential Interconnection example between the CWA and IWA systems.

Hydraulic Modeling of Emergency Interconnections. Hydraulic modeling simulations were not included in the scope of this Study project; however, CWA and IWA hydraulic modeling consultants were engaged during this Study to provide system information, review treatment scenarios, and provide feedback and some preliminary evaluation of the proposed options.

ID Modeling (IDM) is the hydraulic modeling consultant for IWA and maintains the most current version of the IWA hydraulic model. IDM had performed summer demand extended period simulations for IWA confirming that with the addition of treatment at Wells 1E, AA, and 13A and the 7 wells already less than the MCL, IWA could keep the remaining wells in standby and meet summer demands while maintaining system performance criteria.

TKE is the consultant preparing the CWA 2015 Water Master Plan Update. As part of that effort, TKE created a hydraulic model of the CWA system reflecting the most current system information and operating conditions.

IDM and TKE were engaged with the following items to facilitate the emergency Interconnection discussion:

1. Review the current system demand information and basic system performance criteria, including peaking factors, demand allocations, and diurnal patterns.
2. Identify the potential locations and associated system improvements required for emergency interconnections between the IWA/CWA systems. Simulate these connection points and quantify the capacity that could be conveyed between the systems.

For (1), TKE and IDM confirmed the peaking factors, demands, and diurnal pattern to be used during modeling simulations as presented in **Table 23** and **Figure 39** below. For (2), IDM performed initial simulations using six potential IWA/CWA emergency connection points (**Figure 40**). It was found that under steady state simulations, IWA can supply 6 MGD to the connections under MDD conditions while maintaining system performance criteria (**Table 24** and **Figure 41**). When peak hour conditions were simulated in the steady state model, 15 MGD could be supplied with existing wells, although IWA system pressures dropped below 40 psi in many locations (**Figure 42**). 48-hr extended period simulations were also performed (**Table 25**), indicating that additional evaluation is needed to optimize operations (taking into account when tanks are filling over an extended period of time), if additional wells are not brought online. With this information, TKE can also simulate the resulting impact on the CWA system using the CWA hydraulic model.

Table 23. Peaking Factors

Parameter		IWA	CWA
Demands (2013)	Average Day	19.4 MGD	7.1 MGD
	Max Day	28.0 MGD	12.9 MGD
Peaking Factors	MDD/ADD	1.5	1.7[1]
	PHD/ADD	2.5	2.8[2]

[1]Note that although the 2013 MDD/ADD peaking factor was 1.8, historically, this value was closer 1.7, and this value continues to be used for facility planning. [2]Hydrualic modeling conducted by IDM used IWA summer diurnal patter with 2.5 PHD/ADD peaking factor for interconnection simulations.

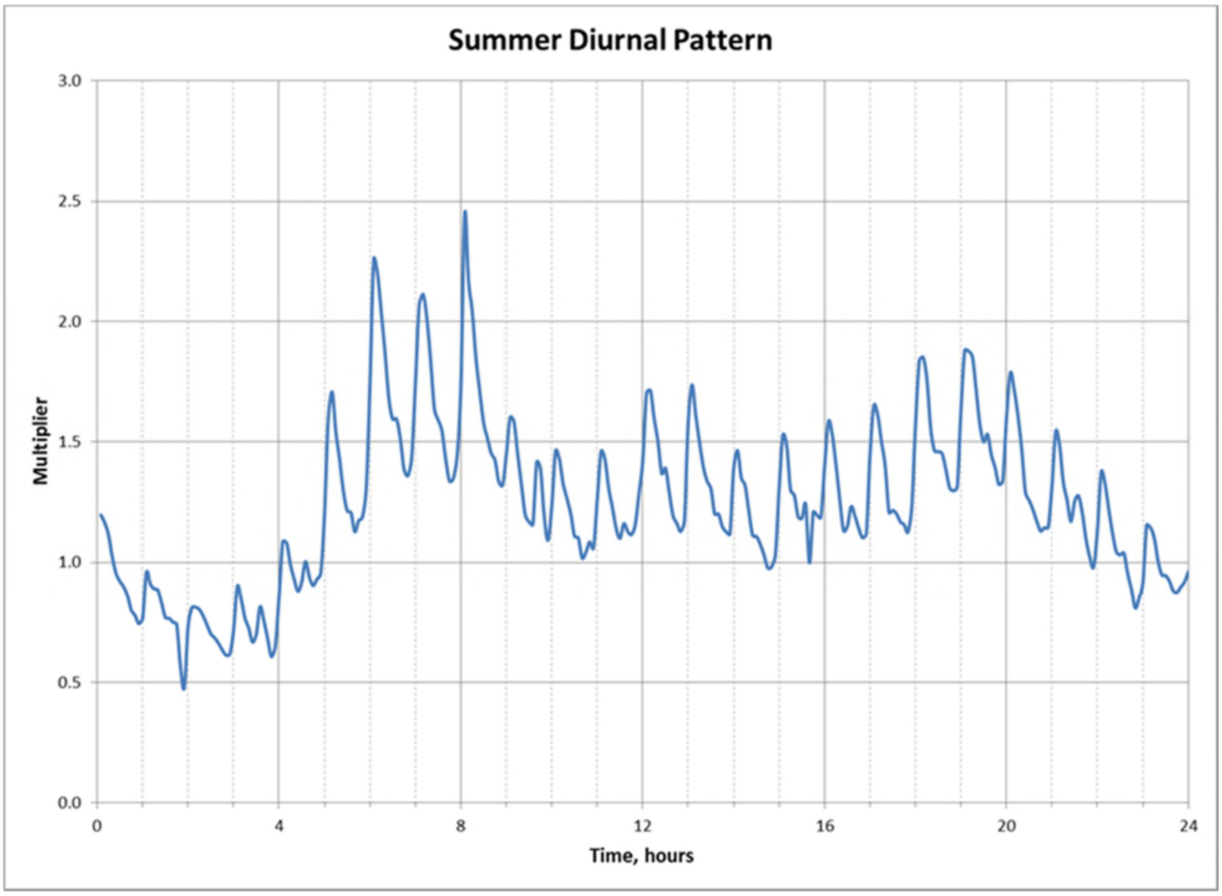

Figure 39. Summer Diurnal Pattern used for IDM for Simulations of CWA/IWA Emergency Interconnection

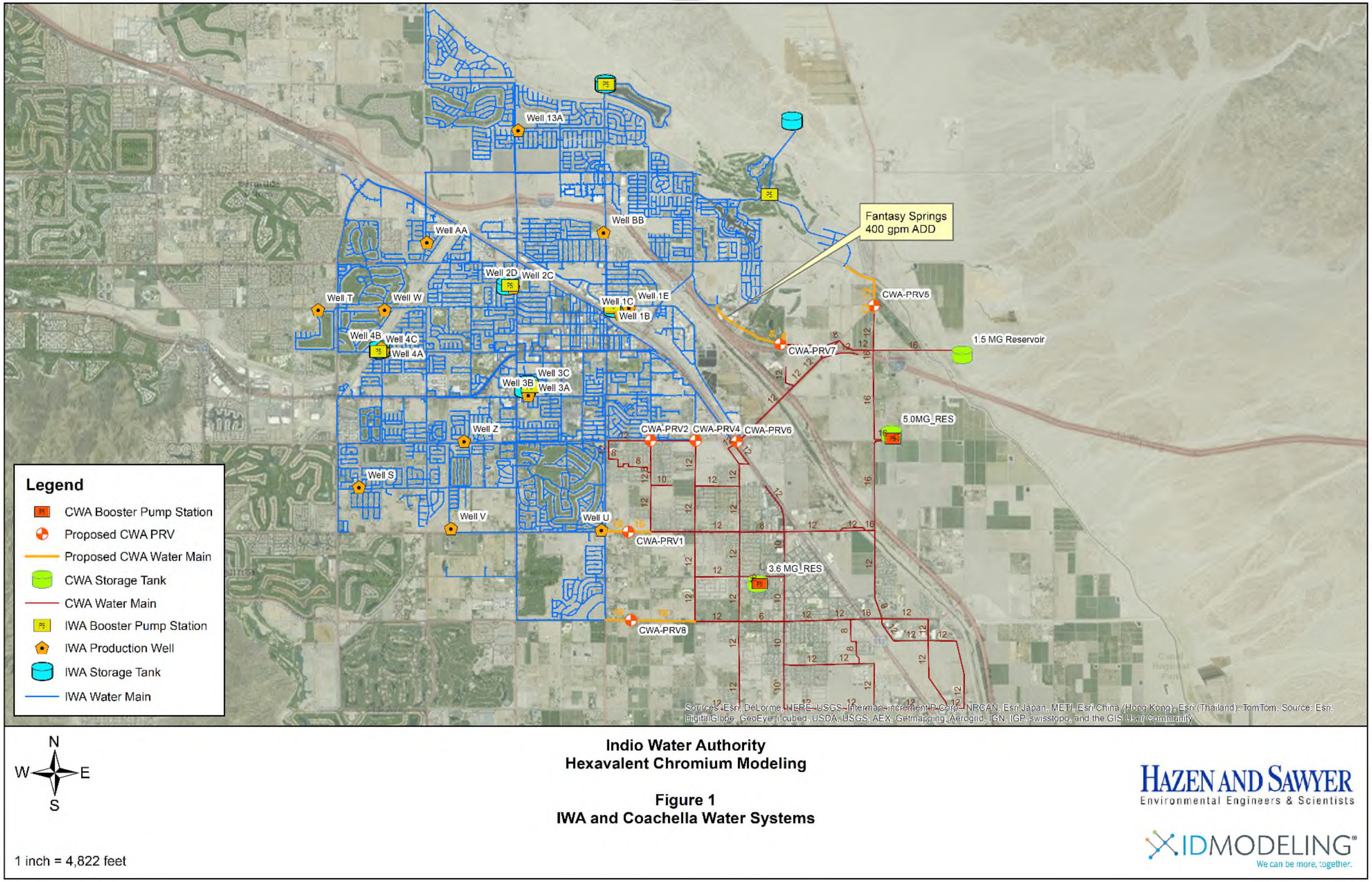

Figure 40. Potential CWA/IWA Emergency Interconnection Locations

Table 24. Steady State Model Simulation by IDM for CWA/IWA Emergency Interconnection

IWA Model Simulation	Total Conveyed for CWA (MGD)	IWA/CWA Emergency Interconnections Minimum Upstream/Downstream HGL (ft)						IWA System Modifications
		CWA-1	CWA-2	CWA-3	CWA-4	CWA-5	CWA-6	
MDD	6.0	173/120	172/120	159/120	322/150	180/150	NA	No additional wells required
PHD	17.8	74/73	87/80	77/75	271/150	128/125	67/58	Additional wells recommended to boost system pressure
Reduced PHD	15.0	95/94	105/100	98/96	288/150	136/134	90/83	No additional wells required but system pressures dropped below 40 psi

Notes:
1. IWA wells in operation include 1C, 1E, 4A, 4B, 4C, S, T, V, AA, 13A for all scenarios
2. PRV6 acts as a connection between the CWA high and low zones
3. Wells 1E, AA, and 13A include Cr6 treatment
4. All model demands assigned IWA Summer pattern
5. Shaded regions represent simulations that resulted in borderline performance criteria

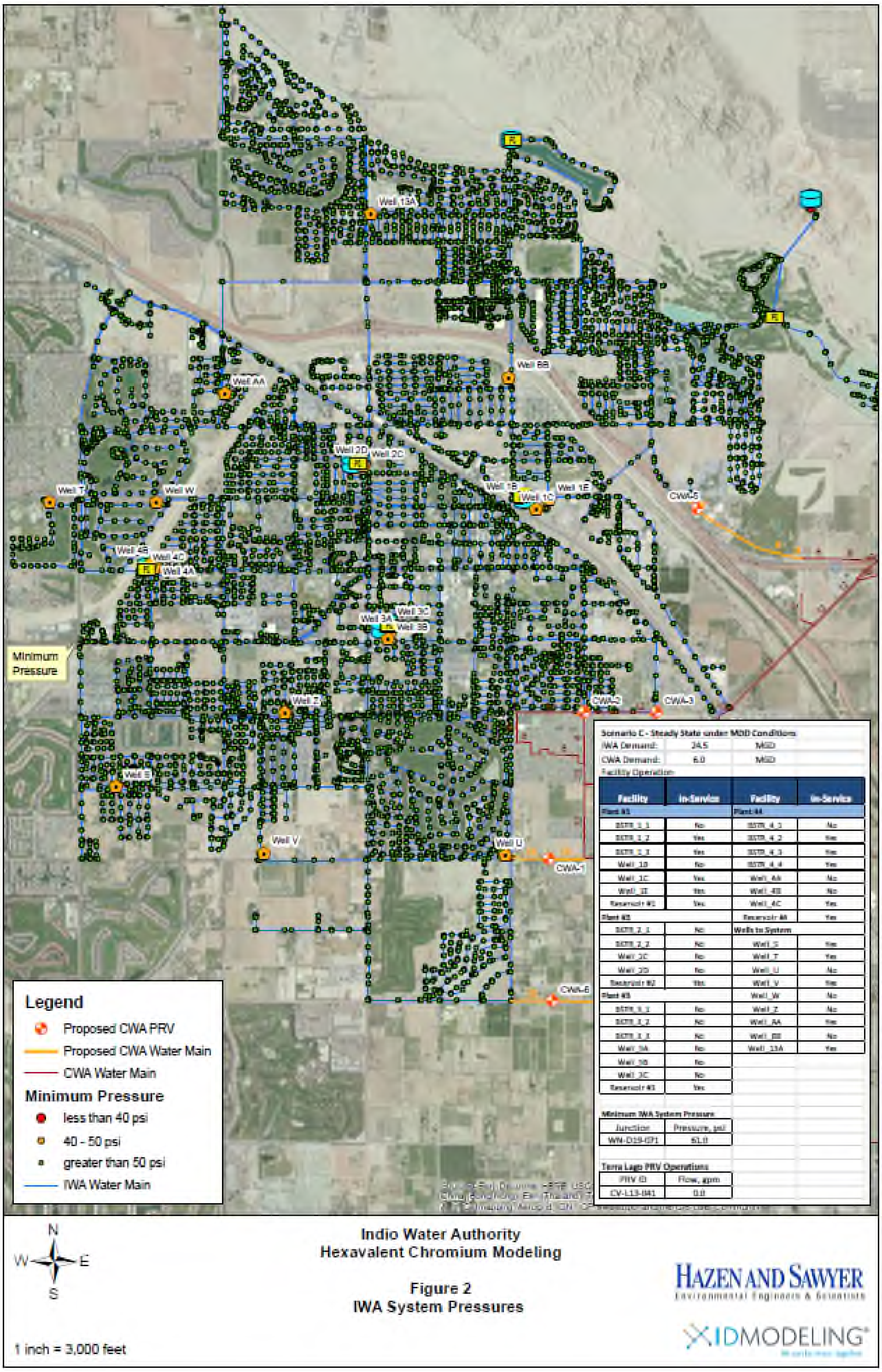

Figure 41. Steady State Simulation of MDD at CWA/IWA Emergency Interconnections

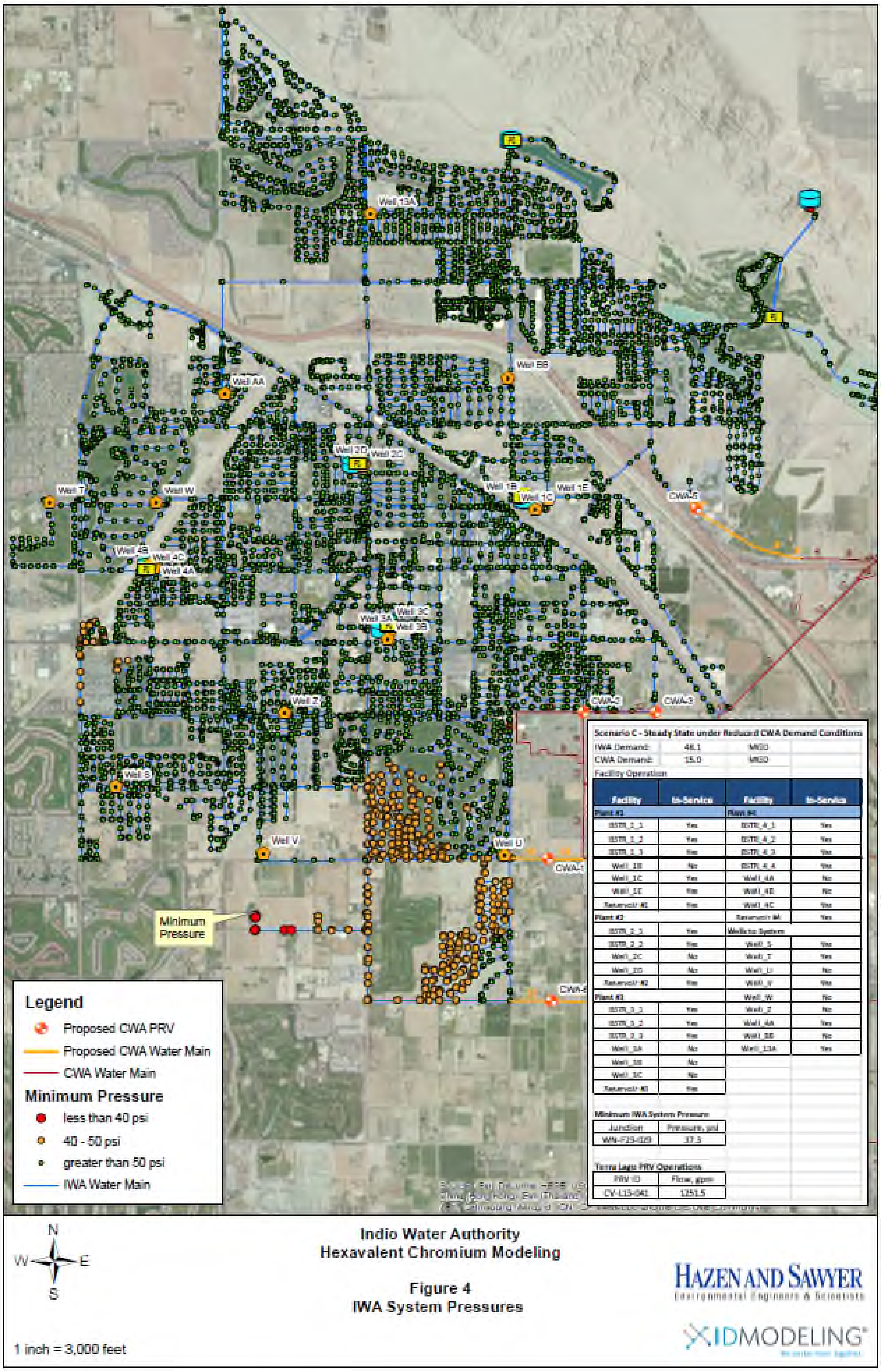

Figure 42. Steady State Simulation of PHD at CWA/IWA Emergency Interconnections

Table 25. 48-hr Extended Period Model Simulation by IDM for CWA/IWA Emergency Interconnection

IWA Model Simulation	Total Conveyed for CWA ADD (MGD)	Total Conveyed for CWA MDD (MGD)	IWA/CWA Emergency Interconnection Minimum Upstream HGL (ft)						IWA System Modifications
			PRV1	PRV2	PRV4	PRV5	PRV7	PRV8	
1	1.20	1.50	122	121	120	318	140	NA	None
2	4.82	6.00	139	124	119	288	101	NA	Requires Well U and Well AA (add'l bowl)
3	6.00	7.47	125	115	109	278	102	NA	Requires Well U and Well AA (add'l bowl)
4	8.03	10.00	123	108	90	223	75	NA	Requires Well U, Well AA (add'l bowl), and Well Z
5	10.04	12.50	94	86	70	191	56	75	Requires Well U, Well AA (add'l bowl), Well W, and Well Z and may also require an additional connection along 52nd Ave

Notes:
1. IWA wells in operation include 1C, 1E, 4A, 4B, 4C, S, T, V, AA, 13A for all scenarios
2. PRV6 acts as a connection between the CWA high and low zones
3. Wells 1E, AA, and 13A include Cr6 treatment
4. All model demands assigned IWA Summer pattern
5. Shaded regions represent simulations that resulted in borderline performance criteria
6. All simulations exclude fire flow analysis; only max day as determined through historical peaking factors

In order to flow any water from IWA to CWA, there needs to be a significantly higher HGL in the IWA system on the upstream side of the Interconnection versus the lower HGL on the CWA side. The rate at which water can flow from IWA to CWA is directly proportional to this difference in HGL, or pressure loss across the potential valve site. The greater the pressure loss, the greater the flow. If the HGL is higher on the CWA side than the IWA side, an in-line booster pump station, or stations, may be required to boost the system pressure to deliver the required flow. This local approach to boosting system pressure at the Interconnection is often recommended over adding more bowls to the IWA vertical turbine well pumps (above what would be needed to overcome treatment system headloss as described below). Adding bowls to the well pumps feeding the IWA system may over pressurize their system, especially in the lower elevations.

Pressure sustaining valves (PSVs) should be used to passively control the flow from IWA to CWA and not pressure reducing valves (PRVs). Both valves are similar with the exception of the PSVs throttle to control upstream pressure with the use of hydraulic pilots versus PRVs that use hydraulic pilots to throttle the valve and control downstream pressure. A PSV will passively allow IWA to flow potable water directly to CWA's distribution system, while ensuring the IWA pressure never drops to a dangerously low level. The PSV will automatically throttle back to keep the pressure on IWA's system while allowing whatever can be delivered to CWA to pass through the valve. This protection is needed on the supply side in the event there was a line break or excessive, prolonged demand (such as fire) on the CWA system. If a PRV were used, it would continually try to open as much as possible to allow the CWA system pressure to be augmented by IWA, thereby acting as a hole in the IWA system where all the local pressure on the IWA side would drop. There are instrumentation and controls that can be used with a PSV to alarm if the valve position is almost closed and the CWA side pressure is dropping, that can allow a temporary override by IWA to let more water flow to CWA to augment the demand. This is only recommended if IWA has the ability to turn on more compliant wells.

Another option to PSVs at the interconnections are micro-turbines that can be used to accomplish the same hydraulic principal of keeping the IWA system within acceptable pressure constraints while flowing excess water to CWA. The exception to the PSV is that the micro-turbine can be used to generate electricity whereas the PSV simply burns hydraulic head (i.e., wastes hydraulic energy potential). This practice requires an extensive micro-turbine feasibility analysis that is outside of this scope.

For the purposes of this evaluation, treatment at the well sites assumed no loss in well capacity and that additional bowls will be added / motors potentially upsized to accommodate any treatment system headloss. This assumption can be refined with subsequent modeling performed as part of the preliminary design process.

Cost Summary

A two-step approach was used for the scenario cost evaluation. The capital cost of treatment equipment, operations and maintenance costs, and resulting annualized lifecycle combination of these costs were initially used to compare and select technologies for each scenario (Section 5.9). Based on the selections, total project costs were then estimated using the industry standard cost factors and engineering factors listed in **Table 26** and **Table 27.** Project level allowance, also known as contingency, was kept at zero as the CWA and IWA well sites are well defined existing project sites and no buildings or land acquisition are anticipated to be required at this time. The total project costs are AACE Class 5 Estimate, with an accuracy range of -30% to +50%.

Treatment equipment costs were estimated for WBA, SBA, and RCMF BATs. For SBA the cost of various options was assessed, including SBA with onsite brine treatment, Containerized SBA with hazardous brine disposal, and SBA with off-site regeneration at a regional CRRF. SBA was estimated as the lowest cost technology for CWA and IWA wells. In summary, the range of costs presented here represent the range of costs for applying SBA with onsite brine treatment option and Containerized SBA options. Additional SBA considerations beyond cost are discussed further in **Chapter 7**.

Table 26. Capital Cost Factors Assumptions

Item	Percentage applied to installed equipment costs	Description
Installation	30%	Equipment Installation costs
General Requirements	7.5%	"Division 1" requirements including labor supervision, field offices, temporary utilities, health and safety, office supplies, clean up, photographs, survey, erosion control, coordination, testing services, and record documents
Earthwork	5%	Excavation, backfill, and fill required to construct the project
Site Work	5%	Roadways, curb and gutter, sidewalk, and landscaping
Valves, piping, and appurtenances	15%	Major system piping and valves
Electrical, Instrumentation and Control	15%	Motor control center (MCC), conduit and wire, programmable logic controller (PLC) and supervisory control and data acquisition (SCADA) equipment

Table 27. Engineering Factors Assumptions

Item	Percentage applied to total direct costs	Description
Contractor's Overhead and Profit	20%	Includes bonds, mobilization and demobilization, insurance, overhead and profit, and management reserves
Engineering, Legal and Administrative	20%	Includes permits, legal fees, and engineering fees for design and construction.

6.1 Total Project Costs

Table 28 summarizes cost estimates for each CWA and IWA treatment location, including total project cost, annual O&M costs, and lifecycle costs. A range is shown to reflect the range in cost for Containerized SBA versus SBA with onsite brine treatment systems. At IWA Plant 1 and Plant 13, the cost for WBA is also noted for comparison. SBA with CRRF is not reflected here; however, the CRRF were to be considered, total project costs could be reduced by more than 25 percent and O&M costs could be reduced by more than 15 percent, as regeneration and brine treatment equipment would not be required on each well site.

For CWA, the capital cost of Cr6 treatment facilities for compliance for existing wells ranges from approximately $14M to $19M (up to $29M given planning level cost range accuracy). In order to meet future maximum day demands, another 7 wells will be needed. With the estimated cost for a new well plus treatment facilities ranging from $5.4 to $6.3M (assuming similar water quality to existing CWA Well 18), a total of $52M to $63M will be the total capital cost of Cr6 compliance to meet future demands. The total O&M cost estimates for CWA for Cr6 treatment facilities at existing wells is approximately $1.4M to $1.5M per year. If future wells are also included, the total is approximately $4M to $4.7M per year. The annualized cost (annualized capital plus annual O&M) and net present value, NPV (present value of 20 years O&M plus capital cost), were estimated by applying a 20 year period and a 5% amortization rate to the estimated total project cost and O&M cost at each Cr6 treatment location. For CWA, the estimated NPV range for Cr6 treatment on current wells is approximately $28M to $48M (given planning level cost range accuracy).

The estimated total capital cost for IWA Cr6 treatment facilities ranges from approximately $35M to $44M (up to $66M given planning level cost range accuracy). IWA has already purchased and installed three 2400 gpm Containerized SBA treatment systems (approximately $7M for the three systems). For Well AA this system can remain in place (and this cost was already incurred). For Wells 1E and 13A, the existing systems could be potentially be moved to other sites (reducing the estimated cost at those sites), allowing for larger facilities to be designed and installed at Plant 1 and Plant 13 in the future. For

IWA, the total O&M cost for Cr6 treatment facilities ranges from approximately $2.9M to $3.1M per year. On a lifecycle basis, this corresponds to a NPV range of approximately $64M to $102M (given planning level cost range accuracy).

Table 28. Project Costs for CWA and IWA Cr6 Facilities

CWA	Production Capacity (gpm)	Treatment Capacity (gpm)	Containerized SBA		SBA with Onsite Brine Treatment	
			Total Project Costs[1] ($M)	O&M	Total Project Costs[1] ($M)	O&M
12	2200	1800	2.9	0.28	4.0	0.29
16	2000	1500	2.7	0.25	3.7	0.28
17	2200	1800	2.8	0.24	3.8	0.28
18	2000	1400	2.6	0.31	3.6	0.31
19	2400	1900	3.0	0.34	4.2	0.33
TOTAL Point Estimate			14	1.4	19	1.5
TOTAL Accuracy Range (-30% to +50%)			**10 to 21**		**14 to 29**	
Annualized Lifecycle Cost			**2.2 to 3.1**		**2.6 to 3.8**	
NPV Lifecycle Cost			**28 to 39**		**33 to 48**	
IWA	**Production Capacity (gpm)**	**Treatment Capacity (gpm)**	**Containerized SBA**		**SBA with Onsite Brine Treatment**	
			Total Project Costs[1] ($M)	**O&M**	**Total Project Costs[1] ($M)**	**O&M**
Plant 1 (1E, BB) [2]	6400	4900	8.0	0.71	9.1	0.63
Plant 2 (2C, 2D)	3600	2700	3.6	0.30	4.8	0.32
Plant 3 (3A, 3B, 3C)	5100	3600	4.4	0.36	5.6	0.34
Plant 13 (13A, 13B) [3]	6600	4600	6.4	0.55	7.6	0.47
AA [4]	3200	2400	3.4	0.28	4.5	0.29
U	3000	2100	3.1	0.32	4.2	0.31
W	3400	2200	3.2	0.27	4.5	0.28
Z	3000	1800	2.8	0.26	3.9	0.27
TOTAL Point Estimate			35	3.1	44	2.9
TOTAL Accuracy Range (-30% to +50%)			**25 to 52**		**31 to 66**	
Annualized Lifecycle Cost			**5.1 to 7.3**		**5.4 to 8.2**	
NPV Lifecycle Cost			**64 to 91**		**67 to 102**	

[1]Applies capital and engineering cost factors to equipment costs to estimate a total project cost.
[2]Includes pipelines to bring BB to Plant 1. For WBA at this site, the total project cost is $11M and O&M cost is $1.2M.
[3]Includes pipelines to 13B to Plant 13. For WBA at this site, the total project cost is $9.3M and O&M cost is $0.86M.
[4]Cr6 Treatment at AA already complete and recommended to remain in place. This treatment cost is already incurred.

6.2 Tier 2 Well Treatment Costs

Impacted wells were categorized into three Tiers for this evaluation:

- **Tier 1 (Cr6 > 10.4 µg/L)** – current treatment required
- **Tier 2 (8 µg/L < Cr6 < 10.4 µg/L)** – no current treatment required, costs estimates included for future contingency planning
- **Tier 3 (Cr6 < 8 µg/L)** – no current treatment required

Tier 1 wells are those wells currently requiring treatment for Cr6 compliance and costs were presented in 0 and 0 above. Tier 2 wells are those that do not currently require treatment, but should be assessed for contingency planning. CWA has no Tier 2 wells. IWA has 7 Tier 2 wells, including 1C, Plant 4 (4A, 4B, 4C), S, T, and V. Treatment at T could be avoided by blending with treated water from Well W. Similar to other IWA wells, SBA was estimated as the lowest cost treatment technology. Costs ranges for SBA treatment for Tier 2 wells are summarized in **Table 29** below as a range for SBA with onsite brine treatment and Containerized SBA options. Should Tier 2 wells require treatment, an estimated additional $18M in capital facilities (up to $27M given planning level cost range accuracy) and $2.3M/year in O&M costs for IWA. There are no Tier 3 wells for CWA and IWA.

Table 29. Treatment Costs for Cr6 Facilities at Tier 2 Wells

IWA	Production Capacity (gpm)	Treatment Capacity (gpm)	Containerized SBA		SBA with Onsite Brine Treatment	
			Total Project Costs[1] ($M)	O&M	Total Project Costs[1] ($M)	O&M
1C	1200	600	1.8	0.31	2.2	0.29
Plant 4 (4A, 4B, 4C)	7200	3500	4.3	0.64	5.5	0.53
S	2800	1100	2.2	0.47	3.0	0.37
T[1]	3000	1700	2.8	0.35	3.8	0.33
V	3300	1700	2.8	0.43	3.8	0.33
TOTAL Point Estimate			14	2.2	18	1.9
TOTAL Accuracy Range (-30% to +50%)			**10 to 21**		**13 to 28**	
Annualized Lifecycle Cost			**3.0 to 3.9**		**2.9 to 4.1**	
NPV Lifecycle Cost			**37 to 48**		**36 to 51**	

[1]Treatment cost for Well T could be avoided by blending with treated water at Well W.

SBA Treatment Systems Operations Comparison

This chapter discusses the sensitivity of the Study analysis to key SBA treatment assumptions and identifies potential risks associated with various SBA treatment approaches.

7.1 Waste Generation and Disposal

The SBA treatment process generates a waste brine that must be managed. There are two ways to reduce the cost of SBA treatment: (1) reduce the volume of waste generated and (2) reduce the cost of disposal of waste brine.

To reduce the volume of waste brine generated, SBA applications include recycling of brine and rinse water during the regeneration process. The Containerized SBA O&M estimates generated in this Study are based on the regeneration procedure suggested by Ionex SG, which incorporate recycling and reduced rinse volumes. This process is compared to traditional SBA applications that are based on resin manufacturer recommendations, which are also estimated in the SBA with Onsite Brine Treatment costs. Whatever the regeneration procedure implemented, regeneration effectiveness to return the resin to full capacity should be validated and potentially optimized for different water qualities. A comparison of how this impacts the brine waste generation as estimated in the O&M costs is provided in **Table 30**.

Table 30. Variations in SBA Regeneration Processes

Regeneration Step	SBA with Onsite Brine Treatment	Containerized SBA[1]
Brine	4 BV of 12% NaCl 75% to be recycled	3 BV of 12% NaCl 50% to be recycled
Slow Rinse	1 BV 100% to be recycled	0.8 BV 100% to be recycled
Fast Rinse	3 BV 0% to be recycled	0 BV
Total Waste	1 BV hazardous 3 BV non-hazardous	1.5 BV hazardous 0 BV non-hazardous

[1]This regeneration process could be further refined to reduce brine waste using the Ionex SG sulfate return if permitted by DDW.

Incorporating recycle of the fast rinse waste, and backwash waste (if filtered) may also be feasible. The Containerized SBA does not implement a fast rinse, and the higher TDS and sulfate concentrations typically associated the freshly regenerated vessel are diluted down to with the treated water from the other parallel vessels. Portions of the spent brine can be recycled, while other portions containing the released anions (i.e., chromium, selenium, arsenic, uranium, etc.) must be disposed of as a hazardous waste or need to be treated before it can be disposed of as a non-hazardous waste. The slow rinse contains the 12% NaCl fraction of the spent brine, and insignificant concentrations of the previously mentioned contaminants; therefore it too can be recycled.

To reduce the cost of brine disposal, multiple options can be considered. First, available facilities that will accept hazardous waste brine should be explored in bidding and the brine composition limits associated with disposal quotes understood. In this Study, two quotations were used as the basis for cost estimates: Containerized SBA systems by Ionex SG utilize a contract with a disposal facility named Phibrotech quoted at $1.12/gallon (brine composition limits unknown); and a similar service provided by Evoqua was quoted at $2.30/gallon (60,000 mg/L TDS and 120 mg/L chromium).

The second option is to treat the hazardous brine on site with chemical precipitation to produce a non-hazardous brine and hazardous solids for disposal. For this Study, the brine treatment process was estimated to include a 7:1 iron-to-Cr6 ratio, which is effective at CVWD's current full-scale SBA treatment facilities. However, CVWD's facilities are regenerated more frequently based on arsenic breakthrough, and the longer run times associated with Cr6 treatment will generate a different brine composition that should be evaluated. For example, recent testing has shown that selenium although present at non-detect levels in groundwater, can accumulate on the SBA resin and subsequently be present in the regeneration waste brine at potentially hazardous levels (in excess of 1 mg/L). If this were the case for CWA and IWA, chemical precipitation may not be fully effective (or may require a higher dose and/or pH adjustment) and other brine treatment techniques may be required. Whatever the treatment approach, it is recommended that the selected brine treatment process be validated and potentially optimized for different water qualities.

To account for the variation in costs associated with various brine management options, the following conditions were assessed in this Study:

- Containerized SBA systems were assessed for disposal costs ranging from $1.12 to $2.30 per gallon. This range in unit cost resulted in approximately a 20% increase in the total annual O&M cost for CWA and IWA systems.
- SBA with onsite brine treatment systems were assessed for two different brine treatment processes- one with the 7:1 iron:Cr6 ratio, and another assuming that selenium requires this dose plus additional processing. In the latter case, mixing of treated brine with rinse water after treatment was included in the cost estimate to reduce selenium concentrations so that brine could be disposed of as a non-hazardous waste. This range in brine treatment operations resulted in approximately a 7% increase in the total annual O&M cost for CWA and IWA systems.

The recently installed IWA Cr6 treatment facilities offer the advantage of being able to fully test and characterize the hazardous brine generated from these full-scale systems. It is highly recommended that brine treatment piloting be performed in preliminary design to assess various brine treatment options. This will allow brine treatment and disposal assumptions to be refined, improving SBA treatment cost estimates.

7.2 System Operations and Maintenance

Containerized SBA systems that utilize multiple smaller (e.g. 4 ft diameter) vessels differ in operational complexity from traditional SBA systems with fewer larger (e.g. 10 to 12 ft diameter) vessels. The multi-vessel approach offers the advantage of blending the treated effluent from multiple vessels at various stages of bed life, which allow for the vessels to be operating to a higher Cr6 breakthrough, blends down chromatographic peaking that could occur for other constituents, and also potentially negates the need for post-treatment stabilization associated with the pH drop experienced after a regeneration. However, the challenge associated with the multiple vessel approach is that the controls that divide the flow across the vessels (effectively staggering bed life, as the flow split amongst vessels is not necessarily equal) involve more complex programming. Additionally, the flow control valves on each vessel that accomplish this are constantly modulating, resulting in more wear and tear and potentially more future maintenance.

In general, maintenance is more complex for a Containerized SBA system as a result of having more equipment and components that could potentially fail, as well as having a severely constrained environment for servicing the equipment. Within the containers, there is limited access with approximately a two foot wide space available to fit an operator and access or the ability to reach some of the equipment and piping is challenging.

More complex programming, system controls, and equipment maintenance can be managed through the use of an Operations Agreement with the equipment provider. The advantage of this approach is that vendor supplied operators who are most familiar with the equipment are responsible for operating and maintaining it. The disadvantage is that there is not a transfer of knowledge of system operations to agency staff who without the operations agreement would be responsible for O&M. Operations agreements offer a cost advantage by allowing for remote system operations and a less frequent presence of onsite personnel; however, this approach comes with an inherent risk that there will be more system downtime and longer response times compared to having operators on staff. Further, the long-term availability and cost of the equipment provider operating the system is a risk. If an operations service agreement is considered, it should be noted that this comprises only a fraction of the total O&M cost for the treatment system.

Based on operational experience for similar SBA facilities, O&M cost estimates developed in this Study for both Containerized SBA and SBA with onsite brine treatment approaches included full-time agency operations staff. The required labor was assumed to be 1.3 to 2.6 full time equivalent (FTE) depending on treatment system size. Generally, labor accounted for approximately a third of the total annual O&M cost estimate.

7.3 Equipment Longevity and System Robustness

Containerized SBA treatment systems are configured differently and are constructed from different materials than traditional SBA systems. For example, fiberglass reinforced plastic (FRP) is used for the containerized IX vessels whereas carbon steel vessels are used for traditional SBA applications. Similarly, interconnecting piping for the containerized systems is PVC, compared with ductile iron for traditional SBA applications. Additionally, due to the very limited access space in the containers, reaching these pipes and fittings for maintenance can be a challenge. According to the Containerized SBA manufacturer, their system implements an “air-locking” practice in the headspace of the pressure vessels that: 1) Reduces the amount of brine/brine waste to occupy backwash headspace; 2) Acts as a mini air bladder tank that helps buffer pressure surges. Instrumentation in the pressure vessels ensures that this air bubble always stays above the top lateral so as not to choke off the flow and cause excessive headloss. Although both treatment systems are intended to reach a 20 year lifetime, equipment longevity is dependent on proper system maintenance, which can be more challenging for containerized systems. This longevity and robustness is viewed as a risk compared to more traditional configurations.

Implementation Timetable

This section presents an implementation timetable for prioritizing treatment for CWA and IWA wells.

CWA needs treatment at five wells (one well is planned for inactivation) to meet current system demands and to achieve Cr6 compliance. If Proposition 1 Grant funding is secured, phased implementation of treatment facilities is not necessary and the design and construction of all five treatment facilities can be completed in parallel bringing the facilities online in 2019. If phasing is needed, CWA can plan to achieve compliance for the existing wells on 5-year timetable:

- **Phase 1** (2015 to 2016) – Wells 12 and 18 allow for flexibility in operations for both CWA pressure zones as these wells fed reservoirs.
- **Phase 2** (2016 to 2018) - Wells 16 and 19. Well 16 is currently being upgraded to add a VFD and is planned to replace the capacity lost with inactivating Well 11. Well 19 is one of CWA's largest producing wells that is highly utilized.
- **Phase 3** (2018 to 2020) – Wells 17 and two new wells to meet future development demand.
- **Phase 4** (2020 to 2030) – 5 new wells to meet future development demand.

Project capital costs broken down by phase for CWA are summarized in **Figure 43**.

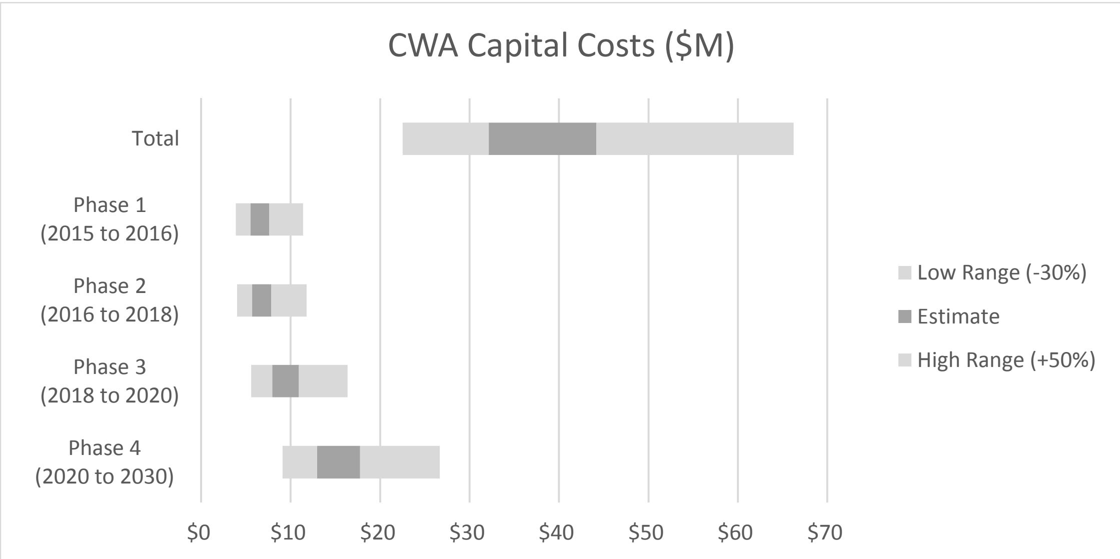

Figure 43. CWA Phased Project Costs

IWA has sufficient supply with the 7 Tier 2 wells and the 3 wells that currently have Cr6 treatment to stay in compliance and meet current demands. If desired to provide system redundancy and diversification, prepare for future water demand increases, or to maximize water to potential future emergency interconnections, IWA can begin preliminary design for additional Cr6 facilities in the following phases:

- **Phase 1 (2015)** – Plant 1 modifications to include blending with Well 1B to increase available supply without the need for additional treatment.
- **Phase 2 (2016 to 2018)** – Plant 1 (Wells 1E, BB) and Plant 13 (Wells 13A, 13B), and evaluate moving the existing treatment units to Wells W and U. Well BB provides flexibility with blending operations at Plant 1. Well W provides redundancy for Well T (currently online without treatment as a Tier 2 well). Well U increases the capacity available for potential future emergency interconnections.
- **Phase 3 (2018 to 2020)** – Plant 2, Plant 3, and Well Z. These wells provide system redundancy and the flexibility to meet increasing future demands.

Project capital costs broken down by phase for IWA are summarized in **Figure 44**.

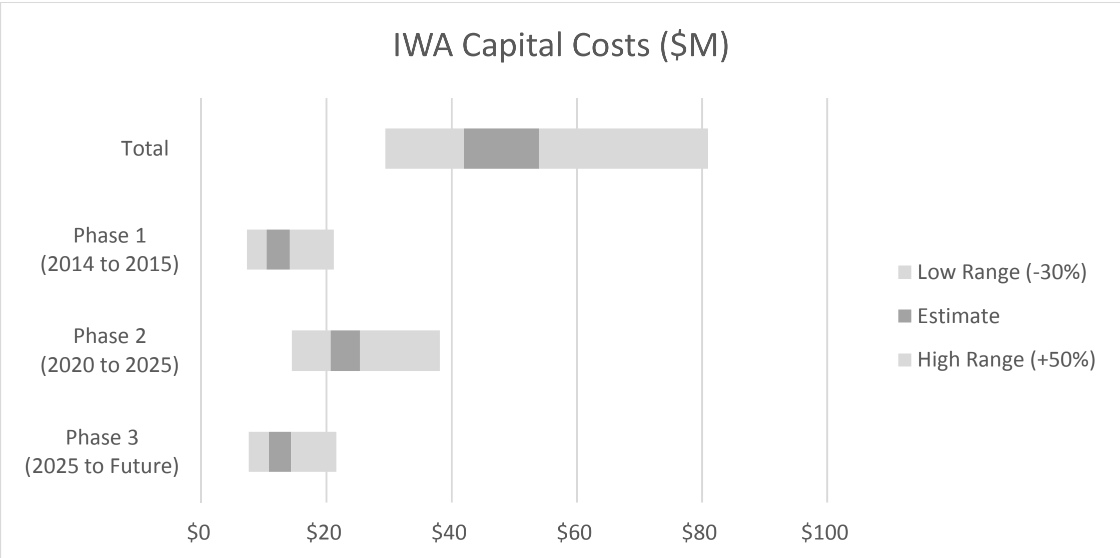

Figure 44. IWA Phased Project Costs

During Phase I and as part of the preliminary design process, CWA and IWA can:

- Make key planning decisions (e.g. additional assessment of the IWA/CWA emergency interconnections option)
- Begin the grant funding application process.
- Perform hydraulic modeling.
- Characterize brine composition and conduct pilot testing of brine treatment options.

Conclusions and Recommendations

9.1 Overall Study Findings and Recommendations

Technologies identified as feasible for CWA and IWA SBA, WBA, or RCMF with recycle of backwash water. RCF without recycle, RCMF without recycle, or RO create much more water loss during treatment (3% for RCF, 5% for RCMF, and 15-25% for RO) compared with ion exchange (<0.05%) and were not considered for this analysis.

SBA was estimated as the least costly Cr6 treatment technology for CWA and IWA wells on a lifecycle basis. Costs were similar across SBA options (i.e., containerized SBA or SBA with onsite brine treatment), with the wells with higher sulfate (and associated greater regeneration frequency), being most sensitive to the brine management assumptions.

With multiple options for implementing ion exchange including different SBA configurations and WBA, it is recommended as a next step that CWA and IWA consider preferences in system operational complexity, equipment longevity, and residuals waste generation, which were identified as the primary risks to the agencies in selection of a technology for long term operations. Details of each, and potential risks for different approaches, are provided in this report.

Emergency interconnections could be used to provide system redundancy and provide a reliable water supply in the event of an emergency or treatment system failure. Interconnections between IWA, CWA, and CVWD agencies should be considered. For the case of IWA/CWA system interconnections, six potential locations were identified by CWA and IWA. Currently, IWA has an estimated capacity of 42 MGD with Cr6 < 10.4 µg/L that could supply the IWA system and the IWA/CWA interconnections. The costs of installing emergency interconnections were not estimated as part of this Study.

9.2 Coachella Water Authority Findings

Current and Future Supply and Demands. With all existing wells utilized, CWA system capacity is 17.6 MGD (15.6 MGD is Well 11 is taken offline), relative to a current MDD of 12.9 MGD and a future MDD of 20.9 MGD. At 2,000 gpm per well, CWA will require 7 additional new wells to meet the anticipated future demand that is projected in the Water System Master Plan. Future wells could be sited in the vicinity of the Well 12 or Well 18 reservoirs to allow for potential benefits that might be achieved with blending and operational flexibility.

Treatment Approach. SBA was estimated as the least costly Cr6 treatment technology for CWA wells. Costs were similar across SBA options (i.e., containerized SBA or SBA with onsite brine treatment), with the wells with higher sulfate (and associated greater regeneration frequency), being most sensitive to the brine management assumptions. RCMF with recycle was not recommended over ion exchange due to the larger footprint, operational complexity, and capital costs.

With multiple options for implementing ion exchange including different SBA configurations, it is recommended as a next step that CWA consider preferences in system operational complexity, equipment longevity, and residuals waste generation, which were identified as the primary risks to the agencies in selection of a specific system confirmation for long term operations. Details of each, and potential risks for different approaches, are provided in this report.

Multiple options for clustering wells to blend or treat at common facilities were evaluated. Analysis showed that cost savings from treatment economies of scale were not sufficient to justify clustering of most wells. An example is provided that assessed clustering CWA's Wells 17 and 19 or IWA's Well U and CWA's Wells 17 and 19 together for treatment. Opportunities for clustering include clustering of future CWA wells.

Cost Estimates. Estimated treatment costs (accuracy range of -30% to 50%) for CWA wells are summarized in **Table 31**. A range of SBA options (including containerized SBA and SBA with onsite brine treatment) are presented. Cr6 treatment facilities for existing wells to meet current demands are estimated to cost approximately $14M to $19M (up to $29M given planning level cost range accuracy) in capital with annual system O&M costs ranging from $1.4M to $1.5M.

Implementation Timetable. CWA needs Cr6 treatment at five wells (one well is planned for inactivation) to meet current system demands and achieve Cr6 compliance. If Proposition 1 Grant funding is secured, phased implementation of treatment facilities is not necessary and the design and construction of all five treatment facilities might be completed in parallel, bringing facilities online in 2019. If phasing is needed, CWA could plan to achieve compliance for the existing wells on 5-year timetable:

- **Phase 1** (2015 to 2016) – Wells 12 and 18 allow for flexibility in operations for both CWA pressure zones as these wells feed reservoirs.
- **Phase 2** (2016 to 2018) - Wells 16 and 19. Well 16 is currently being upgrade to add a VFD and is planned to replace the capacity lost with inactivating Well 11. Well 19 is one of CWA's largest producing wells that is highly utilized.
- **Phase 3** (2018 to 2020) – Wells 17 and two new wells to meet future development demand.
- **Phase 4** (2020 to 2030) – 5 new wells to meet future development demand.

Next Steps. The next step is for CWA to use the analysis presented in this Study report to inform key planning decisions and to begin the grant funding application process. This Study report lays the groundwork for the Proposition 1 grant application process and by working with the State, a timeline for funding options can be established.

In parallel to exploring grant funding options, it is recommended that CWA move forward with preliminary design. During this process, design and cost assumptions can be refined. For example, a key component of the preliminary design is to assess the impact of Cr6 treatment on system hydraulics. It is recommended to perform hydraulic modeling to assess treatment system headloss impacts on well hydraulics, to confirm the impact of pipelines for clustered treatment facilities (for future CWA wells), and to further simulate the use of interconnections. It is also recommended that brine management options be further explored in advance of or as part of the preliminary design process.

It is recommended that CWA remain open to multiple SBA options, by having bid packages be prepared to allow for both containerized SBA and traditional SBA treatment approaches.

Table 31. Summary of Treatment Costs for CWA Cr6 Facilities

	CWA	
Demand		
Average Day Demand	20.9 MGD	
Max. Day Demand	35.6 MGD	
Active with Treatment – Tier 1 (Cr6 > 10.4 µg/L)		
Wells	12, 16, 17, 18, 19	
Well Capacity	15.6 MGD	
Treatment Capacity[1]	12.1 MGD	
Active with Treatment – Tier 2 (8 < Cr6 < 10.4 µg/L)		
Wells	-	
Well Capacity	-	
Treatment Capacity[2]	-	
Standby/Inactive		
Wells	11	
Well Capacity	2.02 MGD	
TOTAL Active Well Capacity (Cr6 < 10.4 µg/L)	15.6 MGD	
SBA Option	Containerized SBA	SBA with Onsite Brine Treatment
Total Project Capital Costs Point Estimate ($M)	$14M	$19M
Total Project Capital Costs Accuracy Range (-30% to +50%, $M)	$10M to $21M	$14M to $29M
Annual O&M Costs ($M/Year)	$1.4M	$1.5M
Annualized Costs ($M/Year)[2]	$2.2M to $3.1M	$2.6M to $3.8M
NPV ($M)[2]	$28M to $39M	$33M to $48M

Planning Level Cost Estimates consistent with AACE Class 5, with an accuracy range of -30% to +50%.
[1] Treatment capacity is less than well capacity because partial stream treatment can be implemented.
[2] Amortized over 20 years at a rate of 5%.

9.3 Indio Water Authority Findings

Current and Future Supply and Demands. With all existing wells utilized and Well 13B equipped, IWA system capacity is 77.5 MGD, relative to a current maximum day demand (MDD) of 28 MGD and a future MDD of 40.8 MGD.

Treatment Approach. Technologies identified as feasible for IWA included ion exchange (strong base anion exchange, SBA or weak base anion exchange, WBA) or reduction/coagulation/microfiltration (RCMF) with recycle of backwash water. RCF without recycle, RCMF without recycle, or reverse osmosis (RO) create much more water loss during treatment (3% for RCF, 5% for RCMF, and 15-25% for RO) compared with ion exchange (<0.05%). Details of each, and potential risks for different approaches, are provided in this report. As additional technologies are developed in the future, it would be beneficial to both agencies to evaluate any new applications of best available technologies as they become available on the market.

SBA was estimated as the least costly Cr6 treatment technology for IWA wells. Two IWA sites with higher sulfate concentrations were identified as potential candidates for WBA that may be a slightly higher cost, but offer IWA operational simplicity for these sites with more brine production. Additionally, this would provide treatment diversification in the system. Costs were similar across SBA options (i.e., containerized SBA or SBA with onsite brine treatment), with the wells with higher sulfate (and associated greater regeneration frequency), being most sensitive to the brine management assumptions. RCMF with recycle was not recommended over ion exchange due to the larger footprint, operational complexity, and capital costs.

With multiple options for implementing ion exchange including different SBA configurations and WBA, it is recommended as a next step that IWA consider preferences in system operational complexity, equipment longevity, and residuals waste generation, which were identified as the primary risks to the agencies in selection of a specific system confirmation for long term operations.

IWA recently installed three containerized SBA treatment systems for Cr6 treatment. In the near term, it is recommended that IWA keep the Containerized SBA treatment equipment at Well 1E and blend with 1B and 1C in the Plant 1 reservoir to increase system capacity. The 2400 gpm Containerized SBA units at Wells 1E and 13A could be moved to other individual well sites (U, W) to accommodate the design and construction of larger treatment facilities in the future (SBA or WBA), or supplemented with additional capacity (Containerized SBA).

Multiple options for clustering wells to blend or treat at common facilities were evaluated. Analysis showed that cost savings from treatment economies of scale were not sufficient to justify clustering of most wells. An example is provided that assessed clustering Well U and CWA's Wells 17 and 19 together for treatment. Opportunities for clustering to provide cost savings and operational flexibility include clustered treatment of Well BB and 1E at Plant 1 (blending the treated effluent with 1C and 1B in the Plant 1 reservoir.

Cost Estimates for IWA. Estimated treatment costs (accuracy range of -30% to 50%) for IWA wells are summarized in **Table 32**. For IWA's current facilities, including the three new Cr6 treatment facilities, are able to meet current system demand. Additional flexibility can be attained by blending Well 1B at Plant 1, and utilizing Well 1E treatment more. To meet future demands, costs of fully utilizing existing wells were estimated to be approximately $35 to $44M (up to $66M given planning level cost range accuracy) in capital with annual system O&M costs ranging from $2.9M to $3.1M. This cost is inclusive of all Cr6 facilities needed, including $7M spent in treating the three wells.

Implementation Timetable. IWA has sufficient supply using the 7 Tier 2 wells and the 3 wells that currently have Cr6 treatment to stay in compliance and meet current demands. If desired to provide system redundancy and diversification, prepare for future water demand increases, or to maximize water to potential future emergency interconnections, IWA can begin preliminary design for additional Cr6 Facilities in the following phases:

- Phase 1 (2015) – Plant 1 modifications to include blending with Well 1B to increase available supply without the need for additional treatment.
- Phase 2 (2016 to 2018) – Plant 1 (Wells 1E, BB) and Plant 13 (Wells 13A, 13B), and evaluate moving the existing treatment units to Wells W and U. Well BB provides flexibility with blending operations at Plant 1. Well W provides redundancy for Well T (currently online without treatment as a Tier 2 well). Well U increases the capacity available for potential future emergency interconnections.
- Phase 3 (2018 to 2020) – Plant 2, Plant 3, and Well Z. These wells provide system redundancy and the flexibility to meet increasing future demands.

Next Steps for IWA. The next step is for IWA to use the analysis presented in this Study report to inform key planning decisions and to begin the grant funding application process. This Study report lays the groundwork for the Proposition 1 grant application process and by working with the State, a timeline for funding options can be established. It is also recommended that brine management options be further explored. IWA has three active Cr6 treatment facilities that present the opportunity to characterize brine composition, to conduct pilot testing of various brine treatment techniques, and to explore further various hazardous and non-hazardous disposal options that may be available.

It is recommended that IWA remain open to multiple SBA options, by having future bid packages be prepared to allow for both containerized SBA and traditional SBA treatment approaches. As the cost of treatment at wells with higher sulfate (and associated greater regeneration frequency) are most sensitive to the brine management assumptions, it is also recommended that WBA vendors be invited to bid at these higher sulfate sites (i.e. Plant 1 and Plant 13) so that the most economical and operationally preferable solution can be implemented for the long-term.

Table 32. Summary of Treatment Costs for IWA Cr6 Facilities

	IWA	
Demand		
Average Day Demand	27.2 MGD	
Max. Day Demand	40.8 MGD	
Active with Treatment – Tier 1 (Cr6 > 10.4 µg/L)		
Wells	Plant 1 (treat 1E, BB blend with 1B, 1C), Plant 2 (2C, 2D), Plant 3 (3A, 3B, 3C), Plant 13 (13A, 13B), AA, U, W, Z	
Well Capacity	52.3 MGD	
Treatment Capacity[1]	35.0 MGD	
Active with Treatment – Tier 2 (8 < Cr6 < 10.4 µg/L)		
Wells	1C, 4A, 4B, 4C, S, T, V	
Well Capacity	25.2 MGD	
Treatment Capacity[1]	12.4 MGD	
Standby/Inactive		
Wells	-	
Well Capacity	-	
TOTAL Active Well Capacity (Cr6 < 10.4 µg/L)	77.5	
SBA Option	Containerized SBA	SBA with Onsite Brine Treatment
Total Project Capital Costs Point Estimate ($M)	$35M	$44M
Total Project Capital Costs Accuracy Range (-30% to +50%, $M)	$25M to $52M	$31M to $66M
Annual O&M Costs ($M/Year)	$3.1M	$2.9M
Annualized Costs ($M/Year)[2]	$5.1M to $7.3M	$5.4M to $8.2M
NPV ($M)[2]	$64M to $91M	$67M to $102M

Planning Level Cost Estimates consistent with AACE Class 5, with an accuracy range of -30% to +50%.
[1] Treatment capacity is less than well capacity because partial stream treatment can be implemented.
[2] Amortized over 20 years at a rate of 5%.

Appendix A: Evaluation of Cr6 Treatment Alternatives for Wells 13A, AA and 1E

HAZEN AND SAWYER
Environmental Engineers & Scientists

Project Number: 20038-000

HAZEN AND SAWYER
Environmental Engineers & Scientists

Indio Water Authority
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Evaluation of Cr6 Treatment Alternatives for Wells 13A, AA and 1E

Introduction

Indio Water Authority (IWA) owns and operates 20 groundwater wells with a total pumping capacity of approximately 72 million gallons per day (MGD). Seven of the 20 wells are currently in operation (24.8 MGD pumping capacity). The other 13 wells have been placed in standby mode because they produce water exceeding the State of California hexavalent chromium (Cr6) maximum contaminant level (MCL) of 10 micrograms per liter (µg/L). IWA is conducting a Cr6 Treatment and Compliance Study that assesses treatment technologies and narrows system-wide compliance options. Prior to the completion of the Compliance Study, IWA Staff identified three wells, 1E, AA, and 13A that with treatment could meet the Cr6 MCL and produce sufficient water to enable IWA to meet peak summer water demands. To meet summer water demands, treatment systems for these three wells would need to designed, permitted, installed and operational by June 1, 2015. IWA contracted Hazen and Sawyer to perform a separate evaluation of treatment options for these three priority wells to identify the cost and schedule implications.

This evaluation focused on the following priorities identified by IWA:

1. **Cr6 Goal**: Ability to meet the Cr6 treatment goal
2. **Schedule:** Availability to have the treatment system installed, permitted and operating by June 1, 2015
3. **Cost:** Primarily capital costs, although operating costs and lifecycle costs were also requested from vendors
4. **Investment**: Treatment on 3 wells with the potential to move the system to other wells for more strategic long-term O&M savings without stranding assets

Hazen and Sawyer contacted vendors for information regarding their Cr6 treatment systems. Some operating cost assumptions are included; however, due to the expedited time frame available to develop this evaluation, lifecycle costs could not be fully vetted for this deliverable. Some of the manufacturers provided non-guaranteed performance estimates based on background water quality, treated flow rate and utilization rate, and some did not provide any; therefore a comparative life cycle analysis could not be provided.

The findings of this evaluation will inform IWA in deciding how to move forward with a fast track approach for addressing these three wells. Initially a design-build (DB) approach was discussed as the delivery approach best suited to meet the June 1 deadline. Since the initial draft of this memorandum, other delivery methods such as a design-bid-build (DBB) approach are now being discussed due to IWA's charter. The ability to deliver these projects using DBB within the needed timeframe is uncertain. Depending on the delivery approach, IWA also requested that an extended timeline of July 1, 2015 be considered.

Existing System

This section discusses the current hydraulic configuration, production trends, and water quality information available for Wells 1E, AA, and 13A that affect the treatment analysis.

Well Configuration

IWA owns and operates 20 groundwater wells with a total pumping capacity of approximately 72 MGD. Eleven of these groundwater wells pump water to above-ground storage reservoirs at four separate production plants. Each production plant has a storage reservoir, booster pumping station, disinfection equipment and, a hydropneumatic tank to maintain system pressure when the pumps are off, and assist in pump transitioning as they turn on/off. The wells that supply these plants are controlled by water levels in three ground storage reservoirs. The remaining wells supply water directly into the distribution system and are controlled by pressure set points and variable frequency drives.

Wells 1E, 1C, and 1B are all located within a 1,000 ft radius of Plant 1's 5MG reservoir, where the flows they produce are combined in a 24-inch diameter inlet header. The flows combine in the reservoir and get re-pumped with the booster pumping station on-site. Well 1B is currently in standby mode as the Cr6 concentration is 15 µg/L. Well 1C is currently in operation (Cr6 concentration is less than 10 µg/L). In the future, Cr6 treatment at Plant 1 for all three wells and a treatment/blending plan for the three wells that optimizes treatment costs. Currently, each well is sampled individually prior to entering the reservoir to determine source compliance. The point of entry to the distribution system is located at the Plant 1 booster pumping station. IWA should confirm with DDW that with Cr6 treatment, the compliance point will be at this location.

Table 1 lists the well pump specifications for Plant 1 wells based on recent wire-to-water efficiency tests conducted at the site. These flows represent a scenario with all wells operating at once. Between 5 to 10 percent more flow can be achieved from each well if operated without the other wells contributing to headloss in the combined manifold/pipe lines. Revised well pump hydraulics were calculated using the existing WaterCAD model (discussed further below).

Table 1. Plant 1 Well Specifications (Operating Simultaneously – Existing Conditions)

Well Site VT Pump	HP	Flow (gpm)	TDH (ft)	VFD / Constant Speed (CS)	Cr6 (µg/L)
1E[1]	250	3200	200	CS	18
1C[2]	100	1150	110	CS	9.5
1B[3]	100	1900	115	CS	15

[1]Evaluated for Cr6 treatment under this scope.
[2]Will blend with treated water from 1E in the Plant 1 Reservoir.
[3]Will be left in standby until future permanent treatment is installed at Plant 1.

Well AA pumps water directly to the distribution system after chlorination. The pump motor operates on a VFD and ramps up and down to satisfy system demand while maintaining system pressure. **Table 2** lists the well pump hydraulic criteria for Well AA based upon recent wire-to-water efficiency tests conducted at the site. Revised well pump hydraulics were calculated using the existing WaterCAD model (discussed further below).

Table 2. Well AA Specifications (Existing Conditions)

Well Site VT Pump	HP	Flow (gpm)	TDH (ft)	VFD / Constant Speed (CS)	Cr6 (µg/L)
AA[1]	400	3220	340	VFD	18

[1]Evaluated for Cr6 treatment under this scope.

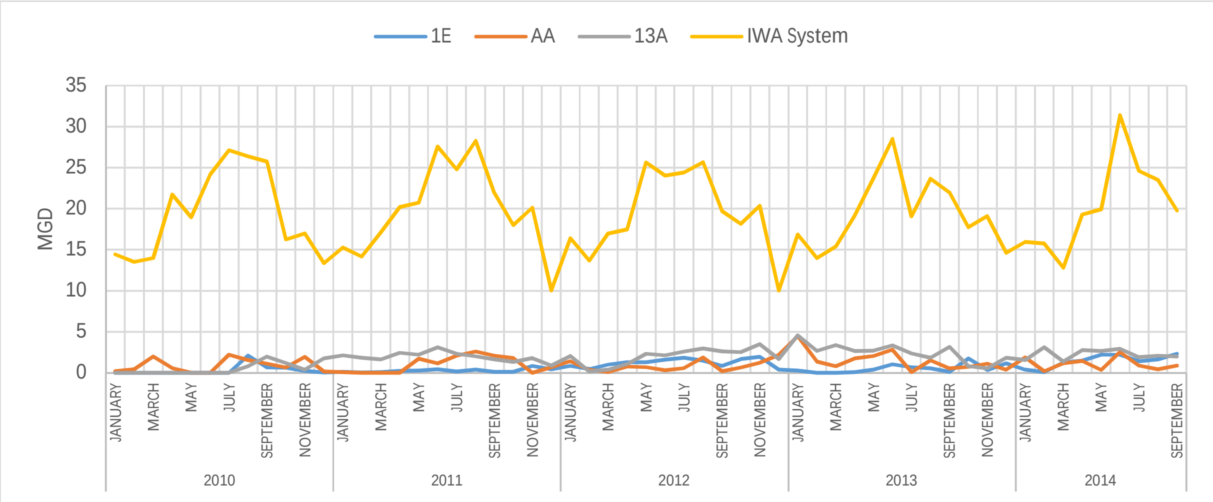
Well 13A pumps water directly to the distribution system after chlorination. The pump operates on a VFD and ramps up and down to satisfy system demand while maintaining system pressure. There are future plans to equip Well 13B located on the corner of Monroe Street and Avenue 41, which is within an 800-ft radius of Well 13A. This well site or an alternative vacant site on the corner of Avenue 40 and Monroe could serve as a future treatment plant location for both wells 13A and 13B; however there is no existing power supply at the Well 13B site and the 40th and Monroe Site only has 220V, single phase residential power. This will be further evaluated during design and could become the preferred treatment plant location for Well 13A (now) and Well 13B (future). **Table 3** lists the well pump specifications for Well 13A based upon recent wire-to-water efficiency tests conducted at the site. Revised well pump hydraulics were calculated using the existing WaterCAD model (discussed further below).

Table 3. Well 13A Specifications

Well Site VT Pump	HP	Flow (gpm)	TDH (ft)	VFD / Constant Speed (CS)	Cr6 (µg/L)
13A[1]	400	3220	340	VFD	14

Historical Production Trends

Production records were reviewed to evaluate well operations trends and understand system hydraulics. Based on monthly production data from each well from 2010 to 2014, average monthly summer demand for the IWA system has ranged from approximately 19.0 to 31.4 MGD in the months May to September (**Figure 1**). **Table 4** summarizes the projected monthly summer demand. With the seven wells currently in operation (Wells 1C, 4A, 4B, 4C, S, T, V), IWA has 24.8 MGD of production capacity. After treatment is installed at Wells 1E, AA, and 13A and they are put back in service, production capacity will increase to 35.2 mgd (based on 2400 gpm production initially) and later 38.7 MGD (based on 3200 gpm) as summarized in **Table 5**. Actual well production will be less than 3200 gpm once treatment system headloss is accounted for if an additional bowl is not added to the well pump to overcome the treatment system headloss (discussed further below). Given that IWA has not operated under this scenario before, it is recommended that IWA run this scenario in an updated version of the hydraulic model to confirm that demands can be met throughout the system.



Notes: MGD based on monthly total gallons produced.

Figure 1. Historical Well Operations (in MGD) for Wells 1E, AA, 13A, and IWA System

Table 4. Projected IWA Summer Demands in MGD

Monthly Demand	Average Daily Demand (ADD)	Maximum Daily Demand (MDD = 1.3*ADD)	Peak Hourly Demand (PHD = 2.3*ADD)
May	21.8	28.3	50.2
June	27.1	35.3	62.4
July	24.0	31.2	55.2
August	25.5	33.1	58.6
September	21.8	28.4	50.2

Table 5. Available Well Capacity in MGD

Well Pumping Capacity	With 2400 gpm from Wells 1E, AA, and 13A[1]	With 3200 gpm from Wells 1E, AA, and 13A[2]
Current 7 Wells[3]	24.8	24.8
Well 1E	3.46	4.61
Well AA	3.46	4.61
Well 13A	3.46	4.61
Total	**35.2**	**38.6**

[1]2400 gpm from each Wells 1E, AA, and 13A with no bypass. This treatment scenario may be used initially to achieve lower finished Cr6 concentrations and keep the RAA less than 10 µg/L.

[2]Total of 3200 gpm from each Wells 1E, AA, and 13A with 2400 gpm treatment plus 800 gpm bypass. This treatment scenario would be used long-term.

[3]Sum of Wells 1C, 4A, 4B, 4C, S, T, V

Historical Water Quality

A review of historical water quality information was performed to define treatment requirements, select applicable treatment technologies, and evaluate parameters that affect the operational costs. To account for variability and provide a level of conservatism in the design, an industry standard practice of using the 90th percentile was applied (**Table 6**).

Table 6. 90th Percentile Historical Water Quality Summary for Wells 1E, AA, and 13A

Parameter	Units	Well 1E	Well AA	Well 13A
Cr6	µg/L	18.0	18.0	14.0
Total Cr	µg/L	18.0	17.6	15.2
Alkalinity	mg/L CaCO3	93	112	92.2
Calcium	mg/L	55	70	70
Chloride	mg/L	8.9	8.8	16.0
Hardness	mg/L CaCO3	73	91	93
Fluoride	mg/L	0.70	0.65	0.97
Molybdenum	µg/L	-	14	21
Nitrate	mg/L NO3	2.1	3.7	1.7
pH	s.u.	8.2	8.2	8.2
Sulfate	mg/L	42	24	96
Strontium	µg/L	333	301	371
TDS	mg/L	200	192	300
Uranium	µg/L	6.9	7.0	6.3
Vanadium	µg/L	23	20	19

Table 7 presents a summary of Cr6 samples that were collected from the wells in the third and fourth quarters of 2014 prior to placing the wells in standby mode. The RAA requirement means that the average of four consecutive quarterly samples must be less than 10 µg/L for each well individually. Thus since there are two quarters results approaching 20 µg/l at each site, the next two quarters' results need to approach zero to provide a four-quarter average less than 10 µg/L. Based on these results and IWA's intention to bring these wells back online by June or July 2015, the projected treatment requirements to keep the RAA below 10 µg/L are also shown. In the fourth quarter of 2015 and beyond, treatment requirements for Cr6 may increase to 8 µg/L as the initial quarters that were above 10 µg/L will no longer impact the RAA calculation.

Table 7. Quarterly Averaged Cr6 data (in µg/L) for Wells 1E, AA, and 13A

Well	IWA Sampling Results			*Projected Treatment Requirements*			*RAA*
	2014	2014	2015	*2015*	*2015*	*Beyond*	
	Q3	Q4	Q1	*Q2*	*Q3*		
1E	16.8	17.9	Standby	*<2*	*<2*	*<8*	*<10*
AA	14.3	14.8	Standby	*<5*	*<5*	*<8*	*<10*
13A	13.8	13.9	Standby	*<6*	*<6*	*<8*	*<10*

Treatment Evaluation

This section discusses applicable Cr6 treatment technologies, the concept of how they could be applied to each well, and how they were assessed for application at Wells 1E, AA, and 13A with respect to implementation, schedule, and cost.

Cr6 Treatment Technologies Considered

Treatment technologies available for the removal of Cr6 include weak base anion exchange (WBA), strong base anion exchange (SBA), reduction coagulation filtration/microfiltration (RCF/RCMF), reverse osmosis (RO), Biological treatment, and adsorptive media. Given the rapid implementation timeline for this project, only proven best available technologies (BAT) were considered, including WBA, SBA, RCF/RCMF, and RO. Biological treatment and adsorptive media are not sufficiently well-proven in practice and thus were eliminated from this evaluation. Due to the availability of technology and sewer system limitations that can be ready to be deployed in the time frame required for this project, RO and RCF/RCMF were also eliminated. The evaluation focused on the application of WBA and SBA (more details presented in **Appendix A**).

Weak Base Anion Exchange (WBA)

A typical WBA process includes bag filters to remove particles to minimize pressure drop in the resin bed, pH adjustment with CO_2 to lower pH from 8.2 to 6.0, multiple ion exchange vessels in lead-lag configuration, and aeration (or membrane de-gassing) to raise the pH so that the treated water quality is not corrosive. Select WBA resins have a much greater Cr6 capacity than SBA resins. For example, WBA resins may last for more than one year between replacements while SBA resins typically need to be regenerated every few weeks. WBA residuals include spent resin, flush water generated at resin replacement and potentially backwash wastewater (although backwash is not expected unless the well is a sand/silt producer). Spent resin is expected to be a non-RCRA hazardous waste due to a high chromium concentration above the California Total Threshold Limit Concentration (TTLC), as experienced at the Glendale, CA Cr6 treatment facility making it a non-RCRA hazardous waste. Due to the removal and concentration of naturally-occurring uranium from the source water, the waste is likely to be a technologically enhanced naturally occurring radioactive material (TENORM) waste and may be a low level radioactive waste (LLRW) requiring special disposal. Wastewater (either flushing water during installation or backwash waste) is expected to be non-hazardous, which can be discharged to a sewer, blow off location, or trucked offsite without treatment.

Strong Base Anion Exchange (SBA)

A typical SBA process includes bag filters to minimize pressure drop in the resin bed and multiple SBA resin vessels operated in parallel. Cr6 in the treated water (i.e. the resin vessel effluent) gradually increases over time as the resin capacity for Cr6 is filled. When treated Cr6 concentration reaches the treatment target level, the resin needs to be regenerated or replaced.

SBA resin is typically regenerated using a 10% to 13% salt (brine) solution. During regeneration, Cr6 is eluted off of the resin into the brine, and the resin's Cr6 capacity is restored. Residuals include spent brine and rinse wastewater. Spent brine disposal is often the greatest challenge for SBA applications due to its high chromium and TDS concentrations. Brine is hazardous waste in California unless chromium (and possibly other constituents) are precipitated, in which case the brine can become non-hazardous, and the precipitated solids become hazardous.

Instead of regeneration, the SBA process can be operated as a single-pass media. This approach calls for disposal of the resin once treated Cr6 reaches the target level.

SBA Brine Management

Residuals management is a critical part of Cr6 treatment by SBA. Spent brine can be either disposed as a non-RCRA hazardous waste at a high price or can be treated to remove Cr6 before disposal. IWA has two options for SBA brine treatment: (1) on-site treatment at individual well sites or (2) off-site treatment through a service contract. On-site brine treatment requires additional equipment including ferrous sulfate (or equivalent) and polymer chemical storage and feed systems, a gravity thickener, filter press, and waste storage tank. Alternatively, off-site brine treatment could be accomplished through a vendor service contract who will be responsible for hauling, treatment, and ultimate recycle or disposal of the brine and waste products. In the future, a regional opportunity may exist whereby IWA could develop a cooperative project with the Coachella Valley Water District (CVWD) to perform the regeneration of SBA resin and/or dispose of the brine.

Treatment Concept and Assessment Approach

In this fast track approach, treatment would be located at individual well sites AA and 13A, as well as Plant 1 for Well 1E. Due to the tight schedule constraints (i.e. 15 weeks for design, construction, and commissioning), the evaluation was kept open to allow multiple treatment technologies and delivery approaches to be proposed:

- **WBA or SBA** – Initial evaluation and conceptual planning-level cost estimates in the compliance study confirmed that both WBA and SBA are viable treatment options on a lifecycle basis. For example, the elevated sulfate levels at Well 13A will result in frequent SBA regenerations that make WBA attractive with respect to cost and operations; however, the location of Well 13A limits truck accessibility and warrants evaluation of both approaches. Also, multiple options for implementing SBA were considered including operating SBA in single pass mode versus SBA with onsite regeneration, and options for both onsite and offsite SBA spent brine treatment.
- **Temporary or Permanent Installations** – Based on equipment availability, a packaged containerized approach may be an attractive option to meet the short-term schedule while allowing time for more permanent facilities to be designed and constructed. This also allows for the containerized units to be moved to other locations in the future.
- **Lease, Lease-to-Own, or Purchase Options** - Initial cost projections may impact IWA's ability to finance this rapid project, therefore various financing options were requested.
- **IWA or Contract Operations** – Operations are critical for effective treatment and ultimately compliance. Operator training that is conducted in parallel with commissioning will be crucial to successful implementation of any new treatment facility. Obtaining an operations service agreement would keep the responsibility in the hands of a third party during initial operations, allowing IWA time to bring operators up to speed.

Information was then compiled to assess four options as summarized in **Table 8**.

Table 8. Treatment Options for Fast Track Installation on Three Wells

	Well 1E	Well AA	Well 13A
Option 1	Single Pass SBA	Single Pass SBA	WBA
Option 2	WBA	WBA	WBA
Option 3	SBA (onsite regen)	SBA (onsite regen)	SBA (onsite regen)
Option 4	Leased Single Pass SBA	Leased Single Pass SBA	Leased Single Pass SBA

Assessment Steps

The following steps were used:

(1) Define project scope for vendors.
(2) Identify vendors and request information.
(3) Evaluate civil, mechanical, electrical, and I&C components associated with the vendor information received to estimate costs for the site improvements that IWA would be responsible for.
(4) Develop a cost summary including capital, O&M, and lifecycle costs for various proposed options.
(5) Compare options using a qualitative comparison matrix.
(6) Identify fatal flaws for ability to meet schedule, and discuss risk.

The following vendors of treatment systems were provided with a brief project background, water quality information, site aerials, and well production and utilization information: IONEX, Envirogen, Wigen, Hungerford and Terry, and EVOQUA. Partial stream treatment with a bypass and blend approach was recommended to reduce the size of required equipment and the associated capital investment. To streamline the cost evaluation, 2400 gpm treatment systems were requested for all three wells. Initially, to meet the Cr6 goals defined in **Table 7**, the systems will be operated without the bypass for six months and will produce 2400 gpm. Long-term, the partial treatment and bypass approach will provide up to 3200 gpm. An annual average well utilization of 30 percent was used for requesting life-cycle costs, although 100 percent was also requested to evaluate summer operational conditions (regeneration frequency, trucking requirements, etc.). Unfortunately, due to the lack of comparative O&M costs from the various vendors, lifecycle costs could not be fully vetted.

To develop conceptual cost estimates and preliminary site layouts the following information was requested from all vendors:

1. Footprint
    a. Each well site has limited footprint for a treatment system that can utilize nearby power.
    b. Preliminary site layouts based on information received show that each of the SBA options can fit onto the three sites.
2. Support equipment required for respective system
    a. Vendors provided variation in addressing waste products and disposal:
        i. IONEX – recycling of brine and rinse water, return of initial regeneration component to treated water (subject to DDW approval), off-site transport and disposal of Cr6 hazardous brine.
        ii. Envirogen – on site treatment of brine, off-site transport and disposal of non-hazardous brine.
        iii. Wigen – did not include brine recycling or treatment components.
        iv. Hungerford and Terry – did not submit a proposal.
        v. EVOQUA- WBA resin does not require regeneration.
3. Headloss across the system
    a. Based on initial quotations, SBA systems appear to have similar headloss curves (15-21 psi at 2400 gpm). WBA was conservatively estimated at 40 psi based on vendor responses.
4. Electrical requirements and ease of I&C integration with site
    a. The service entrance to the site and existing electrical infrastructure must be able to accommodate the well pump motor upgrades, plus any additional equipment loads like HVAC, system controls and miscellaneous pumps. Additionally, the existing site I&C and SCADA system must be able to seamlessly communicate with the treatment system and report status alarms back to operations staff. It appears that the service entrance at each site is sufficiently sized to accommodate well upgrades and support equipment loads and SCADA integration.
    b. The different vendors provided variation in the amount of information the electrical requirements for their systems, as summarized below:

i. IONEX – Uses a different control system than currently employed at the well sites however integration is possible.
ii. Envirogen – Not addressed in proposal.
iii. Wigen – Not addressed in proposal.
iv. Hungerford and Terry – Did not submit a proposal.
v. EVOQUA - Not addressed in proposal.

5. Availability of equipment and delivery schedule
   a. Ability to meet IWA's June 1 deadline for operations was evaluated. The vendors responded with the following information:
      i. IONEX – Can meet June 1, 2015 deadline.
      ii. Envirogen – Can meet June 1, 2015 deadline.
      iii. Wigen – Cannot meet June 1, 2015 deadline.
      iv. Hungerford and Terry – – Did not submit a proposal.
      v. EVOQUA - Cannot meet June 1, 2015 deadline (based on proposal language).

Standard operating agreements and projected O&M lifecycle costs were requested from the vendors, but have not yet been received from all the vendors. Significant variation may be observed between vendors and comprise a large portion of the life cycle costs. We recommend evaluating these costs in detail if information is received, as the lowest cost capital option may not result in the lowest life cycle cost.

Table 9 summarizes the vendors identified and contacted for this effort.

Table 9. Treatment System Manufacturers Contacted

Vendor	Contact	Proposed Technologies	Proposed Waste Residuals Management	Containerized / Skid Mounted	Financing Options	Operations Service Agreement
IONEX	Phil Chandler +44 (0)7502 228868 phil.chandler@ionexsg.co.uk	SBA with On-Site Regeneration	Offsite Brine Treatment	Containerized	Lease, Lease-to-own, Purchase	Available
Envirogen	Heidy Arriola 626.864.8617 harriola@envirogen.com	SBA with On-Site Regeneration	Onsite Brine Treatment	Containerized	Lease-to-own, Purchase	Available
Wigen	Mike Bourke P: (303) 350-3086 michael.bourke@wigen.com	SBA with On-Site Regeneration	Offsite Brine Treatment	Skid Mounted	Lease-to-own, Purchase	
Hungerford and Terry	Frank J. Caligiuri (856) 881-3200 (Ext. 270) fcaligiuri@hungerfordterry.com	Asked for extension until 1/27/15, no response received.				
EVOQUA	Cathy Swanson 562-217-0419 catherine.e.swanson@evoqua.com	WBA with CO2 pH Depression and Membrane Degas for pH up	Resin Replacement at 250k BVs	Skid Mounted	Lease, Lease-to-own, Purchase	Available

Conceptual Cost Estimates

The total capital cost estimate is broken into two categories:

1) Treatment Technology Costs - The treatment technology costs for bulk water Cr6 treatment. These costs are presented in the various proposals and disseminated in the sections below.
2) Site Preparation Costs - The site upgrade costs needed to accommodate Cr6 treatment at the site. These costs were exclusions in some of the vendor proposals and are in addition to the cost identified in the individual proposals from the various treatment technology manufacturers.

Treatment Technology Proposal Breakdown

Hazen & Sawyer provided the individual well site raw water quality, flow rate, utilization rate and standard request (as described above) to the manufacturers to address in their proposals. It was Hazen & Sawyer's intent to use this information to compare equivalently among the various manufacturers so that Options 1-4 can be compared. Unfortunately, due to the expedited nature of the request, complete O&M or lifecycle costs were not received in time for this analysis (discussed further below).

Quotations were received from the following manufacturers:

IONEX

The IONEX system is a containerized SBA Cr6 treatment technology that employs on-site salt brine regeneration. The regeneration frequency depends on the site system flow rate, utilization and water quality. IONEX uses a system to significantly reduce the volume of Cr6-laden spent brine through the use of segmented regeneration. IONEX estimates that the waste rate of its system is 0.004% to 0.006% of the treated water flow. The other portion of the spent brine, consisting primarily containing NaCl, is recycled for various feedstocks in the brining unit process, thereby significantly reducing the amount of fresh brine required for subsequent regenerations. Further, IONEX proposes to recycle the rinse water for removal of sulfate and bicarbonate from the resin, then slowly add this waste into the treated water stream in a diluted manner so as not to affect the quality of the treated water. This component has been approved for IONEX systems in CA that treat for nitrate, and according to IONEX, is close to getting approval for Cr6 treatment systems.

The major components of the IONEX system are:

- Two, parallel 50 um bag filters rated for 2400 gpm each used to prevent suspended solids from accumulating on the resin bed and eliminating the need for backwashing (note this differs from other applications)
- 10 ton briner unit
- 4400 gallon double walled waste tank
- Three IX units with 4 pressure vessels each
- Master regen unit with spent brine sequestering process
- Interconnecting piping, valves and controls
- 630 cf of anionic resin per site

EVOQUA

For Option 3 (a purchased system) EVOQUA provided a quotation for WBA Cr6 treatment that uses pH adjustment with carbon dioxide to depress the pH from approximately 8.2 to 6 so it can achieve long resin life. Once exhausted, the resin is disposed of off-site in a permitted location and new resin is added to the system. On the tail end of the system, a carbon dioxide degassing membrane is used to strip the carbon dioxide from the treated water in an effort to raise the pH back to ambient levels (note this may require demonstration or alternatively an aeration tower can be used). The higher headloss of 6 psi associated with the de-gassing membrane is a trade-off from breaking head in an air stripping tower that requires additional blowers/exhaust fans and re-pumping with new booster pumps.

The replacement frequency depends on the site system flow rate, utilization and water quality. The major components of the EVOQUA WBA system are:

- 5 um bag filters used to prevent suspended solids from accumulating on the resin bed and eliminating the need for backwashing
- 30 ton carbon dioxide dosing unit
- Three lead and three lag vessels each with 420 cf of resin; for a total of 2520 cf per site
- Carbon dioxide stripping membrane
- Interconnecting piping, valves – no automation

For Option 4 (a leased SBA system) EVOQUA provided a quotation for Single Pass SBA treatment. In this option, spent SBA resin would be stored until future regeneration facilities are constructed. The regenerated resin could be used at future SBA facilities. This system would include the following components:

- Two, HP1220SYS systems that include two 12-ft diameter steel vessels operated in parallel and initial loading of resin

In their initial proposal EVOQUA indicated that based on standard delivery time the facilities could not be installed by June 1. EVOQUA has since indicated that the standard delivery time frame in their original proposal could be expedited with the following stipulations:

1. Start working on terms and conditions.
2. Order standard vessels – reduce customization in the final order.
3. Make submittals as "for information only" and skip a formal review process.
4. A letter of intent from the client could speed the process while other paperwork was being finalized.
5. Rush orders could be placed on long lead items, which could cost a little more.

ENVIROGEN

The ENVIROGEN system is a containerized SBA Cr6 treatment technology that employs on-site salt brine regeneration and spent brine treatment with the use of ferric chloride precipitation. The regeneration frequency depends on the site system flow rate, utilization and water quality. It is uncertain if portions of the non-Cr6 laden spent brine, primarily containing NaCl, is recycled for various feedstocks in the brining unit process. Recycling portions of the brine can in some systems significantly reduce the amount of new brine required for subsequent regenerations.

The major components of the ENVIROGEN system are:

- Two , parallel 5 um bag filters rated for 2400 gpm each used to prevent suspended solids from accumulating on the resin bed and eliminating the need of backwashing
- 10 ton briner unit with two brine pump units
- A waste tank sized for a 2 week capacity
- Two IX containerized units with 16 pressure vessels each
- Master regen unit with spent brine recovery and treatment process referred to as Brine Processing Unit (BPU)
- Interconnecting piping, valves and controls
- The volume of resin was not revealed

WIGEN

WIGEN did not submit a quote catered to the IWA sites, but rather a previously quoted submittal for a 2000 gpm SBA unit for California Water Service Company. WIGEN directed us to add 5% to the cost of the California Water proposal to account for the IWA sites. Due to the lack of site specific scoping involved in this proposal, we focused on the quotations from other manufacturers.

Technology Cost Comparison

A comparison of the equipment costs quotations received is summarized in Appendix B. In general, SBA equipment costs were less than WBA equipment costs, due in part to SBA vendors proposing a containerized treatment approach with smaller fiberglass pressure vessels. Detailed operating costs were not received for all technologies. The operating costs that were received varied based on vendor assumptions of regeneration frequency and waste disposal costs and therefore were not directly comparable without understanding the assumptions used (which were not provided in full). Additionally, the costs provided were based on consumables and not inclusive of all the other components necessary for operating a treatment facility. These other operating costs must also be estimated to evaluate a lifecycle cost and can be included as part of the bid process so that options can be compared. **Table 10** presents a summary of the cost components that should be included in a lifecycle cost analysis when comparing SBA and WBA. The table presents general SBA and WBA examples based on previous Hazen and Sawyer designs, as well as a comparison to the IONEX quotation received. IONEX was used as the example in the comparison as they provided the most information on the basis of their operating cost assumptions.

Waste generation and disposal significantly impact the O&M cost and are arguably are the most important factors when evaluating lifecycle costs and long-term project risks and disposal costs specific to IWA should be determined prior to final treatment selection.

Note: A BV is an acronym for bed volume which is a way to represent the life of the resin in relation to the volume of resin used. It is a unitless number that is the total treated water volume passed through the column until 2 ug/L (in this case) is reached divided by the volume of resin in the column.

Table 10. O&M Components to be included in Lifecycle Cost Evaluation

Item	General SBA Example (with onsite brine treatment)	Containerized SBA Example based on IONEX Quote (without onsite brine treatment)	General WBA Example
Waste Generation/ Disposal			
Regeneration Frequency	Estimated based on well water quality and presence of competing constituents (i.e. sulfate) 1E- 5,900 BVs AA- 10,300 BVs 13A - 2,600 BVs	Theoretical loading estimated by IONEX[1] 1E- 18,000 BVs AA- 22,000 BVs 13A - 10,000 BVs	No regeneration required, estimated life at 360,000 BVs based on nearby pilot testing.
Backwash and Rinse Water Volume and Disposal	Backwash and fast rinse water disposal (sewer or trucking fees)	No Backwash. Rinse water is recycled and bled into the finished water (pending DDW approval)	Backwash during initial install, no backwash or rinse thereafter
Hazardous Brine Volume and Disposal	None, on-site treatment included	Trucking and disposal cost or on-site treatment	n/a
Non-Hazardous Brine Volume and Disposal	Cost of trucking and disposal after on-site brine treatment	n/a	n/a

Item	General SBA Example (with onsite brine treatment)	Containerized SBA Example based on IONEX Quote (without onsite brine treatment)	General WBA Example
Non-RCRA Hazardous Solids Disposal	Disposal costs of solids after on-site brine treatment	n/a	n/a
Chemicals			
CO_2	n/a	n/a	Required CO_2 dose to reduce the pH to 6.0 (estimated at 170 to 210 mg/L for IWA wells).
Salt	Pounds consumed based on 12% solution and regeneration frequency	Pounds consumed based 12% solution and regeneration frequency	n/a
Brine Treatment	Metals precipitation using ferric/ferrous and polymer to separate hazardous metals from non-hazardous brine.	n/a	n/a
Consumables			
Bag Filters	6 x year 5 µm	1x year 50 µm	6 x year 5 µm
Resin	Purolite S106 Estimated life – 4 years	Purolite S106 Estimated life – 7 years	ResinTech SIR-700 Estimated life – 2 year
Electricity[2]	15 psi headloss through treatment system, blowers for brine treatment unit aeration	21 psi through treatment system	80 psi to boost to system after aeration, blowers for raising pH in aeration step[3]
Analytical	Annual compliance and operational field and lab samples for finished water and brine	Not included	Annual compliance and operational field and lab samples for finished water
Labor			
# of Full-Time Equivalent (FTE) operations staff	2	Not included	0.65 (simpler system than SBA to operate and maintain)
Burdened FTE Cost	$105,000	Not included	$105,000
Maintenance	1% of equipment cost	Uncertain	1% of equipment cost

[1]Maximum theoretical loading presented by IONEX, although pilot testing was recommended and would be needed prior to a performance guarantee.

[2]Additional pumping associated with treatment system headloss. Existing well operations not included.

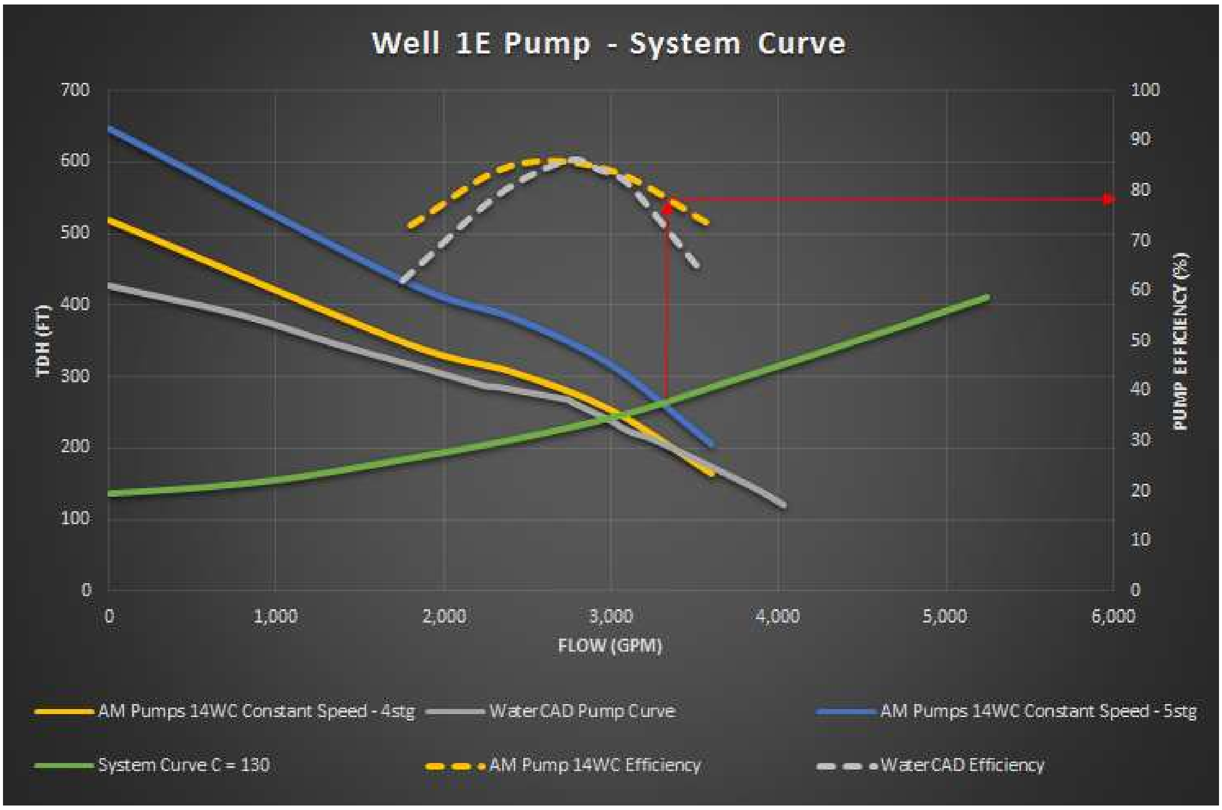
[3]Could be eliminated with inline membrane degassifier that eliminates the need to break head.

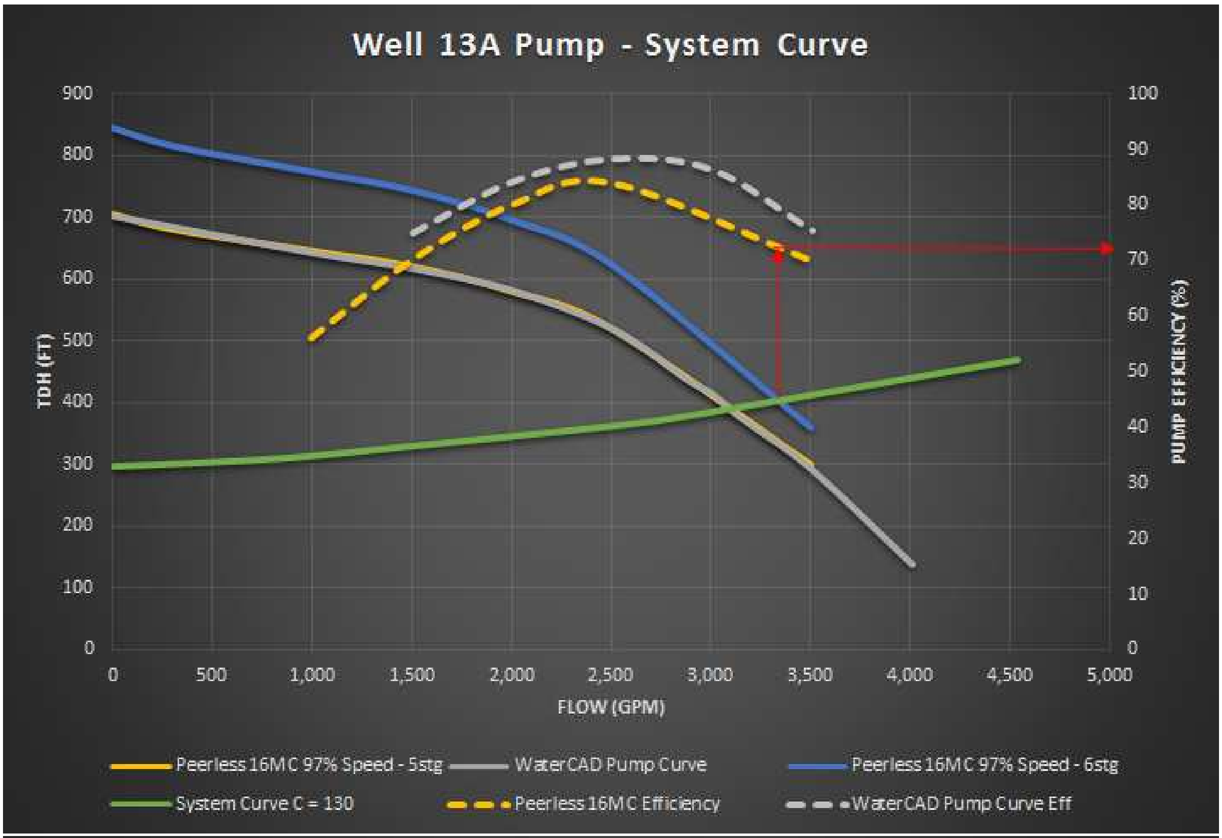
Site Upgrade Costs

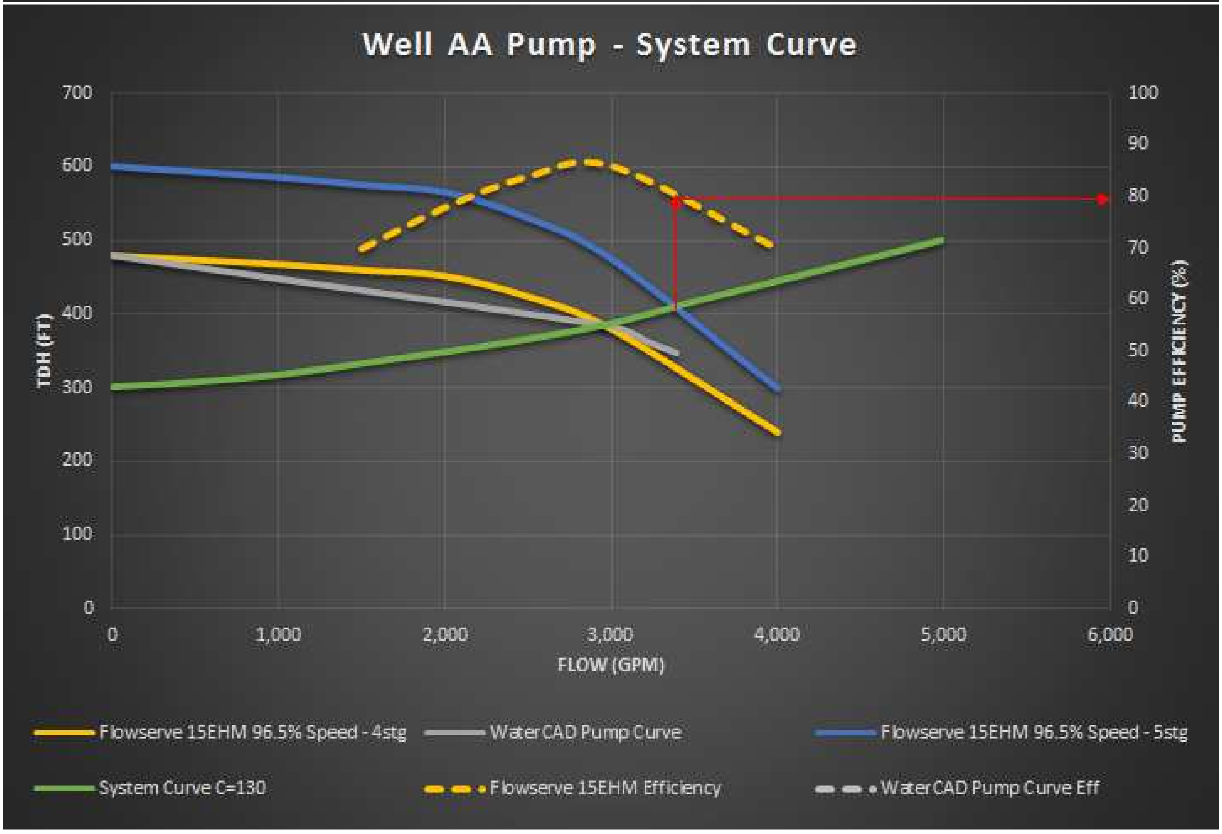
Hazen & Sawyer has a cost estimating methodology that is based on recent geographic labor rates, material costs, contractor proficiency and schedule. Details about cost assumptions, add-on factors, and inclusions are discussed in **Appendix B**. The following site layouts use the IONEX system as an example for the basis of footprint evaluations and detailed Bill of Material Takeoff for the various disciplines follow.

Civil / Mechanical

One of the first components evaluated was the ability of the well to overcome treatment system headloss. An example treatment system headloss of 21 psi at 2400 gpm resulted in a 200-400 gpm reduction in flow rate for Wells 1E, 13A and AA. To ensure the well was capable of overcoming the treatment system headloss while maintaining the 3200 gpm flow rate for all the wells, an additional bowl was modeled in WaterCAD. The results of this evaluation are presented in the Pump-System Curve Graphs below. Notice the design point is to the right of the best efficiency point for all of the three sites. This allows flexibility for the pumps to overcome treatment system headloss in excess of the 21 psi used in the analysis while still operating near the top of the pumps efficiency curve. For VFD scenarios like Wells 13A and AA, the VFD can ramp up to 100% speed to overcome treatment system headloss in excess of 21 psi while maintaining efficiency and the 3200 gpm flow set point if a WBA system were to ever be installed; WBA system has 40 psi of headloss at 2400 gpm as opposed to 21 psi of headloss at 2400 gpm for IONEX system.




Well 13A Pump - System Curve
TDH (FT)
PUMP EFFICIENCY (%)
FLOW (GPM)
Peerless 16MC 97% Speed - 5stg
WaterCAD Pump Curve
Peerless 16MC 97% Speed - 6stg
System Curve C = 130
Peerless 16MC Efficiency
WaterCAD Pump Curve Eff


Well AA Pump - System Curve
TDH (FT)
PUMP EFFICIENCY (%)
FLOW (GPM)
Flowserve 15EHM 96.5% Speed - 4stg
WaterCAD Pump Curve
Flowserve 15EHM 96.5% Speed - 5stg
System Curve C=130
Flowserve 15EHM Efficiency
WaterCAD Pump Curve Eff

The mass balance for an example treatment system with a headloss of 21 psi at 2400 gpm is summarized in **Table 11**. When operating with partial stream treatment and blending, additional operational cost savings can be implemented by treating less than 2400 gpm in the initial resin life and bypassing more, so long as frequent Cr6 samples reveal less than the raw water concentration indicated in **Table 11** or a higher treatment goal.

Table 11. Mass Balance to Achieve 6 µg/L Cr6 with Partial Stream Treatment and Blending

	Well 1E (21 psi @ 2400 gpm)			Well AA (21 psi @ 2400 gpm)			Well 13A (21 psi @ 2400 gpm)		
	No Treatment Headloss (gpm)[1]	With Treatment Headloss (gpm)[2]	Cr6 (µg/L)	No Treatment Headloss (gpm)[1]	With Treatment Headloss (gpm)[2]	Cr6 (µg/L)	No Treatment Headloss (gpm)[1]	With Treatment Headloss (gpm)[2]	Cr6 (µg/L)
Raw	3190	3270	18	3180	3207	18	3220	3203	14
Treated	2400	2395	1.6[3]	2400	2407	2[3]	2200	2403	3.3[3]
Bypass	790	875	18	780	800	18	800	800	14
Finished Water Blend	3190	3270	6	3180	3207	6	3220	3203	6
HP Reqd.	291			443			480		
HP Avail.	250			400			400		
Upsize Motor (Y/N)	Y (300 HP)			Y (500 HP)			Y (500 HP)		

1. Per recent Pump Tests conducted by Pump Check in 2012 for 1E, and 2014 for 13A and AA. Flow for 13A and AA are at 100% speed; 1E is constant speed and assumed flow with 1B and 1C operating at same time.
2. Flow splits as modeled in IWA WaterGems Software (adjusted for draw down, column losses and treatment headloss) and relative mass balance calculations. Flow and required horsepower values were calculated with the addition of a bowl to each existing well pump, and took into consideration pump, motor and VFD (13A and AA) efficiencies.
3. If the treated water Cr6 concentration exceeds this value at the corresponding flow splits and raw water concentrations the finished 6ug/L blend goal will be exceeded.

Refer to APPENDIX C for an output of the revised hydraulic model with the addition of one bowl to accommodate the 21 psi of headloss at 2400 gpm from the ion exchange treatment system.

All of the existing well pumps at the three sites currently operate in the service factor of the motor as revealed in the previous wire-to-water efficiencies conducted at the site by others. At a minimum it is recommended that the motor is upgraded per the Table 11. Currently, ID Modeling is under contract to perform an extended period simulation of a 7 day summer demand timeframe. Results of this modeling effort will reveal if Wells 1E, 13A and AA can operate at the 2400 gpm flow rate for the first two sampling quarter and still meet the summer demand. If so the addition of bowls will likely not need to occur until the three treatment systems can operate in bypass mode at the 3200 gpm flow rate. The addition of one more bowl on each vertical turbine well pump requires even more horsepower, but will still operate beneath the recommended motor horsepower identified in Table 11. The cost implications of upgrading the motor will be discussed further in the "Electrical / I&C Portion.

The civil and mechanical work required to accommodate the footprint of the proposed SBA technologies did not vary significantly based on information provided. The overall footprint of the SBA treatment systems are very similar to the WBA systems. The pressure vessels occupy similar square footage between both technologies. The brine and spent brine management systems with SBA technologies occupy similar square footage as the carbon dioxide injection and stripping systems.

Regardless of the IX technology deployed, the partial stream treatment requires an automated bypass flow control valve to bypass a portion of the raw water around the treatment system and blend back in with the treated water from the IX units. This valve manifold will be placed above grade in the vicinity of the bag filters. Instrumentation and controls involved with this setup will be discussed further in the Electrical/I&C discussion. As previously discussed, this bypass valve will need to remain closed during the next two sampling quarters since the blended water needs to be less than 2 to be compliant with respect to the RAA.

The chlorine injection quill must be relocated downstream of the SBA or WBA system, since anion exchange resin cannot tolerate chlorine.

Please refer to the following figures describing the site modifications needed to accommodate the SBA treatment system (IONEX) for Well 1E, Well 13A and AA. As more information is provided by the vendors, more site renderings could be generated if needed.

Structural

The only structural requirements associated with implementing SBA treatment consists of installing reinforced concrete slabs for the IX systems to rest on. The footprint of the various alternatives is roughly the same as indicated by the green slab perimeter lines in the conceptual site plans. A permanent canopy to cover the treatment systems was excluded from this analysis.

Electrical / I&C

As indicated above, all of the well pumps currently operate in the service factor of their respective motor. Although this operation may be acceptable for short periods of time, extended operation results in reduced motor service life and ultimately motor failure. In addition, photographs of motor nameplates indicate the existing well pump motors are not inverter duty rated. Replacement of the existing motors with properly sized, high efficient, inverter duty rated motors is recommended, especially if the addition of the pump bowls is necessary to overcome the treatment plant headloss and still deliver the required flow rate.

The electrical power distribution system capacity at each site is adequate for the additional treatment equipment; however new power distribution and motor control equipment is required including power and lighting panel boards. After the draft report was submitted, it was determined that the existing Mitsubishi VFDs for Well 13A and AA are rated for variable torque applications, such as a vertical turbine well pump. The existing VFD should be ample for the new 500HP motor with a FLA rating of 610A or less. Note: The Electrical / I&C costs in the estimate were not adjusted to reflect that the VFDS do not need to be replaced, because the VFD replacement cost was offset by the cost to install the new pumps and the likelihood of replacing the vertical turbine shaft with a larger diameter shaft to accommodate the new torque load.

Lighting and a lightning protection system is also included as part of the electrical installation. The capacity of the existing standby generators will be evaluated as the treatment process equipment loads are further developed. For the purpose of this fast track evaluation, the existing generators were assumed to be adequate.

Each of the treatment options will require some degree of instrumentation and automation to perform the required tasks. Vendor-supplied local control panels (LCPs) will accomplish the monitoring and control functions needed to automate the treatment units. Systems such as IONEX that perform on-site regeneration will require a greater degree of automation, but as a minimum the flow blending operation will require an automated strategy.

As noted, each treatment unit will be supplied with an LCP. Each LCP will be equipped with a Programmable Logic Controller, or PLC, to perform local monitoring and control functions. This PLC may be connected to the Authority's existing SCADA system for remote monitoring and, if desired, supervisory control of the treatment and/or blending processes. IWA currently operates a Schneider Electric ClearSCADA human-machine interface (HMI) software product for operator interface along with Schneider SCADAPack 32 remote telemetry units (RTUs) at each well site. The vendor panels are often supplied with Allen-Bradley PLCs, as typified by IONEX, which uses the Allen-Bradley CompactLogix controller as a standard. The SCADAPack 32 RTU features a Modbus TCP Ethernet communication port for remote communications and contains plenty of on-board memory to accommodate new networked data points. The CompactLogix supplied by IONEX also features a Modbus TCP port, which is also an option for the controllers of most manufacturers. Consequently, this will be the most efficient means of connecting the IX system to the IWA SCADA system.

The ClearSCADA operator interface software will need to be configured to show the new IX systems at each well site, including graphic displays, operating data monitoring and storage, alarms, and, where desired, supervisory commands such as setting the blending ratio for each site.

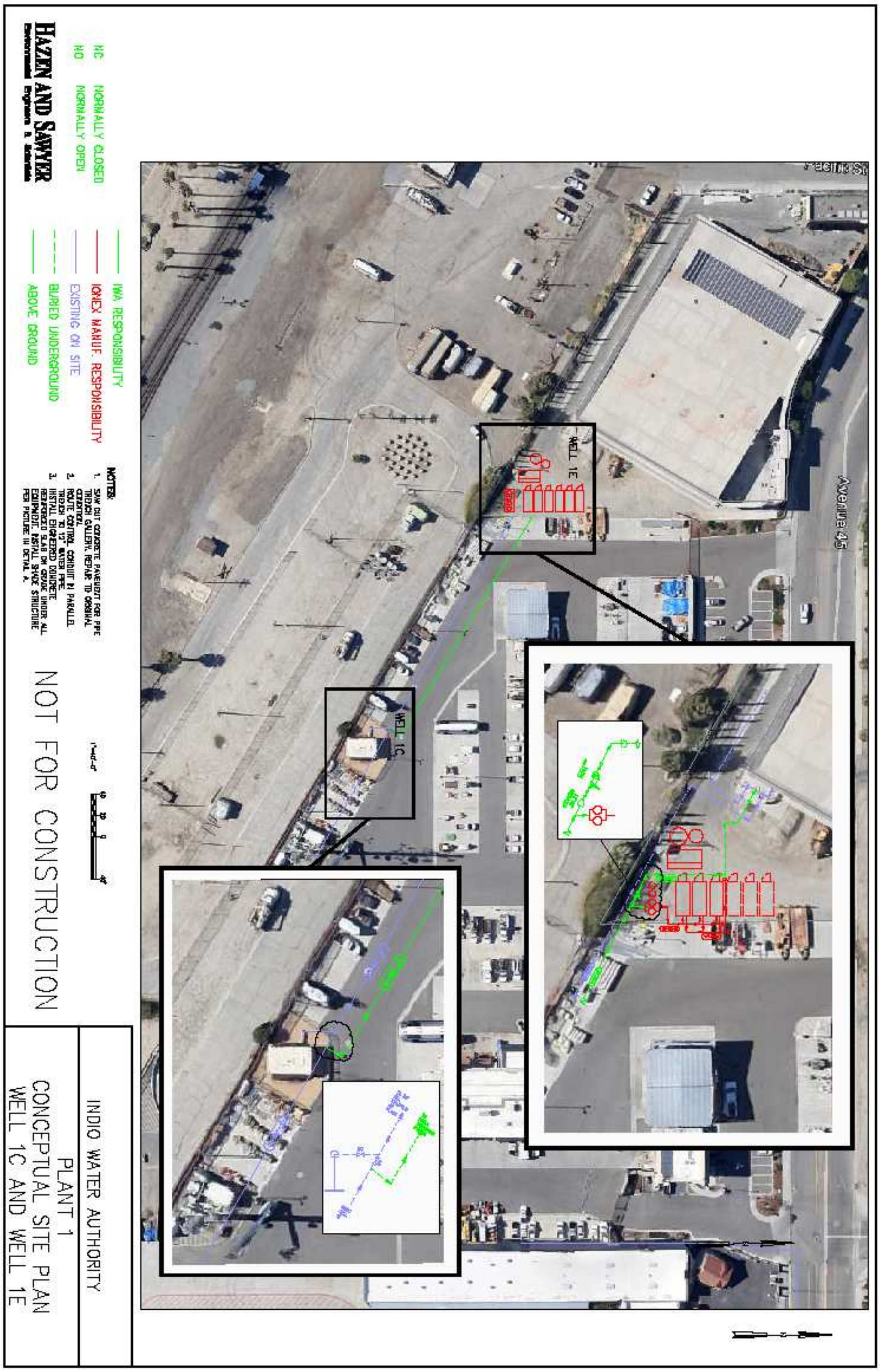
Cost Summary

DRAFT OPINION OF PROBABLE PROJECT COST

Client: Indio Water Authority	Hazen and Sawyer Project No.
Project	Based on vendor budgetary quotes
Item: Well 1E	Updated by C.P. on 1/23/15.

Description	Quantity	Unit	Unit Cost	Total Cost	Notes
Equipment					
IX System	1	LS	$983,002	$983,002	
Upgrade 250 hp motor	1	LS	$68,000	$68,000	Upgrade existing motor to 500 hp, provide 18-pulse VFD
Subtotal				**$1,052,000**	Rounded up to $1000
Equipment Installation Cost	3%			$31,560	Including tax, freight, installation and manufacturer services.
Equipment Concrete Pad	69	CY	$490	$33,810	
Subtotal (Installed Equipment Costs)				**$1,118,000**	Rounded up to $1000
General Requirements	7.5%			$83,850	Division 1 requirements, including Contractor's field supervision, temporary utilities, health and safety, mobilization and demobilization
Earthwork	2%			$22,360	Excavation, backfill, and fill required to construct project
Site Improvements	2%			$22,360	Roadways, curb and gutter, sidewalk and landscaping
Valves, Piping, and Appurtenances				$151,935	Based upon quantity take-off. Major system piping and valves
Electrical, Instrumentation and Controls				$130,000	Based upon quantity take-off. PLC and SCADA equipment to control
Total Direct Costs				**$1,529,000**	Rounded up to $1000
Contractor Mark-Up	5%			$49,150	On Ion Exchange System only
Contractor's Overhead	10%			$54,600	Not including Ion Exchange System Cost
Contractor's Profit	8%			$43,680	Not including Ion Exchange System Cost
Construction Total				**$1,676,000**	Rounded up to $1000
Engineering and Construction Management	15%			$251,400	
Legal and Administrative	5%			$83,800	Includes permits, legal fees and engineering fees for design and construction
Subtotal				**$1,759,800**	
Project Level Allowance (contingency)	30%			$527,940	Budget item to cover change orders due to unforeseen conditions
Project Total				**$2,288,000**	Rounded up to $1000
Low Estimate Accuracy				$1,602,000	-30%
High Estimate Accuracy				$3,432,000	+50%

Notes:
1. This opinion of probable cost is based on AACE Class 5 estimate guidelines. The high and low estimates fall into the acceptable range. These estimates are generally used to compare alternatives.
2. Opinion of Probable Cost in 2015 dollars.
3. Costs for land or easements are not included.


HAZEN AND SAWYER
NC NORMALLY CLOSED
NO NORMALLY OPEN
IWA RESPONSIBILITY
IONEX MANUF. RESPONSIBILITY
EXISTING ON SITE
BURIED UNDERGROUND
ABOVE GROUND
NOTES:
NOT FOR CONSTRUCTION
INDIO WATER AUTHORITY
PLANT 1
CONCEPTUAL SITE PLAN
WELL 1C AND WELL 1E
WELL 1E
WELL 1C
Avenue 45
FIGURE 1

DRAFT OPINION OF PROBABLE PROJECT COST

Client Indio Water Authority	Hazen and Sawyer Project No.
	Based on vendor budgetary quotes
	Updated by C.P. on 1/23/15.
Project	
Item Well AA	

Description	Quantity	Unit	Unit Cost	Total Cost	Notes
Equipment					
IX System	1	LS	$983,002	$983,002	
Upgrade 250 hp motor	1	LS	$115,000	$115,000	Upgrade existing motor to 300 hp, provide 18-pulse VFD
Subtotal				**$1,099,000**	Rounded up to $1000
Equipment Installation Cost	3%			$32,970	Including tax, freight, installation and manufacturer services.
Equipment Concrete Pad	104	CY	$490	$50,960	
Subtotal (Installed Equipment Costs)				**$1,183,000**	Rounded up to $1000
General Requirements	7.5%			$88,725	Division 1 requirements, including Contractor's field supervision, temporary utilities, health and safety, mobilization and demobilization
Earthwork	2%			$23,660	Excavation, backfill, and fill required to construct project
Site Improvements	2%			$23,660	Roadways, curb and gutter, sidewalk and landscaping
Valves, Piping, and Appurtenances				$119,110	Based upon quantity take-off. Major system piping and valves
Electrical, Instrumentation and Controls				$130,000	Based upon quantity take-off. PLC and SCADA equipment to control
Total Direct Costs				**$1,568,000**	Rounded up to $1000
Contractor Mark-Up	5%			$49,150	On Ion Exchange System only
Contractor's Overhead	10%			$58,500	Not including Ion Exchange System Cost
Contractor's Profit	8%			$46,800	Not including Ion Exchange System Cost
Construction Total				**$1,722,000**	Rounded up to $1000
Engineering and Construction Management	15%			$258,300	
Legal and Administrative	5%			$86,100	Includes permits, legal fees and engineering fees for design and construction
Subtotal				**$2,066,400**	
Project Level Allowance (contingency)	30%			$619,920	Budget item to cover change orders due to unforeseen conditions
Project Total				**$2,687,000**	Rounded up to $1000
Low Estimate Accuracy				$1,881,000	-30%
High Estimate Accuracy				$4,031,000	+50%

Notes:

1. This opinion of probable cost is based on AACE Class 5 estimate guidelines. The high and low estimates fall into the acceptable range. These estimates are generally used to compare alternatives.
2. Opinion of Probable Cost in 2015 dollars.
3. Costs for land or easements are not included.


HAZEN AND SAWYER
Environmental Engineers & Scientists
NC NORMALLY CLOSED
NO NORMALLY OPEN
IWA RESPONSIBILITY
IONEX MANUF. RESPONSIBILITY
EXISTING ON SITE
BURIED UNDERGROUND
ABOVE GROUND
NOT FOR CONSTRUCTION
MADISON STREET
SIDEWALK
GATE
GATE
HYDROPNEUMATIC TANK
GENERATOR
AUTOMATIC BRINER
SAFETANK
IX UNITS
MASTER REGEN UNIT
SULPHATE POD
TO DIST. SYS
TO IONEX
FLOW
NOTES:
INDIO WATER AUTHORITY
WELL AA
CONCEPTUAL SITE PLAN
FIGURE 1

DRAFT OPINION OF PROBABLE PROJECT COST

Client Indio Water Authority	Hazen and Sawyer Project No.
Project	Based on vendor budgetary quotes
Item Well 13A	Updated by C.P. on 1/23/15.

Description	Quantity	Unit	Unit Cost	Total Cost	Notes
Equipment					
IX System	1	LS	$983,002	$983,002	
Upgrade 400 hp motor	1	LS	$115,000	$115,000	Upgrade existing motor to 500 hp, provide 18-pulse VFD
Subtotal				**$1,099,000**	Rounded up to $1000
Equipment Installation Cost	3%			$32,970	Including tax, freight, installation and manufacturer services.
Equipment Concrete Pad	69	CY	$490	$33,810	
Subtotal (Installed Equipment Costs)				**$1,166,000**	Rounded up to $1000
General Requirements	7.5%			$87,450	Division 1 requirements, including Contractor's field supervision, temporary utilities, health and safety, mobilization and demobilization
Earthwork	2%			$23,320	Excavation, backfill, and fill required to construct project
Site Improvements	2%			$23,320	Roadways, curb and gutter, sidewalk and landscaping
Valves, Piping, and Appurtenances				$137,515	Based upon quantity take-off. Major system piping and valves
Electrical, Instrumentation and Controls				$130,000	Based upon quantity take-off. PLC and SCADA equipment to control
Total Direct Costs				**$1,568,000**	Rounded up to $1000
Contractor Mark-Up	5%			$49,150	On Ion Exchange System only
Contractor's Overhead	10%			$58,500	Not including Ion Exchange System Cost
Contractor's Profit	8%			$46,800	Not including Ion Exchange System Cost
Construction Total				**$1,722,000**	Rounded up to $1000
Engineering and Construction Management	15%			$258,300	
Legal and Administrative	5%			$86,100	Includes permits, legal fees and engineering fees for design and construction
Subtotal				**$1,808,100**	
Project Level Allowance (contingency)	30%			$542,430	Budget item to cover change orders due to unforeseen conditions
Project Total				**$2,351,000**	Rounded up to $1000
Low Estimate Accuracy				$1,646,000	-30%
High Estimate Accuracy				$3,527,000	+50%

Notes:
1. This opinion of probable cost is based on AACE Class 5 estimate guidelines. The high and low estimates fall into the acceptable range. These estimates are generally used to compare alternatives.

2. Opinion of Probable Cost in 2015 dollars.

3. Costs for land or easements are not included.

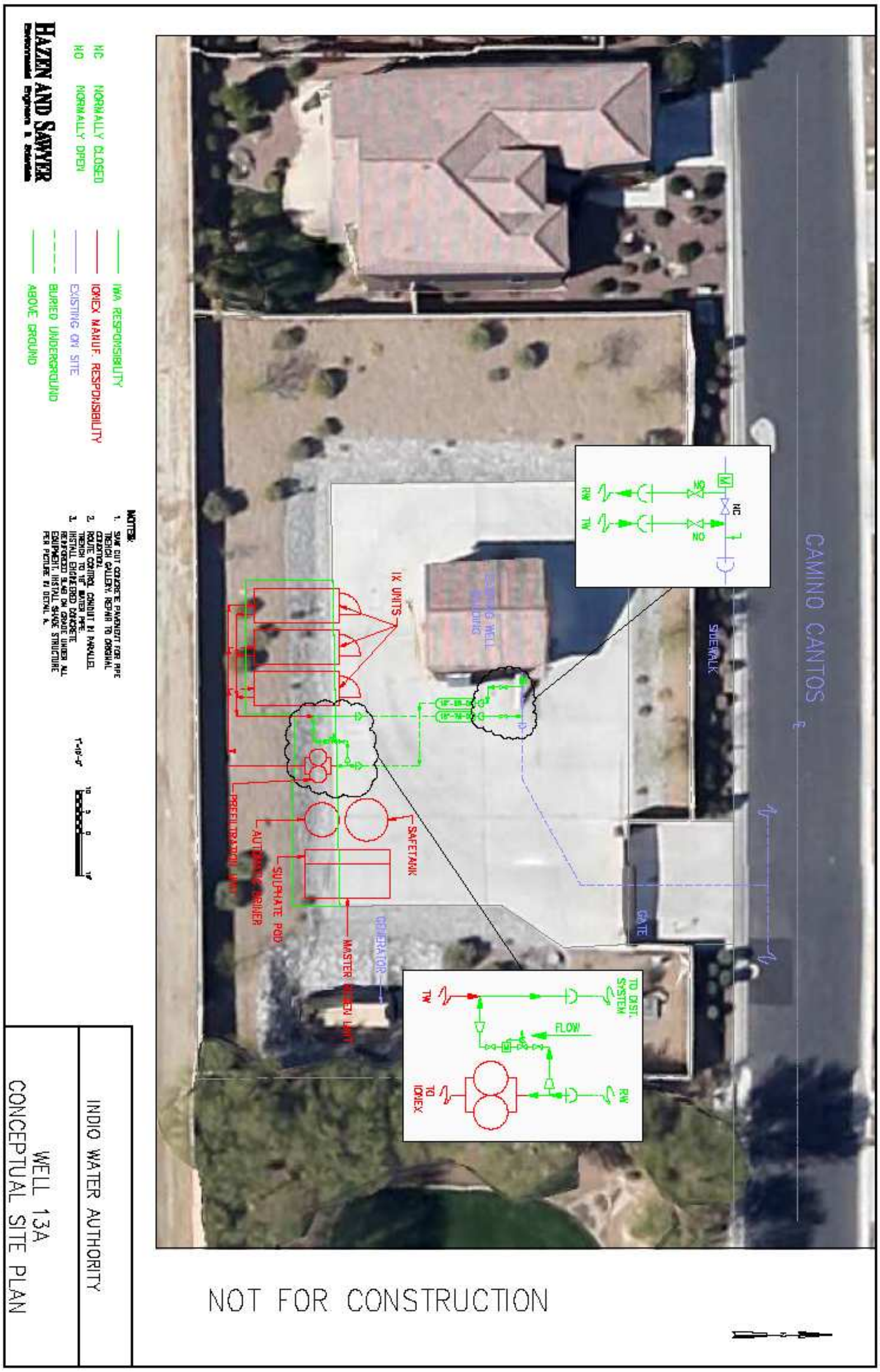

HAZEN AND SAWYER
CAMINO CANTOS
NOT FOR CONSTRUCTION
INDIO WATER AUTHORITY
WELL 13A
CONCEPTUAL SITE PLAN

FIGURE 1

Comparison of Treatment Options

All of the technologies considered have the ability to meet IWA's Cr6 treatment goals. Technologies were then compared based on IWA's remaining priorities of schedule, cost, and investment (applicability to future well sites) (**Table 13**).

Table 13. Comparison of Cr6 Treatment Options based on IWA Priorities

Options Evaluated	Availability	Primary Risk to IWA's Priorities	Applicability to Other Wells in the Future	Capital Costs	Lifecycle Costs
Option 1- Single Pass SBA at 1E and AA, WBA at 13A	(Neutral) Longest lead time quoted initially (20-28 weeks), options possible to expedite request.	(Neutral) Significant capital investment required. SBA resin will require regeneration prior to using at other facilities.	(Neutral) SBA resin, once regenerated, could be used at other treatment facilities.	(Less Favored) $$$ Primary cost driver is resin replacement. Spent resin could be used at other wells in the future after regeneration.	(TBD) SBA only operated in single pass mode until regeneration facilities (onsite or centralized) could be constructed. O&M costs are estimated to be very high.
Option 2- WBA at all wells	(Neutral) Longest lead time quoted initially (20-28 weeks), options possible to expedite request.	(Most Favored) No brine generation reduces disposal cost and operational risk to IWA.	(Neutral) Resin could be replaced with an alternative resin type in the future. Lower life cycle costs may be available from SBA at low sulfate wells.	(Neutral) $$ WBA requires pH adjustment requiring CO_2 and an aeration system. Also, vendors proposed steel vessels, making WBA more expensive then SBA. Steel vessels are expected to have a longer life cycle.	(TBD) Operating costs include WBA resin replacement and disposal, CO_2, and electrical (aeration blowers and boosters).
Option 3- SBA with onsite regen at all wells	(Most Favored) 12 weeks for resin (currently longest lead time item).	(Neutral) Waste brine generation and disposal risks require thorough contract negotiation (manufacturer performance guarantees and waste disposal facilities).	(Most Favored) A containerized SBA system could be moved to other low sulfate wells in the future allowing for more permanent facilities to be designed at the plants.	(Most Favored) $ Vendors proposed a containerized approach with FRP vessels that made SBA more economical than WBA. Life cycle costs for FRP compared with steel vessels are not clear.	(TBD) Based on general system designs, SBA costs are projected to be lower than WBA at low sulfate wells. Innovative waste minimization approaches (i.e. IONEX) make SBA competitive with WBA at high sulfate wells if effective over the long term.
Option 4- Leased Single Pass SBA at all wells	(Most Favored) Rental units available 2-4 weeks from accepted purchase order.	(Most Favored) Rental units with service agreements, while the most expensive option, offer the lowest risk to IWA and time to plan for more permanent facilities.	(Less Favored) No assets beyond spent resin at the end of the lease period for use at other wells.	(Less Favored) $$$ Primary cost driver is resin replacement. Spent resin could be used at other wells in the future after regeneration.	(TBD) Rental units are a temporary approach to meeting system demands, allowing time for the construction of more permanent facilities.

Most Favored Neutral Less Favored TBD as part of bid and selection process.

Additional Factors

Two of the manufacturers, IONEX and Envirogen, indicated that they should be able to meet a deadline of June 1 for delivering an operational system; however an order would need to be placed by mid-February to ensure this date is met. The SBA resin has the longest lead time since it is coming from China. After the initial proposal request, EVOQUA also stated that the deadline could be met. Other factors that will impact schedule must also be considered by IWA, including: permitting (CEQA, DDW, others), start-up, and commissioning period.

Risks to meeting IWA's priorities that were identified include:

- Contractors' ability to deliver the project on time.
- Manufacturer delays in the contract caused by them not having fabrication or delivery capabilities to keep up with demand.
- Impending labor dispute in the Ports that may impact resin shipments from China, such as by slowing delivery or increasing costs if transported from another location.
- IWA cash flow, if reserves are depleted.
- Affordability of the O&M and the impact of high O&M on the lifecycle costs without having pilot or other information to verify manufacturer claims.
- Customer acceptance of the treated water and any potential issues with the water stability/corrosivity. IONEX does not have a caustic addition system to address stability of the blended water.
- Neighbor or property issues with treatment installation or operations.
- Water demands that are higher than projected.
- Fluctuations in water quality that impact the ability to meet the project goals and regulatory goals. Potential control issues due to limited programming resources (these may be mitigated by verification of controls in the factory prior to shipping).

Opportunities for minimizing some of these risks include:

- Performance bond requirements to protect IWA from the Contractor not performing.
- Payment bond requirements to ensure the vendor will perform and get paid for their services and equipment.

Conclusions and Recommendations

Hazen and Sawyer performed an accelerated evaluation of Cr6 treatment for three wells by June 1, 2015. The evaluation was conducted over an accelerated two week period. The brief time did not allow for a comprehensive analysis due to limited completeness of quotations provided by manufacturers. Preliminary information and estimates were provided by four manufacturers for two technologies (SBA and WBA). The capital cost of the WBA system was found to be greater than the SBA systems, so SBA was brought forward in the analysis to determine site upgrade costs. Lifecycle costs and performance guarantees were not thoroughly evaluated due to the limited information provided. Therefore the actual lifecycle costs remain uncertain for the systems with the lowest capital costs. A summary of estimated costs are provided in APPENDIX B. We recommend a number of steps prior to the bid process, including (1) Updating the hydraulic model to assess the feasibility of the proposed operational strategy for meeting summer demands and (2) Evaluating life cycle costs of treatment.

IWA Priorities/Goals based on meetings and conversations were determined to be the following:

1. Cr6 treatment goals for 2015 and beyond
2. Schedule of June 1, 2015
3. Budget available for the project
4. Minimize potential for stranded assets

Based on a comparison of treatment options considering the IWA priorities, the containerized IONEX SBA approach with onsite regeneration is the suggested technology for the fast track project with the following benefits to IWA:

- SBA is a proven technology for Cr6 removal
- SBA provides the lowest upfront capital investment
- SBA from IONEX has high probability of meeting the schedule goals of the project
- SBA from IONEX provides the most thorough proposal that allows for rapid negotiation and procurement of an emergency technology
- SBA from IONEX provides the ability to obtain an operating service agreement and performance guarantee for waste generation
- Implementation of SBA allows for the system to be demonstrated prior to implementation at other wells
- SBA containerized units can be moved to other wells in the future should the life cycle cost of WBA be found to be more cost effective at the wells with higher sulfate

To attempt to meet the IWA's schedule of treatment on the three wells by June 1, 2015, IWA will need to move forward into procurement of the equipment and into design with the selection of one technology/vendor. Although a DBB process with multiple vendor bidding would provide a better comparison of the lifecycle costs of treatment, bidding would require longer than IWA has available to meet the June 1st schedule. IONEX has provided the most complete and transparent proposal during this evaluation, and offers the potential for waste minimization compared with traditional SBA systems.

Appendix B: Water Quality Database and Historical Trends

HAZEN AND SAWYER
Environmental Engineers & Scientists

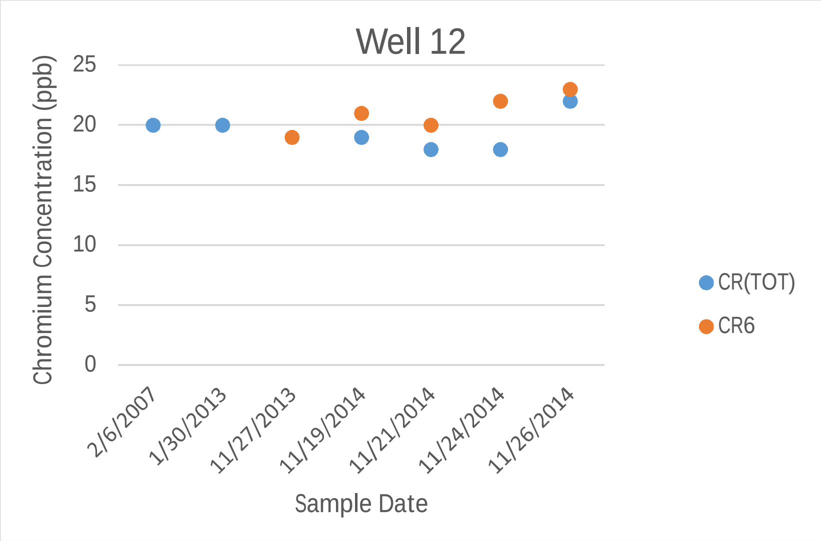
Project Number: 20038-000

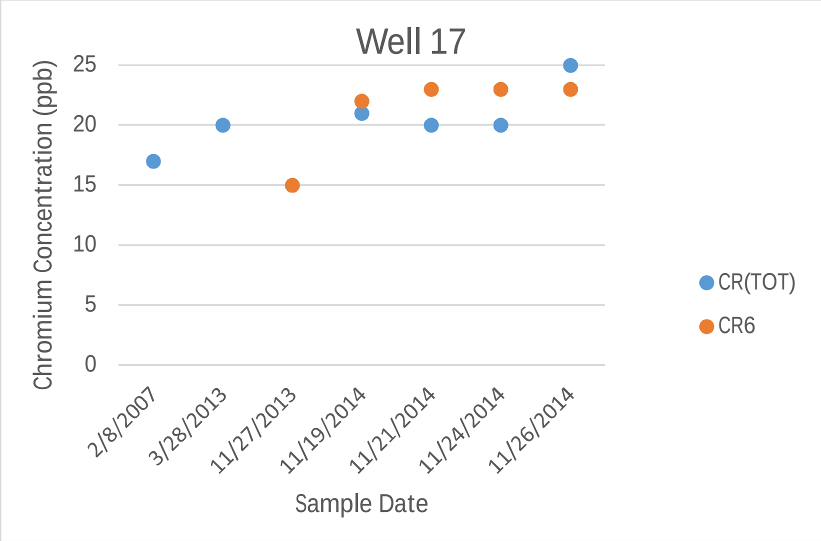
APPENDIX B

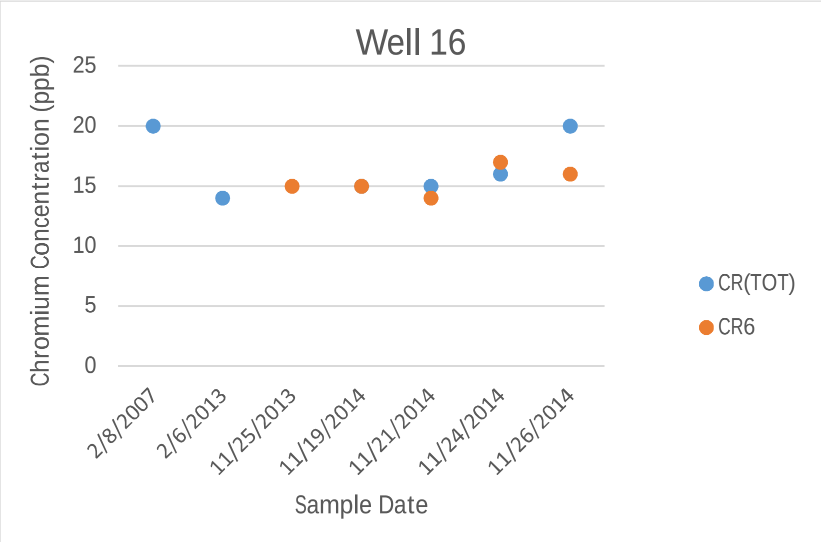
Water Quality Database and Historical Trends

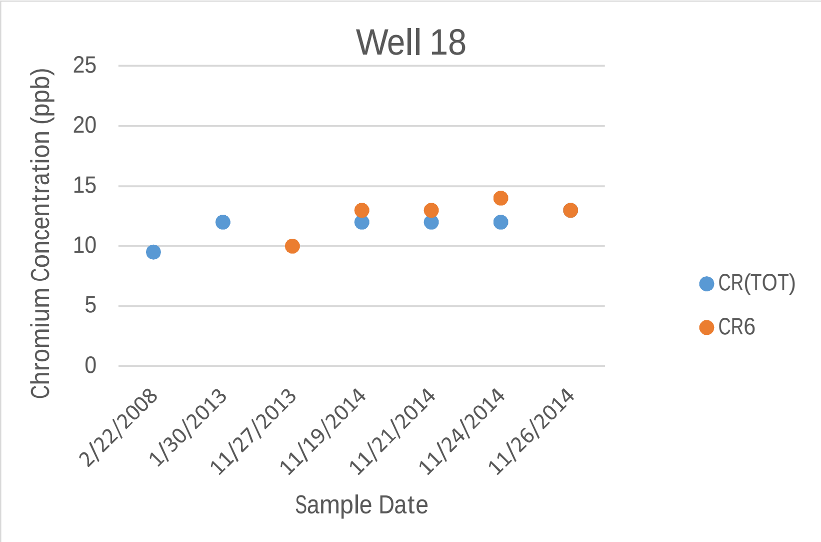
The following figures show historical chromium data and summary tables show additional constituent data for CWA and IWA wells.

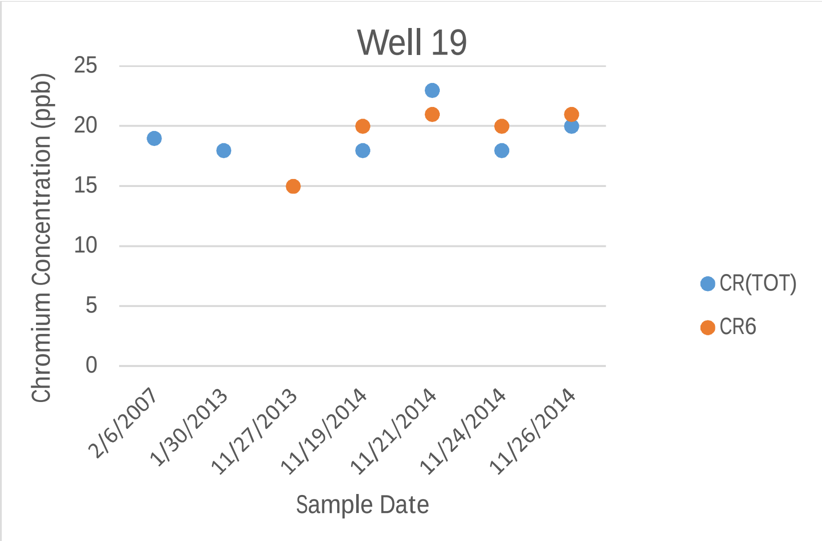
CWA Historical Well Data







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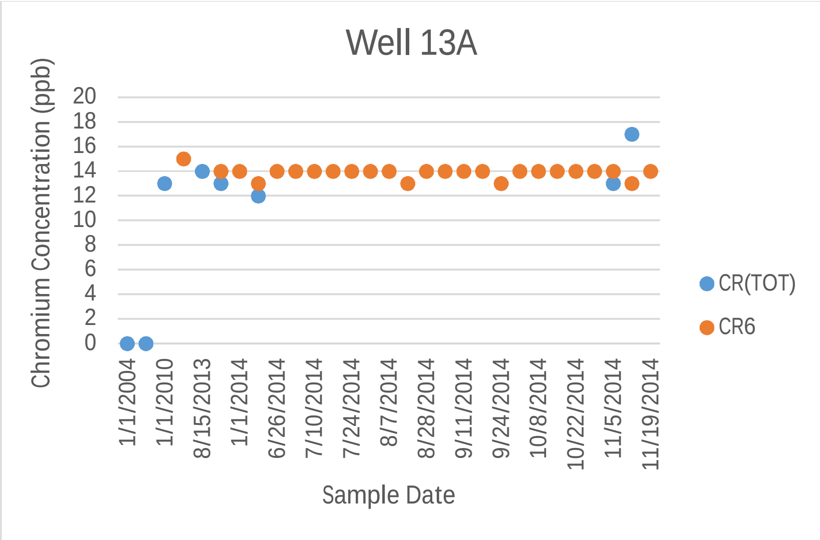
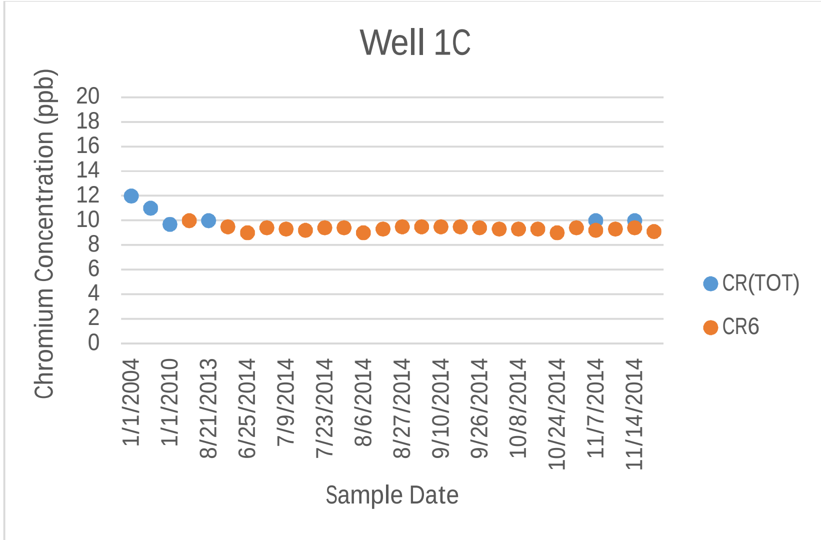
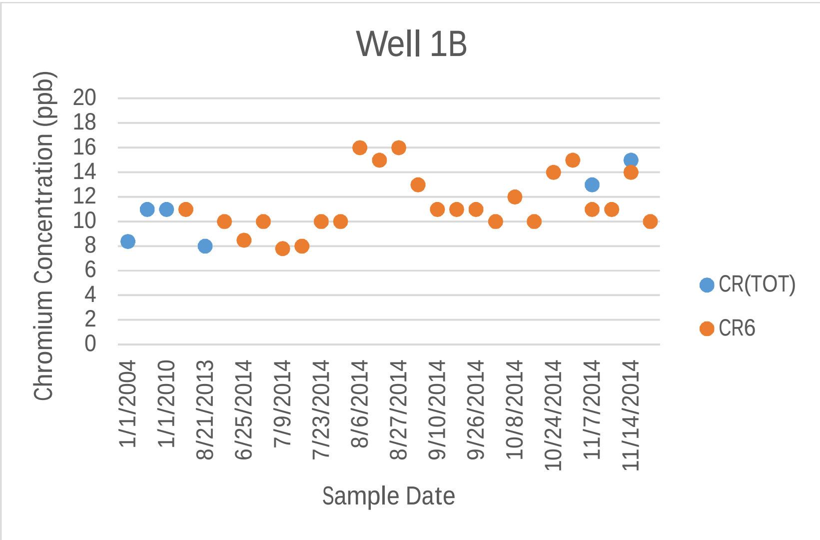
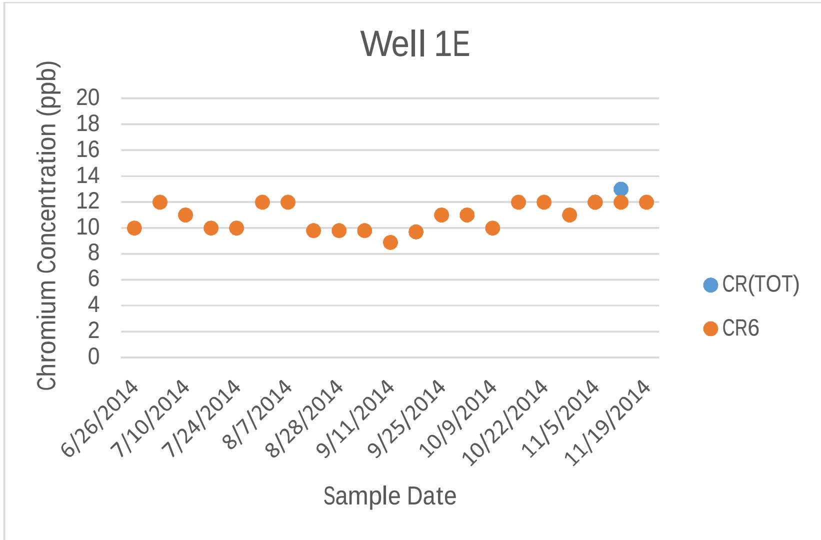
Chromium Concentration (ppb)
25
20
15
10
5
0
2/6/2007
1/30/2013
11/27/2013
11/19/2014
11/21/2014
11/24/2014
11/26/2014
Sample Date
CR(TOT)
CR6

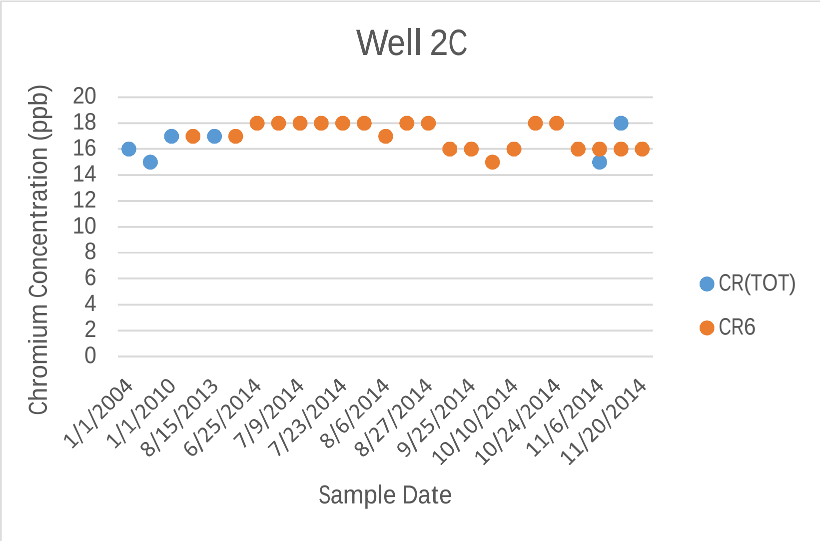
IWA Historical Well Data







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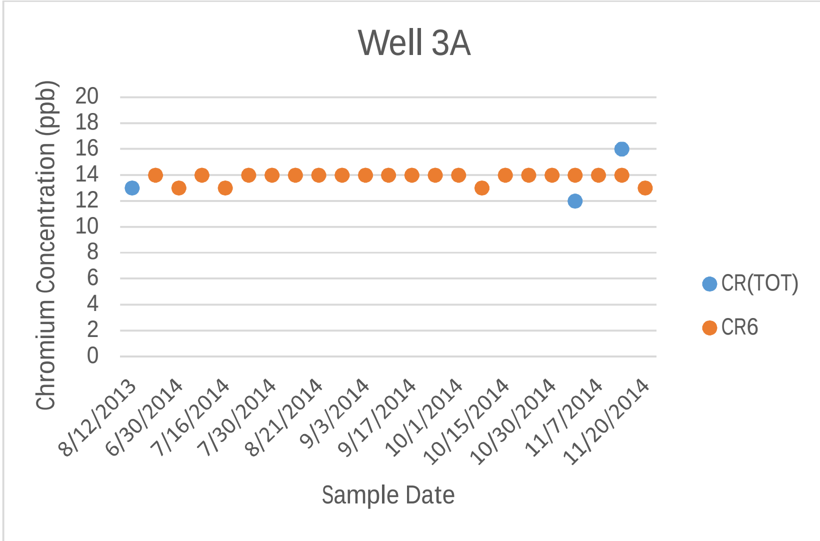
16
14
12
10
8
6
4
2
0
1/1/2004
1/1/2010
8/15/2013
6/25/2014
7/9/2014
7/23/2014
8/6/2014
8/27/2014
9/25/2014
10/10/2014
10/24/2014
11/6/2014
11/20/2014
Sample Date
CR(TOT)
CR6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Chromium Concentration (ppb)
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16
14
12
10
8
6
4
2
0
8/12/2013
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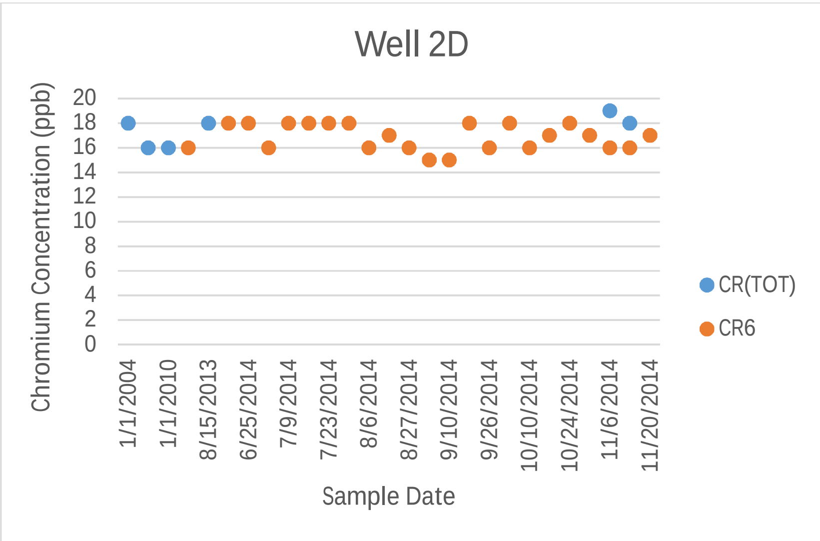
7/16/2014
7/30/2014
8/21/2014
9/3/2014
9/17/2014
10/1/2014
10/15/2014
10/30/2014
11/7/2014
11/20/2014
Sample Date
CR(TOT)
CR6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16
14
12
10
8
6
4
2
0
1/1/2004
1/1/2010
8/15/2013
6/25/2014
7/9/2014
7/23/2014
8/6/2014
8/27/2014
9/10/2014
9/26/2014
10/10/2014
10/24/2014
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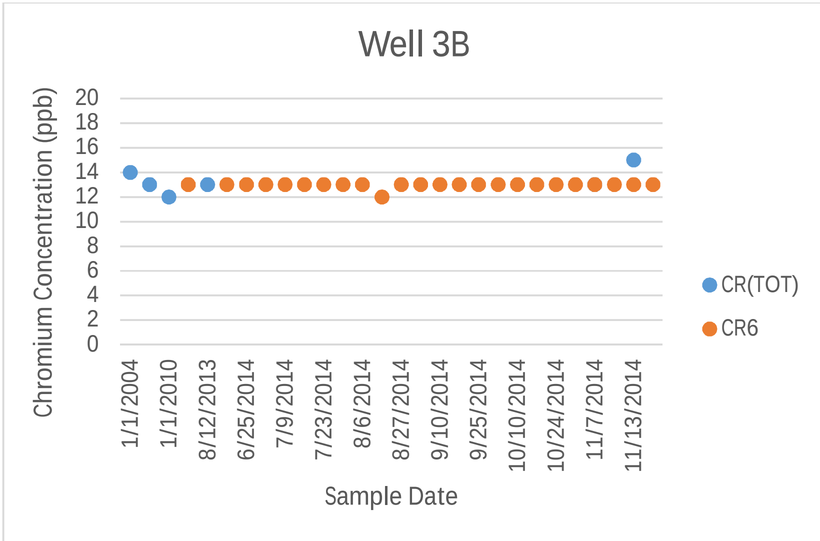
11/20/2014
Sample Date
CR(TOT)
CR6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12
10
8
6
4
2
0
1/1/2004
1/1/2010
8/12/2013
6/25/2014
7/9/2014
7/23/2014
8/6/2014
8/27/2014
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10/10/2014
10/24/2014
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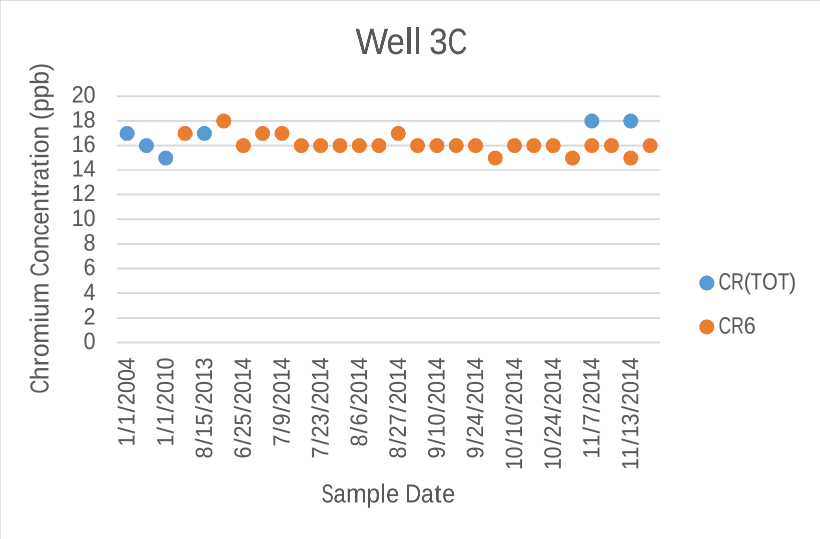
11/13/2014
Sample Date
CR(TOT)
CR6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Chromium Concentration (ppb)
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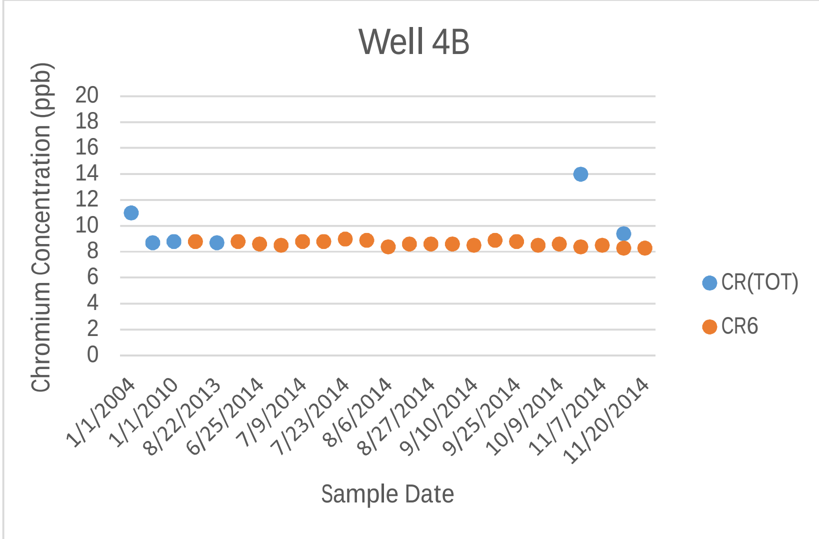
14
12
10
8
6
4
2
0
1/1/2004
1/1/2010
8/15/2013
6/25/2014
7/9/2014
7/23/2014
8/6/2014
8/27/2014
9/10/2014
9/24/2014
10/10/2014
10/24/2014
11/7/2014
11/13/2014
Sample Date
CR(TOT)
CR6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Chromium Concentration (ppb)
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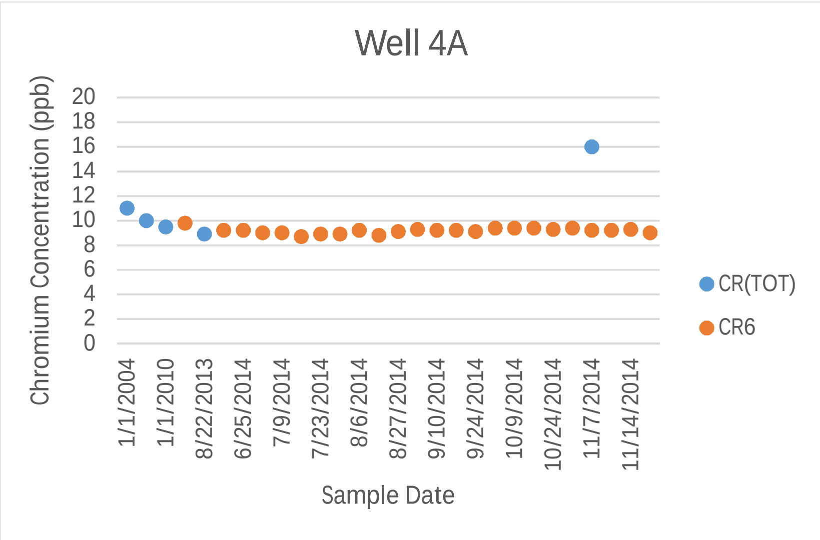
18
16
14
12
10
8
6
4
2
0
1/1/2004
1/1/2010
8/22/2013
6/25/2014
7/9/2014
7/23/2014
8/6/2014
8/27/2014
9/10/2014
9/25/2014
10/9/2014
11/7/2014
11/20/2014
Sample Date
CR(TOT)
CR6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Chromium Concentration (ppb)
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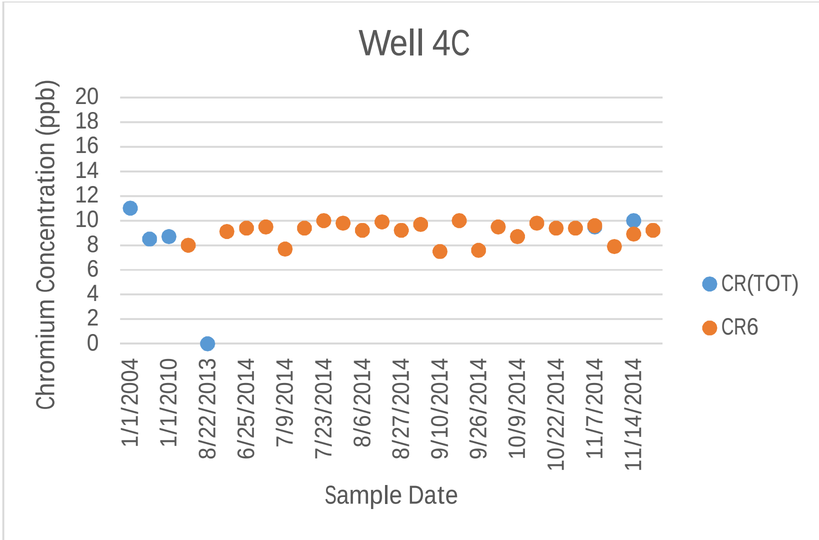
18
16
14
12
10
8
6
4
2
0
1/1/2004
1/1/2010
8/22/2013
6/25/2014
7/9/2014
7/23/2014
8/6/2014
8/27/2014
9/10/2014
9/24/2014
10/9/2014
10/24/2014
11/7/2014
11/14/2014
Sample Date
CR(TOT)
CR6


Well 4C
Chromium Concentration (ppb)
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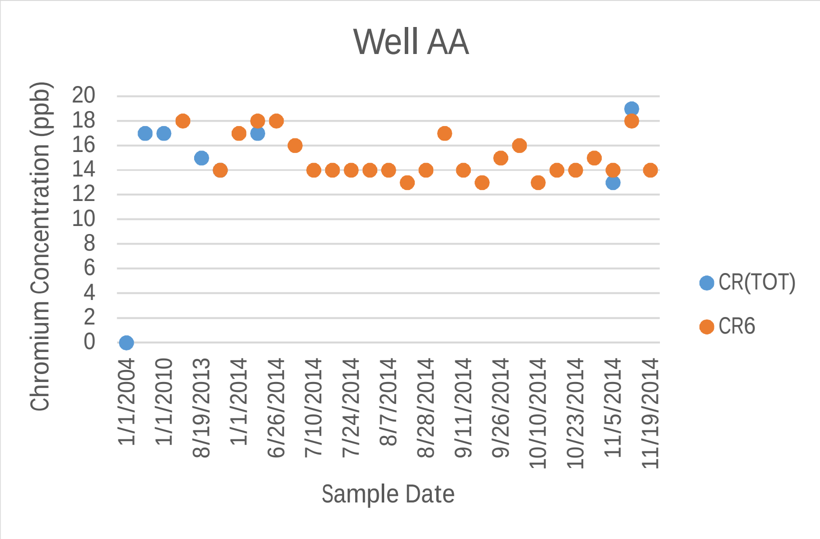
18
16
14
12
10
8
6
4
2
0
1/1/2004
1/1/2010
8/22/2013
6/25/2014
7/9/2014
7/23/2014
8/6/2014
8/27/2014
9/10/2014
9/26/2014
10/9/2014
10/22/2014
11/7/2014
11/14/2014
Sample Date
CR(TOT)
CR6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Chromium Concentration (ppb)
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18
16
14
12
10
8
6
4
2
0
1/1/2004
1/1/2010
8/19/2013
1/1/2014
6/26/2014
7/10/2014
7/24/2014
8/7/2014
8/28/2014
9/11/2014
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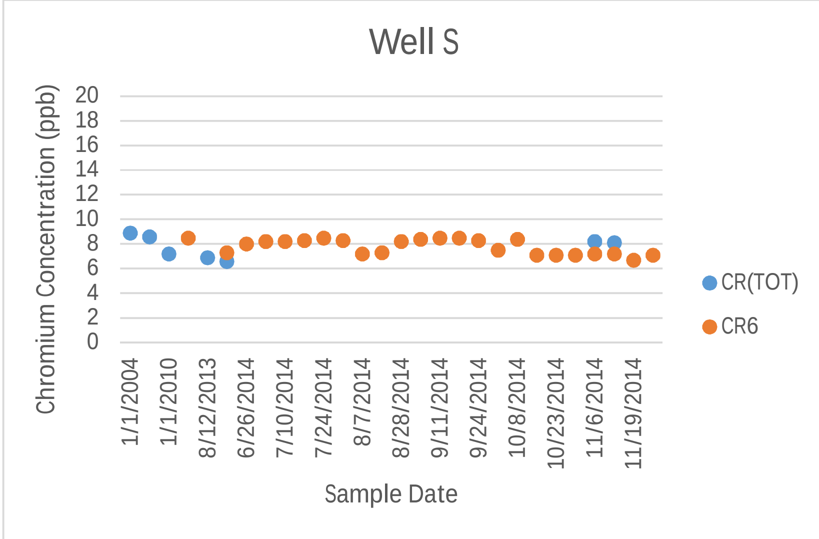
Sample Date
CR(TOT)
CR6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Chromium Concentration (ppb)
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18
16
14
12
10
8
6
4
2
0
1/1/2004
1/1/2010
8/12/2013
6/26/2014
7/10/2014
7/24/2014
8/7/2014
8/28/2014
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9/24/2014
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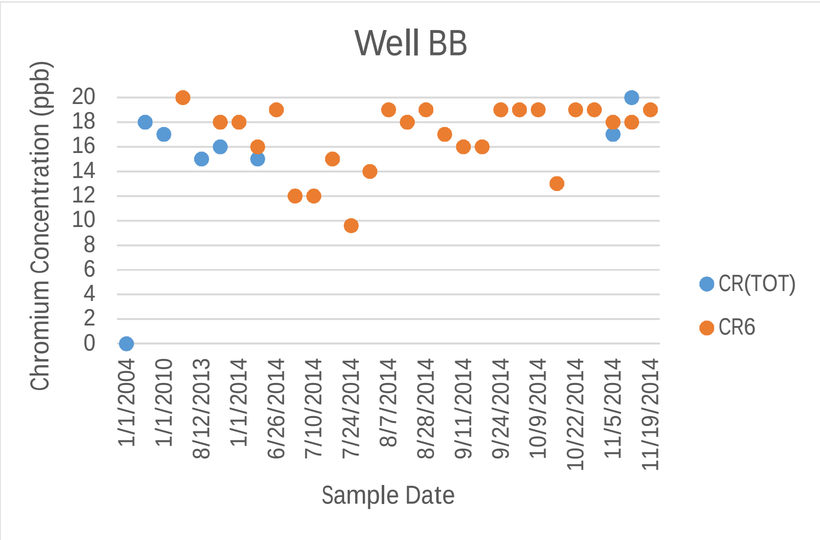
10/23/2014
11/6/2014
11/19/2014
Sample Date
CR(TOT)
CR6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Chromium Concentration (ppb)
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16
14
12
10
8
6
4
2
0
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1/1/2010
8/12/2013
1/1/2014
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7/10/2014
7/24/2014
8/7/2014
8/28/2014
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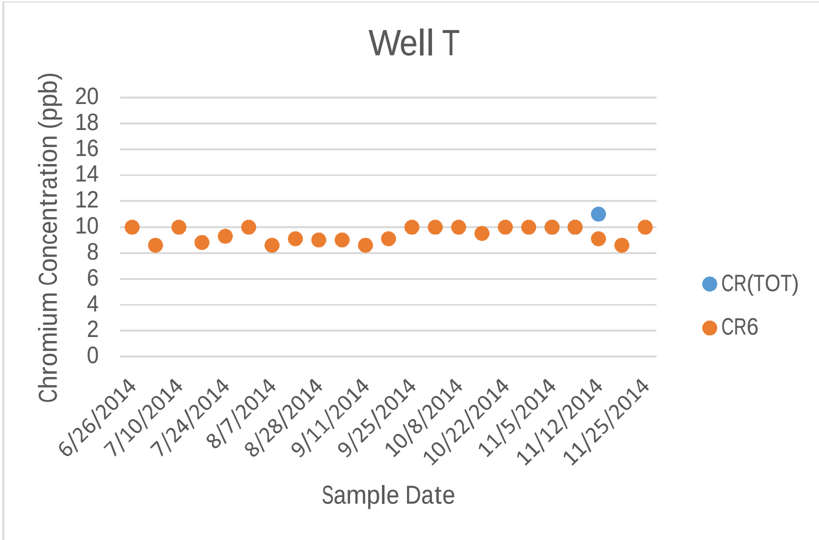
Sample Date
CR(TOT)
CR6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Chromium Concentration (ppb)
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18
16
14
12
10
8
6
4
2
0
6/26/2014
7/10/2014
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8/7/2014
8/28/2014
9/11/2014
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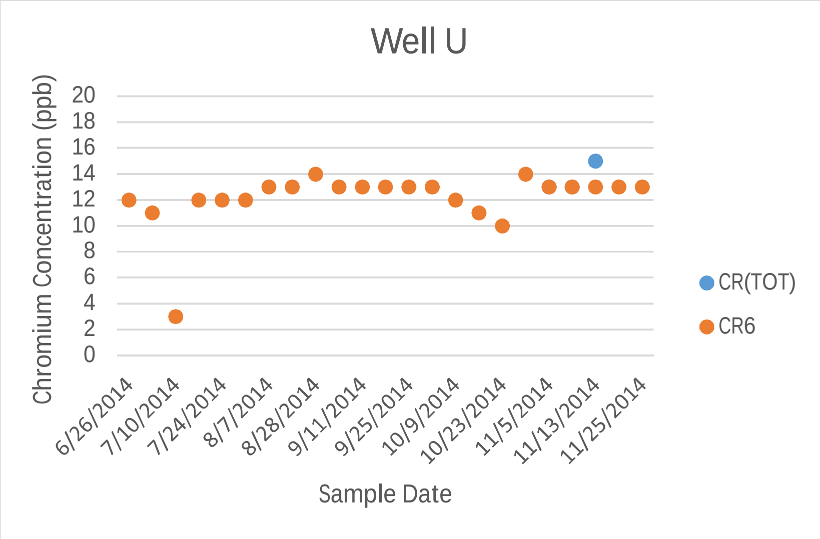
11/25/2014
Sample Date
CR(TOT)
CR6


Well U
Chromium Concentration (ppb)
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18
16
14
12
10
8
6
4
2
0
6/26/2014
7/10/2014
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8/7/2014
8/28/2014
9/11/2014
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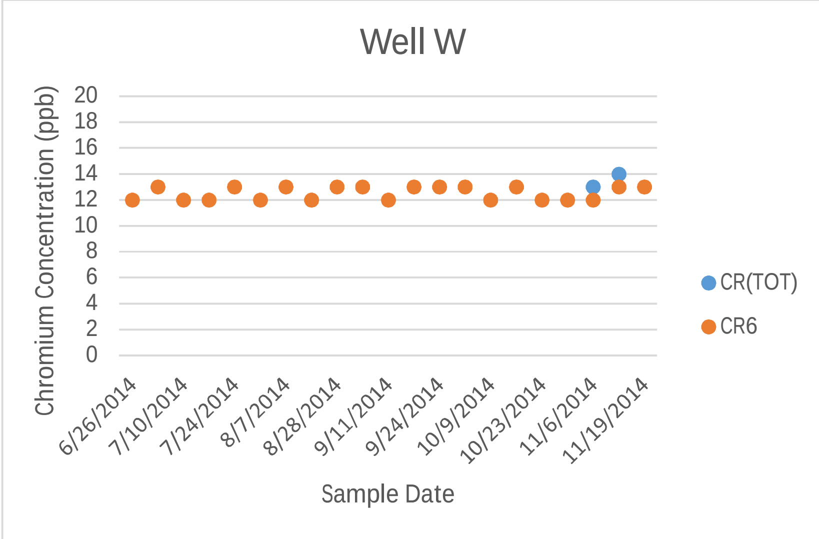
Sample Date
CR(TOT)
CR6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Chromium Concentration (ppb)
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6
4
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6/26/2014
7/10/2014
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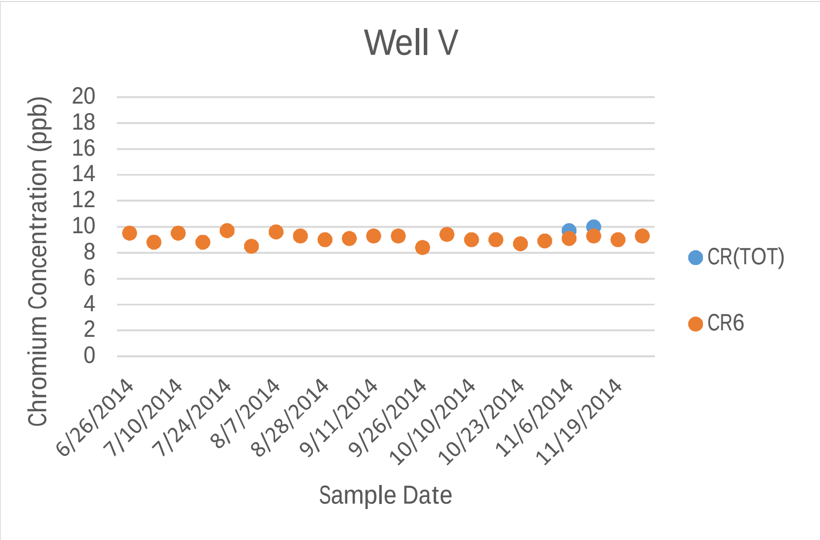
Sample Date
CR(TOT)
CR6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Chromium Concentration (ppb)
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12
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8
6
4
2
0
6/26/2014
7/10/2014
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8/7/2014
8/28/2014
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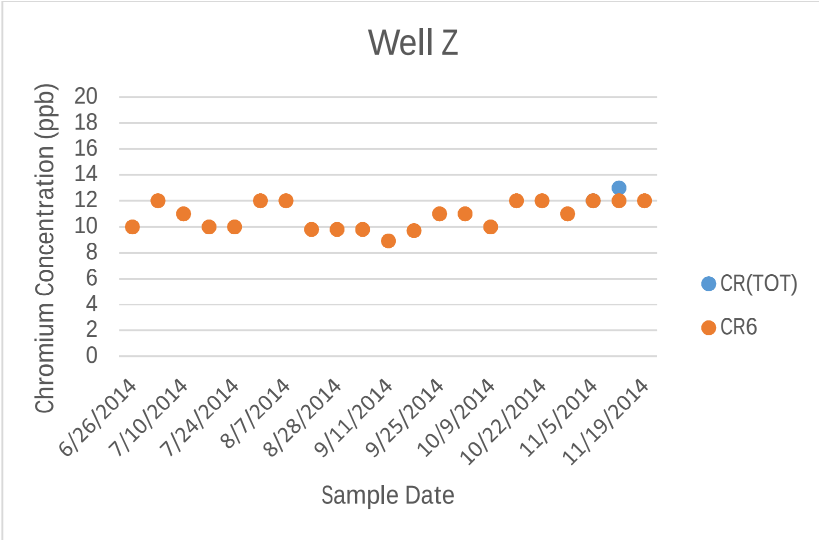
Sample Date
CR(TOT)
CR6


Well Z
Chromium Concentration (ppb)
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12
10
8
6
4
2
0
6/26/2014
7/10/2014
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8/7/2014
8/28/2014
9/11/2014
9/25/2014
10/9/2014
10/22/2014
11/5/2014
11/19/2014
Sample Date
CR(TOT)
CR6

Constituent Concentrations

	ANALYTE																			
	CR6 (ug/L)				Total Chromium (ug/L)				SO4 (mg/L)				ALKALINITY (mg/L)				Calcium (mg/L)			
CWA Wells	Count	MIN	MAX	Average	Count	MIN	MAX	Average	Count	MIN	MAX	Average	Count	MIN	MAX	Average	Count	MIN	MAX	Average
WELL 12	5	19	23	21	6	18	22	20	6	32	49	42	6	80	89	85	2	23	26	25
WELL 16	5	14	17	15	6	14	20	17	6	26	51	41	6	80	88	83	2	17	20	19
WELL 17	5	15	23	21	6	17	25	21	6	27	33	30	6	79	89	84	2	21	22	22
WELL 18	5	10	14	13	6	9.5	13	12	6	38	64	56	6	76	82	80	2	11	13	12
WELL 19	5	15	21	19	6	18	23	19	6	23	29	25	6	91	95	94	2	19	22	21

	ANALYTE																			
	PH				Hardness (mg/L)				TDS (mg/L)				Vanadium (ug/L)				Chlorine (mg/L)			
CWA Wells	Count	MIN	MAX	Average	Count	MIN	MAX	Average	Count	MIN	MAX	Average	Count	MIN	MAX	Average	Count	MIN	MAX	Average
WELL 12	6.0	7.9	8.2	8	2	65	73	69	6	170	240	212	4	16	21	18	4	17	19	18
WELL 16	6.0	8.1	8.3	8	2	48	54	51	6	150	240	192	4	22	24	23	4	8.9	10	10
WELL 17	6.0	8.0	8.3	8	2	59	62	61	6	110	190	168	4	23	26	25	4	9.7	11	10
WELL 18	6.0	8.0	8.5	8	2	34	39	37	6	140	230	198	4	26	28	27	4	9.6	12	11
WELL 19	6.0	7.8	8.3	8	2	60	68	64	6	140	220	177	4	23	24	23	4	8.4	9.9	9

Table 1 CWA well constituent concentrations for various analytes

	ANALYTE																			
	CR6 (ug/L)				Total Chromium (ug/L)				SO4 (mg/L)				Alkalinity (mg/L)				Calcium (mg/L)			
IWA Well	Average	MIN	MAX	Count	Average	MIN	MAX	Count	Average	MIN	MAX	Count	Average	MIN	MAX	Count	Average	MIN	MAX	Count
WELL 1B	12	7.8	16	25	11	7.6	15	7	108	92	180	10	98	91	110	9	86	86	86	1
WELL 1C	9	9	10	25	10	9.1	12	7	101	94	110	10	100	92	110	9	46	46	46	1
WELL 1E	17	14	18	24	16	13	19	6	39	35	43	9	90	83	93	9	22	22	22	1
WELL 2C	17	15	18	22	16	12	18	7	25	23	27	9	98	92	110	9	22	22	22	1
WELL 2D	17	15	18	24	17	13	19	7	22	20	23	9	99	88	110	9	23	23	23	1
WELL 3A	14	13	14	23	12	8.2	16	4	38	31	44	9	112	110	120	9	42	42	42	1
WELL 3B	13	12	13	25	13	9.4	15	7	22	20	30	9	113	110	120	9	34	34	34	1
WELL 3C	16	15	18	25	16	12	18	7	28	20	35	9	108	90	120	8	21	21	21	1
WELL 4A	9	8.7	9.8	24	11	8.9	16	6	29	26	32	9	106	98	120	9	29	29	29	1
WELL 4B	9	8.3	9	22	10	7.5	14	7	32	28	35	6	110	100	120	6	31	31	31	1
WELL 4C	9	7.5	10	25	9	8.2	11	7	40	37	43	9	101	96	110	9	32	32	32	1
WELL 13A	14	13	15	25	14	12	17	9	95	91	97	9	88	79	97	9	28	28	28	1
WELL AA	15	13	18	25	16	13	19	9	23	22	25	9	107	94	120	9	28	28	28	1
WELL BB	17	9.6	20	26	17	15	20	9	50	46	53	9	88	82	97	9	23	23	23	1
WELL S	8	6.7	8.5	26	8	6.6	8.9	9	116	82	130	9	86	79	94	9	76	76	76	1
WELL T	10	8.6	11	27	10	9.6	11	11	22	19	34	9	106	96	110	9	25	25	25	1
WELL U	12	3	15	28	13	8.6	15	11	61	52	76	9	98	91	110	9	38	38	38	1
WELL V	9	8.4	10	27	9	8.4	11	9	54	48	60	9	93	86	100	9	36	36	36	1
WELL W	12	12	13	25	12	10	14	9	23	19	28	9	116	100	120	9	33	33	33	1
WELL Z	11	8.9	12	25	11	8.9	13	9	19	18	22	9	102	98	110	9	24	24	24	1

	ANALYTE																			
	PH				Hardness (mg/L)				TDS (mg/L)				Vanadium (ug/L)				Chlorine (mg/L)			
IWA Well	Average	MIN	MAX	Count	Average	MIN	MAX	Count	Average	MIN	MAX	Count	Average	MIN	MAX	Count	Average	MIN	MAX	Count
WELL 1B	8	7.7	8.1	9	250	250	250	1	357	320	520	9	13	11	21	8	36	34	37	2
WELL 1C	8	7.8	8.1	9	140	140	140	1	322	300	340	9	13	11	19	8	28	27	28	2
WELL 1E	8	7.9	8.3	9	73	73	73	1	183	150	200	9	20	14	24	8	9	8.8	8.9	2
WELL 2C	8	7.7	8.3	9	70	70	70	1	174	150	200	9	18	14	25	8	9	8.5	8.8	2
WELL 2D	8	7.8	8.3	9	73	73	73	1	174	160	190	9	18	15	26	8	8	7.6	7.7	2
WELL 3A	8	7.8	8.2	9	130	130	130	1	227	210	250	9	16	14	23	8	14	13	14	2
WELL 3B	8	7.8	8.2	9	110	110	110	1	183	170	210	9	14	12	21	8	7	7.2	7.4	2
WELL 3C	8	7.8	8.2	8	63	63	63	1	193	180	210	8	18	16	23	8	12	11	12	2
WELL 4A	8	7.8	8.2	9	99	99	99	1	204	200	210	9	14	12	20	8	10	10	10	2
WELL 4B	8	7.8	8.2	6	110	110	110	1	208	190	220	6	11	10	13	5	12	12	12	1
WELL 4C	8	7.8	8.2	9	110	110	110	1	230	200	270	9	13	12	15	8	17	16	17	2
WELL 13A	8	7.8	8.2	8	93	93	93	1	282	260	300	9	17	14	24	10	16	16	16	2
WELL AA	8	7.7	8.2	8	91	91	91	1	188	180	200	9	17	14	24	10	9	8.4	8.8	2
WELL BB	8	7.5	8.3	9	73	73	73	1	203	190	230	9	24	18	30	10	9	9.3	9.4	2
WELL S	8	7.7	8.2	8	220	220	220	1	384	320	420	9	13	12	18	10	48	47	48	2
WELL T	8	7.7	8.2	8	86	86	86	1	186	170	220	9	16	14	23	10	9	8.8	8.9	2
WELL U	8	7.7	8.2	8	110	110	110	1	274	220	320	9	15	13	20	10	27	25	29	2
WELL V	8	7.7	8.2	9	120	120	120	1	251	230	270	9	14	12	21	10	23	22	23	2
WELL W	8	7.7	8.3	8	110	110	110	1	201	190	220	11	15	12	22	10	9	8.8	9.1	2
WELL Z	8	7.8	8.2	8	79	79	79	1	168	160	180	9	19	16	26	10	7	6.4	7	2

Table 2 IWA well constituent concentrations for various analytes

Appendix C: Well Production Data

HAZEN AND SAWYER
Environmental Engineers & Scientists

Project Number: 20038-000

APPENDIX C

Water Production Data

The following figures show well production information for CWA and IWA wells.

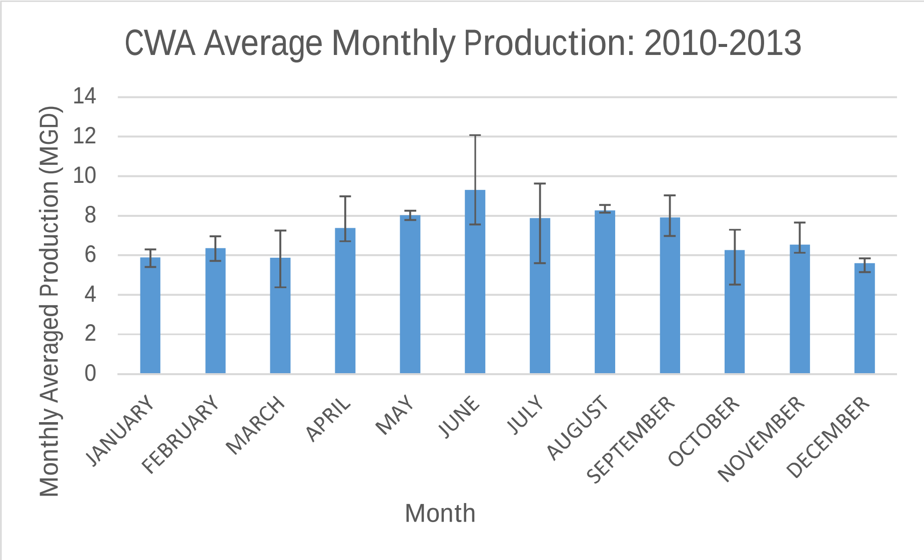


Figure 1 CWA Monthly Average Well Production

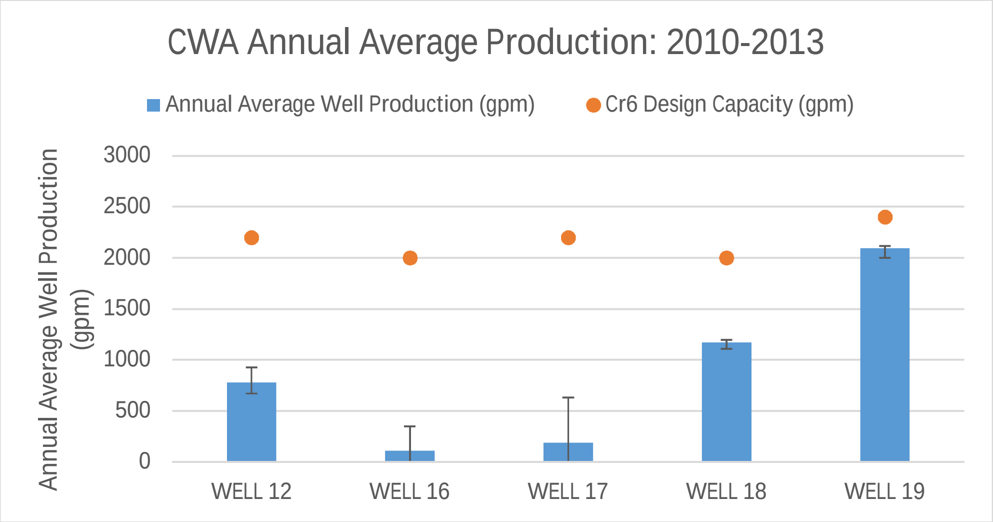


Figure 2 CWA Annual Average Well Production

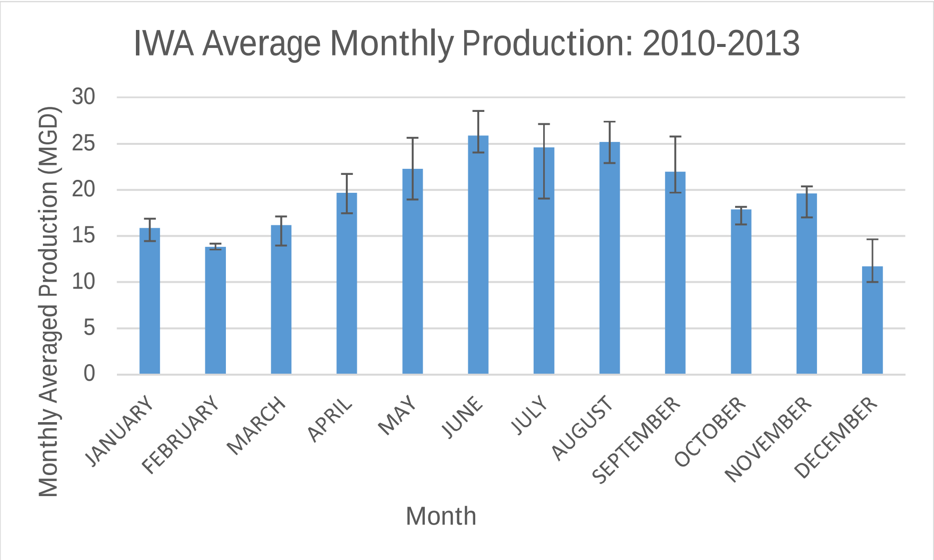


Figure 3 IWA Monthly Average Well Production

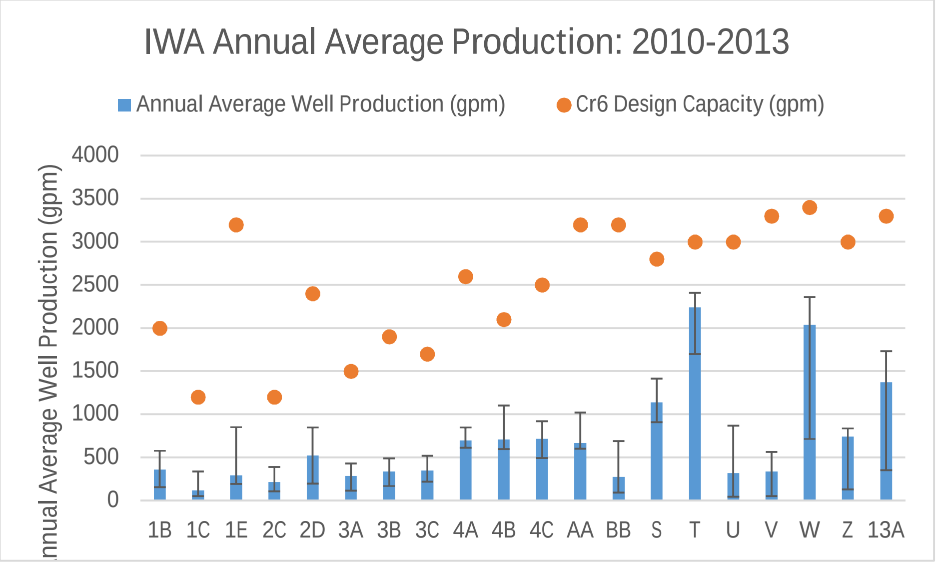


Figure 4 IWA Annual Average Well Production

Appendix D: Example Facility Footprints

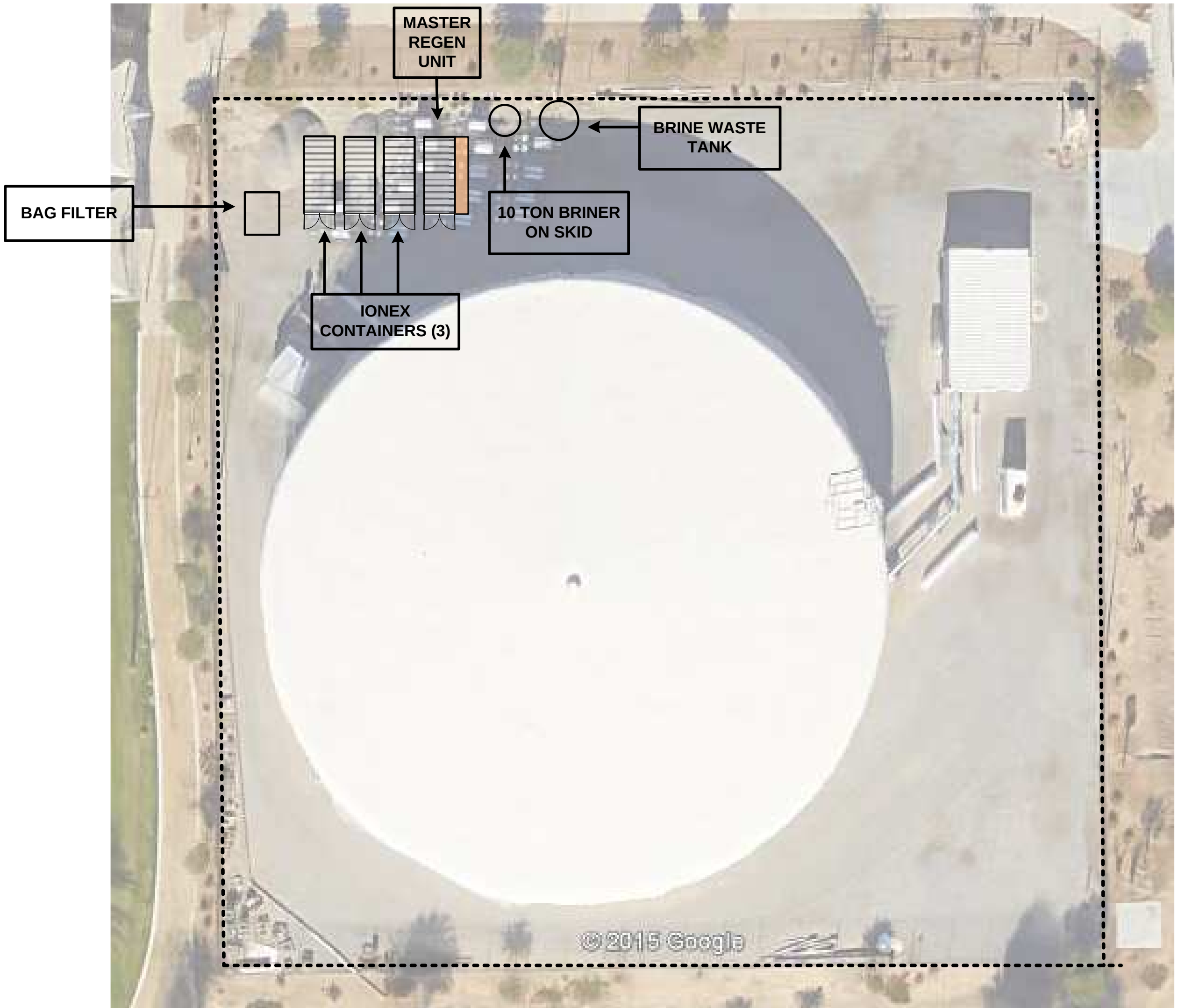
HAZEN AND SAWYER
Environmental Engineers & Scientists

Project Number: 20038-000

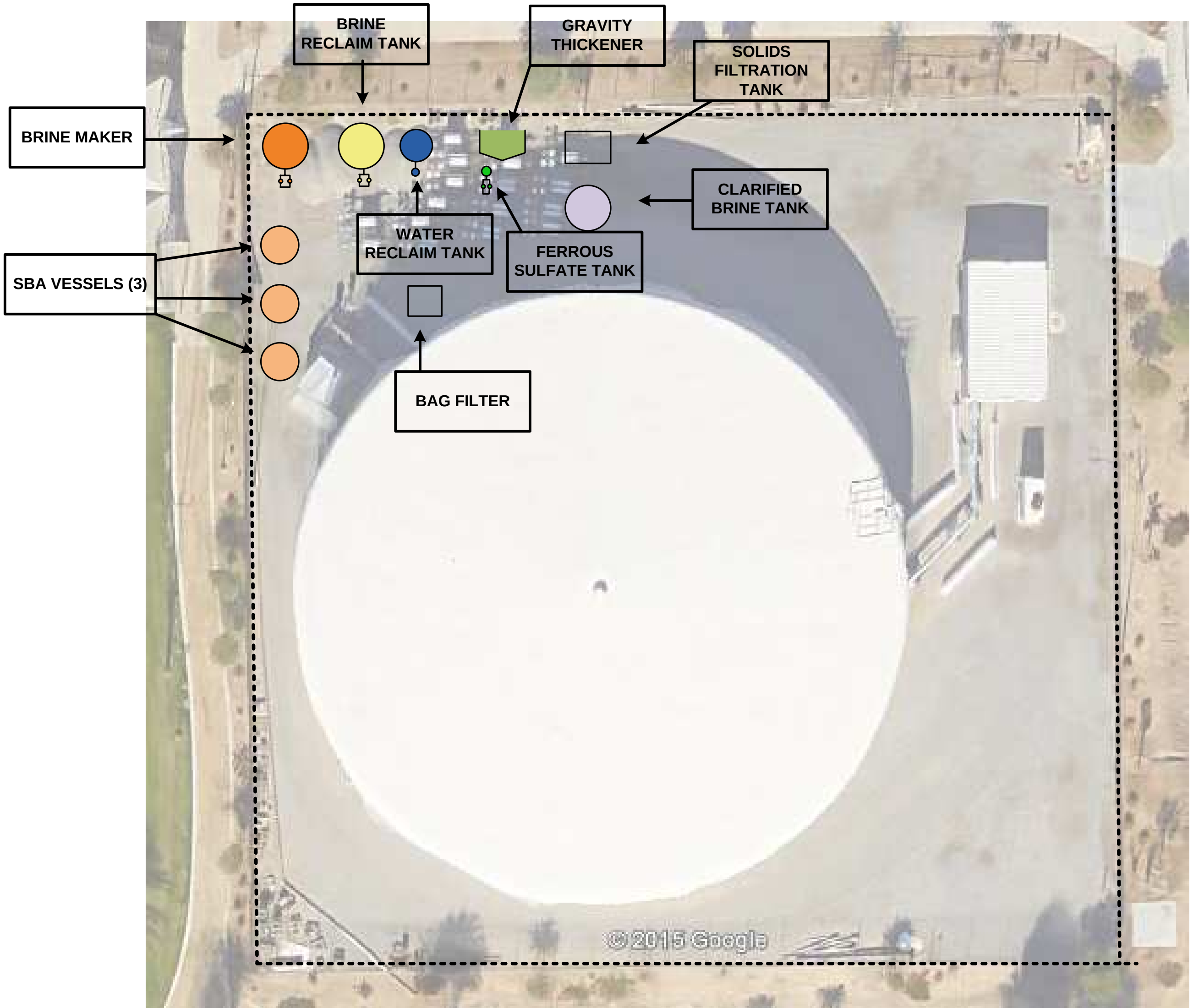
APPENDIX D

Example Facility Footprints

The following figures show example facility footprints for SBA treatment options of CWA and IWA wells.



N	Containerized SBA Well Capacity: 2,200 gpm Treatment Capacity: 1,600 gpm	WELL 12 SCALE 1"= 30 ft

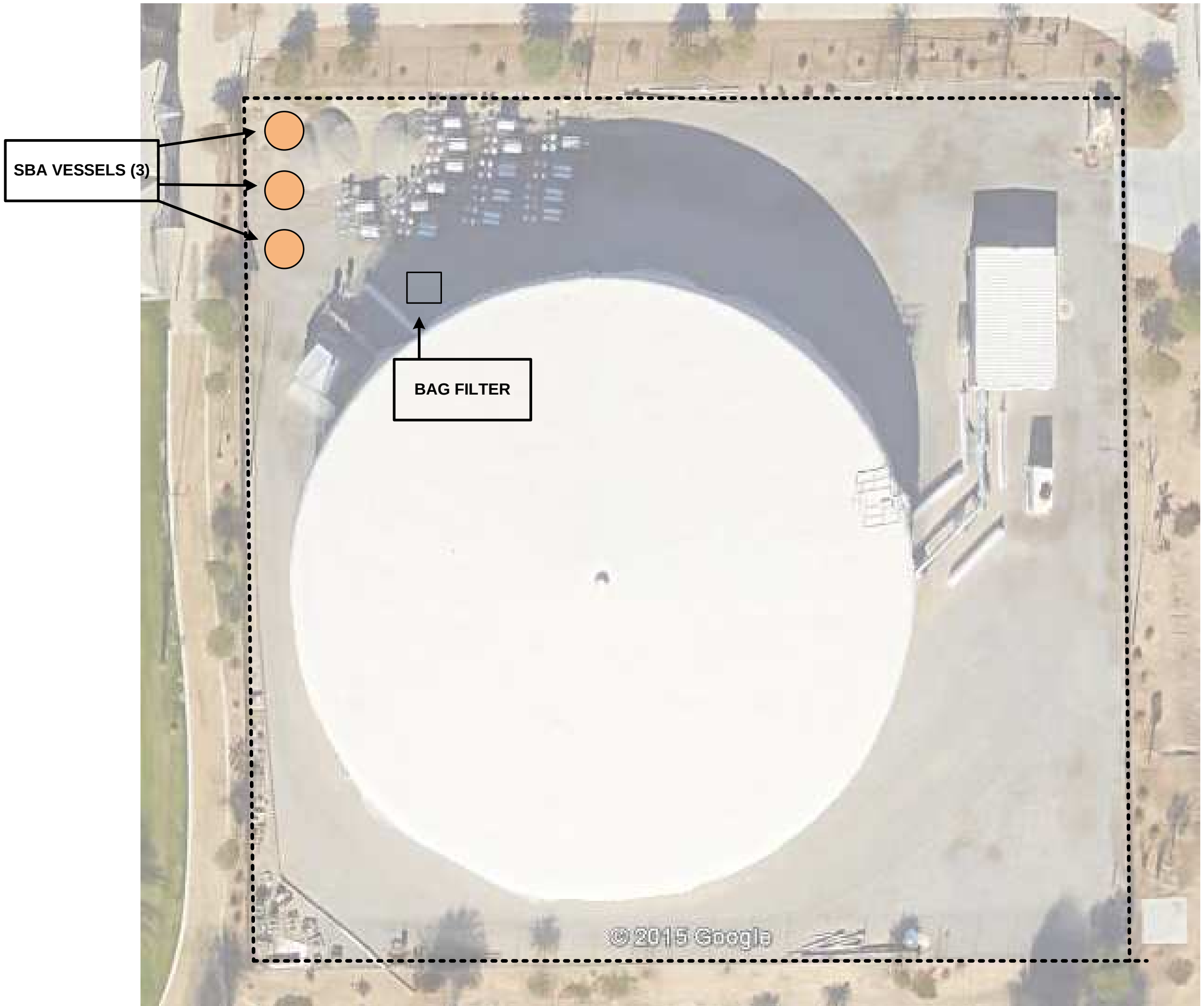


N

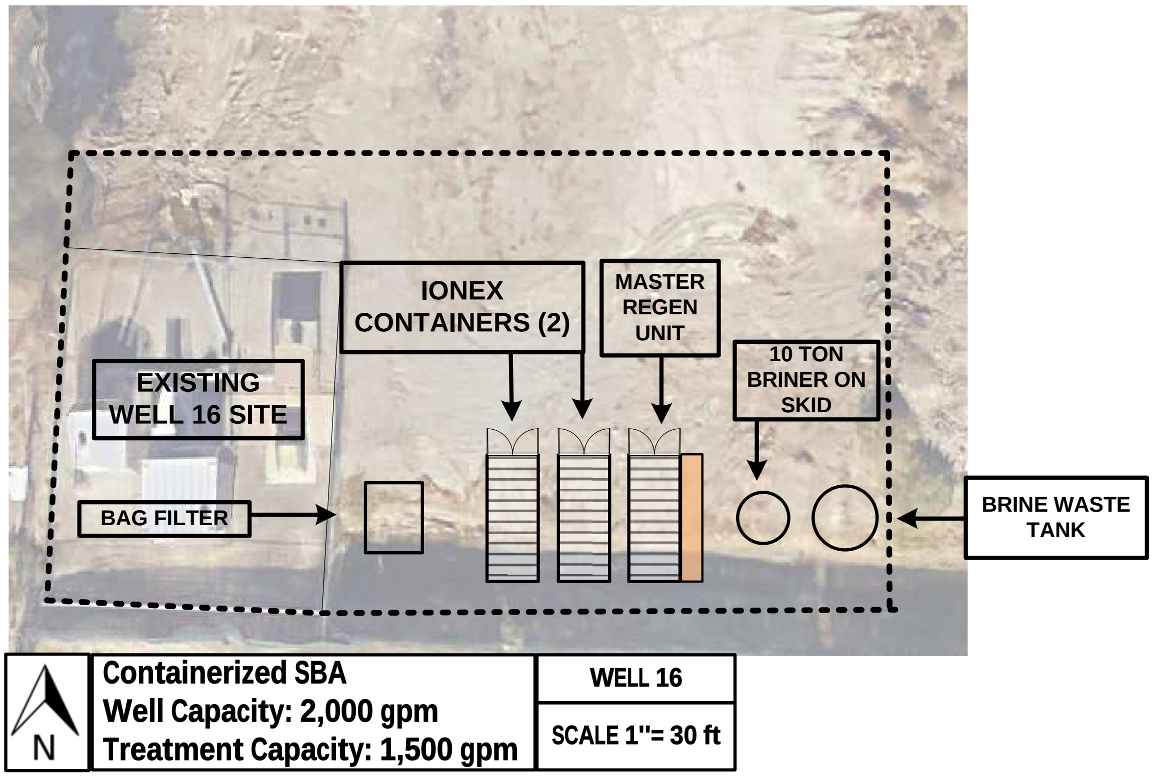
SBA with onsite brine trmt
Well Capacity: 2,200 gpm
Treatment Capacity: 1,600 gpm

WELL 12

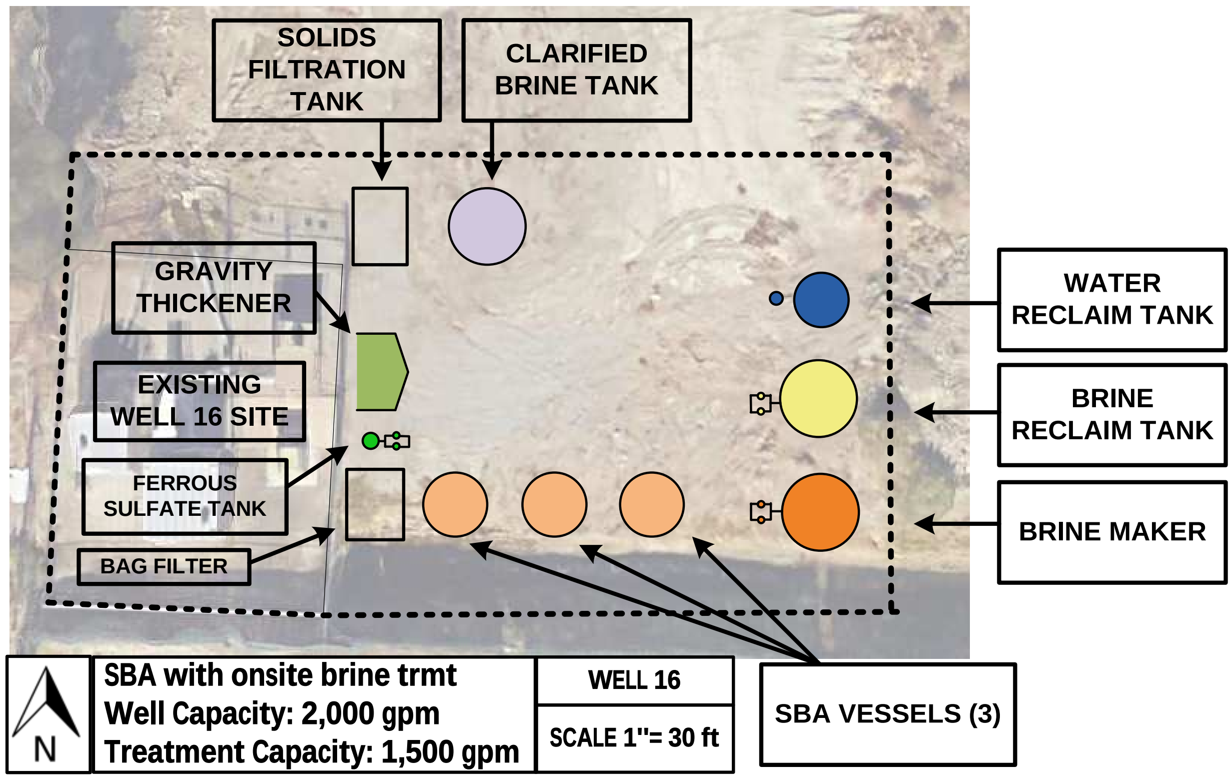
SCALE 1"= 30 ft

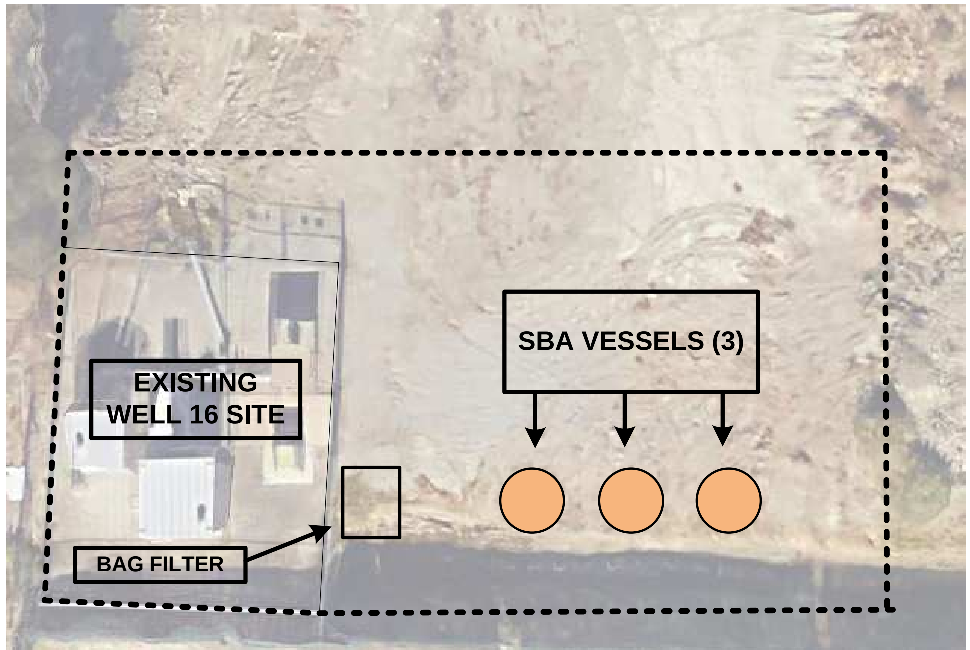


N	Centralized SBA Well Capacity: 2,200 gpm Treatment Capacity: 1,600 gpm	WELL 12 SCALE 1"= 30 ft

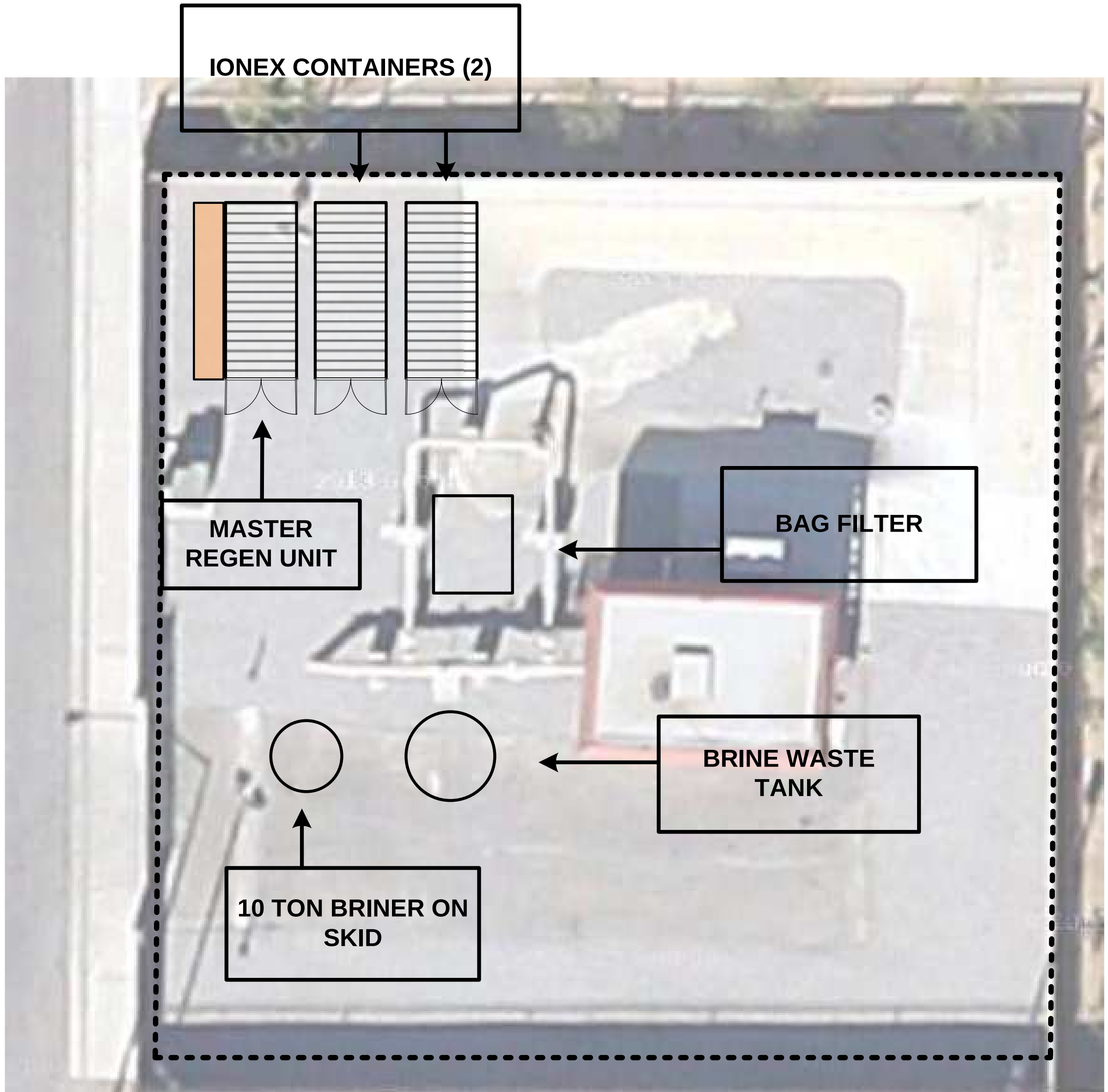


Containerized SBA Well Capacity: 2,000 gpm Treatment Capacity: 1,500 gpm	WELL 16	SCALE 1"= 30 ft


SOLIDS FILTRATION TANK
CLARIFIED BRINE TANK
GRAVITY THICKENER
EXISTING WELL 16 SITE
FERROUS SULFATE TANK
BAG FILTER
WATER RECLAIM TANK
BRINE RECLAIM TANK
BRINE MAKER
SBA VESSELS (3)
N
SBA with onsite brine trmt
Well Capacity: 2,000 gpm
Treatment Capacity: 1,500 gpm
WELL 16
SCALE 1"= 30 ft



N	**Centralized SBA** **Well Capacity: 2,000 gpm** **Treatment Capacity: 1,500 gpm**	**WELL 16** **SCALE 1"= 30 ft**

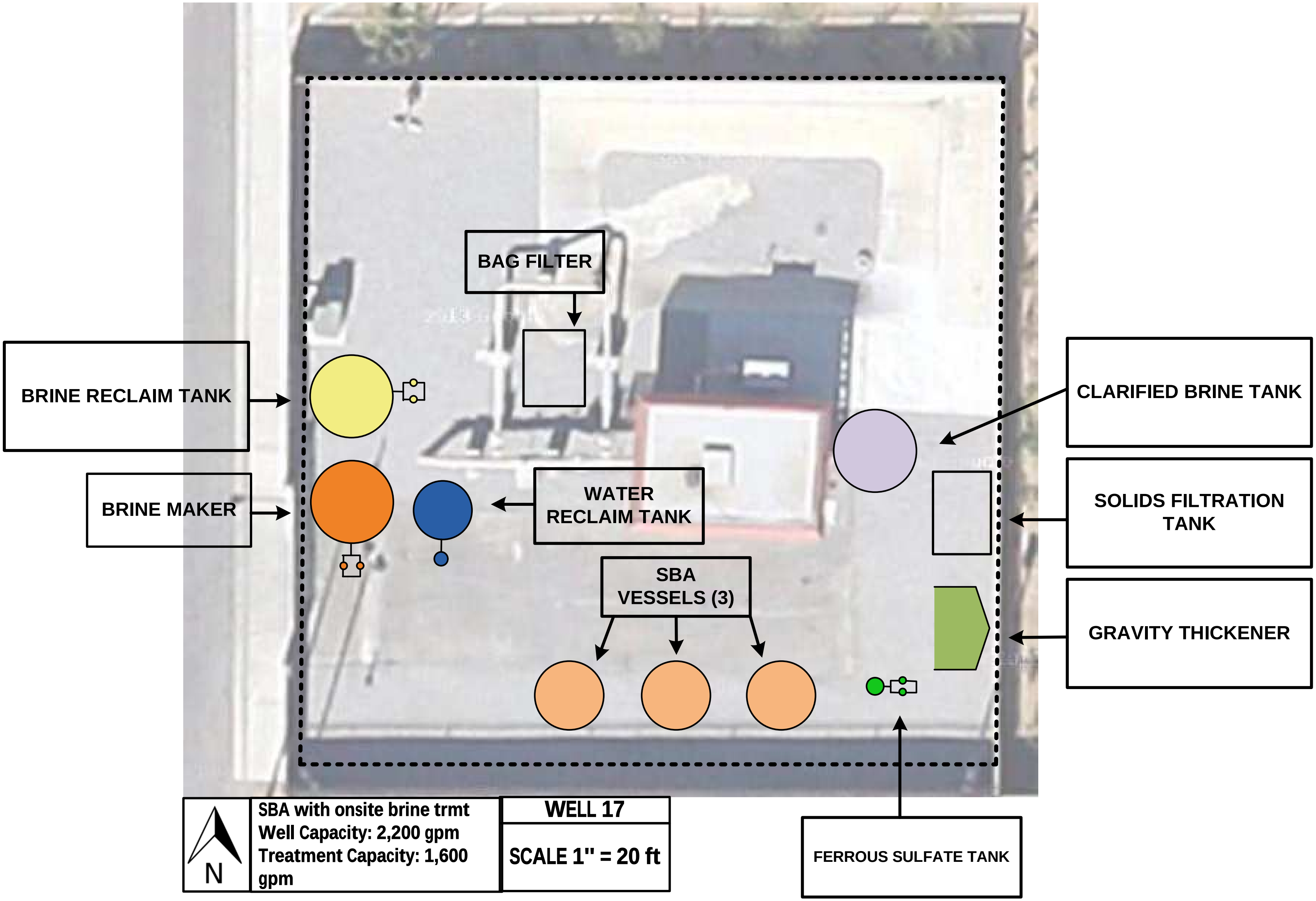


N

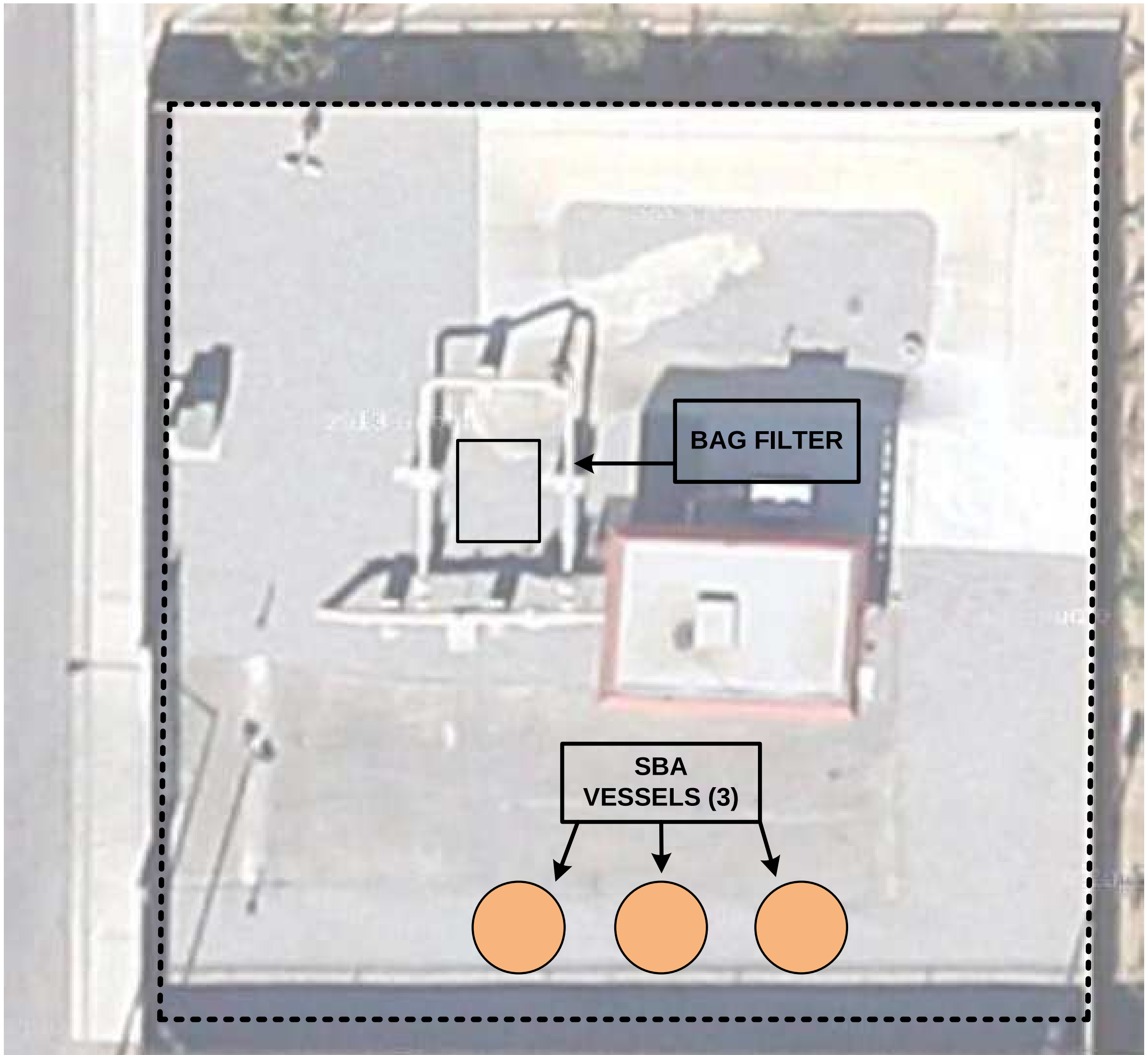
Containerized SBA
Well Capacity: 2,200 gpm
Treatment Capacity: 1,600 gpm

WELL 17

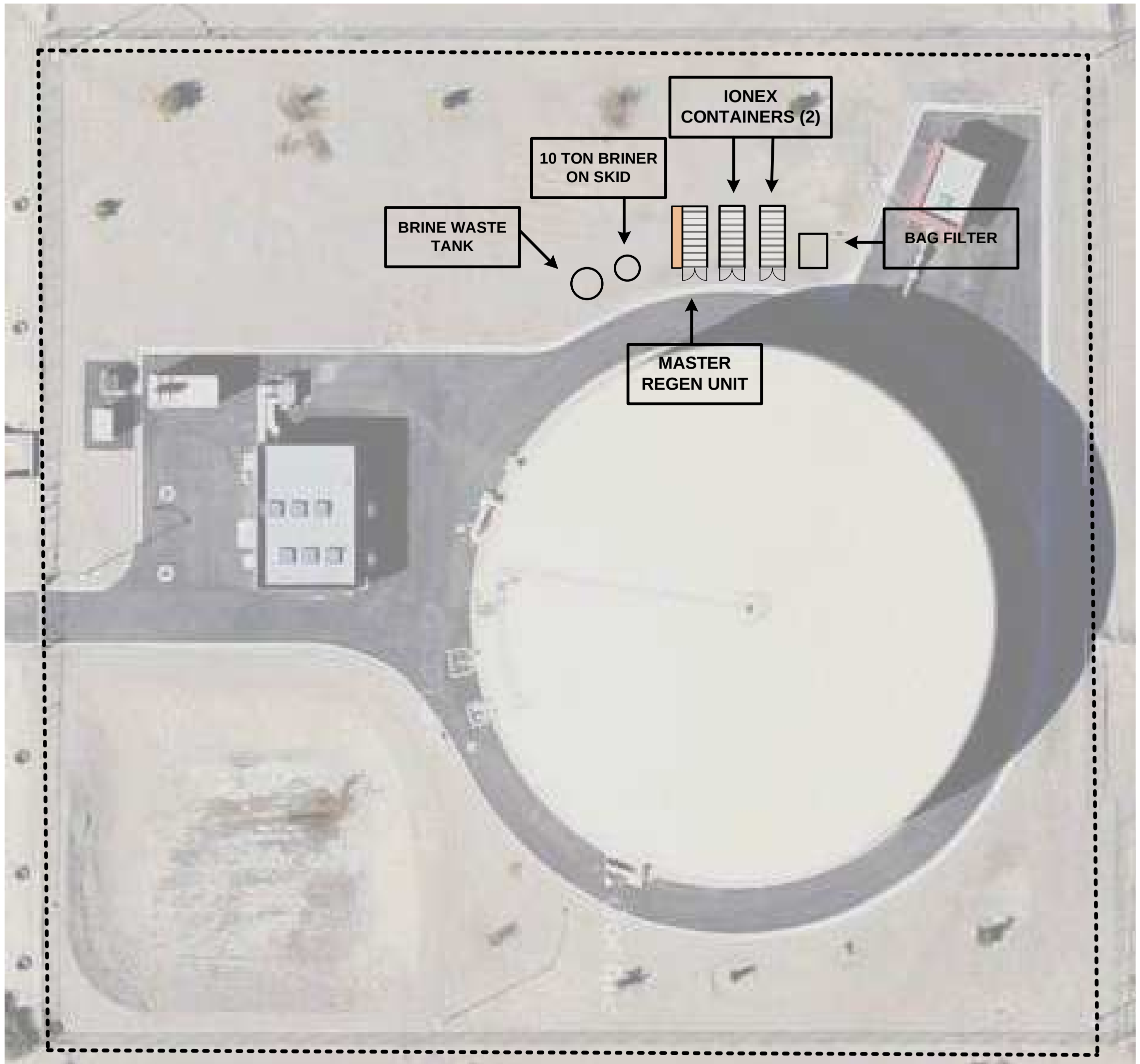
SCALE 1" = 20 ft



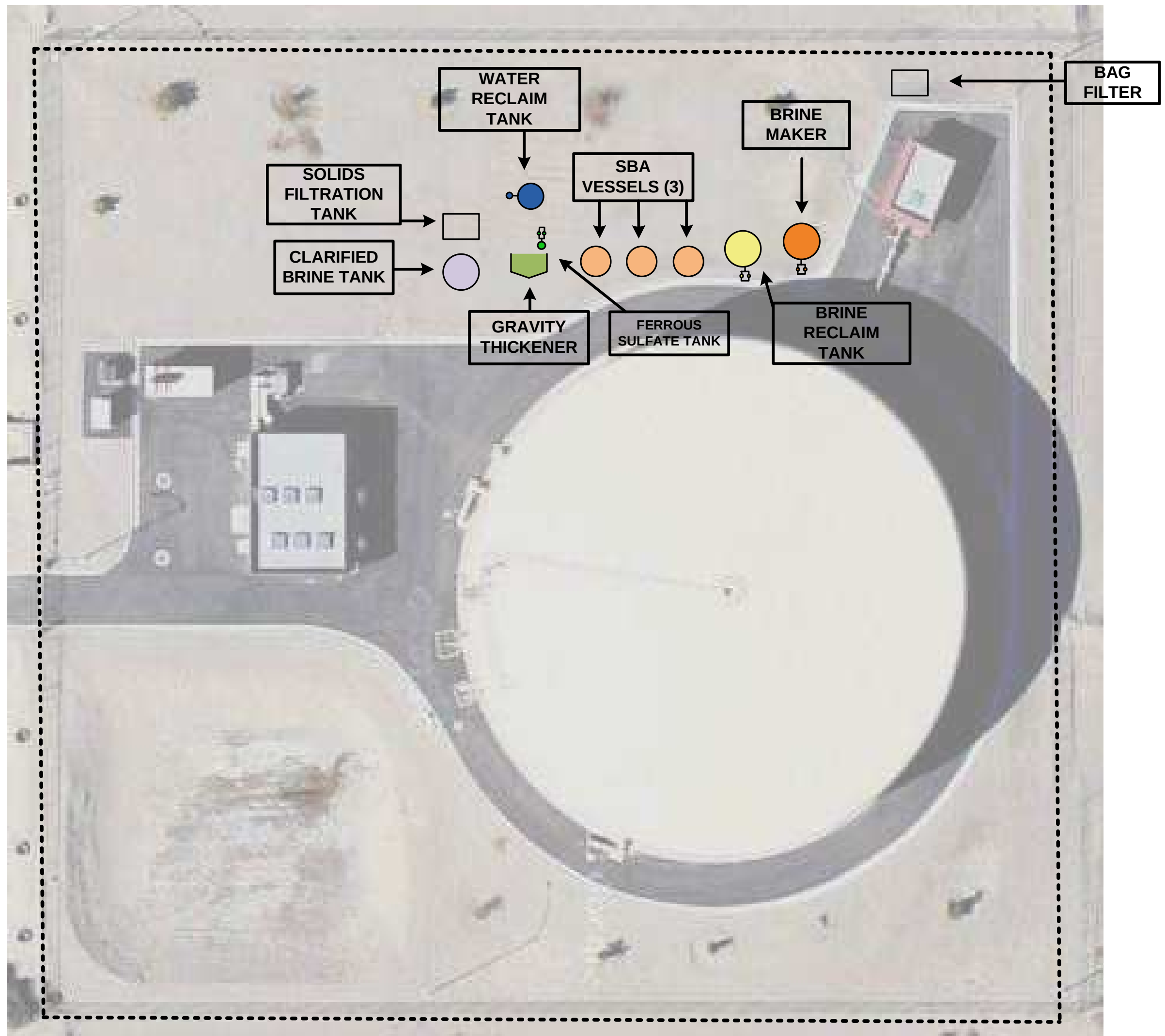
SBA with onsite brine trmt Well Capacity: 2,200 gpm Treatment Capacity: 1,600 gpm	WELL 17 SCALE 1" = 20 ft



N	Centralized SBA Well Capacity: 2,200 gpm Treatment Capacity: 1,600 gpm	WELL 17 SCALE 1" = 20 ft



N	Containerized SBA Well Capacity: 2,000 gpm Treatment Capacity: 1,400 gpm	WELL 18 SCALE 1" = 40ft



N

SBA with onsite brine trmt
Well Capacity: 2,000 gpm
Treatment Capacity: 1,400 gpm

WELL 18

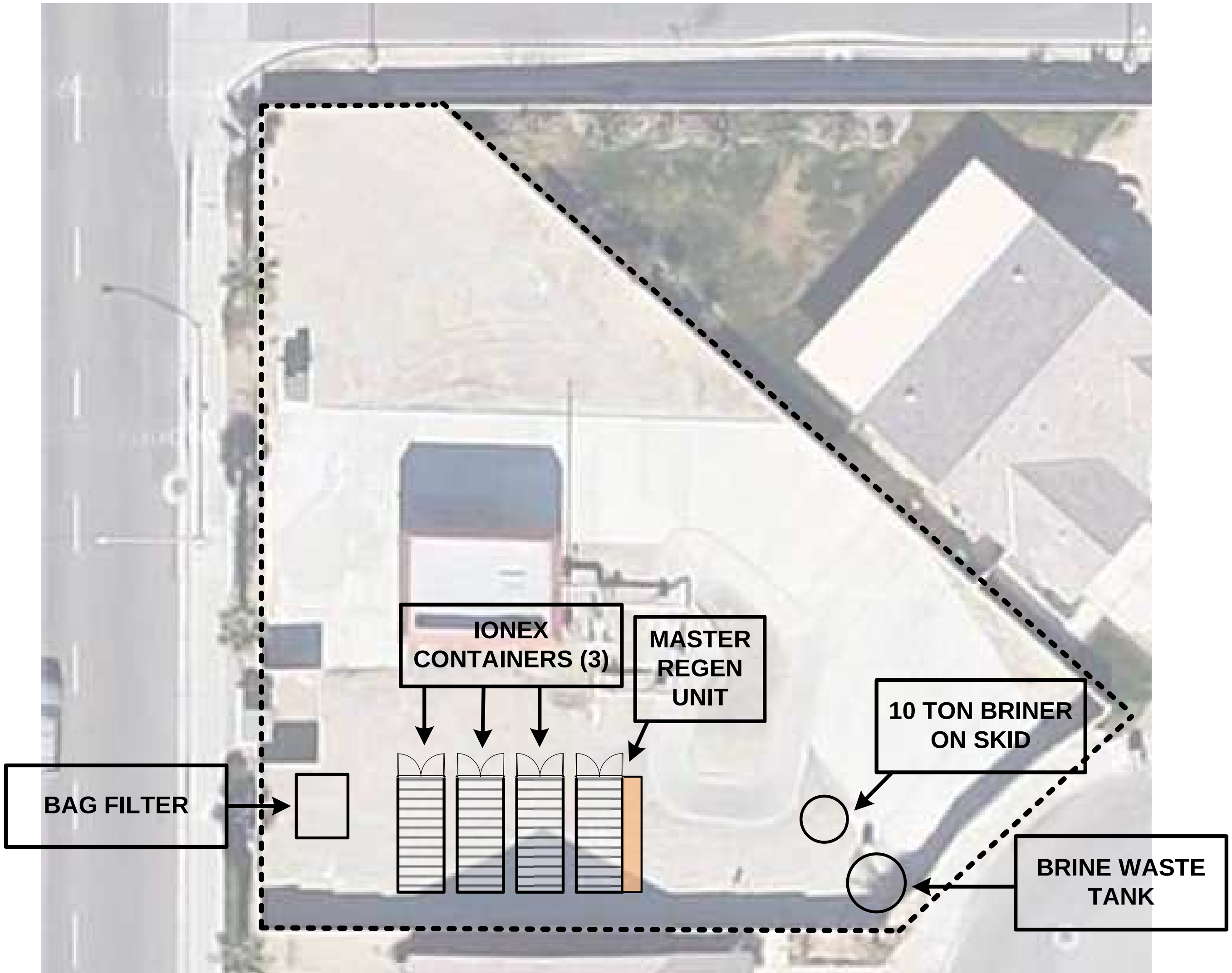
SCALE 1" = 40ft

N

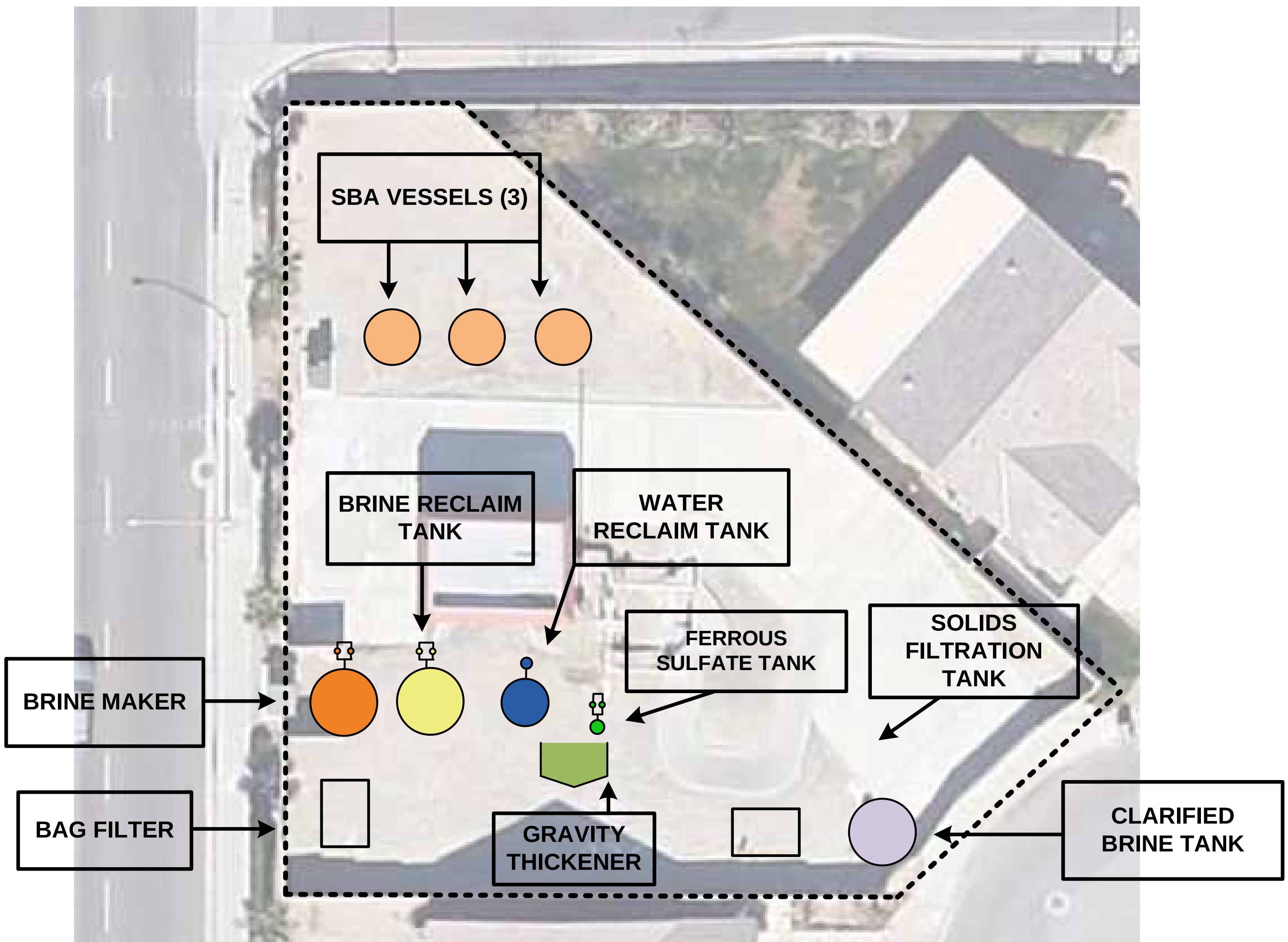
Centralized SBA
Well Capacity: 2,000 gpm
Treatment Capacity: 1,400 gpm

WELL 18

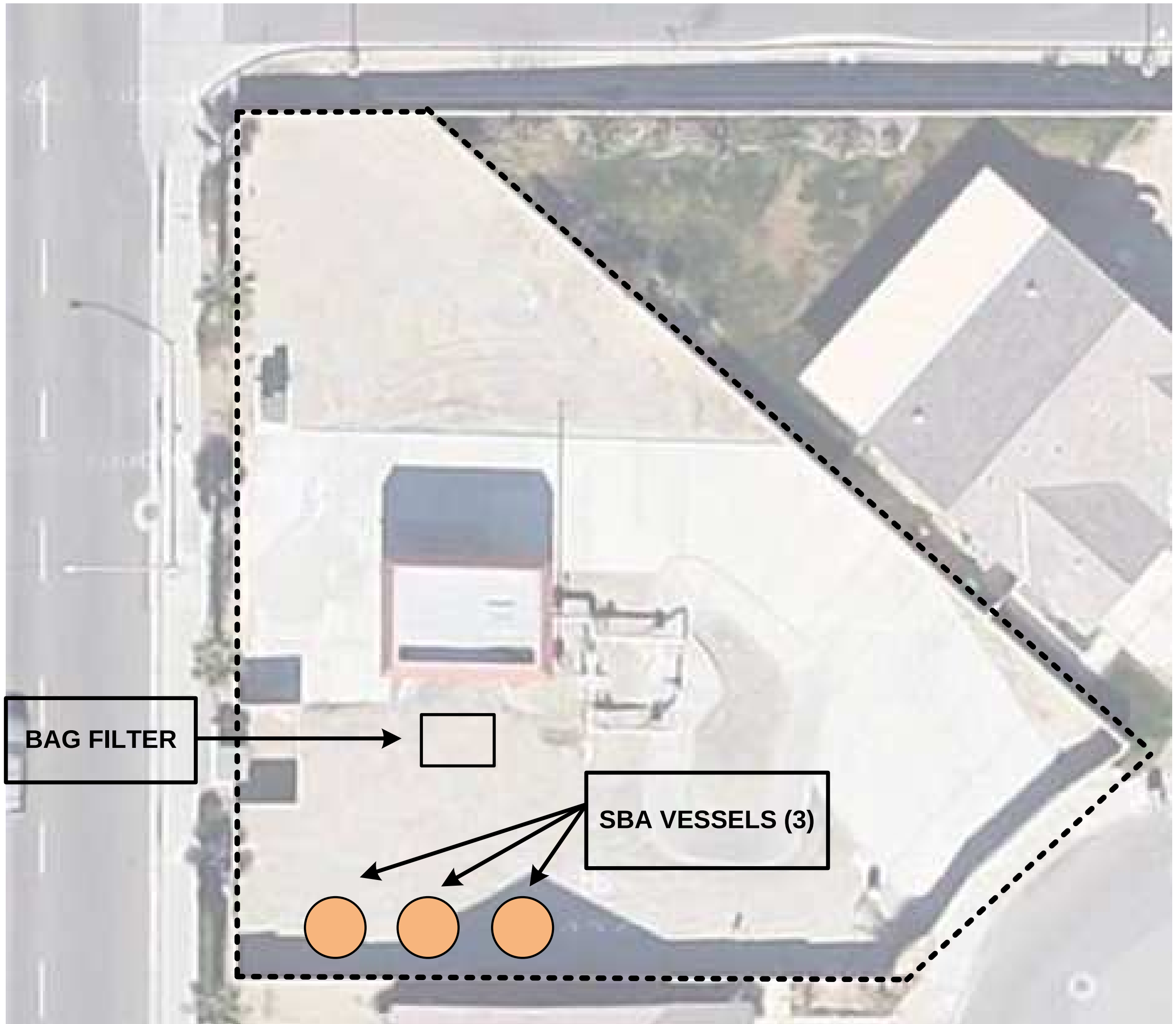
SCALE 1" = 40ft



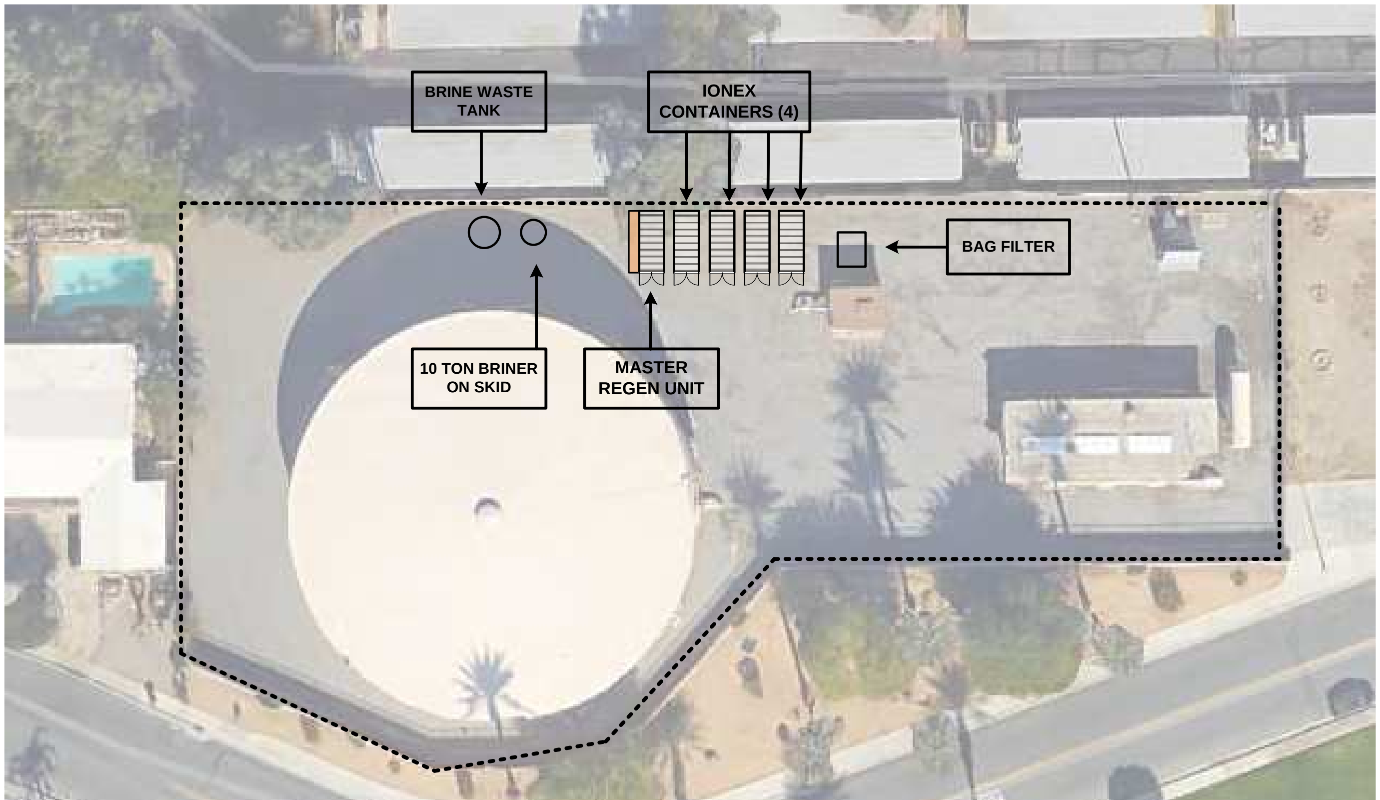
N	Containerized SBA Well Capacity: 2,400 gpm Treatment Capacity: 1,900 gpm	WELL 19 SCALE 1"= 30 ft



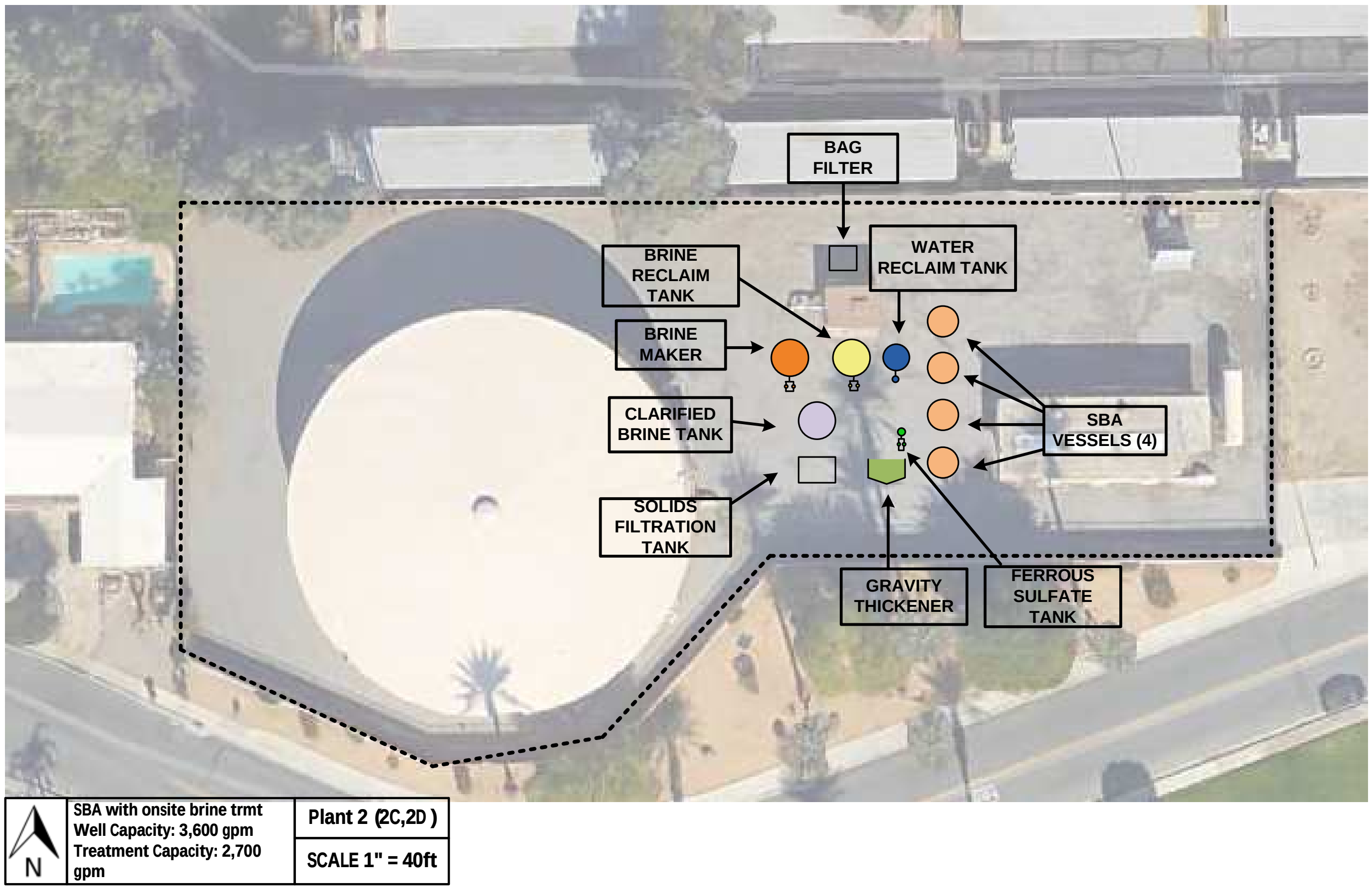
N	SBA with onsite brine trmt Well Capacity: 2,400 gpm Treatment Capacity: 1,900 gpm	WELL 19 SCALE 1"= 30 ft



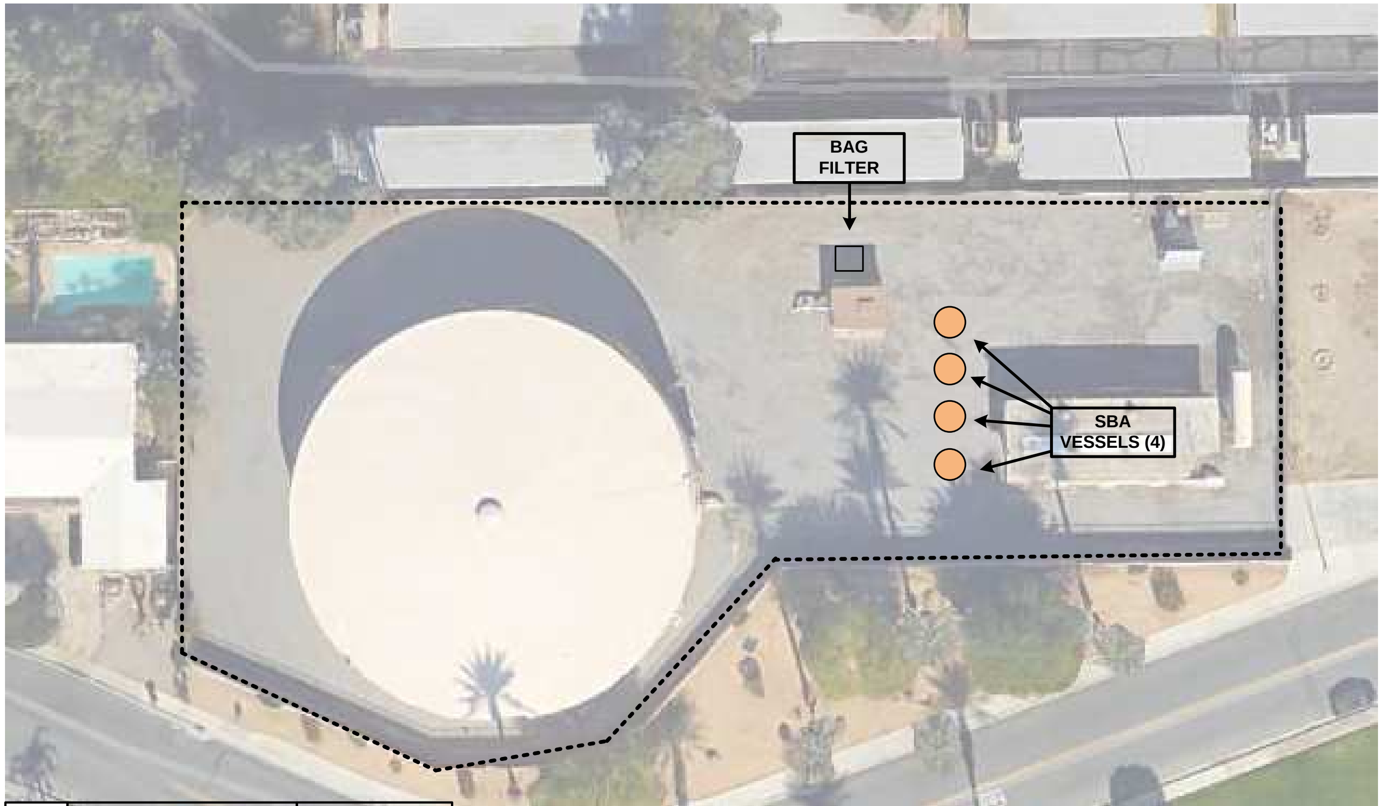
N	Centralized SBA Well Capacity: 2,400 gpm Treatment Capacity: 1,900 gpm	WELL 19 SCALE 1"= 30 ft



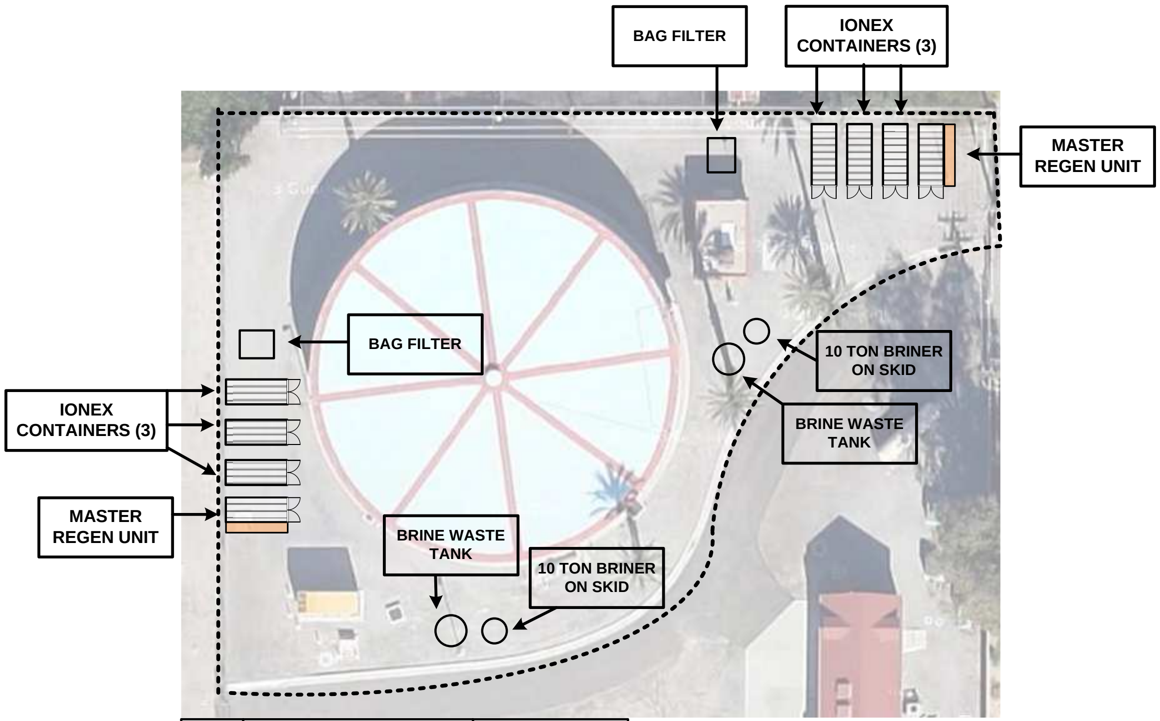
N	Containerized SBA Well Capacity: 3,600 gpm Treatment Capacity: 2,700 gpm	Plant 2 (2C,2D) SCALE 1" = 40ft



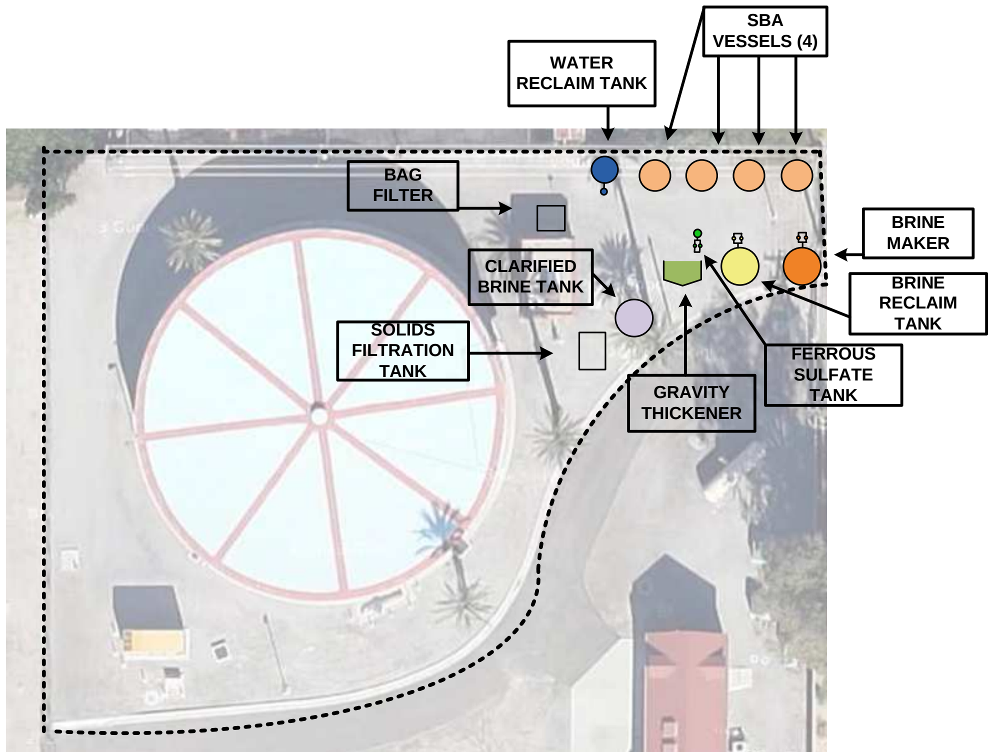
SBA with onsite brine trmt Well Capacity: 3,600 gpm Treatment Capacity: 2,700 gpm	Plant 2 (2C,2D)	SCALE 1" = 40ft



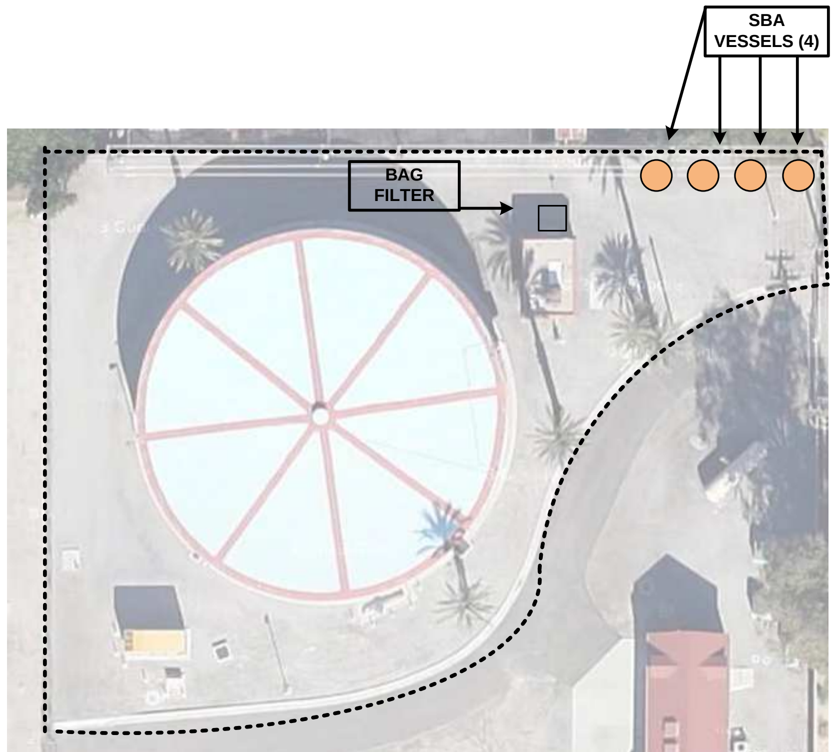
N	Centralized SBA Well Capacity: 3,600 gpm Treatment Capacity: 2,700 gpm	Plant 2 (2C,2D) SCALE 1" = 40ft



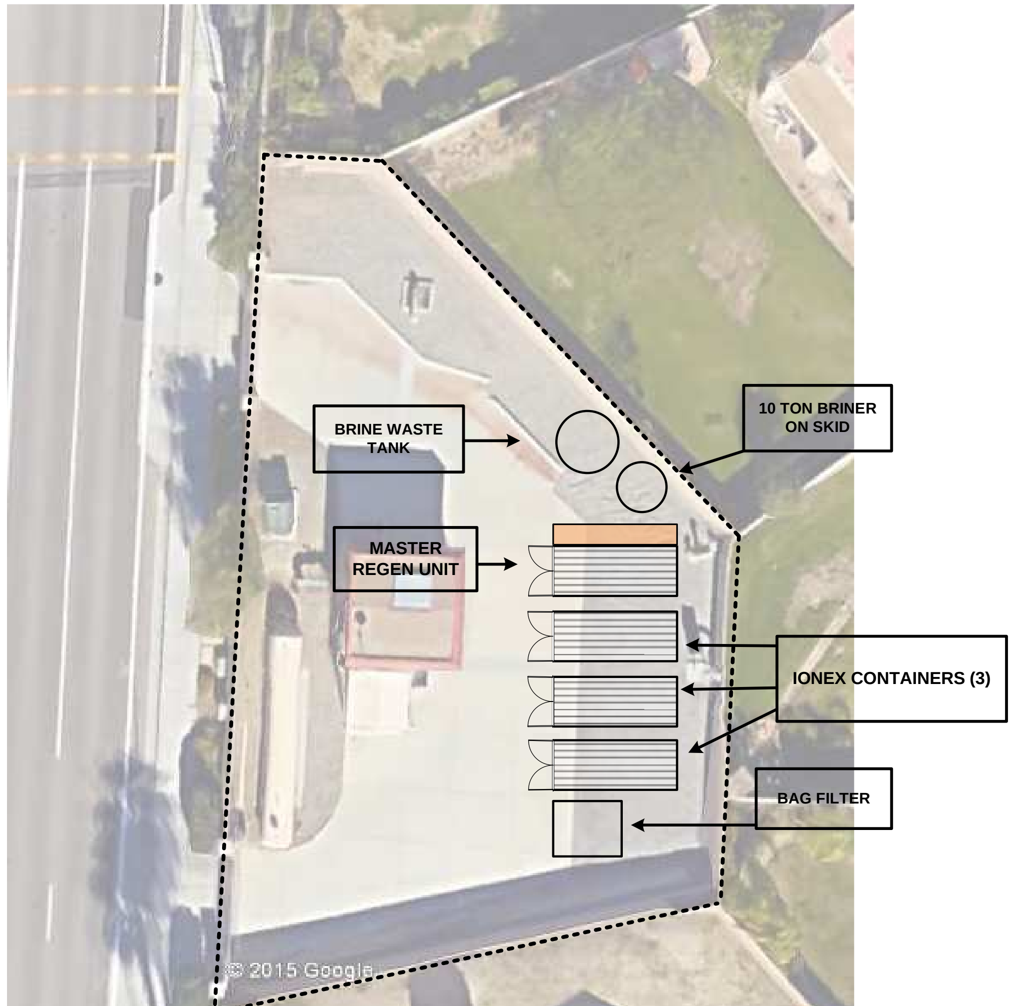
N	Containerized SBA Well Capacity: 5,100 gpm Treatment Capacity: 3,600 gpm	**Plant 3 (3A,3B,3C)** **SCALE 1" = 40ft**



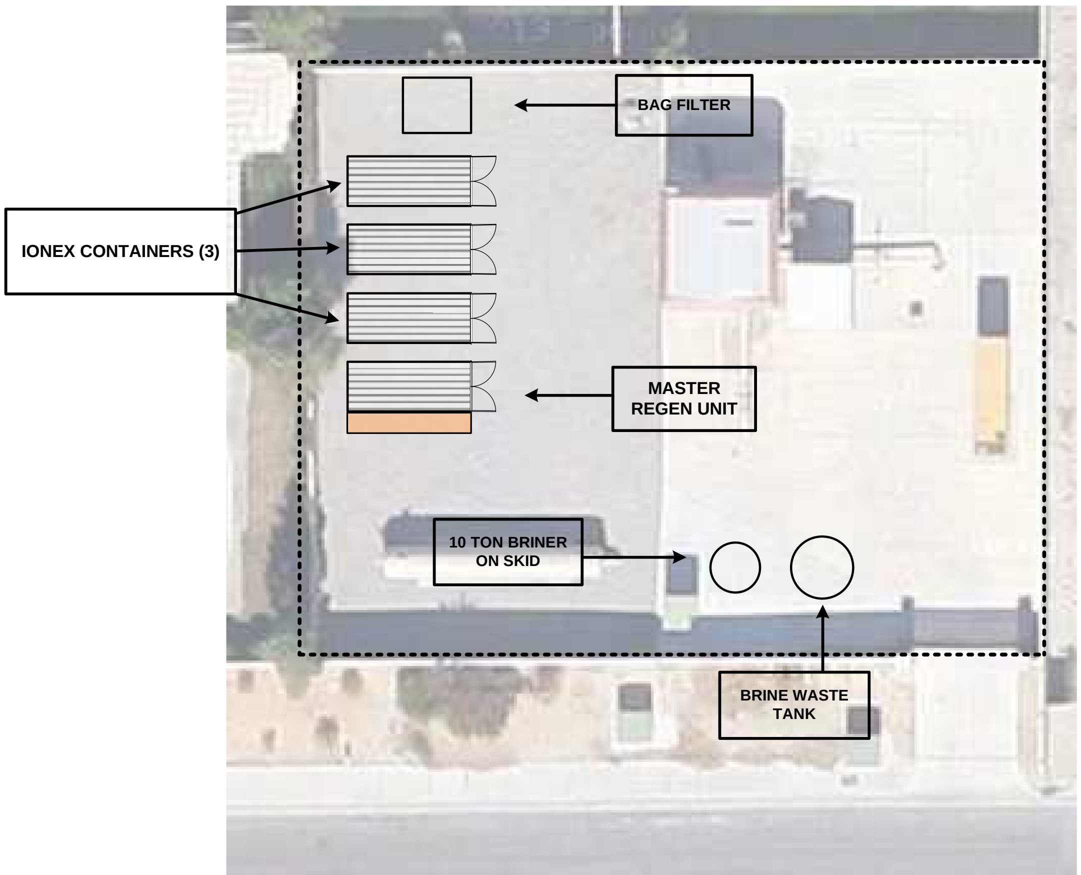
N	SBA with onsite brine trmt Well Capacity: 5,100 gpm Treatment Capacity: 3,600 gpm	Plant 3 (3A,3B,3C) SCALE 1" = 40ft



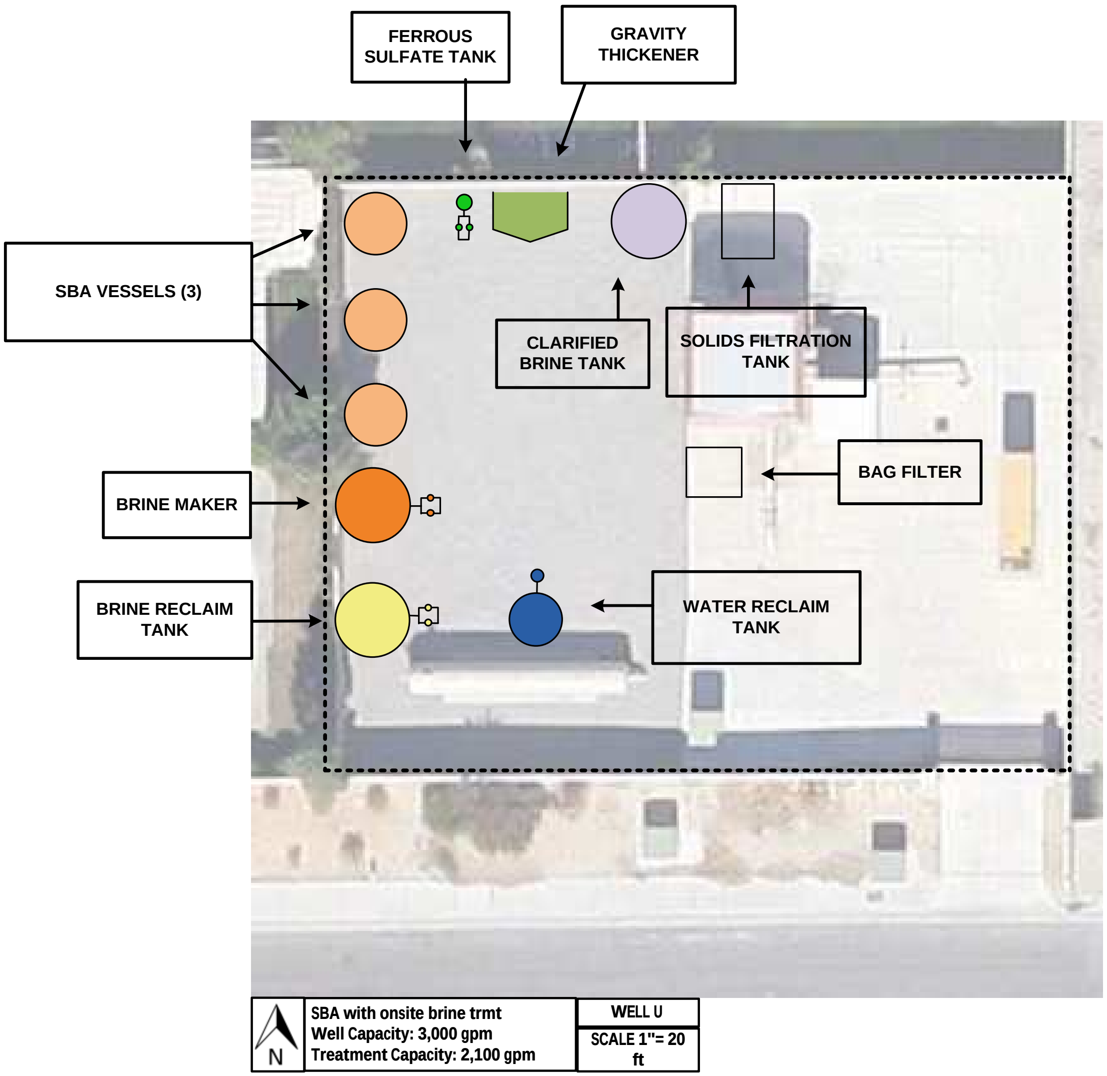
N	Centralized SBA Well Capacity: 5,100 gpm Treatment Capacity: 3,600 gpm	Plant 3 (3A,3B,3C)
		SCALE 1" = 40ft



Containerized SBA Well Capacity: 3,200 gpm Treatment Capacity: 2,400 gpm	WELL AA SCALE 1''= 20 ft



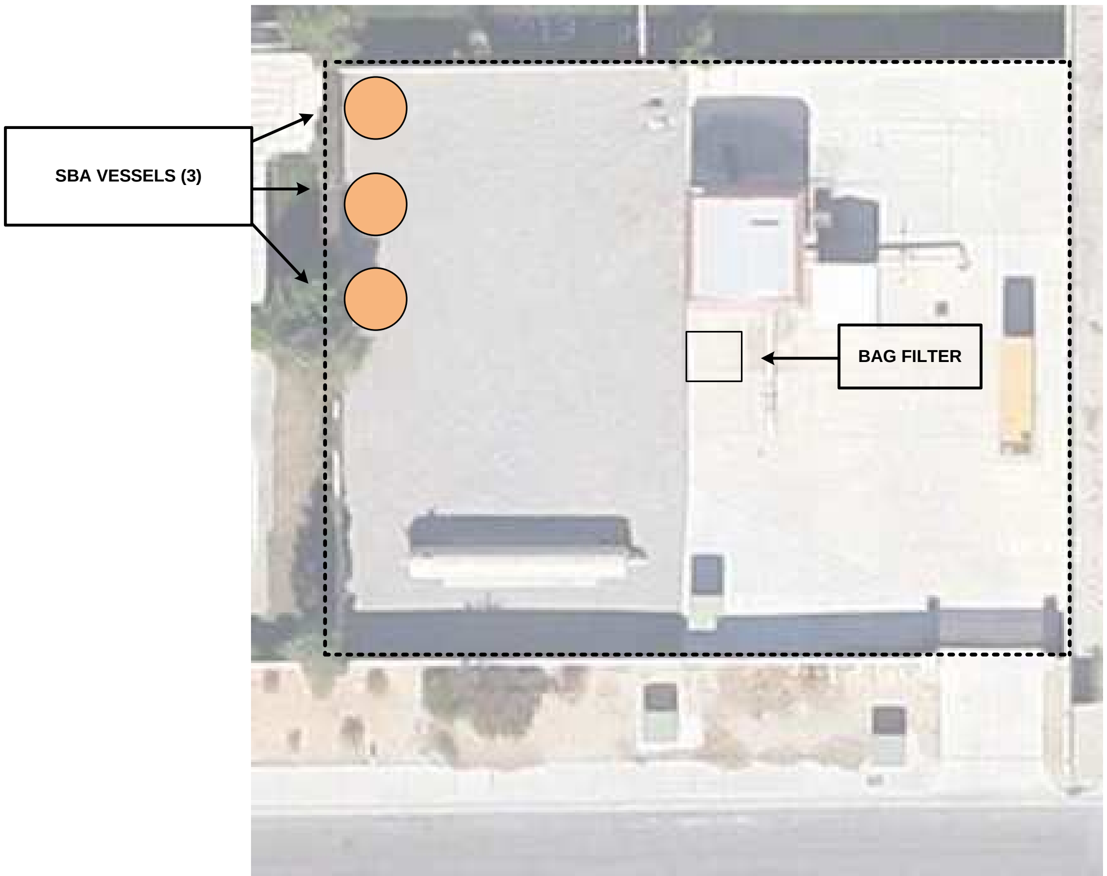
N	Containerized SBA Well Capacity: 3,000 gpm Treatment Capacity: 2,100 gpm	WELL U SCALE 1"= 20 ft



SBA with onsite brine trmt
Well Capacity: 3,000 gpm
Treatment Capacity: 2,100 gpm

WELL U

SCALE 1"= 20 ft

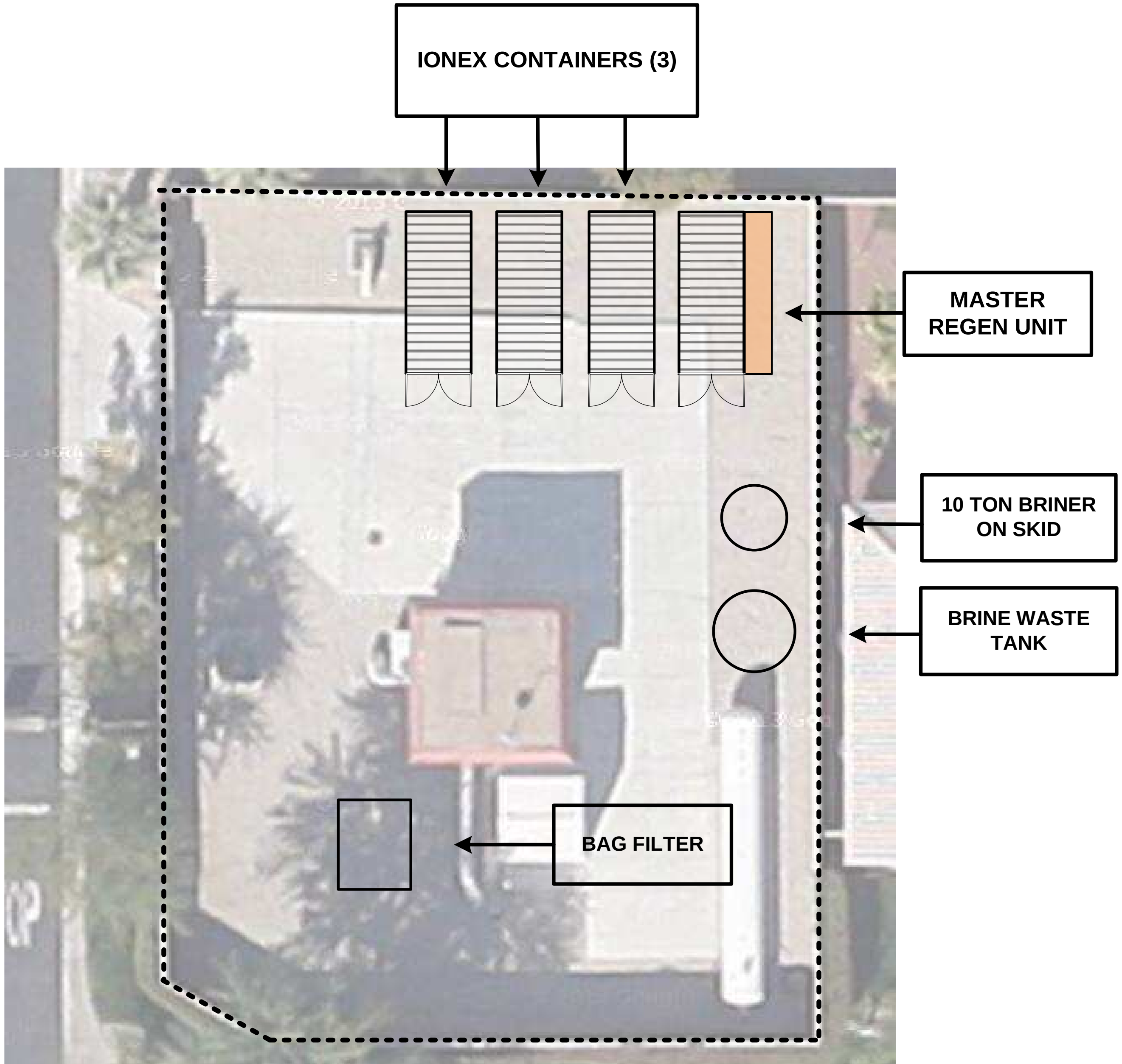


N

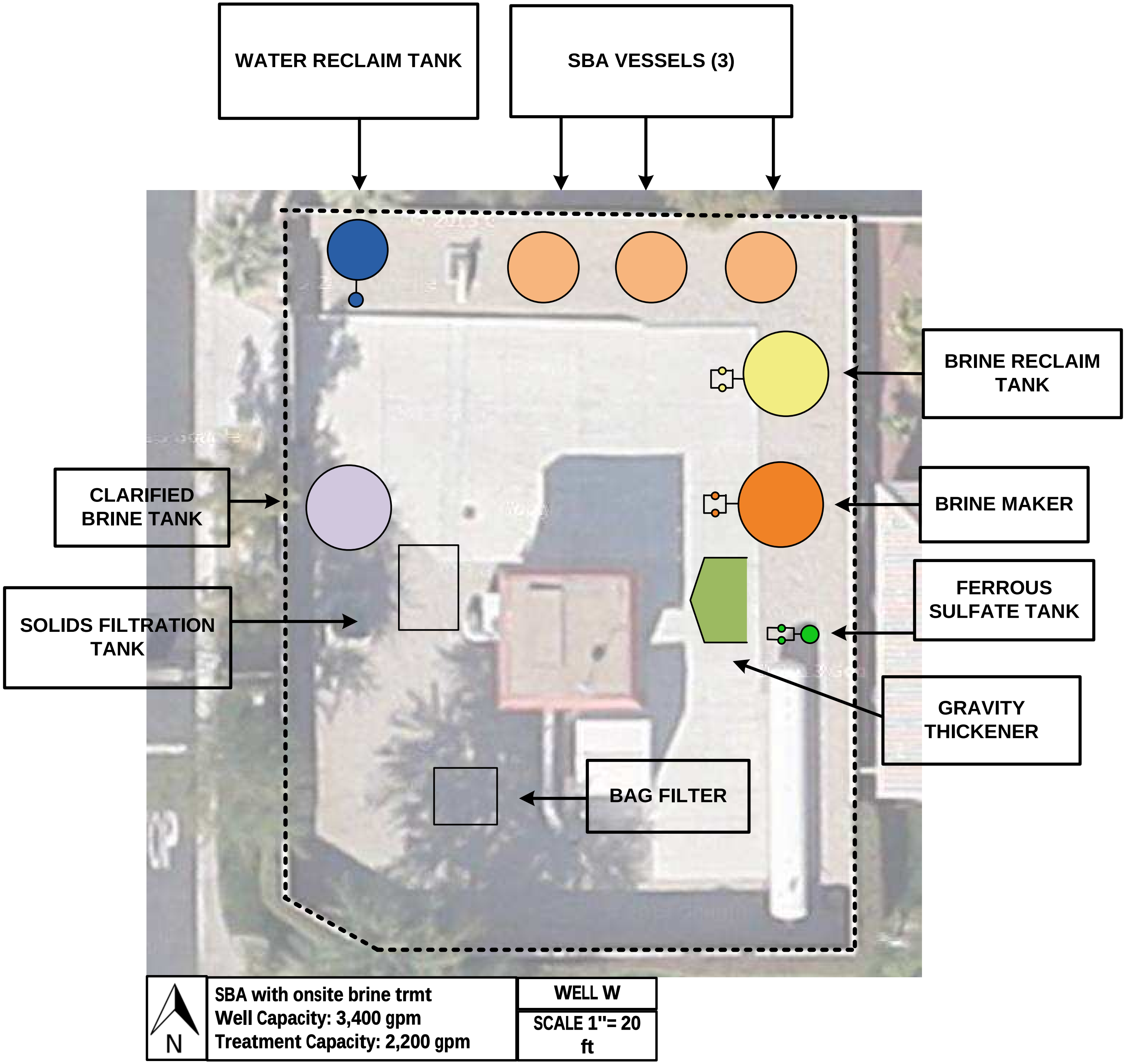
Centralized SBA
Well Capacity: 3,000 gpm
Treatment Capacity: 2,100 gpm

WELL U

SCALE 1"= 20 ft



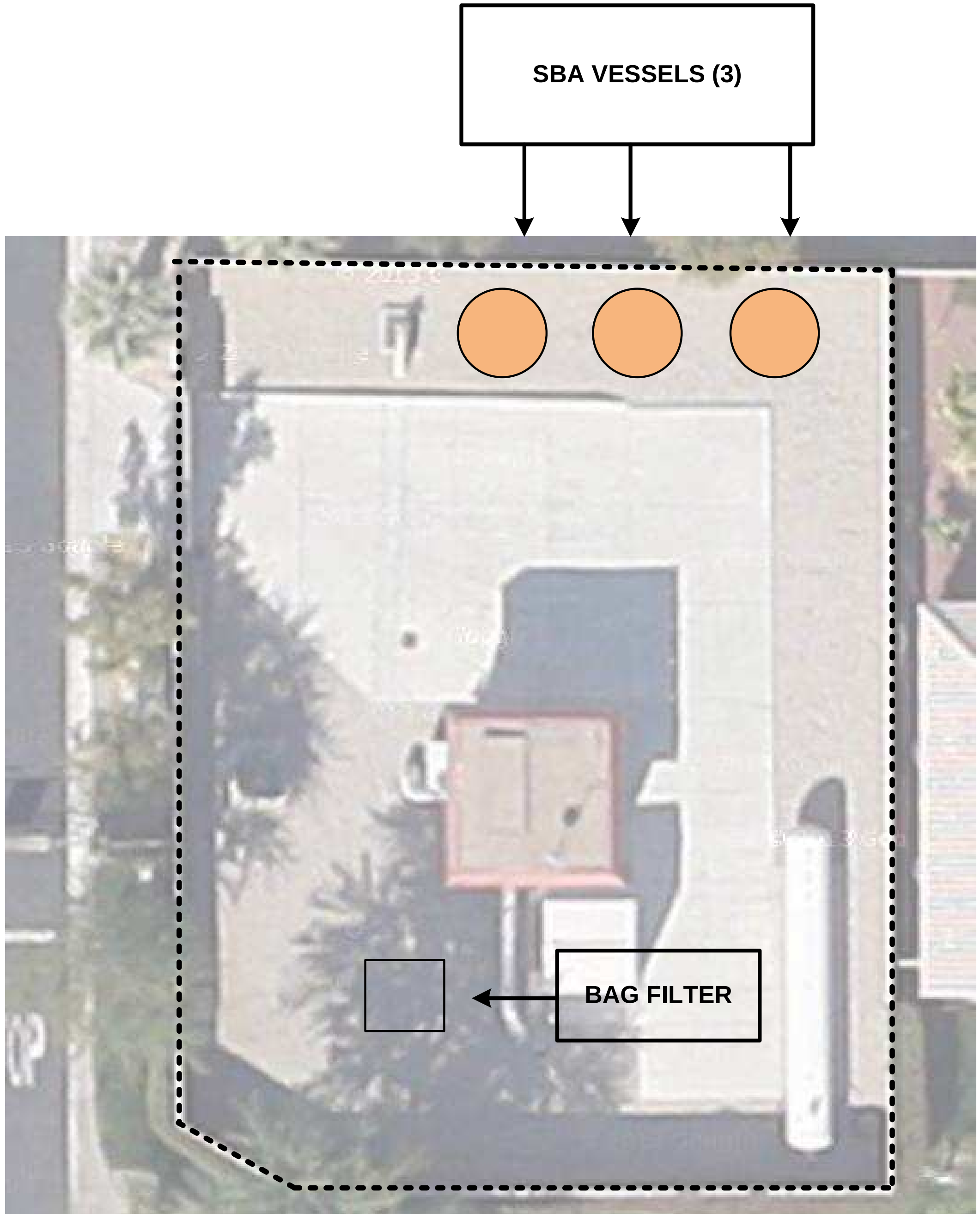
N	Containerized SBA Well Capacity: 3,400 gpm Treatment Capacity: 2,200 gpm	WELL W SCALE 1"= 20 ft



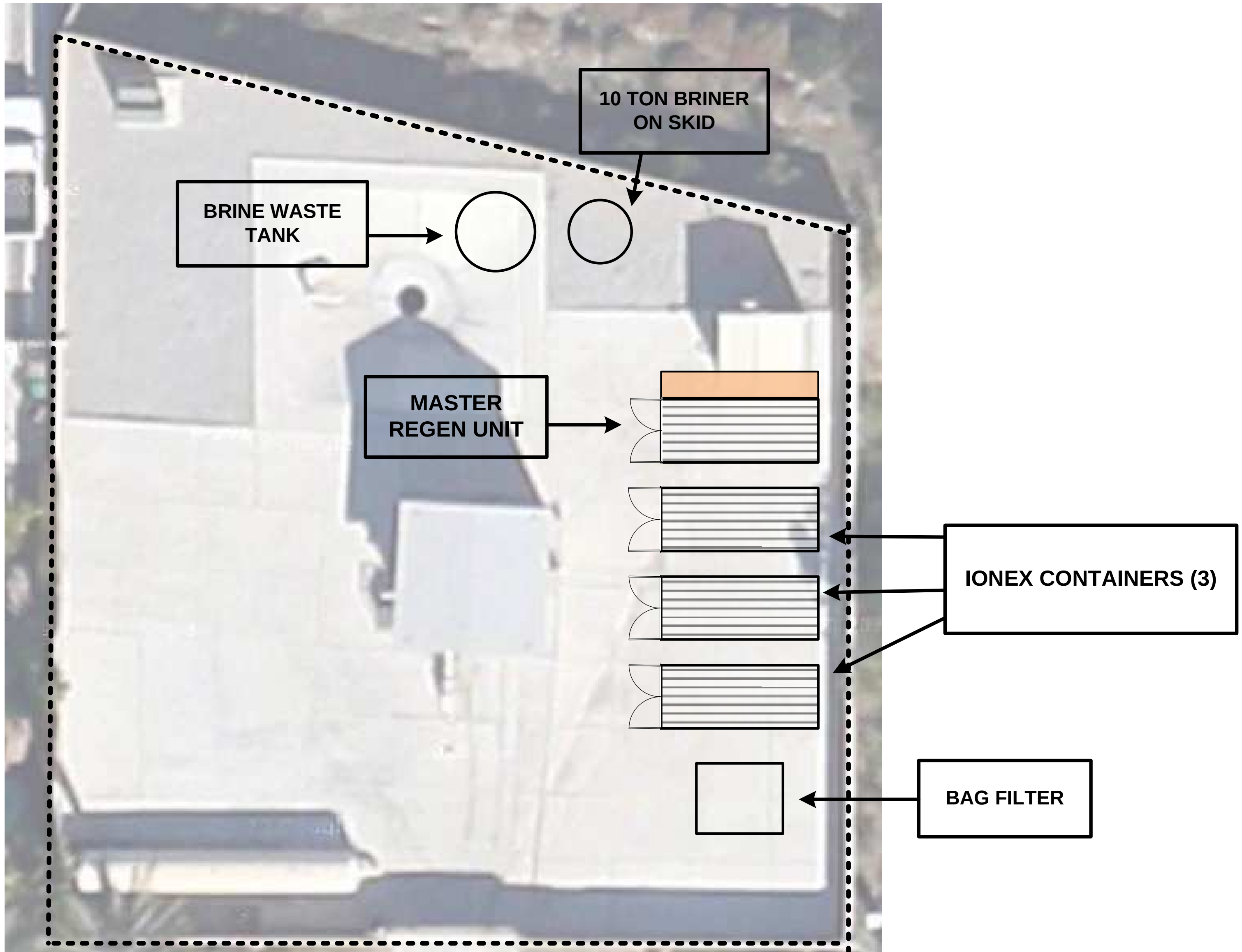
SBA with onsite brine trmt
Well Capacity: 3,400 gpm
Treatment Capacity: 2,200 gpm

WELL W

SCALE 1"= 20 ft



N	Centralized SBA Well Capacity: 3,400 gpm Treatment Capacity: 2,200 gpm	WELL W SCALE 1"= 20 ft

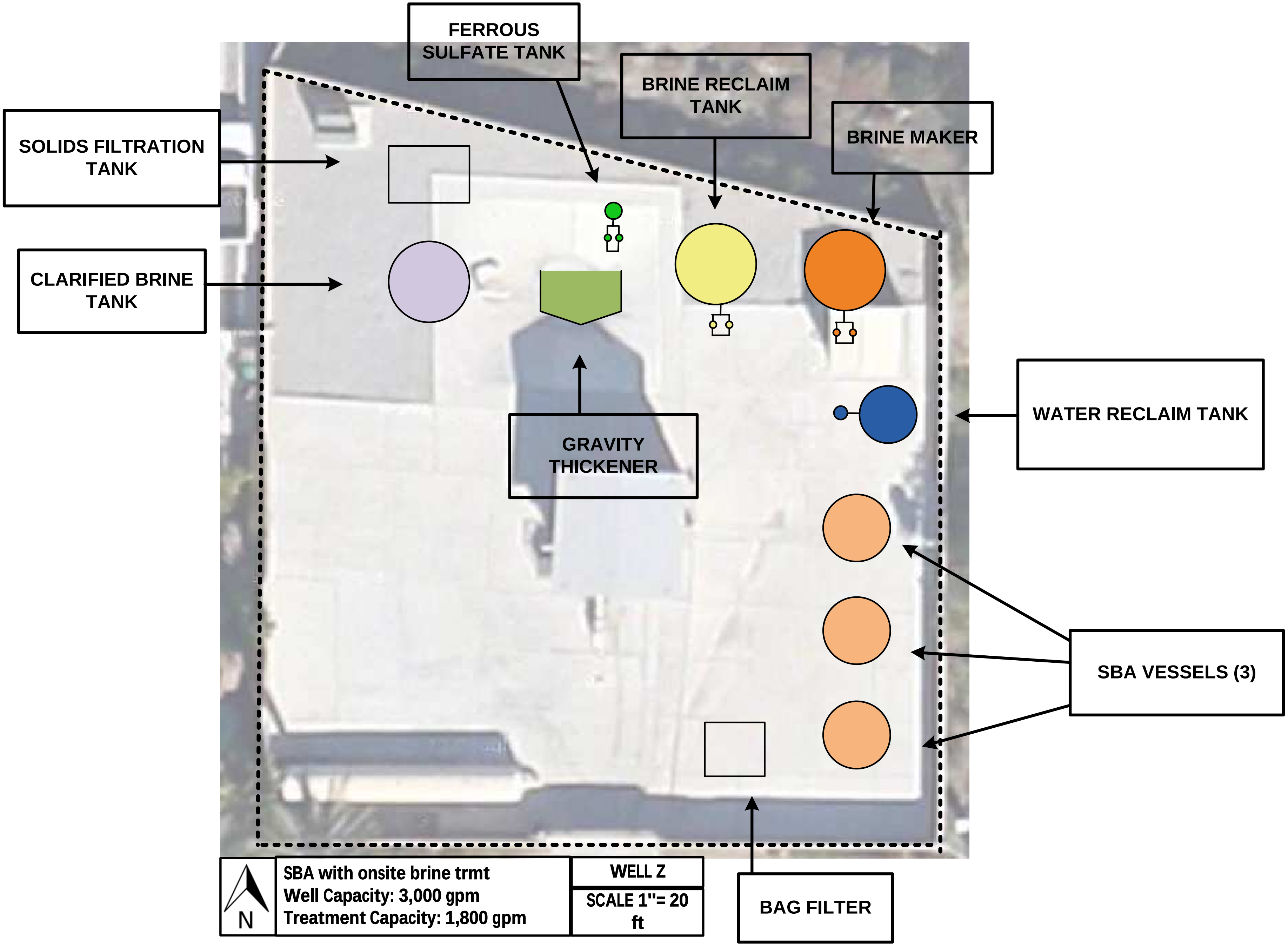


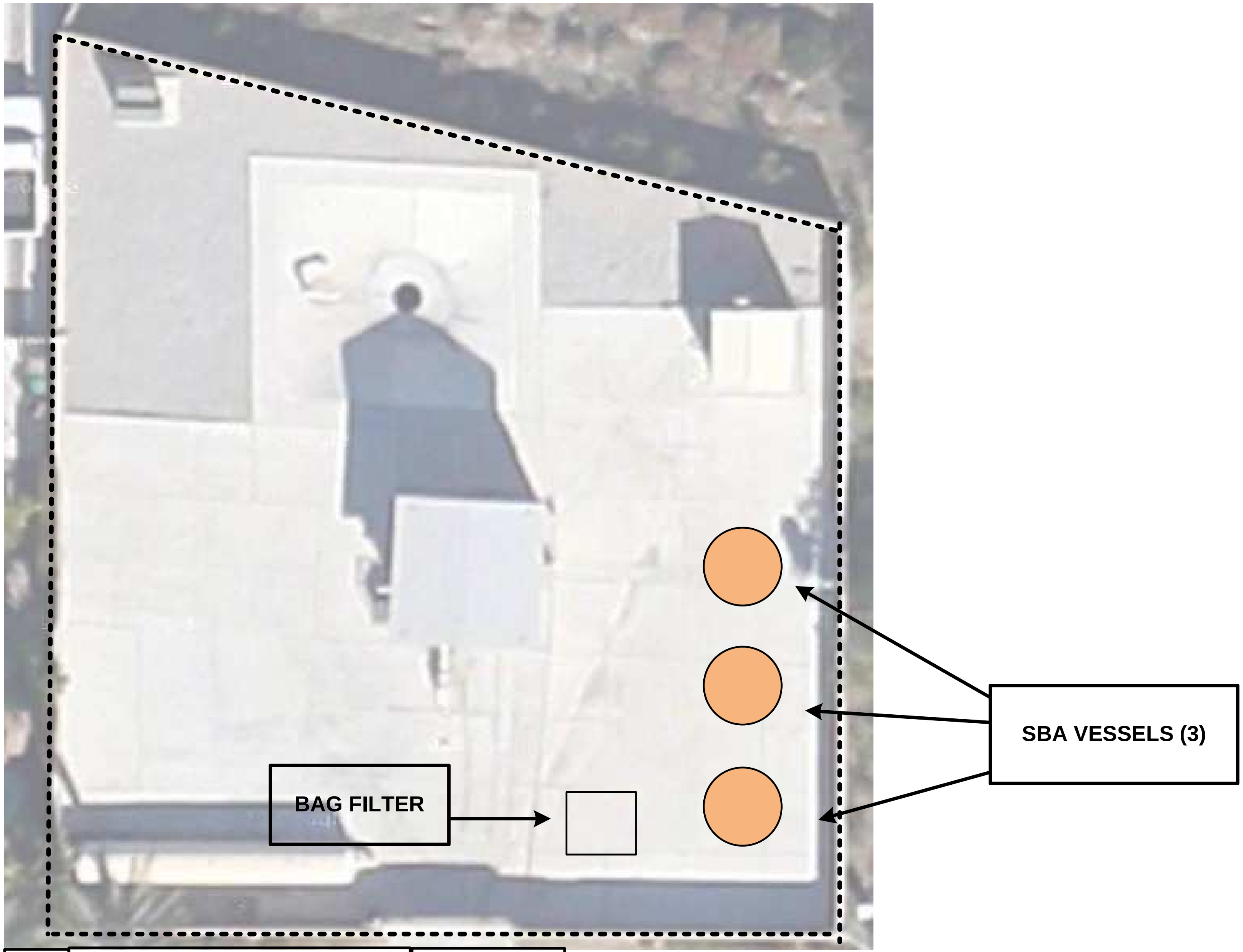
N

Containerized SBA
Well Capacity: 3,000 gpm
Treatment Capacity: 1,800 gpm

WELL Z

SCALE 1"= 20 ft


FERROUS SULFATE TANK
BRINE RECLAIM TANK
BRINE MAKER
SOLIDS FILTRATION TANK
CLARIFIED BRINE TANK
GRAVITY THICKENER
WATER RECLAIM TANK
SBA VESSELS (3)
BAG FILTER
N
SBA with onsite brine trmt
Well Capacity: 3,000 gpm
Treatment Capacity: 1,800 gpm
WELL Z
SCALE 1"= 20 ft



N

Centralized SBA
Well Capacity: 3,000 gpm
Treatment Capacity: 1,800 gpm

WELL Z

SCALE 1"= 20 ft