City of Davis

Sustainable Treatment for Co-Removal of Hexavalent Chromium by Biological Treatment Process Pilot Study

SWRCB Agreement No. 12-539-550 {C/A 353}
Watershed: Lower Sacramento

Davis
California

Kennedy/Jenks Consultants
Engineers & Scientists

K/J 1270031*00
30 April 2013

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30 April 2013

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City of Davis
23 Russell Boulevard
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Funding provided by:

City of Davis

Water Resources Association of Yolo County

Sacramento Groundwater Authority

State Water Resources Control Board

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Abbreviations and Acronyms

µg/l	micrograms per liter
Mm	micrometer
AWWA	American Water Works Association
BAT	Best Available Technologies
bgs	below ground surface
CAA	Cleanup and Abatement Account
CDPH	California Department of Public Health
CO_2	carbon dioxide
CTR	California Toxic Rule
DO	Dissolved Oxygen
EBMUD	East Bay Municipal District
ENR	Engineering News Record
FAC	Free Available Chlorine
FBR	Fluidized Bed Reactor
$FeCl_3$	ferric chloride
GAC	granular activated carbon
gpm	gallons per minute
gpm/sf	gallons per minute per square foot
HRT	Hydraulic Residence Time
ICP-MS	Inductively Coupled Plasma Mass Spectrometer
kw-hr	kilowatt hour
LLRW	Low Level Radioactive Waste
MCL	Maximum Contaminant Level
mg-C/Liter	milligrams carbon per liter
MGD	million gallons per day
mg/l	milligrams per liter
mgP/L	milligrams phosphorus per liter
mL/min	milliliters per minute

NTU	nephelometric turbidity unity
OEHHA	Office of Environmental Health Hazard Assessment
O&M	Operations and Maintenance
ORP	Oxidation Reduction Potential
PHG	Public Health Goal
RCF	Reduction, Coagulation, Filtration
RCRA	Resource Conservation and Recovery Act
RWQCB	Regional Water Quality Control Board
SBA	Strong Base Anion
SWRCB	State Water Resources Control Board
TCLP	Toxicity Characteristic Leaching Procedure
TDS	total dissolved solids
TENORM	Technologically Enhanced Naturally Occurring Radioactive Material
TOC	total organic carbon
TSS	total suspended solids
USEPA	United States Environmental Protection Agency
WaterRF	Water Research Foundation
WBA	Weak Base Anion
WDR	Waste Discharge Requirements
WET	Waste Extraction Test
WTP	water treatment plant
WWTP	wastewater treatment plant

Executive Summary

Introduction

This executive summary provides a summary of the activities, results, and recommendations of the “prove of concept” City of Davis Sustainable Treatment for Co-Removal of Hexavalent Chromium by Biological Treatment Process Pilot Study.

This project was undertaken by the City of Davis with the support of the following agencies and support team:

- State Water Resource Control Board
- Water Resource Association of Yolo County
- Sacramento Groundwater Authority
- Kennedy/Jenks Consultants
- Envirogen Technologies, Inc.
- BSK & Associates, Engineers and Laboratories
- UC Davis

The City of Davis (City) is participating in the Water Research Foundation (WaterRF) Project 4450 that is evaluating the treatment of the City’s Well 20 water used in this study on the treatment and cost of treatment using the three processes piloted by the City of Glendale over the last several years. The results from these two studies will be coordinated.

The purpose of this study is not only to “prove the concept” of a sustainable treatment method for the removal of hexavalent chromium (chromium-6) and other constituents of concern (e.g., nitrates, selenium, and perchlorate), but to provide science-based information for the California Department of Public Health (CDPH), the CA-NV AWWA Technical Advisory Group, and the water community of California as a whole to use as the State of California proposes and prepares a state-wide drinking water standard for chromium-6.

Problem Statement and Relevant Issues

Chromium, a heavy metal, poses potential risks to public health and the environment, specifically chromium-6, which even at low levels poses a potential public health risk in drinking water. There are other constituents of concern in drinking water that also pose a public health risk when they exceed the drinking water standards, such as nitrates, uranium, selenium, and perchlorate.

The California Department of Public Health (CDPH) will be setting a Maximum Contaminant Level (MCL) for chromium-6 (draft MCL anticipated by July 2013) that is anticipated to be somewhere between 1 to 25 μg/l.

Chromium-6 is also a contaminant that the Regional Water Quality Control Board (RWQCB) and State Water Resources Control Board (SWRCB) may regulate in wastewater treatment plant effluent. The Central Valley RWQCB and the SWRCB are also concerned about nitrate and selenium in groundwater as a regional water quality concern.

Currently, there are few demonstrated treatment technologies and those are characterized by high chemical use, high energy use, and residual disposal issues. The search for appropriate treatment technologies to meet anticipated chromium-6 standards will be similar to the utility response that occurred when arsenic standards were made more stringent.

California and City of Davis Drinking Water Quality

It is clear that a chromium-6 MCL could have wide spread impacts throughout California (see Figure ES-1). The City of Davis is one City that may be impacted by a chromium-6 MCL. The City has 20 municipal groundwater wells, of which 15 show relatively high nitrate, selenium, total dissolved solids (TDS), and chromium-6 concentrations. Chromium-6 concentrations range from 2 micrograms per liter (μg/l) to 40 μg/l with concentrations exceeding 10 μg/l in 13 of its 20 wells.

Existing and Emerging Treatment Technologies

There are four technologies listed as Best Available Technologies (BAT) for the removal of total chromium to below 0.05 milligrams per liter (mg/l), but none have been approved for removal of chromium-6 to the low levels expected to be mandated under a new MCL.

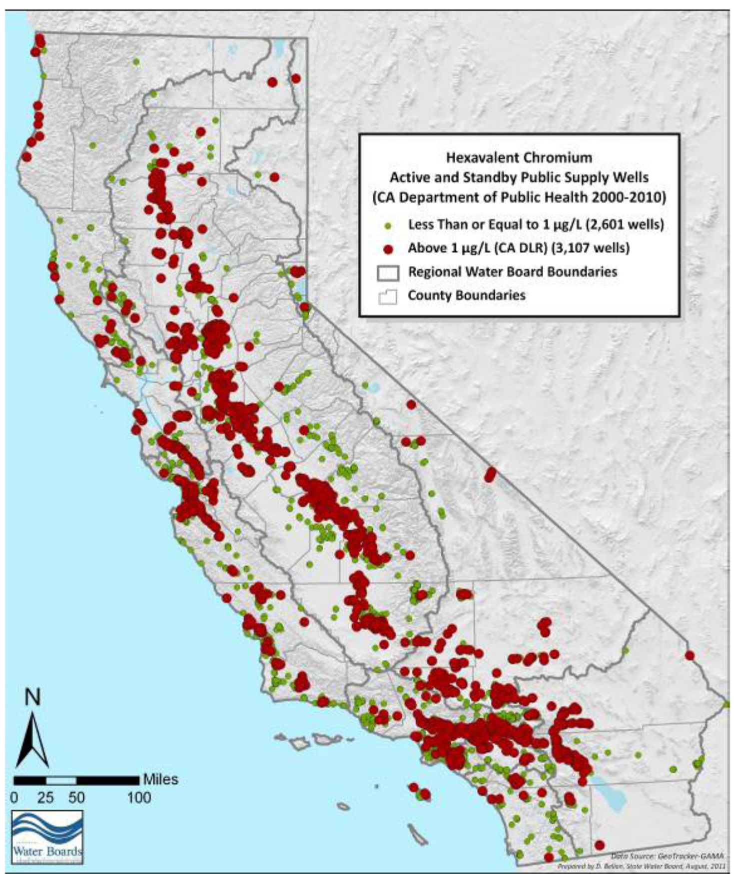

Figure ES-1: Occurrence of Chromium-6 in California

The following technologies have been piloted and/or demonstrated to treat for the removal of chromium-6 at these low levels and are likely to be designated as BATs:

- Strong Base Anion Exchange (SBA),
- Weak Base Anion Exchange (WBA),
- High-Pressure Membrane,
- Reduction, Coagulation, Filtration (RCF)

Two emerging technologies that are currently undergoing research and testing:

- Biological reduction, filtration
- Chemical reduction

This bench-scale biological treatment system pilot test study was completed to test the “prove of concept” of this sustainable treatment for the co-removal of three water quality constituents of concern, nitrates, selenium, and chromium-6.

Project Goals and Methodology

This pilot was conducted to evaluate the feasibility of using a biological treatment process to reduce chromium-6 in the City of Davis Well 20 to chromium-3, which would then be removed by coagulation and filtration. The pilot study objectives are as follows:

- Confirm if this biological treatment system alternative is a reliable and sustainable treatment technology for chromium-6 treatment,
- Evaluate this technology to confirm efficacy and cost effectiveness of treating chromium-6 to low levels (less than 1 μg/l),
- Evaluate effectiveness of concurrently removing multiple constituents such as nitrate, selenium, perchlorate and chromium-6,
- Evaluate the relationship between chromium-6 and total chromium, and potential impacts of the reduction/removal process for water delivered to the distribution system,
- Evaluate the residual management impacts and management options,
- Evaluate this pilot study results with the Water Research Foundation Project 4450 “Impact of Water Quality on Hexavalent Chromium Removal Efficiency and Costs”.

Pilot System Description

The conceptual full-scale treatment process has four main stages: (Step 1) Fluidized Bed Reactor (FBR) with chemical/nutrient addition; (Step 2) Aeration; (Step 3) Filtration; and (Step 4) Disinfection. A full-scale conceptual process flow diagram is depicted in Figure ES-2. The first stage biologically reduces chromium-6 to chromium-3 and denitrifies the water, while the remaining three steps are expected to be required for compliance with current Title 22 drinking water regulations enforced by CDPH.

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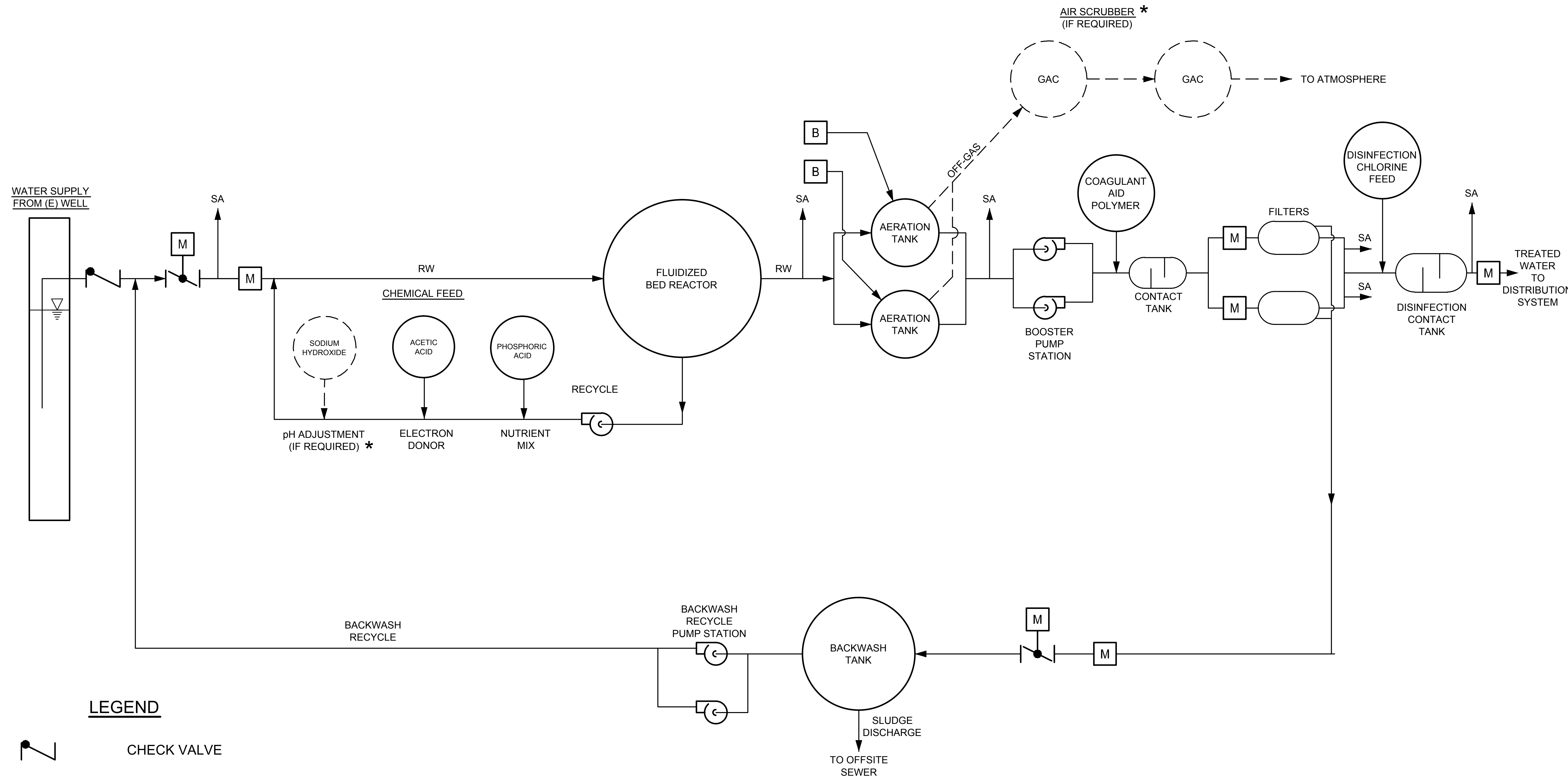

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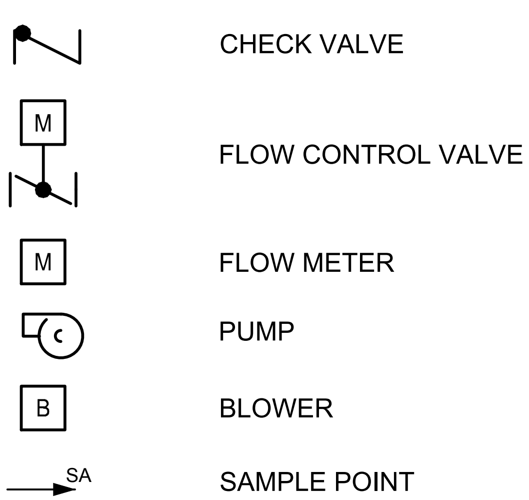

NOTE:

* THESE TWO ADDITIONAL PROCESSES ARE NOT ANTICIPATED TO BE NEEDED.

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CITY OF DAVIS SUSTAINABLE CO-REMOVAL OF HEXAVALENT CHROMIUM BY BIOLOGICAL FILTRATION PROCESS

CONCEPTUAL HEXAVALENT CHROMIUM CO-REMOVAL BIOLOGICAL TREATMENT PROCESS FLOW SCHEMATIC

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FIGURE ES-2

The pilot process employed a bench scale small column FBR. A process flow schematic and photograph of the proposed pilot system is shown in Figure ES-3 and Figure ES-4. The water was fed through the bench scale carbon media FBR column with the addition of acetic acid as an electron donor and phosphoric acid as a nutrient. No pH adjustment was found to be necessary. Adequate aeration was achieved of the effluent through the oversized effluent tubing.

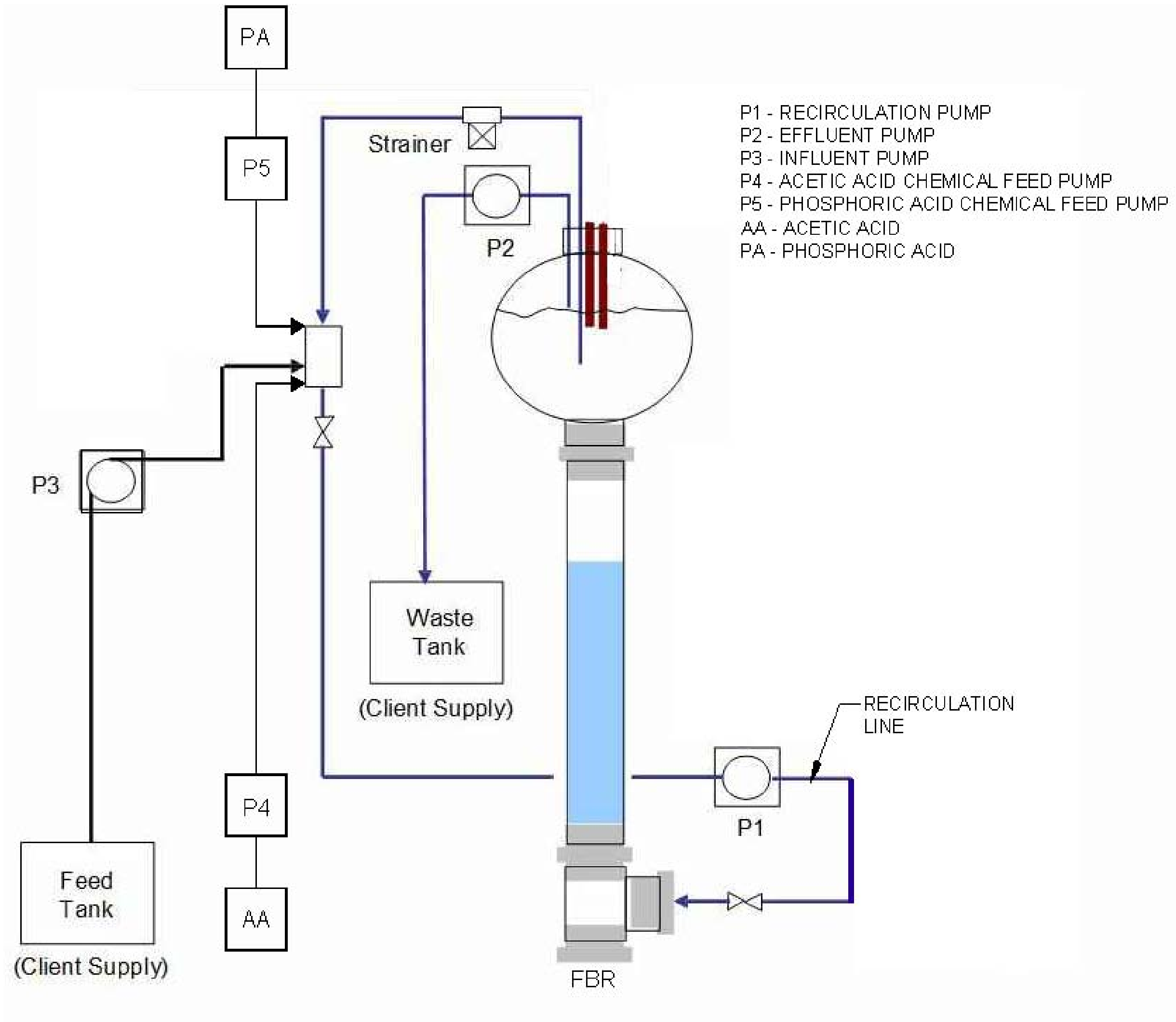


Figure ES-3: Schematic of the FBR

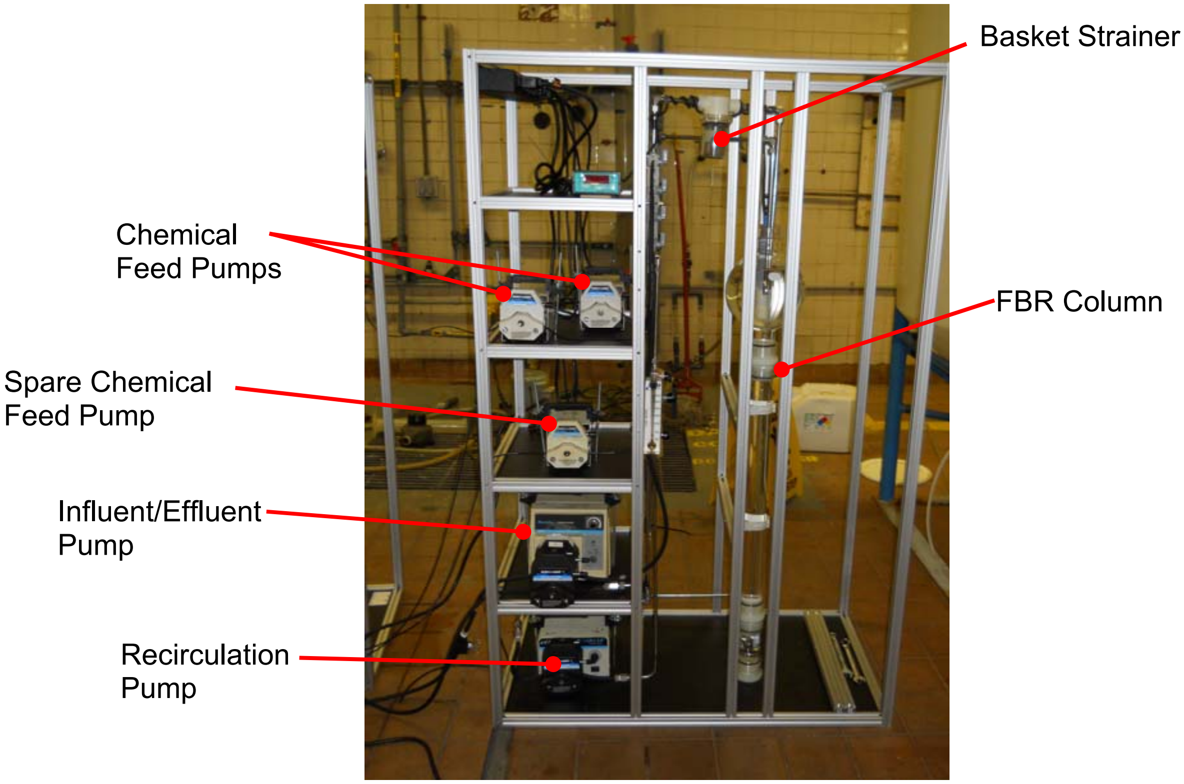


Figure ES-4: Photo of the FBR Pilot System

Filtration was simulated on a bench-scale to simulate granular media filtration and membrane microfiltration. The goal of the filtration step was to characterize particulate and dissolved chromium and determine whether chromium-3 is effectively removed with or without a coagulant aid from the system through filtration. Jar tests were conducted to determine whether additional total chromium removal could be achieved through addition of a coagulant aid.

The final step of the pilot was addition of sodium hypochlorite disinfectant to simulate disinfection and to determine whether any residual chromium-3 within the distribution system is oxidized to reform chromium-6.

During the last week of the pilot, a selenium spike test was completed.

Pilot System Operations

Operation of the system was conducted by Kennedy/Jenks Consultants and Envirogen Technologies staff.

Hydraulic Residence Time

The pilot study was conducted over a 16-week period from early November 2012 through early March 2013. There were four different Hydraulic Residence Times (HRTs) that were targeted, 60, 40, 20, and 15 minutes.

Results

The results of the analysis conducted during this pilot study are described as follows (a summary of the analytical results are provided in Appendix IX).

Biological Reduction

The results for the reduction of chromium-6, nitrate, and selenium in the FBR, as well as a theoretical discussion of the reduction of perchlorate are described below. Based on the results, the system tended to be carbon limited (electron donor) rather than phosphorus limited (nutrient source).

Results showed that altering the amount of carbon added to the system affected the reduction of chromium-6; therefore, milligrams of carbon added (as Acetic Acid) per liter of water treated is shown on Figure ES-5 to demonstrate this change. Better removal occurred when carbon addition was increased to 17 mg/l feed water or greater, the effluent chromium-6 concentration was consistently reduced to below 3 μg/l, often with results at non-detect levels. The effluent total chromium concentration increased as the HRT decreased.

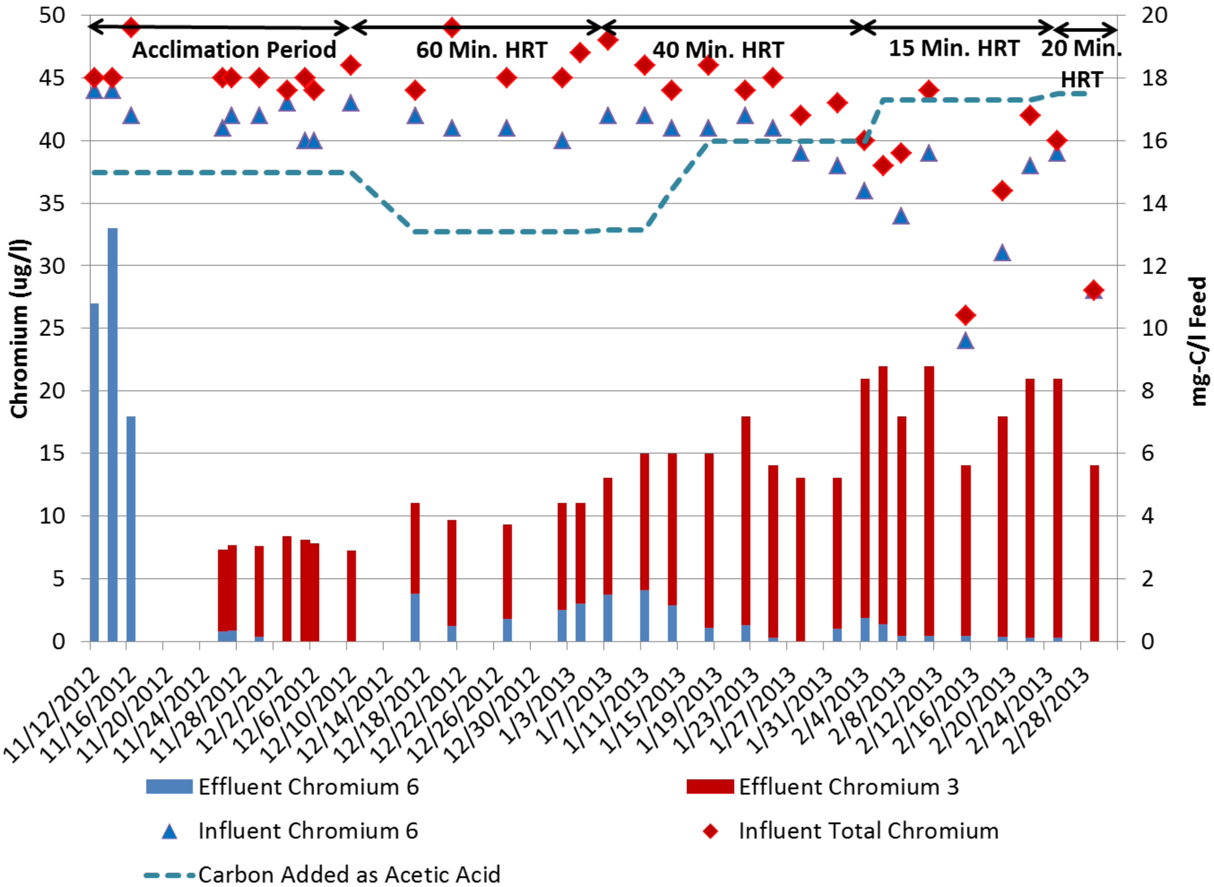


Figure ES-5: Influent and Effluent Chromium-6 and Total Chromium Results

Nitrate Results

The reduction of nitrate in the FBR is achieved similarly to that of chromium-6. An oxidation/reduction reaction occurs where nitrate is reduced to nitrogen gas and acetic acid is oxidized. Milligrams carbon added per liter of water treated is shown on Figure ES-6. Reduction of nitrate-N to levels below 1 mg/l throughout the majority of the pilot was achieved.

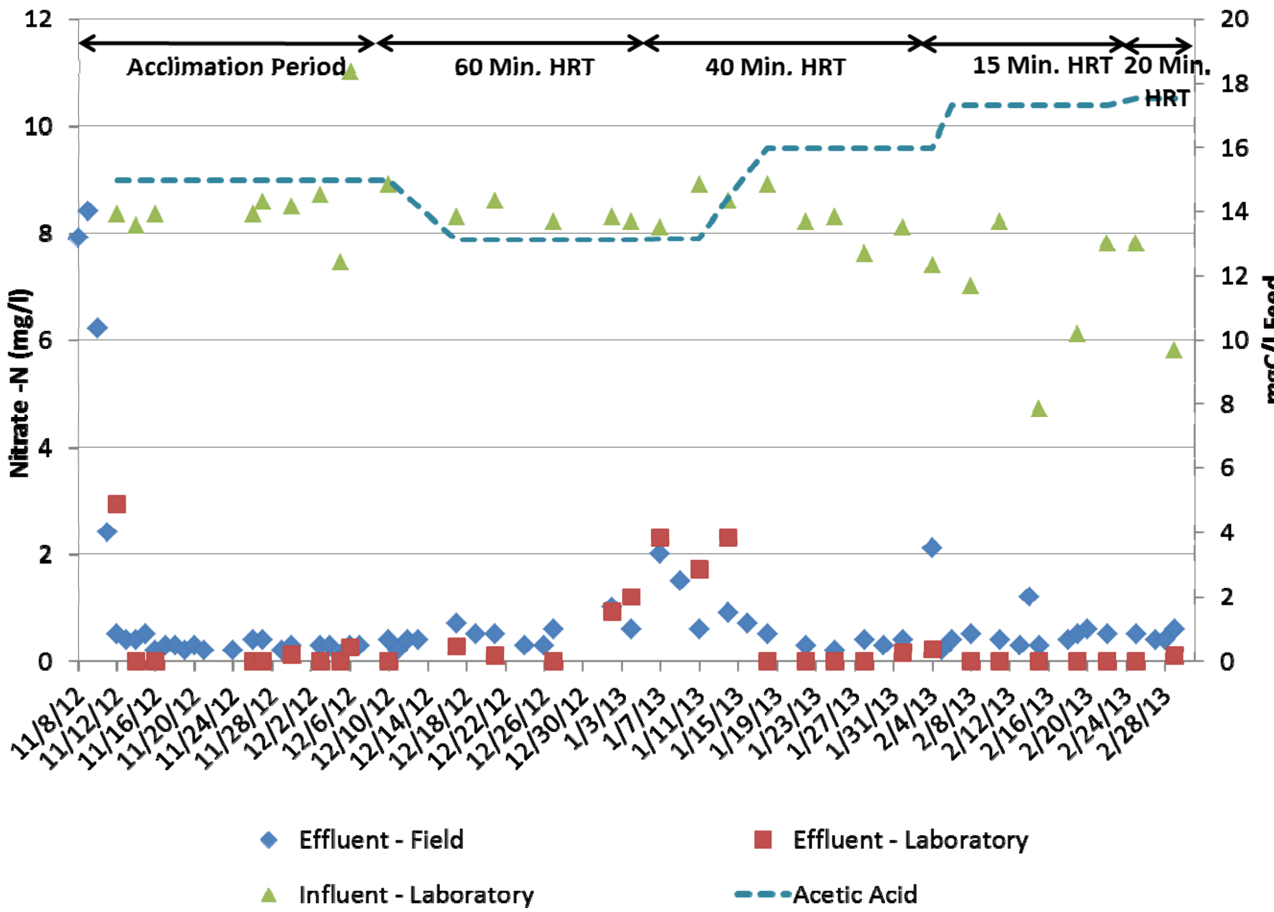


Figure ES-6: Influent and Effluent Nitrate Results

Selenium Spike Results

During the last week of the study, the influent feed tank was spiked to approximately 20 µg/l of selenium. The numerical results showed a removal of about 33%.

Perchlorate Removal Estimated Results

The FBR system is capable of treating perchlorate to non-detect levels based on actual operational FBR systems in California. In general, the oxidation-reduction potential of perchlorate reduction is very close to hexavalent chromium reduction when perchlorate concentrations are at low levels (<0.3 mg/l). The HRT will increase with higher perchlorate concentrations, which will increase the size of the FBR vessel.

Filtration

Bench top filtration was conducted as described above at the three HRTs. The influent and effluent water quality results are shown in Table ES-1 (without coagulant) for a 20-minute HRT. However, there was very little removal of chromium, indicating the residual chromium is likely in a dissolved state.

Table ES-1: Filtration 20 Minute HRT

	Effluent	Aerated	Membrane Filter	Granular Media Filter
Chromium-6 (μg/l)	<0.2	NM	0.34	<0.2
Chromium-3 (μg/l)	14	NM	12.66	13
Total Chromium (μg/l)	14	NM	13	13
Turbidity (NTU)	1.88	NM	0.13	0.52
TSS (mg/l)	NM	NM	<5.0	11

NM- Not Measured
TSS-Total Suspended Solids

Disinfection and Chromium-6 Reformation

The disinfection simulation was conducted and the chromium-6 results for the 20 minute HRT are shown in Figure ES-7. The chromium-6 concentrations increased from 0.34 μg/l to approximately 2 μg/l, showing some indications of reformation potential.

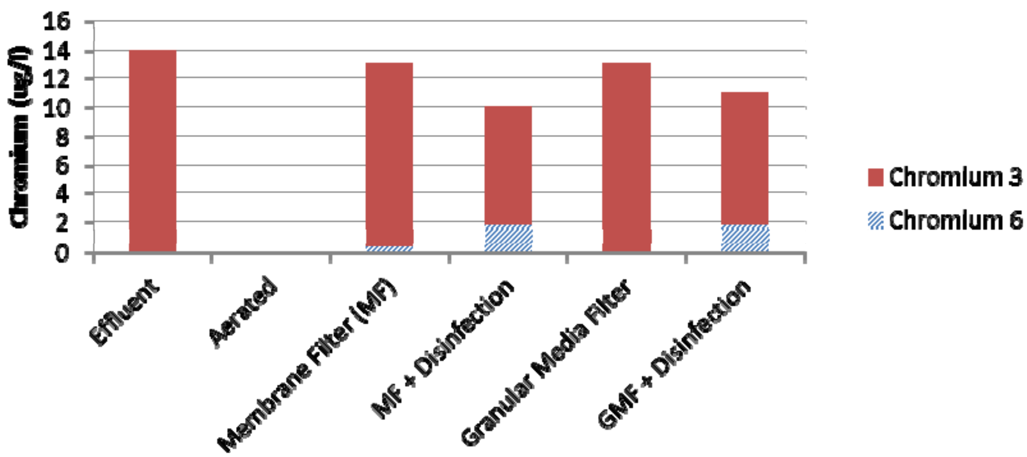


Figure ES-7: Disinfection 20 Minute HRT (1.5 mg/l chlorine dose)

Jar Tests

The total chromium that was seen in the effluent was found to be predominantly in a dissolved form. Jar tests with filtration step were conducted to determine if the addition of ferric chloride ($FeCl_3$) coagulant would increase removal of total chromium. The addition of $FeCl_3$ at 4 mg/l consistently achieved a total filtered chromium effluent concentration less than 5 μg/l and with the addition of $FeCl_3$ at 10 mg/l achieved a total filtered chromium effluent concentration less than 2.5 μg/l.

Selenium removal was also measured during the third jar test. Removal of selenium with addition of ferric chloride as a coagulant was limited and appears to require a higher dosage than for chromium removal (15 to 20 mg/l required to remove about 30 percent of selenium).

FBR Pilot System Performance

FBR pilot filter performance included the following:

- Bed expansion - the granular activated carbon (GAC) media bed height was measured three times a week throughout the pilot study.

- Electron donor and nutrient optimization – electron donor and nutrient addition was adjusted based on the effluent nitrate and chromium results throughout the pilot study to optimize performance.

Residuals - although residuals were not measured, a full scale system would produce solids that will be removed in the downstream granular media or membrane filters. The removed solids will be settled in the backwash tank and discharged to the local sewer system. It is expected that if the residuals were treated onsite and dried, the dried residuals would likely be disposed at a local municipal landfill.

Project Evaluation and Effectiveness

Removal Efficiency and Feasibility for Anticipated MCL

Table ES-2 provides a summary of the chromium-6 reduction, and total chromium and nitrate removal for the different HRTs. Reduction of chromium-6 was high throughout all HRTs and chemical feed concentrations.

Table ES-2: Summary of Results

HRT (min)	AA Addition (mgC-L Feed Water)	PA Addition (mgP/L Feed Water)	% Chromium 6 Reduction	Effluent Chromium-6 (µg/l)	% Total Chromium Removal	% Nitrate Removal	% Selenium Removal
60	15	0.11	98-100%	<0.2-0.83	81-84%	98-100%	N/A
60	13	0.11	91-97%	1.2-3.8	75-80%	85-100%	N/A
40	13.1	0.13	90-91%	3.7-4.1	67-73%	72-81%	N/A
40	16	0.15	95-100%	<0.2-1.3	48-70%	97-100%	N/A
15	17.3	0.16	98-99%	0.31-1.4	42-50%	100%	N/A
20	17.5	0.17	99-100%	<0.2-0.27	48-50%	98-100%	70%

AA – Acetic Acid
PA – Phosphoric Acid

Footprint of Conceptual Treatment System

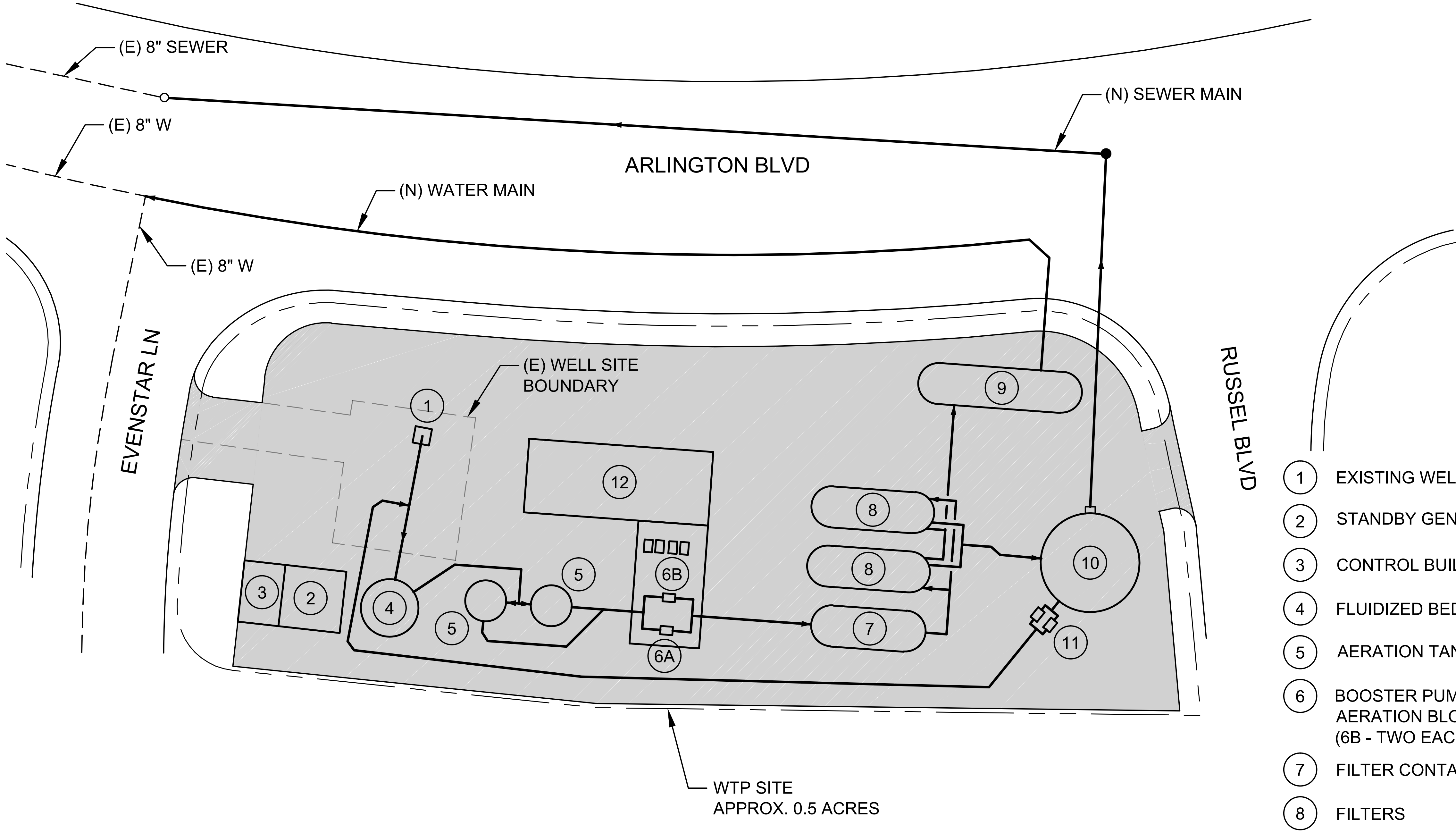
A conceptual footprint to incorporate a biological treatment process at the City of Davis Well 20 site was developed based on a 1,400 gallons per minute (gpm) treatment system flow rate.

The flow schematic for the recommended process is shown in Figure ES-2. Using the current Well 20 site, a site specific footprint for the full scale water treatment facility is shown in Figure ES-8. The current Well 20 site is about 0.14 acres and would require the acquisition of another 0.36 acres as the water treatment facility would encompass about 0.5 acres.

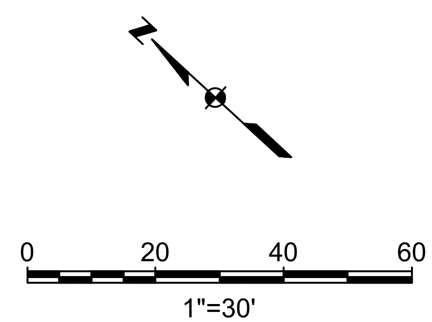
Incorporating this treatment process into a “Greenfield Site”, where a new well would be constructed and a biological treatment process added could yield a smaller footprint. In addition, the sizing of the processes was developed conservatively and could possibly be reduced based on the following alternatives:

- Evaluate the use of one aeration tank.
- Evaluate replacement or reduction of the contact tank with an inline mixer.
- Evaluate if disinfection could occur directly after the aeration basin and achieve the required contact time using the pre-filter contact vessel and/or filter vessels, thus being able to eliminate the chlorine contact vessel.
- Evaluate the pressure filter design loading rate at 5.0 gallons per minute per square foot (gpm/sf) vs. 3.0 gpm/sf.
- Locate booster pump stations outside and only use a covered roof structure with secondary containment for the chemical storage area.

If these alternatives were successful, it is estimated the footprint would be reduced from a 0.5 acre site to a 0.30 acre site, a 40% reduction in footprint as shown in Figure ES-9.



1	EXISTING WELL 20 (125 HP)
2	STANDBY GENERATOR
3	CONTROL BUILDING
4	FLUIDIZED BED REACTOR
5	AERATION TANKS
6	BOOSTER PUMP STATION BUILDING (6A - TWO EACH @ 50 HP EACH) + AERATION BLOWERS (6B - TWO EACH @ 10HP) + RECIRCULATION PUMPS (6B - TWO EACH @ 30 HP)
7	FILTER CONTACT TANK
8	FILTERS
9	CHLORINE CONTACT TANK
10	BACKWASH TANK
11	BACKWASH WATER RECYCLE BOOSTER PUMP STATION (2 EACH @ 5 HP)
12	CHEMICAL BUILDING



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CITY OF DAVIS SUSTAINABLE CO-REMOVAL OF HEXAVALENT CHROMIUM BY BIOLOGICAL FILTRATION PROCESS

WELL 20 - SPECIFIC SITE PLAN

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FIGURE ES-8

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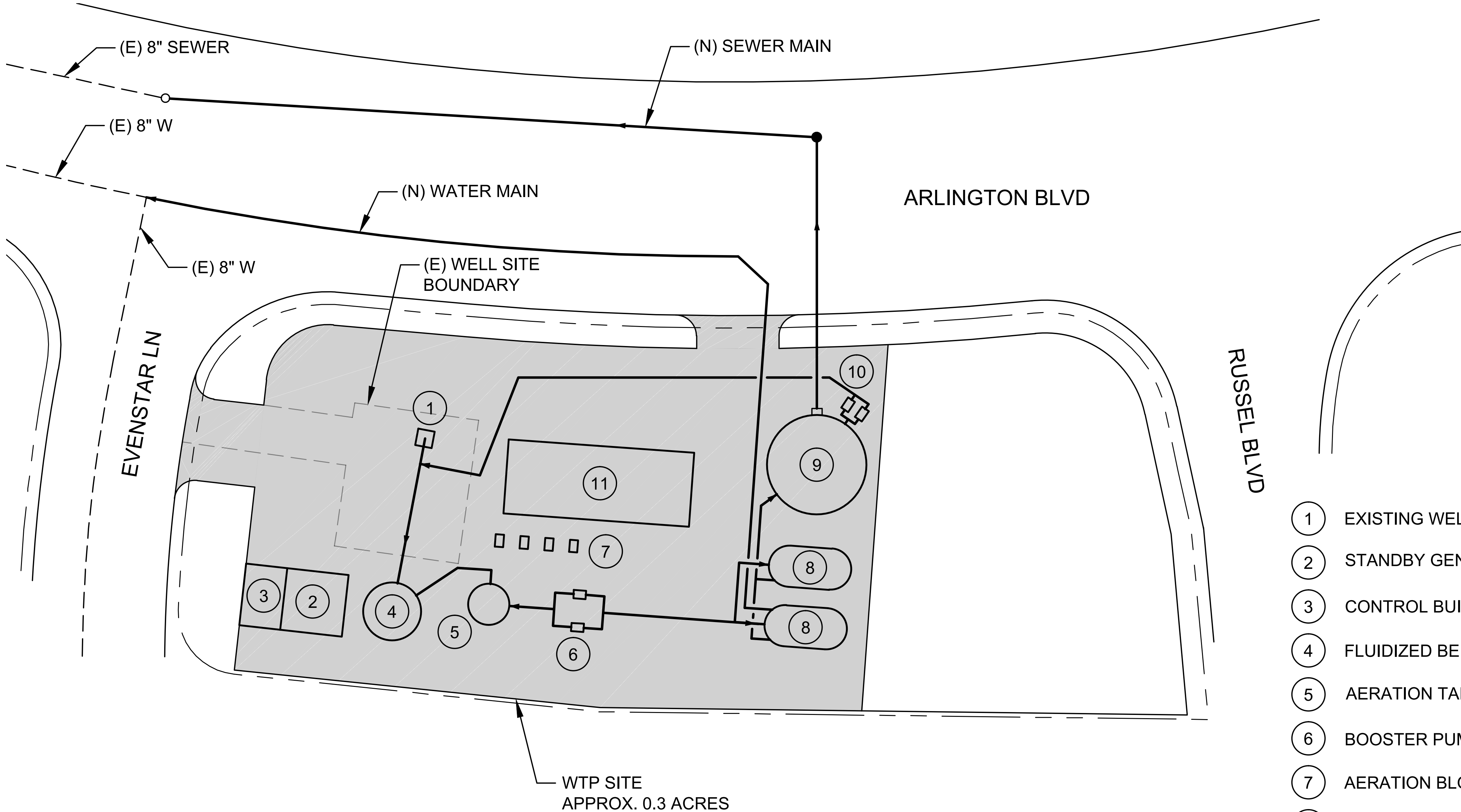
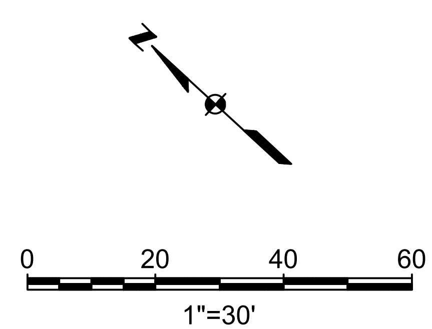


1 EXISTING WELL
2 STANDBY GENERATOR
3 CONTROL BUILDING
4 FLUIDIZED BED REACTOR
5 AERATION TANK
6 BOOSTER PUMP STATION (TWO EACH)
7 AERATION BLOWER (2 EA) + RECIRCULATION PUMP (2 EA)
8 FILTERS
9 BACKWASH TANK
10 BACKWASH WATER RECYCLE BOOSTER PUMP STATION (2 EACH @ 5 HP)
11 CHEMICAL STORAGE AREA

NOTE: ASSUME BARE SITE WITH NEW WELL, AND WTP.



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CITY OF DAVIS SUSTAINABLE CO-REMOVAL OF HEXAVALENT CHROMIUM BY BIOLOGICAL FILTRATION PROCESS

GREENFIELD SITE PLAN

K/J 1270031*00
APRIL 2013
FIGURE ES-9

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Cost Analysis and Comparison

A cost analysis was completed for the 1,400 gpm conceptual water treatment system described in Section 4.2.2 for the Site Specific Well 20 retrofit project. The opinion of probable construction cost, project cost, and annual operation and maintenance (O&M) cost for this conceptual water treatment system is as follows:

- Opinion of Probable Construction Cost is $7.236 million.
- Opinion of Probable Project Cost is $9.769 million (includes construction cost, and engineering, construction administration, environmental, permitting, and City administration and management)
- Opinion of Probable Annual O&M Cost is $0.401 million per year.

For the Greenfield Site the treatment process could be achieved as described above. This would not only reduce the footprint, but also the opinion of probable construction cost, project cost, and annual O&M cost as follows:

- Opinion of Probable Construction Cost is $4.911 million.
- Opinion of Probable Project Cost is $6.630 million (includes construction cost, and engineering, construction administration, environmental, permitting, and City administration and management)
- Opinion of Probable Annual O&M Cost is $0.396 million per year.

An annualized cost analysis was conducted to determine the cost per acre foot as shown in Tables XI-1 in Appendix XI. A summary of the annualized cost analysis is shown in Table ES-3.

Table ES-3: Annualized Cost Analysis

Treatment Method	Annualized Project Cost ($/AF ft)	Annual O&M Cost ($/AF)	Total Annualized Cost ($/AF)
FBR Site Specific Well 20	342	275	617
FBR Greenfield Site	232	272	504

Comparison of Results with WaterRF Project 4450

The costs for two of the water treatment alternatives included in the WaterRF Project 4450 were compared with the cost for the FBR included in this study. Because the costs were based on differing assumptions, the WaterRF costs were adjusted to be more comparable with the cost estimate conducted for this study. The differences and descriptions of these alternatives are:

- The two WaterRF alternatives used were Reduction, Coagulation, and Filtration (RCF) and Strong Base Anion (SBA) treatment systems. The Weak Base Anion alternative was not evaluated as it was the most expensive alternative.
- Two options were used for comparison of the RCF, with Option 1 discharging backwash water and solids to the sewer and no recycling of the backwash water. Option 2 is containing and treating the backwash water on-site to generate solids for offsite disposal and recycling water back to the head of the plant.
- For the WaterRF it used a 1,100 gpm (1.6 MGD) water treatment plant (WTP) capacity for the RCF and SBA treatment alternatives. The Fluidized Bed Reactor is based on a 1,400 gpm WTP capacity.
- The comparison is for the Greenfield option, which is assuming that the site is undeveloped and starting from an undeveloped lot.

The WaterRF report is included in Appendix XII. Table ES-4 includes the Project Capital, O&M and Total cost per acre foot for each system. The values in the table are the adjusted values. A more detailed cost estimate specific to the site location is necessary for full understanding of the costs included for each treatment system.

Table ES-4: Greenfield Alternative Treatment Cost Comparison

Treatment System	Project Capital ($/AF)	O&M ($/AF)	Total ($/AF)
SBA	139	336	475
RCF Option 1	221	2,249	2,470
RCF Option 2	291	295	586
Biological FBR	232	272	504

Comparison of Results with Project Objectives

Table ES-5 provides a summary of the project objectives as well as the results that were found from the project.

Table ES-5: Comparison of Results with Project Objectives

#	Objective	Findings and Conclusions
1	Confirm whether an alternative reliable and sustainable treatment technology, such as biological treatment systems, may provide an effective means of chromium-6 treatment	(1) An FBR treatment system appears to be an effective means to reduce chromium-6 and remove a fraction of the total chromium present and merits additional consideration for full-scale implementation.
2	Provide additional evaluation of technologies to confirm efficacy and cost effectiveness of treating chromium-6 to low levels (less than 1 μg/l)	(1) The bench-scale pilot presented effective chromium-6 reduction to concentrations less than 1 μg/l is achievable. (2) Total organic carbon (TOC) residual was higher than expected and could present water quality challenges if chromium-6 effluent concentrations below 1 μg/l need to be maintained. (3) The cost to retrofit and add the FBR treatment process is in the range of $170 to $250 per acre foot on a annualized construction cost basis.
3	Evaluate effectiveness of concurrently removing multiple constituents such as nitrate, selenium, perchlorate and chromium-6 to provide useful information for water agencies to evaluate treatment alternatives	(1) The FBR was successful in removing multiple constituents including nitrate and selenium to some degree. (2) Effective removal of nitrate-N to below 2 mg/l with average removal rate of 95% (3) With additional filtration, effective chromium-6 reduction to levels below 5 μg/l appears achievable with average reduction rates of 91%. (4) Average removal rate of total selenium of 70%. Addition of ferric chloride as a coagulant did not significantly increase selenium removal. (5) Perchlorate removal has been well demonstrated in full-scale FBR systems, including two installations in Southern CA and one in Northern, CA.
4	Evaluate the relationship between chromium-6 and total chromium, and potential impacts of the reduction/removal process for water delivered to the distribution system	(1) It was estimated that approximately 35% of the chromium-6 that was reduced to chromium-3 was present in a dissolved state. (2) The addition of ferric chloride as a coagulant aid increased total chromium removal efficiency from 65% to 90%, with removal to levels below 5 μg/l. (3) Disinfection tests showed 16-18% reformation of chromium-6 during the last test with a 1.5 mg/l chlorine dose. The potential for greater reformation to occur in a higher continuing residual (>0.1 mg/l free available chlorine (FAC) over 3 day period) should be evaluated.

#	Objective	Findings and Conclusions
5	Evaluate the residual management impacts and management options	Backwash waste solids will ideally be discharged to sewer if available. It is anticipated that disposal of solids to a community landfill would be acceptable. The quantity of solids generated and potential to impact the wastewater treatment plant (WWTP) effluent and solids disposal at a landfill need to be evaluated further.
6	Evaluate this pilot study results with the City of Davis' results from participating in a Water Research Foundation Project	The WaterRF results indicated that the FBR may be more costly than the SBA in project capital cost and comparable to the RCF project capital cost. The FBR had the least costly annual O&M cost. The FBR, SBA and RCF Option 2 for the total annualized cost are in the same order of magnitude considering these are conceptual cost estimates and the level of accuracy. A more detailed study including analysis of site specific requirements would provide a more accurate comparison of these alternatives.

Recommended Next Steps

The proof of concept pilot was successful in demonstrating the efficacy of an FBR system for co-removal of constituents including chromium-6, total chromium, nitrate, perchlorate, and selenium. However, this bench scale pilot was limited in its ability to offer accurate data that can be used to "scale up" to a full sized system. Therefore, we recommend development and proceeding with a demonstration FBR project of the proposed system. The proposed demonstration project would offer numerous benefits including better understanding of the following:

- Evaluate whether there exist any scale-up issues.
- Determine required acclimation periods between temporary and/or long term shut-downs and start-ups.
- Evaluate impacts and requirements of chlorine addition for disinfection, including the potential of reformation of chromium-6 and formation of disinfection byproducts.
- Confirm effective filter coagulants and dosages.
- Estimate filter backwash and solids content.
- Evaluate options for onsite residual management and disposal compared with discharge to sewers, and impacts to WWTPs effluent and solids.
- Evaluate system for enhanced selenium reduction.

- Test system per CDPH requirements to obtain Best Available Technology approval.
- Refine fabrication, construction, and operating costs for the technology.
- Evaluate the speciation of the FBR biomass to determine the type of bacteria.

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Section 1: Problem Statement and Relevant Issues

This report provides a description of the pilot study activities, results, and recommendations regarding the recently completed pilot test prove of concept of a sustainable biological treatment process for co-removal of hexavalent chromium (chromium-6) and other constituents including nitrate and selenium from groundwater. The work was completed in direct collaboration with the City of Davis in Northern California and made possible through funding contributions from the State Water Resources Control Board (SWRCB), Water Resources Association of Yolo County, and Sacramento Groundwater Authority (refer to Section 1.4 Project Participants for additional details).

The City of Davis (City) is participating in the AWWA Water Research Foundation Project 4450 that is evaluating the treatment of the City's Well 20 water used in this study on the treatment and cost of treatment using the three processes piloted by the City of Glendale over the last several years. The results from these two studies will be coordinated.

The purpose of this study is not only "to prove the concept" of a sustainable treatment method for the removal of chromium-6 and other constituents of concern, but to provide science-based information for the California Department of Public Health (CDPH), the California-Nevada American Water Works Association (CA-NV AWWA) Technical Advisory Group, and the water community of California as a whole to use as the State of California proposes and prepares a state-wide drinking water standard for chromium-6.

The following section describes the challenges associated with chromium-6 in the State of California and targeted pilot study evaluation.

1.1 Problem Statement

Chromium poses potential risks to public health. Chromium is a heavy metal that occurs naturally throughout the environment, and can also be present in wastewater and drinking water sources as a result of anthropogenic sources from industrial activities such as chromic pigments, corrosion control agents, and chrome plating solutions. In water, it exists either in its more reduced form, trivalent chromium (chromium-3) or its more oxidized form, hexavalent chromium (chromium-6). Chromium-3 is an essential nutrient, while chromium-6 may pose a potential public health risk, even when present at low levels.

There are other constituents in drinking water that also pose a public health risk when they exceed the drinking water standards, such as nitrates, selenium, and perchlorate.

1.1.1 Upcoming Regulatory Requirements and Presence of Chromium-6 in California

Potential carcinogenic risks resulting from inhalation of chromium-6 have long been recognized, but a drinking water regulation for chromium-6 has not yet been promulgated. Instead, the present drinking water regulations are based on total chromium, with the California maximum contaminant level (MCL) set at 0.05 mg/l (50 μg/l), and the United States Environmental Protection Agency (USEPA) MCL set at 0.10 mg/l (100 μg/l). In 2011, the California Office of

Environmental Health Hazard Assessment (OEHHA) established a public health goal (PHG) for chromium-6 at 0.02 μg/l, which triggers a requirement for the California Department of Public Health (CDPH) to set an MCL for chromium-6 (draft MCL anticipated by July 2013). The USEPA is reviewing toxicity data to determine potential carcinogenicity of chromium-6 in drinking water, and depending on the results of that review, may propose establishing a drinking water standard.

As part of its regulatory process, the CDPH must set the MCL as close to the PHG as feasible, taking analytical methods, treatment technology, costs, and benefits into account. A future MCL at or near the proposed PHG would trigger an extensive need for treatment throughout the State.

Despite the low PHG, the present state of treatment technology and costs suggests an MCL between 1 to 25 μg/l is likely. These regulations will require water utilities to evaluate potential removal or avoidance strategies within a short time frame. Currently, there are few demonstrated treatment technologies and those are characterized by high chemical use, high energy use, and residual disposal issues. The search for appropriate treatment technologies to meet anticipated chromium-6 standards will be similar to the utility response that occurred when arsenic standards were made more stringent.

Chromium-6 is also a contaminant that the Regional Water Quality Control Board (RWQCB) and State Water Resources Control Board (SWRCB) may regulate from wastewater treatment plant effluent per the California Toxic Rule (CTR) or through waste discharge requirements (WDRs) for land application, and in some cases, groundwater cleanups at contaminated sites (e.g., superfund sites). The source of chromium-6 in many of these effluents may be chromium in the drinking water source in the wastewater service area. Thus, not only is the protection of drinking water sources of concern, but the effluent from wastewater treatment plants (WWTPs) that receive influent from those drinking water sources also may be a concern for the RWQCBs and SWRCB. The Central Valley RWQCB and the SWRCB are also concerned about nitrate and selenium in groundwater as a regional water quality issue.

1.2 City of Davis and Greater Sacramento Area Drinking Water Quality

The following summarizes the City of Davis and Greater Sacramento area drinking water quality relative to chromium-6 and associated constituents that were evaluated for removal using the biological treatment process. It is clear from review of the water quality data of the Greater Sacramento Area that a chromium-6 MCL could have wide spread impacts in the region.

1.2.1 City of Davis Drinking Water Quality

The City of Davis has 20 municipal groundwater wells that it uses to supply water. Of these 20 wells, 15 are “intermediate” wells, with total depths ranging from 340-615 feet below ground surface (bgs). The water quality of the intermediate wells shows relatively high nitrate, selenium, TDS, and chromium-6 concentrations. Chromium-6 concentrations range from 2 μg/l to 40 μg/l with concentrations of chromium-6 exceeding 10 μg/l in 13 of its 20 municipal groundwater wells and is therefore interested in finding a sustainable treatment process for the removal of chromium-6 from these wells.

1.2.2 Greater Sacramento Area Drinking Water Quality

Like the City of Davis, many municipalities in the greater Sacramento Area (considered the region spanning from Folsom in the east to Fairfield in the West) have occurrences of constituents including chromium-6 and nitrate. The CDPH water quality database indicates that chromium-6 and elevated nitrate concentrations are present in groundwater supply wells throughout Yolo County and Solano County municipalities including the City of Woodland, Dixon, and Winters. Similarly, a Water Quality Vulnerability Study completed by the Sacramento Groundwater Authority in 2011 revealed many wells in water systems throughout Northern Sacramento County with detections of chromium-6 greater than 5 μg/l. Figure 1-1 shows the occurrence of chromium-6 within the Sacramento Groundwater Authority study area.

1.2.3 City of Davis Wastewater Effluent Quality

Another driver for evaluating a biological reduction treatment process of drinking water supplies is the occurrence of selenium in the water system. The City's intermediate wells have varying selenium concentrations; the deep wells do not have selenium present at the detection limit. Selenium in the water system has been shown to convey through building plumbing into the sewer system and then to the City of Davis Wastewater Treatment Plant, where it is eventually discharged. Selenium is regulated by the RWQCB, and is a permit requirement for the City of Davis's WWTP. The interim and future (2016) selenium effluent discharge limit for the City of Davis is 5.0 and 4.4 μg/l while current discharges at the WWTP average approximately 5 μg/l. Therefore, the City continues to review opportunities to reduce selenium concentrations in its wastewater discharges.

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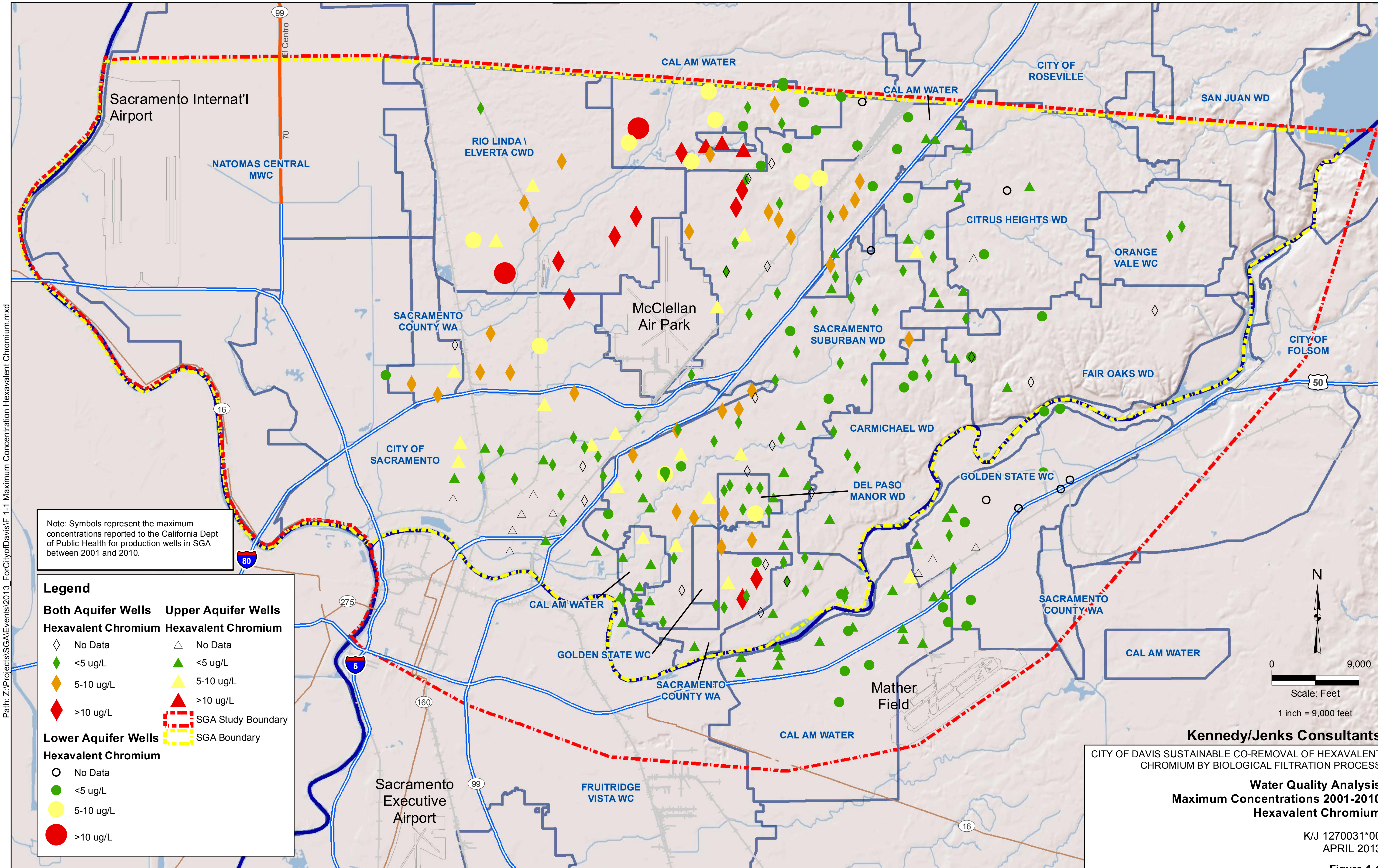

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Note: Copied from Groundwater Vulnerability Assessment for Sacramento Groundwater Authority (0ct. 2011)

1.3 Existing and Emerging Treatment Technologies

Title 22, Chapter 15 of the California Code of Regulations designates four technologies as Best Available Technologies (BAT) for the removal of total chromium to below 0.05 mg/l; namely coagulation/filtration; ion exchange; lime softening (chromium-3 only); and reverse osmosis. However, these technologies have not been approved for removal of chromium-6 to the low levels expected to be mandated under a new MCL (anticipated to be between 1-25 μg/l).

There have only been a few pilot and demonstration level treatment plants for the removal of chromium-6 at these low levels. The technologies used at pilot and demonstration plants include:

- Four mature treatment technologies that are likely to be designated as BAT for chromium-6:
  - Strong Base Anion Exchange (SBA),
  - Weak Base Anion Exchange (WBA),
  - High-Pressure Membrane,
  - Reduction, Coagulation, Filtration (RCF)

- Two emerging technologies that are currently undergoing research and testing:
  - Biological reduction, filtration
  - Chemical reduction

This pilot test study was completed to test the efficacy of the “proof of concept” of a sustainable, biological reduction and filtration treatment process for the co-removal of three water quality constituents of concern: nitrates, selenium, and chromium-6. A bench-scale biological treatment system was operated to evaluate the treatment of chromium-6 in one of the City’s existing drinking water wells to chromium-3, which would then be removed by filtration. The biological filtration process also treats nitrate and selenium from the source water (in fact, nitrates are required for creation of the biomass that will also treat chromium-6).

The City of Davis is also participating in a Water Research Foundation study for chromium-6 treatment using anion exchange and reduction/coagulation/filtration removal processes. Results from the Water Research Foundation study are in progress and have been provided for the City of Davis Well 20 in advance. In Section 4.2.4 an evaluation to compare the results of this study with the WaterRF study results for Well 20 is presented. The WaterRF final report for the full study is expected to be available about July, 2013.

1.4 Project Participants

Because of the regional benefits and potential impact of future chromium-6 regulations, the City has established a partnership with the Water Resources Association of Yolo County and Sacramento Groundwater Authority to help fund this project. In addition, the City has received grant funding through the SWRCB - Cleanup and Abatement Account (CAA). The following entities participated in development, funding, and implementation of this pilot study effort:

1. City of Davis – lead project proponent, contributed staff, project funds, and facilities to use for the pilot test

2. State Water Resources Control Board – provided funding through the Cleanup and Abatement Account and project guidance

3. Water Resources Association of Yolo County – provided funding and supported the pilot project

4. Sacramento Groundwater Authority – provided funding and supported the pilot project

5. Kennedy/Jenks Consultants – lead consultant and engineer responsible for organizing, designing, and implementing the pilot test, and preparing this report

6. Envirogen Technologies – designer and manufacturer of fluidized bed biological treatment systems. Provided pilot testing equipment, staff, and technical support.

7. BSK Associates, Engineers and Laboratories – provided analytical water quality results

8. UC Davis – provided support including research assistant sampling and laboratory analyses

Section 2: Project Description

This section provides a description of the Davis Chromium-6 Pilot Study's project goals and project methodology.

2.1 Project Goals

This pilot was conducted to evaluate the feasibility of using a biological treatment process to reduce chromium-6 in one of the City's existing drinking water wells (Well 20) to chromium-3, a more benign form of chromium and a required nutrient, which would then be removed by coagulation and filtration. Biological treatment processes for chromium-6 could provide an alternative to the reduction/coagulation/filtration and anion exchange processes that were evaluated by the City of Glendale and are currently undergoing further evaluation by a Water Research Foundation (WaterRF) project.

Many water utilities are implementing policies to promote sustainable utility practices. Biological treatment has been demonstrated to be a sustainable drinking water treatment process and is being implemented to reduce contaminants, such as perchlorate, selenium, and nitrate. Accordingly, it may have high potential to effectively reduce chromium-6 to chromium-3, which can then be filtered from the effluent with addition of a coagulant. The development of a sustainable treatment process for chromium-6 would position water utilities to react quickly to the significant number of affected sources that are likely to exist when a California chromium-6 regulation is finalized.

The information that was developed in this pilot test study will be shared with the CDPH to support development of a MCL. The pilot study had the following objectives:

- Confirm whether an alternative reliable and sustainable treatment technology, such as biological treatment systems, may provide an effective means of chromium-6 treatment,
- Provide additional evaluation of technologies to confirm efficacy and cost effectiveness of treating chromium-6 to low levels (less than 1 μg/l),
- Evaluate effectiveness of concurrently removing multiple constituents such as nitrate, selenium, perchlorate and chromium-6 to provide useful information for public water agencies to evaluate treatment alternatives,
- Evaluate the relationship between chromium-6 and total chromium, and potential impacts of the reduction/removal process for water delivered to the distribution system,
- Evaluate the residual management impacts and management options,
- Evaluate this pilot study results with the City of Davis' results from its participation in Water Research Foundation Project 4450 "Impact of Water Quality on Hexavalent Chromium Removal Efficiency and Costs" that treated City water using the reduction/coagulation/filtration and anion exchange processes currently being evaluated by other projects.

The following sections and subsections describe the project costs, project methodology, and pilot system operation that were used in fulfilling the objectives of the pilot study.

2.2 Project Type and Costs

The City of Davis Chromium-6 Pilot Study was a bench-scale pilot system evaluation intended to demonstrate the efficacy of using a fluidized bed reactor for the reduction of chromium-6 to chromium-3 in tandem with other constituents including nitrate and selenium. This study was anticipated as being a precursor to a future full-scale demonstration or pilot study project should the technology prove promising. The total project cost was $150,000. Funding was provided as outlined in Table 2-1. In addition the City of Davis provided in-kind services in the form of grant management and staff time to review documents and provide site access.

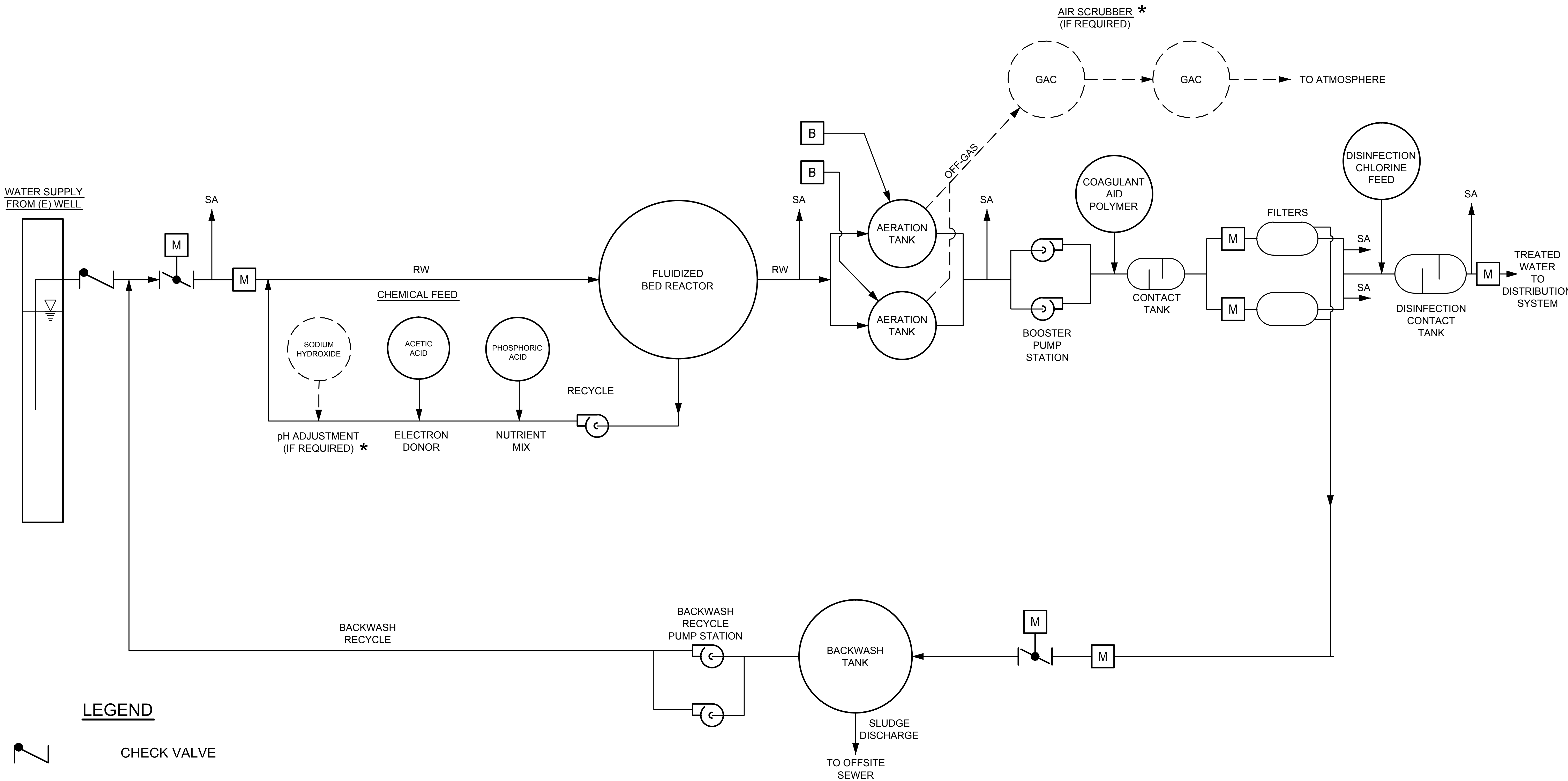
Table 2-1: Project Funding

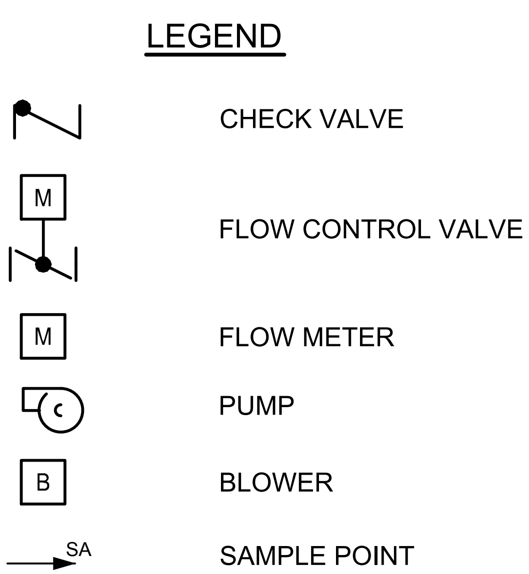
Agency	Funded Amount
State Water Resources Control Board	$100,000
City of Davis	$10,642
Water Resources Association of Yolo County	$19,358
Sacramento Groundwater Authority	$20,000
Total	**$150,000**

2.3 Project Methodology

2.3.1 Pilot System Description

The conceptual full-scale treatment process has four main stages: (Step 1) Fluidized Bed Reactor with chemical/nutrient addition (FBR); (Step 2) Aeration; (Step 3) Filtration; and (Step 4) Disinfection. A full-scale conceptual process flow diagram is depicted in Figure 2-1. The first stage biologically reduces chromium-6 to chromium-3 and denitrifies the water, while the remaining three steps are expected to be required for remove chrome-3 and turbidity, thus complying with current Title 22 drinking water regulations. The CDPH has required the equivalent of surface water treatment for other biological processes it has approved for drinking water systems.





NOTE:

* THESE TWO ADDITIONAL PROCESSES ARE NOT ANTICIPATED TO BE NEEDED.

Kennedy/Jenks Consultants

CITY OF DAVIS SUSTAINABLE CO-REMOVAL OF HEXAVALENT CHROMIUM BY BIOLOGICAL FILTRATION PROCESS

CONCEPTUAL HEXAVALENT CHROMIUM CO-REMOVAL BIOLOGICAL TREATMENT PROCESS FLOW SCHEMATIC

K/J 1270031*00
APRIL 2013
FIGURE 2-1

2.3.1.1 Fluidized Bed Reactor and Aeration Pilot

The pilot process employed a bench-scale small column FBR. The process flow schematic and photograph of the proposed pilot system are shown in Figure 2-2 and Figure 2-3, respectively. The water was fed through the bench-scale FBR column with analogous chemical additions that would be necessary for a full-scale operation. This includes the addition of acetic acid as an electron donor and phosphoric acid as a nutrient. No pH adjustment was found to be necessary. The FBR consists of a vessel containing a carbon media, which provides a surface for bacterial growth. The flow in the system includes a recirculation pump that creates an expanded bed volume.

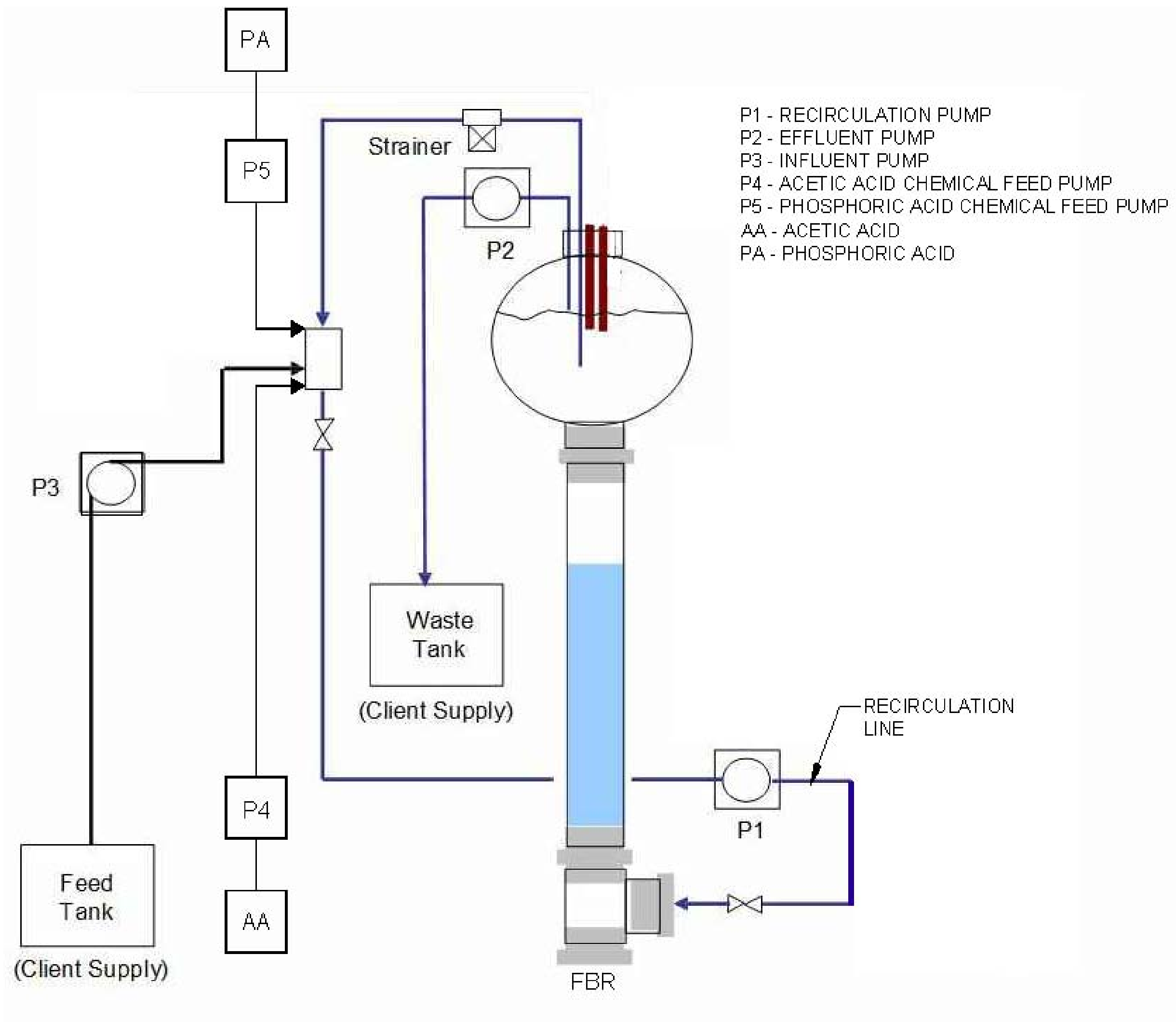


Figure 2-2: Schematic of the FBR

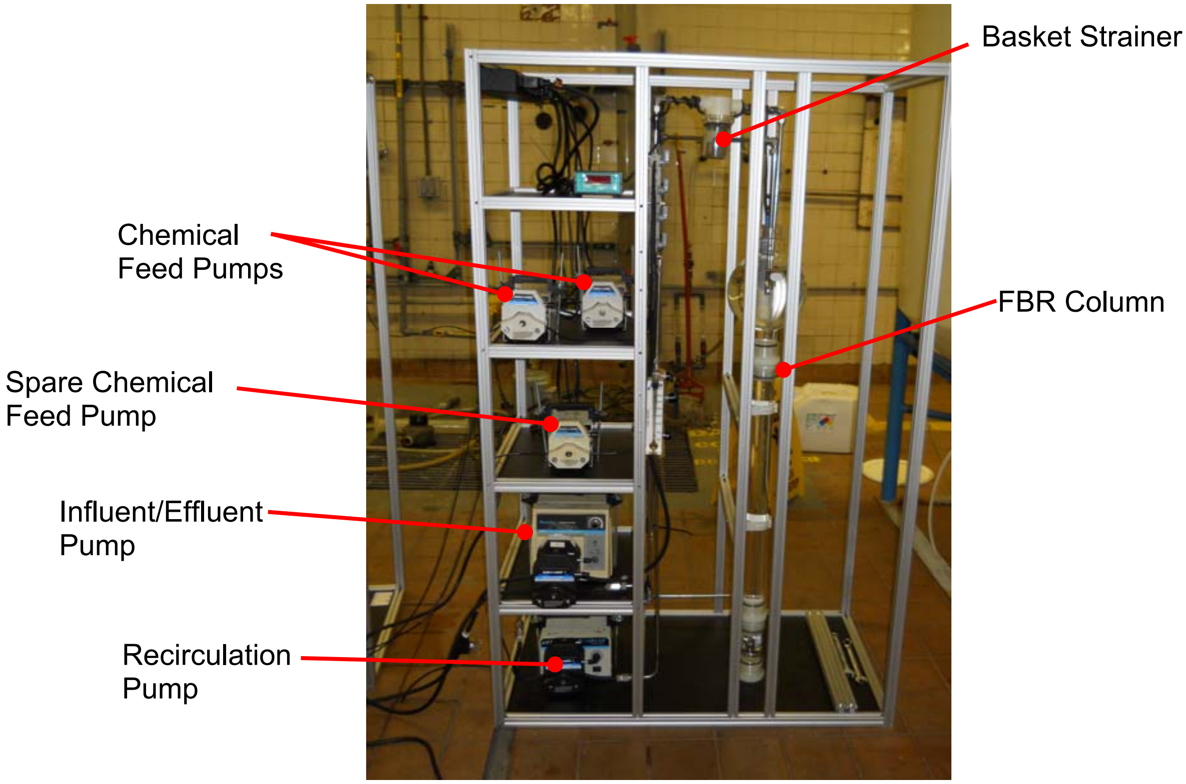


Figure 2-3: Photo of the FBR Pilot System

It was originally planned that after the FBR, the water would be aerated to reintroduce dissolved oxygen and reestablish aerobic conditions through discharging into a small 5-gallon container equipped with an aquarium aeration device. The container and aquarium aeration device was shown to not be needed as the pilot discharge pipeline was oversized to prevent the FBR column from spilling out of the top. The oversized pipeline flowed partially full and the effluent essentially was aerated by the time it reached the end of the pipe. This was proven by the pH returning to an acceptable level.

2.3.1.2 Bench-Scale Filtration, Coagulation and Disinfection

Filtration was simulated on a bench-scale using two different size filter papers to simulate both granular media filtration and membrane microfiltration approaches. The goal of the filtration step at the bench-scale level was to characterize particulate and dissolved chromium and determine whether chromium-3 is effectively removed with or without a coagulant aid from the system through filtration of the samples. It is anticipated that full-scale filtration could include both a contact clarifier and granular media filter or contact tank and pressure filter downstream of the aerator. Alternative treatment processes may include membrane microfiltration. Jar tests were conducted by UC Davis to determine whether additional total chromium removal could be achieved through addition of a coagulant aid.

The final step of the pilot was addition of sodium hypochlorite disinfectant to simulate disinfection and to determine whether any residual chromium-3 within the distribution system is oxidized to reform chromium-6. This test was conducted three times.

During the last week of the pilot, a selenium spike test was completed. Well 20 has relatively low selenium levels compared with the other 13 City intermediate wells (selenium concentrations of 4 to 36 μg/l). The feed tank was spiked with 20 μg/l of selenium for a period of one week.

2.3.2 Pilot System Operations

The water used for the pilot study came from the City of Davis' Well 20. Appendix V contains the Source Water Technical Memorandum that was prepared to describe the water quality of this well. Well water was transported by City staff to the pilot testing location on an as needed basis. The pilot was located at the East Area Tank and Booster Pump Station, located north of I-80 at the Mace Blvd. exit, which is south of the Park and Ride Parking Lot. This location was chosen due to the presence of the pump building, which provided an enclosed semi-temperature regulated and secure area. Temperatures in the building ranged from 45-65°F.

The following sections describe the operations of the pilot system. Operation of the system was conducted by Kennedy/Jenks Consultants and Envirogen Technologies staff.

2.3.2.1 Hydraulic Residence Time

The pilot study was conducted over a 16-week period between November 8, 2012 and March 4, 2013. Over this period, there were four different Hydraulic Residence Times (HRTs) that were targeted. HRT is defined as the average time that the water is exposed to the expanded media in the FBR, which contains the bacterial growth. HRT is a key parameter that is used to gauge FBR system performance. A lower HRT will result in a smaller required FBR footprint.

For this pilot, the four HRTs targeted were 60, 40, 20, and 15 minutes. Flow rates for the system were calculated based on these HRTs. These flow rates were calculated based on the FBR cross sectional area (2" diameter column) and the FBR expanded bed height, which varied due to biological growth and clogging of the filter basket located on the recirculation line. Because of the daily variation of the bed height, it was assumed to be between 22"-26" for HRT calculations, which corresponds to a bed expansion of 30% to 60%.

Below is a list of the targeted HRTs along with their corresponding flow rates for the pilot:

- Acclimation Period (60 Min. HRT) – four week period to allow for growth of indigenous chromium and nitrate reducing bacteria in the FBR.
- 60 Min. HRT – four week period running at a flow rate of approximately 20 mL/min.
- 40 Min. HRT – four week period running at a flow rate of approximately 30 mL/min.
- 15 Min. HRT – three week period running at a flow rate of approximately 77 mL/min.

- 20 Min. HRT – one week period running at a flow rate of approximately 67 mL/min. This period was increased from 15 minutes to allow for better reduction of selenium during the selenium spiking.

2.3.2.2 Adjustment of Chemical Feed

Two chemicals were added to the fluidized bed reactor to assist with chromium and nitrate reducing bacterial growth:

- **Acetic Acid:** Acetic acid provides an electron donor source, which promotes bacterial growth of chromium and nitrate reducing bacteria. The chemical feed system had a single speed peristaltic pump. The estimated feed rate was 0.12 milliliters per minute (mL/min). Field measurements of the feed rate varied. Acetic acid was diluted from the 99% stock solution to a 0.5% to 2.5% solution, which corresponds to a feed rate of 13-18 milligrams carbon per liter (mg-C/Liter) of feed water. Feed rates were adjusted based on the nitrate removal of the system.

- **Phosphoric Acid:** Phosphorus, a necessary nutrient for biological growth was added as phosphoric acid to provide additional nutrients to promote bacterial growth in the FBR. The system has a single speed peristaltic pump. The estimated feed rate was 0.12 mL/min. Field measurements of the feed rate varied. Phosphoric acid was diluted from the 75% stock solution to a 0.005% to 0.035% which corresponds to a feed rate of 0.11-0.17 milligrams phosphorus per liter (mgP/L) of feed water. Feed rates were adjusted based on the nitrate removal of the system and the effluent phosphorus measurements.

The chemical feed data should thus be used with the knowledge that scaling up of the system will likely require different chemical additions than were used in this analysis due to both the inability to measure chemical pumping rates accurately, as well as issues with channeling. Channeling in the system occurs when water does not flow equally throughout all portions of the bed. The major reason for channeling in the bench-scale system was observed as being a result of bacterial production of a biomass that caused clumping of the carbon media together. In a full-scale system, mechanical methods for minimizing channeling exist; however, in the bench-scale system, a more rudimentary method of breaking up the clumps with a pole and nylon brush was practiced throughout the pilot to minimize channeling effects in the bed.

2.3.2.3 Filtration and Disinfection

Two types of filters were used to simulate differing levels of filtration as follows:

1. Granular Media Filter – A Type 541 Whatman filter (paper) was used to simulate the process of a conventional filter system (e.g., gravity or pressure type) used in many water treatment plants. Pore size of 20-25 micrometers (µm).

2. Membrane Filter – A 0.1 µm Osmonics Poretics polycarbonate membrane filter (47 mm diameter) was used to simulate a microfiltration membrane filter system used at many water treatment plants.

Three filtration and disinfection tests were conducted throughout the pilot at the end of each HRT (60, 40, and 20 minutes). During each test, samples were filtered through both types of filter paper and sent to the laboratory for analysis of TSS, total chromium, and chromium-6. Additionally, turbidity and pH were measured in the field.

Disinfection tests were also conducted at all three HRTs. The disinfection was conducted through the addition of 10-12% sodium hypochlorite provided by the City of Davis. For the first two tests, the samples were spiked to 0.5 mg/l chlorine, allowed to sit for 3 days and then sent to the laboratory for total and chromium-6 analysis. The chlorine residual was not measured prior to sending the samples to the laboratory for analysis. During the third test that was conducted samples were spiked to 0.5, 1.0 and 1.5 mg/l total chlorine. Free Available Chlorine (FAC) was measured after spiking, as well as three days later. The 1.5 mg/l sample was sent to the laboratory due to the presence of some residual after the three day period.

2.3.2.4 Jar Tests

Jar testing was conducted to evaluate the opportunity for enhanced chromium removal through use of a coagulant aid prior to filtration. All jar tests were conducted by Ms. Bonnie Robison, a graduate student at UC Davis. The jar tests were conducted through use of standard jar testing apparatus including 2 liter gator jars. After mixing, samples were filtered through the 0.1 µm (membrane) and Type 541 Whatman (granular media) filter paper. Three jar tests were conducted. The coagulant used in all jar tests was ferric chloride ($FeCl_3$).

- Jar Test 1: Addition of 1, 4, 8 and 10 mg/l $FeCl_3$ (during 40 Min. HRT).
- Jar Test 2: Addition of 1, 2, 4, 8 and 10 mg/l $FeCl_3$ (during 15 Min. HRT).
- Jar Test 3: Addition of 2, 4, 10, 15, and 20 mg/l $FeCl_3$ (during 20 Min. HRT).

Total chromium was measured through analysis on an Inductively Coupled Plasma Mass Spectrometer (ICP-MS) owned and operated by UC Davis. Results were calculated from the Cr-53 isotope due to higher interference at the Cr-52 isotope. A more detailed description of the procedure used is provided in Appendix VI.

2.3.2.5 Selenium Spike

On the last week of the pilot, the system was spiked with 20 µg/l of selenium through dilution of sodium selenate, anhydrous. The feed tank was spiked each time it was filled and was mixed thoroughly after each addition. Two samples were taken and sent to the laboratory, one measured total selenium and the second measured speciated selenium. In addition, daily samples of the influent and effluent were sent to the UC Davis Laboratory for measurement by ICP-MS. A more detailed description of the method used for spiking is included in Appendix VII.

2.3.3 Analytical Methods

Throughout the pilot, field measurements and sampling were conducted. As well, some samples were taken and sent to the outside analytical laboratories throughout the pilot study. The schedule of testing that was conducted for both field and laboratory samples is included in the Work Plan (see Appendix VIII).

2.3.3.1 Field Analyses

The following parameters were measured in the field with the indicated equipment and methodology:

- Nitrate: Measured using a HACH DR890 spectrophotometer and the High Range Nitrate Chromotropic Acid Method (0.2-30.0 mg/l).
- Phosphate: Measured using a HACH DR890 spectrophotometer and the Reactive Phosphate Method (0.07-5 mg/l).
- Turbidity: Measured using a La Motte 2020 portable turbidimeter.
- Temperature: Measured using a Hanna Handheld pH/Oxidation Reduction Potential (ORP) Meter.
- Dissolved Oxygen: Measured using an Extech DO Meter (Model 407510).
- pH:
  - Influent/Effluent: Measured using a Hanna Handheld pH/ORP Meter
  - System: Measured using an Eutech Alpha 190 pH Controller with Cole Parmer R-Series Electrode

2.3.3.2 Laboratory Analyses

All outside laboratory analyses were conducted by BSK laboratories, except for the selenium speciation, which BSK contracted out to an outside laboratory. Samples that were sent to the laboratory were collected in bottles provided by BSK Laboratories. BSK included preserved bottles when required for the analyses. The Work Plan (see Appendix G of the Work Plan) contains the methods, detection limits, reporting limits and hold times for the methods used. The entire Work Plan is located in Appendix VIII of this report. Results defined below the reporting limit, but above the detection limit, were included within the results for this study.

Section 3: Public Outreach

One of the objectives of this study is to share the information with the City of Davis, funding partners, regulatory community, and greater water community on the prove of concept for the co-removal of chromium-6 using a biological filtration process.

The Public Outreach efforts that were and will be conducted to meet this objective include:

Present a summary of the pilot study and findings to the:

- City of Davis City Council
- Water Resource Association of Yolo County
- Sacramento Groundwater Authority
- Water Research Foundation and American Water Works Association (AWWA) Hexavalent Chromium Workshop in Sacramento, CA on 5 February 2013.
- CA NV AWWA 2013 Fall Conference in Sacramento, CA (abstract submitted - date to be determined from October 1st to 3rd, 2013)
- AWWA Water Quality Technology Conference in Long Beach, CA (date to be determined from November 3rd to 7th, 2013)

In addition, the following other outreach efforts were conducted:

- Conducted an Open House on February 26, 2013 and had about 40 representatives of various water agencies in the greater Sacramento area attend. At the Open House the attendees were able to view the pilot study, review the preliminary results, and ask questions. The following special guests attended the Open House:
  - Mark Fong, Grant Administrator with the State Water Resource Control Board that funded a significant portion of the project.
  - Andy Soule´, Chair of the Sacramento Groundwater Authority
- Conducted a special site visit on February 28, 2013 with California Department of Public Health staff including:
  - Eugene Leung
  - Bruce Burton
  - Mark Barston
  - John Paul Blanco
- Prepared an article for the City of Davis internal newsletter.
- Prepared an article for the Association of California Water Agencies Newsletter that is Volume 41 No. 4, April 19, 2013 (Appendix XIII).

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Section 4: Results, Conclusions and Recommendations

4.1 Results

The subsections below outline the results of the analysis conducted during this pilot study. A summary of the analytical results are provided in Appendix IX.

4.1.1 Biological Reduction

The results below outline the results for the reduction of chromium-6, nitrate, and selenium in the FBR, as well as a theoretical discussion of the reduction of perchlorate if it had been present in the source water. The system included the addition of acetic acid and phosphoric acid to act as an electron donor and a nutrient source respectively. Based on the results, the system tended to be carbon limited (electron donor) rather than phosphorus limited (nutrient source). Altering the acetic acid concentration in the system affected the reduction of both nitrate and chromium-6.

4.1.1.1 Chromium-6 and Total Chromium Results

The reduction of chromium-6 is achieved through an oxidation/reduction reaction where chromium-6 is reduced to chromium-3 and acetic acid is oxidized. The influent and effluent total chromium and chromium-6 results are shown in Figure 4-1 and Figure 4-2. As described above, it was found that altering the amount of acetic acid (carbon source/electron donor) added to the system affected the percent reduction of chromium-6. This correlation is discussed further in Section 4.1.3.2.

The reduction of chromium to low levels continued even at the 15 minute HRT. The effluent chromium-6 concentration (pre-filtration) was consistently reduced to levels below 5 µg/l, with better reduction with higher carbon addition. Where the carbon addition was increased to 17 mg/l feed water or greater, the effluent chromium-6 concentration was consistently reduced to below 3 µg/l, often with results at non-detect levels. The total chromium removal decreased with increasing HRT, this correlation is shown in Figure 4-3.

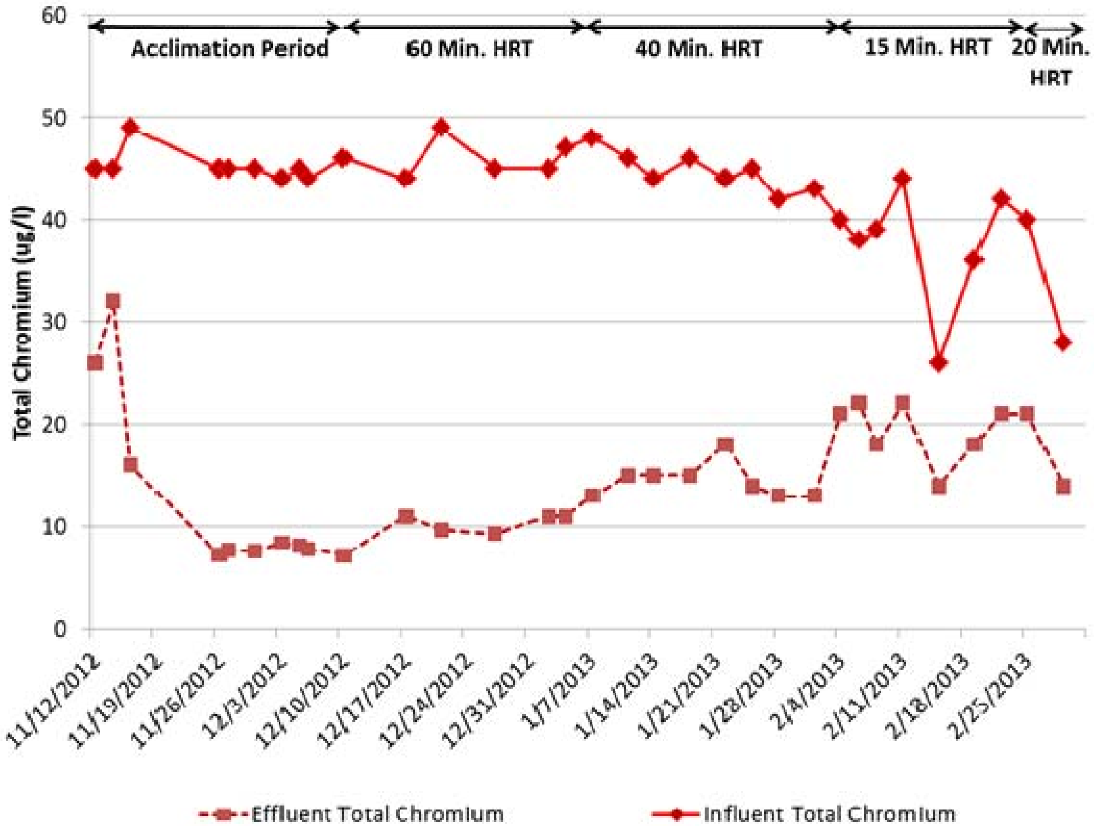


Figure 4-1: Influent and Effluent Total Chromium Results

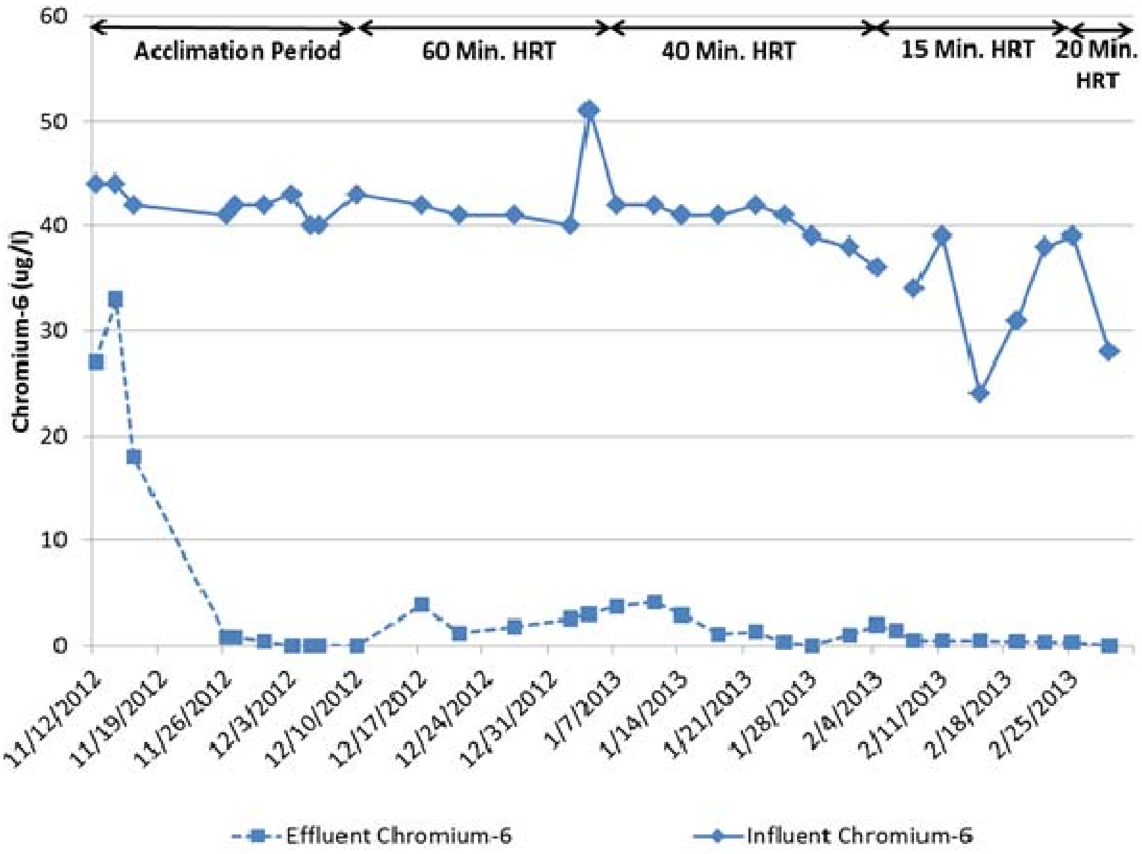


Figure 4-2: Influent and Effluent Chromium-6 Results

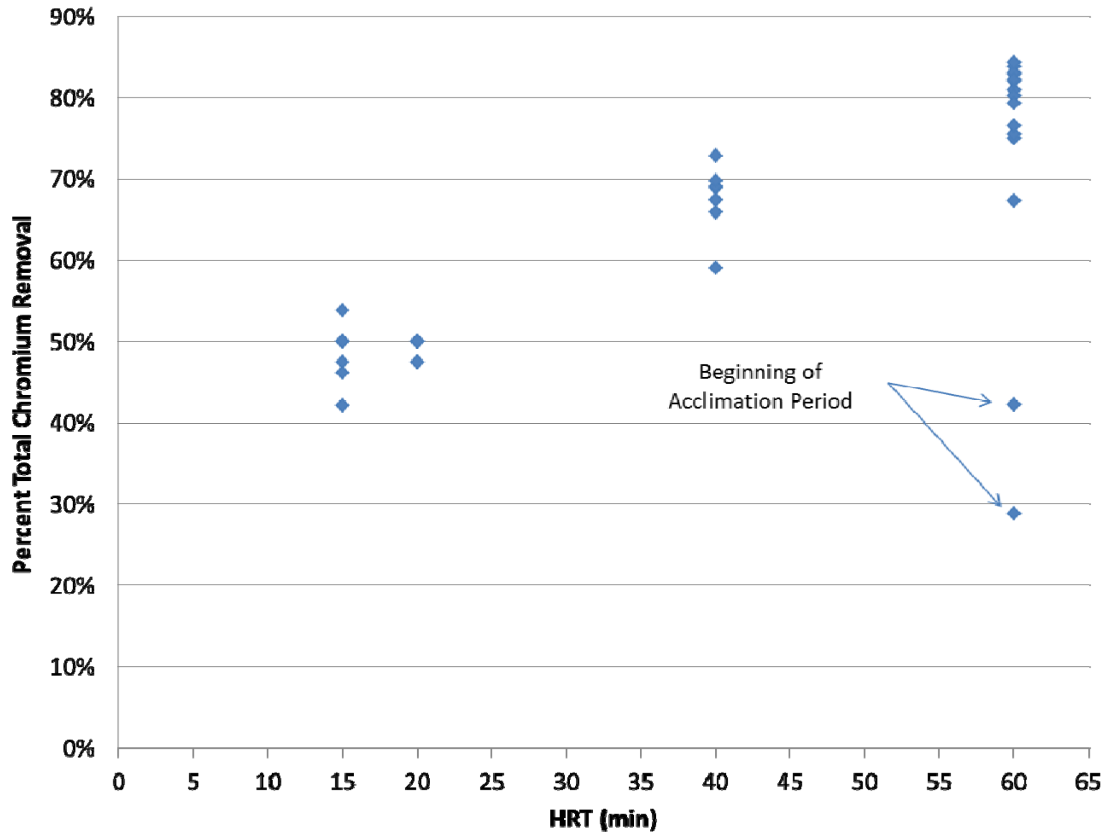


Figure 4-3: Percent Total Chromium Removal vs. HRT

4.1.1.2 Nitrate Results

The reduction of nitrate in the FBR is achieved similarly to that of chromium-6. An oxidation/reduction reaction occurs where nitrate is reduced to nitrogen gas and acetic acid is oxidized. Because nitrate is converted to a gas, nitrate reformation is not an issue. Nitrate was the main food source for the bacteria due to its higher relative concentration in the system (~10 mg/l as N) as compared with chromium. Milligrams carbon added per liter of water treated was shown on Figure 4-4. Reduction of nitrate-N to levels below 1 mg/l throughout the majority of the pilot was achieved. During the transition from 60 to 40 minute HRT, there was a period where the nitrate levels increased to around 2 mg/l. This may have been due to insufficient acetic acid addition.

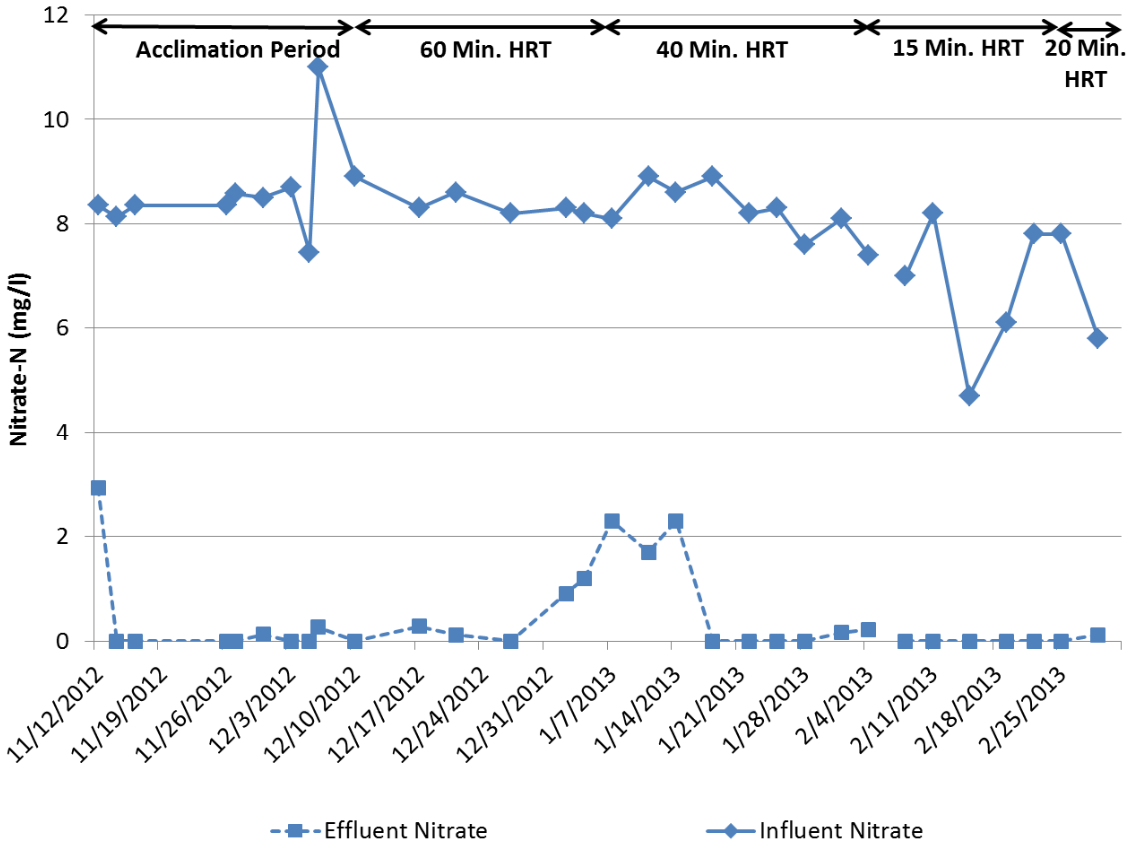


Figure 4-4: Influent and Effluent Nitrate Results

4.1.1.3 Selenium Spike Results

During the last week of the study, the influent feed tank was spiked to approximately 20 μg/l of selenium as selenium-6. All samples were taken within 1 week after the initial spike. Due to the brevity of the spiking period, full acclimation may not have occurred. The water was sampled and analyzed by both BSK and a graduate student from UC Davis, with varying results.

The results from BSK Laboratories indicated an influent of 20 μg/l with removal to 6.4 μg/l on February 25; however, the results provided by UC Davis indicate a spike of 30 μg/l, with the effluent at 10 μg/l for the same day. Figure 4-5 shows the UC Davis selenium results. Although the numerical results were different there was a removal in both cases of about 33%. Effluent samples were taken before filtration (although some filtration occurred in the filter basket). Filtered results are described in Section 4.1.2.4, Figure 4-10 under the coagulant addition testing.

On March 1, the effluent and influent were sent to the outside laboratory to be speciated; however, due to an error in the chain of custody, only the effluent was analyzed. The laboratory reported abnormal results for this test. The results showed Selenium 4 as greater than total selenium, with values of 6.1 μg/l selenium 4 and 3.7 μg/l total selenium. The laboratory indicated that the abnormal results were due to interferences from the matrix (other constituents in the effluent). To analyze interferences laboratories run spike recovery tests. The spike recovery results showed bias for both analysis with the spike recovery for the Se(IV) analysis at ~ 150% indicating moderate negative bias and the spike recovery for the total selenium at ~80% indicating moderate negative bias. This seems to indicate that the Se(IV) analysis provided a higher than actual Se (IV) concentration and the total selenium provided a lower than actual total selenium concentration.

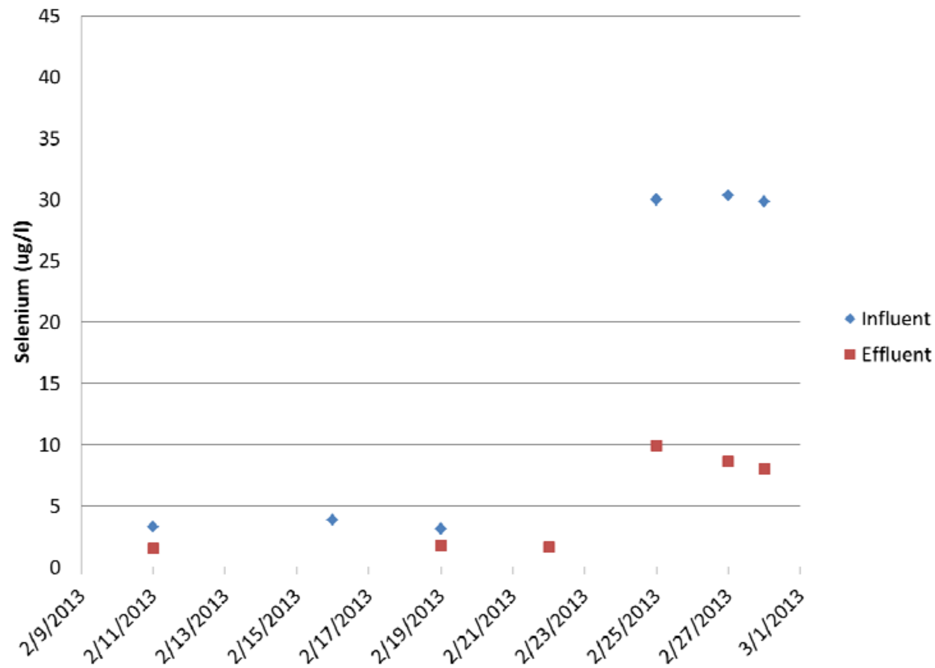


Figure 4-5: UC Davis Selenium Spike Results

4.1.1.4 Perchlorate Removal Estimated Results

The FBR system is capable of treating perchlorate to non-detect levels. The sizing of the FBR will depend on the required HRT, and the HRT will depend on the feed flow rate and concentrations of other constituents in the feed water. In general, the oxidation-reduction potential of perchlorate reduction is very close to hexavalent chromium reduction. With the pilot FBR showing hexavalent chromium reduction higher than 98% at 15-minute HRT, an FBR system with HRT at 19 to 20 minutes should be used to remove perchlorate if it is also present in the feed water at low concentrations (<0.3 mg/l). The HRT will increase with higher perchlorate concentrations, which will increase the size of the FBR vessel.

4.1.2 Aeration, Filtration, Coagulation and Disinfection Results

4.1.2.1 Aeration

The full-scale system will require aeration to reintroduce oxygen into the water after creating an anoxic environment and prior to sending to the distribution system. Envirogen Technologies' pilot did not have an aeration basin, so an aeration basin was created through the use of a five gallon bucket and aquarium aerator. The difference in diameter between the effluent and influent lines caused the effluent to be aerated prior to discharge into the sample container. To confirm that no change in oxidation of the chromium present in the system would occur during aeration, one set of aeration samples were taken. The Dissolved Oxygen (DO) was measured before aeration to be 9.2 mg/l. The effluent was then aerated for 30 minutes after which the DO was re-measured to be 9.5 mg/l. The effluent and aerated samples were sent to the laboratory for analysis. Table 4-1 shows the changes in chromium in the influent, effluent and aeration samples. There was little to no change observed. Based on these data, no additional aeration samples were analyzed.

Table 4-1: Influent, Effluent and Aerated Chromium

	Influent	Effluent	Aerated
Chromium-6 (μg/l)	41	1.8	1.8
Chromium-3 (μg/l)	4	7.5	8
Total Chromium (μg/l)	45	9.3	9.8

4.1.2.2 Filtration

Bench top filtration was conducted as described in Section 2. The influent, effluent, and aerated (for sample 1) samples for filtered chromium, total chromium, turbidity and TSS results are shown for the 60, 40, and 20 minute HRTs in Tables 4-2 to 4-4 (without coagulant). The TSS was non-detect (<5.0 mg/l) in all but one filtered sample. The turbidity decreased significantly from the effluent to the filtered sample, with the membrane filtered sample consistently having a lower turbidity than the granular media filtered sample (see Tables 4-2 to 4-4). However, there was very little removal of chromium, indicating the residual chromium is likely in a dissolved state. Additional chromium-3 removal with addition of a coagulant is discussed in Section 4.1.2.4. Without coagulant addition, reformation of chromium-6 may occur in the presence of a disinfectant such as chlorine.

Table 4-2: Filtration 60 Minute HRT

	Effluent	Aerated	Membrane Filter	Granular Media Filter
Chromium-6 (μg/l)	1.8	1.8	1.8	1.9
Chromium-3 (μg/l)	7.5	8	6.3	7.5
Total Chromium (μg/l)	9.3	9.8	8.1	9.4
Turbidity (NTU)	2.77	0.98	0.07	0.37
TSS (mg/l)	NM	NM	<5.0	<5.0

NM- Not Measured

Table 4-3: Filtration 40 Minute HRT

	Effluent	Aerated	Membrane Filter	Granular Media Filter
Chromium-6 (μg/l)	1	NM	0.79	0.47
Chromium-3 (μg/l)	12	NM	11.21	10.53
Total Chromium (μg/l)	13	NM	12	11
Turbidity (NTU)	0.78	NM	0.15	0.35
TSS (mg/l)	NM	NM	<5.0	<5.0

NM- Not Measured

Table 4-4: Filtration 20 Minute HRT

	Effluent	Aerated	Membrane Filter	Granular Media Filter
Chromium-6 (μg/l)	<0.2	NM	0.34	<0.2
Chromium-3 (μg/l)	14	NM	12.66	13
Total Chromium (μg/l)	14	NM	13	13
Turbidity (NTU)	1.88	NM	0.13	0.52
TSS (mg/l)	NM	NM	<5.0	11

NM- Not Measured

4.1.2.3 Disinfection and Chromium-6 Reformation

The disinfection simulation was conducted as described in Section 2. The chromium-6 results for the disinfection tests conducted during the 60 and 40 minute HRTs (dosed at 0.5 mg/l chlorine) showed little to no re-formation of chromium-6. However, the chlorine residual was not re-measured after allowing the samples to sit for three days; therefore, these tests provide limited information regarding reformation of chromium-6 in the presence of a continuous chlorine residual. These results are shown in Figure 4-6 and Figure 4-7.

For the third disinfection test conducted during the 20 minute HRT, the free chlorine residual (FAC) was measured immediately after chlorination as well as after sitting for three days. The samples were dosed at 0.5, 1.0 and 1.5 mg/l. Because the residuals were low in all of the samples after three days, the one dosed at the highest concentration (1.5 mg/l) was sent to the laboratory for chromium-6 and total chromium analysis. As shown in Figure 4-9, the chromium-6 concentrations increased from 0.34 μg/l to approximately 2 μg/l, showing some indication of reformation potential. Additional testing should be conducted to confirm these results due to the limited sample size.

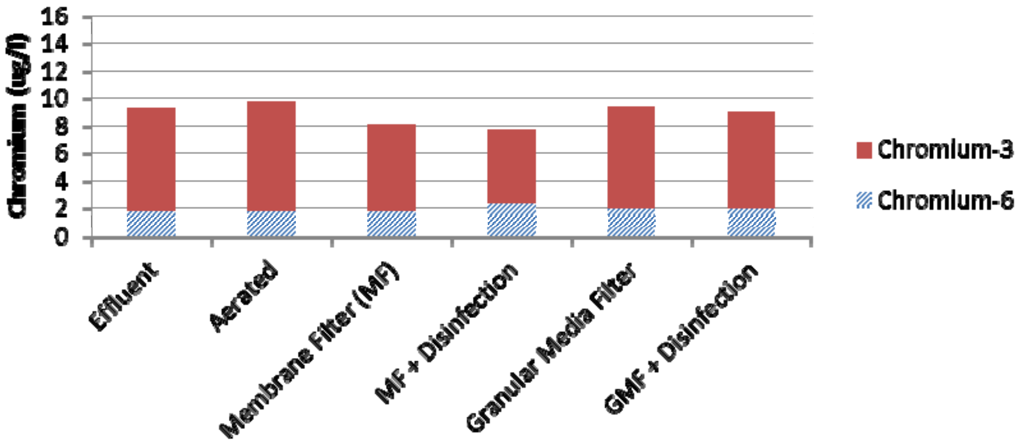


Figure 4-6: Disinfection 60 Minute HRT (0.5 mg/l chlorine dose)

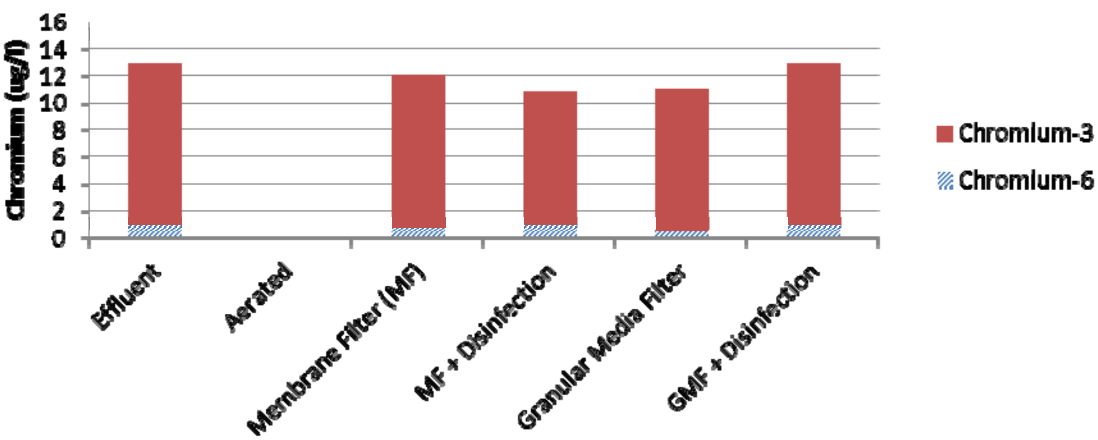


Figure 4-7: Disinfection 40 Minute HRT (0.5 mg/l chlorine dose)

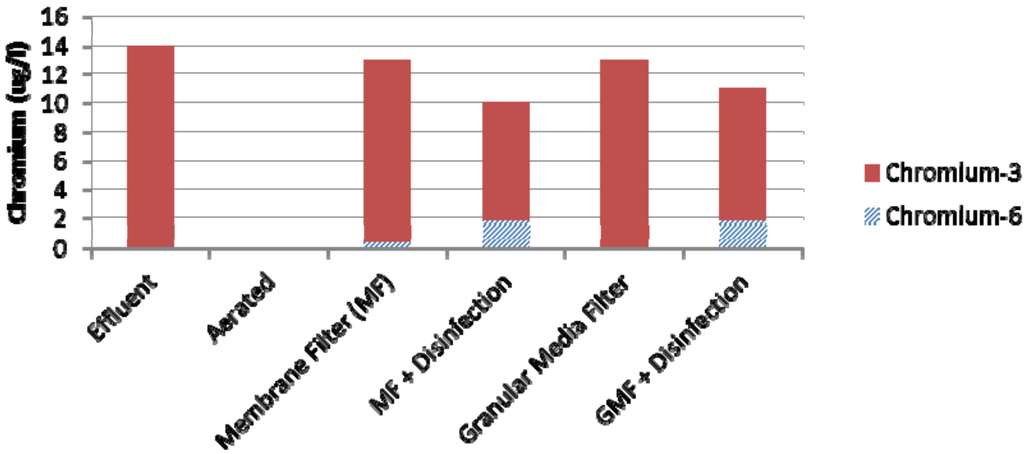


Figure 4-8: Disinfection 20 Minute HRT (1.5 mg/l chlorine dose)

The chlorine residual test also revealed a higher than expected chlorine demand. The City normally doses Well 20 at 0.5 mg/l to maintain a residual of 0.3 mg/l in the water distribution system. Thus, an additional demand of up to 0.2 mg/l can be expected in the source water. The reason for the additional chlorine demand seen in the samples may be due to the higher TOC residual during this period. The system had been adjusted to the 20 minute HRT for about two weeks prior to conducting the disinfection test; however, the acetic acid concentration had not been optimized due to the lag time between sampling and laboratory results (two weeks). The TOC effluent was measured between 3-4.5 mg/l during the 20 minute HRT (with a goal of ~1 mg/l).

The sample that was dosed at 1.5 mg/l had a residual of 0.05 and 0.08 mg/l after three days for the membrane filter and granular media filter, respectively. A blank confirming the Well 20 source water demand was not conducted. This information is shown in Table 4-5. Over this period, the chromium-6 concentration increased from below 0.5 to 1.8 μg/l for both the membrane and granular media filter samples.

Table 4-5: Chlorine Residual Results for 20 Min. HRT

Filter	Chlorine Dose (mg/l)	Chlorine Residual immediately after dosing (mg/l)	Chlorine Residual after Three Days (mg/l)
Membrane	0.5	0.26	Below detection limit of measuring device
Membrane	1	0.23	0.01
Membrane	1.5	0.51	0.05
Granular Media Filter	0.5	0.33	0.02
Granular Media Filter	1	0.31	0.12
Granular Media Filter	1.5	0.65	0.08

4.1.2.4 Jar Tests

Based on the filtration tests conducted during the 60, 40 and 20 minute HRT, the majority of the total chromium that was filterable was removed in the FBR process. It is thought that this portion was removed with the biomass in the filter basket; however, no additional testing was conducted to confirm this theory.

The total chromium that was seen in the effluent was found to be predominantly in a dissolved form (was not filtered out through either the granular media or membrane filter). Therefore, jar tests were conducted to determine if the addition of a coagulant would increase removal of total chromium. The methods used for jar testing are described in more detail in Section 2. The first two jar tests included adding 1, 4, 8, and 10 mg/l of ferric chloride ($FeCl_3$) to the samples and treating them using a modified jar test methodology. The jar test effluents were then filtered through a membrane and granular media filter after which the total chromium concentrations were measured. These results are shown in Figure 4-9 and Figure 4-10. They were conducted during the 40 minute and 15 minute HRT. A third test was conducted where concentrations up to 25 mg/l were added to the effluent. This test was conducted during the 20 minute HRT and the results are shown in Figure 4-9.

Results from the jar tests indicate that addition of $FeCl_3$ at 4 mg/l was capable of achieving a total filtered chromium effluent concentration less than 5 μg/l. Addition of $FeCl_3$ concentrations at 10 mg/l achieved a total filtered chromium effluent concentration less than 2.5 μg/l. Both the granular media and membrane filters performed equivalently.

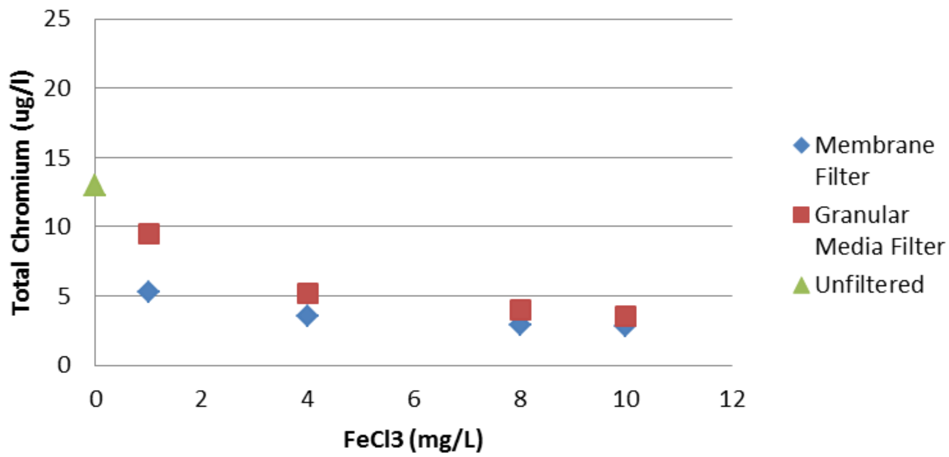


Figure 4-9: Chromium Removal Jar Test 1 (February 1, 40 Min. HRT)

Note: Unfiltered total chromium was measured by BSK Laboratories.

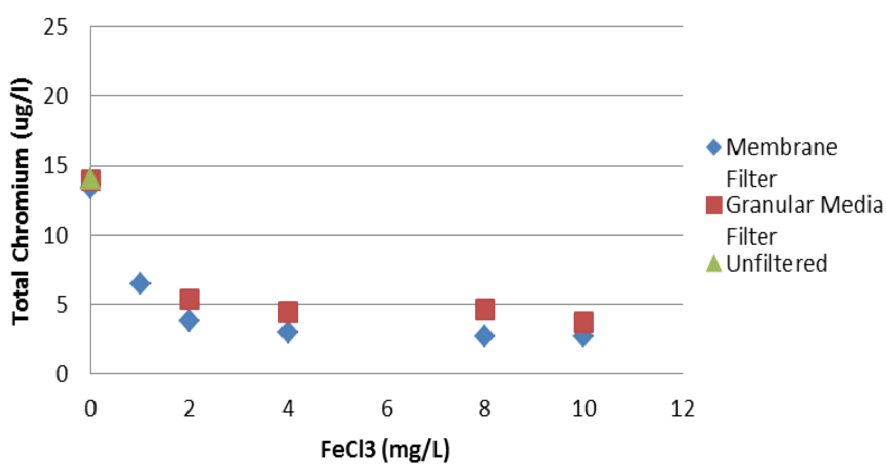


Figure 4-10: Chromium Removal Jar Test 2 (February 15, 15 Min. HRT)

Note: Unfiltered total chromium was measured by BSK Laboratories.

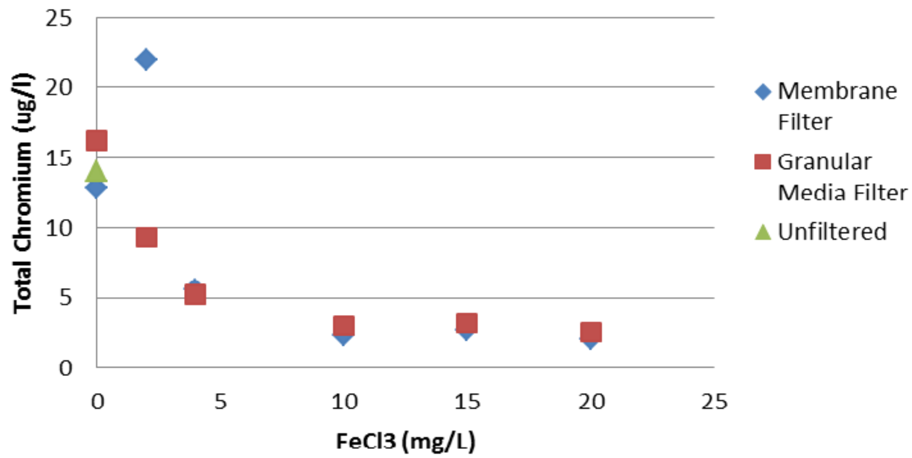


Figure 4-11: Chromium Removal Jar Test 3 (March 1, 20 Min. HRT)

Note: Unfiltered total chromium was measured by BSK Laboratories.

Selenium removal was also measured during the third jar test. Removal of selenium with addition of ferric chloride as a coagulant was limited and appears to require a high dosage than for chromium removal (15 to 20 mg/l required to remove about 30 percent of selenium). Additional testing would be required to optimize selenium removal.

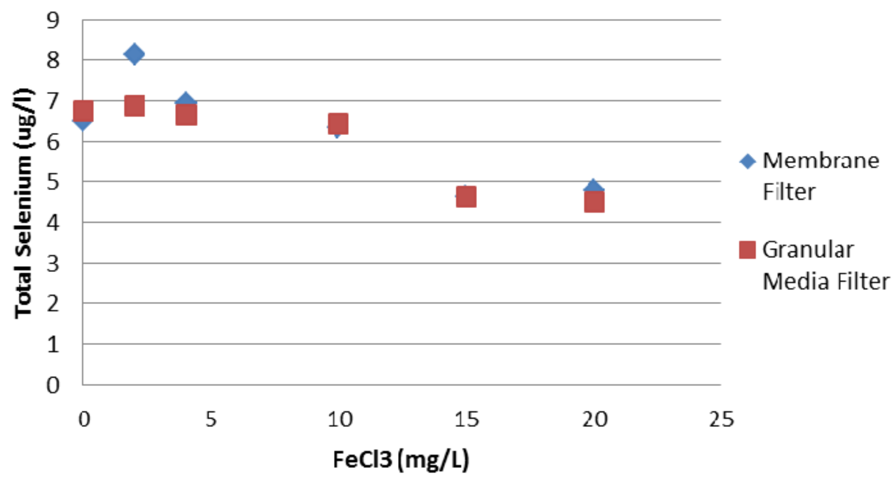


Figure 4-12: Selenium Removal Jar Test 3 (March 1, 20 Min. HRT)

4.1.3 FBR Pilot System Performance

4.1.3.1 Bed Expansion

The GAC media bed height was measured three times a week throughout the pilot study. A bed height of 16.5” was the height when settled. A height of 21.5” was considered 30% expanded and a height of 26.5” was considered 60% expanded. The bed height was affected by a number of factors. The height fluctuated before and after cleaning the filter basket strainer due to backpressure created by the clogging of the filter basket strainer. The values in Figure 4-12 represent the post filter basket strainer cleaning bed height of the system. The GAC bed itself was not cleaned until January, when the bed expansion began to greatly increase after reducing from a 60 minute to a 40 minute HRT. Throughout the 40 minute HRT, periodic cleaning was conducted. During the 15 minute HRT cleaning of the bed was conducted approximately every 1-3 days to maintain bed expansion within the optimal range of 30-60%. In a full-scale system, mechanical methods for maintaining the bed expansion within ideal parameters exist and would be used. The large dip present at the end of January was due to clogging in the lines that caused a lower recirculation rate to occur in the system. This clogging was cleared periodically by flushing the line with distilled water using the recirculation pump.

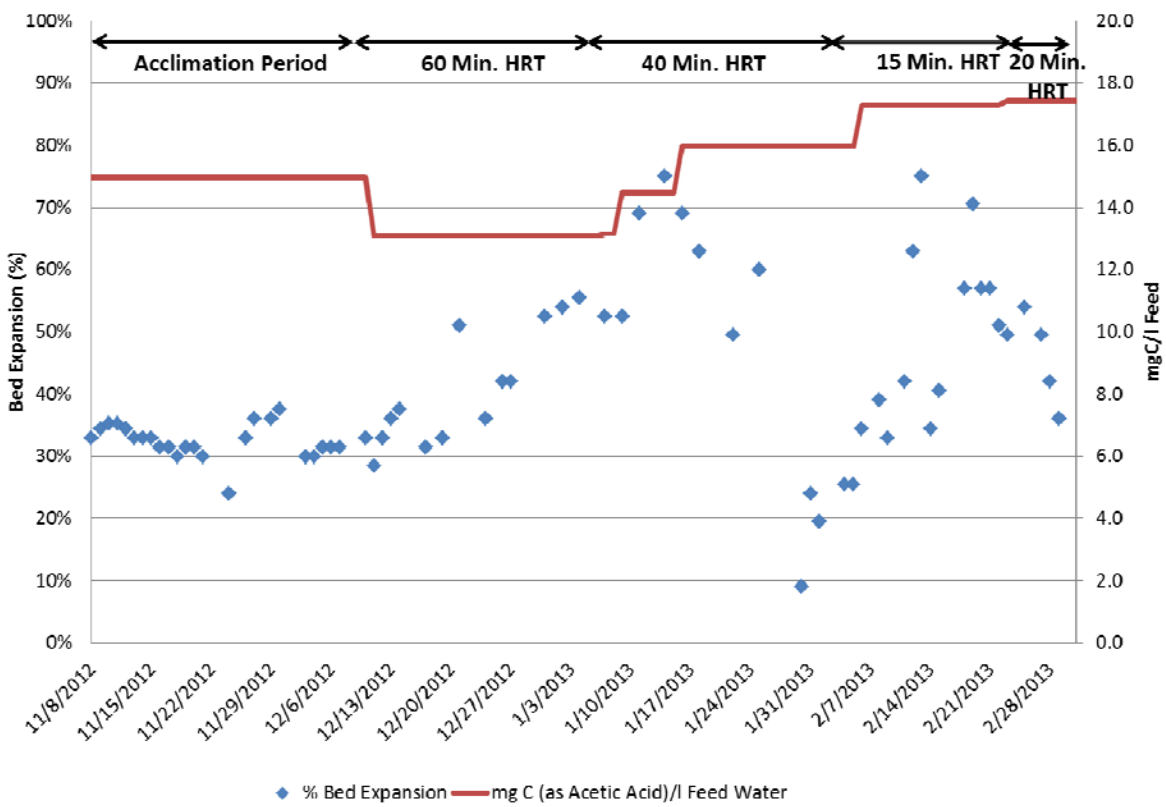


Figure 4-13: Bed Expansion HRT and Electron Donor Feed Rate

4.1.3.2 Electron Donor and Nutrient Optimization

The electron donor was adjusted based on the effluent nitrate and chromium results. Figure 4-15 and Figure 4-15 show the percent chromium-6 reduction and percent nitrate removal versus acetic acid addition. There is a general correlation between the percent chromium-6 reduction and the acetic acid addition where a higher addition of acetic acid resulted in a higher percentage of chromium-6 reduction. For nitrate removal carbon addition in excess of 14 mg C (as Acetic Acid)/ l Feed water was sufficient to remove nitrate. Figure 4-16 shows the TOC added vs. effluent TOC. A high level of TOC in the effluent is a concern due to the potential for occurrence of disinfection byproducts after chlorination. To achieve complete reduction to non-detect of chromium-6, this system required excess TOC (>1 mg/l residual TOC). Reduction down to low levels (chromium-6 <5.0 μg/l) can be achieved with a low (1 mg/l or below) TOC level in the effluent.

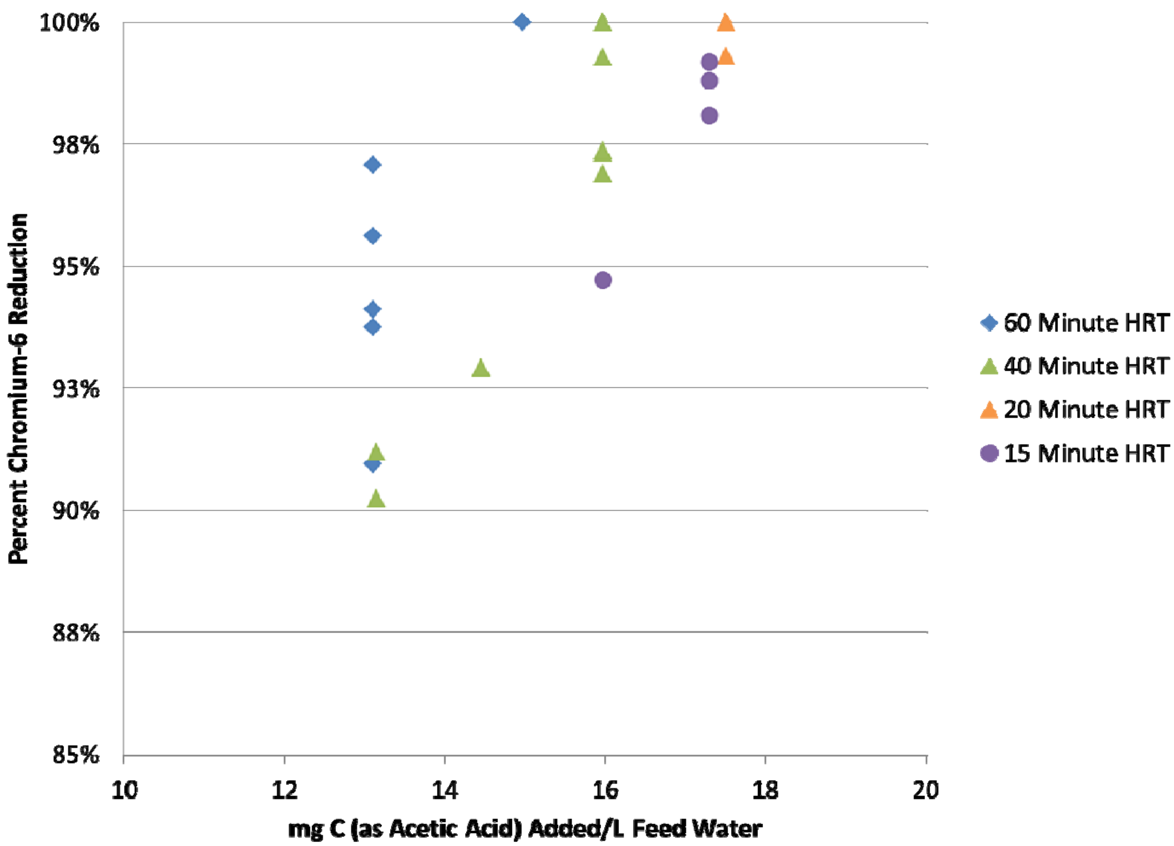


Figure 4-14: Percent Chromium-6 Reduction vs. Acetic Acid Addition

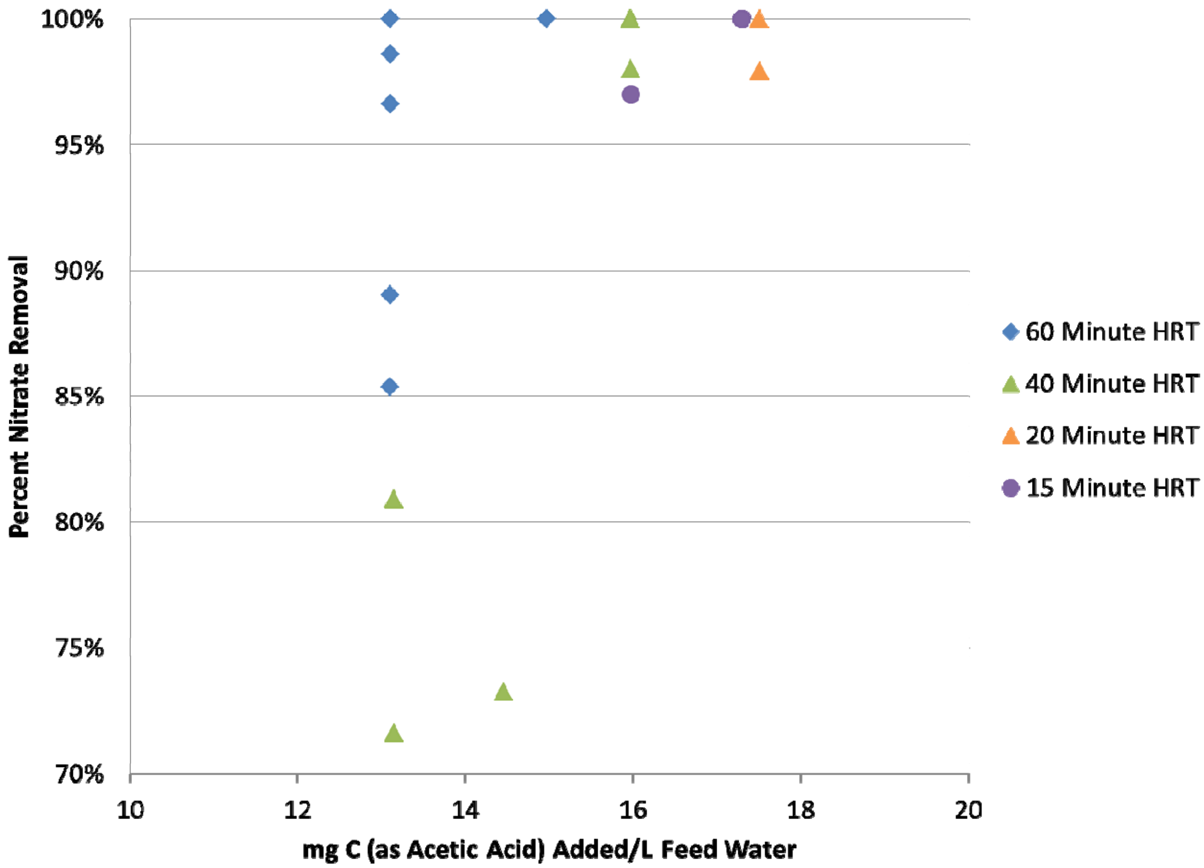


Figure 4-15: Percent Nitrate Removal vs. Acetic Acid Addition

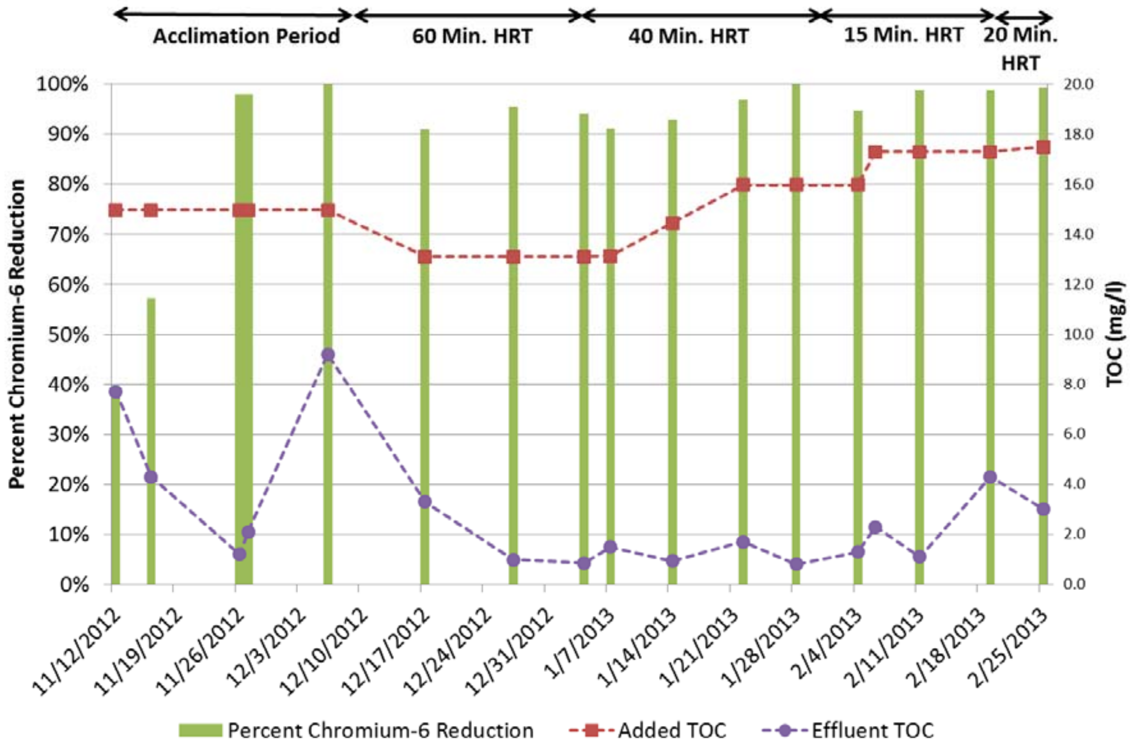


Figure 4-16: Chromium-6 Removal vs. TOC Added and Measured Effluent TOC

Note: % chromium-6 reduction = chromium-6 effluent/chromium-6 influent*100%

Because the FBR creates a highly reducing environment, bacterial reduction of sulfate could become an issue. Sulfate reduction causes the conversion of sulfate to hydrogen sulfide. Hydrogen sulfide is a highly corrosive and noxious gas, which when dissolved in water forms hydrosulfuric acid. Its presence in the effluent water is undesirable, therefore sulfate concentrations in the effluent were measured as a surrogate for hydrogen sulfide formation. The average historic sulfate concentration in Well 20 over the last four years was 36 mg/l as sulfate, with a high of 38 and a low of 33 mg/l. The pilot study influent water was not analyzed for sulfate. Sulfate concentrations in the effluent averaged 39 mg/l with a high of 42 and a low of 35 mg/l. The effluent levels remained within the expected range throughout the pilot, which indicates that sulfate reduction was not occurring in the FBR.

4.1.3.3 Flow Rate, pH and Other Parameters

Figure 4-17 shows the following:

- Actual: Flow rate based on measured changes in the feed tank over time
- Goal: Desired flow rate
- Measured: Flow rate measured from the influent pump. Value is expected to be slightly off because measurement does not include effects of headloss when pumping to the system.

These results showed that the flow rate was within the expected range. The 20 minute HRT was slightly lower than the expected flow rate.

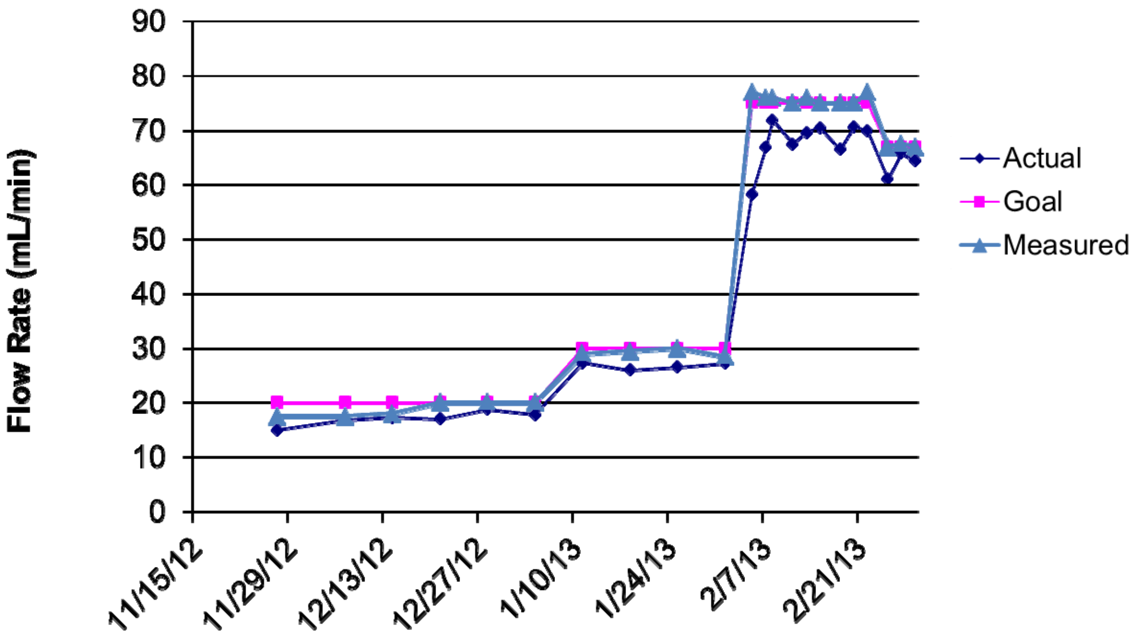


Figure 4-17: Actual Flow Rate vs. Goal

The influent, effluent and system pH were measured throughout the pilot. The average influent pH was 8.2. The average system pH was 7.2 and the average effluent pH was 7.7. Table 4-6 shows the average pH and range of pH for the influent, system and effluent. It was expected that the pH increased between the FBR and the effluent due to aeration in the effluent discharge line.

Table 4-6: pH Pilot Test Results

	Average	Minimum	Maximum
Influent	8.2	7.8	8.5
System	7.2	6.7	8.8
Effluent	8.2	7.8	8.5

4.1.3.4 Residuals

Although residuals were not measured due to the small amount produced in the pilot, a full-scale system would produce solids that would be removed in the granular media or membrane filters. The estimated TSS in the effluent for the Well 20 water is 6.0 mg/l. If the system is pumping at 1,400 gpm and the annual average use of the well is 65%, this would equate to 93 lbs/day solids. These solids will be settled in the backwash tank and discharged to the local sewer system. It is expected that if the residuals were treated onsite and dried, the dried residuals would likely pass the Toxicity Characteristic Leaching Procedure (TCLP) test and the California Waste Extraction Test (WET), and could be disposed at a local municipal landfill.

4.2 Project Evaluation and Effectiveness

4.2.1 Removal Efficiency and Feasibility for Anticipated MCL

Table 4-7 provides a summary of the chromium-6 reduction, and total chromium and nitrate removal for the different HRTs. Reduction of chromium-6 was high throughout all HRTs and chemical feed concentrations. Higher reduction was seen with a higher acetic acid concentration.

Table 4-7: Summary of Results

HRT (min)	AA Addition (mgC-L Feed Water)	PA Addition (mgP/L Feed Water)	% Chromium-6 Reduction	Effluent Chromium-6 (μg/l)	% Total Chromium Removal	% Nitrate Removal	% Selenium Removal
60	15	0.11	98-100%	<0.2-0.83	81-84%	98-100%	N/A
60	13	0.11	91-97%	1.2-3.8	75-80%	85-100%	N/A
40	13.1	0.13	90-91%	3.7-4.1	67-73%	72-81%	N/A
40	16	0.15	95-100%	<0.2-1.3	48-70%	97-100%	N/A
15	17.3	0.16	98-99%	0.31-1.4	42-50%	100%	N/A
20	17.5	0.17	99-100%	<0.2-0.27	48-50%	98-100%	70%

N/A = not applicable.
AA – Acetic Acid
PA – Phosphoric Acid

4.2.2 Footprint of Conceptual Treatment System

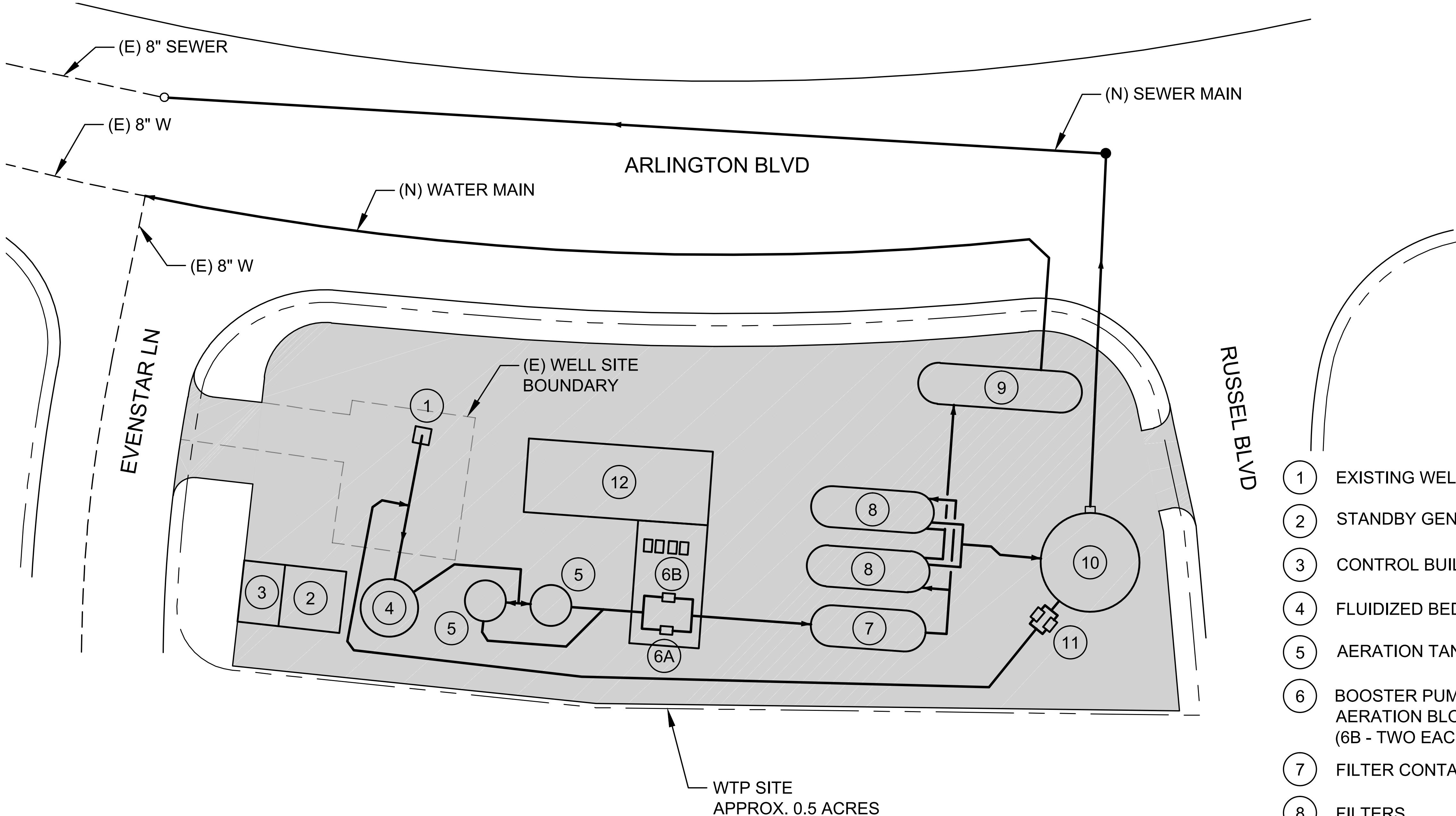
A conceptual footprint to incorporate a biological treatment process at the City of Davis Well 20 site was developed based on a 1,400 gallon per minute (gpm) treatment system flow rate. The following source information was used as the basis for selecting and sizing process components:

- Results from the recent Davis Chromium-6 Pilot Study
- Process design requirements from CDPH for the West Valley Water District and City of Rialto Groundwater Wellhead Treatment System Project, which is using the fluidized biological reactor (FBR) system that was piloted at the City of Davis

The flow schematic for the recommended process is shown in Figure 2-1. The conceptual design criteria and sizing of the key processes are shown in a Tables X-1 to X-3, located in Appendix X. Using the current Well 20 site, a site specific footprint for the full-scale water treatment facility is shown in Figure 4-18. The current Well 20 site is about 0.14 acres and would require the acquisition of another 0.36 acres as the water treatment facility would encompass about 0.5 acres. The facility will not fit within the existing well site footprint, so it was assumed that the treatment system would be constructed on the adjacent open space property.

The following description provides a summary of the treatment processes (in the order of the flow process) and key assumptions that were made in sizing the footprint:

- **Existing Well 20** – The existing Well 20 vertical turbine pump and motor will be modified to meet the revised hydraulic conditions and to provide a variable frequency drive capability.
- **Fluidized Bed Reactor** – It is recommended that only one FBR be used since the unit needs to run fairly continuously. Typically, the FBR can be off-line for about 21 to 30-days before another acclimation period will be required before the treatment plant is ready to deliver water to the system. A recycle booster pump station would be incorporated with the FBR.
- **Aeration Tanks** – Two aeration tanks are provided to raise the dissolved oxygen (DO) and pH of the water received from the FBR. The aeration tanks also act as an intermediate clearwell and provide storage to allow uninterrupted operation of the FBR when the pressure filter goes into backwash. A blower dedicated to each aeration tank will be required.
- **Contact Pressure Vessel** – A baffled filter contact pressure vessel will be used to provide contact time for the ferric chloride coagulant to properly mix and form a filterable floc.



1 EXISTING WELL 20 (125 HP)

2 STANDBY GENERATOR

3 CONTROL BUILDING

4 FLUIDIZED BED REACTOR

5 AERATION TANKS

6 BOOSTER PUMP STATION BUILDING (6A - TWO EACH @ 50 HP EACH) + AERATION BLOWERS (6B - TWO EACH @ 10HP) + RECIRCULATION PUMPS (6B - TWO EACH @ 30 HP)

7 FILTER CONTACT TANK

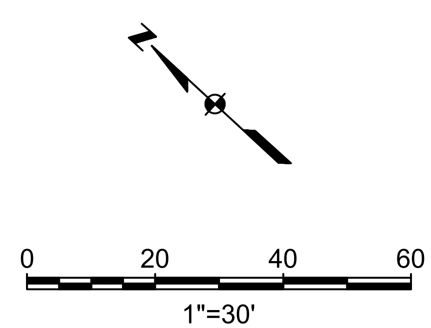
8 FILTERS

9 CHLORINE CONTACT TANK

10 BACKWASH TANK

11 BACKWASH WATER RECYCLE BOOSTER PUMP STATION (2 EACH @ 5 HP)

12 CHEMICAL BUILDING



Kennedy/Jenks Consultants

CITY OF DAVIS SUSTAINABLE CO-REMOVAL OF HEXAVALENT CHROMIUM BY BIOLOGICAL FILTRATION PROCESS

WELL 20 - SPECIFIC SITE PLAN

K/J 1270031*00
APRIL 2013
FIGURE 4-18

N:\2012\1270031.00_CR6-Pilot-Study\127003100-SITE-01.dwg CALVIN SUGG 4/15/2013 1:24 PM

- **Pressure Filter Vessels** – Two pressure filter vessels will be used in parallel to provide a direct filtration treatment process. Each filter vessel will be divided into two cells. When in a backwash mode the three remaining filter cells will provide the backwash water to the cell under backwash. This will essentially stop the flow of water from the treatment plant to the water distribution system. Both cells of a filter vessel will be backwashed during the same cycle before being placed back into operation.

- **Chlorine Contact Tank** – A baffled pressure vessel will be used to provide chlorine contact time to meet the CT requirements equivalent to a surface water treatment plant for virus inactivation. The CT requirements will be equivalent to a 3.0 log virus inactivation as the direct filtration process is credited with 1.0 log virus inactivation.

- **Backwash Water System** – Filter backwash and filter to waste water will be discharged to an above ground welded steel tank. The bottom 6 to 7-feet of the tank will be dedicated to settled solids. After one filter is backwashed the water will be allowed to settle in the tank for about 4 to 6 hours and then the backwash water return pump will be activated to send the decanted water back to just downstream of the wellhead. The backwash water return will be limited to 10% of the well discharge flow rate, in this case about 140 gpm. The backwash tank volume has a 10% contingency built into it.

- **Solids Handling** – It is assumed that the solids in the backwash tank would be periodically discharged to the City of Davis sewer about every four days. If sewer capacity was not available nearby, another option is to construct a much larger backwash tank on site. The backwash tank would increase from a 67,700 gallon tank to a 127,000 gallon tank (about 30 feet in diameter and 24 feet tall) to provide approximately 35 days of solids storage with space above the sludge storage for decant water capacity. This would require trucking about 29,000 gallons each month to the City's Wastewater Treatment Plant. The trucked sludge (estimated at 1% solids) would be discharged to designated sludge drying beds dedicated to dry and dispose of the chromium-6 WTP sludge.

Support facilities will include the following:

- Control room and standby power generation room, both housed in the control building.

- Chemical storage building with acetic acid, phosphoric acid, coagulant aid (i.e., ferric chloride), and sodium hypochlorite storage tanks and chemical feed pumps.

- Building to house the booster pumps and aeration tank blowers.

- Site improvements including security fencing or walls, access ways, on and off-site utilities, site electrical and controls, security systems, and site paving and landscaping.

Incorporating the treatment process into a "Greenfield Site", where a new well would be constructed and a biological treatment process added could yield a smaller footprint. A "Greenfield Site" assumes that the City of Davis owns the property for a new well site, the well is assumed to be added, and the only cost needed is the addition of the FBR treatment system. In addition, the sizing of the processes was developed conservatively and could possibly be reduced based on the alternatives listed below. These alternatives could be considered under future bench-pilot, full-scale pilot or demonstration projects:

- Evaluate the use of one aeration tank since the filter pressure vessel cells provide the backwash water for the one cell under backwash. There is never a need to shut down the flow to the FBR, thus the aeration tanks would not be needed to act as a clearwell.

- Evaluate the contact time required to achieve chemical mixing of the coagulant prior to pressure filters. Currently it is estimated at 10 minutes. Determine if an inline mixer would suffice and the contact clarifier could be reduced in size or eliminated.

- Evaluate if disinfection could occur directly after the aeration tanks and achieve the required contact time using the pre-filter contact vessel and/or filter vessels, thus being able to eliminate the chlorine contact vessel. To confirm if this is possible, conduct an evaluation to see if disinfection byproducts would be formed with the addition of sodium hypochlorite prior to the filtration process.

- Evaluate the pressure filter design loading rate at 5.0 gpm/sf. Based on the bench-scale pilot test, the highest turbidity prior to filtration was 5.8 NTU. Currently the filter loading rate used for sizing the process was 3.0 gpm/sf. This coincides with CDPH standards for direct filtration for a surface water treatment process. If the filter rate could be demonstrated to function satisfactorily at a higher loading rate (5.0 gpm/sf), the size of the filters could be reduced.

- Locate booster pump stations outside and not in a building, and only use a covered roof structure with secondary containment for the chemical storage area.

If these alternatives were successful, it is estimated the footprint would be reduced from a 0.5 acre site to a 0.30 acre site, a 40% reduction in footprint as shown in Figure 4-19.

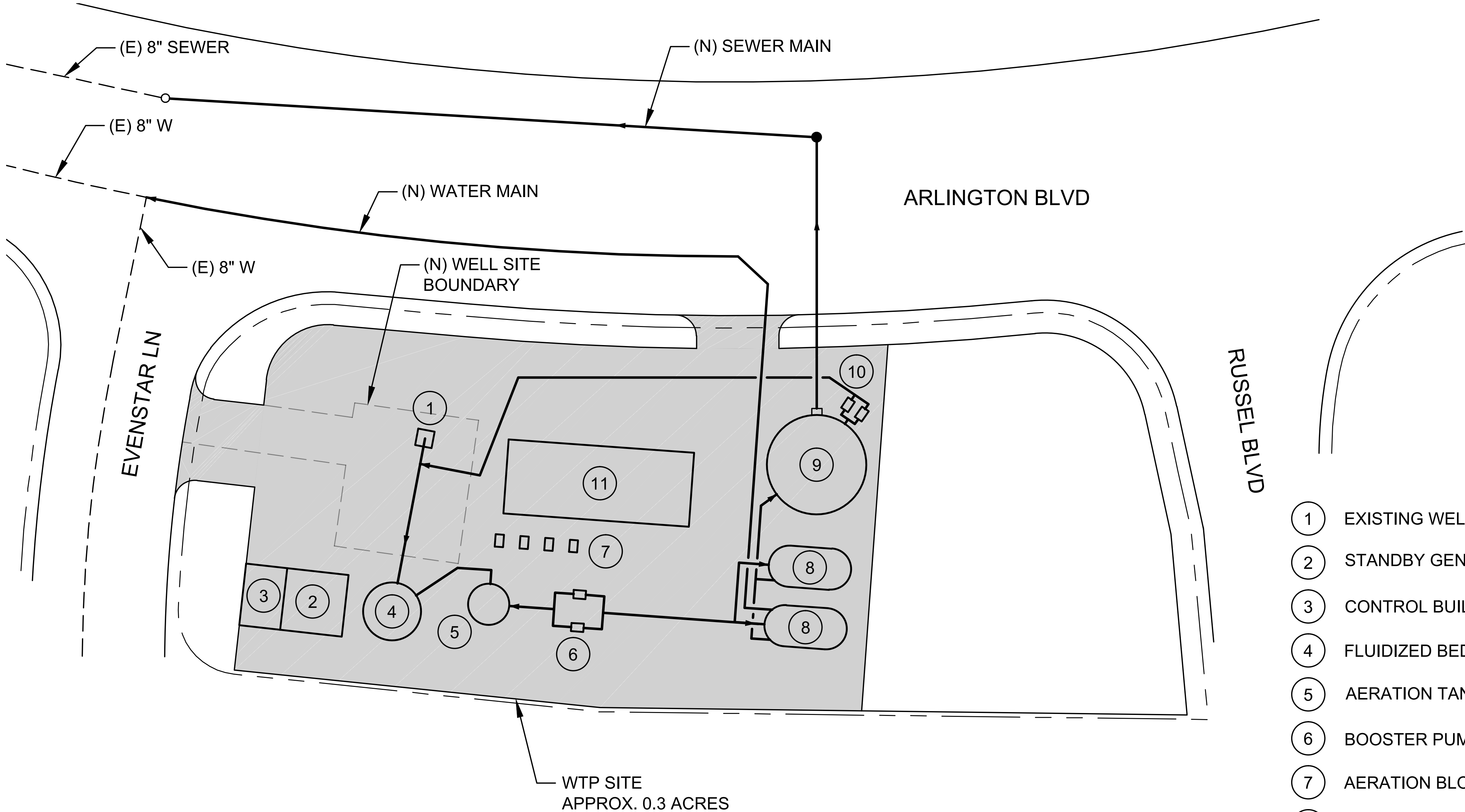
4.2.3 Cost Analysis and Comparison

A cost analysis was completed for the 1,400 gpm (2 million gallons per day or MGD) conceptual water treatment system described under Section 4.2.2 for the Site Specific Well 20 retrofit project. The construction costs are in 2013 dollars based on an Engineering News Record (ENR) National Average Construction Cost Index of 9,456 (March 2013). The accuracy of the conceptual costs is considered +50% to -30%. The opinion of probable construction cost, project cost, annual operation and maintenance (O&M) cost, and annualized project capital cost and O&M cost for this conceptual water treatment system is as follows:

- Opinion of Probable Construction Cost is $7.236 million.

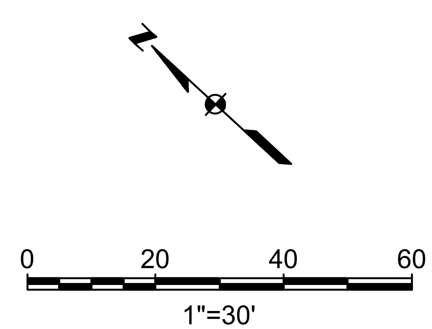
- Opinion of Probable Project Capital Cost is $9.769 million (includes construction cost, and engineering, construction administration, environmental, permitting, and City administration and management)

- Opinion of Probable Annual O&M Cost is $0.401 million per year.



1. EXISTING WELL
2. STANDBY GENERATOR
3. CONTROL BUILDING
4. FLUIDIZED BED REACTOR
5. AERATION TANK
6. BOOSTER PUMP STATION (TWO EACH)
7. AERATION BLOWER (2 EA) + RECIRCULATION PUMP (2 EA)
8. FILTERS
9. BACKWASH TANK
10. BACKWASH WATER RECYCLE BOOSTER PUMP STATION (2 EACH @ 5 HP)
11. CHEMICAL STORAGE AREA

NOTE: ASSUME BARE SITE WITH NEW WELL, AND WTP.



Kennedy/Jenks Consultants

CITY OF DAVIS SUSTAINABLE CO-REMOVAL OF HEXAVALENT CHROMIUM BY BIOLOGICAL FILTRATION PROCESS

GREENFIELD SITE PLAN

K/J 1270031*00
APRIL 2013
FIGURE 4-19

N:\2012\1270031.00_CR6-Pilot-Study\127003100-SITE-03.dwg CALVIN SUGG 4/15/2013 1:31 PM

A breakdown of the opinion of probable construction and project capital costs, and annual O&M cost is shown in Tables XI-1 and XI-2, respectively, in XI. Based on the City's typical use of their high quality groundwater wells, the average use per year is 65% of the time, which was used to determine the annual O&M cost.

For the Greenfield Site the treatment process could be achieved as described under Section 4.2.2. This would not only reduce the footprint, but also the opinion of probable construction cost, project capital cost, annual O&M cost, and annualized project capital and annual O&M costs. The project capital cost is reduced in a much greater extent than the annual O&M cost. If alternative measures were implemented the costs are estimated to be modified as follows:

- Opinion of Probable Construction Cost is $4.911 million.
- Opinion of Probable Project Cost is $6.630 million (includes construction cost, and engineering, construction administration, environmental, permitting, and City administration and management)
- Opinion of Probable Annual O&M Cost is $0.396 million per year.

An annualized cost analysis was conducted to determine the cost per acre foot as shown in Tables XI-1 in Appendix XI. The annualized cost analysis converted the opinion of probable construction cost estimate to an annual cost using an interest rate of 3% and planning period of 30 years. A summary of the annualized cost analysis is shown in Table 4-8.

Table 4-8: Annualized Cost Analysis

Treatment Method	Amortized Project Capital Cost ($/acre ft)	Annual O&M Cost ($/acre ft)	Total Annualized Cost ($/acre ft)
FBR Site Specific	281	275	617
FBR Greenfield Site	232	272	504

4.2.4 Comparison of Results with WaterRF Project 4450

The City of Davis took part in a study funded by the WaterRF (WaterRF, Project 4450) where the researchers took City of Davis water from Well 20 and bench tested the following treatment systems for removal of chromium-6:

- Strong Base Anion Exchange (SBA)
- Weak Base Anion Exchange (WBA)
- Reduction, Coagulation, Filtration (RCF)

The technical report for the City of Davis' water is located in Appendix XII. This section includes a comparison of costs between the biological FBR system and two of the three treatment systems tested in the WaterRF study.

The costs for two of the water treatment alternatives included in the WaterRF Project 4450 were compared with the costs for the FBR included in this study. Because the costs were based on differing assumptions, the WaterRF costs were adjusted to be more comparable with the FBR cost analysis conducted for this study. The differences and descriptions of these alternatives are:

- The two WaterRF alternatives used were RCF and SBA treatment systems. The WBA alternative was not evaluated as it was the most expensive alternative.

- Two options were used for comparison of the RCF, with Option 1 discharging backwash water and solids to the sewer and no recycling of the backwash water. Option 2 is containing and treating the backwash water on-site to generate solids for offsite disposal and recycling water back to the head of the plant.

- The SBA is assumed to capture and transport the waste to the nearest discharge location, East Bay Municipal District (EBMUD) in Oakland, CA. The cost to transport and dispose of the waste was not confirmed, but assumed to be comparable to discharging to the City of Davis sewer system and WWTP.

- For the WaterRF it used a 1,100 gpm (1.6 MGD) water treatment plant (WTP) capacity for the RCF and SBA treatment alternatives. The Fluidized Bed Reactor is based on a 1,400 gpm WTP capacity.

- The comparison of the these alternatives is for the Greenfield Site option, which is assuming that the site is undeveloped and starting from an undeveloped lot.

Strong Base Anion Exchange Treatment System

The strong base anion exchange (SBA) treatment system is identical to that used for arsenic or nitrate removal from groundwater. The system requires a relatively simple treatment train (see Figure 4-20) which includes:

- Strainers – Removes suspended materials prior to SBA contactors.

- SBA Contactors – Remove chromium-6 through replacement of chloride with chromium-6 on the SBA resin.

- Salt Brine – Used to regenerate the SBA Contactors when they are exhausted.

- Waste Regeneration Brine and Slow Rinse Water Tank/Waste Backwash Water and Fast Rinse Water Tank – After regeneration with salt brine, the resin in the contactors undergoes a slow-rinse step and one fast-rinse step. The fast rinse water will be slowly returned to the head of the plant, whereas the slow rinse water will be stored on site for disposal by hauling offsite, which is assumed would be EBMUD WWTP in Oakland, CA.

The major consideration with this system for the City of Davis is the ability to dispose of the spent brine. The WaterRF cost estimate includes costs for hauling brine offsite. If the haul location requires removal of the chromium-6 from the brine, a chemical reduction and clarification system will be required to remove the chromium-6 from the brine. This would add additional costs. In addition, the WaterRF study assumed that the resin would not need to be replaced. This assumption needs to be confirmed over the 30-year planning period used for evaluation of the cost for this study.

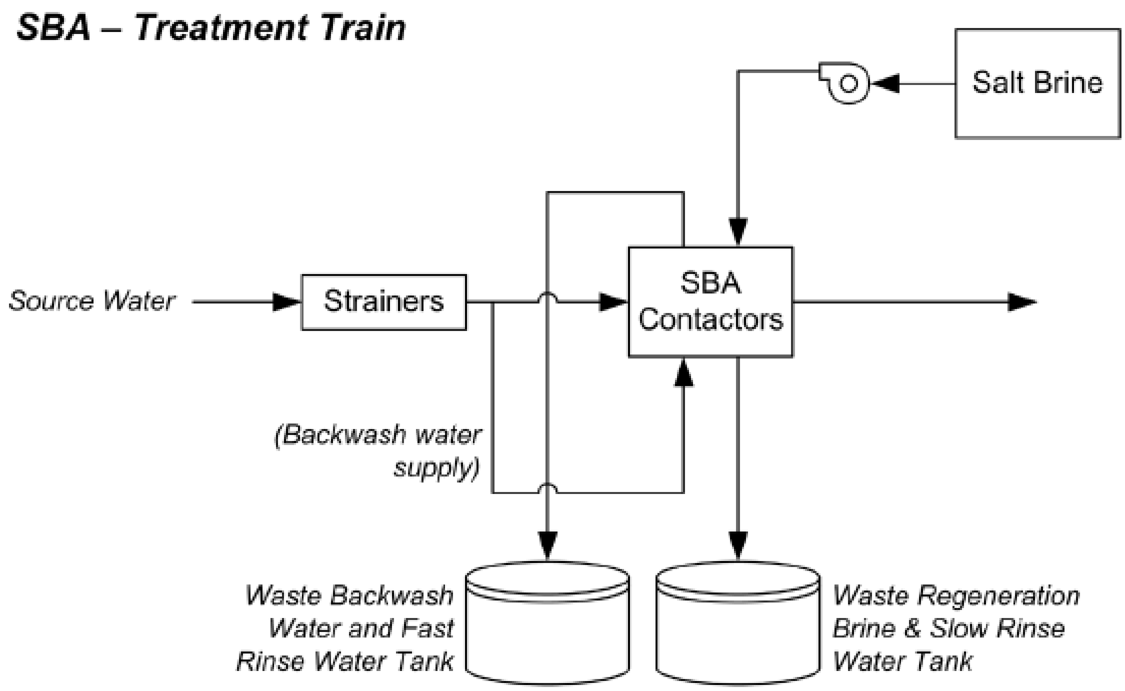


Figure 4-20: Strong Base Anion Exchange Treatment System

Source: WaterRF, 2013.

Reduction, Coagulation, Filtration

The RCF system requires a more complicated treatment train as shown in Figure 4-21. This includes:

- Ferrous (iron-2) Sulfate Addition – Ferrous sulfate is used to reduce chromium-6 to chromium-3 through an oxidation-reduction reaction of iron-2 to iron-3.
- Reduction Contactor – The reduction of chromium-6 to chromium-3 by iron-2 requires time, which is achieved through addition of this contactor to the treatment train.
- Oxidation of Ferrous and coagulant addition – Low dose of chlorine is added to oxidize any remaining iron-2. A coagulant is added to aid in the removal of chromium (however, no cost for the coagulant system was included in the cost estimates).
- Media Filters – Used to remove the coagulated chromium-3 from the water.
- Solids Disposal

- Option 1: Disposal of backwash water to the sewer. If available this is the cheapest option (Note this may not always be the case depending on the connection fees and monthly user fees)

- Option 2: Clarification to remove chromium from the waste backwash water followed by recycling of the clarified waste backwash to the head of the WTP.

Key considerations with this treatment system include a large footprint and the ability to dispose of residuals through the existing sewer system.

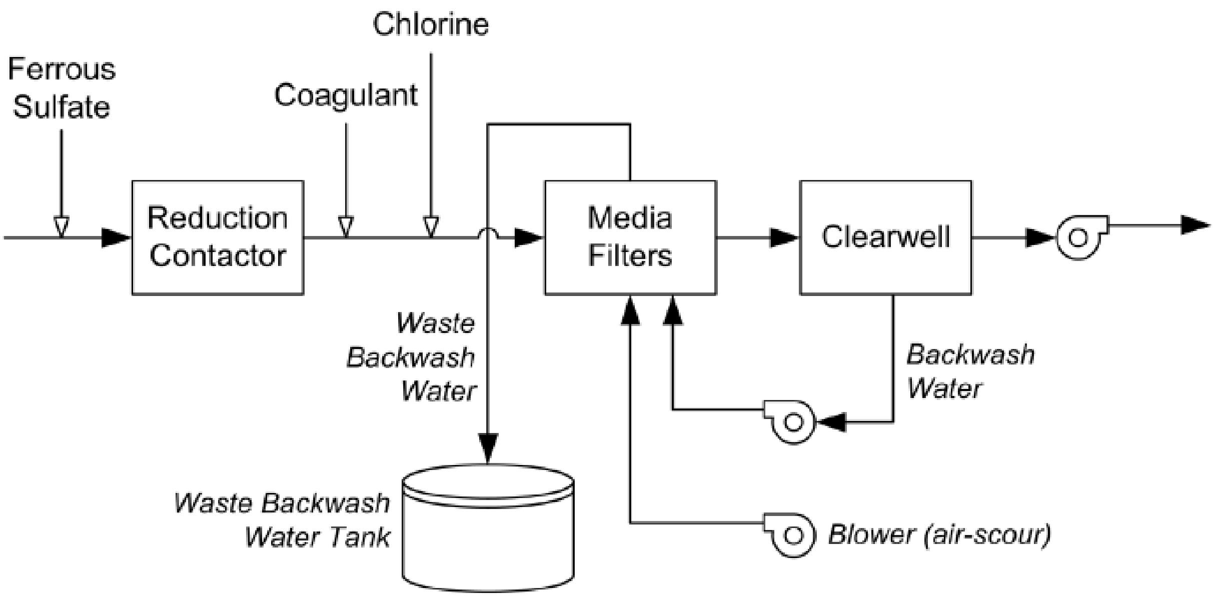


Figure 4-21: Reduction, Coagulation, Filtration Treatment System

Source: WaterRF, 2013.

Weak Base Anion Exchange Treatment System

The weak base anion exchange treatment system requires a treatment train as shown in Figure 4-22. This includes:

- CO_2 Addition – Adds carbon dioxide (CO_2) to pH 6.0 for optimal removal of chromium-6 by the resin. Large amounts of CO_2 or acid are required for Well 20 water due to the high alkalinity of the water.

- Bag Filters – Removes large particles prior to the WBA Contactors.

- Weak Base Anion Contactors – The WBA Contactors exchange contain a weak base anion exchange resin that exchange chloride for chromium-6 and then convert chromium-6 to chromium-3, which binds to the column.

- Backwash Water Tank – Used to “fluff” the resin, such that channeling is minimized.
- CO_2 Stripper – Aeration to increase the pH prior to distribution to the system.

Key considerations for use of this treatment technology include pH adjustment and residual disposal. Disposal of the spent resin will at a minimum require disposal as a California non-Resource Conservation and Recovery Act (RCRA) Hazardous Waste, which requires disposal as a hazardous waste in California or transport out of state as a non-hazardous waste. The resin may also be considered a Technologically Enhanced Naturally Occurring Radioactive Material (TENORM) waste if uranium accumulates on the resin, which limits disposal options further or a Low Level Radioactive Radioactive Waste (LLRW).

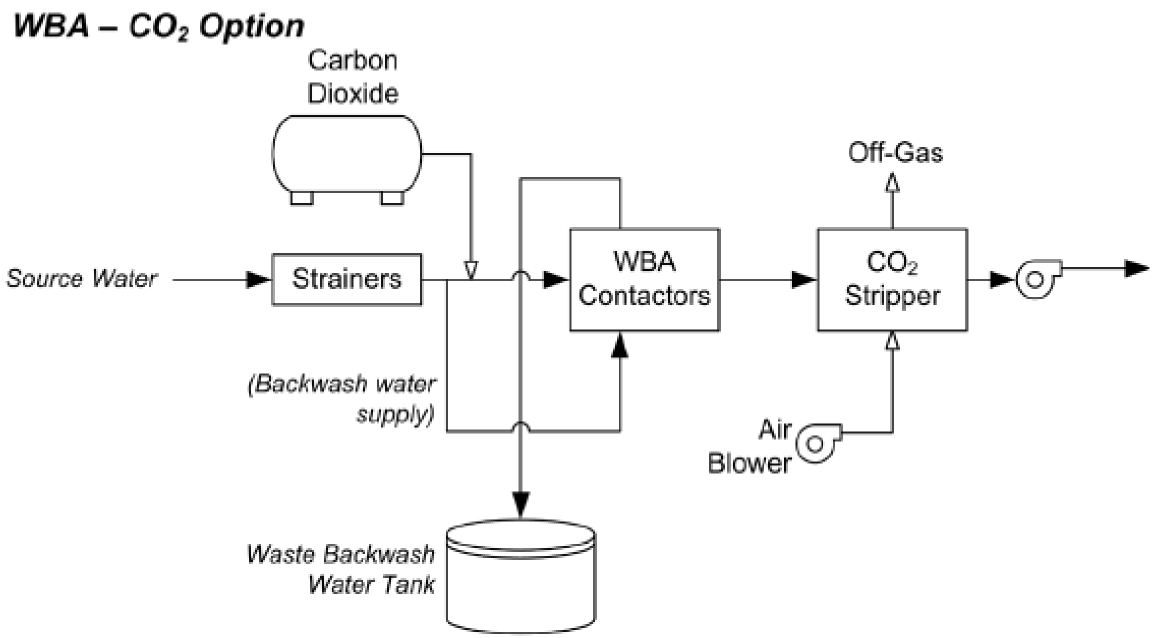


Figure 4-22: Weak Base Anion Exchange Treatment System

Source: WaterRF, 2013.

Footprint Requirements

The footprint requirements of a system can sometimes limit the ability of an agency to use a treatment system. The WaterRF study included estimates of system footprint as a part of their study. The analysis conducted by the WaterRF was a more general analysis that did not take into account specific site limitations unique to Well 20; therefore, the footprint cannot be directly correlated to the footprint estimated for the FBR as part of this study. A summary of the WaterRF study footprints are as follows:

- SBA – 332 square feet (sq. ft.) indoor and 1,848 sq. ft. outdoor

- RCF, Option 1 – 25 sq. ft. indoor and 2,914 sq, ft, outdoor
- RCF, Option 2 – 329 sq. ft. indoor and 3,686 sq. ft. outdoor
- WBA – 1,103 sq. ft. indoor and 3,257 sq. ft. outdoor

Waste Disposal Requirements

Waste disposal requirements include the highest costs for most of these treatment systems. Table 4-9 contains the assumed disposal requirements for each system.

Table 4-9: Waste Disposal Requirements

Treatment System	Disposal Assumptions
SBA	Chromium-6 in the brine is reduced and then removed through clarification. The clarified brine is hauled offsite and the dewatered sludge is disposed of as a California non-RCRA hazardous waste.
RCF Option 1	Direct discharge of the untreated waste backwash water to the sewer.
RCF Option 2	De-watering of backwash water with disposal of the dewatered solids as California non-RCRA hazardous waste.
WBA	Disposal of resin as a TENORM Hazardous Waste
Biological FBR	Discharge of clarified backwash water directly to the sewer.*

* Further analysis of residuals necessary to determine if any waste classification applies.

Cost Comparison

- Because the assumptions made for the WaterRF Study were not completely comparable with those made for this study, the cost estimates proposed in the WaterRF Study were adjusted to be more comparable with those presented in this study. The key differences include: WTP capacity for WaterRF was 1,100 gpm vs. 1,400 gpm for this study.
- Interest and planning period length used in converting project capital to annualized cost was 5% and 20 years for the WaterRF and 3% and 30 years for this study, respectively.
- Electrical power cost was $0.15 per kilowatt hour (kw-hr) vs. $0.12/kw-hr for this study.
- Operation of the WTP was assumed at 40% by the WaterRF, but for this study it was assumed 65% operation.
- Construction cost estimated for 2012 by WaterRF vs. FBR used March 2013 for this study.

The original WaterRF Study costs are shown in Table 4-10.

Table 4-10: WaterRF Unit Treatment System Costs

Treatment System	Capital*	O&M*	Total*
SBA	284	338	622
RCF Option 1	516	187	702
RCF Option 2	589	300	889
WBA	715	749	1,464

* $ per acre-ft

The WBA is much higher than the other cost estimates, thus the WBA system was not considered further in the comparison with the biological filtration system. The SBA, and RCF Options 1 and 2 were adjusted to be more comparable with the costs presented in this study. These compared costs are shown in Table 4-11 and Table 4-12.

Table 4-11: Treatment System Total Cost Comparison

Treatment System	Construction and Project Costs* ($)	O&M Annual Cost ($/year)	Annualized Capital Costs ($/year)	Total Annualized Cost ($/year)
SBA	3,158,000	392,000	161,000	553,000
RCF Option 1	5,054,000	2,620,000	258,000	2,878,000
RCF Option 2	6,636,000	344,000	339,000	683,000
Biological FBR	6,630,000	396,000	338,000	734,000

Table 4-12: Unit Treatment System Costs per Acre-Foot

Treatment System	Capital ($/AF)	O&M ($/AF)	Total ($/AF)
SBA	139	336	475
RCF Option 1	221	2,249	2,470
RCF Option 2	291	295	586
Biological FBR	232	272	504

The costs for the RCF Option 1 were high due to the costs assumed for disposal to the sewer. The assumption for the RCF Option 1 is that the backwash water is sent directly to the sewer. Discussions with the City lead to the costs assumed for disposal directly to the sewer. The original amount of discharge assumed by the WaterRF, with a scaling up to represent a 65% utilization was used to provide the value shown in Table 4-3.

Based on these costs, the SBA is the most cost effective option. The SBA could become more expensive due to O&M costs for brine disposal, depending on the accuracy of the assumed brine disposal fee. As well, the RCF Option 2 O&M could vary due to solids disposal costs. Additionally, the RCF could be adjusted to use a similar method for waste disposal as the Biological FBR assumes, where a portion of the backwash water is recycled and the remainder is sent directly to the sewer, which would alter the disposal cost. Because the O&M for each site due to disposal considerations is a key factor in the overall cost for each treatment system, a better understanding of what these site specific costs would be would provide a more accurate comparison of the different treatment options.

Comparison of Results with Project Objectives

Table 4-13 provides a summary of the project objectives as well as the results that were found from the project.

Table 4-13: Comparison of Results with Project Objectives

#	Objective	Findings and Conclusions
1	Confirm whether an alternative reliable and sustainable treatment technology, such as biological treatment systems, may provide an effective means of chromium-6 treatment	(1) An FBR treatment system appears to be an effective means to reduce chromium-6 and remove a fraction of the total chromium present and merits additional consideration for full-scale implementation.
2	Provide additional evaluation of technologies to confirm efficacy and cost effectiveness of treating chromium-6 to low levels (less than 1 μg/l)	(1) The bench-scale pilot presented effective chromium-6 reduction to concentrations less than 1 μg/l is achievable. (2) TOC residual was higher than expected and could present water quality challenges if chromium-6 effluent concentrations below 1 μg/l need to be maintained. (3) The cost to retrofit and add the FBR treatment process is in the range of $170 to $250 per acre foot on a annualized construction cost basis.
3	Evaluate effectiveness of concurrently removing multiple constituents such as nitrate, selenium, perchlorate and chromium-6 to provide useful information for water agencies to evaluate treatment alternatives	(1) The FBR was successful in removing multiple constituents including nitrate and selenium to some degree. (2) Effective removal of nitrate-N to below 2 mg/l with average removal rate of 95% (3) With additional filtration, effective chromium-6 reduction to levels below 5 μg/l appears achievable with average reduction rates of 91%. (4) Average removal rate of total selenium of 70%. Addition of ferric chloride as a coagulant did not significantly increase selenium removal. (5) Perchlorate removal has been well demonstrated in full-scale FBR systems, including two installations in Southern CA and one in Northern, CA.

#	Objective	Findings and Conclusions
4	Evaluate the relationship between chromium-6 and total chromium, and potential impacts of the reduction/removal process for water delivered to the distribution system	(1) It was estimated that approximately 35% of the chromium-6 that was reduced to chromium-3 was present in a dissolved state. (2) The addition of ferric chloride as a coagulant aid increased total chromium removal efficiency from 65% to 90%, with removal to levels below 5 μg/l. (3) Disinfection tests showed 16-18% reformation of chromium-6 during the last test with a 1.5 mg/l chlorine dose. The potential for greater reformation to occur in a higher continuing residual (>0.1 mg/l FAC over 3 day period) should be evaluated.
5	Evaluate the residual management impacts and management options	Backwash waste solids will ideally be discharged to sewer if available. It is anticipated that disposal of solids to a community landfill would be acceptable. The quantity of solids generated and potential to impact the WWTP effluent and solids disposal at a landfill need to be evaluated further.
6	Evaluate this pilot study results with the City of Davis' results from participating in a Water Research Foundation Project	The WaterRF results indicated that the FBR may be more costly than the SBA in project capital cost and comparable to the RCF Option 2 project capital cost. The FBR had the least costly annual O&M cost. The FBR, SBA and RCF Option 2 for the total annualized cost are in the same order of magnitude considering these are conceptual cost estimates and the level of accuracy. A more detailed study including analysis of site specific requirements would provide a more accurate comparison of these alternatives.

4.3 Recommended Next Steps

The proof of concept pilot was successful in demonstrating the efficacy of an FBR system for co-removal of constituents including chromium-6, total chromium, nitrate, perchlorate, and selenium. However, this bench-scale pilot was limited in its ability to offer accurate data that can be used to "scale up" to a full sized system. Therefore, we recommend development and proceeding with a demonstration FBR project of the proposed system. The proposed demonstration project would offer numerous benefits including better understanding of the following:

- Evaluate whether there exist any scale-up issues.
- Determine required acclimation periods between temporary and/or long term shut-downs and start-ups.

- Evaluate impacts and requirements of chlorine addition for disinfection, including the potential of reformation of chromium-6 and formation of disinfection byproducts.
- Confirm effective filter coagulants and dosages.
- Estimate filter backwash and solids content.
- Evaluate options for onsite residual management and disposal compared with discharge to sewers, and impacts to WWTPs effluent and solids.
- Evaluate system for enhanced selenium reduction
- Test system per CDPH requirements to obtain Best Available Technology approval.
- Refine fabrication, construction, and operating costs for the technology.
- Develop BAT Application Criteria
- Evaluate the speciation of the FBR biomass to determine the type of bacteria.

Appendix I

List of References

1. State Water Resource Control Board, Division of Water Quality, GAMA Program. "Groundwater Information Sheet: Chromium VI." February 2008.
2. Blute, N. and X. Wu, 2013, Chromium Treatment Studies at Glendale, Residuals, and Treatment Testing Guidelines, Presentation at the Water Research Foundation Hexavalent Chromium Workshop 2013, Sacramento, CA, 4 February 2013. http://collab.waterrf.org/Workshops/hexchrom2013/Shared%20Documents/4%20Chromium%20Treatment%20Studies%20at%20Glendale,%20Residuals,%20and%20Treatment%20Testing%20Guidelines%20-Nicole%20Blute.pdf
3. Jacobs Engineering Group, 2011, Screening of Potential Hexavalent Chromium Treatment Technologies, report prepared for Soquel Creek Water District, November 2011. http://www.soquelcreekwater.org/sites/default/files/Jacobs%20SqCWD%20Screening%20Chromium%20Treatment%20Technologies%20DRAFT%20FINAL%20113011.pdf
4. Sacramento Groundwater Authority. Groundwater Quality Vulnerability Assessment: Figure D-3. 2011.
5. West Valley Water District and City of Rialto Groundwater Wellhead Treatment System Project, January 20, 2011 by Envirogen Technologies and Kennedy/Jenks Consultants.
6. ENR Construction Cost Index – National Average for March 2013 (ENR Index = 9456).
7. Water Research Foundation. Technical Report: Probable Capital and Annual Operations & Maintenance Costs for Hexavalent Chromium Removal for Well 20. 2013.

Appendix II

List of Deliverables

The following deliverables were provided for this project:

1. Work Plan – See Appendix VIII
2. Technical Memorandum: Confirmation of Well 20 Water – See Appendix V
3. Final Report – Sustainable Treatment for Co-Removal of Hexavalent Chromium by Biological Treatment Process Pilot Study – this report.

Appendix III

List of Subcontractors

1. Envirogen Technologies – designer and manufacturer of fluidized bed biological treatment systems. Provided pilot testing equipment, staff, and technical support.

2. Kennedy/Jenks Consultants – lead consultant and engineer responsible for organizing, designing, and implementing the pilot test

3. BSK & Associates – Engineers and Laboratories – provided analytical water quality results

Appendix IV

Photos

***Photo #1**:* Well 20

***Photo #2**:* Pilot Location

Photo #3: Pilot System

***Photo #4**:* Pilot System

***Photo #5**:* FBR Pilot in Operation

***Photo #6**:* FBR Pilot in Operation

***Photo #7**:* Biomass Above Media

Photo #8: Clogged Basket Strainer

Photo #9: Clogged Basket Strainer

***Photo #10**:* Filtered Biomass After Cleaning

Appendix V

Source Water Characterization
Technical Memorandum

20 December 2012

Technical Memorandum 1 – Source Water Characterization

To: Jacques DeBra and Dianna Jensen, City of Davis

From: Tim Williams, P.E., Project Manager

Subject: Source Water Characterization for the Sustainable Treatment for Co-Removal of Hexavalent Chromium by Biological Treatment Process Pilot Study
K/J 1270031*00

The purpose of this technical memorandum is to describe the water quality of the Well 20 water, which will be used as the test water for the pilot study due to its moderate to high nitrate and hexavalent chromium concentrations. Detailed information regarding the pilot system's mechanics and process can be found in the Pilot Study Work Plan.

Background – Well 20

The City of Davis has 20 municipal groundwater wells that it uses to supply water. Of these 20 wells, 15 are intermediate wells, with total depths ranging from 340-615 feet below ground surface (bgs) as shown in Figure 1. The water quality of the intermediate wells shows high nitrate, selenium, TDS and hexavalent chromium concentrations. Hexavalent chromium concentrations range from 2 μg/L to 40 μg/L.

This pilot test study is going to test the sustainable treatment for the co-removal of three of these water quality concerns, nitrates, selenium, and hexavalent chromium with the use of a biological treatment system. The biological treatment system will reduce chromium 6 in one of the City's existing drinking water wells (Well 20) to chromium 3, a more benign form of chromium and a required nutrient, which would then be removed by filtration. The biological filtration process removes the nitrates and selenium from source water.

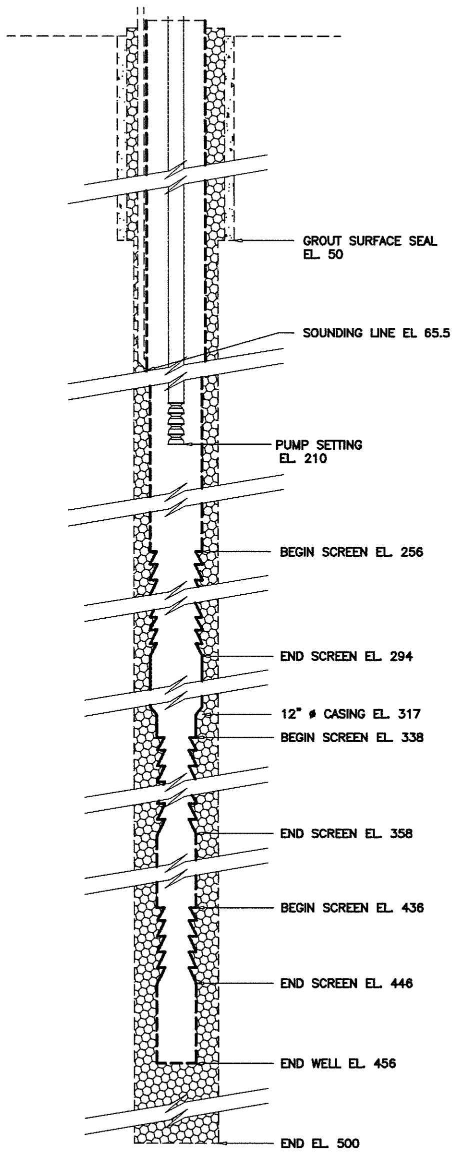
Well 20 has one of the highest concentrations of hexavalent chromium, with an average of 39 μg/L. Because of Well 20's high hexavalent chromium concentration, as well as its high nitrate concentration (average of 32 mg/L) it was chosen to be the water source for this pilot study. In addition, the City of Davis is participating in a Water Research Foundation study for hexavalent chromium removal using anion exchange process and reduction/coagulation/filtration removal process. Well 20 is also the source water for this study and therefore the results from this study will be compared with this Pilot Study.

Well 20 is located in the western portion of Davis at the corner of Arlington Blvd. and Evenstar Lane and was constructed in 1976. The basic information about the well's construction and make-up are shown in Figure 1.

Timothy L Williams

REGISTERED PROFESSIONAL ENGINEER
TIMOTHY L. WILLIAMS
No. 39104
Exp. 06-30-13
CIVIL
STATE OF CALIFORNIA

12-20-12



BORE HOLE DETAIL

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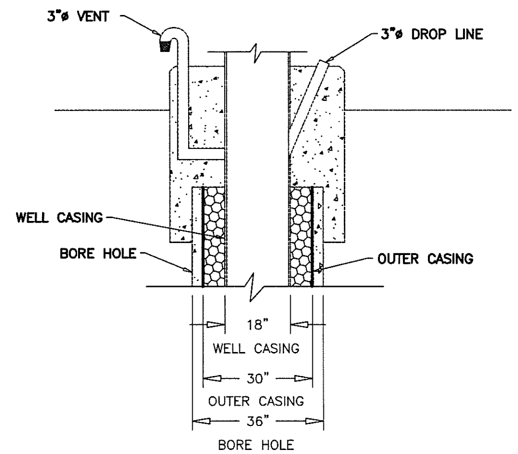

EXISTING PEDESTAL SECTION

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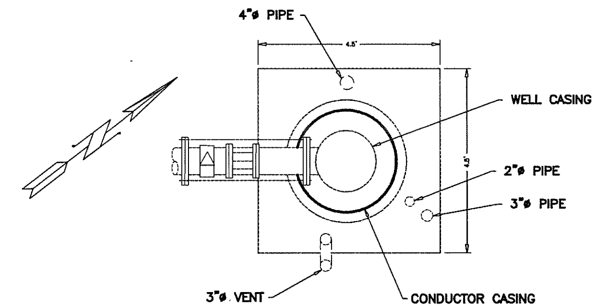

EXISTING PUMP PEDESTAL

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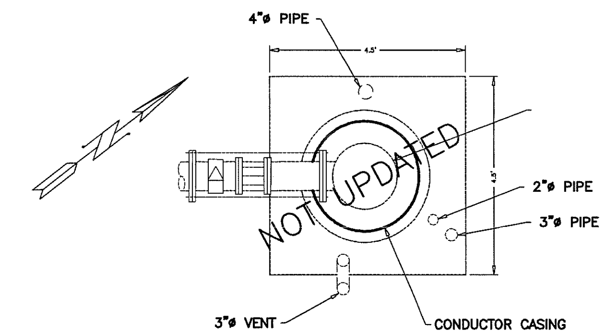
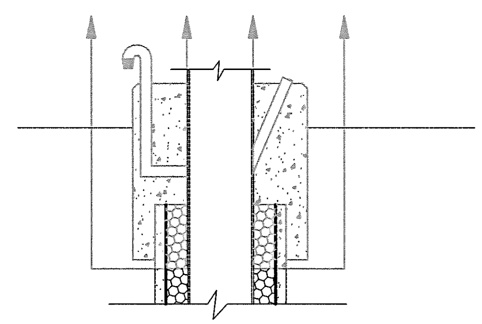


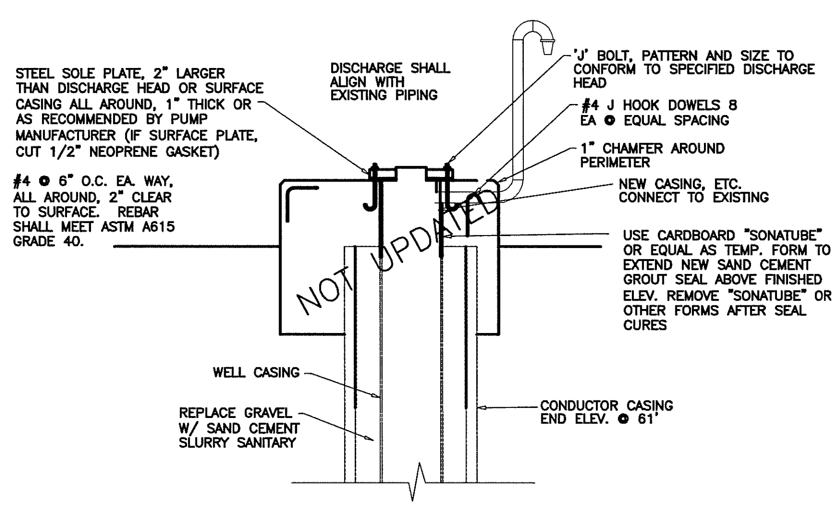
NEW PUMP PEDESTAL

SCALE: 1"=2'



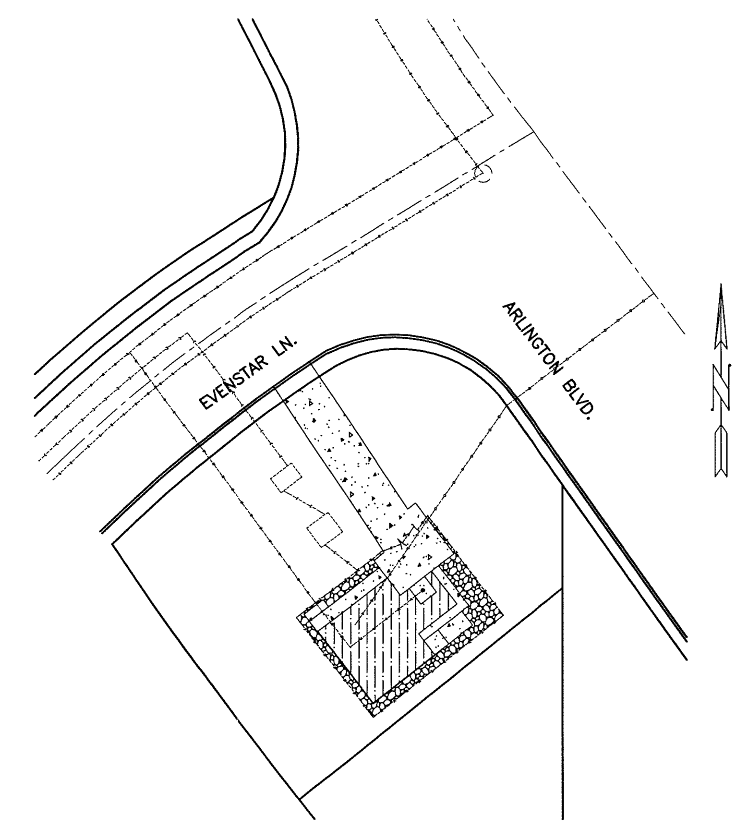
DEMOLITION SECTION

SCALE: 1"=2'



NEW PUMP PEDESTAL SECTION

SCALE: 1"=2'



SITE PLAN

SCALE: 1"=20'

.5' 1.5'
0 1' 2' 3' 4'
SCALE: 1"=2'

1' 3'
0 2' 4' 6' 8'
SCALE: 1"=4'

FIGURE 1: WELL 20

REV.	DATE	DESCRIPTION	BY

EXISTING & NEW PIPING PLAN
WELL NO. 20 - 2300 EVENSTAR LN.
C.I.P. # 8767

PRELIMINARY

Davis California

CITY OF DAVIS
PUBLIC WORKS DEPARTMENT

DESIGNED BY: CAMERON GIBBS — DATE: 5-12-98
CHECKED BY: — DATE:
DRAWN BY: HMikelic — DATE: 5-12-98
SHEET 2 OF 4 SHEETS
DWG. NO. 104-061

Water Quality – Well 20

The City of Davis has conducted annual Title 22 water quality sampling for Well 20. These data were compiled and are included as Attachment 2. The key water quality constituents for the last four (4) years that will be monitored during the pilot study are presented in Table 2.

Table 1: Well 20 Water Quality

Constituent	Units	Nov-09	Aug-10	Aug-11	Aug-12	Oct-12	Average
Temperature	°F					66.7 (F)	66.7
Sulfate	mg/L	37	35	33	38		36
Chloride	mg/L	29	26	25	31		28
pH		7.7	8.2	8.2	8.3	7.9 (F); 8.2	8.1
Color	units	0	5	<1.0	<1.0		1.8
Turbidity	NTU	0.2	<0.1	<0.1	<0.1		0.1
Nitrate	mg/L	34	32	30	33		32
Nitrite	mg/L	<.05	<.05	<0.1	<0.1		<0.1
Total Organic Carbon	mg/L					0.41	0.41
Total Suspended Solids	mg/L					<5.0	<5.0
Metals							
Total Chromium	µg/L	41	40	39	37		39
Hexavalent Chromium	µg/L		40				40
Manganese	µg/L	<10	<10	<10	<10		<10
Selenium	µg/L	4	2.6	2.2	<2.0		2.6

F = Field measured

Hexavalent and Total Chromium Concentrations

Hexavalent chromium concentrations in the Well 20 water have been consistent over the past four (4) years, ranging from 37-40 µg/L. Hexavalent chromium is the primary form of chromium within the Well 20 water, with calculated concentrations of chromium 3 ranging from 1-3 µg/L (chromium 3 is calculated by subtraction of hexavalent chromium from total chromium). Figure 2 shows the hexavalent and total chromium concentrations over the past four (4) years.

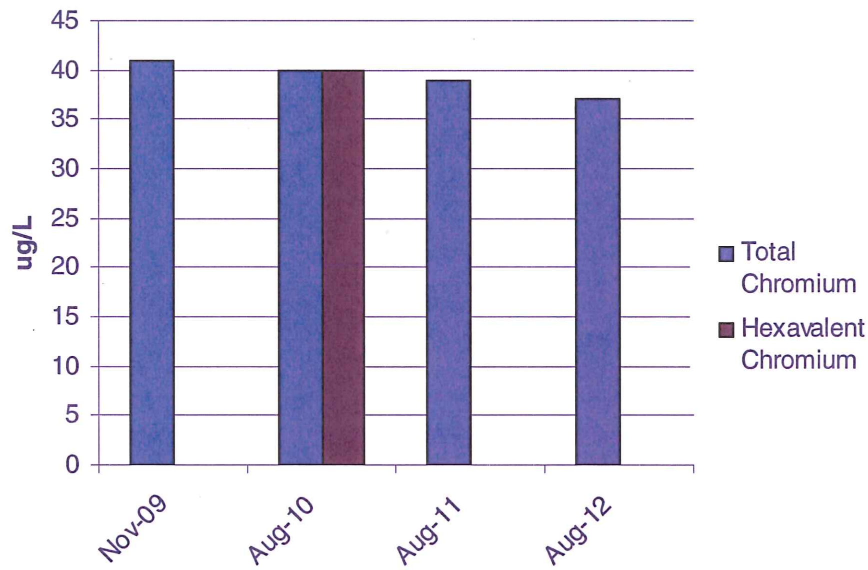


Figure 2: Well 20 Hexavalent and Total Chromium Concentrations

Other Potentially Reducible Constituents

The other constituents that would be expected to be reduced within the pilot system are nitrate, manganese, selenium and sulfate. The order of reduction is not entirely understood, but it would be expected for nitrate to be reduced first and sulfate to be reduced last within the pilot system.

The Well 20 water has had high nitrate concentrations of 30-35 mg/L over the past four (4) years (see Figure 3).The Well 20 water has consistently had non-detect levels of manganese and low or non-detect levels of selenium, as shown in Table 1. Therefore, reduction in selenium and manganese is expected to be undetectable.

The average sulfate concentration in Well 20 over the past four years is 35 mg/L. If the treated water nitrate and hexavalent chromium concentrations become too reduced, it could lead to the reduction of sulfate within the system creating hydrogen sulfide. The amount of electron donor therefore will need to be carefully monitored to allow for chromium reduction, while not creating an environment that will easily reduce sulfates.

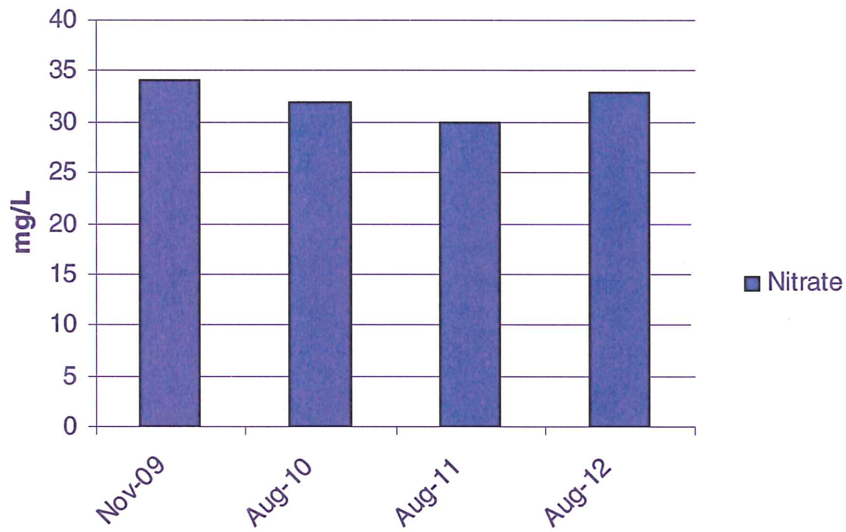


Figure 3: Well 20 Nitrate Concentrations

pH Adjustment

The pH of the Well 20 water is moderate, with an average pH of 8.0. It is not expected that the effluent from the pilot system will require pH adjustment; however, effluent pH will be monitored to confirm this assumption. Ideally, the biological reactor operates most effectively at a pH range of 6.0 to 7.0. If pH adjustment to optimize the biological filtration process is needed then sulfuric acid and/or sodium hydroxide will be used to adjust pH in the optimum range and return it to an acceptable drinking water supply range of 6.5 to 8.5.

Conclusion

Well 20 is a suitable candidate for the Pilot Study to evaluate the co-removal of hexavalent chromium and other constituents of concern to the City, State Water Resources Control Board, California Department of Public Health, and other local water agencies that may be impacted by a revised hexavalent chromium drinking water standard.

Davis California

WELL DATA SHEET
WELL #20

DATA SHEET GENERAL INFORMATION		
System Name	City of Davis	Actual
System Number	5710001	Actual
Source of information	Well log/City files/City Staff	Actual
Organization Collecting Information	City of Davis	Actual
Date Information Collected/Updated	2001/2002	Actual
WELL IDENTIFICATION		
* Well Number or Name	Well #20	Actual
* DHS Source Identification Number (FRDS ID No.)		Unknown
DWR Well Log on File?	Yes	Actual
State Well Number	08N/02E-08P01 M	Actual
Well Status	Active	Actual
WELL LOCATION		
Latitude	38^o 32' 49"	Actual
Longitude	121^o 46' 37"	Actual
Ground Surface Elevation (ft above Mean Sea Level)	55'	Actual
Street Address	2300 Evenstar Lane	Actual
Nearest Cross Street	Arlington Boulevard	Actual
City	Davis	Actual
County	Yolo	Actual
* Neighborhood/Surrounding Area	Re;A	Actual
Site Plan on File?	Yes	Actual
DWR Ground Water Basin	Lower Cache-Putah Basin	Actual
DWR Ground Water Sub-basin		
SANITARY CONDITIONS		
** Distance to closest Sewer Line, Sewage Disposal, Septic Tank	75'	Actual
Distance to Active Wells (ft)	2500' (Well 18; U C Davis)	Actual
Distance to Abandoned Wells (ft)	1200' (Russell Ranch)	Estimated
Distance to Surface Water (ft)	<5 miles	Actual
** Size of controlled area around well (square feet)	30 x 40	Actual
* Type of access control to well site	Fencing	Actual
* Surface Seal? (Concrete slab)	Yes	Actual
* Dimensions of concrete slab: Length (ft)/Width (ft)/Thick (in)	4.5/4.5/.75	Actual
* Within 100 year flood plain?	No	Actual
* Drainage away from well?	Yes	Actual
ENCLOSURE/HOUSING		
Enclosure Type	None	Actual
Floor Material	Concrete	Actual
Located in Pit?	No	Actual
Pit depth (feet) (if applicable)	N/A	
WELL CONSTRUCTION		
Date drilled	January 5, 1976	Actual
Drilling Method	Rotary	Actual
Depth of Bore Hole (fbgs)	533'	Actual
Casing Beginning Depth/Ending Depth (fbgs)	0-60; 60-317; 317-456	Actual
Casing Diameter (inches); 2nd Casing Diameter; 3rd Casing, etc.	30";18 5/8; 12.75	Actual
Casing Material; 2nd Casing Material; 3rd Casing, etc.	Steel	Actual

WELL 20 CONSTRUCTION (continued)

Conductor casing used?	Yes	Unknown
Conductor casing removed?	Unknown	Unknown
*Depth to Highest perforations/screens (fbgs)	258'	Actual
Screened Interval Beginning Depth/Ending Depth (fbgs)	256-294; 338-358; 436-446	Actual
* Total length of screened interval (ft)	66'	Actual
* Annular Seal?	Yes	Actual
* Depth of Annular Seal (ft)	60'	Actual
Material of Annular Seal	Neat Cement	Actual
Gravel Pack, Depth to top (fbgs)	0	Actual
Total length of gravel pack (ft)	456'	Actual

AQUIFER

* Aquifer Materials	silt, clay, silty fine sand, sand and gravel, silt and gravel	Actual
* Effective porosity (decimal percent) (Default = 0.2)	0.03 - 0.25	Actual
* Confining layer (Impervious Strata) above aquifer?	Yes	Actual
Thickness of confining layer, if known (ft)	23'	Actual
Depth to confining layer, if known (fbgs)	28'	Actual
* Static water level (ft below ground surface)	52.2	Actual
Static water level measurement: Date/Method	11/20/01; Electrical Sounder	Actual
Pumping water level (fbgs)	168.1	Actual
Pumping water level measurement: Date/Method	7/14/01; Electrical Sounder	Actual

WELL PRODUCTION

Well yield (gpm)	1266	Actual
Well Yield Based On	Flow Meter/Efficiency Test	Actual
Date Measured	Daily	Actual
Is the well metered?	Yes	Actual
Production (gallons per year)	546,294,000	Actual
Frequency of Use (hours/year)	7,744.8	Actual
Typical Pumping Duration (hours/day)	21.22	Actual

PUMP

Make	Verticle Turbine	Actual
Type	Submersible	Actual
Size (hp)	125	Actual
* Capacity (gpm)	1100 - 1400	Estimated
Depth to suction intake (fbgs)	210'	Actual
Lubrication Type	Water	Actual
Type of Power	Electric	Actual
Auxiliary power available?	No	Actual
Operation controlled by	SCADA	Actual
Pump to Waste capability	Yes	Actual
Discharges to	Storm Drain	Actual

Davis California

Well 20: Title 22 Results

General Mineral, Physical, and Inorganic Analyses

Constituent	Common Name	Units	MCL	PHG or (MCLG)	Nov-09 20	Aug-10 20	Aug-11 20	Aug-12 20	Average
Hardness	$CaCO_3$	mg/L			**420**	**390**	**400**	**390**	**400**
Calcium	Ca	mg/L			**38**	**39**	**40**	**39**	**39**
Magnesium	Mg	mg/L			**79**	**70**	**73**	**71**	**73**
Sodium	Na	mg/L			**54**	**57**	**59**	**56**	**57**
Potassium	K	mg/L			**1.4**	**<2.0**	**<2.0**	**<2.0**	**1.9**
Alkalinity	$CaCO_3$	mg/L			**410**	**430**	**380**	**400**	**405**
Hydroxide	OH	mg/L			**<1.0**	**<1.0**	**<3.0**	**<3.0**	**<3.0**
Carbonate	CO_3	mg/L			**<1.0**	**<1.0**	**<3.0**	**<3.0**	**<3.0**
Bicarbonate	HCO_3	mg/L			**410**	**520**	**380**	**400**	**428**
Sulfate	SO_4	mg/L	*250*		**37**	**35**	**33**	**38**	**36**
Chloride	Cl	mg/L	*250*		**29**	**26**	**25**	**31**	**28**
Nitrate	NO_3	mg/L	**45**		**34**	**32**	**30**	**33**	**32**
Fluoride	F	mg/L	**2**		**0.3**	**0.28**	**0.28**	**0.3**	**0.3**
pH			*6.5-8.5*		**7.7**	**8.2**	**8.2**	**8.3**	**8.1**
Specific Conductance	E.C.	µmhos/cm	*900*		**890**	**920**	**1300**	**920**	**1008**
Total Filterable Residue	TDS	mg/L	*500*		**510**	**510**	**770**	**520**	**578**
Color		units	*15*		**0**	**5**	**<1.0**	**<1.0**	**1.8**
Odor		TON	*3*		**1.0**	**1**	**<1.0**	**<1.0**	**1.0**
Turbidity		NTU	**5**		**0.2**	**<0.1**	**<0.1**	**<0.1**	**0.1**
MBAS (foaming agents)		mg/L	*0.5*		**<.05**	**<.05**	**<0.05**	**<0.05**	**<0.05**
Aluminum	Al	µg/L	**1000**	200	**<50**	**<50**	**<50**	**<50**	**<50**
Arsenic	As	µg/L	**10**		**3.5**	**3.6**	**<2.0**	**<2.0**	**2.8**
Antimony	Sb	µg/L	**6**		**<2.0**	**<2.0**	**<2.0**	**<2.0**	**<2.0**
Barium	Ba	µg/L	**1000**		**200**	**170**	**180**	**180**	**183**
Beryllium	Be	µg/L	**4**		**<1.0**	**<1.0**	**<1.0**	**<1.0**	**<1.0**
Cadmium	Cd	µg/L	**5**		**<1.0**	**<1.0**	**<1.0**	**<1.0**	**<1.0**
Total Chromium	Cr	µg/L	**50**	2.5	**41**	**40**	**39**	**37**	**39**
Hexavalent Chromium**	Cr V1	µg/L		0.2		**40**			**40**
Copper	Cu	µg/L	**1000**	150	**<50**	**<50**	**<50**	**<50**	**<50**
Total Iron	Fe	µg/L	*300*		**<50**	**<50**	**<50**	**<30**	**<50**
Lead	Pb	µg/L	**15**		**<5.0**	**<5.0**	**<5.0**	**<5.0**	**<5.0**
Manganese	Mn	µg/L	*50*		**<10**	**<10**	**<10**	**<10**	**<10**
Mercury	Hg	µg/L	**2**		**<.4**	**<.4**	**<0.4**	**<0.4**	**<0.4**
Nickel	Ni	µg/L	**100**		**<10**	**<10**	**<10**	**<10**	**<10**
Selenium	Se	µg/L	**50**		**4**	**2.6**	**2.2**	**<2.0**	**2.6**
Silver	Ag	µg/L	*100*		**<10**	**<10**	**<10**	**<10**	**<10**
Thallium	Tl	µg/L	**2**		**<1.0**	**<1.0**	**<1.0**	**<1.0**	**<1.0**
Zinc	Zn	µg/L	*5000*		**<50**	**<50**	**<50**	**<50**	**<50**
Boron	B	µg/L	1000		**520**	**520**	**580**	**520**	**535**
Nitrite	NO_2	µg/L	**1000 (as N)**		**<.05**	**<.05**	**<0.1**	**<0.1**	**<0.1**

Note: Constituents with levels below their detection limit were assumed to have values at that detection limit as part of the average value calculation. If two detection limits were present for a sample, the higher of the two was shown as the average.

Appendix VI

Jar Test Procedure

JAR TEST PROCEDURE FOR CITY OF DAVIS PILOT STUDY

INTRODUCTION

This jar test procedure has been developed specifically for the City of Davis pilot study, as the focus of the jar tests is to determine whether the hexavalent chromium reduced by the biological process can be removed by filtration rather than sedimentation.

The results of the jar tests will be used in the cost estimates for the overall process evaluation. For that purpose, ferric chloride will be used as the coagulant. As a starting point, ferric chloride dosages of 1, 2, 4, 8, and 10 mg/L should be evaluated with a control (no coagulant addition). After these initial tests, the analyst can optimize the treatment.

EQUIPMENT AND APPARATUS

1. Variable speed jar test apparatus with six paddles. If available, an illuminated base will aid the analyst in observing the formation of floc particles.

2. Gator jars made of plexiglass with capacity of 2,000 mL (2 L) with taps 10 cm below the water surface (2 liter mark).

3. Large glass or plastic containers to collect FBR effluent samples for jar tests. Sample containers should be refrigerated if stored for more than two hours.

4. Syringes of 1 mL, 5 mL, 10 mL, and 25 mL, graduated in 0.1 mL increments for coagulant addition. As an alternative, pipettes can be used.

5. pH meter

6. Turbidimeter

7. Thermometer

8. Necessary coagulant(s) and equipment to make stock solutions for jar test experiments. At this time, the primary coagulant will be ferric chloride. Stock solutions should be made up so that one mL of solution contains 2 mg of the coagulant. Note: other coagulants that may be studied include alum and cationic polymers.

PROCEDURE

1. The jar tests will be performed with effluent from the fluidized bed reactor (FBR). Each jar test run should be performed from the same batch.

2. Prepare all glassware by washing with soapy water and rinsing first with tap water, and then with distilled water (or use your lab standard operating procedure for cleaning glassware).

3. Characterize the FBR effluent for turbidity, water temperature, pH, total chromium, and Cr[VI].

4. Shake all samples prior to use. Fill each Gator jar to the 2 liter mark.

5. Place Gator jars on the jar mixer and lower the paddles into the jars.

6. Start stirrer and set mixer speed to maximum value (about 300 rpm or a G ~ 270 s^{-1}).

7. Add coagulant into each jar using predetermine dosage of coagulant. Use of syringes with pre-measured dosage is preferred over pipettes filled separately.

8. After coagulant(s) is (are) added, continue mixing at maximum speed for one minute.

9. Decrease mixing speed to 50 rpm (G of ~ 45 s^{-1}) and continue mixing at 50 rpm for 5 minutes.

10. At completion of the mixing process, while continuing mixing at 50 rpm, withdraw samples through the tap 10 cm below the water surface for filtration with:

    a. Whatman No. 541 filter paper to simulate filtration through granular media. This can be done under gravity conditions.

    b. Membrane filter (0.1 µm size, product to be determined) to simulate filtration through a microfilter. This can be done using a vacuum filter apparatus.

11. Sufficient sample must be collected to run the following analyses on the filtered water: turbidity, temperature, pH, total chromium, and Cr[VI]. If possible, the first 25 mL of filtrate should be wasted.

12. Record jar test results and include any visual observations about floc formation.

Appendix VII

Selenium Spiking Methodology

20 February 2013

Memorandum

To: Tim Williams

From: Sarah Laybourne

Subject: Procedure for spiking Davis source water with 20 µg/L Selenium
K/J 1270031*00

The purpose of this memorandum is to provide a procedure for spiking the Davis source water with 20 µg/l of Selenium using sodium selenate.

Procedure:

Step 1: Add 0.1 g Na_2O_4Se to 100 mL deionized water. This creates a 1,000 mg/l solution of Na_2O_4Se. Dilution was conducted in the UC Davis laboratory by measuring out 0.101 grams onto a weigh paper and rinsing with deionized water through a glass funnel into a 100 mL volumetric flask. Both the funnel and paper were thoroughly rinsed to remove any small particles of selenium from the surfaces. Added deionized water to the fill line. Mixed thoroughly through inversion at least 20 times using parafilm as the "stopper". This is Dilution 1. To store Dilution 1, the volumetric flask was wrapped with aluminum foil and stored in a fridge.

Step 2: Add 1.81 mL of Dilution 1 per 10 gallons of water added to the feed tank using a syringe or 25 mL graduated cylinder as appropriate. Total amount of Dilution 1 used will be 16.3 mL per 90 gallon tank. For the first dilution the tank will be filled to 1/3 full and then the spike added. After this, the remaining 60 gallons of water will be added and the tank will be mechanically mixed using a plastic oar for at least 1 minute. Subsequent dilutions will be added on Monday, Wednesday and Friday. The appropriate spike (based on water to be added) will be added and then the tank will be filled to the 90 gallon mark. The tank will be mechanically mixed using a plastic oar for at least 1 minute.

Appendix VIII

Work Plan

Kennedy/Jenks Consultants

10850 Gold Center Drive, Suite 350
Rancho Cordova, California 95670
916-858-2700
FAX: 916-858-2754

Final Work Plan
for
Sustainable Treatment for Co-Removal of Hexavalent Chromium by Biological Treatment Process Pilot Study

1 November 2012

REGISTERED PROFESSIONAL ENGINEER
TIMOTHY L. WILLIAMS
No. 39104
Exp. 06-30-13
CIVIL
STATE OF CALIFORNIA

Timothy L. Williams

11-01-12

Prepared for

City of Davis
23 Russell Boulevard
Davis, California 95616

K/J Project No. 1270031*00

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Section 1: Introduction

This work plan has been developed to assist the City of Davis in developing strategies to address future chromium 6 drinking water regulations. The work plan includes the following information:

- Pilot program contacts, roles and responsibilities
- Safety requirements
- Pilot process descriptions
- Waste handling procedures
- Pilot testing schedule
- Water quality sampling plan

1.1 Background

Chromium 6 poses potential risks to public health. Chromium 6 is a heavy metal that occurs naturally throughout the environment, and can also be present in wastewater and drinking water sources as a result of anthropogenic sources from industrial activities such as chromic pigments, corrosion control agents, and chrome plating solutions.

Potential carcinogenic risks resulting from inhalation of chromium 6 have long been recognized, but a drinking water regulation for chromium 6 has not yet been promulgated. Instead, the present drinking water regulations are based on total chromium, with the California maximum contaminant level (MCL) set at 0.05 mg/l (50 μg/l), and the United States Environmental Protection Agency (USEPA) MCL set at 0.10 mg/l (100 μg/l). In 2011, the California Office of Environmental Health Hazard Assessment (OEHHA) established a public health goal (PHG) for chromium 6 at 0.02 μg/l, which triggers a requirement for the California Department of Public Health (CDPH) to set an MCL for chromium 6 (draft MCL anticipated by July 2013). The USEPA is reviewing toxicity data to determine potential carcinogenicity of chromium 6 in drinking water, and depending on the results of that review, will propose establishing a drinking water standard.

As part of its regulatory process, the CDPH must set the MCL as close to the PHG as feasible, taking analytical methods, treatment technology, costs, and benefits into account. A future MCL at or near the proposed PHG would trigger an extensive need for treatment throughout the State. However, the present state of treatment technology and costs suggests an MCL of 1 to 25 μg/l. These regulations will require water utilities to evaluate potential removal or avoidance strategies within a short time frame. Currently, there are few demonstrated treatment technologies and those are characterized by high chemical use, high energy use, and residual disposal issues. The search for appropriate treatment technologies to meet anticipated chromium 6 standards will be similar to the utility response that occurred when arsenic standards were made more stringent.

Chromium 6 is also a contaminant that the Regional Water Quality Control Board (RWQCB) and State Water Resources Control Board (SWRCB) may regulate from wastewater treatment plant effluent per the California Toxic Rule (CTR) or through waste discharge requirements (WDRs) for land application, and in some cases, groundwater cleanups at contaminated sites (e.g., superfund sites). The source of chromium 6 in many of these effluents may be chromium in the drinking water source in the wastewater service area. Thus, not only is the protection of drinking water sources of concern, but the effluent from wastewater treatment plants that receive influent from those drinking water sources also may be a concern for the RWQCBs and SWRCB. The Central Valley RWQCB and the SWRCB are also concerned about nitrate in groundwater as a regional water quality concern.

Because of the regional benefits and potential impact of future chromium 6 regulations, the City has established a partnership with the Water Resources Association of Yolo County and Sacramento Groundwater Authority to help fund this project. In addition, the City has received grant funding through the SWRCB - Cleanup and Abatement Account (CAA).

1.1.1 The Chromium 6 Issue is Widespread

Chromium 6 monitoring under California's Unregulated Contaminant Monitoring Regulations led to the discovery of chromium 6 in many drinking water aquifers throughout the State. It has been detected in many groundwater supply wells at concentrations greater than 2 μg/l, notably the following areas:

- San Fernando Valley Basin affecting drinking water sources in the Los Angeles Metropolitan Area including the cities of Glendale, Burbank, San Fernando, La Canada-Flintridge, and the unincorporated area of La Crescenta,
- Coachella Valley,
- Yolo and Solano Counties including the Cities of Davis, Woodland, and Winters, and the University of California Davis,
- Sacramento County including City of Sacramento, Sacramento County Water Agency, and numerous other water agencies,
- Santa Cruz County including Soquel Creek Water District, City of Watsonville, and potentially other areas,
- City of Los Banos.

Some utilities have voluntarily monitored their drinking water sources and treated water using low level analytical techniques with detection limits for reporting in the 0.020 to 0.050 μg/l range. Additional monitoring is likely to result in a significant increase in the number of Community Water Systems detecting concentrations of chromium 6 at these low levels.

1.1.2 City of Davis and Other Water Providers

The City of Davis has concentrations of chromium 6 greater than 10 μg/l in 13 of its 21 municipal groundwater wells and is interested in finding a sustainable treatment process for the removal of chromium 6 from these wells.

1.2 Pilot Objectives

The City and Kennedy/Jenks will conduct a pilot study of a biological treatment system that would reduce chromium 6 in one of the City's existing drinking water wells (Well 20) to chromium 3, a more benign form of chromium and a required nutrient, which would then be removed by filtration. Biological treatment processes for chromium 6 could provide a sustainable, environmentally friendly alternative to the reduction/coagulation/filtration and anion exchange processes that were evaluated by the City of Glendale and are currently undergoing further evaluation by a Water Research Foundation (WaterRF) project using source water from other utilities (e.g., City of Davis) besides Glendale.

Many water utilities are implementing policies to promote sustainable utility practices. Biological treatment has been demonstrated to be a sustainable drinking water treatment process and is being implemented to reduce other contaminants, such as perchlorate, arsenic, selenium, and nitrate. Accordingly, it may have high potential to effectively reduce chromium 6 to chromium 3, which can then be filtered from the effluent. The development of a sustainable treatment process for chromium 6 would position water utilities to react quickly to the significant number of contamination cases that are likely to exist when a California chromium 6 regulation is finalized.

Information developed in the proposed pilot test study will be shared with the CDPH to support development of a MCL. While chromium 6 treatment pilot study efforts by the City of Glendale in Southern California and ongoing work by other utilities and WaterRF have provided significant information towards understanding treatment efficacy, this preliminary work by the City and Kennedy/Jenks will be completed to prove the concepts addressing the following objectives:

- Confirm whether an alternative reliable and sustainable treatment technology, such as biological treatment systems, may provide an effective means of chromium 6 treatment,
- Provide additional evaluation of other technologies to confirm efficacy and cost effectiveness of treating chromium 6 to low levels (less than 1 μg/l),
- Evaluate effectiveness of concurrently removing multiple constituents such as nitrate, selenium, perchlorate and chromium 6 to provide useful information for public water agencies to evaluate treatment alternatives,
- Evaluate the relationship between chromium 6 and total chromium, and potential impacts of the reduction/removal process for water delivered to the distribution system,
- Evaluate the residual management impacts and management options,
- Evaluate this pilot study results with the City of Davis' results from participating in a Water Research Foundation Project 4450 "Impact of Water Quality on Hexavalent Chromium Removal Efficiency and Costs" that will be treating City water using the reduction/coagulation/filtration and anion exchange processes currently being evaluated by other projects.

1.3 Pilot Location and Schedule

The water used for the pilot study will come from the City of Davis' Well 20. City staff will transport water from Well 20 to the pilot testing location. The pilot testing will be completed at the East Area Tank and Booster Pump Station, located north of I-80 at the Mace Blvd. exit, which is south of the Park and Ride Parking Lot.

The pilot test will be conducted over a sixteen (16) week period between November 2012 and March 2013. A detailed description of the pilot testing schedule is provided in Section 6 of this Work Plan.

Section 2: Contacts, Roles, and Responsibilities

This section includes the pilot program primary contacts with roles and responsibilities. Frequent and effective communication is key to ensuring a successful pilot is implemented. The City of Davis will be responsible for on-site safety procedures as well as access to the site location. The City of Davis will also help maintain the pilot throughout the project period and help Kennedy/Jenks with sampling. Kennedy/Jenks will be responsible for the operation, testing, and sampling of the pilot processes, with assistance from the City of Davis. The primary project team members contact information, roles, and primary responsibilities are presented in Table 1.

Table 1: Key Contacts, Roles, and Responsibilities

Name	Role	Company / Address	Phone #	Cell #	Email
KJ Team					
Tim Williams	Project Manager	Kennedy/Jenks Consultants 10850 Gold Center Drive, Suite 350 Rancho Cordova, CA 95670	916-858-2722	916-849-3262	timwilliams@kennedyjenks.com
Joe Drago	Senior Project Engineer	Kennedy/Jenks Consultants 303 Second Street, Suite 300 South San Francisco, CA 94107	415-243-2436		joedrago@kennedyjenks.com
Sean Maguire	Project Engineer	Kennedy/Jenks Consultants 10850 Gold Center Drive, Suite 350 Rancho Cordova, CA 95670	916-858-2728	916-601-8365	seanmaguire@kennedyjenks.com
Sarah Laybourne	Staff Engineer	Kennedy/Jenks Consultants 10850 Gold Center Drive, Suite 350 Rancho Cordova, CA 95670	916-858-2714		sarahlaybourne@kennedyjenks.com
Lynn Takaichi	QA/QC	Kennedy/Jenks Consultants 32001 32nd Avenue South, Suite 100 Federal Way, WA 98001	253-835-6403		lynntakaichi@kennedyjenks.com
KJ Team Subs					
Todd Webster Regional Vice President- West Region	Pilot Test Equipment	Envirogen Technologies, Inc. 8740 White Oak Ave. Rancho Cucamonga, CA 91730	877-312-8950	619-887-1385	twebster@envirogen.com
Brenda Hamilton Sacramento Microbiology Lab Manager	Laboratory Testing	BSK Associates Engineers & Laboratories 3140 Gold Camp Drive, Suite 160 Rancho Cordova, CA 95670	916-853-9293 x110	916-825-0135	bhamilton@bskinc.com
City Team					
Jacques DeBra Utilities Manager	Co-Project Manager	City of Davis Public Works Department Mail: 23 Russell Blvd. Davis, CA 95616 Office: 1717 Fifth St. Davis, CA 95616	530-757-5679	530-681-8563	jdebra@cityofdavis.org
Dianna Jensen Water Operations Manager	Co-Project Manager	Same	530-757-5639	530-304-8384	djensen@cityofdavis.org

Name	Role	Company / Address	Phone #	Cell #	Email
Marie Graham Utilities Program Coordinator	Utilities Program Coordinator	Same	530-757-5686		mgraham@cityofdavis.org
Gary Wells, Water Production Systems Supervisor	Water Production Systems Supervisor	Same	530-757-5686	530-681-8993	gwells@cityofdavis.org
SWRCB					
Mark Fong	Grant Manager	State Water Resources Control Board 1001 "I" Street, 16th Floor Sacramento, CA 95814	916-341-5827		mfong@waterboards.ca.gov
Lola Barba	Program Analyst	Division of Financial Assistance State Water Resources Control Board 1001 "I" Street, 17th Floor Sacramento, CA 95814	916-341-5638		lbarba@waterboards.ca.gov
Ruben Mora Water Resources Control Engineer		Integrated Regional Water Management Unit State Water Resources Control Board Project Management and Technical Support Unit Division of Financial Assistance 16th Floor 1001 I Street Sacramento, CA 95812	916-341-5387		rmora@waterboards.ca.gov
Julé Rizzardo State Revolving Fund		State Water Resources Control Board	916-341-5822		jrizzardo@waterboards.ca.gov
Water Resources Association of Yolo County					
Donna Gentile	Administrative Coordinator	P.O. Box 8624 Woodland, CA 95776	530-666-2733		info@yolowra.org
Sacramento Groundwater Authority					
John Woodling	Executive Director	Regional Water Authority 5620 Birdcage Street, Suite 180 Citrus Heights, CA 95610	916-967-7692		jwoodling@rwah2o.org
Robert Swartz	Senior Project Manager	Same	916-967-7692		rswartz@rwah2o.org

Section 3: Safety Requirements

The project will include significant time onsite at the City's East Area Tank and Booster Pump Station site to oversee setup and removal of the bench scale pilot equipment and to monitor, sample, and deliver samples to BSK laboratories in Rancho Cordova, CA. A Hazard Appraisal and Recognition Plan (HARP) is attached in Appendix A for this field work.

3.1 Site Specific Training

There is no required site specific training. While inside the East Area Tank and Booster Pump Station site, team members shall follow the health and safety recommendations of the accompanying City of Davis operator.

3.2 Health and Safety Plan

A HARP has been prepared for this project. A summary of some of the basic safety procedures is:

- Always wear the appropriate personal protective gear (e.g., goggles and gloves), especially when handling chemicals.
- Be cautious with 110v electrical cords to operate equipment in and around the pilot equipment. Make sure electrical cords are not placed in water.
- Secure electrical cords and drain pipes or tubing so that they do not create a tripping hazard.

3.3 Chemical Handling, Storage, and Disposal

Kennedy/Jenks, Envirogen and City of Davis staff expected to handle chemicals shall review the MSDS sheets and be aware of the hazards and responses to accidental exposure. Chemicals will be ordered by Kennedy/Jenks staff from Sierra Chemical, a local supplier used by the City of Davis. Kennedy/Jenks or Sierra Chemical will deliver the chemicals to the City of Davis Corporation Yard or directly to the East Area Tank Booster Pump Station pilot testing site. The anticipated chemical requirements are as presented in Table 2.

Table 2: Chemicals

Chemical	Supplier	Container Volume	Anticipated Delivery
75% Phosphoric Acid[(a)]	Sierra Chemicals	2.5 L (x2)	10/15/2012
99% Acetic Acid[(a)]	Sierra Chemicals	2.5 L	10/15/2012
Sodium Hypochlorite[(b)]	City of Davis	50 mL	12/15/2012
93% Sulfuric Acid[(a)]	Sierra Chemicals	1 quart	10/15/2012
25% Sodium Hydroxide[(b)]	Sierra Chemicals	1 L	10/15/2012
Sodium Selenate[(a)]	Sigma Aldrich	10 grams	12/14/2012

(a) Non-NSF 60 approved
(b) NSF 60 approved

Stock chemicals will be stored in the East Area Tank Booster Pump Station main room near the bench scale pilot set-up. The containers will be stored in small plastic tubs to provide secondary containment and prevent the potential for spillage into the on-site drain. Each chemical will be stored in a separate plastic tub and separated at a safe distance from each other to prevent mixing of the chemicals in case of a spill. Keeping the acids away from the sodium hydroxide is especially important for safety. Chemicals left over will be removed and disposed of by the City of Davis.

Section 4: Pilot Testing System Description

The conceptual full-scale treatment process has four main stages: (Step 1) Fluidized Bed Reactor (FBR), (Step 2) Aeration, (Step 3) Filtration, and (Step 4) Disinfection. A full-scale conceptual process flow diagram is depicted in Figure 1. The first stage will biologically reduce chromium 6 to chromium 3 and denitrify the water, while the remaining three steps are expected to be required for compliance with current Title 22 drinking water regulations. The CDPH has required the equivalent of surface water treatment for other biological processes it has approved for drinking water systems.

This section provides detailed descriptions of each of the processes including functionality, operating conditions, and any specific considerations for the process. A description of the chemical feed systems is also included.

4.1 Fluidized Bed Reactor and Aeration Pilot

The proof-of-concept pilot process will employ a bench scale small column FBR pilot to demonstrate the effective reduction of chromium 6 within the FBR system. The bench scale FBR will have a flow rate of approximately 20 to 70 milliliters per minute (mL/min) of City of Davis groundwater (i.e., Well 20). A detailed description, process flow schematic, and photograph of the proposed pilot system is provided in Figures 2 and 3 below, respectively. The water will be fed through the bench scale FBR column with analogous chemical additions that would be necessary for a full-scale operation. This includes the addition of nutrients, an electron donor and potentially pH adjustment to promote the growth of the biomass. The acclimation period for the process is estimated to require approximately four weeks, at which point a sufficient colony of indigenous nitrate and chromium 6 reducing bacteria will have grown within the system.

Laboratory and field analyses will be conducted throughout the acclimation and steady state test periods to confirm the proper performance of the bacteria and demonstrate chromium reduction within the system. Once steady state conditions are established, three different contact times (60, 40, and 20 minutes) will be tested to determine an optimal contact time within the FBR for the reduction of chromium 6. The other potential electron acceptor within this system is nitrate and selenium (when the influent is spiked), depending on its oxidation state. Nitrate and selenium concentrations will be monitored before and after the FBR to determine co-removal efficiencies within the system.

After the FBR, the water will be aerated to reintroduce dissolved oxygen and reestablish aerobic conditions. Aeration will occur by discharging into a small 5-gallon container that is equipped with an aquarium aeration device.

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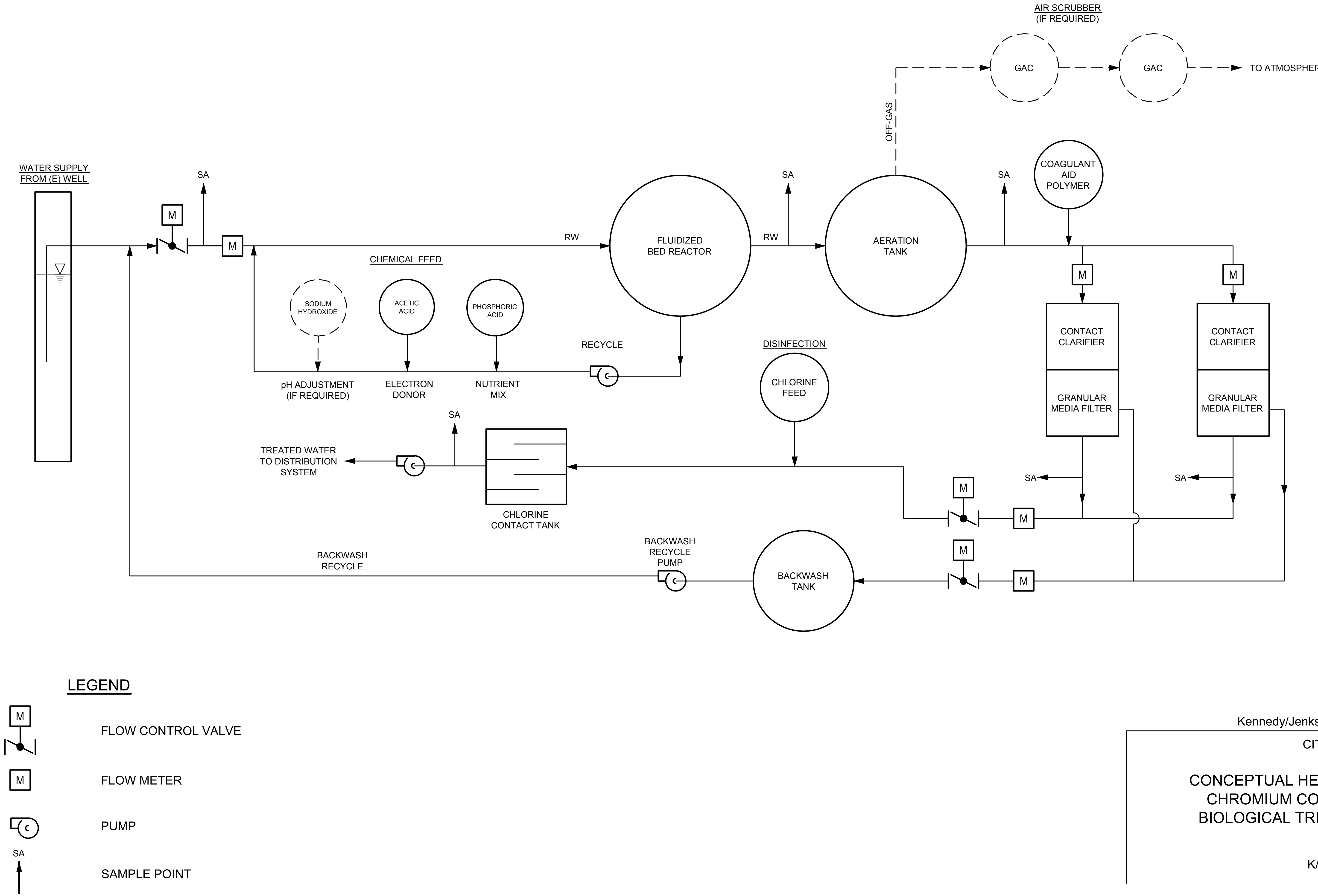

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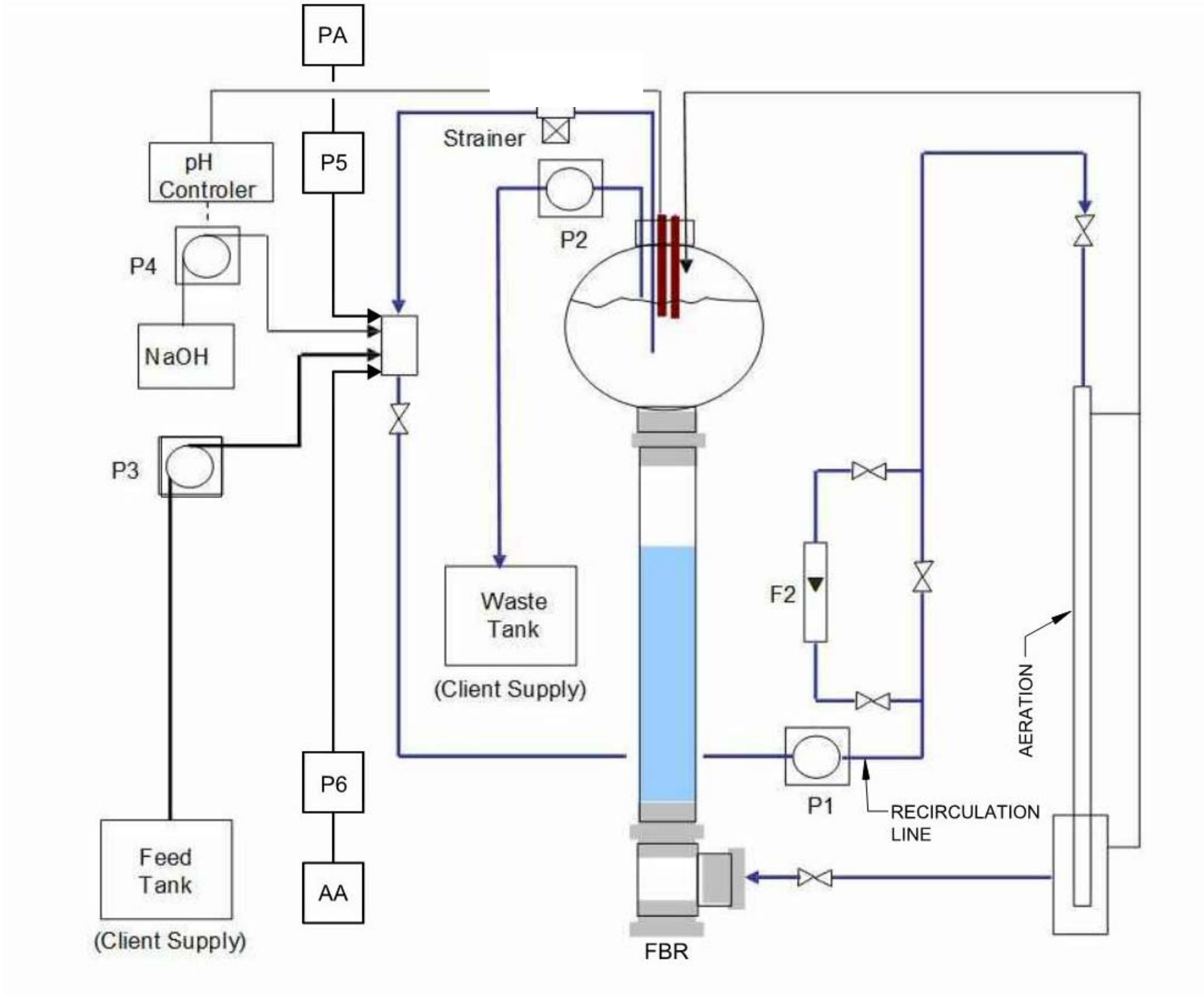
Kennedy/Jenks Consultants

CITY OF DAVIS

CONCEPTUAL HEXAVALENT CHROMIUM CO-REMOVAL BIOLOGICAL TREATEMENT PROCESS

K/J 11700031.00

FIGURE 1



P1 – Recirculation Pump
P2 – Effluent Pump
P3 – Influent Pump
P4 – Sodium Hydroxide Chemical Feed Pump
P5 – Phosphoric Acid Chemical Feed Pump
P6 – Acetic Acid Chemical Feed Pump
F2 – Recirculation Tank 2
AA – Acidic Acid
PA – Phosphoric Acid

Figure 2: Schematic of the FBR System

Figure 3: Photo of the FBR Pilot System

It is anticipated that full-scale filtration could include both a contact clarifier and a granular media filter. Alternative treatment processes may include membrane microfiltration. Filtration will be simulated on a bench-scale using two different size filter papers to simulate both granular media filtration and membrane microfiltration approaches. The bench-scale test will characterize particulate and dissolved chromium and will determine whether chromium 3 is effectively removed from the system through filtration of the samples. Filtration aides including iron coagulants and polymers will not be evaluated in this study. Nitrate, as well as total chromium and chromium 6 concentrations, will be measured before and after filtration. To simulate the two types of filtration the following process will be used:

1. Conventional Filter – A Type 541 Whatman filter (paper) will be used to simulate the process of a conventional filter system (e.g., gravity or pressure type) used in many water treatment plants.

2. Membrane Filter – A Whatman 12-4530-03 filter (paper) will be used to simulate a microfiltration membrane filter system used at many water treatment plants.

The final step of the pilot will be disinfection through the addition of 10-12% sodium hypochlorite (as provided by the City of Davis) to determine whether any residual chromium 3 within the system is oxidized to reform chromium 6. Chromium 6 concentrations will be measured before and after disinfection and following a contact time of 24 hours in a non-preserved sealed sample bottle to simulate typical residence time in the City water distribution system. Typically the conversion of chromium 3 to chromium 6, if any, will occur in a matter of hours.

The sample would then be transferred to a sample bottle that contains ammonium sulfate preservative. This sample will be collected, shipped to BSK and tested within 3 days (maximum holding time for chromium 6 test is 5 days). The preservative ammonium sulfate will convert the chlorine to chloramines and slow the conversion of chromium 3 to chromium 6.

In addition, an estimate of the volume of solids removed from automatic backwash filtration processes will be provided based on historical observations at other similar facilities.

During the last week of the pilot, a selenium spike test will be completed. Well 20 has relatively low selenium levels compared to the other 13 City intermediate wells (selenium concentrations of 4 to 36 μg/l). The average for the 14 City intermediate wells is about 15 μg/l. A batch of water will be spiked with selenium at a concentration equivalent to the average selenium concentration in the Davis wells. The removal of selenium will be monitored with two samples over this week by monitoring the FBR influent and effluent.

4.2 Pilot System Flow Rates

The entire pilot system will require a flowrate of approximately 20 to 70 milliliters per minute (mL/min), which is 0.32 gallons per hour (gph) to 1.12 gph.

Source Water Feed Pump: The source water feed pump will be manually adjusted for speed and use a 120 volt, single phase power supply and will be a Masterflex L/S Precision Variable Speed Console Drive peristaltic pump with a flow range of 0.06 to 3400 mL/min (see Appendix B for source water feed pump data sheet and specification sheet for Masterflex Model 07528-30). The source water feed pump connections will be clear tubing. The source water feed pump will be supplied by Envirogen. Envirogen will provide additional tubing and fuses as these are the typical parts that may fail and need to be replaced.

Source Water Feed Tank: The pump will be connected to a 100 to 120 gallon plastic source water (i.e., chemical storage type) feed tank with bottom outlet provided by the City of Davis. The City of Davis operators will refill the source water feed tank with Well 20 water on an as needed basis, which will vary from about once every 11 days to once every 4 days to ensure adequate water is in the tank.

Pilot Test Equipment: Figure 2 presents a process schematic of the FBR. The laboratory FBR system is constructed of 5 cm diameter glass, stainless steel, neoprene, and Teflon® materials to minimize abiotic chemical losses (see Figure 3). The FBR has a total liquid volume of approximately 4 L.

The laboratory pilot-scale FBR is designed to operate continuously. The water feed to the FBR is introduced in the recycle line on the downstream side of the recirculation pump (see Appendix B – peristaltic pump Masterflex model no. 7554-90, 115v ac, 60 hz). The granulated activated carbon (GAC) bed in the reactor is fluidized at approximately 1.5 L/min using a peristaltic pump on the recycle line (i.e., recirculation pump). This flow provides an initial bed expansion of approximately 25%, which is typical for full-scale systems.

The FBR will have a settled bed height of approximately 42 cm and an expanded bed height of 70 cm when biofilm is fully formed on the media. The system is designed such that a portion of the water exiting the top of the reactor is recycled to maintain fluidization; the balance exits as treated effluent.

The FBR does not have an automatic backwash. As the bed volume expands to nearly 1.7 times the settled bed height, a manual backwash is completed. This will be done Kennedy/Jenks by removing the top 1/3 of the media, washing the media and then placing the media back in the FBR. Based on the loading conditions, it is uncertain how often this will occur or need to be completed during the pilot.

The reactor pH will be maintained at approximately 6.0-7.0 by direct addition of acid and base solutions, if necessary (sulfuric acid and sodium hydroxide). If required, based on the temperature of the feed water normally encountered at the Well 20 compared to the temperature in the East Area Tank Booster Pump Station site, the lower third of each reactor could be insulated to assist in maintaining a constant temperature of the water inside the unit.

The untreated feed will come from the City of Davis supplied water as described above. A source water feed pump will provide the water at a starting rate of 20 ml/min to a maximum rate of 70 mL/min (depending on treatment performance). Adjustments in feed flow will occur to potentially reach this maximum flowrate over the course of the study. The feed flow will be measured and the pump calibrated by operating the unit and measuring the flow using a graduated cylinder that the discharge pipe will pump into.

Three different hydraulic residence times (HRTs) as described below will be tested through the FBR.

The pilot's FBR will be run at three (3) different hydraulic residences that will dictate the flow rate required for the pilot as follows:

- Acclimation Period – Flow rate during the four week acclimation period will assume a hydraulic residence of 60 minutes. This will be a flow rate of approximately 20 mL/min.
- 60-Minute Hydraulic Residence – For the first four weeks of the pilot study, the FBR will be targeted to have a hydraulic residence of 60 minutes. This will be a flow rate of approximately 20 mL/min. This will depend on the degree of biological bed expansion.
- 40-Minute Hydraulic Residence – For the second four weeks of the pilot study, the FBR will be targeted to have a hydraulic residence of 40 minutes. This will be a flow rate of approximately 20-40 mL/min. This will depend on the degree of biological bed expansion.
- 20-Minute Hydraulic Residence – For the third four weeks of the pilot study, the FBR will be targeted to have a hydraulic residence of 20 minutes. This will be a flow rate of approximately 50-70 mL/min. This will depend on the degree of biological bed expansion.

Pilot system flow rates will be adjusted if the hydraulic residence times need to be reevaluated based on chromium 6 removal rates.

4.3 Chemical Feed Systems

Two chemical types will be evaluated and added prior to the fluidized bed reactor to assist with chromium and nitrate reducing bacterial growth:

- **Acetic Acid:** Acetic acid will provide an electron donor source, which will promote bacterial growth of chromium and nitrate reducing bacteria. Feed rates will be set initially at less than 0.01 mL/min, but may be adjusted during the acclimation period, based on bacterial growth indicators that are analyzed, such as oxidation-reduction potential (ORP) and dissolved oxygen (DO). Acetic acid will be diluted from the 99% stock solution to a 0.5% to 3% solution so as to be compatible with the Envirogen provided chemical feed pump.

- **Phosphoric Acid:** Phosphorus, a necessary nutrient for biological growth will be added as phosphoric acid to provide additional nutrients to promote bacterial growth in the FBR. Phosphoric acid will be diluted from the 75% stock solution to a 0.00075% to 0.1% solution so as to be compatible with the Envirogen provided chemical feed pump.

- **Sodium Hydroxide:** Anoxic bacteria grow best within a certain pH range of 6.0 to 7.0. If the pH range becomes inhibitory to anoxic growth due to a pH that is too low, sodium hydroxide may be required to increase the pH back to a more optimal range. Sodium hydroxide will be diluted from the 25% stock solution to a 0.5% to 5% solution so as to be compatible with the Envirogen provided chemical feed pump.

- **Sulfuric Acid:** If the pH range becomes inhibitory to anoxic growth due to a pH that is too high, sulfuric acid may be required to decrease the pH back to a more optimal range. Sulfuric acid will be diluted from the 93% stock solution to a 0.5% to 3% solution so as to be compatible with the Envirogen provided chemical feed pump.

The three chemical feed pumps are all the same and consist of a Masterflex L/S fixed flow drive peristaltic pump, model number 7540-02, 115v ac, 60 hz (see Appendix B for pump specification sheet).

4.3.1 Chemical Feed Rates and Concentrations

Envirogen calculated estimates for initial acetic acid, phosphoric acid and pH adjustment for a hydraulic residence time of 60 minutes. These calculations were based on the concentrations of nitrate, hexavalent chromium and other water quality parameters that were measured during the Title 22 sampling that was conducted by the City of Davis in August of 2012. According to this analysis, the chemical feed rates as shown in Table 3 will be used for the initial hydraulic residence time.

Table 3: Chemical Feed Rates and Chemical Concentrations for a Hydraulic Residence of 60 Minutes

Chemical	Stock Concentration	Diluted Standard Concentration	Feed Rate (mL/min)
Acetic Acid	99%	0.50%	0.15
Phosphoric Acid	75%	0.00075%	0.9
Sodium Hydroxide	25%	N/A	None Anticipated
Sulfuric Acid	93%	N/A	None Anticipated
Sodium Selenate	Solid	15 µg/l	None for 60 or 40 min. HR

4.4 Residuals Handling and Disposal

The effluent from the pilot will be discharged to the floor drain in the pump room located in the East Area Tank Booster Pump Station (see Figure 4) through temporary tubing and spilled out of the 5-gallon container with the aquarium aeration unit. The effluent is not considered hazardous waste and will be within the limitations required for disposal to the City of Davis sewer system. When installing the temporary tubing, it should be done in such a way as to minimize any potential tripping hazard.

The filtration tests will not filter sufficient water to accumulate enough solids to become hazardous waste due to chromium accumulation on the filter. The filtered water not sampled will be discharged in the floor drain or sink in the pump room and the filter paper will be disposed of in the on-site trash bin.

4.5 Equipment List

The major equipment to be provided by Kennedy/Jenks, Envirogen, and the City of Davis is shown in Table 4 (see Appendix C).

Section 5: Pilot System Setup and Demobilization

This section includes a description of the pilot system setup, responsibilities, and demobilization proceedings required for each participant.

The pilot testing using a FBR will be completed using a pre-assembled bench-scale system provided by Envirogen (see Figure 5 at the end of this Section). The system includes a FBR and aeration basin as well as a continuous effluent pH analyzer. The dimensions of the system are about 3 ft. wide x 2 ft. long x 5 ft. high. The column test equipment will be set up at the City of Davis' East Area Tank Booster Pump Station pump room as shown in Figure 4. The 100 to 120 gallon chemical storage tank (or similar, as decided by the City of Davis) and source water feed pump will be used to supply the pilot with a continuous supply of water. This chemical storage tank will need to be periodically refilled with Well 20 water by the City of Davis staff on an as needed basis. The chemicals required for the system will be delivered to the City of Davis. The chemicals required include an electron donor (acetic acid), a nutrient source (phosphoric acid), sodium hypochlorite (provided by the City of Davis) and possibly pH control chemical (sodium hydroxide and/or sulfuric acid).

5.1 Source Water

Raw water from Well 20 has been routinely sampled and analyzed for constituents as required under Title 22. A summary of Title 22 water quality results are shown in Table 5 (see Appendix D). In addition, prior to the beginning of the pilot test characterization of this water sampling will be conducted to confirm water quality parameters key to the pilot, which include total organic carbon, total suspended solids, pH, and chromium speciation.

Kennedy/Jenks will prepare a Technical Memorandum that characterizes the source water results. The City will review the data. Envirogen will also review the data to confirm initial requirements and confirm pilot treatment target objectives.

5.2 Pilot Plant Site Setup Requirements and Responsibilities

The pilot plant site will be located within the booster pump station pump room at the Davis East Area Tank site. Access to the site to install the equipment will require a staff member from the City of Davis to open the gate to the East Area Tank site and booster pump station building using the roll-up door and/or standard entry door. Requirements identified during investigation into an acceptable area for the pilot plant included:

- Secure site
- Temperature controlled (no freezing or extreme heating)
- Accessibility
- Sufficient space
- Drain to sewer
- Availability of electrical hook-up

The location identified for the pilot test and site layout is shown in Figure 4 (located at the end of this Section).

The City of Davis will assist with the pilot test equipment setup by providing staff, tools, and the following equipment: source water feed tank, and inlet and outlet tubing, two ball valves to isolate the source water feed pump from the tank to the pump and from the pump to the pilot test equipment, water, and sodium hypochlorite chemical (very minimal amount).

Envirogen and Kennedy/Jenks will be responsible for providing and assembling the pilot test equipment, including providing spare tubing and fuses for each of the three types of peristaltic pumps, one source water feed pump, one recycling and three chemical feed pumps, on-site testing equipment, 110v power strip(s), extension cords, filter media, filter test apparatus with filter paper, jar testing apparatus, and chemical storage tubs.

It is anticipated that the setup will take 1 to 2 days. Envirogen will be on site for this set-up.

5.3 Maintenance of Pilot

Envirogen will start up the pilot test equipment on the first day after the set-up is complete to start the acclimation period (four weeks). Envirogen will train Kennedy/Jenks and the City of Davis staff on the proper operation, testing, monitoring and troubleshooting required for the pilot equipment and testing period.

The City of Davis will assist with maintaining the pilot test equipment by repairing piping, maintaining pumping systems, and other support to keep the pilot test equipment in operation. The designated City staff will participate in the pilot test training, sampling, onsite testing and data recording, and site safety that will occur throughout the pilot test period.

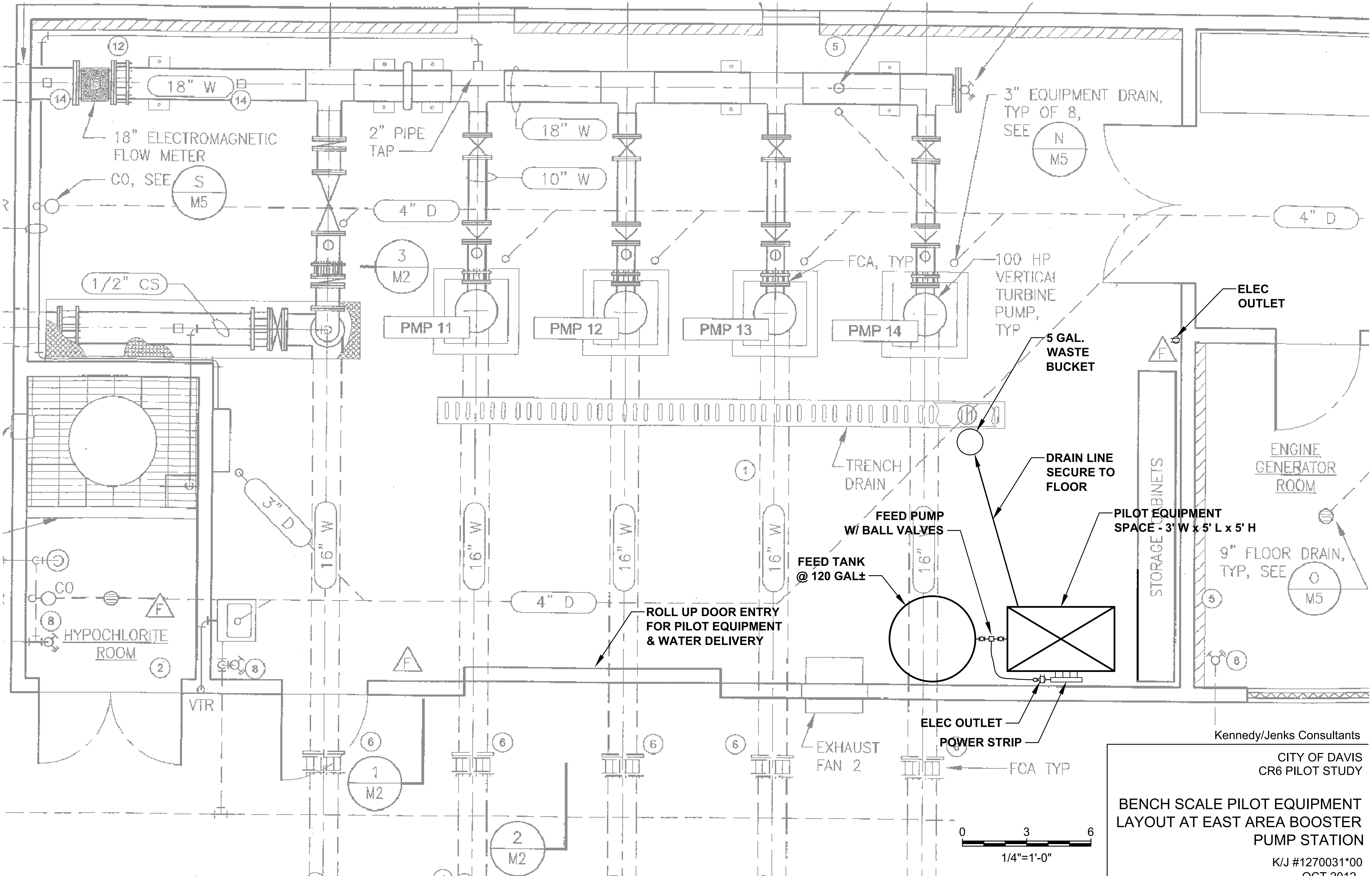
Manual backwashing of the media as described in Section 4.1 – Pilot Test Equipment, if required, will be completed by Kennedy/Jenks.

5.4 Miscellaneous Materials

Miscellaneous materials (e.g., spare source water and chemical metering pumps) needed for the pilot plant will be stored at a location as designated by the City of Davis inside the booster pump room.

5.5 Demobilization

Kennedy/Jenks with assistance from the City of Davis staff will demobilize the bench scale pilot system, ancillary tubing and associated equipment. All equipment and tubing provided by Envirogen will be disassembled, removed and packaged for shipment back to Envirogen by Kennedy/Jenks. The City of Davis will be responsible for removal and disposal of any remaining chemicals and biological filter media. It is estimated that demobilization will take approximately 1 to 2 days.



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Kennedy/Jenks Consultants

CITY OF DAVIS
CR6 PILOT STUDY

BENCH SCALE PILOT EQUIPMENT LAYOUT AT EAST AREA BOOSTER PUMP STATION

K/J #1270031*00
OCT 2012

FIGURE 4

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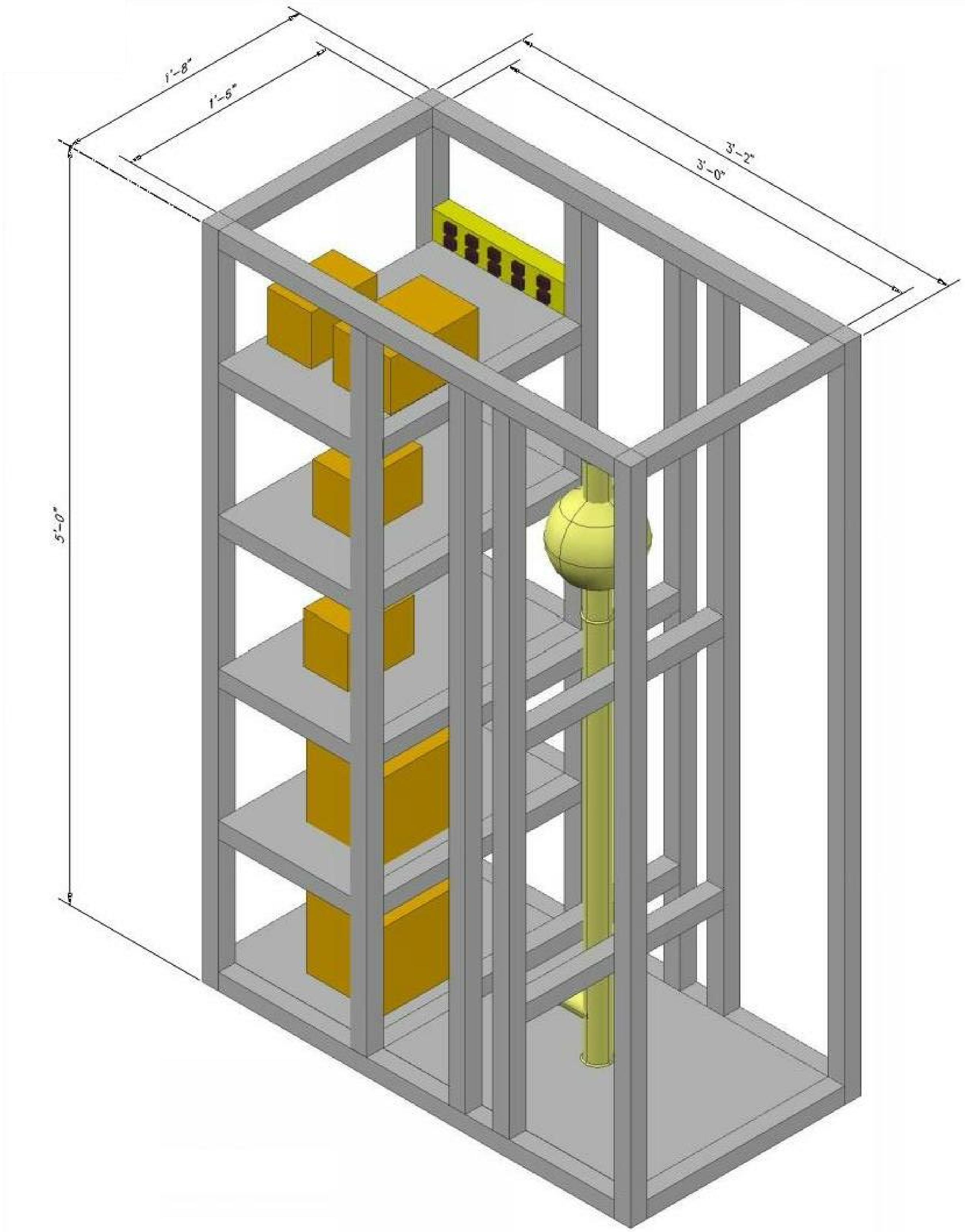

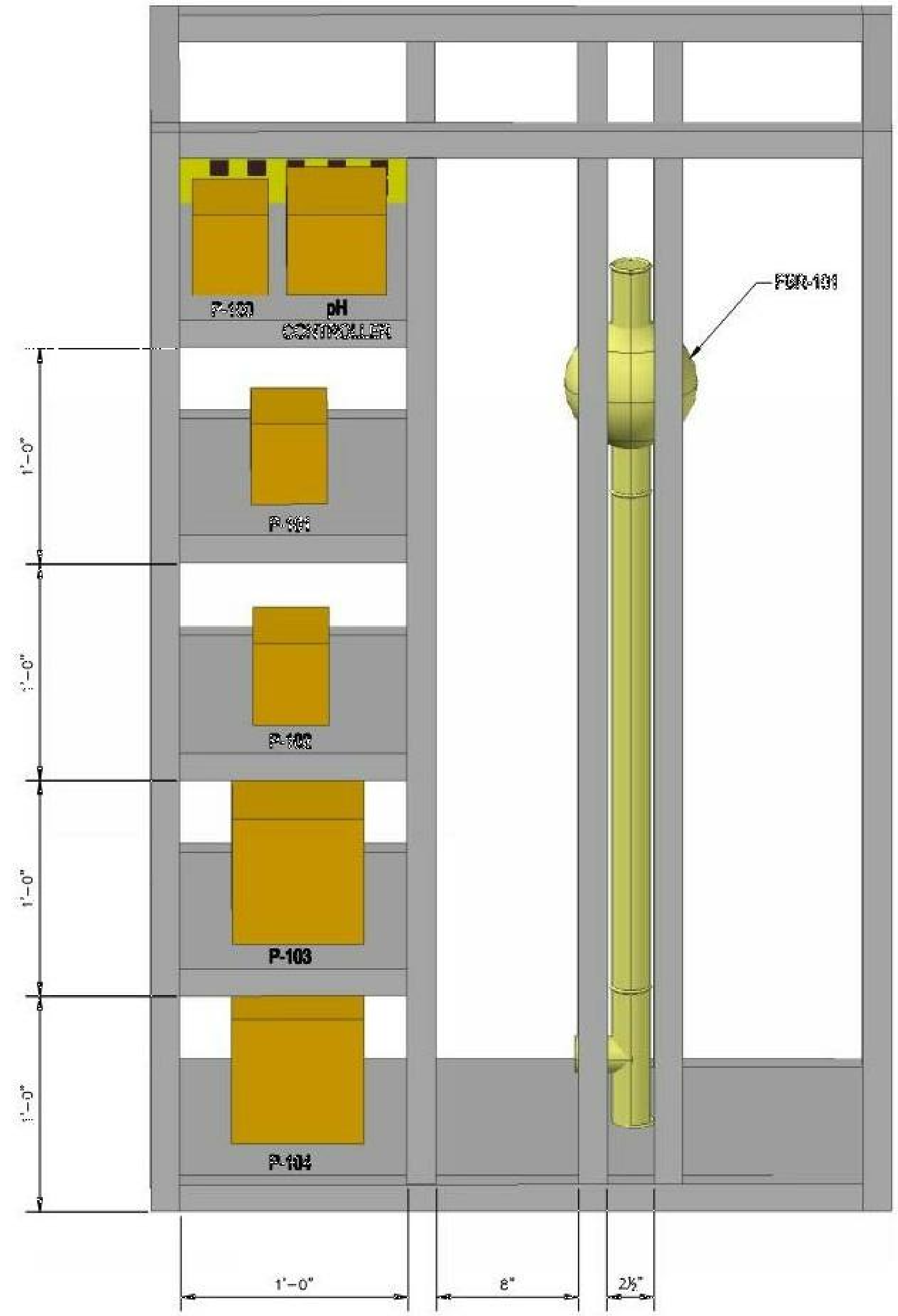

Kennedy/Jenks Consultants

CITY OF DAVIS
CR6 PILOT STUDY

PREASSEMBLED BENCH SCALE
CR6 PILOT SYSTEM

K/J #1270031*00
SEPT 2012
FIGURE 5

Section 6: Pilot Testing and Schedule

The project schedule is attached as Table 6 (see Appendix E). It is critical that the draft study be completed by early May 2013 and the project is completed no later than 26 June 2013, as shown, so that the grant funding from the three agencies is not jeopardized.

The pilot testing phase will last for 12 weeks once the system has been acclimated and has been confirmed to be operating properly. The schedule assumes a 4 week acclimation period. The proposed operating time does not include time required for system setup and take down. The pilot system will operate 24 hours per day during the testing, and will be monitored daily by City of Davis and/or Kennedy/Jenks staff members, except for major holidays (e.g., Thanksgiving day, Christmas day, New Years day, and Presidents day).

The pilot plant will be operated during the weekend, but no sampling will occur during the weekend, unless an upset is occurring or additional samples are necessary to better understand how to optimize the pilot plant.

6.1 Confirmation of Well 20 Water Characterization

Water quality characterization results from Title 22 analysis conducted annually by the City of Davis Well 20 water constituent make-up were relatively consistent, as presented in Table 5 (see Appendix D). This data is relatively recent and was tested by BSK Laboratories, the same lab that will be conducting the testing for this pilot study. These test results will be used to represent the constituent make-up of the source water, Well 20.

6.2 Pilot Test Schedule

This section presents the proposed pilot test schedule. The bench scale pilot plant is currently scheduled to be delivered on 5 November 2012. The anticipated pilot testing schedule is as follows:

1. 5 November 2012 – Pilot setup
2. 12 November 2012 – Acclimation period begins
3. 10 December 2012 – 60-minute FBR hydraulic residence time begins
4. 7 January 2013 – 40-minute FBR hydraulic residence time begins
5. 4 February 2013 – 20-minute FBR hydraulic residence time begins
6. 4 March 2013 – Demobilization

The planned test format has three (3) different hydraulic residence times of 60, 40 and 20 minutes. If however, it is found that a hydraulic residence time is not sufficient to achieve the chromium 6 treatment goal, then the hydraulic residence times may be increased to address this. The chromium 6 treatment goal throughout the pilot study is 1 μg/l.

6.3 Bench Filtration and Disinfection Test

Additional bench filtration and disinfection testing will be conducted during the last week of each hydraulic residence period.

6.4 Perchlorate and Nitrate Co-Removal

Include in the Pilot Test Study an evaluation of the co-removal potential by biological filtration of chromium 6 along with perchlorates and nitrates. We will use previous research, pilot study, and full scale treatment results from across the United States that have successfully used biological filtration for co-removal of perchlorates and/or nitrates and report on the likelihood of the effectiveness of treatment of those constituents along with chromium 6.

Section 7: Water Quality Sampling Plan

Kennedy/Jenks and Envirogen will compile and analyze the field and analytical results from the pilot to evaluate the extent in which the pilot objectives were achieved. The overall removal efficiency for chromium 6 and total chromium for the duration of the study will be reviewed and compared to the 1 μg/l treatment target goal for chromium 6 of the study, which is based on early considerations by CDPH to potentially establish a chromium 6 maximum contaminant limit (MCL) between 1 and 25 μg/l.

Other analyses will include:

- Determination of recommended hydraulic residence time,
- Demonstration of oxidation of chromium 3 to chromium 6 during simulated disinfection,
- Determination of recommended nutrient, pH, and electron donor dosing for system,
- Efficiency of nitrate and selenium and nitrogen removal,
- Potential residual handling and disposal.

This section includes a list of the pilot sample test procedures and frequency of sampling.

7.1 Confirm Well 20 Water Characterization

A sample of the raw water from Well 20 was taken to confirm the concentration of chromium 6 for the Well 20 water and compare them with the existing Title 22 sample results. In addition, total suspended solids and total organic carbon will also be tested. The sampling was conducted on 2 October 2012. The sample was collected by Kennedy/Jenks and brought to BSK Laboratories for analysis. BSK Laboratories will perform the analysis listed in Table 7 using the Title 22 testing methods. Temperature and pH were measured in the field by Kennedy/Jenks staff.

The City recently sampled and tested for the full Title 22 water quality constituents for Well 20 on 6 August 2012 (see Table 5, Appendix B). The summary of the key constituent results and the constituent tests to be completed the week of 24 September 2012 are listed in Table 7. This data will be used to confirm Well 20 source water characterization and determine the initial electron donor and chemical feed dosage rates to initially use during the acclimation pilot start-up period.

Table 7: Well 20 Characterization Confirmation Sampling and Results

Analyte	Title 22 Sample Results	Additional Sampling
Temperature	-	66.7 °F
pH	-	7.87 SU
Chloride	31 μg/l	-
Chromium, Hexavalent	-	L
Chromium, Total	37 μg/l	-
Metals:		
Barium	180 μg/l	-
Cadmium	<1.0 μg/l	-
Zinc	<50 μg/l	-
Manganese	<10 μg/l	-
Mercury	<0.4 μg/l	-
Nickel	<10 μg/l	-
Lead	<5.0 μg/l	-
Iron	<30 μg/l	-
Nitrate - N	33 μg/l	-
Sulfate	38 μg/l	-
Total Dissolved Solids	520 μg/l	-
Total Suspended Solids	-	L
Selenium, Total	<2 μg/l	-
Total Organic Carbon	-	L

L= Analyzed by BSK Laboratories

7.2 Pilot Sample Locations and Analyses

Samples for the pilot study will be taken at three locations on the pilot system: (1) influent to FBR, (2) effluent from FBR, and (3) with one spot sample every two weeks of effluent from the aeration tank.

Kennedy/Jenks will monitor the pilot test process during Monday through Friday and collect samples and submit them to BSK Associates for testing. During the first two (2) weeks of the pilot study, the City will monitor the pilot test process Saturday and Sunday. Monitoring over the weekend will be conducted on an as needed basis after the first two (2) weeks of the pilot. As described above, the equipment will not be monitored and samples will not be collected on major holidays. It is not anticipated that samples will be taken on the weekends or holidays.

A schedule for the collection of field test data and laboratory samples during the study is provided in Table 8. More frequent analyses are anticipated during the Acclimation Period of the piloting as the system is being adjusted. Field and laboratory analysis will be conducted at the stated frequency, except during holidays.

Continuous on-line pH, along with daily (Monday through Friday) temperature, oxidation reduction potential (ORP) nitrate, phosphate, pH, dissolved oxygen (DO) and turbidity field analyses of the FBR effluent, will be conducted to monitor system performance. The FBR influent will be monitored for temperature, pH and ORP daily (Monday through Friday). Field test data will be recorded onto standardized log sheets. Separate log sheets will be maintained for recording the pH, flow, and chemical dosages. Sample log sheets are located in Appendix G. All data sheets will be available for review as the test proceeds.

Table 8: Sample Analysis Schedule

Week		5-16	1-4	5-16		8, 12, and 16		
	Source Water Charc.	Aerated Effluent	Acclimation	Hydraulic Residence 1-3	Location	Filtration Test 1-3	Location	Total
BSK Laboratories								
Chloride		X6		1XW	*E*			18
Chromium, Hexavalent	X1	X6	3XW	2XW	*I,E*	X15	See Table 9	94
Chromium, Total		X6	3XW	2XW	*I,E*	X15	See Table 9	93
Color		X6		1XW	*E*			18
Corrosivity		X6		1XW	*E*			18
Metals		X6		1XW	*E*			18
pH	X1							1
Total Organic Carbon (TOC)	X1		X6	1XW	*E*			19
Total Oxidizable Nitrogen (Nitrate and Nitrite)		X6	3XW	2XW	*I,E*			78
Sulfate		X6		1XW	*E*			18
Total Dissolved Solids		X6		1XW	*E*			18
Total Suspended Solids	X1	X6		1XW	*E*	X9	See Table 9	28
Field Testing								
Nitrate-N			M-F Daily	M-F Daily	*E*			80
Phosphate			M-F Daily	M-F Daily	*E*			80
Turbidity			M-F Daily	M-F Daily	*E*	X9	See Table 9	89
Temperature	X1	X6	M-F Daily	M-F Daily	*I,E*	X9	See Table 9	176
Dissolved Oxygen			M-F Daily	M-F Daily	*E*			80
pH	X1	X6	M-F Daily	M-F Daily	*I,E*	X9	See Table 9	176
Oxidation Reduction Potential			M-F Daily	M-F Daily	*I,E*			80

E = Effluent from Aeration Basin
I = Influent to Pilot Plant
AE = Aerated Effluent
X1 = 1 Time
3XW = 3 Times per Week
1XW = 1 Time per Week
2XW = 2 Times per Week
M = Monday
F = Friday
X6= 6 Times
X9= 9 Times
X15 = 15 Times

7.3 Filtration and Disinfection Testing

Kennedy/Jenks will conduct a bench scale filtration and disinfection analysis to simulate the results that may be found should a full system pilot be conducted. The bench studies will be completed in the final week of each of the hydraulic residence time scenarios.

Testing will occur at the pilot test site. The samples should be stored on ice or in a refrigerator prior to transport to BSK Laboratories. The only chemical used during filtration and disinfection testing will be a small amount of sodium hypochlorite supplied by the City of Davis. The remaining sodium hypochlorite will be returned to the City of Davis for proper disposal after the testing is complete.

Three filtration bench tests will be conducted, with one being conducted per hydraulic residence time. For each bench test, the aeration effluent will be sampled, along with the effluent from the two bench scale filtration analyses (i.e., conventional and membrane filtration simulation), as well as the two filtration effluent samples after chlorination for a total of five (5) samples per bench test as shown in Table 9. The effluent from the two filtration tests, as well as the aeration effluent without filtration will be tested at one contact time designated at 24 hours in a sealed holding container with no preservative and then transferred to a sample container with preservative and tested after 3 days in the laboratory. The total number of samples will be 15 for chromium 6 and 15 for total chromium.

Table 9: Filtration and Disinfection Testing Sampling

Analyte	Sample # per Hydraulic Residence	Total # Samples	Notes
Aeration Effluent			
Chromium 6	1	3	1 Sample per HR (20, 40, 60 min.)
Total Chromium	1	3	1 Sample per HR (20, 40, 60 min.)
Total Suspended Solids	1	3	1 Sample per HR (20, 40, 60 min.)
Turbidity	1	3	1 Sample per HR (20, 40, 60 min.)
Filtered Water			
Chromium 6	2	6	1 sample per filtration type (gravity and membrane)
Total Chromium	2	6	1 sample per filtration type (gravity and membrane)
Total Suspended Solids	2	3	1 sample per filtration type (conventional and membrane)
Turbidity	2	3	1 sample per filtration type (conventional and membrane)
Disinfection			
Chromium 6	2	6	1 sample per contact time (24 hours) by filtration type
Total Chromium	2	6	1 sample per contact time (24 hours) by filtration type

7.4 Sampling Procedures

Samples will be collected by the City of Davis operator or Kennedy/Jenks staff according to the sampling matrix. BSK Laboratories will provide the sample bottles and chain of custody forms along with instructions for handling and delivery of the samples. The samples will be taken to BSK Laboratories in Rancho Cordova by either a Kennedy/Jenks staff member or the BSK Laboratories courier. BSK Laboratories will package and ship the samples to their Fresno office.

7.4.1 Field Measurements

Kennedy/Jenks will provide the HACH DR890 colorimeter that will be used to conduct field analyses of nitrate and phosphate. The HACH DR890 colorimeter has a user’s manual that provides directions for each analytical measurement. These directions will be used during this pilot study. Kennedy/Jenks will provide a YSI Model 556 meter to field measure Dissolved Oxygen (DO), ORP, pH, turbidity, and temperature of the influent and effluent. The YSI Model

556 meter user's manual will be used to calibrate, maintain and followed in conducting the tests. A summary of the field analysis methods is listed in Table 10.

The City of Davis operators will record the time, date, volume (estimate), and Well 20 nitrate concentration when they refill the source water storage tank at the pilot plant. The nitrate concentration for Well 20 will be recorded from the existing online nitrate analyzer at Well 20 (see Sample Log Sheet in Appendix G). These results will be reported to Kennedy/Jenks to compare with the field and laboratory nitrate measurements. The pH continuous monitoring values will be data logged at the pilot test site and also field measured by a pH probe.

Table 10: Field Analysis Methods Summary

Parameter	Method
Flow Rate	Measure using graduated cylinder or beaker and stop watch to calculate flow
Dissolved Oxygen	YSI Model 556 DO meter
Oxidation Reduction Potential	YSI Model 556 ORP meter
pH	YSI Model 556 pH meter
Temperature	YSI Model 556 Thermometer
Turbidity	YSI Model 556
Nitrate	HACH DR890 Colorimeter
Phosphate	HACH DR890 Colorimeter

During the pilot test, phosphate will be monitored so that the addition of phosphoric acid modified to maintain a phosphate residual of about 1 mg/l.

The flow rate will be measured using a graduated cylinder or beaker of 100 to 200 ml capacity and a stop watch used to time how long it takes to fill the cylinder or beaker, the flow rate will be recorded.

The temperature measurement will be performed by measuring the temperature of the water in the aerated effluent container, measured after the thermometer has been immersed in the water for a minute, and then recorded.

7.4.1.1 Field QA/QC

Kennedy/Jenks will be responsible for proper calibration and maintenance of instrumentation according to manufacturer instructions. Equipment calibration results will be recorded and maintained onsite with the appropriate instrument. Where appropriate, field measurements will be taken from duplicate samples collected for both field analysis and analysis by a fixed analytical laboratory. A limited comparison between the field and a certified laboratory will also be conducted after sampling is completed to evaluate the precision and accuracy of the field results.

7.4.1.2 Sampling and Sample Handling

Sample bottles will be rinsed with fresh sample water prior to collection, unless they contain a preservative then no rinsing will be done. Once the analyses are complete, any excess sample water will be disposed of on location, down the existing drain or sink. The bottles will be rinsed with distilled water for use at the next sampling event.

7.4.2 Laboratory Analysis

Sampling requiring laboratory analysis will be conducted by the City of Davis or Kennedy/Jenks staff. Both the City of Davis and Kennedy/Jenks will be responsible for proper handling, packaging, label, and chain of custody documentation. Kennedy/Jenks staff will be responsible for sample transport to BSK Laboratories in Rancho Cordova. The list of samples, analytical methods, holding times and detection limits is shown in Table 11 (see Appendix F).

7.4.2.1 Sample Containers/Preservation

Samples to be sent to BSK Laboratories will be collected in bottles provided by BSK Laboratories. The number and type of bottles provided may vary depending on analyses to be conducted. When required, the sample bottles will already contain the necessary preservative for the analyses. BSK Laboratories estimated a sample size requirement of one-liter for the characterization sampling analysis and a sample size requirement of 250-300 mL for other sampling events.

7.4.2.2 Sampling and Sample Handling

The City of Davis and/or Kennedy/Jenks will collect samples in accordance with the frequency presented in Table 8. Samples that do not contain preservative will be rinsed with the sample prior to collection. During sample collection the sample ports will be opened for a short period of time to purge potential stagnant water and debris from the sample port.

Samples collected for offsite analysis will be labeled with a unique sample, sample date and time, appropriate analysis and sample preservative. An example of the sample identification system used is as follows: the first sample collected from the influent sample location on 10 November 2012 at 7:00 am would be Inf-01-1011-700am.

Following sample collection, the sample information will be recorded on a chain of custody form. The samples will then be placed in a refrigerator or cooler filled with ice, until they are delivered to BSK Laboratories.

7.4.2.3 Laboratory QA/QC

The California Department of Public Health Environmental Laboratory Accreditation Program Branch has certified the contract laboratory for the analyses required by this pilot test work plan. The laboratories follow Standard Operating Procedures for all laboratory analyses and QA/QC. QA/QC data will be provided with the analytical reports.

Appendix A

Hazard Appraisal and Recognition Plan

Kennedy/Jenks Consultants

303 Second Street, Suite 300 South
San Francisco, California 94107
415-243-2150
FAX: 415-896-0999

Hazard Appraisal & Recognition Plan (HARP)

City of Davis Sustainable Treatment for Co-Removal of Cr6 by Biological Treatment Process Pilot Study

1717 Fifth Street, Davis, CA 95616

Prepared for

City of Davis
1717 Fifth Street
Davis, CA 95616

K/J Project No. 1270031*00

Hazard Appraisal & Recognition Plan (HARP) Summary

Project Name Sustainable Treatment for Co-Removal of Cr6 by Biological Treatment Process Pilot Study

Project No. 1270031*00

Prepared by Sarah Laybourne

Date 10-5-12

Project Manager Tim Williams

Office Sacramento

Field Services Description

Field Services Date(s) October 2012 through May 2013

Site Name City of Davis Well No. 20 and East Area Tank & Booster Pump Station

Location Shasta Drive & Arlington Blvd. or Mace Blvd. and 2nd St. Davis, CA 95616

Site Contact Dianna Jensen

Site Telephone (530) 757-5639

Site Activities

- ☐ Onsite Inspection or Construction-Related Services
- ☐ Entry into a Confined Space or Excavation[1]
- ☐ Work on an Unprotected Platform
- ☐ Work from a Mobile Elevated Work Platform
- ☐ Entry into an Excavation or Trench with a Depth of 5' or Greater (4' in Oregon and Washington)
- ☒ Field Investigation Requiring
  - ☐ a. Entry into (potentially) hazardous area
  - ☐ b. Interruption of vehicular traffic
  - ☐ c. Interruption of plant processes
  - ☒ d. Operation of pilot plant
- ☐ Chemical Use[2]
- ☐ Other - *specify*

[1] Completion of K/J Confined Space Pre-entry Checklist and Entry Authorization is required or review of Client's Confined Space Procedures.

[2] A Field Chemical Use Plan must be completed.

Section 1: Site Activity Description

Provide additional detail of site activity (attach additional sheets if necessary).

Pilot study including inspection of pilot construction, sampling, and maintenance of pilot plant.

Section 2: Site Description/Hazards

Describe physical site features (attach additional sheets if necessary).

Normal operations of the well site are expected to take place. The pilot will be conducted during the winter months, so adverse weather conditions may occur. The pilot includes fluidized bed reactor with chemical feeds for acetic acid and phosphoric acid.

Acetic Acid (99% concentration food grade) will use about 2.5 liters over the course of the 16 week pilot plant operation. The acetic acid will be diluted from a 99% solution to about 5% to 10% to work within the chemical metering feed pump output range. **CAUTION - Acid will always be poured into the water filled day tank to prevent a reaction.**

Phosphoric Acid (75% concentration) will use about 5 liters over the course of the 16 week pilot plant operation. The acetic acid will be diluted from a 75% solution to about 5% to 10% to work within the chemical metering feed pump output range. **CAUTION - Acid will always be poured into the water filled day tank to prevent a reaction.**

Sodium hydroxide (liquid 25% concentration), a base, will use about 1 liter over the course of the 16 week pilot plant operation, if needed. It will be diluted from a 25% solution to a 5% to 10% to work within the chemical metering feed pump output range.

Sodium hypochlorite (10% to 18% solution) will use between 10 ml to 50 ml to run a bench scale jar / filtration test. The City of Davis will provide this amount of chemical from their on site source.

Sulfuric Acid (99% solution) will be used on an as-needed basis for pH adjustment. Kennedy/Jenks will provide this chemical.

Sodium Selenate (solid) will use 1 gram. Kennedy/Jenks will provide this chemical.

Section 3: Sampling Investigations

Describe samples to be taken and sample source.

Samples will be taken at the influent (raw well water) and effluent of the pilot plant. Samples will be sent to a contracting laboratory for analysis. On site sampling will include temperature, pH, dissolved oxygen, oxidation reduction potential, nitrate, and phosphate using a HACH 890 spectrometer, test strips, and other testing equipment.

Section 4: Hazard Assessment

Every job must be assessed for potential hazards which may cause an injury or an accident. The preferred method of assessing a job for hazards is to break down each job into smaller tasks. Each task may then be scrutinized by performing a Job Hazard Analysis (JHA).

While a documented JHA is not required, the K/J Job Hazard Analysis Form provides examples to assist employees in performing their own JHA. The JHA process is intended to provide a brief, consistent means of identifying and addressing hazards which may injure employees.

Identify source and/or chemical(s) to be considered in a JHA.

☐ Fire/explosion	
☐ Dust	
☒ Mist/fume/vapor	Fumes from phosphoric acid, acetic acid, and sulfuric acid
☐ Oxygen deficiency	
☐ Oxygen enrichment	
☐ Gases	
☒ Acid	Chemical feeds of phosphoric acid, acetic acid, and sulfuric acid
☐ Base	
☐ Biohazard	
☒ Cold	Project conducted during winter months.
☐ Heat	
☐ Petroleum hydrocarbons	
☐ Metals and metal oxides	
☐ Solvents	
☐ Noise (dB)	
☐ Caving earth	
☐ Falling from heights	
☐ Falling objects	
☐ Electrical circuits	
☐ Lifting heavy objects	
☐ Remote-controlled machinery	
☐ Operating machinery	
☐ Vehicular equip./traffic	

☐ Tripping hazard
☐ Heavy equipment
☐ Vessels/pipes under pressure
☐ Welding/fab. equipment
☒ Other — Chemical feed of sodium hydroxide and sulfuric acid may be used for pH control of the water, 1 gram of sodium selenate for selenium removal test, and 10 ml to 50 ml of sodium hypochlorite will be used for a filtration test.

Section 5: Chemical Characteristics

Describe chemicals (attach additional sheets if necessary) or attach Material Safety Data Sheets.

Chemical

Acetic Acid; Phosphoric Acid, Sodium Hydroxide, Sodium Hypochlorite, Sulfuric Acid, and Sodium Selenate

See attached MSDS sheets for more complete information on Acetic Acid, Phosphoric Acid, Sodium Hydroxide, Sulfuric Acid, and Sodium Selenate. The City of Davis will be supplying the sodium hypochlorite and we will obtain an MSDS sheet from them.

Physical/Chemical Characteristics

Acetic acid, phosphoric acid, sodium hydroxide, sulfuric acid, sodium hypochlorite, & sodium selenate

Regulatory Standards

No RMPP required

Exposure Routes

Inhalation and contact with skin and eyes.

Symptoms

Burning/itching sensation upon inhalation or skin contact. Burning, itching, watering upon eye contact.

Section 6: Potential Hazard Mitigation

Describe action(s) to mitigate potential hazards (attach additional sheets if necessary).

Avoid inhalation and contact with skin and eyes. Wear gloves approved for potential contact with acids and bases. Wear eye protection. Wear clothing protection to minimize potential for damage if acid splashes, including closed toe rubber soled shoes. Refill supply bottles outdoors in well-ventilated area and be prepared to acquire respirator if needed. Should respirator be needed, training is required. Contact RSR for training requirements.

6.1 Personal Protective Equipment (PPE)

- ☒ Eyes/face/glasses/shield
- ☒ Gloves: ☐ *Work* ☐ *Neoprene* ☒ *Rubber* ☐ *Other*
- ☐ Suits: ☐ *Cotton* ☐ *Tyvek* ☐ *Nylon* ☐ *Other*
- ☐ Hard hat
- ☐ Ear muffs/plugs
- ☐ Boots (*type:specify*)
- ☒ Respirator (*cartridge type: specify*)
- ☒ First aid kit
- ☒ Eyewash/shower
- ☐ Spill kit
- ☐ Fire extinguisher
- ☐ Air horn
- ☐ Life jackets
- ☐ Camera/video
- ☐ Safety belt/harness/tripod
- ☒ Cell Phone
- ☐ Lockout tags and locks
- ☐ Ventilator/fan
- ☐ Volt/ampere meter
- ☐ Combust. gas, oxygen deficiency meter *(calib.: specify)*
- ☐ OVA *(calibration date: specify)*
- ☐ OVM *(calibration date: specify)*
- ☐ Hydrogen sulfide meter *(calibration date: specify)*
- ☐ Draeger detection tubes
- ☐ Soil sampling kit
- ☐ pH meter/paper
- ☐ Conductivity/temperature meter
- ☐ Metal detector
- ☐ Air sampling equipment
- ☐ Peristaltic pump (tank sampling)
- ☐ Lights *(type: specify)*
- ☐ Other: specify

6.2 Hygiene/Comfort Facilities Required

	Yes	No	Location
Shower	☐	☒	
Washing	☐	☒	
Drinking Water	☐	☒	Use bottled water at well site
Eating Area	☐	☒	Eat near park or local restaurants
Restrooms	☒	☐	Use nearby park restroom

Section 7: Emergency/Team Contacts & Approvals

Emergency Telephone Numbers

	Name	Phone
Site Contact	Gary Wells	W:(530) 757-5686 C:(530)68108993
WorkCare (Non-Critical Injuries)	WorkCare	(888) 449-7787
Fire Department[1]	9-1-1	
Hospital: *****	Sutter Davis Hospital	(530) 756-6440
Directions to hospital[2]: *****	Attached	
Ambulance	Sutter Davis Hospital	(530) 756-6440
Police	Davis Police Dept.	(530) 747-5400
Kennedy/Jenks Consultants:		
Project Manager	Tim Williams	(916) 858-2722
Regional Safety Representative (RSR)	Katie McCoy	(916) 858-2767
Site Safety Officer (SSO)	*****	
Corporate Health & Safety Manager	Bert Drews	(415) 243-2526

[1] The local fire department prefers the public use 911 to assure the proper assistance in case of accident or injury.
[2] Attach written directions and map showing route to hospital.

Project Team Members Participating in Field Activities

Name	Affiliation	Responsibility	Signature
Tim Williams	Kennedy/Jenks	Project Manger, Technical Advisor	
Sean Maguire	Kennedy/Jenks	Field Personnel	
Sarah Laybourne	Kennedy/Jenks	Field Personnel	
Steve Grilley	Kennedy/Jenks	Field Personnel	

Approvals

	Name	Signature/Date
Project Manager	Tim Williams	
Regional Safety Representative (RSR)	Katie McCoy	Kathryn M McCoy

CC: Project File
Office Representative

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Appendix A: Support Documents

A.1 Material Safety Data Sheets

A.2 Maps to Hospital

COMPANY IDENTITY: Univar USA Inc.
PRODUCT IDENTITY: SULFURIC ACID 77 - 100%

DATE: 07/29/11

SAFETY DATA SHEET

This Safety Data Sheet conforms to ANSI Z400.5, and to the format requirements and the International Chemical Safety Cards of the Global Harmonizing System.
THIS SDS COMPLIES WITH 29 CFR 1910.1200 (HAZARD COMMUNICATION STANDARD)
IMPORTANT: Read this SDS before handling & disposing of this product.
Pass this information on to employees, customers, & users of this product.

SECTION 1. IDENTIFICATION OF THE SUBSTANCE OR MIXTURE AND OF THE SUPPLIER

PRODUCT IDENTITY: SULFURIC ACID 77 - 100%
SDS NUMBER: CDS1741
NEW MSDS DATE: 07/29/2011
COMPANY IDENTITY: Univar USA Inc.
COMPANY ADDRESS: 17425 NE Union Hill Road
COMPANY CITY: Redmond, WA 98052
COMPANY PHONE: 1-425-889-3400
EMERGENCY PHONES: CHEMTREC: 1-800-424-9300 (USA)
CANUTEC: 1-613-996-6666 (CANADA)

SECTION 2. HAZARDS IDENTIFICATION

DANGER!!

EXPOSURE PREVENTION: AVOID ALL CONTACT!
PREVENT DISPERSION OF MISTS OR DUST!

RISK STATEMENTS:
R35 Causes severe burns.

SAFETY STATEMENTS:
S1/2 Keep locked up and out of the reach of children.
S24/25 Avoid contact with skin and eyes.
S26 In case of contact with eyes, rinse immediately with plenty of water and seek medical advice.
S30 Never add water to this product.
S45 In case of accident, or if you feel unwell, seek medical advice immediately. (Show the label where possible).

SECTION 3. COMPOSITION/INFORMATION ON INGREDIENTS

MATERIAL	CAS#	EINECS#	WT %
Sulfuric Acid*	7664-93-9	231-639-5	85-95
Water	7732-18-5	231-791-2	5-15

SEE SECTIONS 8, 11 & 12 FOR TOXICOLOGICAL INFORMATION.

SECTION 4. FIRST AID MEASURES

EYE CONTACT:
If this product enters the eyes, open eyes while under gently running water. Use sufficient force to open eyelids. "Roll" eyes to expose more surface. Minimum flushing is for 15 minutes. Seek immediate medical attention.

SKIN CONTACT:
If the product contaminates the skin, immediately begin decontamination with running water. Minimum flushing is for 15 minutes. Remove contaminated clothing, taking care not to contaminate eyes. If skin becomes irritated and irritation persists, medical attention may be necessary. Wash contaminated clothing before reuse, discard contaminated shoes.

INHALATION:
If mists or sprays of this product are inhaled, remove to fresh air. If necessary, use artificial respiration to support vital functions. Seek immediately medical attention.

SWALLOWING:
If swallowed, CALL PHYSICIAN OR POISON CONTROL CENTER FOR MOST CURRENT INFORMATION. If professional advice is not available, give water to drink and seek medical attention. Do NOT give liquids to someone who is unconscious, having convulsions, or unable to swallow.

Victims of chemical exposure must be taken for medical attention. Rescuers should be taken for medical attention, if necessary. Take a copy of label and SDS to physician or health professional with victim.

SECTION 5. FIRE FIGHTING MEASURES

FIRE & EXPLOSION PREVENTIVE MEASURES
Not Applicable.

EXTINGUISHING MEDIA
Expect violent reaction with water. For small fires use dry chemical, carbon dioxide or halon. For large fires, flood fire area with water from a distance. Donot get solid stream of water on spilled material.

SPECIAL FIRE FIGHTING PROCEDURES
Water spray may be ineffective on fire but can protect fire-fighters
& cool closed containers. Use fog nozzles if water is used.
Do not enter confined fire-space without full bunker gear.
(Helmet with face shield, bunker coats, gloves & rubber boots).
Use NIOSH approved positive-pressure self-contained breathing apparatus.

UNUSUAL EXPLOSION AND FIRE PROCEDURES
Noncombustible.
Reacts with most metals producing hydrogen which is extremely flammable & may explode. Applying to hot surfaces requires special precautions. Closed containers may explode if exposed to extreme heat.

SECTION 6. ACCIDENTAL RELEASE MEASURES

SPILL AND LEAK RESPONSE AND ENVIRONMENTAL PRECAUTIONS:
Uncontrolled releases should be responded to by trained personnel using pre-planned procedures. Proper protective equipment should be used. In case of a spill, clear the affected area, protect people, and respond with trained personnel.

PERSONAL PROTECTIVE EQUIPMENT
The proper personal protective equipment for incidental releases (such as: 1 Liter of the product released in a well-ventilated area), use impermeable gloves (triple-gloves (rubber gloves and nitrile gloves, over latex gloves), goggles, face shield, and appropriate body protection. In the event of a large release, use impermeable gloves, specific for the material handled, chemically resistant suit and boots, and hard hat. Self-Contained Breathing Apparatus or respirator may be required where engineering controls are not adequate or conditions for potential exposure exist. When respirators are required, select NIOSH/MSHA approved based on actual or potential airborne concentrations in accordance with latest OSHA and/or ANSI recommendations.

ENVIRONMENTAL PRECAUTIONS:
Stop spill at source. Construct temporary dikes of dirt, sand, or any appropriate readily available material to prevent spreading of the material. Close or cap valves and/or block or plug hole in leaking container and transfer to another container. Keep from entering storm sewers and ditches which lead to waterways, and if necessary, call the local fire or police department for immediate emergency assistance.

CONTAINMENT AND CLEAN-UP MEASURES:
Absorb spilled liquid with polypads or other suitable absorbent materials. If necessary, neutralize using suitable buffering material, (acid with soda ash or base with phosphoric acid), and test area with litmus paper to confirm neutralization. Clean up with non-combustible absorbent (such as: sand, soil, and so on). Shovel up and place all spill residue in suitable containers. dispose of at an appropriate waste disposal facility according to current applicable laws and regulations and product characteristics at time of disposal (see Section 13 - Disposal Considerations).

SECTION 7. HANDLING AND STORAGE

HANDLING
Use only with adequate ventilation. Do not get in eyes, on skin or clothing.
Wear OSHA Standard full face shield. Consult Safety Equipment Supplier. Wear gloves, apron & footwear impervious to this material. Wash clothing before reuse.
NEVER pour water into this substance. When dissolving or diluting, always add it slowly to the water.
To minimize static discharge when transferring, ensure electrical continuity by bonding and grounding all equipment. Use an inlet line diameter of at least 3.5 inches (8.9 centimeters) with a maximum flow rate of 1 meter/second.

STORAGE
Keep separated from strong oxidants, strong bases, combustible & reducing substances, metals, food & feedstuffs, incompatible materials.
May be stored in stainless steel containers.
See: Section 10, <Materials to Avoid>. Do not store above 49 C/120 F.
Keep container tightly closed & upright when not in use to prevent leakage.
Reacts with most metals producing hydrogen which is extremely flammable & may explode.
Wear full face shield, gloves & full protective clothing when opening or handling.
When empty, drain completely, replace bungs securely.

NONBULK: CONTAINERS:
Store containers in a cool, dry location, away from direct sunlight, sources of intense heat, or where freezing is possible. Material should be stored in secondary containers or in a diked area, as appropriate. Store containers away from incompatible chemicals (see Section 10, Stability and Reactivity). Post warning and "NO SMOKING" signs in storage and use areas, as appropriate. Empty containers should be handled with care. Never store food, feed, or drinking water in containers which held this product.

COMPANY IDENTITY: Univar USA Inc.
PRODUCT IDENTITY: SULFURIC ACID 77 - 100%

SECTION 7. HANDLING AND STORAGE (CONTINUED)

BULK CONTAINERS:
All tanks and pipelines which contain this material must be labeled. Perform routine maintenance on tanks or pipelines which contain this product. Report all leaks immediately to the proper personnel.

TANK CAR SHIPMENTS:
Tank cars carrying this product should be loaded and unloaded in strict accordance with tank-car manufacturer's recommendation and all established on-site safety procedures. Appropriate personal protective equipment must be used (see Section 8, Engineering Controls and Personal Protective Equipment.). All loading and unloading equipment must be inspected, prior to each use. Loading and unloading operations must be attended, at all times. Tank cares must be level, brakes must be set or wheels must be locked or blocked prior to loading or unloading. Tank car (for loading) or storage tanks (for unloading) must be verified to be correct for receiving this product and be properly prepared, prior to starting the transfer operations. Hoses must be verified to be in the correct positions, before starting transfer operations. A sample (if required) must be taken and verified (if required) prior to starting transfer operations. All lines must be blown-down and purged before disconnecting them from the tank car or vessel.

PROTECTIVE PRACTICES DURING MAINTENANCE OF CONTAMINATED EQUIPMENT:
Follow practices indicated in Section 6 (Accidental Release Measures). Make certain application equipment is locked and tagged-out safely. Always use this product in areas where adequate ventilation is provided. Collect all rinsates and dispose of according to applicable Federal, State, or local procedures.

SECTION 8. EXPOSURE CONTROLS/PERSONAL PROTECTION

MATERIAL	CAS#	EINECS#	TWA (OSHA)	TLV (ACGIH)
Sulfuric Acid*	7664-93-9	231-639-5	None Known	None Known
Water	7732-18-5	231-791-2	None Known	None Known

This product contains no EPA Hazardous Air Pollutants (HAP) in amounts > 0.1%.

RESPIRATORY EXPOSURE CONTROLS
Maintain airborne contaminant concentrations below exposure limits given above. If respiratory protection is needed, use only protection authorized in 29 CFR 1910.134, European Standard EN 149, or applicable State regulations. If adequate ventilation is not available or there is potential for airborne exposure above the exposure limits, a respirator may be worn up to the respirator exposure limitations, check with respirator equipment manufacturer's recommendations/limitations. For a higher level of protection, use positive pressure supplied air respiration protection or Self Contained Breathing Apparatus or if oxygen levels are below 19.5% or are unknown.

EMERGENCY OR PLANNED ENTRY INTO UNKNOWN CONCENTRATIONS OR IDLH CONDITIONS
Positive pressure, full-face piece Self Contained Breathing Apparatus; or positive pressure, full-face piece Salf Contained Breathing Apparatus with an auxilliary positive pressure Self Contained Breathing Apparatus.

VENTILATION

LOCAL EXHAUST:	Necessary	MECHANICAL (GENERAL):	Necessary
SPECIAL:	None	OTHER:	None

Please refer to ACGIH document, "Industrial Ventilation, A Manual of Recommended Practices", most recent edition, for details.

EYE PROTECTION:
Splash goggles or safety glasses. Face-shields are recommended when the operation can generate splashes, sprays or mists.

SECTION 8. EXPOSURE CONTROLS/PERSONAL PROTECTION (CONTINUED)

HAND PROTECTION:
Wear appropriate impervious gloves for routine industrial use. Use impervious gloves for spill response, as stated in Section 6 of this SDS (Accidental Release Measures).
NOTICE: The selection of a specific glove for a particular application and duration of use in a workplace should also take into account all relevant workplace factors such as, but not limited to: Other chemicals which may be handled, physical requirements (cut/puncture protection, dexterity, thermal protection), potential body reactions to glove materials, as well as the instructions/specifications provided by the glove supplier.

BODY PROTECTION:
Use body protection appropriate for task. Cover-all, rubber aprons, or chemical protective clothing made from impervious materials are generally acceptable, depending on the task.

WORK & HYGIENIC PRACTICES:
Provide readily accessible eye wash stations & safety showers. Wash after each workshift & before eating, smoking or using the toilet. Promptly remove contaminated clothing. Destroy contaminated leather articles. Launder or discard contaminated clothing.

SECTION 9. PHYSICAL & CHEMICAL PROPERTIES

APPEARANCE:	Oily Liquid, Water-White
ODOR:	None
ODOR THRESHOLD:	Not Available
pH (Neutrality):	0.0
MELTING POINT/FREEZING POINT:	-11 to -29 C / +12 to -20 F
BOILING RANGE (IBP,50%,Dry Point):	193 to 276 C / 380 to 529 F
FLASH POINT (TEST METHOD):	Not Applicable
EVAPORATION RATE (n-BUTYL ACETATE=1):	Not Applicable
FLAMMABILITY CLASSIFICATION:	Non-Combustible
LOWER FLAMMABLE LIMIT IN AIR (% by vol):	Not Applicable
UPPER FLAMMABLE LIMIT IN AIR (% by vol):	Not Available
VAPOR PRESSURE (mm of Hg)@20 C	17.5
VAPOR DENSITY (air=1):	Not Applicable
GRAVITY @ 68/68F / 20/20C:	
SPECIFIC GRAVITY (Water=1):	1.70 to 1.84
POUNDS/GALLON:	14.2 to 15.3
WATER SOLUBILITY:	Complete
PARTITION COEFFICIENT (n-Octane/Water):	Not Available
AUTO IGNITION TEMPERATURE:	Not Applicable
DECOMPOSITION TEMPERATURE:	Not Available

SECTION 10. STABILITY & REACTIVITY

STABILITY
Stable but Reacts with most metals producing hydrogen which is extremely flammable & may explode.

CONDITIONS TO AVOID
Avoid alkalis. When diluting, always add acid to diluent. DON'T add diluent to acid.

MATERIALS TO AVOID
The substance is a strong acid, reacts violently with bases and is corrosive. Upon heating, irritating and toxic fumes are formed including sulfur oxides, The substance is a strong oxidant & reacts violently with combustible & reducing materials. Corrosive to most common metals forming flammable/explosive gas (hydrogen).
Sulfuric acid reacts violently with water & organic materials with much heat. Isolate from organics, chlorates, carbides, fulminates, picrates, metals. Fire risk on contact with organic materials and chemicals such as nitrates, carbides, and chlorates.

HAZARDOUS DECOMPOSITION PRODUCTS
Sulfur Oxides.

HAZARDOUS POLYMERIZATION
Will not occur.

SECTION 11. TOXICOLOGICAL INFORMATION

ACUTE HAZARDS

EYE & SKIN CONTACT:
Severe burns to skin, defatting, dermatitis.
Severe burns to eyes, redness, tearing, blurred vision.
Liquid can cause severe skin & eye burns. Wash thoroughly after handling.

INHALATION:
Severe respiratory tract irritation may occur. Vapor harmful.

SWALLOWING:
Harmful or fatal if swallowed.

SUBCHRONIC HAZARDS/CONDITIONS AGGRAVATED

CONDITIONS AGGREVATED:
Persons with skin conditions should avoid use.

CHRONIC HAZARDS

CANCER, REPRODUCTIVE & OTHER CHRONIC HAZARDS:
This product has no carcinogens listed by IARC, NTP, NIOSH, OSHA or ACGIH, as of this date, greater or equal to 0.1%.

IRRITANCY OF PRODUCT: This product is irritating to contaminated tissue.

SENSITIZATION TO THE PRODUCT: No component of this product is known to be a sensitizer.

MUTAGENICITY: This product is not reported to produce mutagenic effects in humans.

EMBRYOTOXICITY: This product is not reported to produce embryotoxic effects in humans.

TERATOGENICITY: This product is not reported to produce teratogenic effects in humans.

REPRODUCTIVE TOXICITY: This product is not reported to cause reproductive effects in humans.

A mutagen is a chemical which causes permanent changes to genetic material (DNA) such that the changes will propagate through generational lines. An embryotoxin is a chemical which causes damage to a developing embryo (such as: within the eight weeks of pregnancy in humans), but the damage does not propagate across generational lines. A teratogen is a chemical which causes damage to a developing fetus, but the damage does not propagate across generational lines. A reproductive toxin is any substance which interferes in any way with the reproductive process.

MAMMALIAN TOXICITY INFORMATION

Oral LD50 (Rats):	2140 mg/kg
Dermal LD50 (Rabbit):	Not Available
LC50 (Inhalation, Rats):	510 mg/m3 (4 hour exposure)
Skin effects (Rabbit):	Severe irritation
Eye effects (Rabbit):	Severe irritation
LD (adult human):	between 5 ml and 15 ml (concentrated sulfuric acid)

SECTION 12. ECOLOGICAL INFORMATION

AQUATIC ANIMAL INFORMATION:
No aquatic environmental information is available on this product.
The substance is harmful to aquatic organisms.

MOBILITY IN SOIL
Mobility of this material has not been determined.

DEGRADABILITY
This product is completely biodegradable.

ACCUMULATION
Bioaccumulation of this product has not been determined.

SECTION 13. DISPOSAL CONSIDERATIONS

Processing, use or contamination may change the waste management options. Recycle / dispose of observing national, regional, state, provincial and local health, safety & pollution laws. If in doubt, contact appropriate agencies.

SECTION 14. TRANSPORT INFORMATION

DOT SHIPPING NAME: UN1830, Sulfuric acid, 8, PG-II
DRUM LABEL: (CORROSIVE)
IATA / ICAO: UN1830, Sulfuric acid, 8, PG-II
IMO / IMDG: UN1830, Sulfuric acid, 8, PG-II
EMERGENCY RESPONSE GUIDEBOOK NUMBER: 137

SECTION 15. REGULATORY INFORMATION

EPA REGULATION:
SARA SECTION 311/312 HAZARDS: Acute Health

All components of this product are on the TSCA list.
SARA Title III Section 313 Supplier Notification
This product contains the indicated <*> toxic chemicals subject to the reporting requirements of Section 313 of the Emergency Planning & Community Right-To-Know Act of 1986 & of 40 CFR 372. This information must be included in all MSDSs that are copied and distributed for this material.

SARA TITLE III INGREDIENTS	CAS#	EINECS#	WT%	(REG.SECTION)	RQ(LBS)
Sulfuric Acid	7664-93-9	231-639-5	85-95	(302,311,312,313)	1000

SECTION 15. REGULATORY INFORMATION (CONTINUED)

> 1099 LB / 499 KG OF THIS PRODUCT IN 1 CONTAINER EXCEEDS THE "RQ" OF SULFURIC ACID.

Any release equal to or exceeding the RQ must be reported to the National Response Center (800-424-8802) and appropriate state and local regulatory agencies as described in 40 CFR 302.6 and 40 CFR 355.40 respectively. Failure to report may result in substantial civil and criminal penalties. State & local regulations may be more restrictive than federal regulations.

SARA Title III Section 302 (Extremely Hazardous Substance List) : Sulfuric Acid.

STATE REGULATIONS:

CALIFORNIA PROPOSITION 65: This product contains no chemicals known to the State of California to cause cancer & reproductive toxicity.

INTERNATIONAL REGULATIONS

The components of this product are listed on the chemical inventories of the following countries:

Australia (AICS), Canada (DSL, NDSL), China (IECSC), Europe (EINECS, ELINCS), Japan (METI/CSCL, MHLW/ISHL), South Korea (KECI), New Zealand (NZIoC), Philippines (PICCS), Switzerland (SWISS), Taiwan (NECSI), USA (TSCA).

CANADA: WORKPLACE HAZARDOUS MATERIALS INFORMATION SYSTEM (WHMIS)

D2B: Irritating to skin / eyes.

E: Corrosive Material.

SECTION 16. OTHER INFORMATION

HAZARD RATINGS:

HEALTH (NFPA): 3, HEALTH (HMIS): 3, FLAMMABILITY: 0, REACTIVITY: 2

(Personal Protection Rating to be supplied by user based on use conditions.) This information is intended solely for the use of individuals trained in the NFPA & HMIS hazard rating systems.

EMPLOYEE TRAINING

See Section 2 for Risk & Safety Statements. Employees should be made aware of all hazards of this material (as stated in this SDS) before handling it.

Univar USA Inc Material Safety Data Sheet

For Additional Information contact MSDS Coordinator during business hours, Pacific time: (425) 889-3400

Notice

Univar USA Inc. ("Univar") expressly disclaims all express or implied warranties of merchantability and fitness for a particular purpose, with respect to the product or information provided herein, and shall under no circumstances be liable for incidental or consequential damages.

Do not use ingredient information and/or ingredient percentages in this MSDS as a product specification. For product specification information refer to a product specification sheet and/or a certificate of analysis. These can be obtained from your local Univar sales office.

All information appearing herein is based upon data obtained from the manufacturer and/or recognized technical sources. While the information is believed to be accurate, Univar makes no representations as to its accuracy or sufficiency. Conditions of use are beyond Univar's control and therefore users are responsible to verify this data under their own operating conditions to determine whether the product is suitable for their particular purposes and they assume all risks of their use, handling, and disposal of the product, or from the publication or use of, or reliance upon, information contained herein.

This information relates only to the product designated herein, and does not relate to its use in combination with any other material or in any other process

MATERIAL SAFETY DATA SHEET

NFPA 704 DESIGNATION
HAZARD RATING

4=Extreme
3=High
2=Moderate
1=Slight
0=Insignificant

Health: 3 | Fire: 0 | Reactivity: 1 | Special: ---

LA CHEMICAL SINCE 1972

MSDS Revision/Issue Date:	8/09/02
Supercedes Revision Date:	04/14/98

1. CHEMICAL PRODUCT IDENTIFICATION & COMPANY IDENTIFICATION

PRODUCT IDENTIFIER: **CAUSTIC SODA LIQUID 50%, (All Grades)**

GENERAL USE: Used in industry to neutralize acids; to precipitate alkaloids; in metal finishing; in cleaners; and to precipitate most metals (as hydroxides) from aqueous solutions.

PRODUCT DESCRIPTION: An aqueous solution of Sodium Hydroxide. Synonyms for Sodium Hydroxide include: caustic soda, lye soda, sodium hydrate and white caustic.

INFORMATION PROVIDED BY: L.A. CHEMICAL CO.
CORPORATE OFFICE
4545 ARDINE STREET
SOUTH GATE, CA 90280
For MSDS call: PHONE: 323-832-5000

EMERGENCY PHONE NUMBERS

L.A. CHEMICAL CO.: 323-832-5000
CHEMTREC: 800-424-9300

2. COMPOSITION & INFORMATION ON INGREDIENTS

				ACGIH		OSHA	
COMPONENT	CAS #	OSHA HAZARD	WT %	$TLV_{(TWA)}$	STEL	$PEL_{(TWA)}$	STEL
Sodium Hydroxide	001310-73-2	Corrosive; Lung Toxin	50 ± 1	None Ceiling: 2 mg/m^3	None	2 mg/m^3	None

NDA = No Data Available N/A = Not Applicable

3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW: A clear to slightly turbid, colorless liquid having no characteristic odor. Mists and liquid are corrosive to all tissues contacted. Inhalation of mists may cause permanent lung damage. This material reacts with water to release a large amount of heat and can react violently with acids and other substances. **The NIOSH I.D.L.H. for Sodium Hydroxide is: 10 mg/m^3.**

POTENTIAL HEALTH EFFECTS

INHALATION: Inhalation of mists or an aerosol can cause severe irritation or burns to the nose, mouth, throat, mucous membranes and lungs. Symptoms of exposure can include coughing, sneezing, choking, shortness of breath, chest pain and impairment of lung function. Inhalation of a high concentration may result in permanent lung damage.

EYE CONTACT: Exposure to mists or liquid can cause severe eye irritation and/or burns. Symptoms of exposure can include tearing redness, swelling and pain. Exposure may cause corneal damage and/or visual impairment even when prompt treatment is provided.

SKIN CONTACT: Exposure to mists or liquid can cause severe skin irritation and/or burns. Symptoms of exposure may include redness, swelling, pain and possible ulceration. Prolonged skin exposure to this material may cause destruction of the dermis with impairment of the skin, at site of contact, to regenerate. No published data indicates this material is absorbed through the skin.

INGESTION: Ingestion can cause severe irritation and/or burns to the entire gastrointestinal tract, including the stomach and intestines characterized by nausea, vomiting, abdominal pain, bleeding, tissue ulceration and possible diarrhea.

CHRONIC: The chronic health effects of exposure to this material are expected to be the same as for acute exposure.

4. FIRST AID MEASURES

INHALATION: If inhaled, immediately move to fresh air. If not breathing, give artificial respiration. Do not use mouth-to-mouth method if victim ingested or inhaled the substance; use the Holger Nielsen method (back pressure-arm lift) or proper respiratory device. If breathing is difficult, give oxygen. Call a physician.

EYE CONTACT: In case of contact, immediately flush eyes with plenty of clean running water for at least 15 minutes, lifting the upper and lower lids occasionally. Remove contact lenses, if worn. Get medical attention immediately.

SKIN CONTACT: In case of contact, immediately flush skin with plenty of clean running water for at least 15 minutes, while removing contaminated clothing and shoes. If burn or irritation occurs, call a physician.

INGESTION: If swallowed, DO NOT induce vomiting. Get medical attention immediately. If victim is fully conscious, give plenty of water to drink. Never give anything by mouth to an unconscious person.

NOTE TO PHYSICIANS: Sodium Hydroxide has a low oral toxicity, but it can be corrosive to the eyes, skin and mucous membranes. Consideration should be given to careful endoscopy as stomach or esophageal burns, perforations or strictures may occur. Careful gastric lavage with an endotracheal tube in place should be considered. Treat exposure symptomatically.

5. FIRE FIGHTING MEASURES

Flashpoint and Method: Does not flash.

Flammable Limits (in air, % by volume) **Lower:** Not applicable **Upper:** Not applicable

Autoignition Temperature: Not applicable

GENERAL HAZARD: The Uniform Fire Code physical hazard classification for this material is: **Water Reactive, Class I.** Direct contact with water causes an exothermic reaction (generation of heat). The Uniform Fire Code health hazard classification for this material is: **Corrosive (Alkaline).** This material may generate flammable / explosive Hydrogen gas on contact with some soft metals. This material may produce hazardous decomposition products.

FIRE FIGHTING INSTRUCTIONS: **EXTINGUISHING MEDIA:** Foam, CO_2 or dry chemicals.
If water must be used and it can contact this material, it is best to use a water flood technique.

FIRE FIGHTING EQUIPMENT: Fire fighters should wear full protective equipment, including self-contained breathing apparatus.

HAZARDOUS COMBUSTION PRODUCTS: When heated to dryness and decomposition, it emits toxic sodium oxide.

6. ACCIDENTAL RELEASE MEASURES

LAND SPILL: Wearing recommended protective equipment and clothing, dike the spill and pick up the bulk of liquid using pumps or a vacuum truck, or absorb the liquid in sand or a commercial absorbent. Place in approved containers for recovery, disposal, or satellite accumulation. Neutralize the alkalinity, of the remaining liquid, using a dilute acid solution appropriate for neutralizing alkaline liquids. Liberally cover the spill area with sodium bicarbonate. Flush the spill area with water; collect the rinsates for disposal or sewer, as appropriate.

WATER SPILL: Wear recommended protective equipment and clothing if contact with hazardous material can occur. Stop or divert water flow. Dike contaminated water and remove for disposal and/or treatment. As appropriate, notify all downstream users of possible contamination.

7. HANDLING AND STORAGE

STORAGE TEMPERATURE: Ambient **STORAGE PRESSURE:** Ambient

GENERAL: Store in a cool, dry area away from incompatible materials and products. Do not breathe mists or aerosols. Use only with adequate ventilation. Do not get this material in eyes, on skin or on clothing. Wear recommended personnel protective equipment. Do not take internally. Keep the container tightly closed when not in use. Wash thoroughly after handling. This material is corrosive to aluminum, magnesium, tin, zinc and alloys containing these metals, and it will react violently with these metals in powder form.

Considerable heat is generated when this material is mixed with water. Never add water to this material. Always add this material slowly, with constant stirring, to the surface of cool to lukewarm (40 – 90 °F) water. If this material is added too rapidly, or without stirring, and becomes concentrated at the bottom of the mixing vessel, excessive heat may be generated, resulting in dangerous boiling and spattering, and a possible immediate and violent eruption of a highly caustic solution.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

CONTROL MEASURES: Use a local or general mechanical exhaust ventilation system capable of maintaining emissions in the work area below the OSHA-PEL or ACGIH Ceiling level.

RECOMMENDED PERSONAL PROTECTIVE EQUIPMENT

RESPIRATOR: For exposures above the OSHA-PEL or ACGIH Ceiling level, wear a NIOSH approved full facepiece or half mask air-purifying cartridge respirator equipped with a good particulate / mist cartridge or supplied air.

EYES: Wear chemical goggles (recommended by ANSI Z87.1-1979), unless a full facepiece respirator is worn.

GLOVES: Neoprene, nitrile or rubber gloves.

CLOTHING & EQUIPMENT: Wear a neoprene, nitrile or rubber apron, or full protective clothing when handling this material. An eye wash station and safety shower should be available in the work area.

FOOTWEAR: Neoprene, nitrile or rubber boots.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance:	Clear to slightly turbid, colorless	Bulk Density (pounds/ft^3):	Not applicable
Physical State:	Liquid	Vapor Pressure:	13 mm Hg @ 60 °F
Odor:	No characteristic	Vapor Density (air=1):	No data available
Odor Threshold:	No data available	Evaporation Rate (n-Butyl Acetate=1):	No data available
Molecular Formula:	NaOH (in water)	VOC Content:	Nil
Molecular Weight:	40.00 (in water)	% Volatile:	49 – 51
Boiling Point:	Approximately 142.2 °C (288 °F)	Solubility in H_2O:	Complete
Freezing/Melting Point:	Approximately 12.2 °C (54 °F)	Octanol/Water Partition Coefficient:	No data available
Specific Gravity:	Approximately 1.525 @ 20 °C	pH (as is):	14.0
Density (pounds/gallon):	Approximately 12.72	pH (1% solution):	13.5 – 14.0

10. STABILITY AND REACTIVITY

GENERAL: This product is stable and hazardous polymerization will not occur.

CONDITIONS TO AVOID: Avoid contact with small amounts of water.

INCOMPATIBLE MATERIAL: Acids or acidic salts, chlorinated or fluorinated hydrocarbons, acetaldehyde, acrolein, aluminum, magnesium, tin, zinc, chlorine trifluoride, hydroquinone, maleic anhydride, phosphorus pentoxide and tetrahydrofuran.

HAZARDOUS DECOMPOSITION PRODUCTS: When heated to decomposition, it emits toxic oxides of sodium.

SENSITIVITY TO MECHANICAL IMPACT: This material is not sensitive to mechanical impact.

SENSITIVITY TO STATIC DISCHARGE: This material is not sensitive to static discharge.

11. TOXICOLOGICAL INFORMATION

Components:	Sodium Hydroxide
Eye Contact:	Rabbit: 50 ug/24 hours; Severe
Skin Contact:	Rabbit: 500 mg/24 hours; Severe
Oral Rat LD_{50}:	No data available
Dermal Rabbit LD_{50}:	1,350 mg/kg
Inhalation Rat LC_{50}:	No data available
Human Data:	No data available
Other Toxicological Data:	Oral Rabbit LDLo: 500 mg/kg
Carcinogenicity:	No data available
Teratogenicity:	No data available
Mutagenicity:	Cytogenetic Analysis – Hamster Lung: 10 mmol/Liter
Synergistic Products:	None Reported
Target Organs:	Eyes, Skin, Mucous Membranes, Lungs
Medical Conditions Aggravated By Exposure:	Skin, Respiratory Disorders

12. ECOLOGICAL INFORMATION

ENVIRONMENTAL FATE:

This material is completely soluble in water and will significantly affect the pH of water. No specific environmental fate information is available.

ENVIRONMENTAL CONSIDERATIONS:

The aquatic toxicity for this material has not been determined.

13. DISPOSAL CONSIDERATIONS

RCRA 40 CFR 261 CLASSIFICATON: Corrosive Waste

U.S. EPA WASTE NUMBER/DESCRIPTION: D002

If this product is disposed of as shipped, it meets the criteria of a hazardous waste as defined under 40 CFR 261 due to its corrosivity. If this product becomes a waste, it will be a hazardous waste, which is subject to the Land Disposal Restrictions under 40 CFR 268 and must be managed accordingly. As a hazardous liquid waste, it must be disposed of in accordance with local, state, and federal regulations in a permitted hazardous waste treatment, storage, and disposal facility.

14. TRANSPORTATION INFORMATION

DOT PROPER SHIPPING NAME: Sodium Hydroxide, Solution

Hazard Class: 8 **UN Number:** UN1824 **Packing Group:** II

Primary Label: Corrosive **Subsidiary Label(s):** None Required

Primary/Subsidiary Placards: Corrosive / None Required

DOT Reportable Quantity (RQ): 1,000 pounds (NaOH) **RQ for Product:** 2,000 pounds (157.2 gallons)

Marine Pollutant: No

DOT 1996 North American Emergency Response Guidebook No.: 154

TDG PROPER SHIPPING NAME: Sodium Hydroxide, Solution

Hazard Class: 8 (9.2) **UN Number:** UN1824 **Packing Group:** II

Primary Label: Corrosive **Subsidiary Label(s):** None Required

Primary/Subsidiary Placards: Corrosive / None Required

TDG Reportable Quantity (RQ): # At least 5 kg or 5 liters

TDG Schedule XII: No

Regulated Limit (RL): ## 50 kg (NaOH) **RL for Product:** 100 kg (65.6 liters)

Other Shipping Information: None

Canadian Transportation of Dangerous Goods Regulations (TDGR), Part IX, Table I, Quantities or levels for Immediate Reporting: releases of reportable quantities, RQ, that meet the definition of a "dangerous occurrence" (a threat to life, health, property, or the environment) must be reported to the appropriate authorities as outlined in TDGR 9.13(1) and 9.14(1).

Reporting to Environment Canada is required for any releases exceeding the regulated limits, RL, of 9.2 materials (primary or secondary). The regulated limits are found in Schedule XII of the TDGR.

15. REGULATORY INFORMATION

COMPONENTS:	**Sodium Hydroxide**
OSHA Target Organs:	Eyes, Skin, Lungs, Mucous Membranes
Carcinogenic Potential:	
Regulated by OSHA:	No
Listed on NTP Report:	No
Listed by IARC:	No
IARC Group:	Not applicable
ACGIH Appendix A:	Not listed
A1 Confirmed Human:	Not applicable
A2 Suspected Human:	Not applicable
U.S. EPA Requirements	
Release Reporting	
CERCLA (40 CFR 302)	
Listed Substance:	Yes
Reportable Quantity:	1,000 pounds
Category:	C
RCRA Waste No.:	Not listed
Unlisted Substance:	Not applicable
Reportable Quantity:	Not applicable
Characteristic:	Not applicable
RCRA Waste No.:	Not applicable
SARA TITLE III	
Section 302 & 303 (40 CFR 355):	
Listed Substance:	No
Reportable Quantity:	Not applicable
Planning Threshold:	Not applicable
Section 311 & 312 (40 CFR 370):	
Hazard Categories (product):	Fire: N Sudden Release of Pressure: N Reactive: N Acute Health: Y Chronic Health: N
Planning threshold:	10,000 pounds
Section 313 (40 CFR 372):	
Listed Toxic Chemical:	No
Reporting Threshold:	Not applicable
U.S. TSCA Status	
Listed (40 CFR 710):	Yes
State Regulations	
State of California: Safe Drinking Water and Toxins Enforcement Act, 1986 (Proposition 65):	
Carcinogen:	No
Reproductive Toxin:	No
Other Regulations	
State Right To Know Laws:	MA, NJ, PA
Canadian Regulations	
Product Information:	
Controlled Product:	Yes
WHMIS Hazard Symbols:	Corrosive Material
WHMIS Class & Division:	E
Ingredient Information:	
IDL Substance:	Yes
Domestic Substance List:	Yes

16. OTHER INFORMATION

EPA Registration number: Not applicable

Approved Product Uses: Not applicable

Special Notes:

NOTE: Deadly carbon monoxide gas can form when this material contacts food soil containing sugars. After cleaning operations are completed, thoroughly ventilate enclosed areas before entering. Always monitor oxygen and carbon monoxide levels when personnel are in enclosed areas. For proper tank entry procedures, see ANSI Z117-1-1977.

MSDS Revision Information: Information Revised This Issue Date: **Revised per the Canadian 3 year update requirement.**

Form Revision made 08/01/00

MSDS Distributed by: L.A. CHEMICAL CO.
Environmental Department
Phone: 323-832-5000 FAX: 323-773-0909

Prepared By:	Jay Hensel	Date Prepared:	08/09/02

PRODUCT: PHOSPHORIC ACID

ORDER NO: 807165
PROD NO : 320150

SIERRA CHEMICAL
788 NORTHPORT DRIVE

W SACRAMENTO,CA 95691 ,

UNIVAR USA INC. (425)889-3400
17425 NE UNION HILL RD , REDMOND , WA 98052

---------------------------- EMERGENCY ASSISTANCE ----------------------------

FOR EMERGENCY ASSISTANCE INVOLVING CHEMICALS CALL - CHEMTREC
(800)424-9300

PRODUCT NAME: PHOSPHORIC ACID

MSDS NUMBER: MZP3973

DATE ISSUED: 2/15/2006

SUPERSEDES: 12/10/2004

ISSUED BY: 008614

==
PHOSPHORIC ACID
==

1. PRODUCT IDENTIFICATION

SYNONYMS: ORTHO-PHOSPHORIC ACID; WHITE PHOSPHORIC ACID
CAS NO: 7664-38-2
MOLECULAR WEIGHT: 98.00
CHEMICAL FORMULA: H3PO4 IN H2O

Distributed by:
Univar USA Inc.
17425 NE Union Hill Road
Redmond, WA 98052

PRODUCT: PHOSPHORIC ACID

ORDER NO: 807165
PROD NO : 320150

425-889-3400

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2. COMPOSITION/INFORMATION ON INGREDIENTS

INGREDIENT	CAS NO	PERCENT	HAZARDOUS
PHOSPHORIC ACID	7664-38-2	55 - 95%	YES
WATER	7732-18-5	5 - 45%	NO

---

3. HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

DANGER! CORROSIVE. CAUSES SEVERE IRRITATION AND BURNS TO EVERY AREA OF CONTACT. HARMFUL IF SWALLOWED OR INHALED.

POTENTIAL HEALTH EFFECTS

INHALATION:
INHALATION IS NOT AN EXPECTED HAZARD UNLESS MISTED OR HEATED TO HIGH TEMPERATURES. MIST OR VAPOR INHALATION CAN CAUSE IRRITATION TO THE NOSE, THROAT, AND UPPER RESPIRATORY TRACT. SEVERE EXPOSURES CAN LEAD TO A CHEMICAL PNEUMONITIS.

INGESTION:
CORROSIVE. MAY CAUSE SORE THROAT, ABDOMINAL PAIN, NAUSEA, AND SEVERE BURNS OF THE MOUTH, THROAT, AND STOMACH. SEVERE EXPOSURES CAN LEAD TO SHOCK, CIRCULATORY COLLAPSE, AND DEATH.

SKIN CONTACT:
CORROSIVE. MAY CAUSE REDNESS, PAIN, AND SEVERE SKIN BURNS.

EYE CONTACT:
CORROSIVE. MAY CAUSE REDNESS, PAIN, BLURRED VISION, EYE BURNS, AND PERMANENT EYE DAMAGE.

CHRONIC EXPOSURE:
NO INFORMATION FOUND.

AGGRAVATION OF PRE-EXISTING CONDITIONS:
PERSONS WITH PRE-EXISTING SKIN DISORDERS OR EYE PROBLEMS, OR IMPAIRED RESPIRATORY FUNCTION MAY BE MORE SUSCEPTIBLE TO THE EFFECTS OF THE SUBSTANCE.

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4. FIRST AID MEASURES

INHALATION:
REMOVE TO FRESH AIR. IF NOT BREATHING, GIVE ARTIFICIAL RESPIRATION. IF BREATHING IS DIFFICULT, GIVE OXYGEN. CALL A PHYSICIAN IMMEDIATELY.

INGESTION:
IF SWALLOWED, DO NOT INDUCE VOMITING. GIVE LARGE QUANTITIES OF WATER. NEVER GIVE ANYTHING BY MOUTH TO AN UNCONSCIOUS PERSON. GET MEDICAL ATTENTION IMMEDIATELY.

SKIN CONTACT:
IMMEDIATELY FLUSH SKIN WITH PLENTY OF WATER FOR AT LEAST 15 MINUTES WHILE REMOVING CONTAMINATED CLOTHING AND SHOES. CALL A PHYSICIAN, IMMEDIATELY. WASH CLOTHING BEFORE REUSE.

EYE CONTACT:
IMMEDIATELY FLUSH EYES WITH GENTLE BUT LARGE STREAM OF WATER FOR AT LEAST 15 MINUTES, LIFTING LOWER AND UPPER EYELIDS OCCASIONALLY. CALL A PHYSICIAN IMMEDIATELY.

5. FIRE FIGHTING MEASURES

FIRE:
NOT CONSIDERED TO BE A FIRE HAZARD. CONTACT WITH MOST METALS CAUSES FORMATION OF FLAMMABLE AND EXPLOSIVE HYDROGEN GAS.

EXPLOSION:
NOT CONSIDERED TO BE AN EXPLOSION HAZARD.

FIRE EXTINGUISHING MEDIA:
USE ANY MEANS SUITABLE FOR EXTINGUISHING SURROUNDING FIRE. WATER SPRAY MAY BE USED TO KEEP FIRE EXPOSED CONTAINERS COOL. IF WATER IS USED, USE IN ABUNDANCE TO CONTROL HEAT AND ACID BUILD-UP.

SPECIAL INFORMATION:
IN THE EVENT OF A FIRE, WEAR FULL PROTECTIVE CLOTHING AND NIOSH-APPROVED SELF-CONTAINED BREATHING APPARATUS WITH FULL FACEPIECE OPERATED IN THE PRESSURE DEMAND OR OTHER POSITIVE PRESSURE MODE.

6. ACCIDENTAL RELEASE MEASURES

VENTILATE AREA OF LEAK OR SPILL. WEAR APPROPRIATE PERSONAL PROTECTIVE EQUIPMENT AS SPECIFIED IN SECTION 8. ISOLATE HAZARD AREA. KEEP UNNECESSARY AND UNPROTECTED PERSONNEL FROM ENTERING. CONTAIN AND RECOVER LIQUID WHEN POSSIBLE. NEUTRALIZE WITH ALKALINE MATERIAL (SODA ASH, LIME), THEN ABSORB WITH AN INERT MATERIAL (E. G., VERMICULITE, DRY SAND, EARTH), AND PLACE IN A CHEMICAL WASTE CONTAINER. DO NOT USE COMBUSTIBLE MATERIALS, SUCH AS SAW DUST. DO NOT FLUSH TO SEWER! US REGULATIONS (CERCLA) REQUIRE REPORTING SPILLS AND RELEASES TO SOIL, WATER AND AIR IN EXCESS OF REPORTABLE QUANTITIES. THE TOLL FREE NUMBER FOR THE US COAST GUARD NATIONAL RESPONSE CENTER IS (800) 424-8802.

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7. HANDLING AND STORAGE

KEEP IN A TIGHTLY CLOSED CONTAINER. PROTECT FROM PHYSICAL DAMAGE. STORE IN A COOL, DRY, VENTILATED AREA AWAY FROM SOURCES OF HEAT, MOISTURE, INCOMPATIBILITIES, AND DIRECT SUNLIGHT. CORROSIVE TO MILD STEEL. STORE IN RUBBER LINED OR 316 STAINLESS STEEL DESIGNED FOR PHOSPHORIC ACID. DO NOT WASH OUT CONTAINER AND USE IT FOR OTHER PURPOSES. WHEN DILUTING, THE ACID SHOULD ALWAYS BE ADDED SLOWLY TO WATER AND IN SMALL AMOUNTS. NEVER USE HOT WATER AND NEVER ADD WATER TO THE ACID. WATER ADDED TO ACID CAN CAUSE UNCONTROLLED BOILING AND SPLASHING. PROTECT FROM FREEZING. CONTAINERS OF THIS MATERIAL MAY BE HAZARDOUS WHEN EMPTY SINCE THEY RETAIN PRODUCT RESIDUES (VAPORS, LIQUID); OBSERVE ALL WARNINGS AND PRECAUTIONS LISTED FOR THE PRODUCT.

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8. EXPOSURE CONTROLS/PERSONAL PROTECTION

AIRBORNE EXPOSURE LIMITS:
-OSHA PERMISSIBLE EXPOSURE LIMIT (PEL):
1 MG/M3 (TWA)

-ACGIH THRESHOLD LIMIT VALUE (TLV):
1 MG/M3 (TWA), 3 MG/M3 (STEL)

VENTILATION SYSTEM:
A SYSTEM OF LOCAL AND/OR GENERAL EXHAUST IS RECOMMENDED TO KEEP EMPLOYEE EXPOSURES BELOW THE AIRBORNE EXPOSURE LIMITS. LOCAL EXHAUST VENTILATION IS GENERALLY PREFERRED BECAUSE IT CAN CONTROL THE EMISSIONS OF THE CONTAMINANT AT ITS SOURCE, PREVENTING DISPERSION OF IT INTO THE GENERAL WORK AREA. PLEASE REFER TO THE ACGIH DOCUMENT, "INDUSTRIAL VENTILATION, A MANUAL OF RECOMMENDED PRACTICES", MOST RECENT EDITION, FOR DETAILS.

PERSONAL RESPIRATORS (NIOSH APPROVED):

IF THE EXPOSURE LIMIT IS EXCEEDED, A FULL FACEPIECE RESPIRATOR WITH HIGH EFFICIENCY DUST/MIST FILTER MAY BE WORN UP TO 50 TIMES THE EXPOSURE LIMIT OR THE MAXIMUM USE CONCENTRATION SPECIFIED BY THE APPROPRIATE REGULATORY AGENCY OR RESPIRATOR SUPPLIER, WHICHEVER IS LOWEST. FOR EMERGENCIES OR INSTANCES WHERE THE EXPOSURE LEVELS ARE NOT KNOWN, USE A FULL-FACEPIECE POSITIVE-PRESSURE, AIR-SUPPLIED RESPIRATOR. WARNING: AIR PURIFYING RESPIRATORS DO NOT PROTECT WORKERS IN OXYGEN-DEFICIENT ATMOSPHERES.

SKIN PROTECTION:
WEAR IMPERVIOUS PROTECTIVE CLOTHING, INCLUDING BOOTS, GLOVES, LAB COAT, APRON OR COVERALLS, AS APPROPRIATE, TO PREVENT SKIN CONTACT.

EYE PROTECTION:
USE CHEMICAL SAFETY GOGGLES AND/OR A FULL FACE SHIELD WHERE SPLASHING IS POSSIBLE. MAINTAIN EYE WASH FOUNTAIN AND QUICK-DRENCH FACILITIES IN WORK AREA.

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9. PHYSICAL AND CHEMICAL PROPERTIES

PHYSICAL DATA BELOW REFERS TO CONCENTRATED PHOSPHORIC ACID.

APPEARANCE:
CLEAR, COLORLESS SYRUPY LIQUID.

BOILING POINT:
158C (316F)

ODOR:
ODORLESS.

MELTING POINT:
21C (70F)

SOLUBILITY:
MISCIBLE IN ALL PROPORTIONS IN WATER.

VAPOR DENSITY (AIR=1):
3.4

SPECIFIC GRAVITY:
1.69 @ 25C

VAPOR PRESSURE (MM HG):
0.03 @ 20C (68F)

PH:
1.5 (0.1 N AQUEOUS SOLUTION)

EVAPORATION RATE (BUAC=1):
NO INFORMATION FOUND.

% VOLATILES BY VOLUME @ 21C (70F):
100

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10. STABILITY AND REACTIVITY

STABILITY:
STABLE UNDER ORDINARY CONDITIONS OF USE AND STORAGE. SUBSTANCE CAN

SUPERCOOL WITHOUT CRYSTALLIZING.

HAZARDOUS DECOMPOSITION PRODUCTS:
PHOSPHORUS OXIDES MAY FORM WHEN HEATED TO DECOMPOSITION.

HAZARDOUS POLYMERIZATION:
WILL NOT OCCUR.

INCOMPATIBILITIES:
LIBERATES EXPLOSIVE HYDROGEN GAS WHEN REACTING WITH CHLORIDES AND STAINLESS STEEL. CAN REACT VIOLENTLY WITH SODIUM TETRAHYDROBORATE. EXOTHERMIC REACTIONS WITH ALDEHYDES, AMINES, AMIDES, ALCOHOLS AND GLYCOLS, AZO-COMPOUNDS, CARBAMATES, ESTERS, CAUSTICS, PHENOLS AND CRESOLS, KETONES, ORGANOPHOSPHATES, EPOXIDES, EXPLOSIVES, COMBUSTIBLE MATERIALS, UNSATURATED HALIDES, AND ORGANIC PEROXIDES. PHOSPHORIC ACID FORMS FLAMMABLE GASES WITH SULFIDES, MERCAPTANS, CYANIDES AND ALDEHYDES. IT ALSO FORMS TOXIC FUMES WITH CYANIDES, SULFIDE, FLUORIDES, ORGANIC PEROXIDES, AND HALOGENATED ORGANICS. MIXTURES WITH NITROMETHANE ARE EXPLOSIVE.

CONDITIONS TO AVOID:
INCOMPATIBLES.

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11. TOXICOLOGICAL INFORMATION

ORAL RAT LD50: 1530 MG/KG; INVESTIGATED AS A MUTAGEN.

--------/CANCER LISTS/--------

INGREDIENT	---NTP CARCINOGEN--- KNOWN	ANTICIPATED	IARC CATEGORY
PHOSPHORIC ACID (7664-38-2)	NO	NO	NONE
WATER (7732-18-5)	NO	NO	NONE

===

12. ECOLOGICAL INFORMATION

ENVIRONMENTAL FATE:
WHEN RELEASED INTO THE SOIL, THIS MATERIAL MAY LEACH INTO GROUNDWATER. WHEN RELEASED TO WATER, ACIDITY MAY BE READILY REDUCED BY NATURAL WATER HARDNESS MINERALS. THE PHOSPHATE, HOWEVER, MAY PERSIST INDEFINITELY.

ENVIRONMENTAL TOXICITY:
NO INFORMATION FOUND.

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13. DISPOSAL CONSIDERATIONS

WHATEVER CANNOT BE SAVED FOR RECOVERY OR RECYCLING SHOULD BE HANDLED AS HAZARDOUS WASTE AND SENT TO A RCRA APPROVED INCINERATOR OR DISPOSED IN A RCRA APPROVED WASTE FACILITY. PROCESSING, USE OR CONTAMINATION OF THIS PRODUCT MAY CHANGE THE WASTE MANAGEMENT OPTIONS. STATE AND LOCAL DISPOSAL REGULATIONS MAY DIFFER FROM FEDERAL DISPOSAL REGULATIONS.

DISPOSE OF CONTAINER AND UNUSED CONTENTS IN ACCORDANCE WITH FEDERAL, STATE AND LOCAL REQUIREMENTS.

14. TRANSPORT INFORMATION

DOMESTIC (LAND, D.O.T.)

PROPER SHIPPING NAME: PHOSPHORIC ACID SOLUTION
HAZARD CLASS: 8
UN/NA: UN1805 PACKING GROUP: III

INTERNATIONAL (WATER, I.M.O.)

PROPER SHIPPING NAME: PHOSPHORIC ACID SOLUTION
HAZARD CLASS: 8
UN/NA: UN1805 PACKING GROUP: III

15. REGULATORY INFORMATION

--------/CHEMICAL INVENTORY STATUS - PART 1/--------

INGREDIENT	TSCA	EC	JAPAN	AUSTRALIA
PHOSPHORIC ACID (7664-38-2)	YES	YES	YES	YES
WATER (7732-18-5)	YES	YES	YES	YES

--------/CHEMICAL INVENTORY STATUS - PART 2/--------

INGREDIENT	KOREA	--CANADA-- DSL	NDSL	PHIL.
PHOSPHORIC ACID (7664-38-2)	YES	YES	NO	YES
WATER (7732-18-5)	YES	YES	NO	YES

-------/FEDERAL, STATE & INTERNATIONAL REGULATIONS - PART 1/--------

INGREDIENT	-SARA 302- RQ	TPQ	------SARA 313----- LIST	CHEMICAL CATG

PRODUCT: PHOSPHORIC ACID

ORDER NO: 807165
PROD NO : 320150

PHOSPHORIC ACID (7664-38-2)	NO	NO	NO	NO
WATER (7732-18-5)	NO	NO	NO	NO

--------/FEDERAL, STATE & INTERNATIONAL REGULATIONS - PART 2/--------------

INGREDIENT	CERCLA	-RCRA- 261.33	-TSCA- 8(D)
PHOSPHORIC ACID (7664-38-2)	5000	NO	NO
WATER (7732-18-5)	NO	NO	NO

CHEMICAL WEAPONS CONVENTION: NO TSCA 12(B): NO CDTA: NO
SARA 311/312: ACUTE: YES CHRONIC: NO FIRE: NO PRESSURE: NO
REACTIVITY: NO (PURE / LIQUID)

AUSTRALIAN HAZCHEM CODE: 2R
POISON SCHEDULE: S5

WHMIS: THIS MSDS HAS BEEN PREPARED ACCORDING TO THE HAZARD CRITERIA OF THE CONTROLLED PRODUCTS REGULATIONS (CPR) AND THE MSDS CONTAINS ALL OF THE INFORMATION REQUIRED BY THE CPR.

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16. OTHER INFORMATION

NFPA RATINGS:
HEALTH: 3 FLAMMABILITY: 0 REACTIVITY: 0

PRODUCT: PHOSPHORIC ACID

ORDER NO: 807165
PROD NO : 320150

------------------------- FOR ADDITIONAL INFORMATION -------------------------

CONTACT: MSDS COORDINATOR UNIVAR USA INC.
DURING BUSINESS HOURS, PACIFIC TIME (425)889-3400

05/31/07 17:57 PRODUCT: 320150 CUST NO: 252504 ORDER NO: 807165

----------------------------------- NOTICE -----------------------------------

******** UNIVAR USA INC("UNIVAR"), EXPRESSLY DISCLAIMS

ALL EXPRESS OR IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A

PARTICULAR PURPOSE, WITH RESPECT TO THE PRODUCT OR INFORMATION PROVIDED

HEREIN, AND SHALL UNDER NO CIRCUMSTANCES BE LIABLE FOR INCIDENTAL OR

CONSEQUENTIAL DAMGAGES. **

DO NOT USE INGREDIENT INFORMATION AND/OR PERCENTAGES IN THIS MSDS AS A PRODUCT SPECIFICATION. FOR PRODUCT SPECIFICATION INFORMATION REFER TO A PRODUCT SPECIFICATION SHEET AND/OR A CERTIFICATE OF ANALYSIS. THESE CAN BE OBTAINED FROM YOUR LOCAL UNIVAR SALES OFFICE.

ALL INFORMATION APPEARING HEREIN IS BASED UPON DATA OBTAINED FROM THE MANUFACTURER AND/OR RECOGNIZED TECHNICAL SOURCES. WHILE THE INFORMATION IS BELIEVED TO BE ACCURATE, UNIVAR MAKES NO REPRESENTATIONS AS TO ITS ACCURACY OR SUFFICIENCY. CONDITIONS OF USE ARE BEYOND UNIVARS CONTROL AND THEREFORE USERS ARE RESPONSIBLE TO VERIFY THIS DATA UNDER THEIR OWN OPERATING CONDITIONS TO DETERMINE WHETHER THE PRODUCT IS SUITABLE FOR THEIR PARTICULAR PURPOSES AND THEY ASSUME ALL RISKS OF THEIR USE, HANDLING, AND DISPOSAL OF THE PRODUCT, OR FROM THE PUBLICATION OR USE OF, OR RELIANCE UPON , INFORMATION CONTAINED HEREIN. THIS INFORMATION RELATES ONLY TO THE PRODUCT DESIGNATED HEREIN, AND DOES NOT RELATE TO ITS USE IN COMBINATION WITH ANY OTHER MATERIAL OR IN ANY OTHER PROCESS.

* * * E N D O F M S D S * * *

Univar USA Inc.
6100 Carillon Point
Kirkland, WA 98033
(425) 889-3400

UNIVAR

For Emergency Assistance involving chemicals call - CHEMTREC (800) 424-9300

The Version Date and Number for this MSDS is : 01/23/2006 - #013

PRODUCT NAME:	GLACIAL ACETIC ACID
MSDS NUMBER:	EZ060433
DATE ISSUED:	05/05/2005
SUPERSEDES:	09/21/2004
ISSUED BY:	009292

****
****

MATERIAL SAFETY DATA SHEET

1. CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Product Name GLACIAL ACETIC ACID
Distributed by:
Univar USA Inc.
6100 Carillon Point
Kirkland, WA 98003-7357
425-889-5000

Chemical Name	acetic acid
Molecular Formula	C2H4O2
Molecular Weight	60.05
Product Use	solvent
OSHA Status	hazardous

For emergency transportation information, call CHEMTREC at 800-424-9300

2. COMPOSITION INFORMATION ON INGREDIENTS

(Typical composition is given, and it may vary. A certificate of analysis can be provided, if available.)

Weight %	Component	CAS Registry No.
100%	acetic acid	64-19-7

3. HAZARDS IDENTIFICATION

DANGER!
CAUSES SEVERE SKIN AND EYE BURNS
MIST OR VAPOR IRRITATING TO EYES AND RESPIRATORY TRACT
HARMFUL IF SWALLOWED
COMBUSTIBLE LIQUID AND VAPOR

HMIS Hazard Ratings: Health - 3, Flammability -2, Chemical Reactivity 0

HMIS rating involves data interpretations that may vary from company to company. They are intended only for rapid, general identification of the magnitude of the specific hazard. To deal adequately with the safe handling of this material, all the information contained in this MSDS must be considered.

4. FIRST-AID MEASURES

Inhalation: Move to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention immediately.

Eyes: Immediately flush with plenty of water for at least 15 minutes. If easy to do, remove contact lenses. Call a physician or poison control center immediately. In case of irritation from airborne exposure, move to fresh air. Get medical attention if symptoms persist.

Skin: Immediately flush with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Call a physician or poison control center immediately. Wash contaminated clothing before reuse. Destroy or thoroughly clean contaminated shoes.

Ingestion: Call a physician or poison control center immediately. Do NOT induce vomiting. If victim is fully conscious, give a cupful of water. Never give anything by mouth to an unconscious person. If vomiting occurs, keep head lower than the hips to help prevent aspiration.

5. FIRE FIGHTING MEASURES

Extinguishing Media: water spray, dry chemical, carbon dioxide, alcohol foam

Special Fire-Fighting Procedures: Wear self-contained breathing apparatus and protective clothing. Use water spray to keep fire-exposed containers cool.

Hazardous Combustion Products: carbon dioxide, carbon monoxide

Unusual Fire and Explosion Hazards: Combustible.

6. ACCIDENTAL RELEASE MEASURES

Wear a self-contained breathing apparatus and appropriate personal protective equipment. (See EXPOSURE CONTROLS/PERSONAL PROTECTION.) Eliminate all ignition sources. Neutralize spill area and washings with soda ash or lime. Absorb spill with vermiculite or other inert material, then place in a container for chemical waste.

For Large Spills: Flush spill area with water spray. Prevent runoff from entering drains, sewers, or streams. Dike for later disposal.

7. HANDLING AND STORAGE

Personal Precautionary Measures: Do not get in eyes, on skin, on clothing. Do not taste or swallow. Avoid breathing mist or vapor. Use only with adequate ventilation. Wash thoroughly after handling.

Prevention of Fire and Explosion: Keep away from heat and flame. Keep from contact with oxidizing materials.

Storage: Keep container closed.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Country specific exposure limits have not been established or are not applicable unless listed below.

ACETIC ACID
US. ACGIH Threshold Limit Values

Time Weighted Average (TWA): 10 ppm,
US. ACGIH Threshold Limit Values
Short Term Exposure Limit (STEL): 15 ppm,
US. NIOSH: Pocket Guide to Chemical Hazards
Recommended exposure limit (REL): 10 ppm, 25 mg/m3
US. NIOSH: Pocket Guide to Chemical Hazards
Short Term Exposure Limit (STEL): 15 ppm, 37 mg/m3
US. OSHA Table Z-1 Limits for Air Contaminants (29 CFR 1910.1000)
PEL: 10 ppm, 25 mg/m3
US. California Code of Regulations, Title 8, Section 5155. Airborne Contaminants
Time Weighted Average (TWA) Permissible Exposure Limit (PEL): 10 ppm, 25 mg/m3
US. California Code of Regulations, Title 8, Section 5155. Airborne Contaminants
Ceiling Limit Value: 40 ppm,
US. California Code of Regulations, Title 8, Section 5155. Airborne Contaminants
Short Term Exposure Limit (STEL): 15 ppm, 37 mg/m3

Ventilation: Good general ventilation (typically 10 air changes per hour) should be used. Ventilation rates should be matched to conditions. If applicable, use process enclosures, local exhaust ventilation, or other engineering controls to maintain airborne levels below recommended exposure limits. If exposure limits have not been established, maintain airborne levels to an acceptable level.

Respiratory Protection: If engineering controls do not maintain airborne concentrations below recommended exposure limits (where applicable) or to an acceptable level (in countries where exposure limits have not been established), an approved respirator must be worn. In the United States of America, if respirators are used, a program should be instituted to assure compliance with OSHA Standard 63 FR 1152, January 8, 1998. Respirator type: Air-purifying respirator with an appropriate, government approved (where applicable), air-purifying filter, cartridge or canister. Contact health and safety professional or manufacturer for specific information.

Eye Protection: Wear safety glasses with side shields (or goggles) and a face shield. Wear a full-face respirator, if needed.

Skin Protection: Wear chemical-resistant gloves, footwear, and protective clothing appropriate for the risk of exposure. Contact health and safety professional or manufacturer for specific information.

Recommended Decontamination Facilities: eye bath, safety shower, washing Facilities

9. PHYSICAL AND CHEMICAL PROPERTIES

Physical Form:	liquid
Color:	colorless
Odor:	vinegar, pungent
Odor Threshold:	0.48 ppm
Specific Gravity:	1.05 (20 deg C)
Vapor Pressure:	20 deg C; 15.2 mbar
Vapor Density:	2.1
Melting Point:	17 deg C
Boiling Point:	118 deg C
Evaporation Rate:	0.97 (n-butyl acetate = 1)
Viscosity:	1.2 mPa.s (20 deg C) ,
Solubility in Water:	complete
pH:	2.4

Octanol/Water Partition Coefficient: P: 0.49; log P: -0.31
Flash Point: 39 deg C (Tag closed cup)
Autoignition Temperature: 516 deg C (ASTM D2155)
Thermal Decomposition Temperature: (DTA) No exotherm to 500 deg C

10.STABILITY AND REACTIVITY

Stability: Stable.

Incompatibility: Material reacts violently with strong oxidizing Agents

Hazardous Polymerization: Will not occur.

11.TOXICOLOGICAL INFORMATION

Acute toxicity data, if available, are listed below. Additional toxicity data may be available on request.

Oral LD-50:(rat)	3,310 - 3,530 mg/kg
Oral LD-50:(mouse)	4,960 mg/kg
Inhalation LC-50: (mouse)	1 h: 5620 ppm
Dermal LD-50: (rabbit)	1,060 mg/kg
Skin Irritation (rabbit)	severe
Eye Irritation (rabbit)	severe

12. ECOLOGICAL INFORMATION

Acute toxicity data, if available, are listed below. Additional toxicity data may be available on request.

This material is a strongly acidic aqueous solution, and this property may cause adverse environmental effects.

Oxygen Demand Data:
BOD-5: 340 - 880 mg/g
BOD-20: 900 mg/g

COD: 1,030 mg/g

Acute Aquatic Effects Data:
96 h LC-50 (fathead minnow): > 100 mg/L

48 h LC-50 (golden orfe): 410 mg/L
48 h LC-50 (mosquito fish): 251 mg/L
96 h LC-50 (daphnid): > 100 mg/L

13. DISPOSAL CONSIDERATIONS

Discharge, treatment, or disposal may be subject to national, state, or local laws. Incinerate. Since emptied containers retain product residue, follow label warnings even after container is emptied.

14.TRANSPORT INFORMATION

Important Note: Shipping descriptions may vary based on mode of transport, quantities, package size, and/or origin and destination. Consult your company's Hazardous Materials/Dangerous Goods expert for information specific to your situation.

DOT (USA)
Reportable Quantity: 2,270 kg (acetic acid)

Possible Shipping Description(s):
Acetic acid, glacial
8 (3) UN 2789 II

Sea - IMDG (International Maritime Dangerous Goods)

Possible Shipping Description(s):
ACETIC ACID, GLACIAL
8 (3) UN 2789 II

Air - ICAO (International Civil Aviation Organization)

Possible Shipping Description(s):
Acetic acid, glacial
8 (3) UN 2789 II

15. REGULATORY INFORMATION

SARA 311-312 Hazard Classification(s):
immediate (acute) health hazard
fire hazard

SARA 313: none, unless listed below

Carcinogenicity Classification (components present at 0.1% or more): none, unless listed below

TSCA (US Toxic Substances Control Act): This product is listed on the TSCA inventory. Any impurities present in this product are exempt from listing.

DSL (Canadian Domestic Substances List) and CEPA (Canadian Environmental Protection Act):
This product is listed on the DSL. Any impurities present in this product are exempt from listing.

EINECS (European Inventory of Existing Commercial Chemical Substances): This product is listed on EINECS or otherwise complies with EINECS requirements.
EINECS Number: 200-580-7

AICS / NICNAS (Australian Inventory of Chemical Substances and National

Industrial Chemicals Notification and Assessment Scheme): This product is listed on AICS or otherwise complies with NICNAS.

MITI (Japanese Handbook of Existing and New Chemical Substances): This product is listed in the Handbook or has been approved in Japan by new substance notification.

ECL (Korean Toxic Substances Control Act): This product is listed on the Korean inventory or otherwise complies with the Korean Toxic Substances Control Act.

For Additional Information:
Contact: MSDS Coordinator - Univar USA
During business hours, Pacific Time - (425) 889-3400

NOTICE
Univar USA expressly disclaims all express or implied warranties of merchantibility and fitness for a particular purpose with respect to the product or information provided herein, and shall under no circumstances be liable for incidental or consequential damages.

Do not use ingredient information and/or ingredient percentages in this MSDS as a product specification. For product specification information refer to a Product Specification Sheet and/or a Certificate of Analysis. These can be obtained from your local Univar USA Sales Office.

All information appearing herein is based upon data obtained from the manufacturer and/or recognized technical sources. While the information is believed to be accurate, Univar USA makes no representations as to its accuracy or sufficiency. Conditions of use are beyond Univar USA's control. Therefore, users are responsible to verify this data under their own operating conditions to determine whether the product is suitable for their particular purposes, and they assume all risks of their use, handling, and disposal of the product or from the publication or use of, or reliance upon, information contained herein. This information relates only to the product designated herein and does not relate to its use in combination with any other material or in any other process.

END OF MSDS

SIGMA-ALDRICH

sigma-aldrich.com

Material Safety Data Sheet

Version 5.0
Revision Date 09/20/2012
Print Date 10/04/2012

1. PRODUCT AND COMPANY IDENTIFICATION

Product name	:	Sodium selenate
Product Number	:	S8295
Brand	:	Sigma
Supplier	:	Sigma-Aldrich 3050 Spruce Street SAINT LOUIS MO 63103 USA
Telephone	:	+1 800-325-5832
Fax	:	+1 800-325-5052
Emergency Phone # (For both supplier and manufacturer)	:	(314) 776-6555
Preparation Information	:	Sigma-Aldrich Corporation Product Safety - Americas Region 1-800-521-8956

2. HAZARDS IDENTIFICATION

Emergency Overview

OSHA Hazards
Target Organ Effect, Toxic by inhalation., Highly toxic by ingestion

Target Organs

Central nervous system, Liver, Kidney, Spleen., Gastrointestinal tract, Teeth.

GHS Classification
Acute toxicity, Oral (Category 1)
Acute toxicity, Inhalation (Category 3)
Specific target organ toxicity - repeated exposure (Category 2)
Acute aquatic toxicity (Category 1)
Chronic aquatic toxicity (Category 1)

GHS Label elements, including precautionary statements

Pictogram

Signal word: Danger

Hazard statement(s)

H300	Fatal if swallowed.
H331	Toxic if inhaled.
H373	May cause damage to organs through prolonged or repeated exposure.
H410	Very toxic to aquatic life with long lasting effects.

Precautionary statement(s)

P261	Avoid breathing dust/ fume/ gas/ mist/ vapours/ spray.
P264	Wash hands thoroughly after handling.
P273	Avoid release to the environment.
P301 + P310	IF SWALLOWED: Immediately call a POISON CENTER or doctor/ physician.
P311	Call a POISON CENTER or doctor/ physician.
P501	Dispose of contents/ container to an approved waste disposal plant.

HMIS Classification

Health hazard:	3
Flammability:	0
Physical hazards:	0

NFPA Rating

Health hazard:	2
Fire:	0
Reactivity Hazard:	0

Potential Health Effects

Inhalation	Toxic if inhaled. May cause respiratory tract irritation.
Skin	May be harmful if absorbed through skin. May cause skin irritation.
Eyes	May cause eye irritation.
Ingestion	May be fatal if swallowed.

3. COMPOSITION/INFORMATION ON INGREDIENTS

Formula : Na_2O_4Se

Molecular Weight : 188.94 g/mol

Component		Concentration
Sodium selenate		
CAS-No.	13410-01-0	-
EC-No.	236-501-8	
Index-No.	034-002-00-8	

4. FIRST AID MEASURES

General advice
Move out of dangerous area.Consult a physician. Show this safety data sheet to the doctor in attendance.

If inhaled
If breathed in, move person into fresh air. If not breathing, give artificial respiration. Consult a physician.

In case of skin contact
Wash off with soap and plenty of water. Take victim immediately to hospital. Consult a physician.

In case of eye contact
Flush eyes with water as a precaution.

If swallowed
Never give anything by mouth to an unconscious person. Rinse mouth with water. Consult a physician.

5. FIREFIGHTING MEASURES

Suitable extinguishing media
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.

Special protective equipment for firefighters
Wear self contained breathing apparatus for fire fighting if necessary.

Hazardous combustion products
Hazardous decomposition products formed under fire conditions. - Sodium oxides, Selenium/selenium oxides

6. ACCIDENTAL RELEASE MEASURES

Personal precautions
Wear respiratory protection. Avoid dust formation. Avoid breathing vapors, mist or gas. Ensure adequate ventilation. Evacuate personnel to safe areas. Avoid breathing dust.

Environmental precautions
Prevent further leakage or spillage if safe to do so. Do not let product enter drains. Discharge into the environment must be avoided.

Methods and materials for containment and cleaning up
Pick up and arrange disposal without creating dust. Sweep up and shovel. Keep in suitable, closed containers for disposal.

7. HANDLING AND STORAGE

Precautions for safe handling
Avoid contact with skin and eyes. Avoid formation of dust and aerosols.
Provide appropriate exhaust ventilation at places where dust is formed. Normal measures for preventive fire protection.

Conditions for safe storage
Keep container tightly closed in a dry and well-ventilated place.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Components with workplace control parameters

Components	CAS-No.	Value	Control parameters	Basis
Sodium selenate	13410-01-0	TWA	0.2 mg/m3	USA. Occupational Exposure Limits (OSHA) - Table Z-1 Limits for Air Contaminants
		TWA	0.2 mg/m3	USA. ACGIH Threshold Limit Values (TLV)
Remarks	Eye & Upper Respiratory Tract irritation			
		TWA	0.2 mg/m3	USA. OSHA - TABLE Z-1 Limits for Air Contaminants - 1910.1000
		TWA	0.2 mg/m3	USA. NIOSH Recommended Exposure Limits

Personal protective equipment

Respiratory protection
Where risk assessment shows air-purifying respirators are appropriate use a full-face particle respirator type N100 (US) or type P3 (EN 143) respirator cartridges as a backup to engineering controls. If the respirator is the sole means of protection, use a full-face supplied air respirator. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).

Hand protection
Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Immersion protection
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: > 480 min
Material tested:Dermatril® (Aldrich Z677272, Size M)

Splash protection
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: > 30 min
Material tested:Dermatril® (Aldrich Z677272, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 873000, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the CE approved gloves. This recommendation is advisory only and must be evaluated by an Industrial Hygienist familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

Eye protection
Face shield and safety glasses Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU).

Skin and body protection
Complete suit protecting against chemicals, The type of protective equipment must be selected according to the concentration and amount of the dangerous substance at the specific workplace.

Hygiene measures
Avoid contact with skin, eyes and clothing. Wash hands before breaks and immediately after handling the product.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance

Form	solid
Colour	white

Safety data

pH	5.5 - 7.5 at 18.9 g/l at 25 °C (77 °F)
Melting point/freezing point	no data available
Boiling point	no data available
Flash point	not applicable
Ignition temperature	no data available
Autoignition temperature	no data available
Lower explosion limit	no data available
Upper explosion limit	no data available
Vapour pressure	no data available
Density	no data available
Water solubility	ca.18.9 g/l at 20 °C (68 °F)
Partition coefficient: n-octanol/water	log Pow: 5
Relative vapour density	no data available
Odour	no data available
Odour Threshold	no data available
Evaporation rate	no data available

10. STABILITY AND REACTIVITY

Chemical stability
Stable under recommended storage conditions.

Possibility of hazardous reactions
no data available

Conditions to avoid
no data available

Materials to avoid
Strong oxidizing agents

Hazardous decomposition products
Hazardous decomposition products formed under fire conditions. - Sodium oxides, Selenium/selenium oxides
Other decomposition products - no data available

11. TOXICOLOGICAL INFORMATION

Acute toxicity

Oral LD50
LD50 Oral - rat - 1.6 mg/kg

Inhalation LC50
no data available

Dermal LD50
no data available

Other information on acute toxicity
no data available

Skin corrosion/irritation
no data available

Serious eye damage/eye irritation
no data available

Respiratory or skin sensitization
no data available

Germ cell mutagenicity

no data available

Carcinogenicity

This product is or contains a component that is not classifiable as to its carcinogenicity based on its IARC, ACGIH, NTP, or EPA classification.

IARC:	3 - Group 3: Not classifiable as to its carcinogenicity to humans (Sodium selenate)
ACGIH:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by ACGIH.
NTP:	No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.
OSHA:	No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.

Reproductive toxicity

no data available

Teratogenicity

no data available

Specific target organ toxicity - single exposure (Globally Harmonized System)
no data available

Specific target organ toxicity - repeated exposure (Globally Harmonized System)

May cause damage to organs through prolonged or repeated exposure.

Aspiration hazard
no data available

Potential health effects

Inhalation	Toxic if inhaled. May cause respiratory tract irritation.
Ingestion	May be fatal if swallowed.
Skin	May be harmful if absorbed through skin. May cause skin irritation.
Eyes	May cause eye irritation.

Signs and Symptoms of Exposure
anemia, Vomiting, Diarrhoea, Cough, Difficulty in breathing, Acute selenium poisoning produces central nervous system effects, which include nervousness, convulsions, and drowsiness. Other signs of intoxication can include skin eruptions, lassitude, gastrointestinal distress, teeth that are discolored or decayed, odorous ("garlic") breath, and partial loss of hair and nails. Chronic exposure by inhalation can produce symptoms that include pallor, coating of the tongue, anemia, irritation of the mucosa, lumbar pain, liver and spleen damage, as well as any of the other previously mentioned symptoms. Chronic contact with selenium compounds may cause garlic odor of breath and sweat, dermatitis, and moderate emotional instability.

Synergistic effects
no data available

Additional Information
RTECS: VS6650000

12. ECOLOGICAL INFORMATION

Toxicity

Toxicity to fish	mortality NOEC - Pimephales promelas (fathead minnow) - 1.25 mg/l - 5.0 d
	LC50 - Pimephales promelas (fathead minnow) - 0.69 mg/l - 96.0 h
	mortality LOEC - Pimephales promelas (fathead minnow) - 2.42 mg/l - 5.0 d
Toxicity to daphnia and other aquatic invertebrates	EC50 - Daphnia magna (Water flea) - 0.39 mg/l - 48 h
Toxicity to algae	Growth inhibition LOEC - Chlorella vulgaris (Fresh water algae) - 0.083 mg/l - 7 d
	Growth inhibition EC50 - Ankistrodesmus falcatus - 0.033 mg/l - 14 d

Persistence and degradability
no data available

Bioaccumulative potential

Bioaccumulation	Pimephales promelas (fathead minnow) - 8 Weeks Bioconcentration factor (BCF): 153.8

Mobility in soil
no data available

PBT and vPvB assessment
no data available

Other adverse effects

Very toxic to aquatic life with long lasting effects.

An environmental hazard cannot be excluded in the event of unprofessional handling or disposal.

13. DISPOSAL CONSIDERATIONS

Product
Offer surplus and non-recyclable solutions to a licensed disposal company. Contact a licensed professional waste disposal service to dispose of this material. Dissolve or mix the material with a combustible solvent and burn in a chemical incinerator equipped with an afterburner and scrubber.

Contaminated packaging
Dispose of as unused product.

14. TRANSPORT INFORMATION

DOT (US)
UN number: 2630 Class: 6.1 Packing group: I
Proper shipping name: Selenates (Sodium selenate)
Marine pollutant: No
Poison Inhalation Hazard: No

IMDG
UN number: 2630 Class: 6.1 Packing group: I EMS-No: F-A, S-A
Proper shipping name: SELENATES (Sodium selenate)
Marine pollutant: No

IATA
UN number: 2630 Class: 6.1 Packing group: I
Proper shipping name: Selenates (Sodium selenate)

15. REGULATORY INFORMATION

OSHA Hazards
Target Organ Effect, Toxic by inhalation., Highly toxic by ingestion

SARA 302 Components
The following components are subject to reporting levels established by SARA Title III, Section 302:

	CAS-No.	Revision Date
Sodium selenate	13410-01-0	2007-07-01

SARA 313 Components
The following components are subject to reporting levels established by SARA Title III, Section 313:

	CAS-No.	Revision Date
Sodium selenate	13410-01-0	2007-07-01

SARA 311/312 Hazards
Acute Health Hazard, Chronic Health Hazard

Massachusetts Right To Know Components

	CAS-No.	Revision Date
Sodium selenate	13410-01-0	2007-07-01

Pennsylvania Right To Know Components

	CAS-No.	Revision Date
Sodium selenate	13410-01-0	2007-07-01

New Jersey Right To Know Components

	CAS-No.	Revision Date
Sodium selenate	13410-01-0	2007-07-01

California Prop. 65 Components
This product does not contain any chemicals known to State of California to cause cancer, birth defects, or any other reproductive harm.

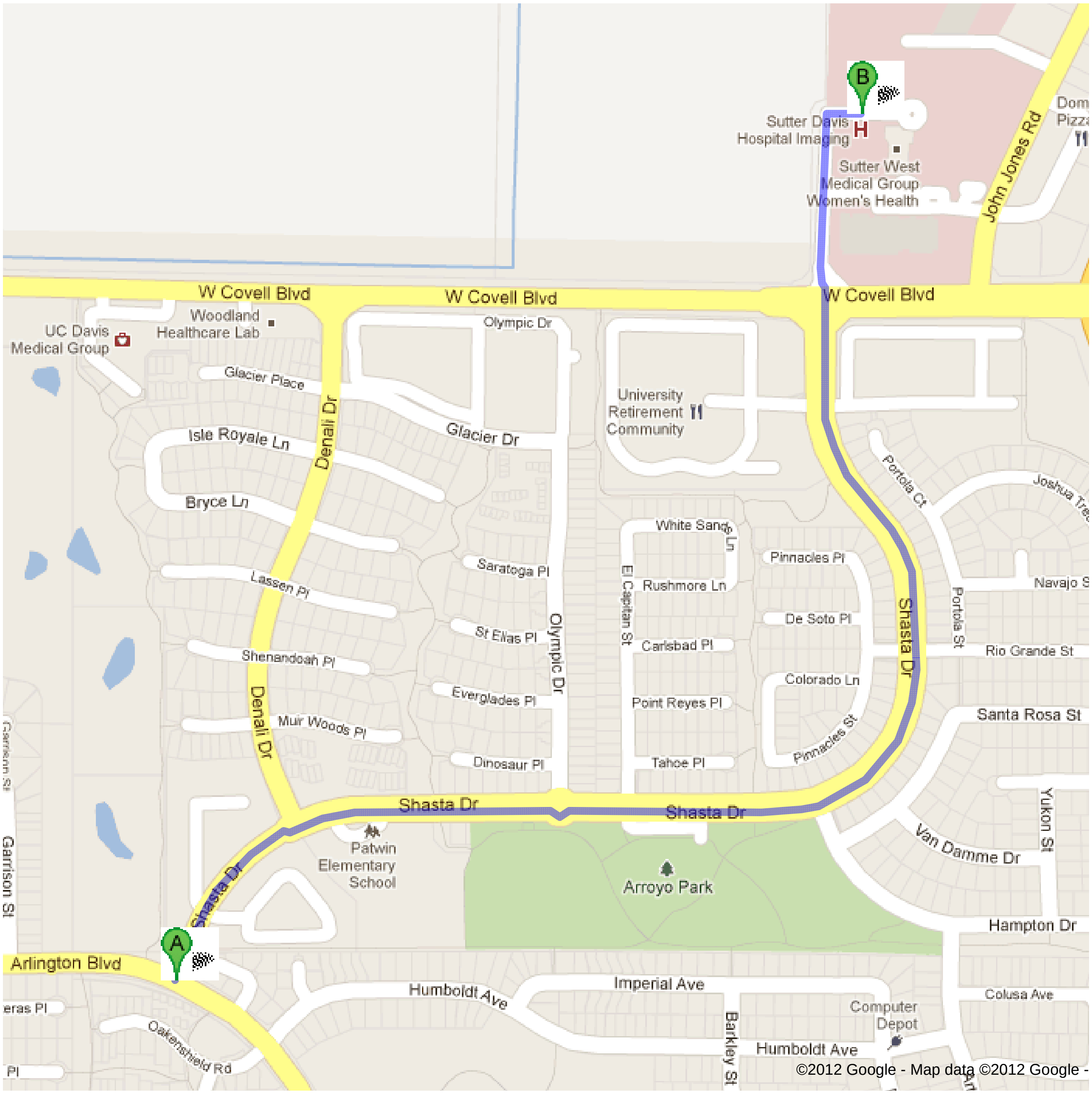
16. OTHER INFORMATION

Further information

The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

Google

Directions to Sutter Davis Hospital Imaging
2000 Sutter Place, Davis, CA 95616
1.1 mi – about **3 mins**



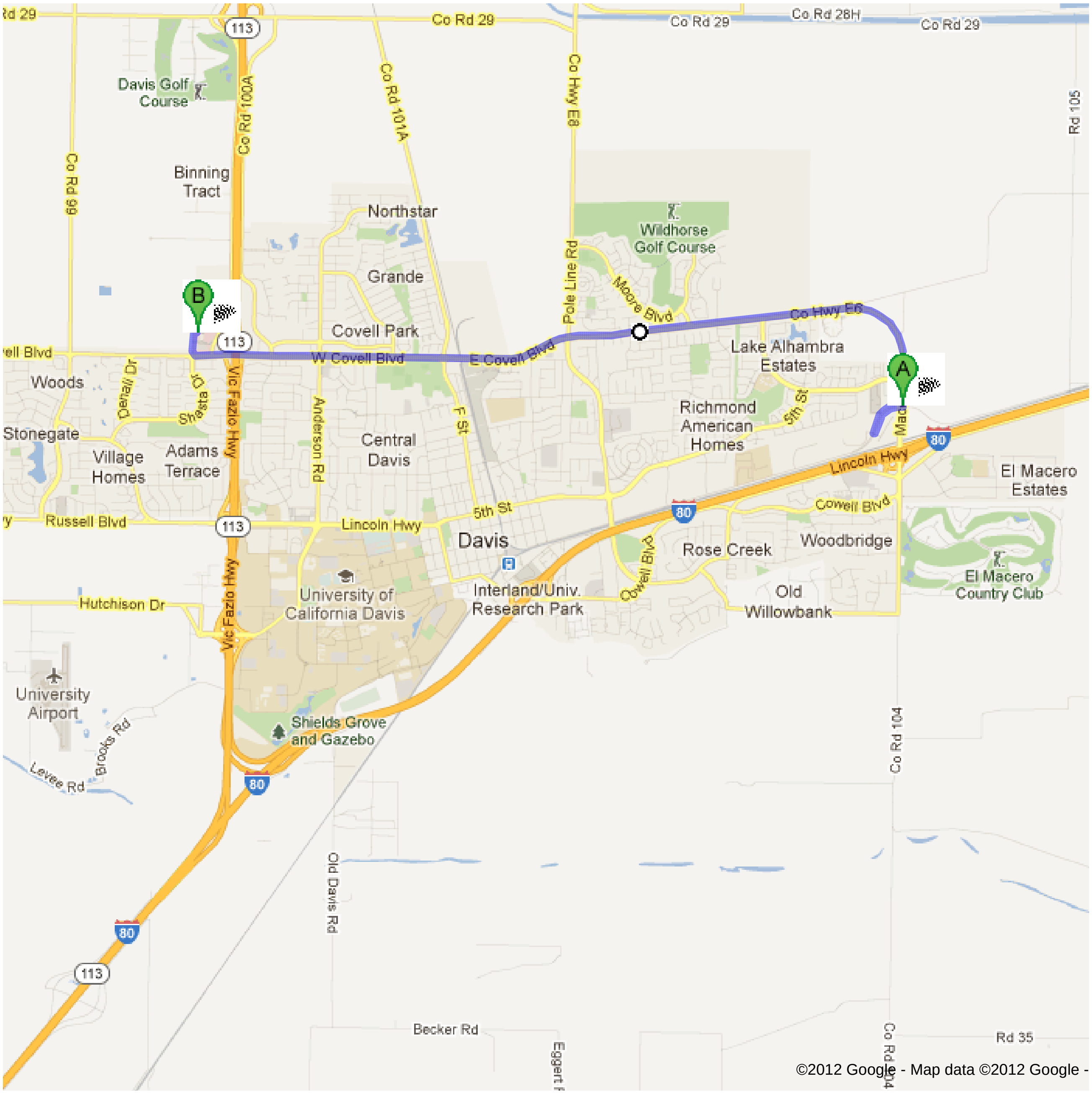
Shasta Dr & Arlington Blvd, Davis, CA 95616

1.	Head **northeast** on **Shasta Dr** toward **Denali Dr**	go 0.3 mi total 0.3 mi
2.	At the traffic circle, continue straight to stay on **Shasta Dr** About 1 min	go 0.6 mi total 1.0 mi
3.	**Shasta Dr** turns slightly left and becomes **Risling Ct** About 54 secs	go 0.1 mi total 1.1 mi
4.	**Risling Ct** turns right and becomes **Sutter Pl** Destination will be on the right	go 135 ft total 1.1 mi

Sutter Davis Hospital Imaging
2000 Sutter Place, Davis, CA 95616

Google

Directions to Sutter Davis Hospital Imaging
2000 Sutter Place, Davis, CA 95616
5.4 mi – about **15 mins**



A Mace Blvd & 2nd St, Davis, CA 95618

1.	Head **west** on **2nd St/Co Rd 32A** toward **Faraday Ave**	go 0.3 mi total 0.3 mi
2.	Make a U-turn at **Faraday Ave** About 56 secs	go 0.3 mi total 0.5 mi
3.	Turn left onto **Co Rd 104/Mace Blvd** About 56 secs	go 0.4 mi total 1.0 mi
4.	Continue onto **E Covell Blvd** About 12 mins	go 4.3 mi total 5.3 mi
5.	Turn right onto **Risling Ct**	go 0.1 mi total 5.4 mi
6.	**Risling Ct** turns right and becomes **Sutter Pl** Destination will be on the right	go 135 ft total 5.4 mi

B **Sutter Davis Hospital Imaging**
2000 Sutter Place, Davis, CA 95616

These directions are for planning purposes only. You may find that construction projects, traffic, weather, or other events may cause conditions to differ from the map results, and you should plan your route accordingly. You must obey all signs or notices regarding your route.

Directions weren't right? Please find your route on maps.google.com and click "Report a problem" at the bottom left.

Appendix B

Source Water Feed Pump Data and Specification Sheets

Tag # P-103; Model # S-07528-30

MASTERFLEX® L/S®

OPERATING MANUAL:

L/S® PRECISION VARIABLE SPEED CONSOLE DRIVES

MASTERFLEX® L/S® 07528-10

Model Nos.

07528-10
07528-20
07528-30

A-1299-1059
Edition 01

Cole-Parmer®
1-800-MASTERFLEX (627-8373) (U.S. and Canada only) • 11 (847) 549-7600 (Outside U.S.)
(847) 549-7600 (Local) • www.masterflex.com • techinfo@coleparmer.com

ORIGINAL INSTRUCTIONS

A-1299-1059

01	17651	110520	First Edition	RW
REV	**ECR/ECN**	**DATE**	**DESCRIPTION**	**By**

SAFETY PRECAUTIONS

DANGER: Remove power from the pump before any cleaning operation is started.

WARNING: Remove power from the pump before attempting any maintenance.

WARNINGS: Tubing breakage may result in fluid being sprayed from pump. Use appropriate measures to protect operator and equipment.

Turn Pump System off before removing or installing tubing. Fingers or loose clothing could get caught in drive mechanism.

CAUTIONS: When changing flow direction, allow the pump to come to a complete stop before starting again. Failure to do so could cause permanent damage to the motor.

Replace the fuse only with one of the same type and rating. The fuse rating and type are stated on the rear panel.

CAUTION: To avoid electrical shock, the power cord protective grounding conductor must be connected to ground. Not for operation in wet locations as defined by EN61010-1.

If the product is not used in a manner specified in the instructions, the protection provided by the equipment may be impaired.

Explanation of Symbols

CAUTION: Risk of Danger. Consult Operator's manual for nature of hazard and corrective actions.

CAUTION: Risk of crushing. Keep fingers away from rotor while pump is in operation. Stop pump before loading or unloading tubing.

CAUTION: Hot Surface. Do not touch.

CAUTION: Risk of electric shock. Consult Operator's manual for nature of hazard and corrective actions.

WARNING: Product Use Limitation

This product is not designed for, nor intended for use in patient connected applications; including, but not limited to, medical and dental use, and accordingly has not been submitted for FDA approval.

This product is not designed for, nor intended for use in hazardous duty areas as defined by ATEX or the NEC (National Electrical Code); including, but not limited to use with flammable liquids.

Safety

1. Read instructions before operating the unit.
2. Observe safety precautions at all times, especially when pumping dangerous liquids.
3. If the pump runs unusually noisy or if bunching of the tubing in the pump can be observed, make sure the tubing is clamped down tightly and/or replace it with a new piece of tubing.
4. The L/S Precision Variable-Speed Console Drives must be well-grounded at all times.
5. The L/S Precision Variable-Speed Console Drives are equipped with a current-limiting circuit that will shut the motor down if any of the following conditions exist:
   a. Tubing that is too hard is loaded in the pump.
   b. Incorrect tubing size or wall thickness is loaded in the pump.
   c. Tubing is improperly loaded into the Pump Head.
6. The unit is fused and grounded to protect the operator in the event of short circuits that could be caused by liquid entering the case.

CAUTION: Replace the fuse only with one of the same type and rating. The fuse rating and type are stated on the rear panel.

7. The L/S Precision Variable-Speed Console Drives should not be used in outdoor or hazardous locations.

Table of Contents

Figures

Page

Section 1 Introduction

General Description

The L/S Precision Variable-Speed Console Drives control the speed of MASTERFLEX® Pump Heads to provide flow rates from 0.06 to 3400 mL/min.

The 300 and 600 rpm L/S Precision Variable-Speed Console drives can mount up to two (2) MASTERFLEX Pump Heads or other pumps adapted to MASTERFLEX drives.

The 100 rpm L/S Precision Variable-Speed Console drive can mount up to four (4) MASTERFLEX Pump Heads or other pumps adapted to MASTERFLEX drives.

Application Solutions

Advantages of Peristaltic Pumps:

- Handle abrasive slurries and corrosive fluids with minimal wear. Ideal for titanium dioxide or diatomaceous earth filter aid applications.
- Low maintenance; sealless and valveless design
- Valveless design prevents clogging.
- Inner surfaces are smooth and easy to clean.
- Contamination free; fluid contacts only the tubing or tube material.
- Suction lift and priming up to 8.8m water column at sea level.
- Low shearing for handling the most shear sensitive of fluids such as latex or fire fighting foam.
- Capable of running dry and pumping fluids with high quantities of entrained air, such as black liquor soap.
- High volumetric efficiency allows operation in metering or dosing applications where high accuracy is required.
- Handles extremely viscous fluids.
- Availability of tubing and tube materials that are suitable for food and pharmaceutical use.

Controls, Indicators and Connectors

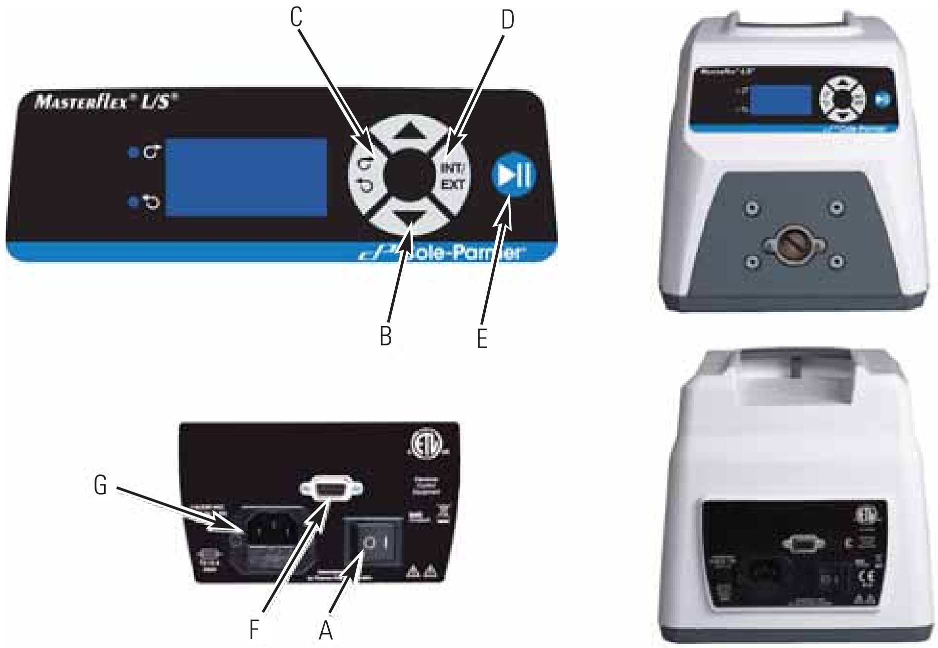


Figure 1-1. Controls, Indicators and Connectors

A. **POWER (ON/OFF) SWITCH**: Turns the unit ON or OFF.

B. **SPEED KEYS:** Sets the speed of the pump. The higher the number, the faster the speed of the pump. When the speed key is depressed the smallest speed units change first followed by an increasing rate of change.

C. **FLOW DIRECTION KEY:** Sets the direction of pump rotation Clockwise/Counterclockwise. An LED annunciator indicates the active direction. The motor is brought to a controlled stop before reversing direction.

D. **INTERNAL/EXTERNAL KEY:** Changes the drive operation mode. Internal (Local) operation from the front panel keypad is designated by INT, external (Remote) operation is designated by EXT. In INT mode, START/STOP, FLOW DIRECTION, and SPEED keys on the front panel determine operating state. Depression and release of keys enables toggling between the two operating states.

E. **START/STOP KEY:** Upon depression, key toggles the motor ON/OFF during INT mode. This key will not start the drive if in EXT mode. If pressed while operating in EXT mode (stop desired), the button will always stop the drive and a toggle of the EXT Start/Stop is required to restart the drive.

F. **EXTERNAL/REMOTE CONNECTOR:** Utilized to connect wiring for remote control operation with a DB9 connector.

G. **IEC Power Entry Module/Line Cord:** Utilized to connect line cord to drive. See *page 4-1* for alternative cords.

Section 2 Installation and Setup

Before Starting Drive

- The drive should be mounted on a flat horizontal surface. Up to a maximum of two (2) Pump Heads can be added for 300 rpm and 600 rpm drives or four (4) Pump Heads for 100 rpm drives.
- The ambient air temperature should not exceed 104° F (40° C) and adequate air flow should be provided for.
- The drives are provided with a grounded plug. If used in a GFCI protected circuit, nuisance tripping may occur.
- Tubing should be clean and routed so that bend radii are at a minimum four (4) times the tube diameter and as short as possible.

WARNING: Turn drive off before removing or installing tubing. Fingers or loose clothing could get caught in drive mechanism.

- Use a tube size of appropriate diameter for the flow rate and viscosity required.
- For tubing selection and compatibility, see *Tubing Selection Guide* within this CD.
- For Pump Head information, see *Pump Head* datasheets within this CD.
- Before cleaning or conducting maintenance on unit remove power from the drive.

DANGER: High voltages exist and are accessible. Use extreme caution when servicing internal components.

Mounting the Pump Head

Mount Pump Head and load tubing (See *Pump Head* datasheets within this CD). Check to ensure that rollers are clean and free of defects.

Section 3 Operation

Inserting Tubing

WARNINGS: Tubing breakage may result in fluid being sprayed from pump. Use appropriate measures to protect operator and equipment.

Turn Pump System off before removing or installing tubing. Fingers or loose clothing could be caught in the pump mechanism.

CAUTION: To avoid electrical shock, the power cord protective grounding conductor must be connected to ground. Not for operation in wet locations as defined by EN61010-1.

If the product is not used in a manner specified in the instructions, the protection provided by the equipment may be impaired.

Tubing Inspection and Replacement

Tubing should be inspected periodically for tears, cracks, cut marks, abrasions, inability to hold pressure, bubbles in the flow stream and reduction or loss of flow.

Tubing life may be extended by periodically moving the worn tubing inside the occlusion bed of the pump to the outside of the occlusion bed to the suction side of the pump. This will avoid excessive tubing wear at any specific point.

Always move the worn tubing to the suction side of the pump.

Pump Controls

CAUTION: When changing flow direction, allow the pump to come to a complete stop before starting again. Failure to do so could cause permanent damage to the motor.

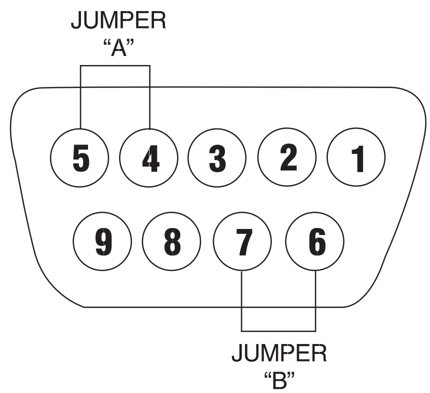
1. Make sure the speed is set to the minimum setting.
2. Turn the power switch ON. Increase the speed to start the pump action. The higher the rpm setting, the faster the speed of the pump.
3. The L/S Precision Variable-Speed Console Drives are self-priming. To begin pumping, select a flow direction with the flow direction button, insert the intake and output tubing into a reservoir, and turn the unit ON. Prime the tubing for at least 5 minutes. If accurate flow control is important, allow the pump to prime for approximately 20 minutes for more stable flow conditions.

Keypad Lockout Enable/Disable

Press and hold the INT/EXT key. After five (5) seconds, display will change to all dashes. Release INT/EXT key and press UP ARROW key (▲) five (5) times. Repeat this process to unlock the keypad. When the keypad is locked out, display will change to display all dashes (- - - - -) when a key is depressed.

External Operation

Models are equipped with inputs that can be controlled by external signals connected at the rear panel 9-pin "D" shell connector. The external inputs permit control of the pump by remote equipment or accessories. Figure 3-1 indicates the signal locations in the connector.



Note: Jumpers "A" and "B" are optional. See *page 3-3 External Inputs* for correct usage.

Pin No.	Description
1	Speed Control Voltage Input (0–10V) (+) input
2	Speed Control Current Input (4–20 mA) (+) input
3	Speed Control Input Reference Common
4	Local/Remote Speed Control
5	Local/Remote Speed Control Reference
6	Start/Stop and CW/CCW Reference
7	Start/Stop (+) Control
8	CW/CCW
9	Chassis (Earth) Ground

Figure 3-1. DB9 Pin Configuration with Wiring Scheme

External Inputs

The front INT/EXT key enables external functions. Switching to INT on the display disables the external functions, allowing the front panel controls to operate the pump.

When the INT/EXT key is in the EXT position, starting and stopping the pump is controlled by an external contact closure between pins 6 and 7 (Jumper B), and the pump speed is determined by an externally supplied 0–10V or 4–20 mA source. Connection must be made between pins 6 and 7 to Start/Stop the drive and a control voltage greater than 0V between pins 1 and 3 or a control current greater than 4 mA between pins 2 and 3 must be applied for the pump to run.

If setting the speed from the front panel is desired with external Start/Stop contact operation, the INT/EXT key must again be in the EXT position. In addition, Jumper A should be in place. Jumper A connects pin 4 of the "D" shell connector (Local/Remote) to pin 5 (Local/Remote Reference). Start/Stop will then be controlled from the rear panel (Jumper B), and the pump speed will be controlled from the front panel. The accessory Footswitch (part no. 77595-35) and Handheld Remote Controller (part no. 07528-80) are connected internally in this way.

NOTE: The signal common for the speed control voltage and current inputs is not referenced to earth ground.

The START/STOP (pin 7), CW/CCW (pin 8) and Local/Remote (pin 4) are digital inputs. They are internally pulled up to +5 V with respect to earth ground via pins 5 and 6. They can alternately be driven with open collector logic. For increased noise immunity, use of contact closures is recommended.

Section 4 Maintenance

Replacement Parts

WARNING: Remove power from the pump before attempting any maintenance.

Description	Part Number
Brushes (set of 2)	07520-04
Brush Cap Holder	07520-03
Fuse-T3.15A, 5 x 20 mm	77500-25
Gear Service Kit (600 & 300)	07553-06
Gear Only (600 & 300 rpm)	07553-09
Gear Service Kit (100 rpm)	07553-08
Ferrite, Line Cord Snap-on, (CE Required)	B-3689-CR
Line Cord, Australia	50001-60
Line Cord, Denmark	50001-62
Line Cord, India	50001-64
Line Cord (115V), United States	50001-68
Line Cord, Israel	50001-69
Line Cord, Europe	50001-70
Line Cord, England	50001-72
Line Cord, Switzerland	50001-74
Line Cord, Italy	50001-76
Line Cord (230V), United States	50001-78
Line Cord, China	50001-79

Fuse Replacement

1. Place the power switch in the off position.
2. Disconnect the AC power input line cord from the receptacle.
3. Remove and check the fuse and replace if defective.

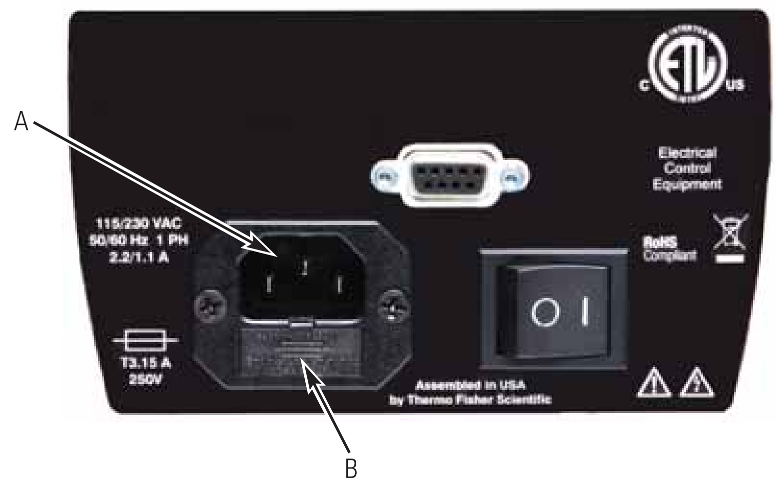
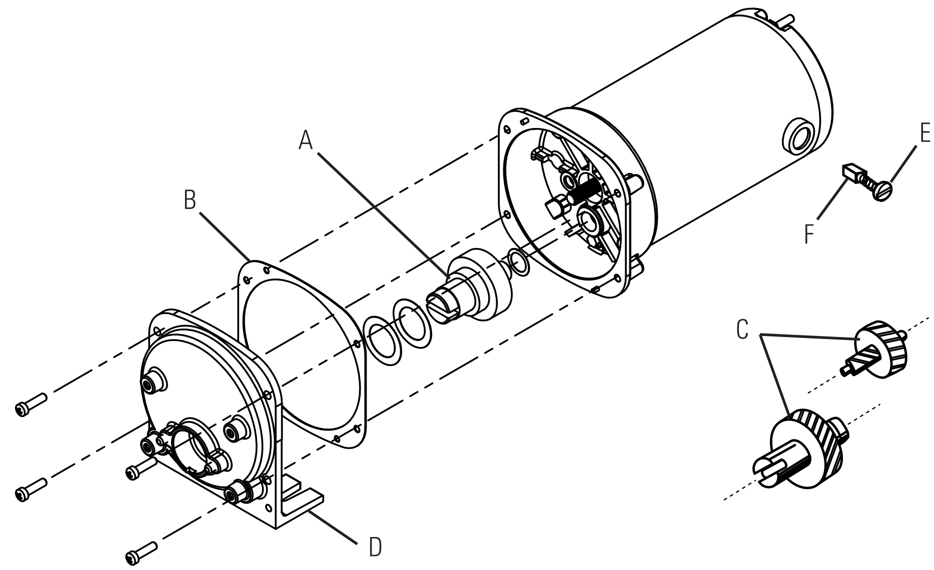


Figure 4-1. Fuse Replacement

Item	Description
A	IEC Power Entry Module / Line Cord
B	3.15A (5×20 mm) Fuse – Do Not Substitute

Motor Gear and Brush Replacement



A. 6-600 & 3-300 rpm gear assembly (included in service kit 07553-06)
B. Gasket
C. 1-100 rpm gear set (included in service kit 07553-08)
D. Gear Case cover assembly
E. Brush Cap
F. Motor Brush (set of two included in 07520-04)

Figure 4-2. Motor Gear and Brush Replacement

Cleaning

WARNING: Remove power from the pump before any cleaning operation is started.

Keep the drive enclosure clean with mild detergents. Do not immerse or use excessive fluid when cleaning.

Section 5 Troubleshooting

Troubleshooting Chart

Symptom	Remedy
Unit will not turn on	If the unit is plugged into a GFCI protected circuit verify that the circuit has not been tripped or reset the circuit.
	Verify that the unit is plugged into a functioning outlet.
	Verify that the power cord is firmly attached to the unit.
	Verify that the fuse for the incoming voltage is not blown (located in the slot next to the power cord).
Unit will turn on but pump will not spin	Check the tubing. Tubing should be snug, but not tight, against the rollers.
	Verify that the mode EXT/INT is set correctly.
Error XX is displayed on the screen	Err's 3 & 10, check pump for obstructions, all other Errs return unit for repair.
Unit will turn on but display would dim and pump will not spin	Verify that the incoming voltage meets the required minimum of 90Vrms.
Unit vibrates excessively when pump is running	Check that the tubing was loaded properly.

Section 6 Accessories

Accessories

1.	Footswitch w/DB-9 male	77595-35
2.	Handheld Remote Controller	07528-80
3.	DB-9 External Control Connector	07595-45
4.	DB-9 Remote control cable, 25 FT.	07595-47
5.	Tilt Bail	07523-98

Section 7 Specifications

Output:	
Speed:	
07528-30	1 - 100 rpm
07528-20	3 - 300 rpm
07528-10	6 - 600 rpm
Torque, Maximum:	
300 & 600 rpm models	180 oz-in (13 kg•cm), 540 oz-in Starting
100 rpm models	360 oz-in (26 kg•cm), 1080 oz-in Starting
Input:	
Operating Voltage/Frequency:	90-260Vrms, 50/60 Hz, 2.2A @ 115Vrms, 1.1A @ 230 Vrms
External Inputs:	
START/STOP, CW/CCW, Remote/Local Speed Control	Contact closure
Voltage input	0–10V DC @ 10 kohm,
Accuracy:	±0.5% Full Scale
Current input	4–20 mA @ 250 ohm,
Accuracy:	±0.5% Full Scale
Environment:	
Operating Temperature:	32 to 104°F (0 to 40°C)
Storage Temperature:	-13 to 149°F (-25 to 65°C)
Humidity:	10% to 90% non-condensing
Altitude:	Less than 6562 ft (2000 m)
Pollution Degree:	Pollution degree 2 (indoor use–lab, office)
Construction:	
Dimensions (L × W × H):	10.5 in × 8 in × 8 in (267 × 203 × 203 mm)
Weight:	6.9 kgs (15.2lbs)
Color:	Light Grey (5% Black)
Material:	Aluminum, ABS plastic and vinyl
Enclosure Rating:	IP33 per IEC-60529

Compliance: UL 61010-1, CAN/CSA-C22.2 No. 61010-1
This product has been tested to the requirements of CAN/CSA-C22.2 No. 61010-1, second edition, including Amendment 1, or a later version of the same standard incorporating the same level of testing requirements.
(For CE Mark):
EN61010-1: (EU Low Voltage Directive) and
EN61326: (EU EMC Directive)

Section 8 Warranty, Product Return and Technical Assistance

Warranty

Use only MASTERFLEX precision tubing with MASTERFLEX pumps to ensure optimum performance. Use of other tubing may void applicable warranties.

This product is warranted against defects in material or workmanship, and at the option of the manufacturer or distributor, any defective product will be repaired or replaced at no charge, or the purchase price will be refunded to the purchaser, provided that: (a) the warranty claim is made in writing within the period of time specified on the warranty card, (b) proof of purchase by bill of sale or receipted invoice is submitted concurrently with the claim and shows that the product is within the applicable warranty period, and (c) the purchaser complies with procedures for returns set forth in the general terms and conditions contained in the manufacturer's or distributor's most recent catalog.

This warranty shall not apply to: (a) defects or damage resulting from: (i) misuse of the product, (ii) use of the product in other than its normal and customary manner, (iii) accident or neglect, (iv) improper testing, operation, maintenance, service, repair, installation, or storage, (v) unauthorized alteration or modification, or (b) post-expiration dated materials.

THIS WARRANTY IS THE EXCLUSIVE REMEDY OF THE PURCHASER, AND THE MANUFACTURER AND DISTRIBUTOR DISCLAIM ALL OTHER WARRANTIES, WHETHER EXPRESS, IMPLIED, OR STATUTORY, INCLUDING WITHOUT LIMITATION, WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. NO EMPLOYEE, AGENT, OR REPRESENTATIVE OF THE MANUFACTURER OR DISTRIBUTOR IS AUTHORIZED TO BIND THE MANUFACTURER OR DISTRIBUTOR TO ANY OTHER WARRANTY. IN NO EVENT SHALL THE MANUFACTURER OR DISTRIBUTOR BE LIABLE FOR INCIDENTAL, INDIRECT, SPECIAL OR CONSEQUENTIAL DAMAGES.

The warranty period for this product is two (2) years from date of purchase.

Product Return

To limit charges and delays, contact Cole-Parmer or authorized seller for authorization and shipping instructions before returning the product, either within or outside of the warranty period. When returning the product, please state the reason for the return. For your protection, pack the product carefully and insure it against possible damage or loss. Any damages resulting from improper packaging are your responsibility.

Technical Assistance

If you have any questions about the use of this product, contact the Cole-Parmer or authorized seller.

Cole-Parmer®

1-800-MASTERFLEX (627-8373) (U.S. and Canada only)
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(847) 549-7600 (Local)
www.masterflex.com
techinfo@coleparmer.com

Printed in U.S.A.

Tag # P-100/101/102; Model # 5740-02

OPERATING MANUAL

MASTERFLEX® L/S®

FIXED FLOW PUMP DRIVES

Model Nos.

7540-01	7540-30	7542-12
7540-02	7540-60	7542-20
7540-06	7542-01	7542-30
7540-12	7542-02	7542-60
7540-20	7542-06	

Note: Drive is shown with optional Pump Head.

Cole Parmer®

Cole-Parmer Instrument Co.

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(847) 549-7600 (Local)
www.masterflex.com

Barnant Company

1-800-637-3739 (U.S. and Canada only)
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(847) 381-7050 (Local)
www.barnant.com

ISO 9001 SUPPLIER CERTIFIED

A-1299-1034
Edition 02

ISO 9001 REGISTERED

TABLE OF CONTENTS

SAFETY PRECAUTIONS

WARNINGS: ***To reduce risk of electrical shock, connect only to a properly grounded, grounding-type receptacle.***

Remove power from the drive before attempting any maintenance.

Remove power before any cleaning operation is started.

WARNINGS: ***Tubing breakage may result in fluid being sprayed from pump. Use appropriate measures to protect operator and equipment.***

Turn drive off before removing or installing tubing. Fingers or loose clothing could be caught in the drive mechanism.

WARNING: PRODUCT USE LIMITATION

These products are not designed for, nor intended for use in, patient-connected applications, including, but not limited to, medical and dental use, and, accordingly, have not been submitted for FDA approval.

Trademarks bearing the ® symbol in this publication are registered in the U.S. and in other countries.

INTRODUCTION AND GENERAL DESCRIPTION

The MASTERFLEX® L/S® fixed flow drives provide continuous fixed speed pumping of fluids while power is supplied.

Different models provide various speeds as summarized:

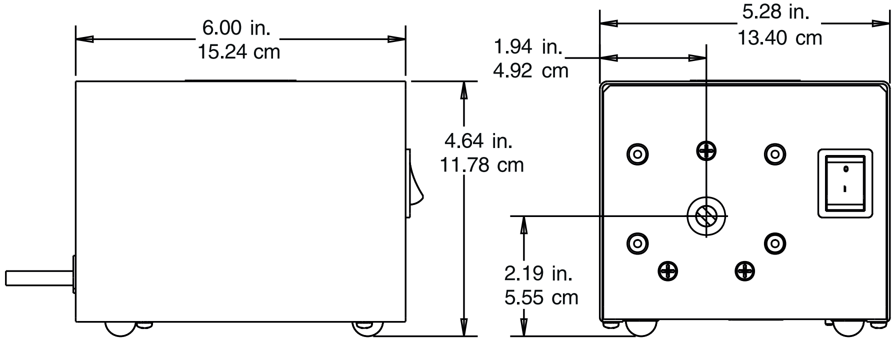
Model#	Description	Speed (rpm)	Pump Heads Accepted
7540-01	L/S Fixed Speed, 115V AC, 60 Hz	1	2
7540-02	L/S Fixed Speed, 115V AC, 60 Hz	2	2
7540-06	L/S Fixed Speed, 115V AC, 60 Hz	6	2
7540-12	L/S Fixed Speed, 115V AC, 60 Hz	12	2
7540-20	L/S Fixed Speed, 115V AC, 60 Hz	20	2
7540-30	L/S Fixed Speed, 115V AC, 60 Hz	30	2
7540-60	L/S Fixed Speed, 115V AC, 60 Hz	60	1
7542-01	L/S Fixed Speed, 230V AC, 50 Hz	1	2
7542-02	L/S Fixed Speed, 230V AC, 50 Hz	2	2
7542-06	L/S Fixed Speed, 230V AC, 50 Hz	5	2
7542-12	L/S Fixed Speed, 230V AC, 50 Hz	10	2
7542-20	L/S Fixed Speed, 230V AC, 50 Hz	17	2
7542-30	L/S Fixed Speed, 230V AC, 50 Hz	25	2
7542-60	L/S Fixed Speed, 230V AC, 50 Hz	50	1

SETUP AND OPERATION

Use only MASTERFLEX precision tubing with MASTERFLEX pumps to ensure optimum performance.
Use of other tubing may void applicable warranties.

Unpack the drive and retain all packing material until proper product operation has been verified. Select the pump head and tubing according to the flow desired, while considering chemical compatibility and tubing life. Pump installation instructions are included with the pump head. Connect the line cord to a grounded three-wire AC receptacle.

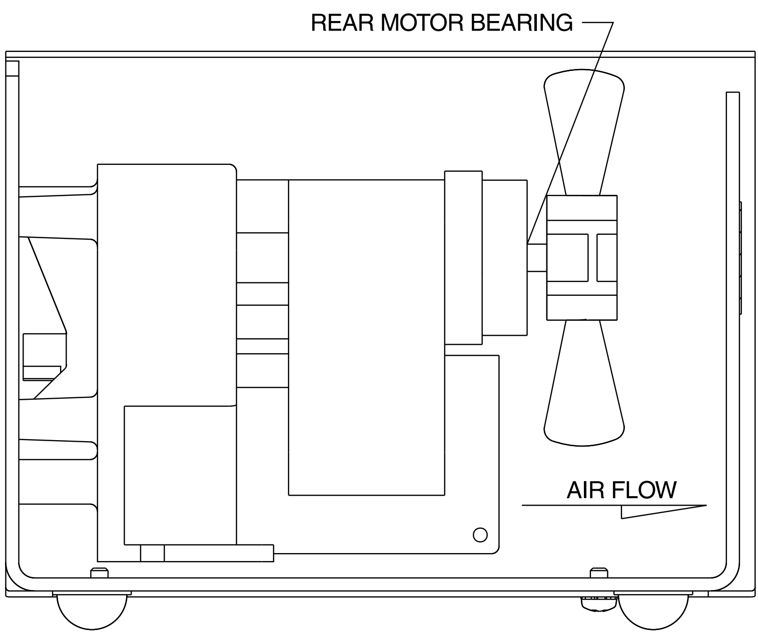
The following sketch shows the dimensional outline of the drive:



MAINTENANCE

WARNING: Remove power from the drive before attempting any maintenance.

The rear motor bearing should be given two drops of #20 non-detergent oil every three months. **Do not over oil.** Clean off any accumulated dust or dirt. The drive gear/motor assembly can be replaced if necessary. Exact “life” will depend on the number of heads and the speed used.



Cleaning

WARNING: Remove power before any cleaning operation is started.

Keep the drive enclosure clean by using a mild detergent solution. Never immerse or use excessive fluid when cleaning the drive.

SPECIFICATIONS

Output:

Model#	Speed (rpm)	Torque (in-oz)	Torque (kg-cm)	Pump Heads	Current (Amps)
7540-01	1	180	16	2	.3
7540-02	2	180	16	2	.3
7540-06	6	180	16	2	.5
7540-12	12	180	16	2	.5
7540-20	20	180	16	2	.6
7540-30	30	180	16	2	.9
7540-60	60	90	8	1	.9

Model#	Speed* (rpm)	Torque (in-oz)	Torque (kg-cm)	Pump Heads	Current (Amps)
7542-01	1	180	16	2	.2
7542-02	2	180	16	2	.2
7542-06	5	180	16	2	.2
7542-12	10	180	16	2	.2
7542-20	17	180	16	2	.4
7542-30	25	180	16	2	.4
7542-60	50	90	8	1	.4

***Note:** Speed for the 7542 series drives is 5/6 that of the 7540 series due to operation at 50 Hz. All motors are thermally protected.

Input:

Operating Voltage/Frequency:

7540 Series 115V AC ± 10%, 60 Hz

7542 Series 230V AC ± 10%, 50 Hz

SPECIFICATIONS (Cont.)

Environment:	
Operating Temperature:	0°C to 40°C
Storage Temperature:	–25°C to 65°C
Humidity:	10% to 90% non-condensing
Altitude:	Less than 2000 meters
Pollution Degree:	Pollution degree 2 (indoor usage—lab,office)
Construction:	
Dimensions (L x W x H):	15.2 cm x 13.4 cm x 11.8 cm (6 in x 5.3 in x 4.6 in)
Weight:	3 kgs (6.5 lbs)
Color:	Ghost Gray and black
Material:	Painted steel housing
Enclosure Rating:	IP22 per IEC 60529
Compliance:	115 V UL778, CSA C22.2 No. 108-01 230V (For CE Mark): EN61010-1 (EU Low Voltage Directive) and EN61326 (EU EMC Directive)

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(847) 381-7053 (Local Fax)
www.barnant.com
e-mail: barnant@barnant.com
ISO 9001 REGISTERED

Printed in U.S.A.

Tag # P-104,
Model # 07554-90

MASTERFLEX®

L/S®

07554-80 with pump head 07518-12

OPERATING MANUAL:
PUMP DRIVES

MANUEL DE L'UTILISATEUR :
ENTRAÎNEMENTS DE POMPE

BEDIENUNGSANLEITUNG:
PUMPENANTRIEBE

MANUAL DE OPERACIÓN:
PROPULSORES DE LA BOMBA

MANUALE DI ISTRUZIONI:
AZIONAMENTI

Model No.
N° de modèle
Modellnummern
Modelo No.
Modello No.

7554-80
7554-85
7554-90
7554-95

ISO 9001 SUPPLIER CERTIFIED

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A-1299-0650
Edition 02

SAFETY PRECAUTIONS

DANGER: High voltages exist and are accessible in the Console Drive. Use extreme caution when servicing internal components.

WARNING: PRODUCT USE LIMITATION

This product is not designed for, nor intended for use in patient connected applications; including, but not limited to, medical and dental use, and accordingly has not been submitted for FDA approval.

Variety of Pump Heads Accepted

Mount up to 1 (600 rpm) or 2 (200 rpm) MASTERFLEX® L/S® pump heads and all MASTERFLEX-compatible pump heads.

Setup and Drive Operation

1. Mount pump head and load tubing. (See pump head manual.)
2. Adjust flow rate with the 1-turn potentiometer speed control.

MESURES DE SÉCURITÉ

DANGER: Des hautes tensions existent et sont présentes dans la console. Soyez très prudent lors de l'entretien des composants internes.

AVERTISSEMENT: LIMITATION D'UTILISATION DU PRODUIT

Ce produit n'est pas conçu ni supposé être utilisé dans les applications relatives à des patients; y compris, mais sans s'y limiter, l'utilisation médicale ou dentaire, et par conséquent n'a pas été soumis à l'accord de la FDA.

Variété de têtes de pompe acceptées

Supporte 1 (600 t/min) ou 2 (200 t/min) têtes de pompe L/S® MASTERFLEX® et toutes les têtes de pompe compatibles MASTERFLEX.

Configuration et fonctionnement de l'entraînement

1. Monter la tête de la pompe et charger le tube. (Voir le manuel de tête de pompe.)
2. Régler le débit de la pompe avec la commande de vitesse du potentiomètre à 1 tour.

SICHERHEITSMASSNAHMEN

GEFAHR: Im Antrieb herrscht Hochspannung, die unter Umständen zugänglich ist. Äußerste Vorsicht beim Öffnen des Gehäuses!

ACHTUNG: ANWENDUNGSEINSCHRÄNKUNGEN

Dieses Gerät ist nicht für den Einsatz am Patienten vorgesehen und auch nicht für diesen Zweck bestimmt (z. B.im medizinischen oder zahnmedizinischen Bereich) und entspricht demgemäß auch keinen FDA (Food & Drug Administration) Normen.

Auswahlmöglichkeiten der Pumpenköpfe

Bis zu 1 (600 U/min) oder 2 (200 U/min) MASTERFLEX® L/S® Pumpenköpfe und alle MASTERFLEX-kompatiblen Pumpenköpfe.

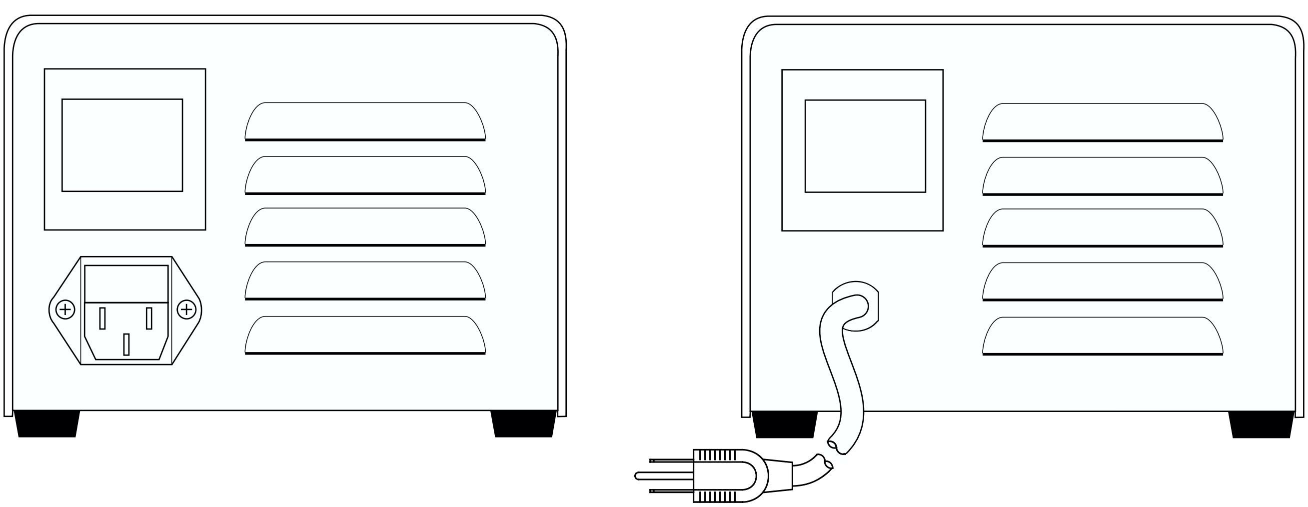
Montage und Betrieb

1. Pumpenkopf montieren und Schlauch einlegen. (Siehe Bedienungsanleitung für Pumpenköpfe.)
2. Einstellen der Fördermenge mittels de 1-Gang Potentiometer.

Rear view of drive
Vue arrière de la pompe
Rückansicht des Antriebs
Vista Posterior del Propulsor
Vista posteriore dell' azionamento

A) IEC Power Entry module (230VAC)
Prise IEC 320 (230VAC)
Netzanschluß (230VAC)
Modulo de entrada de energía (230VAC)
Presa di alimentazione IEC 320 (230VAC)

B) 115V Cable
Câble 115V
115V Anschluß
Cable 115V
Cavo 115V



PRECAUCIONES DE SEGURIDAD

PELIGRO: Existe alto voltaje y está al alcance en la Consola del Propulsor. Tenga extrema precaución cuando esté revisando los componentes internos.

ADVERTENCIA: RESTRICCIONES EN EL USO DEL PRODUCTO

Este producto no está diseñado ni destinado para ser usado en aplicaciones conectadas en pacientes, incluyendo, pero no limitado a, uso médico y dental, y por lo tanto no ha sido sometido a la aprobación del FDA.

Variedad de las Cabezas de Bomba Aceptadas

Instale hasta 1 (600 rpm) o 2 (200 rpm) cabezas de bomba MASTERFLEX® L/S® y todas las cabezas de bomba compatibles con MASTERFLEX.

Montaje y Operación del Propulsor

1. Instale la cabeza de la bomba y cargue la tubería. (Vea el manual de la cabeza de la bomba.)
2. Ajuste la rata de flujo mediante el giro del control de velocidad del potenciómetro de 1 vuelta.

PRECAUZIONI RIGUARDANTI LA SICUREZZA

PERICOLO: nell'azionamento si trovano componenti ad alto voltaggio. Prestare la massima attenzione durante lavori di manutenzione.

ATTENZIONE: LIMITI DI USO DEL PRODOTTO

Questo prodotto non ha l'approvazione FDA per uso medico o dentistico. Non usarlo direttamente sui pazienti.

Compatibilita' con teste pompanti

Possibilità di installare fino a 1 (600 g/min) o 2 (200 g/min) teste pompanti MASTERFLEX® L/S® o teste pompanti compatibili con le MASTERFLEX.

Avvio e funzionamento

1. Installare la testa pompante ed inserire il tubo. (Cfr. il manuale della testa pompante.)
2. Regolare la portata con il potenziometro da 1 giri per il controllo della velocità.

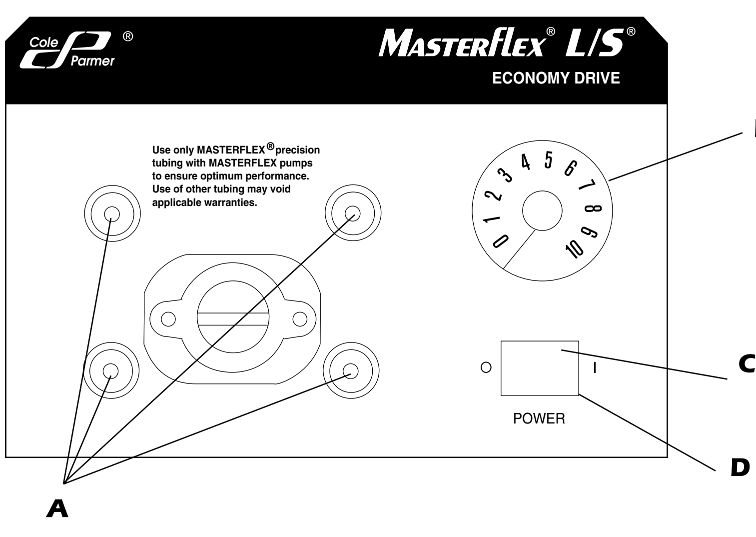
SAFETY PRECAUTIONS
SETUP AND DRIVE OPERATION

MESURES DE SÉCURITÉ
CONFIGURATION ET FONCTIONNEMENT DE L'ENTRAINEMENT

SICHERHEITSMASSNAHMEN
MONTAGE UND BETRIEB

PRECAUCIONES DE SEGURIDAD
MONTAJE Y OPERACIÓN DEL PROPULSOR

PRECAUZIONI RIGUARDANTI LA SICUREZZA
AVVIO E FUNZIONAMENTO



A) PUMP HEAD MOUNTING HOLES
POINTS DE FIXATION DE LA TÊTE DE POMPE
ÖFFNUNGEN FÜR DIE MONTAGE DER PUMPENKÖPFE
ORIFICIOS DE MONTAJE PARA LA CABEZA DE LA BOMBA
FORI DI FISSAGGIO DELLA TESTA POMPANTE

B) 1-TURN SPEED CONTROL
POTENTIOMETRE 1 TOUR
1-GANG POTENTIOMETER
GIRO DEL CONTROL DE VELOCIDAD DE 1 VUELTA
POTENZIOMETRO A 1 GIRO

C) POWER INDICATOR
Illuminates when power is on.
INDICATEUR D'ALIMENTATION
S'allume lorsque l'appareil est sous tension.
BETRIEBSANZEIGE
Leuchtet auf, wenn das Gerät eingeschaltet ist.
INDICADOR DE ENERGIA
Está iluminado cuando la unidad está encendida.
SPIA DI ALIMENTAZIONE
Si illumina a unità accesa.

D) POWER SWITCH
COMMUTATEUR D'ALIMENTATION
EIN/AUS SCHALTER
INTERRUPTOR DE ENERGIA
COMMUTATORE DI ALIMENTAZIONE

MOTOR BRUSH CHECK/REPLACEMENT

NOTE: Brushes should be checked every 6 months or 2000 operating hours if erratic operation occurs.

DANGER: High voltages exist and are accessible in the Console Drive. Use extreme caution when servicing internal components.

1. Place the POWER SWITCH in the off position.
2. Disconnect the AC power input line cord from the AC receptacle.
3. Remove the screws from each side of the housing and lift off the housing.
4. Carefully unscrew each brush cap. Withdraw the brush, and examine it for wear.

NOTE: Replace both brushes, if either brush is less than 7.6 mm (0.300 in) long from base to point.

5. Insert brushes and install brush cap.
6. Install housing and secure with the screws on each side.
7. Connect the AC power input line cord to the AC receptacle.

Fuses

NOTE: These drives have current limiting which cause drive to stop under overload conditions. If drive does not start return to dealer for servicing.

INSPECTION ET REMPLACEMENT DES BALAIS DU MOTEUR

REMARQUE: Les balais doivent être inspectés tous les 6 mois ou toutes les 2000 heures de fonctionnement.

DANGER: Des hautes tensions existent et sont présentes dans la console. Soyez très prudent lors de l'entretien des composants internes.

1. Placer le COMMUTATEUR D'ALIMENTATION sur la position arrêt.
2. Débrancher le cordon d'alimentation en courant alternatif de la prise de courant alternatif.
3. Déposer les vis de chaque côté du boîtier et soulever le boîtier.
4. Dévisser soigneusement chaque capuchon de balai. Enlever le balai et examiner son usure.

REMARQUE: Remplacer les deux balais, si la longueur de l'un d'entre eux est inférieure à 7,6 mm de la base à la pointe.

5. Insérer les balais et installer le capuchon de balai.
6. Installer le boîtier et bloquez-le avec les vis de chaque côté.
7. Brancher le cordon d'alimentation en courant alternatif sur la prise de courant alternatif.

Fusibles

REMARQUE: Ces entraînements ont des limiteurs de courant qui provoquent l'arrêt de l'entraînement en cas de surcharge. Si l'entraînement ne démarre pas, renvoyer l'appareil au concessionnaire pour un entretien.

ÜBERPRÜFUNG UND AUSWECHSELN DER KOHLEBÜRSTEN

HINWEIS: Die Bürsten sollten alle 6 Monate oder 2,000 Betriebsstunden geprüft werden, wenn sich Fehler in der Anwendung bemerkbar machen.

Gefahr: Im Antrieb herrscht Hochspannung, die zugänglich ist. Äußerste Vorsicht beim Öffnen des Gehäuses!

1. Den Schalter Ein/Aus- auf AUS stellen.
2. Netzstecker ziehen.
3. Die Schrauben auf jeder Seite des Gehäuses entfernen und das Gehäuse öffnen.
4. Vorsichtig die beiden Abdeckkappen der Bürsten abschrauben. Bürsten herausnehmen und auf Abnutzungserscheinungen prüfen.

HINWEIS: Die Bürsten sind zu wechseln, wenn beide bis auf weniger als 7,6 mm (0,3 Zoll) abgenutzt sind.

5. Bürsten einsetzen und Abdeckkappen wieder befestigen.
6. Gehäuse aufsetzen und mit den Schrauben auf beiden Seiten befestigen.
7. Netzstecker wieder anschließen.

Sicherungen

HINWEIS: Diese Antriebe haben einen Auto-Stop, der bei Überlastung die Pumpe ausschaltet. Wenn ein Antrieb nicht funktioniert, geben Sie ihn Ihrem Fachhändler zur Überprüfung zurück.

CLEANING

Keep the drive enclosure clean with mild detergents. Never immerse nor use excessive fluid.

NETTOYAGE

Utiliser des détergents peu agressifs, lors du nettoyage du capot moteur. Ne pas immerger le moteur, et ne pas utiliser de liquides trop agressifs.

REINIGUNG

Gehäuse mit mildem Reiniger säubern. Nie eintauchen oder zu viel Flüssigkeit benutzen.

LIMPIEZA

Mantenga la cubierta dél motor limpia con detergentes suaves. Nunca sumerja ni utilice excesiva cantidad de liquido.

PULIZIA

Pulire la custodia degli azionamenti con detersivi non aggressivi. Non immergere mai, né usare eccessive quantitá di liquido.

REVISION DE LAS ESCOBILLAS/REEMPLAZO

NOTA: Las escobillas deberán ser revisadas cada 6 meses o cada 2000 horas de operación, si se observa un funcionamiento irregular.

PELIGRO: Existe alto voltaje que está al alcance en la Consola del Propulsor. Tenga extrema precaución cuando esté revisando los componentes internos.

1. Coloque el interruptor de energía/dirección “POWER SWITCH” en la posición de apagado.
2. Desconecte el cable de energía AC del tomacorriente AC.
3. Quite los tornillos a cada lado de la carcaza y levante la carcaza.
4. Cuídadosamente desatornille la tapa de cada escobilla. Retire las escobillas y examine si están desgastadas.

NOTA: Reemplace ambas escobillas, si cualquiera de las escobillas tiene una longitud de menos de 7,6 mm (0,3000 in) de la base a la punta.

5. Introduzca las escobillas e instale la tapa.
6. Instale la carcaza y asegúrela con los tornillos a cada lado.
7. Conecte el cable de entrada de energía AC al tomacorriente AC.

FUSIBLES

NOTA: Estos propulsores tienen limitadores de corriente que hacen que el propulsor se pare bajo condiciones de sobrecarga. Si el propulsor no arranca devuélvalo al distribuidor para que sea revisado.

CONTROLLO/SOSTITUZIONE SPAZZOLE MOTORE

N.B.: Le spazzole devono essere controllate ogni 6 mesi oppure ogni 2000h di funzionamento in caso di operazioni errate.

PERICOLO: Nell’azionamento si trovano componenti ad alto voltaggio. Prestare la massima attenzione nel trattare detti componenti.

1. Mettere l’interruttore POWER in posizione OFF.
2. Staccare il cavo di alimentazione CA.
3. Togliere le viti da ogni lato dell’involucro e sollevarlo.
4. Svitare con cura il tappo di ogni spazzola. Togliere le spazzole per verificare lo stato di usura.

N.B.: Sostituire entrambe le spazzole nel caso in cui misurino meno di 7,6 mm (0,300 in) da un’estremità all’altra.

5. Inserire le spazzole e rimettere il tappo.
6. Riporre l’involucro e fissarlo con viti su ogni lato.
7. Collegare il cavo di alimentazione CA.

Fusibili

N.B.: Questi azionamenti hanno dei limiti di corrente per cui si bloccano in caso di sovraccarico. Se l’azionamento non dovesse funzionare e' necessario farlo riparare.

MOTOR BRUSH CHECK/REPLACEMENT CLEANING

INSPECTION ET REMPLACEMENT DES BALAIS DU MOTEUR NETTOYAGE

ÜBERPRÜFUNG UND AUSWECHSELN DER KOHLEBÜRSTEN REINIGUNG

REVISION DE LAS ESCOBILLAS/REEMPLAZO LIMPIEZA

CONTROLLO/SOSTITUZIONE SPAZZOLE MOTORE PULIZIA

A) 20-600 rpm gear assembly (included in service kit 07553-06)
Pignon de 20 à 600 tr/min. (inclus dans le nécessaire d'entretien 07553-06)
Getrieberad Typ 20-600 U/min (im Service-Kit 07553-06 enthalten)
Montura del engranaje de20-600 rpm (incluído en el kit de servicio 07553-06)
Gruppo ingranaggi 20-600 g/min (incluso nel kit 07553-06)

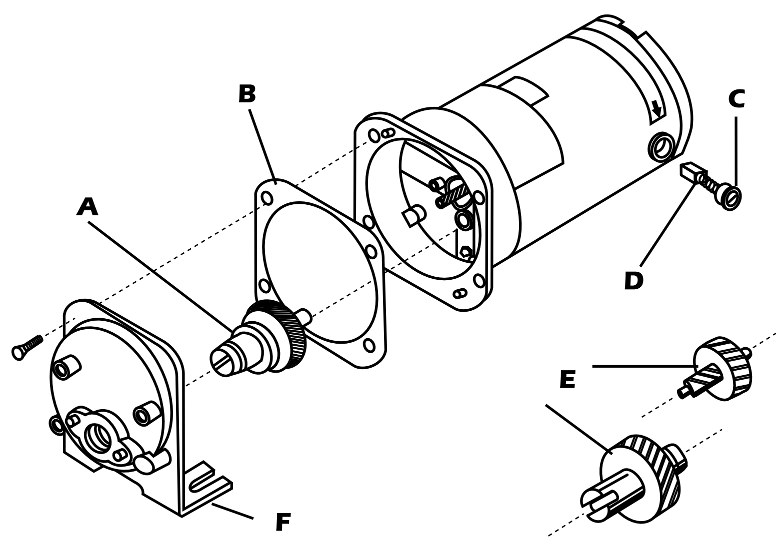
B) Gasket
Joint d'´étanchéité
Dichtung
Empaquetadura
Guarnizione

C) Cap
Capuchon
Abdeckkappe
Tapa
Cappuccio

D) Motor Brush
Balai
Kohlebürste
Escobilla del motor
Spazzola motore

E) 7-200 rpm gear set (included in service kit 07553-11)
Ensemble de pignons de 7 à 200 tr/min (inclus dans le nécessaire d'entretien 07553-11)
E) Getrieberad Typ 7-200 U/min (im Service-Kit 07553-11 enthalten)
Juego de engranajes de 7-200 rpm (incluído en el kit de servicio 07553-11)
Gruppo ingranaggi 7-200 g/min (incluso nel kit 07553-11)

F) Gear case cover assembly
Couvercle du boîtier d'engrenage
Antriebsgehäuse
Tapa de la caja de engranaje
Coperchio scatola ingranaggi



REPLACEMENT PARTS AND ACCESSORIES ▪ ACCESSOIRES ET PIÈCES DE RECHANGE ZUBEHÖR UND ERSATZTEILE ▪ ACCESSORI E PARTI DI RICAMBIO ▪ PIEZAS DE REPUESTO Y ACCESORIOS

Description Description Beschreibung Descripción Descrizione	Part Number N° de Modèle Artikelnummer Parte Número Codice
Gear Service Kit (600 rpm) Kit d'entretien de pignon (600 rpm) Service-Kit (600 U/min) Kit de servicio del engranaje (600 rpm) Kit ingranaggi (600 g/min)	**07553-06**
Gear Only (600 rpm) Pignon uniquement (600 rpm) Ersatzdichtung, einzeln (600 U/min) Engranaje de repuesto (600 rpm) Ingranaggi (600 g/min)	**07553-09**
Gear Service Kit (200 rpm) Kit d'entretien de pignon (200 rpm) Service-Kit (200 U/min) Kit de servicio del engranaje (200 rpm) Kit ingranaggi (200 g/min)	**07553-11**
Brushes (set of 2) Balais (2/jeu) Kohlebürsten, 2 Stück Escobillas (juego de 2) Spazzole (set da 2)	**07520-06**

Description Description Beschreibung Descripción Descrizione	Part Number N° de Modèle Artikelnummer Parte Número Codice
Fuse (7554-85,-95) T1.0A 250V; 4 x 20 mm Fusible (7554-85,-95) T1,0A 250V; 4 x 20 mm Sicherung (7554-85,-95) T1,0A 250V; 4 x 20 mm Fusible (7554-85,-95) T1,0A 250V; 4 x 20 mm Fusibile (7554-85,-95) T1,0A 250V; 4 x 20 mm	**B-1115-0056**

SPECIFICATIONS

Model Number	Drive Speed Range	Maximum Torque	Line Voltage Limits (50–60 Hz)
7554-80	7–200 rpm	180 oz-in	90–130 V
7554-85	7–200 rpm	180 oz-in	180–260 V
7554-90	20–600 rpm	90 oz-in	90–130 V
7554-95	20–600 rpm	90 oz-in	180–260 V

Power Output: 37 W (0.05 hp)

Maximum Current:
- **115 V Units:** 1.5A, shorted output conditions
- **230 V Units:** 0.9A, shorted output conditions

Speed Regulation:
- **Line:** ±2%
- **Load:** ±3%
- **Temperature Drift:** ±10%

Enclosure Rating: IP22 per IEC529

Humidity (non-condensing): 10% to 90%

Operating Temperature: 0° to 40°C

Storage Temperature: –45° to 60°C

Chemical Resistance: Exposed material is painted steel housing

Altitude: Less than 2000 m

Display: Green LED

Dimensions (L × W × H): 220 mm × 180 mm × 135 mm (8¹¹⁄₁₆ in × 7⅛ in × 5⁵⁄₁₆ in)

Weight: 4.1 kg (9 pounds)

Compliance: 115V: UL508, CSA C22.2, No. 14-M91
230V (For CE Mark):
EN61010-1/A2: 1995 (EU Low Voltage Directive) and
EN61326-1/A1: 1998 (EU EMC Directive)

Pollution Degree: Pollution Degree 2 per IEC 664 (Indoor usage—lab, office)

Installation Category: Installation Category II per IEC 664 (Local level—appliances, Portable Equipment, etc.)

CHARACTERISTIQUES TECHNIQUES

Numéro de modèle	Entraînements de Vitesse	Couple maximum	Limites de tension d'alimentation (50–60 Hz)
7554-80	7–200 t/min	13 kg•cm	90–130 V
7554-85	7–200 t/min	13 kg•cm	180–260 V
7554-90	20–600 t/min	6,5 kg•cm	90–130 V
7554-95	20–600 t/min	6,5 kg•cm	180–260 V

Puissance de sortie : 37 W (0,05 CV)

Courant maximum :
- **Unités 115 V :** 1,5 A, sorties en court-circuit
- **Unités 230V :** 0,9 A, sorties en court-circuit

Régulation de vitesse :
- **Régulation en ligne :** ±2%
- **Régulation de charge :** ±3%
- **Dérive en température :** ±10%

Homologation du boîtier : IP22 (IEC 529)

Humidité (sans condensation) : 10% à 90%

Température de fonctionnement : 0 à 40° C

Température de stockage : –45°C à 60°C

Résistance chimique : Le matériau exposé est un boiter en acier peint

Altitude d'utilisation : Inférieure à 2000 m

Affichage : DEL verte

Dimensions (L × l × h) : 220 mm × 180 mm × 135 mm

Poids : 4,1 kg

Conformités : 115 V : UL508 ACNOR C22.2 n° 14-M91
230 V (pour conformité aux normes européennes) :
EN61010-1/A2 : 1995 (directives concernant les basses tensions) et
EN61326-1/A1 : 1998 (la compatibilité électromagnétique)

Degré de pollution : Degré de pollution niveau 2 selon la norme IEC 664 (Usage interne—laboratoire, bureaux)

La Catégorie d'installation : La catégorie d'installation par IEC 664 (le niveau local—appareils, équipements portatifas, etc.)

TECHNISCHE DATEN

Modell-nummer	Drehzahl (U/min)	Maximales Drehmoment	Netzspannungsbereich (50–60 Hz)
7554-80	7–200	13 kg•cm	90–130 V
7554-85	7–200	13 kg•cm	180–260 V
7554-90	20–600	6,5 kg•cm	90–130 V
7554-95	20–600	6,5 kg•cm	180–260 V

Leistung: 37 W (0,05 PS)
Maximale Stromstärke:
- **115 V-Modelle:** 1,5 A, kurzzeitig
- **230 V-Modelle:** 0,9 A, kurzzeitig

Drehzahlregelung:
- **linear:** ±2%
- **in Betrieb:** ±3%
- **Temperaturabweichung:** ±10%

Schutzklasse: IP22 (IEC 529)
Feuchte (nicht kondensiert): 10 bis 90%
Betriebstemperatur: 0 bis 40˚C
Lagertemperatur: –45 bis 60˚C
Chemische Verträglichkeit: Verwendetes Material: Lackiertes Stahlgehäuse
Höhe: Weniger als 2000 m
Display: LED-Anzeige, grün
Abmessungen (L×B×H): 220 mm × 180 mm × 135 mm
Gewicht: 4,1 kg
Entspricht den Normen: 115 V: UL508 CSA C22.2 Nr. 14-M91
230 V (für CE-Kennzeichen):
EN61010-1/A2: 1995 (Niederspannungsrichtlinie der EU) und EN61326-1/A1: 1998 (EMV-Richtlinie der EU)
Umweltverschmutzungsgrad: Umweltverschmutzungsgrad 2 nach IEC 664 (Innengebrauch—Labor, Büroräume)
Installationsklasse: Installationsklasse II nach IEC 664 (Haushaltsgeräte, tragbare Geräte u.s.w)

ESPECIFICACIONES

Modelo Numero	Velocidad del Propulsor	Máximo Torque	Voltaje Límite de Línea (50–60 Hz)
7554-80	7–200 rpm	13 kg•cm	90–130 V
7554-85	7–200 rpm	13 kg•cm	180–260 V
7554-90	20–600 rpm	6,5 kg•cm	90–130 V
7554-95	20–600 rpm	6,5 kg•cm	180–260 V

Energía de Salida: 37 W (0,05 hp)
Corriente Máxima:
- **115 V Unidades:** 1,5 A, condiciones de salida en corto circuíto
- **230 V Unidades:** 0,9 A, condiciones de salida en corto circuíto

Regulación de Velocidad:
- **Línea:** ±2%
- **Carga:** ±3%
- **Desplazamiento de Temperatura:** ±10%

Clasificación del Cerramiento: IP22 (IEC 529)
Humedad (sin condensación): De 10% a 90%
Temperatura de Operación: De 0 a 40°C
Temperatura de Almacenaje: De –45 a 60°C
Resistencia Química: El material expuesto es la carcaza de acero pintado
Altitud: Inferior a 2000 m
Indicador Visual: LED verde
Dimensiones (L × A × Al): 220 mm × 180 mm × 135 mm
Peso: 4,1 kg
Cumplimiento: 115V: UL508 CSA C22.2 No. 14-M91
230V (para la marca CE):
EN61010-1/A2: 1995 (Directiva de alto voltaje de la UE) y
EN61326-1/A1: 1998 (Directiva EMC de la UE)
Grado de contaminación: Grado de contaminación 2 para IEC 664 (uso interior—laboratorio, oficina)
Instalación: Categoria II para IEC 664 (Aplicaciones locales, equipo transportable, etc.)

SPECIFICHE

Modello	Velocità azion.	Coppia massima	Limiti di voltaggio (50–60 Hz)
7554-80	7–200 g/min	13 kg•cm	90–130 V
7554-85	7–200 g/min	13 kg•cm	180–260 V
7554-90	20–600 g/min	6,5 kg•cm	90–130 V
7554-95	20–600 g/min	6,5 kg•cm	180–260 V

Potenza: 37 W (0,05 hp)
Corrente massima:
- **115V:** 1,5 A, con output in corto
- **230V:** 0,9 A, con output in corto

Regolazione di velocità:
- **variazioni di linea:** ±2%
- **variazioni di carico:** ±3%
- **sbalzi di temperatura:** ±10%

Classe di protezione: IP22 (IEC 529)
Umidità (non condensante): da 10 a 90%
Temperatura di funzionamento: da 0° a 40° C
Temperatura di stoccaggio: da –45° a 60° C
Resistenza chimica: Il materiale esposto e' acciaio verniciato
Altezza: Inferiore a 2000 m
Display: LED verde
Dimensioni (L×S×h): 220 mm × 180 mm × 135 mm
Peso: 4,1 kg
Normativa: 115V: UL508 CSA C22.2 N. 14-M91
230V (per indicazione CE):
EN61010-1/A2: 1995 (Direttiva europea sulla bassa tensione) e
EN61326-1/A1: 1998 (Direttiva europea compatibilità eletromagnetica)
Grado di inquinamento: Grado di inquinamento 2 secondo la norma IEC 664 (Uso interno—laboratorio, ufficio)
Categoria di Installazione: Categoria di Installazione II per IEC 664 (Livello di applicazione locale, equipaggiamento portatile, ecc.)

EU Declaration of Conformity

Name of Apparatus: MASTERFLEX® Economy Analog Console L/S® Pump Drives
Model Numbers: 7554-85 & -95, 77910-25
Description of Apparatus: Variable speed, peristaltic pump motor drive. Used with pump head and peristaltic tubing to pump fluids.
7554-85 (200 rpm) & -95 (600 rpm);
77910-25; (Bundled 7554-95)

Barnant Company declares that the above models are in conformity to the following harmonized standards and directives

Applicable Directives	Applicable Specifications	Manufacturer's Report Number
73/23/EEC 93/68/EEC	EN61010-1/A2:1995	TR9651
89/336/EEC 92/31/EEC 93/68/EEC	EN61326-1/A1:1998	TR9652

The last two digits of the year in which the current configuration of the above models were assessed per the Low Voltage Directive is :00.

Manufacturer: Barnant Company Division
Cole-Parmer Instrument Company
28W092 Commercial Avenue
Barrington, IL 60010-2392
USA
Tel: 847-381-7050

Manufacturer's Signature: James W. Doll (signature) — 17 July, 2000
James W. Doll — Date
Vice President, Engineering

MASTERFLEX® L/S®

WARRANTY

Use only MASTERFLEX precision tubing with MASTERFLEX pumps to ensure optimum performance. Use of other tubing may void applicable warranties.

The Manufacturer warrants this product to be free from significant deviations from published specifications. If repair or adjustment is necessary within the warranty period, the problem will be corrected at no charge if it is not due to misuse or abuse on your part, as determined by the Manufacturer. Repair costs outside the warranty period, or those resulting from product misuse or abuse, may be invoiced to you.

The warranty period for this product is noted on the Warranty Card.

PRODUCT RETURN

To limit charges and delays, contact the seller or Manufacturer for authorization and shipping instructions before returning the product, either within or outside of the warranty period. When returning the product, please state the reason for the return. For your protection, pack the product carefully and insure it against possible damage or loss. Any damages resulting from improper packaging are your responsibility.

TECHNICAL ASSISTANCE

If you have any questions about the use of this product, contact the Manufacturer or authorized seller.

GARANTIE

Utiliser uniquement les tubes MASTERFLEX extrudés avec précision, garantissant des performances optimales. L'utilisation d'autres tubes peut entrainer la non validité de cette garantie.

Nous garantissons que nos produits sont conformes aux descriptifs publiés. Si une réparation ou un réglage s'avère nécessaire durant la période de garantie, le problème sera corrigé sans frais, si celui-ci n'est pas rendu nécessaire par un abus ou une mauvaise utilisation de la part du client. Notez que les réparations hors période de garantie, ou rendues nécessaires par un abus ou une mauvaise utilisation de la part du client, seront à la charge du client.

La période de garantie pour ce produit est indiquée sur la carte de GARANTIE.

RETOUR DE MARCHANDISES

Pour limiter les frais et délais, aucun produit ne doit être retourné sans notre permission préalable et sans avoir obtenu nos instructions pour envoi. Lors du renvoi de matériel, merci de nous adresser la raison du retour. Pour votre protection, les articles retournés doivent être soigneusement emballés pour éviter une détérioration au cours de l'expédition et être assurés contre des dégâts ou une perte possible. Nous ne serons pas responsables de dégâts résultant d'un emballage négligé ou insuffisant.

ASSISTANCE TECHNIQUE

Pour toutes questions et conseils d'utilisation de ce produit, contacter MASTERFLEX ou son distributeur MASTERFLEX.

GARANTIE

Verwenden Sie für MASTERFLEX Pumpen ausschließlich MASTERFLEX Präzisionsschläuche für optimale Anwendungsergebnisse. Der Einsatz anderer Schläuche kann eine Verweigerung der Garantieleistung nach sich ziehen.

Der Hersteller garantiert, daß dieses Produkt keinen nennenswerten Abweichungen von den veröffentlichten Spezifikationen unterliegt. Falls während der Garantiezeit eine Reparatur oder Nachbesserung erforderlich werden sollte, wird dies kostenlos vorgenommen, vorausgesetzt, es liegt kein vom Hersteller feststellbares Verschulden des Anwenders vor Reparaturkosten außerhalb der Garantiezeit oder aufgrund von falschem Gebrauch des Produktes werden Ihnen in Rechnung gestellt.

Die Garantiezeit für dieses Produkt ist auf der Garantiekarte vermekt.

WARENRÜCKSENDUNGEN

Um Kosten und Lieferzeiten so gering wie möglich zu halten, fragen Sie in jedem Fall Ihren Fachhändler oder den Hersteller nach einer Rücksendungsgenehmigung und den Versandkonditionen, bevor Sie Ware zurückschicken, Geben Sie bitte den Rücksendungsgrund mit an. Verpacken Sie die Ware sorgfältig und versichern Sie die Sendung gegen Beschädlgung bzw. Verlust; dies ist in Ihrem eigenen Interesse. Für Transportschäden aufgrund unsachgemäßer Verpackung halten Sie.

TECHNISCHE BERATUNG

Wenn Sie Fragen zur Anwendung dieses Produktes haben, fragen Sie den Hersteller oder autorisierten Fachhändler.

GARANTIA

Para asegurar el óptimo rendimiento de las bombas MASTERFLEX use unicamente tubería de precisión MASTERFLEX. El uso de otros tipos de tuberías, puede anular las garantías aplicables.

El fabricante garantiza que este producto está libre de desviaciones significativas de las especifica-ciones publicadas. Si es necesario un ajuste o una reparación dentro del período de garantía este será hecho sin cargo solo si el mismo no se debió a un mal uso o abuso de su parte, lo cual será determi-nado por el fabricante. Los Costos de reparación fuera del período de garantía o aquellos que resulten por mal uso o abuso de su parte serán a cargo del cliente.

El período de garantía para este producto esta anotado en la carta de garantía.

RETORNO DEL PRODUCTO

Para evitar cargos innecesarios y demoras, contacte al fabricante o a su vendedor, quién le propor-cionará instrucciones de envío y autorización antes de retornar el producto dentro o fuera del período de garantía. Cuando retorne el producto, por favor anote la razón del mismo. Para su protección, empaque el producto cuidadosamente y asegurelo contra cualquier posible pérdida o daño. Cualquier daño resultante de empaques inadecuados será bajo su responsabilidad.

ASISTENCIA TECNICA

Si usted tiene alguna pregunta acerca del uso de este producto, contactar al fabricante o al vendedor autorizado.

GARANZIA

Per garantire le prestazioni ottimali con le pompe MASTERFLEX utilizzare esclusivamente i tubi di precisione MASTERFLEX. L'utilizzo di altri tubi potrebbe rendere nulla la garanzia.

Il Costruttore garantisce che i suoi prodotti non hanno differenze significative rispetto alle specifiche dichiarate. In caso siano necessarie riparazioni o regolazioni all'interno del periodo di garanzia, il problema verràcorretto senza aggravio di costi a patto che a guidizio del Costruttore non Vi sia stato un cattivo uso o un eccesso d'uso del prodotto. I costi di riparazione fuori del periodo di garanzia e quelli risultanti da cattivo o eccessivo uso del prodotto potranno essere addebitati.

Il periodo di garanzia per questo prodotto é indicato sulla cartolina di garanzia (Warranty Card).

RESTITUZIONE DEL PRODOTTO

Al fine di evitare aggravio di costi e ritardi, é necessario contattare il Rivenditore o il Costruttore prima di restituire il prodotto ed ottenerne l'autorizzazione al reso e le istruzioni di spedizione, sia durante che dopo il periodo di garanzia. All'atto della resituzione del prodotto indicarne per iscritto le motivazioni.

Si consiglia di imballare accuratamente a assicurare il prodotto contro possibili danni o perdite durante la spedizione. Qualsiasi danno derivante de carenze di imballo resterà sotto la Vostra responsabilità.

ASSISTENZA TECNICA

Contattare il Costruttore o il Rivenditore Autorizzato per qualsiasi informazione relativa all'uso di questo prodotto.

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Appendix C

Table 4: Major Equipment List

Table 4: Major Equipment List

Responsible Party	Equipment	Quantity
City of Davis	Source Water Equipment	
	Source Water Feed Pump Connections (PE 0.375" OD)	TBD
	Source Water Feed Tank, 100 to 120 gallons	1
	Source Water Transportation Tank	1
	Effluent Water to Waste Connection PVC to Tubing (e.g., hose clamps)	TBD
	Sodium Hypochlorite	50 mL
Envirogen	Pumps	
	Recirculation Pump	2
	Source Water Feed Pump	2
	Effluent Pump	2
	Chemical Feed Pumps (Acetic Acid, Phosphoric Acid, Sodium Hydroxide or Sulfuric Acid)	6
	Bench Scale Pilot Equipment	1
	ORP and pH Meter with Recorder	1
Kennedy/Jenks	Field Measurement Equipment	
	D.O. Meter	1
	ORP Meter	
	Thermometer	1
	HACH Meter (nitrate and turbidity testing)	1
	Chemicals	
	Acetic Acid	2.5 L
	Phosphoric Acid	5 L
	Sodium Hydroxide	1 L
	Sulfuric Acid	1 quart
	Sodium Selenate	10 grams
	Power Strip	1
	Filter Paper	1
	Chemical Storage Containers - Day Tank	2
	Ice Chest	1
	5-gallon Waste Tank	2
BSK	Laboratory Sampling Containers	As needed from BSK

Appendix D

Table 5: Summary of Well 20 Title 22 Water Quality Results

Table 5: Summary of Well 20 Title 22 Water Quality Results

Constituent	Units	Nov-09	Aug-10	Aug-11	Aug-12	Average
Hardness	mg/L	420	390	400	390	405
Calcium	mg/L	38	39	40	39	39
Magnesium	mg/L	79	70	73	71	75
Sodium	mg/L	54	57	59	56	56
Potassium	mg/L	1.4	<2.0	<2.0	<2.0	<2.0
Alkalinity	mg/L	410	430	380	400	420
Hydroxide	mg/L	<1.0	<1.0	<3.0	<3.0	<3.0
Carbonate	mg/L	<1.0	<1.0	<3.0	<3.0	<3.0
Bicarbonate	mg/L	410	520	380	400	465
Sulfate	mg/L	37	35	33	38	36
Chloride	mg/L	29	26	25	31	28
Fluoride	mg/L	0.3	0.28	0.28	0.30	0.27
pH		7.7	8.2	8.2	8.3	8.0
Specific Conductance	µmhos/cm	890	920	1300	920	905
Total Filterable Residue	mg/L	510	510	770		510
Color	units	0	5	<1.0	<1.0	3
Odor	TON	1.0	1	<1.0	<1.0	1
Turbidity	NTU	0	<0.1	<0.1	<0.1	<0.1
MBAS (foaming agents)	mg/L	<.05	<.05	<0.05	<0.05	<0.05
Boron	µg/L	520	520	580	520	535
Nitrate [4]	mg/L	34	32	30	33	32
Nitrite	µg/L	<50	<50	<100	<100	<100
Total Dissolved Solids	mg/L	510	510	770	520	578
Metals						
Aluminum	µg/L	<50	<50	<50	<50	<50
Arsenic	µg/L	3.5	3.6	<2.0	<2.0	4
Antimony	µg/L	<2.0	<2.0	<2.0	<2.0	<2.0
Barium	µg/L	200	170	180	180	183
Beryllium	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Cadmium	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Total Chromium [4]	µg/L	41	40	39	37	40
Hexavalent Chromium [4]	µg/L	38	38	40		39
Copper	µg/L	<50	<50	<5.0	<50	<50
Cyanide	µg/L				<5	<5
Total Iron [1]	µg/L	<50	<50	<50	<30	<50
Lead	µg/L	<5.0	<5.0	<5.0	<5.0	<5.0
Manganese	µg/L	<10	<10	<10	<10	<10
Mercury	µg/L	<.4	<.4	<0.4	<0.40	<0.4
Nickel	µg/L	<10	<10	<10	<10	<10
Selenium [4]	µg/L	4	2.6	2.2	<2.0	3
Silver	µg/L	<10	<10	<10	<10	<10
Thallium	µg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Zinc	µg/L	<50	<50	<50	<50	<50

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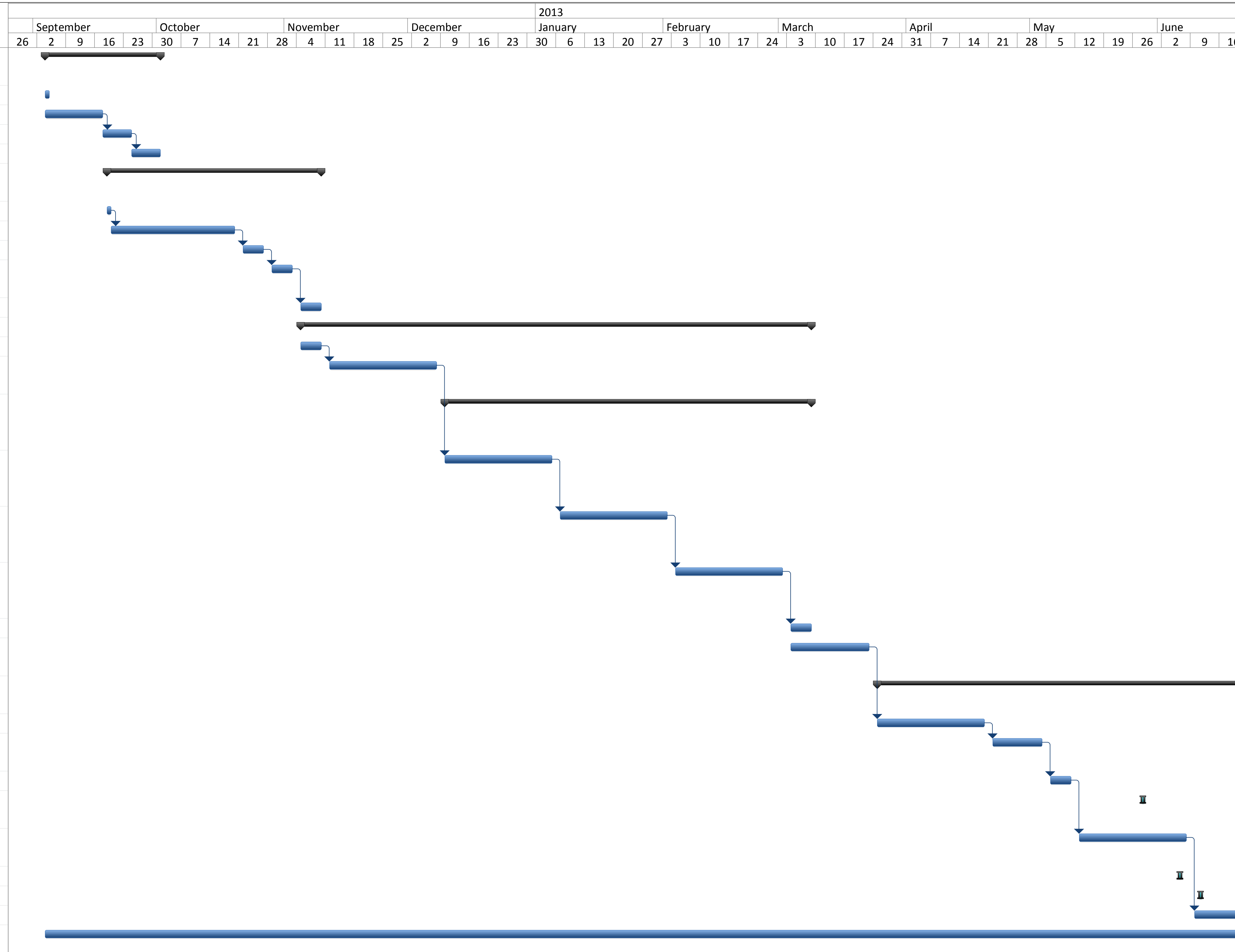
Appendix E

Table 6: Project Schedule

Schedule for Sustainable Treatment for Co-removal of Hexavalent Chromium by Biological Treatment Process Pilot Study
(Updated: June 29, 2012)

ID	Task Name	Duration	Start	Finish
1	**Task 1 Kick Off and Work Plan Development**	**20 days**	**Tue 9/4/12**	**Mon 10/1/12**
2	Kick Off Meeting	1 day	Tue 9/4/12	Tue 9/4/12
3	Draft Work Plan	10 days	Tue 9/4/12	Mon 9/17/12
4	City Review	5 days	Tue 9/18/12	Mon 9/24/12
5	Final Work Plan	5 days	Tue 9/25/12	Mon 10/1/12
6	**Task 2 Sampling/Data Review**	**38 days**	**Wed 9/19/12**	**Fri 11/9/12**
7	Sampling	1 day	Wed 9/19/12	Wed 9/19/12
8	Data Review	22 days	Thu 9/20/12	Fri 10/19/12
9	Draft Tech Memo 1	5 days	Mon 10/22/12	Fri 10/26/12
10	City Review of Tech Memo 1	5 days	Mon 10/29/12	Fri 11/2/12
11	Final Tech Memo 1	5 days	Mon 11/5/12	Fri 11/9/12
12	**Task 3 - Piloting**	**90 days**	**Mon 11/5/12**	**Fri 3/8/13**
13	Task 3.1 Pilot Setup	5 days	Mon 11/5/12	Fri 11/9/12
14	Task 3.2 Acclimation Period	20 days	Mon 11/12/12	Fri 12/7/12
15	Task 3.3 & 3.4 Steady State Pilot and Bench Studies	65 days	Mon 12/10/12	Fri 3/8/13
16	60 Min. FBR Hydraulic Residence Time	20 days	Mon 12/10/12	Fri 1/4/13
17	40 Min. FBR Hydraulic Residence Time	20 days	Mon 1/7/13	Fri 2/1/13
18	20 Min. FBR Hydraulic Residence Time	20 days	Mon 2/4/13	Fri 3/1/13
19	Demobilization	5 days	Mon 3/4/13	Fri 3/8/13
20	**Task 4 - Analysis of Results**	**15 days**	**Mon 3/4/13**	**Fri 3/22/13**
21	**Task 5 - Prepare Draft and Final Project Report**	**65 days**	**Mon 3/25/13**	**Fri 6/21/13**
22	Prepare Draft	20 days	Mon 3/25/13	Fri 4/19/13
23	Draft Review by the City of Davis	10 days	Mon 4/22/13	Fri 5/3/13
24	Prepare Final Draft	5 days	Mon 5/6/13	Fri 5/10/13
25	Present to City Council	1 day	Tue 5/28/13	Tue 5/28/13
26	Draft Review by WRA, SGA, and SWRCB	20 days	Mon 5/13/13	Fri 6/7/13
27	Present to WRA	1 day	Thu 6/6/13	Thu 6/6/13
28	Present to SGA	1 day	Tue 6/11/13	Tue 6/11/13
29	Final Report	10 days	Mon 6/10/13	Fri 6/21/13
30	**Task 6 - Project Management**	**209 days**	**Tue 9/4/12**	**Fri 6/21/13**



K/J by Sarah Laybourne
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Appendix F

Table 11: Laboratory Analysis Sampling Criteria

Table 11: Sample Handling Guide for Laboratory Analysis

Analyte	Units	Method	Method Detection Limit	Method Reporting Limit	Holding Time (days)	Preservative	Temperature
Chloride	mg/L	EPA 300.0		1.0	28	None	Refrigerate
Chromium, Hexavalent	µg/L	EPA 218.6		0.05	5	Ammonium sulfate buffer to pH 9.3-9.7	Refrigerate
Chromium, Total Low Level	µg/L	EPA 200.8		0.50		Add HNO3 to pH <2	Ambient
Color	Color Units	SM 2120B		1.0	2	None	Refrigerate
pH							
Nitrogen (NO3), Total Oxidizable	mg/L	SM 4500-NO3 F		0.50	28	Add H2SO4 to pH<2	Refrigerate
Sulfate	mg/L	EPA 300.0		2.0	28	None	Refrigerate
Total Dissolved Solids	mg/L	SM 2540C		5.0	7	None	Refrigerate
Total Organic Carbon	mg/L	SM-5310C		0.2		Add H3PO4	Refrigerate
Total Suspended Solids	mg/L	SM 2540D		5.0	7	None	Refrigerate
Metals							
Barium (Total)	µg/L	EPA 200.8	2.27	5.0	180	Add HNO3 to pH <2	Ambient
Cadmium (Total)	µg/L	EPA 200.8	0.45	1.0	180	Add HNO3 to pH <2	Ambient
Chromium (Total, Low Level)	µg/L	EPA 200.8	0.27	0.50	180	Add HNO3 to pH <2	Ambient
Iron (Total)	mg/L	EPA 200.7	0.013	0.030	180	Add HNO3 to pH <2	Ambient
Lead (Total)	µg/L	EPA 200.8	2.27	5.0	180	Add HNO3 to pH <2	Ambient
Manganese (Total)	mg/L	EPA 200.7	0.0045	0.01	180	Add HNO3 to pH <2	Ambient
Mercury (Total)	µg/L	EPA 200.8	0.18	0.40	180	Add HNO3 to pH <2	Ambient
Nickel (Total)	µg/L	EPA 200.8	4.54	10	180	Add HNO3 to pH <2	Ambient
Zinc (Total)	µg/L	EPA 200.8	22.7	50	180	Add HNO3 to pH <2	Ambient

Appendix G

Sample Log Sheets

Sample Worksheet: FBR Effluent **KENNEDY/JENKS CONSULTANTS**

Project: **Sustainable Treatment for Co-Removal of Hexavalent Chromium by Biological Treatment Process Study**

K/J Proj. No. 1270031*00

Building, Area: City of Davis, East Area Tank Booster Pump Station

Sampling Frequency: Daily
Hydraulic Residence Time: _________ min.
Sample Location: FBR Effluent & Influent
Week: _________

			FBR Effluent										FBR Influent		
Day	Date	Time	Temp. (F)	pH	Nitrate (mg/L)	Phosphate (mg/L)	Turbidity (NTU)	D.O. (mg/L)	ORP	Color	Smell		Temp. (F)	pH	ORP
Monday															
Tuesday															
Wednesday															
Thursday															
Friday															

Day	Notes	Sampler Name (print)	Initial
Monday			
Tuesday			
Wednesday			
Thursday			
Friday			

Chemical Feed and Maintenance Worksheet **KENNEDY/JENKS CONSULTANTS**

Project: **Sustainable Treatment for Co-Removal of Hexavalent Chromium by Biological Treatment Process Study** **K/J Proj. No.** 1270031*00

Building, Area: City of Davis, East Area Tank Pump Station

Sampling Frequency: Daily
Hydraulic Residence Time:
Location: Pilot System
Week:
Additional Notes:

Day	Date	Time	Pilot Flow Rate	Phosphoric Acid Feed Rate/Concentration	Acetic Acid Feed Rate/Concentration	Sodium Hydroxide Feed Rate/Concentration	Sampler Name (print)	Initial
Monday								
Tuesday								
Wednesday								
Thursday								
Friday								

Day	Notes (include notes regarding equipment malfunction, upset, adjustments made, etc.)	FBR Media Description
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		

Sample Worksheet: Filtration & Disinfection Test **KENNEDY/JENKS CONSULTANTS**

Project: **Sustainable Treatment for Co-Removal of Hexavalent Chromium by Biological Treatment Process Study** **K/J Proj. No.** 1270031*00

Building, Area: City of Davis, East Area Tank Booster Pump Station

Sampling Frequency: One Time per Hydraulic Residence
Hydraulic Residence Time: ________ min.
Filtration & Disinfection Test #: ________
Week: ________

Location	Date	Time	pH	Turbidity	Temp (F)	Color	Smell	Sampler Name (print)	Initial
FBR Effluent									
Aeration Effluent									
Filter 1 (Granular) Effluent									
Filter 2 (Membrane) Effluent									

Notes:

Sample Worksheet: Aerated Effluent **KENNEDY/JENKS CONSULTANTS**

Project: **Sustainable Treatment for Co-Removal of Hexavalent Chromium by Biological Treatment Process Study** **K/J Proj. No.** 1270031*00

Building, Area: City of Davis, East Area Tank Booster Pump Station

Sampling Frequency: Biweekly
Hydraulic Residence Time: ________ min.
Sample Location: Aerated Effluent
Week: ________

Day	Date	Time	Temp. (F)	D.O.(mg/L)	pH	Color	Smell
Sample 1							
Sample 2							

Day	Notes	Sampler Name (print)	Initial
Sample 1			
Sample 2			

Well 20 Water Addition & Nitrate Readings Worksheet **KENNEDY/JENKS CONSULTANTS**
Project: **Sustainable Treatment for Co-Removal of Hexavalent Chromium by Biological Treatment Process Study** **K/J Proj. No.** 1270031*00

Building, Area: Well 20
Sampling Frequency: As needed
Hydraulic Residence Time:
Location: Well 20

Date	Time	Well 20 Nitrate Reading (mg/L)	Volume Added @ Pilot Test Site Tank (gal)	Notes	City Staff Name (print)	Initial

Appendix IX

Summary of Field and Laboratory Results

Laboratory Results

					Influent					Effluent																											
Period	Week	Day	Date	Time	Sample Name	Hexavalent Chromium (ug/L)	Total Chromium (ug/L)	UC Davis - Total Chromium (ug/L) - Cr 53	Total Oxidizable Nitrogen - N (mg/L)	Sample Name	Hexavalent Chromium (ug/L)	Total Chromium (ug/L)	UC Davis - Total Chromium (ug/L) - Cr 53	Field Nitrate as N (mg/L)	Total Oxidizable Nitrogen-N (mg/L)	Total Organic Carbon (mg/L)	Alkalinity as CaCO3 (mg/L)	Bicarbonate as CaCO3	Carbonate as CaCO3 (mg/L)	Hydroxide as CaCO3 (mg/L)	Chloride (mg/L)	Color, Apparent	pH	Sulfate as SO4 (mg/L)	TDS (mg/L)	TSS (mg/L)	Hardness as CaCO3 (mg/L)	Barium (ug/L)	Cadmium (ug/L)	Calcium (ug/L)	Iron (mg/L	Lead (ug/L)	Magnesium (mg/L)	Manganese (mg/L)	Mercury (ug/L)	Nickel (ug/L)	Zinc (ug/L)
A-2	2	Monday	11/12/2012	7:52 AM	INF-01-1112-757AM	44	45		8.35	EFF-01-1112-752AM	27	26		0.5	2.94	7.7																					
A-2	2	Wednesday	11/14/2012	7:10 AM	INF-02-1114-710AM	44	45		8.13	EFF-02-1114-710AM	33	32		0.4	<0.5	NM																					
A-2	2	Friday	11/16/2012	7:45 AM	INF-03-1116-745AM	42	49		8.35	EFF-03-1116-745AM	18	16		<.3	<0.5	4.3																					
A-4	4	Monday	11/26/2012	7:30 AM	INF-04-1126-735AM	41	45		8.35	EFF-04-1126-730AM	0.79	7.3		0.4	<0.5	1.2																					
A-4	4	Tuesday	11/27/2012	7:50 AM	INF-05-1127-0755AM	42	45		8.58	EFF-05-1127-0750AM	0.83	7.7		0.4	<0.5	2.1																					
A-4	4	Friday	11/30/2012	8:10 AM	INF-06-1130-815AM	42	45		8.5	EFF-06-1130-810AM	0.39	7.6		<.3	0.13	15																					
A-5	5	Monday	12/3/2012	7:35 AM	INF-07-1203-740AM	43	44		8.7	EFF-07-1203-735AM	<0.2	8.4		<.3	<0.5	NM																					
A-5	5	Wednesday	12/5/2012	8:15 AM	INF-08-1205-820AM	40	45		7.45	EFF-08-1205-815AM	<0.2	8.1		0.1	<0.5	NM																					
A-5	5	Thursday	12/6/2012	8:10 AM	INF-09-1206-815AM	40	44		11	EFF-09-1206-810AM	<0.2	7.8		<.3	0.26	9.2																					
60-1	6	Monday	12/10/2012	7:45 AM	INF-10-1210-755AM	43	46		8.9	EFF-10-1210-745AM	<0.2	7.2		0.4	<.1	NM																					
60-2	7	Monday	12/17/2012	8:40 AM	INF-11-1217-840AM	42	44		8.3	EFF-11-1217-835AM	3.8	11		0.7	0.28	3.3																					
60-2	7	Friday	12/21/2012	8:08 AM	INF-12-1221-810AM	41	49		8.6	EFF-12-1221-808AM	1.2	9.7		0.5	0.12	NM	460	460	<3.0	<3.0	33	ND	8.2	39	560	13	430	190	<1.0	43	<0.030	<5.0	80	<0.010	<.40	<10	<50
60-3			12/27/2012	7:45 AM	INF-12-1227-745AM	41	45		8.2	EFF-12-1227-705AM	1.8	9.3			<.1	0.98	460	460	<3.0	<3.0	35	ND	8.3	42	540	<5.0	440	200	<1.0	42	<0.030	<5.0	81	<0.010	<.40	<10	<50
	8	Thursday								AER-1-1227-800AM	1.8	9.8		0.6	0.16		470	460	9.5	<3.0	35	ND	8.3	42	570	<5.0	440	190	<1.0	42	<0.030	<5.0	80	<0.010	<.40	<10	<50
60-4	9	Wednesday	1/2/2013	7:50 AM	INF-13-0102-755AM	40	45		8.3	EFF-13-0102-750AM	2.5	11		1	0.91																						
60-4	9	Friday	1/4/2013	8:00 AM	INF-15-0104-755AM	51	47		8.2	EFF-15-0104-800AM	3	11		0.6	1.2	0.85	470	460	6.1	<3.0	43	ND	8.3	39	560	<5.0	440	190	<1.0	43	<0.03	<5.0	81	<0.010	<.40	<10	<50
40-1	10	Monday	1/7/2013	8:00 AM	INF-16-0107-810AM	42	48		8.1	EFF-16-0107-800AM	3.7	13		2	2.3	1.5	450	450	6.1	<3.0	66	ND	8.3	39	600	5	430	190	<1.0	42	<0.03	<5.0	80	<0.010	<.40	<10	<50
40-1	10	Friday	1/11/2013	8:10 AM	INF-17-0111-810AM	42	46		8.9	EFF-17-0111-800AM	4.1	15		0.6	1.7																						
40-2	11	Monday	1/14/2013	7:40 AM	INF-18-0114-750AM	41	44		8.6	EFF-18-0114-740AM	2.9	15		0.9	2.3	0.93	460	460	<3.0	<3.0	34	ND	8.2	41	560	<5.0	450	190	<1.0	44	<0.03	<5.0	82	<0.010	<.40	<10	<50
40-2	11	Friday	1/18/2013	7:00 AM	INF-19-0118-700AM	41	46		8.9	EFF-19-0118-700AM	1.1	15		0.5	<0.1																						
40-3	12	Tuesday	1/22/2013	7:05 AM	INF-20-0122-0800AM	42	44		8.2	EFF-20-0122-705AM	1.3	18		0.3	<0.1	1.7	460	460	<3.0	<3.0	34	ND	8.2	40	210	1.7	420	190	<1.0	41	<0.03	<5.0	77	<0.010	<.40	<10	<50
40-3	12	Friday	1/25/2013	7:00 AM	INF-21-0125-710AM	41	45		8.3	EFF-21-0125-700AM	0.29	14		0.2	<0.1																						
40-4	13	Monday	1/28/2013	7:45 AM	INF-22-0128-755AM	39	42		7.6	EFF-22-0128-745AM	<0.2	13		0.4	<0.1	0.81	450	450	<3.0	<3.0	32	ND	8.1	41	540	6	410	190	<1.0	41	<0.03	<5.0	75	<0.010	<.40	<10	<50
40-4	13	Friday	2/1/2013	7:30 AM	INF-23-0101-800AM	38	43		8.1	EFF-23-0201-730AM	1	13		0.4	0.16																						
15-1	14	Monday	2/4/2013	7:30 AM	INF-24-0204-730AM	36	40		7.4	EFF-24-0204-720AM	1.9	21		2.1	0.22	1.3	450	450	<3.0	<3.0	31	ND	8.2	37	530	5	390	180	<1.0	39	<0.03	<5.0	71	<0.010	<.40	<10	<50
15-1	14	Wednesday	2/6/2013	7:45 AM	INF-25-0206-845AM		38			EFF-25-0206-745AM	1.4	22		0.4		2.3																					
15-1	14	Friday	2/8/2013	7:15 AM	INF-26-0208-800AM	34	39		7	EFF-26-0208-715AM	0.46	18		0.5	<0.1																						
15-2	15	Monday	2/11/2013	7:30 AM	INF-27-0211-745AM	39	44	39.4	8.2	EFF-27-0211-730AM	0.47	22	19.7	0.4	<0.1	1.1	470	470	<3.0	<3.0	32	5.0	8.2	39	540	<5.0	430	190	<1.0	43	<0.03	<5.0	78	<0.010	<.40	<10	<50
15-2	15	Friday	2/15/2013	8:30 AM	INF-28-0215-830AM	24	26		4.7	EFF-28-0215-710AM	0.46	14		0.3	<0.1																						
15-3	16	Tuesday	2/19/2013	7:30 AM	INF-29-0219-730AM	31	36	31.8	6.1	EFF-29-0219-715AM	0.37	18	19.9	0.5	<0.1	4.3	430	430	<3.0	<3.0	29	ND	7.9	35	490	10	370	190	<1.0	38	<0.03	<5.0	67	<0.010	<.40	<10	<50
15-3	16	Friday	2/22/2013	7:50 AM	INF-30-0222-800AM	38	42		7.8	EFF-30-0222-750AM	0.31	21	21.6	0.5	<0.1																						
20-1	17	Monday	2/25/2013	7:20 AM	INF-31-0225-715AM	39	40	43.8	7.8	EFF-31-0225-720AM	0.27	21	24.8	0.5	<0.1	3	470	470	<3.0	<3.0	33	5	8.2	38	540	<5.0	410	190	<1.0	42	<0.03	<5.0	74	<0.010	<.40	<10	<50
20-1	17	Friday	3/1/2013	7:40 AM	INF-32-0301-730AM	28	28		5.8	EFF-32-0301-740AM	<0.2	14		0.6	0.12											8											

Filtration and Chlorination Bench Tests

60 Min. HRT Filtration and Disinfection Tests (12/27/2013)

	Effluent	Aerated	Membrane Filter (MF)	MF + Disinfection	Gravity Filter (GF)	GF + Disinfection
Chromium 6 (ug/l)	1.8	1.8	1.8	2.3	1.9	1.9
Chromium 3 (ug/l)-Calc	7.5	8	6.3	5.4	7.5	7.1
Total Chromium (ug/l)	9.3	9.8	8.1	7.7	9.4	9
TSS (mg/l)			<5.0		<5.0	

Note: Added 0.5 mg/L Chlorine. Did not re-check chlorine residual after 3 days or measure chlorine residual after adding.

40 Min. HRT Filtration and Disinfection Tests (2/1/2013)

	Effluent	Aerated	Membrane Filter (MF)	MF + Disinfection	Gravity Filter (GF)	GF + Disinfection
Chromium 6 (ug/l)	1		0.79	0.93	0.47	1
Chromium 3 (ug/l)-Calc	12		11.21	10	10.53	12
Total Chromium (ug/l)	13		12		11	
TSS (mg/l)			<5.0		<5.0	

Note: Added 0.5 mg/L Chlorine. Did not re-check chlorine residual after 3 days .

20 Min. HRT Filtration and Disinfection Tests (3/1/2013)

	Effluent	Aerated	Membrane Filter (MF)	MF + Disinfection	Gravity Filter (GF)	GF + Disinfection
Chromium 6 (ug/l)	<0.2		0.34	1.8	<0.2	1.8
Chromium 3 (ug/l)-Calc	14		12.66	8.2	13	9.2
Total Chromium (ug/l)	14		13	10	13	11
TSS (mg/l)	8		<5.0		11	

Note: Added 1.5 mg/L chlorine. Chlorine Residual after three days was 0.05 mg/l chlorine for the MF and 0.08 mg/l chlorine for the GF.

Appendix X

Design Criteria

APPENDIX X: TABLE X-1

City of Davis			**Designed by:**	T Williams	
Chromium 6 Pilot Study			**Date:**	4/4/2013	
Process Sizing & Design Criteria			**Checked by:**	Joe Drago	
Project No.	**1270031*00 / 9.03**		**Date:**	4/5/2013	
Process	**Quantity**	**Design Criteria**	**Sizing**	**Unit**	**Notes**
Well #20 Max. Capacity		1,400		gpm	
Fluidized Bed Reactor	1			each	
Hydraulic Residence Time		19.3		min.	
D.O. concentration		5.0		ppm	
Avg. Nitrate concentration as N		9.0		ppm	
Diameter			14	ft.	
Height			30	ft.	
Capacity			34,544	gallons	
Recycle Booster Pump	1		75	hp	
Aeration Tanks	2			each	
Diameter			11	ft.	
Height			24	ft.	
Capacity per tank			17,060	gallons	
Filter Contact Tank - Horizontal Pressure Vessel	1			each	Baffled for coagulation chemical mixing
Hydraulic residence time		10		min.	
Capacity			14,000	gallons	
Diameter			10	ft	
Length			23.83	ft	
Vessel end cap length			2	ft	Two - on on each end
Total Length			27.83	ft	Use 28 ft.
Filter Tank - Horizontal Pressure Vessel	2			each	two cells per filter vessel
Filter rate		3		gpm/sf	

City of Davis			**Designed by:**	T Williams	
Chromium 6 Pilot Study			**Date:**	4/4/2013	
Process Sizing & Design Criteria			**Checked by:**	Joe Drago	
Project No.	**1270031*00 / 9.03**		**Date:**	4/5/2013	
Process	**Quantity**	**Design Criteria**	**Sizing**	**Unit**	**Notes**
Capacity			18,144	gallons	
Diameter			10	ft.	
Length			25.7	ft.	
Vessel end cap length			2	ft.	
Total Length			29.7	ft.	Use 30.0 ft
Backwash loading rate		15		gpm/sf	
Backwash duration		10		min.	
Backwash volume/cell			19,250	gallons	
Backwash volume/vessel			38,500	gallons	
Filter to Waste Duration		5		min.	
Filter to Waste Volume/vessel			3,850	gallons	
Backwash Tank	1			each	Designed to handle one filter vessel BW + FTW
Tank Volume Contingency		10		percent	
BW + FTW Volume per vessel			46,585	gallons	
Available Capacity			57,526	gallons	(overflow set at 17 ft. for 20 ft. tall tank)
Full Tank Capacity			67,677	gallons	
Diameter			24	ft.	
Height			20	ft.	Overflow set at 17 ft.
Dead storage height			6.23	ft.	Sludge storage height
Backwash Recycle					
Backwash Volume			42,350	gallons	
Backwash Cycle			8		
Required floc/recirc rate to empty			56	hours	

City of Davis		**Designed by:**	T Williams
Chromium 6 Pilot Study		**Date:**	4/4/2013
Process Sizing & Design Criteria		**Checked by:**	Joe Drago
Project No.	**1270031*00 / 9.03**	**Date:**	4/5/2013

Process	**Quantity**	**Design Criteria**	**Sizing**	**Unit**	**Notes**
Required floc/recirc rate to empty per well utilization @ 65%			86	hours	
Disinfection					
ph		7.7			
Lowest Temperature		10		deg C	
C, Chlorine Residual		0.5		mg/L	In water distribution system
Free Chlorine Dose		1.2		mg/L	
Virus inactivation		4.0		log inactivation	
Direct Filtration Inactivation Credit		1.0		log inactivation	
Table C-7: CT Values for Inactivation of Viruses by Free Chlorine, ph 6.0 - 9.0		4.0		mg/L-min	Based on 3.0 log Virus Inactivation per USEPA Guidance Manual Disinfection Profiling & Benchmarking, Aug. 1999, Appendix C, Table C-7
T10 Contact Time Required		8		minutes	T10 = CT/ C
Chlorine Contact Pressure Vessel					
Capacity			22,400	gallons	0.5 efficiency for baffled vessel
Diameter			10	ft.	
Length			38.1	ft.	
End Cap Length			2	ft.	
Total Length			42.1	ft.	Use 42 ft.
Booster Pump	2			each	Pump from Aeration Tank thru filter system + chlorine contact tank and into the distribution system
Flow rate		1,400		gpm	
System pressure and headlosses		180		ft	
Horsepower			41.36	hp	use 50 hp VFD

City of Davis			**Designed by:**	T Williams	
Chromium 6 Pilot Study			**Date:**	4/4/2013	
Process Sizing & Design Criteria			**Checked by:**	Joe Drago	
Project No.	**1270031*00 / 9.03**		**Date:**	4/5/2013	
Process	**Quantity**	**Design Criteria**	**Sizing**	**Unit**	**Notes**
Modify Well	1			each	
Pumping Water Level		157		ft bgs	below ground surface
Static Head to FBR and Aeration Tank + Headloss		40		ft	30' static head + 10' headloss
Capacity		1,400		gpm	
Horsepower			107	hp	Use existing 125 hp pump & convert to VFD motor drive
Backwash Return Booster Pump Sta	2			each	
Static Head and System Pressure Head			40	ft	Assume BW tank nearly empty and pump into 30 ft tall FBR tank
Capacity			140	gpm	10% of WTP flow rate
Horsepower			2.8		Use 5 hp VFD
Acetic Acid	2			each	Chemical pumps
Chemical Concentration		50%			
Feed Rate			174.3	gpd	Based on Envirogen information
Storage Tanks			5,229	gallons	30 day min. storage - Use two 3,000 gal tanks
Phosphoric Acid	2			each	Chemical pumps
Chemical Concentration		75%			
Feed Rate			2.1	gpd	Based on Envirogen information
Storage Tanks			63	gallons	30 day min. storage - use one 100 gallon tank
Disinfection - Sodium Hypochlorite	2			each	Chemical pumps
Chemical Concentration		12.5%			
Feed Rate			19.2	gpd	
Storage Tanks			577	gallons	30 day min. storage - use two 300 gallon tanks

APPENDIX X: TABLE X-1

City of Davis			**Designed by:**	T Williams	
Chromium 6 Pilot Study			**Date:**	4/4/2013	
Process Sizing & Design Criteria			**Checked by:**	Joe Drago	
Project No.	**1270031*00 / 9.03**		**Date:**	4/5/2013	
Process	**Quantity**	**Design Criteria**	**Sizing**	**Unit**	**Notes**
Coagulant Aid - Ferric Chloride	2			each	Chemical pumps
Chemical Concentration		40%			
Feed Rate		9		gpd	Based on 4 mg/L and achieving ≤ 5.0 ppb of total Cr in the treated water
Storage Tank			272	gallons	Based on avg. use of 9 gpd and 30 day storage
Solids Disposal					
1% Solids stored in Backwash Tank		93		cf/day	
s accumulation in the Backwash Tank		1.32		ft/day	
Discharge to sewer		4.7		day	
Discharge volume (bottom 6.23 ft of Backwash Tank)			4,471	gpd	Assume discharge over a set period
Discharge rate			600	gph	
Length of time to discharge			7.5	hours	

Appendix X: Table X-2
City of Davis Well 20 - Filtration after Fluidized Bed Reactor
K/J 1270031*00 / 9.03

Calcs by:	Tim Williams
Date:	4/4/2013
Checked:	Joe Drago
Date:	4/5/2013

Treatment Vessel Sizing

Line	Description	Sand Media Value		Unit		
1	Well Design Flowrate:	1,400		gpm		
2	No. Filter vessels:	2				
3	Filter vessel flowrate:	770		gpm	1,540	(Two Vessels With Recycle Water)
4	Target loading rate:	3.0		gpm/sf		
5	Min. filter surface area:	257		sf		
6	Vessel diameter:	10		ft		
7	No. Cells:	2				
8	Backwash loading rate:	15		gpm/sf		
9	Backwash duration:	10		minutes		
10	Backwash flowrate per cell:	1,925		gpm		
11	Backwash volume/cell:	19,250		gallons		
12	Backwash volume/filter:	38,500		gallons		
13	Cell Flowrate:	385		gpm/cell		
14	**Shell Length required:**	**25.7**		**ft**		
15	Length per cell:	12.8		ft		
16	Vessel end cap:	2.0		feet		
17	Total vessel length:	29.7		feet		
18	**Total length rounded:**	**30**		**feet**		
19	Surface Wash Loading Rate:	0.0		gpm/sf		
20	Surface Wash Duration:	0.0		minutes		
21	Surface Wash Volume/vessel:	0		gallons		
22	Filter to Waste Duration:	5		minutes		
23	Filter to Waste Volume/vessel:	3,850		gallons	Filter to waste in gpm	1,925
		42,350		gallons	Subtotal Backwash Cycle - one of two filters	

Backwash Tank Size

24	Tank Volume Contingency:	10	0	percent	
25	**BW + FTW Volume/filter:**	**46,585**	**42,350**	**gallons**	**42,350**
26	**FULL SYSTEM BW:**	**93,170**	**84,700**	**gallons**	**84,700**

Appendix X: Table X-2
City of Davis Well 20 - Filtration after Fluidized Bed Reactor
K/J 1270031*00 / 9.03

Calcs by:	Tim Williams
Date:	4/4/2013
Checked:	Joe Drago
Date:	4/5/2013

Backwash Tank — Conclusion -Size based on Sand Media and BW + FTW for one filter

26	Backwash Tank volume (nominal)	46,585	42,350	gallons		
27	volume required, CF	6,228	5,662	cubic foot		
28	Diameter	24.0	24.0	feet		
29	Shell Height	20	20	feet	High Level Alarm	(Overflow Set @ 17')
30	Volume, CF	9,048	9,048	cubic foot		
	Volume, gal	67,677	67,677	gallons		
	Dead Storage	6.23	7.48	feet	Sludge Storage Height	
Sewer Discharge or Recycle Back to Head of the Plant						
30	Backwash Volume	42,350		gallons		
31	Backwash cycle	8		number		
32	Required flow/recirc rate to empty	88.23		hours		
33	Required flow/recirc rate to empty per well utilization @ 65%	135.74		hours	Well Utilization =	0.65

Appendix X: Table X-3: FBR WTP - Solids Handling and Disposal				
City of Davis			**Designed by:**	T Williams
Chromium 6 Pilot Study			**Date:**	4/4/2013
Process Sizing & Design Criteria			**Checked by:**	Joe Drago
Project No.	**1270031*00 / 9.03**		**Date:**	4/5/2013
Ferric Chloride (FeCl3) Use				
Dosage	4	mg/L	This will achieve per the pilot test a total chromium of 5 ppb or less	
WTP Flow rate	2	mgd		
% Plant Operation	65	%	Well operates 65% of the year on average	
Ferric Chloride Concentration	40	%		
Specific gravity of FeCl3	1.432			
Conversion	8.34	lbs/gal		
Pounds of FeCl3/gal solution	4.8	lbs/gal	= 0.4 x 1.432 spg x 8.34 lbs/gal	
Gal/Day of FeCl3	9.1	gpd	= 4 mg/L x 2 mgd x0.65 x 8.34 lg/day/mg/L) / (4.78 lb / gal)	
30 Day Supply of FeCl3	272	gallons	= 9.1 gpd x 30 days	
Backwash Solids Generated				
WTP Flow rate	2	mgd		
% Plant Operation	65	%	Well operates 65% of the year on average	
Sludge concentration	1	%		
Backwash Tank Diam.	24	ft.		
TSS estimated from FBR	6	mg/L	Estimate provided by Envirogen	
Fe(OH)3 estimated from FeCl3 dosage	2.6	mg/l	= 4 mg/l FeCl3 dosage x 0.65 converts to Fe(OH)3 solids	
TSS Sludge production rate	65	lbs/day	=2 mgd x 0.65 x 8.34 lbs/gal x 6 mg/L	
Fe(OH)3 Sludge production rate	28	lbs/day	=2 mgd x 0.65x 8.34 lbs/gal x 2.6 mg/l	
Total Estimated sludge production rate	93	lbs/day	= 65 + 28 lbs/day	
Density of water	62.4	lbs/cf		
At 1% solids density of sludge	0.624	lbs/cf	= 62.4 lb/cf * 1% sludge conc.	
Sludge generation	149	cf/day	= 93 lb/day / 0.624 lbs/cf	
Backwash Tank Surface Area	113.10	sf	= (24 ft / 4)^2* 3.1416	
Sludge generation	1.32	ft/day	= 149 cf/day / 113.10 sf	
Dead storage height in tank	6.23	ft		
Days before dead storage full	4.7	days	= 3.38 ft / 1 ft/day	

Appendix X: Table X-3: FBR WTP - Solids Handling and Disposal									
City of Davis			**Designed by:**	T Williams					
Chromium 6 Pilot Study			**Date:**	4/4/2013					
Process Sizing & Design Criteria			**Checked by:**	Joe Drago					
Project No.	**1270031*00 / 9.03**		**Date:**	4/5/2013					
Discharge to sewer every 4 days (not 4.7 days)	4,471	gallons	= 149 cf/day * 7.48 gal/cf * 4 days						
Discharge rate	600	gph	selected to not overload sewer with flow						
Length of time to discharge	7.5	hours	= 4,471 gallons / 600 gph						

Appendix XI

Opinion of Probable Construction and O&M Costs

Table XI-1: OPINION OF PROBABLE CONSTRUCTION COST WELL 20 FBR WTP SITE SPECIFIC

KENNEDY/JENKS CONSULTANTS

Project:	City of Davis - Co-Removal of Cr6 Pilot Study				**Prepared By:**	T Williams
					Date Prepared:	26-Apr-13
					Checked By:	J Drago
NOTE: Accuracy of Cost Estimate is +50% to -30%					**Date Prepared:**	26-Apr-13
Based on 1,400 gpm WTP					**K/J Proj. No.**	1270031*00
					Current at Natl Avg ENR	9,456
Estimate Type:	[x]	**Conceptual**			**Escalated to Natl Avg ENR**	9,456
	[ ]	**Preliminary (w/o plans)**				
	[ ]	**Design Deve**	________	**% Complete**		

Item	Quantity	Unit	Unit Cost	Extended Cost	Notes
1. Modify Existing Well to VFD motor with enclosure	1	**EACH**	$59,000	$59,000	Replace pump & convert from fixed speed to VFD & add sound enclosure
2. FBR and Aeration System	1	**EACH**	$1,629,000	$1,629,000	One FBR tank and two Aeration Tanks with blowers and recirculation pumps
3. Acetic Acid and Phosphoric Acid Feed System	1	**EACH**	$181,000	$181,000	Two of each chemical pump with one 100 gallon storage tank for phosphoric acid and two each chemical pump and two 3,000 gallon acetic acid storage tanks
4. Booster Pump Station	1	**EACH**	$100,000	$100,000	1,400 gpm VFD dual pump station, 50 hp each
5. Booster Pump Station Building	510	**SF**	$400	$204,000	30' L x 17' W x 12' H for the 2 booster pumps & 2 aeration tank blowers
6. Contact Tank and Filter System	1	**EACH**	$600,000	$600,000	Contact Tank - 14,000 gal horiz press. Vessel + 2 ea 18,144 gal. press. Vessels
7. Coagulant Filter Aid Chemical System	1	**EACH**	$40,000	$40,000	Two chemical feed pumps & 300 gallon chemical storage tank
8. Chlorine Contact Tank	1	**EACH**	$150,000	$150,000	22,400 gal baffled press vessel
9. Disinfection Feed System	1	**EACH**	$60,000	$60,000	Two ea. 300 gal tanks + 2 pumps

Table XI-1: OPINION OF PROBABLE CONSTRUCTION COST WELL 20 FBR WTP SITE SPECIFIC					KENNEDY/JENKS CONSULTANTS			
Project:	City of Davis - Co-Removal of Cr6 Pilot Study						**Prepared By:**	T Williams
							Date Prepared:	26-Apr-13
							Checked By:	J Drago
NOTE: Accuracy of Cost Estimate is +50% to -30%							**Date Prepared:**	26-Apr-13
Based on 1,400 gpm WTP							**K/J Proj. No.**	1270031*00
							Current at Natl Avg ENR	9,456
Estimate Type:	[X]	**Conceptual**					**Escalated to Natl Avg ENR**	9,456
	[ ]	**Preliminary (w/o plans)**						
	[ ]	**Design Deve**	_________	**% Complete**				
Item	Quantity	**Unit**	Unit Cost	Extended Cost	Notes			
10. Chemical Building	860	**SF**	$500	$430,000	46.5' L x 18.5' W x 14' H for Acetic and Phosphoric Acids, Ferric Chloride Coag., and Sod. Hypochlorite			
11. Backwash Tank	1	**EACH**	$135,400	$135,400	67,700 gallons welded steel tank			
12. Backwash Water Return Booster Pump Sta	1	**EACH**	$12,000	$12,000	Two each 5 hp			
13. Control Building	509	**SF**	$400	$204,000	27' L x 18.5' W x 12' H for control room and standby generator			
14. Standby Generator	1	**EACH**	$55,000	$55,000	Assume 175 kw standby generator			
15. Civil Site Work and Security	1	**LUMP SUM**	$965,000	$965,000	Assume 25% of items 1 to 14			
16. Electrical Power and Instrumentation & Controls	1	**LUMP SUM**	$965,000	$965,000	Assume 25% of items 1 to 14			
17. Construction Cost Subtotal of Items 1 to 16 (rounded to nearest thousand)				$5,789,000				
18. Contingency (25%)			0.25	$1,447,000	25% of the Subtotal Cost			
19. Total Construction Cost Estimate				$7,236,000	Sum of Items 17 and 18			
20. Engineering & Construction Administration (20%)			0.2	$1,447,000	20% of Item 19 Cost			

Table XI-1: OPINION OF PROBABLE CONSTRUCTION COST WELL 20 FBR WTP SITE SPECIFIC					KENNEDY/JENKS CONSULTANTS				
Project:	City of Davis - Co-Removal of Cr6 Pilot Study							**Prepared By:**	T Williams
								Date Prepared:	26-Apr-13
								Checked By:	J Drago
NOTE: Accuracy of Cost Estimate is +50% to -30%								**Date Prepared:**	26-Apr-13
Based on 1,400 gpm WTP								**K/J Proj. No.**	1270031*00
								Current at Natl Avg ENR	9,456
Estimate Type:	[X]	**Conceptual**						**Escalated to Natl Avg ENR**	9,456
	[ ]	**Preliminary (w/o plans)**							
	[ ]	**Design Deve**	________	**% Complete**					
Item	Quantity	**Unit**	Unit Cost	Extended Cost	Notes				
21. Environmental and Permitting (5%)			0.05	$362,000	5% of Item 19 Cost				
22. City Admin and Management (10%)			0.1	$724,000	10% of Item 19 Cost				
23. Land Purchase	0.36	**ACRES**	$150,000	$54,000	Purchase addl 0.46 acres out of 0.5 ac site				
24. TOTAL OPINION OF PROBABLE PROJECT COST				$9,769,000	Sum of Items 19 through 23				
25. Cost per gallon to construct				$6.11	1.6 mgd WTP				
26. Cost per gallon to construct for West Valley WD Perchlorate WTP				$4.10	2.86 mgd WTP				
Annualized Cost Analysis - Convert Capital to Annual Cost									
27. Planning period	30	YEARS							
28. Interest Rate, I =	3	%							
29. Convert Capital Cost to Annual Cost Factor	0.05102								
30. Total Estimated Project Cost			$9,769,000						
31. Annualized Project Cost (round to nearest thousand)			$498,000	= Item 29 * Item 30					
32. Annual O&M Cost			$401,000						

Table XI-1: OPINION OF PROBABLE CONSTRUCTION COST WELL 20 FBR WTP SITE SPECIFIC					KENNEDY/JENKS CONSULTANTS				
Project:	City of Davis - Co-Removal of Cr6 Pilot Study							**Prepared By:**	T Williams
								Date Prepared:	26-Apr-13
								Checked By:	J Drago
NOTE: Accuracy of Cost Estimate is +50% to -30%								**Date Prepared:**	26-Apr-13
Based on 1,400 gpm WTP								**K/J Proj. No.**	1270031*00
								Current at Natl Avg ENR	9,456
Estimate Type:	[X]	**Conceptual**						**Escalated to Natl Avg ENR**	9,456
	[ ]	**Preliminary (w/o plans)**							
	[ ]	**Design Deve**	_________	**% Complete**					
Item	Quantity	**Unit**	Unit Cost	Extended Cost	Notes				
33. Total Annualized Cost			$899,000	= Item 31 + Item 32					
34. Cost Per Acre Foot		$ / AF-YR	$617	= (Total Annualized Cost * 0.32585 mg / AF) / (2.0 mgd * 0.65 * 365 days/yr)					

J:\2012\1270031.00_City of Davis Cr6 Pilot Study\09-Reports\9.09-Reports\Final Report\FBR Cost Est & Size\Conceptual Cost Est-final 4-29-13.xlsx
Well 20 FBR Proj Cost

Table XI-2: OPINION OF PROBABLE ANNUAL O&M COST - WELL 20 FBR SITE SPECIFIC						KENNEDY/JENKS CONSULTANTS	
Project:	**City of Davis - Co-Removal of Cr6 Pilot Study**					Prepared By:	T Williams
						Date Prepared:	4/26/2013
Note: Based on 1,400 gpm FBR WTP						Checked By:	J Drago
						Date Prepared:	4/26/2013
						K/J Proj. No.	1270031*00
ITEM	**QUANTITY**	**UNIT**	**UNIT COST**	**EXTENDED COST**	**NOTES**		
Energy							
Well Pump - 125 HP	530,966	kw-hrs/yr	$0.12	$63,716	Assume operate 65% of the time through the year		
Aeration Blower - 10 HP @ 2 ea	84,954	kw-hrs/yr	$0.12	$10,195	Assume operate 65% of the time through the year		
FBR Recycle Pump - 30 HP	127,432	kw-hrs/yr	$0.12	$15,292	Assume operate 65% of the time through the year		
Booster Pump - 50 HP	212,386	kw-hrs/yr	$0.12	$25,486	Assume operate 65% of the time through the year		
Chemical Pumps - total sum = 10 HP	42,477	kw-hrs/yr	$0.12	$5,097	Assume operate 65% of the time through the year		
Backwash Return Pump - 5 HP	21,239	kw-hrs/yr	$0.12	$2,549	Assume operate 65% of the time through the year		
Miscellaneous Energy = 10 HP	42,477	kw-hrs/yr	$0.12	$5,097	Assume operate 65% of the time through the year		
Chemicals & FBR Media							
Phosphoric Acid @ 2.1 gpd	498	gal/yr	$9.23	$4,599	Assume operate 65% of the time through the year		
Acetic Acid @ 87.2 gpd	20,688	gal/yr	$5.28	$109,234	Use 100% Acetic Acid and dilute to 50% concentration. Assume operate 65% of the time through the year		
Sodium Hypochlorite @ 19.2 gpd	4,555	gal/yr	$2.00	$9,110	Assume operate 65% of the time through the year		
Coagulant -Ferric Chloride	2,135	gal/yr	$4.50	$9,609	Assume operate 65% of the time through the year		
FBR Media Replacement	1,302	lbs/yr	$1.25	$1,628			
Filter Media	1	LS / yr	$500	$500			
Solids Disposal							
Discharge to sewer, treat @ WWTP & dry and dispose solids per year	406,861	gal / yr	$0.24	$97,647	Assume discharge 4,471 gals every 4 days. Industrial pretreatment program cost for discharge is provided by the City of Davis.		
Operation Staff							
Operator	260	hrs/yr	$60	$15,600	Assume 5 hrs per week, 52 weeks per year		
Maintenance	156	hrs/yr	$60	$9,360	Assume 3 hrs per week, 52 weeks per year		
Electrician	104	hrs/yr	$60	$6,240	Assume 2 hrs per week, 52 weeks per year		
Miscellaneous Equipment and Materials	1	LS / yr	$10,000	$10,000			
Total (rounded to nearest thousand)		cost / yr		$401,000	Annual cost per year		
Cost per acre foot per year		$/ AF - YR		$275	= ($401,000*0.32585 mg/af) / (2 mgd x 0.65 x 365 days/yr)		

Table XI-1: OPINION OF PROBABLE CONSTRUCTION COST FOR AN GREENFIELD FBR WTP - UNDEVELOPED SITE

KENNEDY/JENKS CONSULTANTS

Project:	City of Davis - Co-Removal of Cr6 Pilot Study
Prepared By:	T Williams
Date Prepared:	26-Apr-13
Checked By:	J Drago
Date Prepared:	26-Apr-13
K/J Proj. No.	1270031*00
Current at Natl Avg ENR	9,456
Escalated to Natl Avg ENR	9,456

NOTE: Accuracy of Cost Estimate is +50% to -30%

Based on 1,400 gpm WTP

Estimate Type:

- [x] **Conceptual**
- [ ] **Preliminary (w/o plans)**
- [ ] **Design Deve** _________ **% Complete**

Item	Quantity	Unit	Unit Cost	Extended Cost	Notes
1. New Well to VFD motor with enclosure	1	**EACH**	$0	$0	Assume new well is in place
2. FBR and Aeration System	1	**EACH**	$1,262,000	$1,262,000	One FBR tank and one Aeration Tank with blowers and recirculation pumps
3. Acetic Acid and Phosphoric Acid Feed System	1	**EACH**	$181,000	$181,000	Two of each chemical pump with one 100 gallon storage tank for phosphoric acid and two each chemical pump and two 3,000 gallon acetic acid storage tanks
4. Booster Pump Station	1	**EACH**	$100,000	$100,000	1,400 gpm VFD dual pump station, 50 hp each
5. Booster Pump Station Slab on Grade	200	**SF**	$100	$20,000	Located outside on a 20' x 10' rectangle slab on grade
6. Chemical Mixing and Filter System	1	**EACH**	$335,000	$335,000	Inline mixer for coagulant mixing + 2 ea 12,096 gal. press. Filter vessels
7. Coagulant Filter Aid Chemical System	1	**EACH**	$40,000	$40,000	Two chemical feed pumps & 300 gallon chemical storage tank

Table XI-1: OPINION OF PROBABLE CONSTRUCTION COST FOR AN GREENFIELD FBR WTP - UNDEVELOPED SITE

KENNEDY/JENKS CONSULTANTS

Project:	City of Davis - Co-Removal of Cr6 Pilot Study		**Prepared By:**	T Williams
			Date Prepared:	26-Apr-13
			Checked By:	J Drago
NOTE: Accuracy of Cost Estimate is +50% to -30%			**Date Prepared:**	26-Apr-13
Based on 1,400 gpm WTP			**K/J Proj. No.**	1270031*00
			Current at Natl Avg ENR	9,456
Estimate Type:	[X]	**Conceptual**	**Escalated to Natl Avg ENR**	9,456
	[ ]	**Preliminary (w/o plans)**		
	[ ]	**Design Deve** _________ **% Complete**		

Item	Quantity	Unit	Unit Cost	Extended Cost	Notes
8. Chlorine Contact Tank - NOT NEEDED	0	**EACH**	$0	$0	Meet CT through filters
9. Disinfection Feed System	1	**EACH**	$60,000	$60,000	Two ea. 300 gal tanks + 2 pumps
10. Chemical Roof Structure	860	**SF**	$250	$215,000	46.5' L x 18.5' W x 14' H for Acetic and Phosphoric Acids, Ferric Chloride Coag., and Sod. Hypochlorite - roof covering and concrete secondary containment- no building, similar to West Valley WD
11. Backwash Tank	1	**EACH**	$135,200	$135,200	67,700 gallons welded steel tank
12. Backwash Water Return Booster Pump Sta	1	**EACH**	$12,000	$12,000	Two each 5 hp
13. Control Building	509	**SF**	$400	$204,000	27' L x 18.5' W x 12' H for control room and standby generator
14. Standby Generator	1	**EACH**	$55,000	$55,000	Assume 175 kw standby generator
15. Civil Site Work and Security	1	**LUMP SUM**	$655,000	$655,000	Assume 25% of items 1 to 14
16. Electrical Power and Instrumentation & Controls	1	**LUMP SUM**	$655,000	$655,000	Assume 25% of items 1 to 14

Table XI-1: OPINION OF PROBABLE CONSTRUCTION COST FOR AN GREENFIELD FBR WTP - UNDEVELOPED SITE

KENNEDY/JENKS CONSULTANTS

Project:	City of Davis - Co-Removal of Cr6 Pilot Study			**Prepared By:**	T Williams
				Date Prepared:	26-Apr-13
				Checked By:	J Drago
NOTE: Accuracy of Cost Estimate is +50% to -30%				**Date Prepared:**	26-Apr-13
Based on 1,400 gpm WTP				**K/J Proj. No.**	1270031*00
				Current at Natl Avg ENR	9,456
Estimate Type:	X	**Conceptual**		**Escalated to Natl Avg ENR**	9,456
	☐	**Preliminary (w/o plans)**			
	☐	**Design Deve**	_________ **% Complete**		

Item	Quantity	**Unit**	Unit Cost	Extended Cost	Notes
17. Construction Cost Subtotal of Items 1 to 16 (rounded to nearest thousand)				$3,929,000	
18. Contingency (25%)			0.25	$982,000	25% of Item 17 Cost
19. Total Construction Cost Estimate				$4,911,000	Sum of Items 17 and 18
20. Engineering & Construction Administration (20%)			0.2	$982,000	20% of Item 19 Cost
21. Environmental and Permitting (5%)			0.05	$246,000	5% of Item 19 Cost
22. City Admin and Management (10%)			0.1	$491,000	10% of Item 19 Cost
23. Purchase Land	0	**ACRES**	$150,000	$0	Assume land already owned
24. TOTAL OPINION OF PROBABLE PROJECT COST				$6,630,000	Sum of Items 19 through 22
25. Cost per gallon to construct				$4.14	1.6 mgd WTP
26. Cost per gallon to construct for West Valley WD Perchlorate WTP				$4.10	2.86 mgd WTP
Annualized Cost Analysis - Convert Capital to Annual Cost					
27. Planning period	30	YEARS			
28. Interest Rate, I =	3	%			

Table XI-1: OPINION OF PROBABLE CONSTRUCTION COST FOR AN GREENFIELD FBR WTP - UNDEVELOPED SITE					KENNEDY/JENKS CONSULTANTS			
Project:	City of Davis - Co-Removal of Cr6 Pilot Study						**Prepared By:**	T Williams
							Date Prepared:	26-Apr-13
							Checked By:	J Drago
NOTE: Accuracy of Cost Estimate is +50% to -30%							**Date Prepared:**	26-Apr-13
Based on 1,400 gpm WTP							**K/J Proj. No.**	1270031*00
							Current at Natl Avg ENR	9,456
Estimate Type:	[X]	**Conceptual**					**Escalated to Natl Avg ENR**	9,456
	[ ]	**Preliminary (w/o plans)**						
	[ ]	**Design Deve**	________	**% Complete**				
Item	Quantity	**Unit**	Unit Cost	Extended Cost	Notes			
29. Convert Capital Cost to Annual Cost Factor	0.05102							
30. Total Estimated Project Cost			$6,630,000					
31. Annualized Project Cost (round to nearest thousand)			$338,000	= Item 29 * Item 28				
32. Annual O&M Cost			$396,000					
33. Total Annualized Cost			$734,000	= Item 30 + Item 31				
34. Cost Per Acre Foot		$ / AF-YR	$504	= (Total Annualized Cost * 0.32585 mg / AF) / (2.0 mgd * 0.65 * 365 days/yr)				

Table XI-2: OPINION OF PROBABLE ANNUAL O&M COST FBR WTP GREENFIELD SITE					KENNEDY/JENKS CONSULTANTS	
Project:	**City of Davis - Co-Removal of Cr6 Pilot Study**				Prepared By:	T Williams
					Date Prepared:	4/11/2013
NOTE:					Checked By:	J Drago
Based on 1,400 gpm WTP						4/12/2013
					K/J Proj. No.	1270031*00

ITEM	QUANTITY	UNIT	UNIT COST	EXTENDED COST	NOTES
Energy					
Well Pump - 125 HP	530,966	kw-hrs/yr	$0.12	$63,716	Assume operate 65% of the time through the year
Aeration Blower - 10 HP @ 1 ea	42,477	kw-hrs/yr	$0.12	$5,097	Assume operate 65% of the time through the year
FBR Recycle Pump - 30 HP	127,432	kw-hrs/yr	$0.12	$15,292	Assume operate 65% of the time through the year
Booster Pump - 50 HP	212,386	kw-hrs/yr	$0.12	$25,486	Assume operate 65% of the time through the year
Chemical Pumps - total sum = 10 HP	42,477	kw-hrs/yr	$0.12	$5,097	Assume operate 65% of the time through the year
Backwash Return Pump - 5 HP	21,239	kw-hrs/yr	$0.12	$2,549	Assume operate 65% of the time through the year
Miscellaneous Energy = 10 HP	42,477	kw-hrs/yr	$0.12	$5,097	Assume operate 65% of the time through the year
Chemicals & FBR Media					
Phosphoric Acid @ 2.1 gpd	498	gal/yr	$9.23	$4,599	Assume operate 65% of the time through the year
Acetic Acid @ 87.2 gpd	20,688	gal/yr	$5.28	$109,234	Use 100% Acetic Acid and dilute to 50% concentration. Assume operate 65% of the time through the year
Sodium Hypochlorite @ 19.2 gpd	4,555	gal/yr	$2.00	$9,110	Assume operate 65% of the time through the year
Coagulant -Ferric Chloride	2,135	gal/yr	$4.50	$9,609	Assume operate 65% of the time through the year
FBR Media Replacement	1,302	lbs/yr	$1.25	$1,628	
Filter Media	1	LS	$500	$500	
Solids Disposal					
Discharge to sewer, treat @ WWTP & dry and dispose solids	406,861	gal	$0.24	$97,647	Assume discharge 4,471 gals every 4 days. Industrial pretreatment program cost for discharge is provided by the City of Davis.
Operation Staff					
Operator	260	hrs/yr	$60	$15,600	Assume 5 hrs per week, 52 weeks per year
Maintenance	156	hrs/yr	$60	$9,360	Assume 3 hrs per week, 52 weeks per year
Electrician	104	hrs/yr	$60	$6,240	Assume 2 hrs per week, 52 weeks per year
Miscellaneous Equipment and Materials	1	LS	$10,000	$10,000	
Total (rounded to nearest thousand)		cost / yr		$396,000	Annual cost per year
Cost per acre foot per year		$/ AF - YR		$272	= ($396,000*0.32585 mg/af) / (2.0 mgd x 0.65 x 365 days/yr)

Table XI-1: OPINION OF PROBABLE CONSTRUCTION COST FOR A GREENFIELD SBA WTP - UNDEVELOPED SITE

KENNEDY/JENKS CONSULTANTS

Project: City of Davis - Co-Removal of Cr6 Pilot Study

Prepared By: T Williams
Date Prepared: 26-Apr-13
Checked By: J Drago
Date Prepared: 26-Apr-13

NOTE: Accuracy of Cost Estimate is +50% to -30%

Source is Probable Capital & Annual O&M Costs for Cr6 Removal from Well 20 Technical Report prepared for Wtr Res Fnd by WQTS (4-22-13)

K/J Proj. No. 1270031*00

Based on 1,100 gpm not 1,400 gpm WTP system

Current at Natl Avg ENR 9,456
Escalated to Natl Avg ENR 9,456

Estimate Type:
- [x] **Conceptual**
- [ ] **Preliminary (w/o plans)**
- [ ] **Design Deve** ________ **% Complete**

Item	Quantity	Unit	Unit Cost	Extended Cost	Notes
1. Equipment including 7.5% sales tax + installation	1	EACH	$738,275	$738,275	Strong Base Acid treatment system
2. Building Cost	1	EACH	$142,000	$142,000	Building to house WTP and equipment
3. Construction Activities	1	EACH	$991,000	$991,000	
4. Construction Cost Subtotal of Items 1 to 3 (rounded to nearest thousand)				$1,871,000	
5. Contingency (25%)			0.25	$468,000	25% of Item 4 Cost
6. Total Construction Cost Estimate				$2,339,000	Sum of Items 4 and 5
7. Engineering & Construction Administration (20%)			0.2	$468,000	20% of Item 6 Cost

Table XI-1: OPINION OF PROBABLE CONSTRUCTION COST FOR A GREENFIELD SBA WTP - UNDEVELOPED SITE

KENNEDY/JENKS CONSULTANTS

Project:	City of Davis - Co-Removal of Cr6 Pilot Study	**Prepared By:**	T Williams
		Date Prepared:	26-Apr-13
		Checked By:	J Drago
NOTE: Accuracy of Cost Estimate is +50% to -30%		**Date Prepared:**	26-Apr-13
Source is Probable Capital & Annual O&M Costs for Cr6 Removal from Well 20 Technical Report prepared for Wtr Res Fnd by WQTS (4-22-13)		**K/J Proj. No.**	1270031*00
Based on 1,100 gpm not 1,400 gpm WTP system		**Current at Natl Avg ENR**	9,456
Estimate Type:	[x] **Conceptual**	**Escalated to Natl Avg ENR**	9,456
	[ ] **Preliminary (w/o plans)**		
	[ ] **Design Deve** _________ **% Complete**		

Item	Quantity	Unit	Unit Cost	Extended Cost	Notes
8. Environmental and Permitting (5%)			0.05	$117,000	5% of Item 6 Cost
9. City Admin and Management (10%)			0.1	$234,000	10% of Item 6 Cost
10. Purchase Land	0	**ACRES**	$150,000	$0	Assume land already owned
11. TOTAL OPINION OF PROBABLE PROJECT COST				$3,158,000	Sum of Items 6 through 10
12. Cost per gallon to construct				$1.58	1.6 mgd RFC WTP
13. Cost per gallon to construct for West Valley WD Perchlorate FBR WTP				$4.10	2.86 mgd FBR WTP
Annualized Cost Analysis - Convert Capital to Annual Cost					
14. Planning period	30	YEARS			
15. Interest Rate, I =	3	%			
16. Convert Capital Cost to Annual Cost Factor	0.05102				
17. Total Estimated Project Cost			$3,158,000		
18. Annualized Project Cost (round to nearest thousand)			$161,000	= Item 15 * Item 16	
19. Annual O&M Cost			$392,000	Using SBA Total Annual Cost based on 65% operation not 40%	

Table XI-1: OPINION OF PROBABLE CONSTRUCTION COST FOR A GREENFIELD SBA WTP - UNDEVELOPED SITE					**KENNEDY/JENKS CONSULTANTS**			
Project:	City of Davis - Co-Removal of Cr6 Pilot Study						**Prepared By:**	T Williams
							Date Prepared:	26-Apr-13
							Checked By:	J Drago
NOTE: Accuracy of Cost Estimate is +50% to -30%							**Date Prepared:**	26-Apr-13
Source is Probable Capital & Annual O&M Costs for Cr6 Removal from Well 20 Technical Report prepared for Wtr Res Fnd by WQTS (4-22-13)							**K/J Proj. No.**	1270031*00
Based on 1,100 gpm not 1,400 gpm WTP system					**Current at Natl Avg ENR**			9,456
Estimate Type:	[X]	**Conceptual**			**Escalated to Natl Avg ENR**			9,456
	[ ]	**Preliminary (w/o plans)**						
	[ ]	**Design Deve**	________	**% Complete**				
Item	Quantity	**Unit**	Unit Cost	Extended Cost	Notes			
20. Total Annualized Cost			$553,000	= Item 18 + Item 19				
21. Cost Per Acre Foot		$ / AF-YR	$475	= (Total Annualized Cost * 0.32585 mg / AF) / (1.6 mgd * 0.65 * 365 days/yr)				

Table XI-2: OPINION OF PROBABLE ANNUAL O&M COST SBA WTP GREENFIELD SITE						KENNEDY/JENKS CONSULTANTS	
Project:	**City of Davis - Co-Removal of Cr6 Pilot Study**					Prepared By:	T Williams
						Date Prepared:	4/26/2013
Note:						Checked By:	J Drago
Based on brine hauled off site						Date Prepared:	4/26/2013
Based on 1,100 gpm WTP						K/J Proj. No.	1270031*00
ITEM	**QUANTITY**	**UNIT**	**UNIT COST**	**EXTENDED COST**	**NOTES**		
Energy							
Increased from 40% to 65% operation and adjusted from $0.15/kw-hr to $0.12/kw-hr	1	energy/yr	$3,900	$3,900	Assume operate 65% of the time through the year		
Chemicals							
Increased from 40% to 65% operation	1	chem/yr	$58,500	$58,500	Assume operate 65% of the time through the year		
Solids Disposal							
Liquid Waste disposal trucks per year hauled to EBMUD for disposal	481,100	gallons/yr	$0.24	$115,464	Assume 296,100 gallons for 40% operation so increase to 481,100 gallons for 65% operation		
Solids Disposal	1,820	cu ft / yr	$50	$91,000	Assume 1,120 cu ft for 40% operation so increase to 1,820 cu ft for 65% operation		
Operation Staff							
Operations staff increase from 40% to 65% operation	1	cost/yr	$107,250	$107,250	Includes labor and maintenance costs		
Miscellaneous Equipment and Materials	1	LS	$16,250	$16,250	Includes analytical costs. Adjust to 65% operation from 40%		
Total (rounded to nearest thousand)		cost / yr		$392,000	Annual cost per year		
Cost per acre foot per year		$/ AF - YR		$336	= ($392,000*0.32585 mg/af) / (1.6 mgd x 0.65 x 365 days/yr)		

Table XI-1: OPINION OF PROBABLE CONSTRUCTION COST FOR A GREENFIELD RCF WTP - UNDEVELOPED SITE, OPTION 1

KENNEDY/JENKS CONSULTANTS

Project:	City of Davis - Co-Removal of Cr6 Pilot Study						**Prepared By:**	T Williams
							Date Prepared:	26-Apr-13
							Checked By:	J Drago
NOTE: Accuracy of Cost Estimate is +50% to -30%							**Date Prepared:**	26-Apr-13
Source is Probable Capital & Annual O&M Costs for Cr6 Removal from Well 20 Technical Report prepared for Wtr Res Fnd by WQTS (4-22-13)							**K/J Proj. No.**	1270031*00
Based on 1,100 gpm not 1,400 gpm WTP system							**Current at Natl Avg ENR**	9,456
Based on discharging solids to the sewer							**Escalated to Natl Avg ENR**	9,456
Estimate Type:	[X]	**Conceptual**						
	[ ]	**Preliminary (w/o plans)**						
	[ ]	**Design Deve**	________	**% Complete**				
Item	Quantity	**Unit**	Unit Cost	Extended Cost	Notes			
1. Equipment including 7.5% sales tax + installation	1	**EACH**	$1,310,475	$1,310,475	Reduction, Coagulation and Filtration treatment system			
2. Building Cost	1	**EACH**	$149,000	$149,000	Building to house WTP and equipment			
3. Construction Activities	1	**EACH**	$1,536,000	$1,536,000				
4. Construction Cost Subtotal of Items 1 to 3 (rounded to nearest thousand)				$2,995,000				
5. Contingency (25%)			0.25	$749,000	25% of Item 4 Cost			
6. Total Construction Cost Estimate				$3,744,000	Sum of Items 4 and 5			
7. Engineering & Construction Administration (20%)			0.2	$749,000	20% of Item 6 Cost			

Table XI-1: OPINION OF PROBABLE CONSTRUCTION COST FOR A GREENFIELD RCF WTP - UNDEVELOPED SITE, OPTION 1

KENNEDY/JENKS CONSULTANTS

Project:	City of Davis - Co-Removal of Cr6 Pilot Study
Prepared By:	T Williams
Date Prepared:	26-Apr-13
Checked By:	J Drago
Date Prepared:	26-Apr-13
K/J Proj. No.	1270031*00
Current at Natl Avg ENR	9,456
Escalated to Natl Avg ENR	9,456

NOTE: Accuracy of Cost Estimate is +50% to -30%

Source is Probable Capital & Annual O&M Costs for Cr6 Removal from Well 20 Technical Report prepared for Wtr Res Fnd by WQTS (4-22-13)

Based on 1,100 gpm not 1,400 gpm WTP system

Based on discharging solids to the sewer

Estimate Type:

- [X] **Conceptual**
- [ ] **Preliminary (w/o plans)**
- [ ] **Design Deve** _________ **% Complete**

Item	Quantity	**Unit**	Unit Cost	Extended Cost	Notes
8. Environmental and Permitting (5%)			0.05	$187,000	5% of Item 6 Cost
9. City Admin and Management (10%)			0.1	$374,000	10% of Item 6 Cost
10. Purchase Land	0	**ACRES**	$150,000	$0	Assume land already owned
11. TOTAL OPINION OF PROBABLE PROJECT COST				$5,054,000	Sum of Items 6 through 10
12. Cost per gallon to construct				$3.16	1.6 mgd RFC WTP
13. Cost per gallon to construct for West Valley WD Perchlorate FBR WTP				$4.10	2.86 mgd FBR WTP
Annualized Cost Analysis - Convert Capital to Annual Cost					
14. Planning period	30	YEARS			
15. Interest Rate, I =	3	%			
16. Convert Capital Cost to Annual Cost Factor	0.05102				
17. Total Estimated Project Cost			$5,054,000		
18. Annualized Project Cost (round to nearest thousand)			$258,000	= Item 15 * Item 16	

Table XI-1: OPINION OF PROBABLE CONSTRUCTION COST FOR A GREENFIELD RCF WTP - UNDEVELOPED SITE, OPTION 1

KENNEDY/JENKS CONSULTANTS

Project:	City of Davis - Co-Removal of Cr6 Pilot Study
Prepared By:	T Williams
Date Prepared:	26-Apr-13
Checked By:	J Drago
Date Prepared:	26-Apr-13
K/J Proj. No.	1270031*00
Current at Natl Avg ENR	9,456
Escalated to Natl Avg ENR	9,456

NOTE: Accuracy of Cost Estimate is +50% to -30%

Source is Probable Capital & Annual O&M Costs for Cr6 Removal from Well 20 Technical Report prepared for Wtr Res Fnd by WQTS (4-22-13)

Based on 1,100 gpm not 1,400 gpm WTP system

Based on discharging solids to the sewer

Estimate Type:
- [x] **Conceptual**
- [ ] **Preliminary (w/o plans)**
- [ ] **Design Deve** _________ **% Complete**

Item	Quantity	Unit	Unit Cost	Extended Cost	Notes
19. Annual O&M Cost			$2,620,000	Using RCF Total Annual Cost based on 65% operation not 40%	
20. Total Annualized Cost			$2,878,000	= Item 18 + Item 19	
21. Cost Per Acre Foot		$ / AF-YR	$2,470	= (Total Annualized Cost * 0.32585 mg / AF) / (1.6 mgd * 0.65 * 365 days/yr)	

Table XI-2: OPINION OF PROBABLE ANNUAL O&M COST RCF WTP GREENFIELD SITE OPTION 1						KENNEDY/JENKS CONSULTANTS	
Project:	**City of Davis - Co-Removal of Cr6 Pilot Study**					Prepared By:	T Williams
						Date Prepared:	4/26/2013
Note:						Checked By:	J Drago
Based on discharge solids to sewer						Date Prepared:	4/26/2013
Based on 1,100 gpm WTP						K/J Proj. No.	1270031*00
ITEM	**QUANTITY**	**UNIT**	**UNIT COST**	**EXTENDED COST**	**NOTES**		
Energy							
Increased from 40% to 65% operation and adjusted from $0.15/kw-hr to $0.12/kw-hr	1	energy/yr	$3,900.00	$3,900	Assume operate 65% of the time through the year		
Chemicals							
Increased from 40% to 65% operation	1	chem/yr	$79,625.00	$79,625	Assume operate 65% of the time through the year		
Solids Disposal							
Discharge to sewer, treat @ WWTP & dry and dispose solids. Increased from 40% to 65% operation	10,075,000	gal/yr	$0.24	$2,418,000	Assume discharge to sewer.		
Operation Staff							
Operations staff increase from 40% to 65% operation	1	cost/yr	$95,875	$95,875	Includes labor and maintenance costs		
Miscellaneous Equipment and Materials	1	LS	$22,750	$22,750	Includes analytical costs. Adjust to 65% operation from 40%		
Total (rounded to nearest thousand)		cost / yr		$2,620,000	Annual cost per year		
Cost per acre foot per year		$/ AF - YR		$2,249	= ($2,620,000*0.32585 mg/af) / (1.6 mgd x 0.65 x 365 days/yr)		

Table XI-1: OPINION OF PROBABLE CONSTRUCTION COST FOR A GREENFIELD RCF WTP - UNDEVELOPED SITE OPTION 2					KENNEDY/JENKS CONSULTANTS			
Project:	City of Davis - Co-Removal of Cr6 Pilot Study						**Prepared By:**	S Laybourne
							Date Prepared:	26-Apr-13
							Checked By:	J Drago
NOTE: Accuracy of Cost Estimate is +50% to -30%							**Date Prepared:**	26-Apr-13
Source is Probable Capital & Annual O&M Costs for Cr6 Removal from Well 20 Technical Report prepared for Wtr Res Fnd by WQTS (4-22-13)							**K/J Proj. No.**	1270031*00
Based on 1,100 gpm not 1,400 gpm WTP system							**Current at Natl Avg ENR**	9,456
Based on drying solids on site and disposal offsite, no sewer discharge							**Escalated to Natl Avg ENR**	9,456
Estimate Type:	X	**Conceptual**						
	☐	**Preliminary (w/o plans)**						
	☐	**Design Deve**	_________	**% Complete**				
Item	Quantity	**Unit**	Unit Cost	Extended Cost	Notes			
1. Equipment including 7.5% sales tax + installation	1	**EACH**	$1,685,950	$1,685,950	Reduction, Coagulation and Filtration treatment system			
2. Building Cost	1	**EACH**	$234,000	$234,000	Building to house WTP and equipment			
3. Construction Activities	1	**EACH**	$2,012,000	$2,012,000				
4. Construction Cost Subtotal of Items 1 to 3 (rounded to nearest thousand)				$3,932,000				
5. Contingency (25%)			0.25	$983,000	25% of Item 4 Cost			
6. Total Construction Cost Estimate				$4,915,000	Sum of Items 4 and 5			
7. Engineering & Construction Administration (20%)			0.2	$983,000	20% of Item 6 Cost			

Table XI-1: OPINION OF PROBABLE CONSTRUCTION COST FOR A GREENFIELD RCF WTP - UNDEVELOPED SITE OPTION 2

KENNEDY/JENKS CONSULTANTS

Project:	City of Davis - Co-Removal of Cr6 Pilot Study	**Prepared By:**	S Laybourne
		Date Prepared:	26-Apr-13
		Checked By:	J Drago
NOTE: Accuracy of Cost Estimate is +50% to -30%		**Date Prepared:**	26-Apr-13
Source is Probable Capital & Annual O&M Costs for Cr6 Removal from Well 20 Technical Report prepared for Wtr Res Fnd by WQTS (4-22-13)		**K/J Proj. No.**	1270031*00
Based on 1,100 gpm not 1,400 gpm WTP system		**Current at Natl Avg ENR**	9,456
Based on drying solids on site and disposal offsite, no sewer discharge		**Escalated to Natl Avg ENR**	9,456

Estimate Type:
- [X] **Conceptual**
- [ ] **Preliminary (w/o plans)**
- [ ] **Design Deve** _________ **% Complete**

Item	Quantity	Unit	Unit Cost	Extended Cost	Notes
8. Environmental and Permitting (5%)			0.05	$246,000	5% of Item 6 Cost
9. City Admin and Management (10%)			0.1	$492,000	10% of Item 6 Cost
10. Purchase Land	0	**ACRES**	$150,000	$0	Assume land already owned
11. TOTAL OPINION OF PROBABLE PROJECT COST				$6,636,000	Sum of Items 6 through 10
12. Cost per gallon to construct				$4.15	1.6 mgd RFC WTP
13. Cost per gallon to construct for West Valley WD Perchlorate FBR WTP				$4.10	2.86 mgd FBR WTP
Annualized Cost Analysis - Convert Capital to Annual Cost					
14. Planning period	30	YEARS			
15. Interest Rate, I =	3	%			
16. Convert Capital Cost to Annual Cost Factor	0.05102				
17. Total Estimated Project Cost			$6,636,000		
18. Annualized Project Cost (round to nearest thousand)			$339,000	= Item 15 * Item 16	

Table XI-1: OPINION OF PROBABLE CONSTRUCTION COST FOR A GREENFIELD RCF WTP - UNDEVELOPED SITE OPTION 2

KENNEDY/JENKS CONSULTANTS

Project: City of Davis - Co-Removal of Cr6 Pilot Study

Prepared By: S Laybourne
Date Prepared: 26-Apr-13
Checked By: J Drago
Date Prepared: 26-Apr-13

NOTE: Accuracy of Cost Estimate is +50% to -30%

Source is Probable Capital & Annual O&M Costs for Cr6 Removal from Well 20 Technical Report prepared for Wtr Res Fnd by WQTS (4-22-13)

K/J Proj. No. 1270031*00

Based on 1,100 gpm not 1,400 gpm WTP system

Current at Natl Avg ENR 9,456

Based on drying solids on site and disposal offsite, no sewer discharge

Escalated to Natl Avg ENR 9,456

Estimate Type:
- [X] **Conceptual**
- [ ] **Preliminary (w/o plans)**
- [ ] **Design Deve** ________ **% Complete**

Item	Quantity	Unit	Unit Cost	Extended Cost	Notes
19. Annual O&M Cost			$344,000	Using RCF Total Annual Cost based on 65% operation not 40%	
20. Total Annualized Cost			$683,000	= Item 18 + Item 19	
21. Cost Per Acre Foot		$ / AF-YR	$586	= (Total Annualized Cost * 0.32585 mg / AF) / (1.6 mgd * 0.65 * 365 days/yr)	

Table XI-2: OPINION OF PROBABLE ANNUAL O&M COST RCF WTP GREENFIELD SITE OPTION 2						KENNEDY/JENKS CONSULTANTS	
Project:	**City of Davis - Co-Removal of Cr6 Pilot Study**					Prepared By:	S. Laybourne
						Date Prepared:	4/26/2013
Note:						Checked By:	J Drago
Based on drying solids on site and disposal offsite, no sewer discharge						Date Prepared:	4/26/2013
Based on 1,100 gpm WTP						K/J Proj. No.	1270031*00
ITEM	**QUANTITY**	**UNIT**	**UNIT COST**	**EXTENDED COST**	**NOTES**		
Energy							
Increased from 40% to 65% operation and adjusted from $0.15/kw-hr to $0.12/kw-hr	1	energy/yr	$3,900.00	$3,900	Assume operate 65% of the time through the year		
Chemicals							
Increased from 40% to 65% operation	1	chem/yr	$79,625.00	$79,625	Assume operate 65% of the time through the year		
Solids Disposal							
Dewatered sludge dipsosal. Increased from 40% to 65% operation	1,788	cu ft / yr	$50.00	$89,375	Assume $50/cubic foot		
Operation Staff							
Operations staff increase from 40% to 65% operation	1	cost/yr	$139,750	$139,750	Includes labor and maintenance costs		
Miscellaneous Equipment and Materials	1	LS	$30,875	$30,875	Includes analytical costs. Adjust to 65% operation from 40%		
Total (rounded to nearest thousand)		cost / yr		$344,000	Annual cost per year		
Cost per acre foot per year		$/ AF - YR		$295	= ($344,000*0.32585 mg/af) / (1.6 mgd x 0.65 x 365 days/yr)		

Appendix XII

WaterRF Project 4450 Data

PROBABLE CAPITAL AND ANNUAL OPERATIONS & MAINTENANCE COSTS FOR HEXAVALENT CHROMIUM REMOVAL FROM WELL 20

TECHNICAL REPORT

Submitted to:

CITY OF DAVIS PUBLIC WORKS
DAVIS, CALIFORNIA

Submitted by:

WATER QUALITY & TREATMENT SOLUTIONS, INC.
LOS ANGELES, CALIFORNIA

www.WQTS.com

April 22, 2013

1.0 BACKGROUND

The City of Davis ("City") is participating in a Water Research Foundation Project titled: *"Impact of Water Quality on Hexavalent Chromium Removal Efficiency and Cost"*. Bench-scale testing was conducted of three treatment technologies for removal of hexavalent chromium, Cr(VI), from the City's Well 20 water. While the bench-scale testing is ongoing, the preliminary testing results have been analyzed and presented to the City. This report includes a budgetary estimate of the probable capital and annual operations & maintenance (O&M) costs for implementing each of the three treatment technologies for removing Cr(VI) from the City's Well 20 water to meet various potential maximum contaminant levels (MCLs).

Section 2 of this report includes a description of each treatment technology, its configuration, and its various components. Section 3 includes a discussion of how each treatment system was designed, and the design assumptions used. Section 4 presents a discussion of how the costs were developed, and the cost assumptions made. Section 5 presents the budgetary estimates of the probably capital and annual O&M costs. Finally, Section 6 presents a set of observations made based on the cost estimates.

2.0 CONFIGURATIONS OF Cr(VI) TREATMENT SYSTEMS

Three treatment technologies were evaluated, and costs were developed for each of them. The technologies are:

1. Disposable Weak Base Anion (**WBA**) Resin
2. Regenerable Strong Base Anion (**SBA**) Resin
3. Reduction, Coagulation, & Filtration (**RCF**)

This section includes descriptions for the three Cr(VI) treatment technologies incuding treatment components as well as treatment alternatives for the residuals streams generated by the SBA and RCF treatment systems.

2.1 WBA Treatment System

Weak Base Anion (WBA) exchange resins have a high capacity for Cr(VI) such that they are operated on a throw-away basis without regeneration. For WBA resin to operate efficiently, the water pH must be reduced to 6.0. The pH must then be raised to non-corrosive levels after treatment. Figure 1 shows a schematic of a WBA treatment system that uses carbon dioxide (CO_2) for pH suppression, and then air stripping to raise the pH in the treated water. Figure 2 shows the same schematic, but with hydrochloric acid (HCl) used for pH suppression followed by caustic soda (NaOH) addition to raise the pH in the treated water. Aside from the differences in pH adjustment method, the two treatment systems have identical components, including pre-filters to remove suspended matter from the water to protect the resin. During initial resin installation, the resin may need to be backwashed and rinsed. The waste backwash water will be collected in an onsite tank before it is disposed of. The backwash is also used to "fluff" the resin if needed during operation to prevent channeling caused by cementing of the resin. It is noted that, while chlorination of the treated water is required before it is injected into the distribution system, the cost estimates presented in this report do not include chlorine addition. The reason is that the existing wells would already have a chlorine feed system, and therefore, no new chlorination system will be required. This assumption was applied to all the treatment technologies.

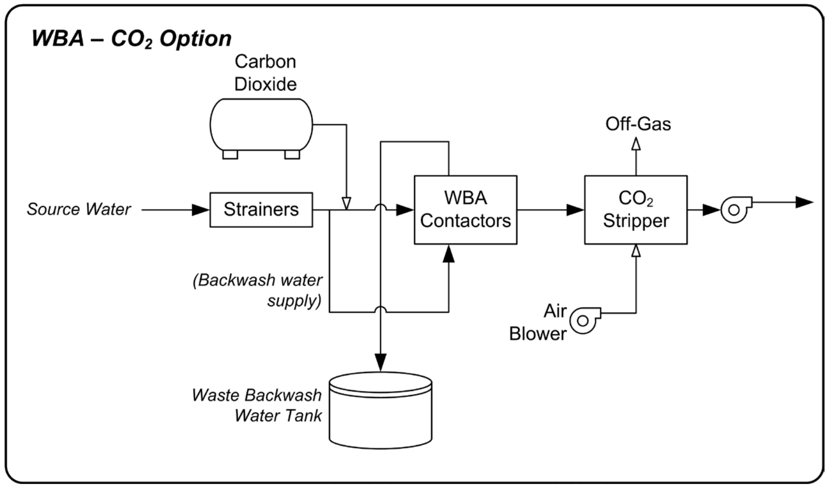

Figure 1 – Line Schematic of WBA Treatment System Using CO_2 for pH Suppression

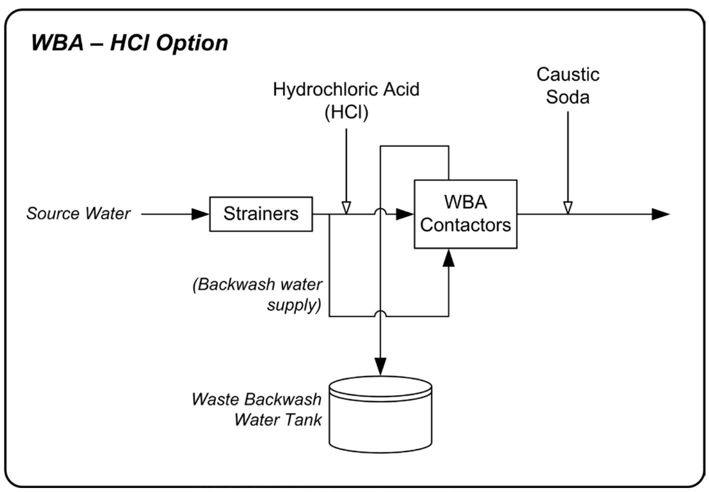

Figure 2 – Line Schematic of WBA Treatment System Using HCl for pH Suppression

Disposal of the spent resin from the WBA process is challenging. At a minimum, considering that it will be loaded with chromium, it is fairly certain to be classified as California non-RCRA Hazardous Waste, and will need to be disposed of as hazardous waste in California or transported out of state to be disposed of as non-hazardous waste. Furthermore, WBA resin also adsorbs uranium from water. As we currently understand the disposal requirements in California, if the uranium+thorium load on the spent resin is below 0.05% by weight at the time of disposal, then the resin needs to be disposed of as a Technologically Enhanced Naturally Occurring Radioactive Material (TENORM), which limits its disposal options. If the uranium+thorium load exceeds 0.05% by weight, then the resin becomes classified as a Low Level Radioactive Waste (LLRW). There are currently only four sites in the entire US that take

LLRW, and only two of them could accept LLRW from California; one is in Utah, and one is in Texas.

2.2 SBA Treatment System

An SBA treatment system used for Cr(VI) removal is identical to that used for arsenic or nitrate removal from groundwater. Figure 3 shows a schematic of the main components of an SBA treatment system. The water is first treated through strainers to remove suspended material before it enters the SBA contactors. The SBA-treated water is then discharged into the distribution system. A salt-brine feed system is used to regenerate the resin when it is exhausted. After regeneration with the salt brine, the resin in a vessel will undergo one slow-rinse step and one fast-rinse step. The waste salt brine and waste slow-rinse water, together referred to in this report as "waste brine", are collected in a waste brine tank, while the fast rinse water is collected in a separate tank. The idea is that the fast-rinse water contains a low(er) TDS level and can be slowly returned to the head of the plant, while the higher-TDS waste brine will be handled separately.

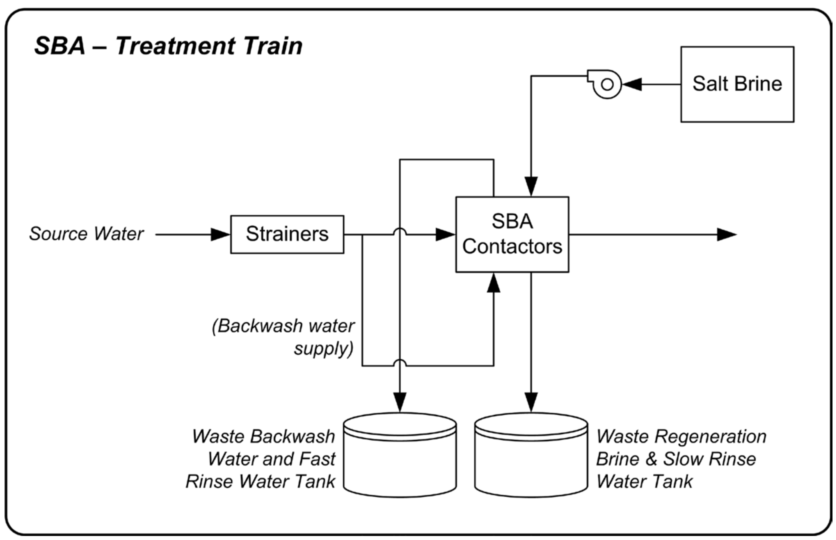

Figure 3 – Line Schematic of an SBA Treatment System

The greatest challenge facing the use of SBA resin for Cr(VI) removal is the handling and disposal of the waste brine. While there are some locations where the waste brine could be disposed of in the sewer under an industrial discharge permit, the high salt content, in addition to the Cr(VI) and other metals accumulated in the waste brine, will greatly limit the availability of this option to most water utilities. One alternative is to haul the waste brine to a dedicated facility for disposal. However, disposal facilities are likely to require that the Cr(VI) and other metals be removed from the waste brine as a condition of accepting it.

If the Cr(VI) needs to be removed from the waste brine before it can be disposed of, then a chemical reduction and clarification system will be required to convert the Cr(VI) to Cr(III) and then precipitate it as $Cr_2O_{3(s)}$. The precipitated chromium will need to be disposed of separately. Figure 4 shows a conceptual waste brine treatment system. The system includes a clarifier to precipitate the Cr(III) after it is reduced from Cr(VI) with ferrous addition. The clarified brine is pumped to a dedicated tank. The sludge collected at the bottom of the clarifier is further treated through a dewatering process to generate a >20% solids product that is disposed of separately. Depending on the anticipated waste brine production rate, the clarifier can be operated as a batch system (small flows) or as a continuous-flow system (large flows).

Experience suggests that the dewatered sludge will be classified as California non-RCRA hazardous waste. This means that its disposal is limited to a hazardous waste site in California or a non-hazardous waste site outside California. The clarified waste brine, as well as the recovered brine water from the dewatering process will then either be discharged into an onsite sewer (if available and allowable) or will be hauled offsite for disposal at an appropriate facility (i.e., a wastewater facility that accepts high-salt brine).

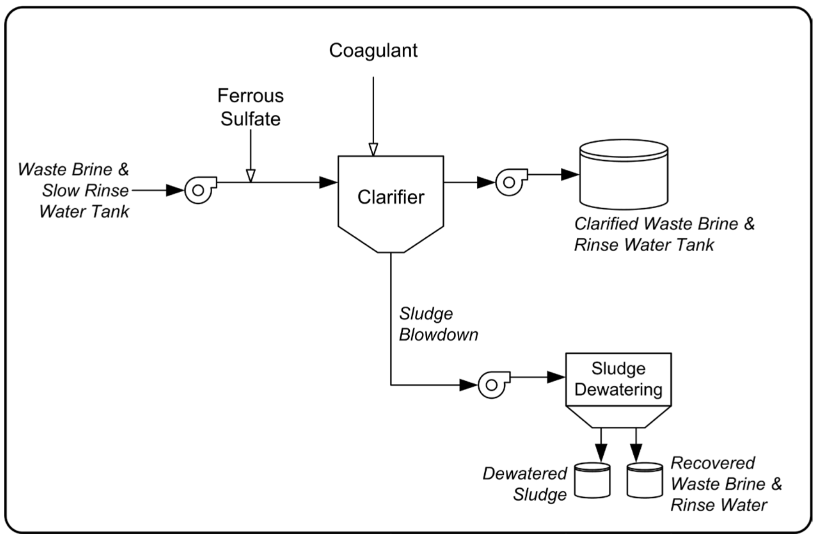

Figure 4 – Line Schematic of an SBA Waste Brine & Rinse Water Treatment System

2.3 RCF Treatment System

Figure 5 shows a schematic of the RCF treatment system. This system is similar to a coagulation/filtration process used for arsenic treatment, with two exceptions: 1) ferrous sulfate ($FeSO_4$) is added to the raw water to reduce Cr(VI) to Cr(III); and 2) a reduction contactor is required upstream of the filter. The purpose of this contactor is to provide the time necessary for the added ferrous iron to reduce the Cr(VI) to Cr(III). A low dose of chlorine is added upstream of the filters for the purpose of oxidizing any residual ferrous iron to ferric iron. A coagulant is also added to improve the removal of the precipitated Cr(III) through the media filters. Filtered water is discharged to a clearwell, which is used for backwashing the filters. Water is then pumped from the clearwell and dosed with chlorine before it enters the distribution system. The waste backwash water is collected in a tank. As indicated earlier, the cost estimates presented in this report do not include the chlorine feed systems as they are expected to be already utilized at any well site.

Similar to the other treatment technologies, the biggest challenge with the operation of an RCF process is the handling and disposal of the waste backwash water, which will contain all the chromium removed from the water as well as all the iron added to remove the chromium. In limited cases, it is possible to discharge this waste backwash water into the sanitary sewer. This approach is currently used by a number of systems using coagulation/filtration for removing arsenic from groundwater. However, if this option is not available to a water agency, then the waste backwash water needs to be treated on site.

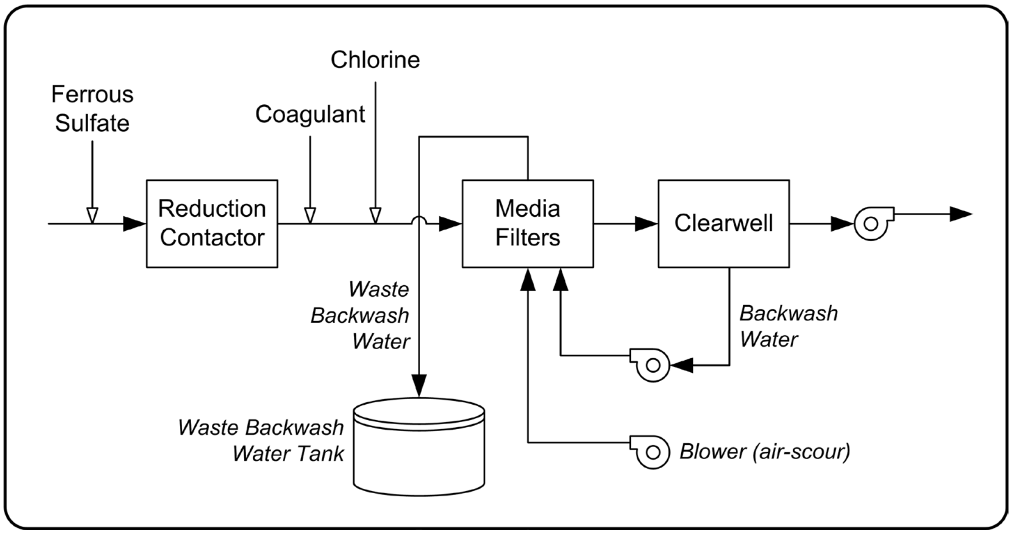

Figure 5 – Line Schematic of an RCF Treatment System

Figure 6 shows a schematic of an RCF waste backwash water treatment system. The water may need to be dosed with a coagulant (if needed) and then clarified. The settled sludge is collected in a sludge tank, while the supernatant is collected in a treated washwater tank. The settled sludge is then dewatered to >20% solids. The dewatered sludge is collected in a container for off-site disposal, while the recovered water is collected in a separate tank. The clarified water and the water recovered from the dewatering process can be returned to the head of the plant or discharged to the onsite sewer when available. Experience suggests that the dewatered sludge will be classified as California non-RCRA hazardous waste, which limits its disposal options to a hazardous waste site in California or a non-hazardous waste site outside California.

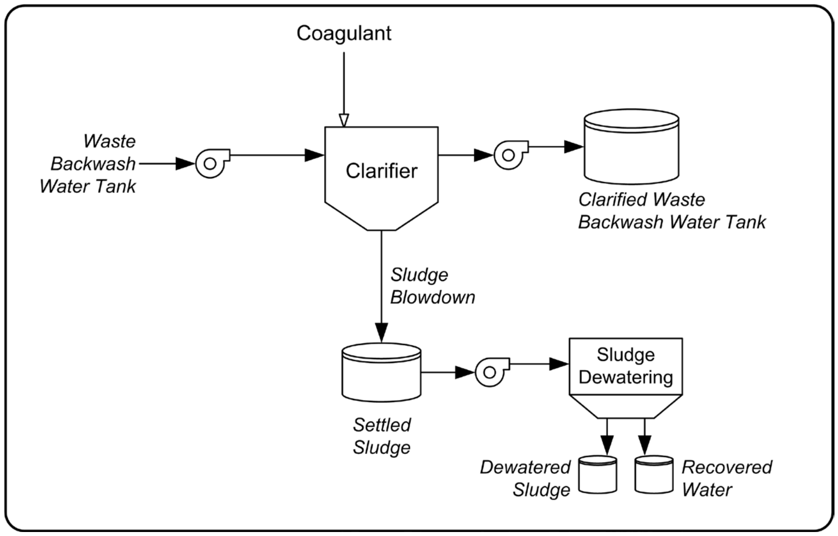

Figure 6 – Line Schematic of an RCF Waste Backwash Water Treatment System

3.0 TREATMENT SYSTEM DESIGN ASSUMPTIONS

This section presents the design approach, assumptions, and criteria used to size each treatment system.

3.1 By-Pass Blending

While bench testing showed that all three technologies removed Cr(VI) to less than its MRL of 0.02 µg/L, the MRL for total Cr was only 1 µg/L during the study. Since any remaining Cr(III) in the water could be oxidized to Cr(VI) by the chlorine residual in the distribution system, the minimum Cr achieved by any of the three technologies was set at the total Cr MRL of 1.0 µg/L. Using this assumption, and based on the groundwater Cr(VI) level, a mass balance was used to size each treatment system to treat only a portion of the well water, which is then blended with the untreated portion to result in a blended water Cr(VI) level that is always less than 80% of an MCL scenario. A schematic of the by-pass treatment system configuration is presented in Figure 7. The following equation was used to size the treatment system under each scenario:

$$Q_{TW} = Q_{GW} \times \frac{(C_{GW} - C_{FW})}{(C_{GW} - C_{TW})} \quad (1)$$

Where Q_{TW} = Treatment system capacity, gpm
Q_{GW} = Groundwater well capacity, gpm
C_{GW} = Cr(VI) concentration in the groundwater, µg/L
C_{FW} = target Cr(VI) concentration in the finished water, µg/L (herein set at 80% of MCL)
C_{TW} = Cr(VI) in treated water, µg/L (herein set to 1 µg/L)

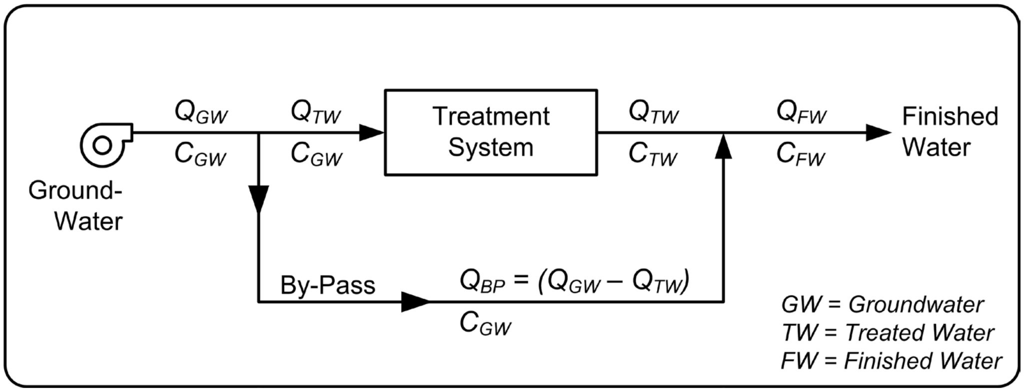

Figure 7 – By-Pass Treatment Configuration

3.2 SBA Treatment System

Table 1 presents the parameters used to design the SBA treatment system including ion-exchange (IX) vessels, salt brine system, waste brine and slow rinse tank, and waste fast rinse tank. The design empty-bed contact time (EBCT) for the SBA system is set at 3.0 minutes at maximum treatment capacity. Based on the bench-scale testing results, the volume treated before Cr(VI) begins to break through the effluent was estimated at approximately 5,500 Bed Volumes (BVs).

The regeneration conditions were set at their corresponding levels used during bench testing including salt loading rate (15 lbs/ft^3), waste brine volume (1.5 BVs), and slow rinse volume (3.0 BVs). A total of 10 BVs was set to rinse the residual salt off the resin before it is returned into service. While the waste salt brine and waste slow rinse water are combined as the residual waste stream, the waste fast rinse water is collected separately and returned to the head of the treatment system. The assumption is that the TDS concentration in the waste fast rinse water is low enough to allow for blending it back with the treated water.

The salt brine system for each treatment system was sized to hold 30 days of supply up to a maximum of 30 tons. The 30-ton value was selected to accommodate a full truck supply of 25 tons. Larger salt storage systems are available, but would require larger footprint while not reducing the frequency of salt delivery to the site.

The waste brine tank was sized to store the waste salt brine and waste slow-rinse water from the regeneration of one vessel. Similarly, the waste fast rinse water tank was sized to store the waste fast rinse water after the regeneration of one vessel.

Table 1 – SBA Treatment System Design Parameters

Process	Parameter	Value	Rationale
Strainers	Type	Automatic Backwash	Unattended Operation
IX Vessels	EBCT	3 min	Typical value for anion exchange (AIX) systems. This value was used during bench-scale testing.
	Media Depth	36 inches	Typical value for AIX systems.
	Runtime between Regenerations	3,500 BVs	Bench-scale Results
	Salt Loading Rate	15 lbs/ft^3	Value used during bench testing
	Brine Volume	1.5 BVs	Value used during bench testing
	Slow Rinse Volume	3.0 BVs	Value used during bench testing
	Fast Rinse Volume	10 BVs	Value used during bench testing
Salt Brine System	Salt Density	75 lbs/ft^3	Information from Vendor
	Desired minimum Operational Storage	30 days	To minimize truck traffic
	Truck Bulk Delivery	25 tons	
	Maximum Salt Tank Size	30 tons	Larger tank will still require multiple truckloads, and therefore, the cost was minimized by relying on higher frequency of truck deliveries to a smaller tank.
Waste Brine Tank (Waste Salt Brine & Slow Rinse)	Number of Regenerations & Slow Rinses Stored	1 vessel regeneration	To minimize tank cost.
Waste Fast Rinse Tank	Number of Fast Rinses Stored	1 vessel regeneration	To minimize tank cost.

The waste brine generated by the SBA process will contain approximately 60,000 mg/L of Total Dissolved Solids (TDS), and a high concentration of Cr. Since the City's wastewater is treated at a wastewater treatment plant that discharges into a fresh water body, it is assumed that the City would not be allowed to discharge the waste brine into the sanitary sewer. Alternatively, the City would need to truck the waste brine to another wastewater facility that can accept the waste. However, considering that the Cr level in the waste brine will exceed 10 mg/L, it is assumed that any receiving facility would require that the City remove the Cr from the waste brine before it is hauled off site for disposal.

Based on the above discussion, a waste brine treatment system is required to separate the concentrated Cr from the waste brine. Table 2 includes the design parameters for the various components of the waste brine treatment system. The system includes a ferrous sulfate addition system to reduce Cr(VI) to Cr(III), followed by a clarifier to settle the precipitated and coagulated Cr(III). The clarifier is sized to require operation during 6 hrs/day, 5 days/wk, in order to avoid weekend operation and limit it to one shift per workday. The settled solids are then dewatered using a plate-and-frame filter press to generate a dewatered sludge containing approximately 20% solids by wt. The clarified brine is then collected in a tank sized to hold waste brine production from 4 days of clarifier operation. The clarified waste brine is then hauled away for off-site disposal. The dewatered sludge is then disposed of as solid waste as a California non-RCRA hazardous waste.

Table 2 – SBA Waste-Brine Handling & Treatment System Design Assumptions

Process	Parameter	Value	Basis
Clarifier	Days of Operation	5 days/wk	To prevent the need for weekend operator presence at the site to operate the clarifier and dewatering process.
	Hours of Operation	6 hrs/day	In order to limit the attendance to one shift.
	Clarifier Loading Rate	0.1 gpm/sf	To result in relatively thickened sludge.
	Fe(II):Cr(VI) Ratio	75 mg/mg	Based on RCF bench testing results.
	% Solids in Clarifier Sludge	1.5%	Professional Opinion based on the low Clarifier Loading Rate
Ferrous Sulfate Feed System	$FeSO_4$ Stock Concentration	0.7 lbs/gal	Based on vendor information
	Minimum Desired Operational Storage Days during Operation	30 days	To minimize truck deliveries.
	Delivery Volume	4,500 gallons	Bulk delivery to minimize cost and reduce truck deliveries.
	Maximum $FeSO_4$ Storage Tank Size	5,000 gallons	Larger tank would require multiple deliveries. Therefore, the cost is minimized by storing no more than one truckload.
Clarified Brine Tank	Minimum Clarifier Production Operational Storage Days	4 days	To prevent the need for waste brine hauling over a long weekend.
Dewatering Process	Type	Plate and Frame Press	Placeholder system based on availability of quotes from Supplier
	Percent Solids in Dewatered Sludge	20%	Based on information received from the Vendor (Siemens)
	Dewatering Cycles per Operational Day	1 cycle	To minimize demand on operator time.
	Dewatered Sludge Specific Gravity	1.15	Assumed.

3.3 WBA Treatment System

Table 3 presents the parameters used to design the WBA treatment system including IX vessels and slow rinse tank, and waste fast rinse tank. Bench-scale testing was conducted at EBCT values of 1.5 and 3 minutes, and the results showed that the adsorption kinetics are slow enough that the resin could be loaded with more Cr(VI) at an EBCT of 3 minutes compared to an EBCT of 1.5 minutes. Therefore, for the purpose of this cost-estimating effort, a two-vessel system will be utilized with the vessels set up in a lead-lag configuration. The media volume in each vessel is selected to result in an EBCT of 3 minutes per vessel for a total EBCT of 6 minutes at treatment capacity.

Table 3 – WBA Treatment System Design Parameters

Process	Parameter	Value	Basis
WBA Vessels	Configuration	2-vessel, Lead-Lag	Goal to increase resin life. Increase in resin life is assumed to be 50% above that achieved during bench-scale testing at 3-minute EBCT.
	EBCT	3 min/vessel; 6-min total	
	Media Depth	36 inches	
	Run Length	90,000 BVs	Based on Bench-Scale Results
	Waste Backwash Water Tank Size	1 backwash of all vessels	With a maximum of 60,000 gallons.
CO_2 Feed System	Target pH	6.0	This is the pH used in the bench-scale study.
	Bulk Delivery	22 tons	Based on information from Vendor (TOMCO2)
	Desired Operational Storage	30 days	In order to minimize truck deliveries
	Max. Onsite Storage	77 tons	Largest single CO_2 storage container available from TOMCO2
	Storage Location	Outdoor	
CO_2 Stripping System	Type	Low-Profile, Multi-Stage Air Strippers	Based on Lowry Systems
	Components	Air-Stripper; Blower; and Water Booster Pump	Booster pump sized to boost the treated-water pressure to 50 psi.
	Location	Indoors	To minimize noise impact of the blower and booster pump.

One of the key factors that affect the cost of WBA treatment is the projected Bed Volumes (BVs) treated before the resin has to be replaced with new resin. Based on an analysis of the bench-scale testing results conducted at an EBCT of 3.0 minutes, the WBA resin is expected to treat approximately 60,000 BVs before Cr begins to breakthrough. Since the system developed in this document has a lead-lag configuration, with each vessel sized for an EBCT of 3.0 minutes, the lead vessel should be able to treat more BVs before Cr breakthrough in the effluent of the lag vessel is reached. To account for this additional capacity, a 50% increase in the BVs treated was assumed in this analysis, and therefore the total BVs treated per vessel is projected at 90,000 BVs before the resin in that vessel will need to be replaced with new resin.

Although the WBA resin is operated without regeneration, it will require backwashing, especially during installation, to remove the fines from the resin before it is put in service. It may also require infrequent backwashing during operation to remove silt that may get trapped in the resin bed and cause increased headloss and short-circuiting. A tank is provided to store the waste backwash water from one backwash cycle of all vessels, with a maximum size of 60,000 gallons in order to reduce the overall footprint.

Cost analyses conducted on this project and others showed that the use of CO_2 and air stripping for pH adjustment is significantly less costly than that of the use of HCl and NaOH for pH adjustment. Therefore, for the purpose of this report, the WBA treatment system evaluation will be limited to that with CO_2 and air-stripping for pH adjustment. Table 3 shows the specifics of the CO_2 feed system. The CO_2 storage volume is selected to provide approximately 30 days of operational storage, but no larger than 77 tons of CO_2. After WBA treatment, air-stripping is used to re-adjust the pH of the treated water to neutral or slightly-caustic levels. For the purpose of this cost-estimating effort, air stripping is achieved using low-profile multi-stage air strippers sized for the specific flow rate being treated. Each stripper includes a booster pump to re-boost the water pressure to the distribution system value, which is set in this cost-estimating effort at 50 psi. The air-stripper and the booster pump will be located indoors to reduce outdoor noise pollution.

3.4 RCF Treatment System

Table 4 outlines the design parameters used to select and size the components of the RCF treatment systems. The reduction contactor was selected to be a horizontal pressure vessel instead of an open contactor in order to maintain the hydraulic profile through the treatment system. While the bench testing utilized 30 minutes of reduction contact time, limited testing results showed that a contact time of 10 minutes is sufficient to achieve full reduction of Cr(VI) to Cr(III) at the levels present in the water samples evaluated (up to 42 µg/L). Therefore, for the purpose of cost development, a 10-minute contact time was assumed for the reduction contactor.

The pressure filtration vessels are configured either vertically or horizontally depending on size, with horizontal vessels favored for large(r) plants. Each vessel will contain a total of 36 inches of sand and anthracite and will be designed for a maximum filtration rate of 3.0 gpm/sf. This value was based on the work conducted at the City of Glendale. The unit filter run volume (UFRV) was set at 7,500 gal/ft^2, and the unit filter backwash volume (UFBV) was set at 200 gal/ft^2. The UFRV is the volume of water treated through 1-ft^2 of filter surface area between two consecutive backwashes. The UFBV is the volume of water used to backwash 1-ft^2 of filter surface area. Both parameters are used to size the treatment system and the waste backwash water storage and handling systems.

Based on the bench-scale testing results, a 3 mg/L ferrous iron dose was required to achieve full reduction of the Cr(VI) present in Well 20 water. The $FeSO_4$ feed system was sized to provide a minimum of 30 days of operational storage. However, with a maximum bulk delivery of 4,500 gallons, the maximum $FeSO_4$ storage tank size was limited to 5,000 gallons in order to minimize the footprint requirements.

Table 4 – RCF Treatment System Design Parameters

Process	Parameter	Value	Basis
Reduction Contactor	Configuration	Horizontal pressure vessel	
	HRT	10 minutes	Based on limited bench testing results
Pressure Vessels	Configuration	Single-Stage	vertical or horizontal, depending on size.
	Media Type	Sand & Anthracite	
	Media Depth	36 inches	
	Filtration Rate	3.0 gpm/sf	Based on Glendale work
	Unit Filter Run Volume	7,500 gal/sf	Assumed
	Unit Filter Backwash Volume	200 gpm/sf	Assumed
$FeSO_4$ Feed System	$FeSO_4$ Stock Concentration	0.7 lbs/gal	Based on vendor information
	Ferrous Iron Dose	3 mg/L	Based on bench testing results
	Minimum Desired Operational Storage Days during Operation	30 days	To minimize truck deliveries.
	Delivery Volume	4,500 gallons	Bulk delivery to minimize cost and reduce truck deliveries.
	Maximum $FeSO_4$ Storage Tank Size	5,000 gallons	Larger tank would require multiple deliveries. Therefore, the cost is minimized by storing no more than one truckload.
	Storage Location	Outdoor	
Backwash System	Max. Pumping Rate	22 gpm/sf	High-rate value for sand/anthracite (20 gpm/sf) plus 10%
	Number of Backwash Pumps	2	
	Number of Backwashes Stored in Waste Backwash Water Tank	2	

As shown in Table 4, the RCF treatment system includes a backwash system, which in turn includes two backwash pumps and a waste backwash water tank. The two pumps are sized to backwash one filter at a high rate of 20 gpm/ft^2, and the waste backwash water tank is sized to store two individual-filter backwashes.

Similar to the waste brine water from the SBA process, there are multiple handling and disposal options for the waste backwash water generated by the RCF process including the following:

Option 1 – Disposal to a local sewer without treatment

Option 2 – Clarification to remove Cr from the waste backwash water, followed by recycling of the clarified waste backwash water to the head of the plant.

Under Option 1, no additional system components are required other than the waste storage tank, which was included in Table 4. Under Option 2, a waste backwash water treatment system is required to separate the concentrated Cr from the water before the recovered water is returned to the head of the plant. Table 5 includes the design parameters for the various components of the waste backwash water treatment system required under Option 2. The system will include a clarifier to settle the precipitated and coagulated Cr(III). Due to the high(er) waste backwash water volume compared to that of the waste brine from the SBA process, the clarifier will operate seven days a week, 24 hrs/day. The settled sludge, which is assumed to have a solids content of 1.5% by wt., is diverted to a wet sludge tank, while the clarified water is collected in another tank. The sludge tank is sized to hold four days of clarifier operational storage, while the clarified water tank is sized to hold the water generated from two filter backwashes. The wet sludge is dewatered in a frame-and-plate filter press to 20% solids. The filter press is sized for an operational schedule of only 5 days per week in order to avoid operation during weekend days. The dewatered sludge is then disposed of as a California non-RCRA hazardous waste.

Table 5 – RCF Waste Backwash Water Handling & Treatment System Design Assumptions

Process	Parameter	Value	Basis
Clarifier	Days of Operation	7 days/wk	Large backwash water volume requires continuous operation of clarifier
	Hrs. of Operation	24 hrs/day	
	Clarifier Loading Rate	0.1 gpm/sf	To result in relatively thickened sludge.
	% Solids in Clarifier Sludge	1.5%	Professional opinion based on the low clarifier loading rate
Clarified Waste Backwash Water Tank	Number of Backwashes Stored	2	
Clarifier Sludge Blowdown Tank	Days of Operational Storage	4 days	To allow for sludge storage during press down-time
Dewatering Process	Type	Plate and Frame Press	Placeholder system based on availability of quotes from Supplier
	Percent Solids in Dewatered Sludge	20%	Based on information received from the Vendor (Siemens)
	Dewatering Process Operation Schedule	5 days/wk	To avoid the need for an operator over the weekend.
	Dewatering Cycles per Operational Day	1 cycle	To minimize demand on operator time.
	Dewatered Sludge Specific Gravity	1.15	Assumed.

4.0 COST DEVELOPMENT APPROACH AND ASSUMPTIONS

This section presents the approach used in developing the probable capital and annual O&M costs for applying each of the three treatment technologies to meet a range of potential Cr(VI) MCL values. At this budgetary cost estimating level, all costs presented in this report are expected to have a certainty range between –30% and +50% of the values presented.

4.1 Probable Capital Cost Development

Table 6 summarizes the approach and assumptions used in developing the probable capital costs for all treatment systems. The capital cost is divided into four main categories:

1. Equipment, equipment pads, chemical tanks containment pads, and building.
2. Construction activities, including mobilization; site work and yard piping; electrical and HVAC equipment and installation; instrumentation and control; construction contingency; contractor overhead and profit; and initial media/resin load.
3. Professional services, including engineering design; verification testing; environmental permitting; construction management; startup support services; and administration and legal services.
4. Fees, which are currently limited to the sewer connection fee.

Costs of equipment were obtained from a number of sources including communications with vendors, quotes on past projects, and analysis of costs incurred by water agencies for similar equipment. A 15% allowance was added to the total equipment cost to account for miscellaneous components such as valves and flowmeters. A 30% markup was applied on all equipment for installation cost. Indoor building cost was estimated at $\$150/ft^2$, while outdoor slab and chemical containment cost was estimated at $\$50/ft^2$. For indoor cost, a 25% allowance was added for working area in the building to allow for electrical and communication cabinets, as well as other items.

Standard markups were used for contractor mobilization (5%), site work & yard piping (10%), electrical and HVAC (15%), and instrumentation and control (15%). A 25% construction contingency was added, followed by a 15% allowance for contractor overhead and profit. An initial resin/media load was added to the construction cost, along with allowances for sales tax (7.5%) and installation cost (5%). The total construction cost was then set as the sum of the equipment, building, pads, and construction services.

Professional services were estimated as percent markups applied to the total construction cost less the initial media cost. Professional services included engineering design (10%), verification testing (3%), environmental permitting (2%), construction management (10%), startup services (2%), administration and legal services (1.5%).

Finally, for the RCF treatment system with sewer discharge, a sewer connection fee was estimated based on fees imposed by the Los Angeles County Sanitation District for industrial waste discharges. These fees take into account average and peak discharge flow rates, the chemical oxygen demand (COD) of the waste discharge, and its total suspended solids (TSS) content. The COD content of the waste backwash water from the RCF process was set at 100 mg/L, while its TSS content was set at 200 mg/L due to the presence of the iron coagulant in the washwater.

Table 6 – Approach Adopted in Developing the Probable Capital Costs (2012)
[All costs have a projected accuracy between –30% and +50% of stated values]

Category	ID	Component	Cost Basis
A. Equipment, Building, and Equipment Pads	A.1	Itemized equipment including strainers; vessels; chemical feed systems; tanks; blowers; clarifiers; dewatering equipment; backwash pumps; and booster pumps.	Quotes from vendors, when available, and experience and information from other projects.
	A.2	Misc. Equipment (valves, flowmeters, etc.)	15% of A.1
	A.3	Installation	30% Percent of sum of A.1 and A.2
	A.4	Indoor Equipment Area (Chemical feed pumps; blowers and pumps)	$150/sf multiplied by sum of individual equipment footprints plus clearances.
	A.5	Indoor Working Space	25% of A.4
	A.6	Outdoor Equipment Area (chemical tanks, water tanks, filter vessels and contactors)	$50/sf multiplied by individual equipment footprints plus clearances.
	A.7	Subtotal	Sum of A1 through A6.
B. Construction Activities	B.1	Mobilization	5% of A.7
	B.2	Site Work & Yard Piping	10% of A.7
	B.3	Electrical & HVAC equipment and installation	15% of A.7
	B.4	Instrumentation components, installation, and programming	15% of A.7
	B.5	Construction Contingency	25% of sum of A.7 thru B.4
	B.6	Contractor Overhead and Profit	15% of sum of A.7 thru B.5
	B.7	Initial Resin/Media Load WBA Resin: $\$500/ft^3$ SBA Resin: $\$150/ft^3$ Sand/Anth: $\$20/ft^3$	Based on calculated volume of resin/media, and their unit cost (plus 7.5% sales tax and 5% media installation cost)
	B.8	Subtotal	Sum of B.1 thru B.7
C. Total Construction	C.1	Construction Cost	Sum of A.7 and B.8
D. Professional Services	D.1	Engineering Design	10% of (C.1 – B.7)
	D.2	Verification Testing	3% of (C.1 – B.7)
	D.3	Environmental Permitting	2% of (C.1 – B.7)
	D.4	Construction Management	10% of (C.1 – B.7)
	D.5	Startup Support Services	2.0% of (C.1 – B.7)
	D.6	Administrative & Legal Services	1.5% of (C.1 – B.7)
	D.7	Professional Services Contingency	25% of sum of D.1 thru D.6.
	D.8	Total of Professional Services	Sum of D.1 thru D.7.
E. Fees	E.1	Sewer Connection Fee	Based on sewer connection fee in the Los Angeles County Sanitation District service area.
F. Capital Cost	F.1	Total Capital Cost	Sum of A.7, B.8, C.1, D.8, & E.1

4.2 Probable Annual O&M Cost Development

Table 7 summarizes the approach used in determining the annual O&M costs for all treatment systems. The annual O&M cost is divided into seven categories: 1) Chemicals, 2) Labor, 3) Energy, 4) Analytical, 5) Resin Replacement, 6) Waste Disposal, and 7) Maintenance. It is noted that all annual costs, including labor and maintenance, were prorated to the average annual flowrate, which was determined by multiplying the well production rate by its annual utilization rate.

Chemical costs were set based on information provided by current water agency users, as well as quotes from various suppliers. For estimating labor cost, the cost estimate assumes an operator salary of $50,000/yr and a supervisor salary of $75,000/yr. A utility overhead of 100% of labor cost was also assumed. For treatment conditions that did not include residuals treatment, a 0.5 Full-Time Equivalent (FTE) operator was assumed. If the treatment system included residuals treatment, then a 1.0 FTE operator was assumed.

Energy consumption was limited to three components: general headloss through the treatment system, air blower for the WBA treatment system air-stripping used for pH, and booster pumping to re-pump the water downstream of the air-strippers. The unit energy cost was set at $0.15/KW-hr. The headloss through the treatment system was assumed to be 10 psi. The blower HP rating was provided by the air-stripping vendor, and the booster pump energy consumption was calculated based on an assumed pumping head of 50 psi.

The analytical cost for water quality samples collected from the treatment system during normal operation was determined by developing a list of projected analytical requirements for a treatment system. Sample collection was assumed for the influent and effluent water flows, as well as the effluents of individual vessels.

Resin replacement from the WBA process was based on the projected replacement frequency discussed earlier. For the purpose of this analysis, no replacement resin was assumed for the SBA process, although some resin loss is commonly experienced requiring resin replenishment at some low frequency. However, the amount lost is greatly dependent on the appropriateness of the system design and operation.

Waste disposal options covered liquid waste disposal (sewer or hauled off site), and solid waste disposal into hazardous waste facilities ($2,000/ton or $50/ft^3). Based on the analysis conducted in this project, the uranium+thorium load onto the WBA resin at the time of resin replacement is projected to be less than 0.05% by wt. Therefore, the WBA resin is expected to be disposed of as a TENORM at a unit cost of $326/ft^3. This value was based on the report prepared by ARCADIS for the Association for California Water Agencies (ACWA).

Finally, general annual maintenance cost was set at 1.5% of construction cost less the media cost. The maintenance cost was prorated by the well utilization rate. For example, if the construction cost was $3M, and the utilization rate was 40%, then the annual general maintenance cost was estimated at:

$$Maintenance\ Cost = \$3{,}000{,}000 \times \frac{1.5}{100} \times \frac{40}{100} = \$18{,}000/yr \qquad (4)$$

Table 7 – Approach Adopted in Developing the Probable Annual O&M Costs (2012)
[All Costs have a projected accuracy between –30% and +50% of stated values]

Category	ID	Component	Unit Cost	Cost Basis
A. Chemicals	A.1	Salt (NaCl)	$160/ton	Based on Information from water agencies
	A.2	Ferrous Sulfate ($FeSO_4$)	$2.2/gallon for a 7% solution	Based on quote from Basic Chemical for deliveries in Southern California
	A.3	Carbon Dioxide (CO_2)	$120/ton	Based on information from TOMCO2
	A.4	Chemical Cost	Sum of A.1 thru A.3	
B. Labor	B.1	Operator	$50,000/yr	0.5 FTE (or 1.0 FTE if residuals treatment is required)
	B.2	Supervisor	$75,000/yr	0.25 FTE
	B.3	Overhead	100%	Percent of sum of B.1 and B.2
	B.4	Labor Total	Sum of B.1 thru B.3.	
C. Energy	C.1	Headloss through Treatment System	10 psi headloss	Assumed ($0.15/KW-hr)
	C.2	Air Blower for CO_2 stripping	Variable	Air blower HP consumption provided by vendor
	C.3	Booster Pump	Variable	HP required to pump treatment flow against a TDH of 50 psi
	C.4	Energy Total	Sum of C.1 through C3.	
D. Analytical Cost	D.1	Analytical Requirements	Variable	Based on detailed assessment of monitoring requirements for different types of treatment systems.
E. Resin Replacement	E.1	WBA Resin Replacement	$500/cu-ft	Based on estimates prepared for the Glendale Project
	E.2	SBA Resin Replacement	No Replacement Required	Assumed
F. Waste Disposal	F.1	Sewer Discharge	Variable	Based on costs for sewer disposal within the Los Angeles County Sanitation District.
	F.2	Hauling of Liquid Waste	$230/1000 gallon	Based on cost incurred by Coachella Valley Water District
	F.3	Dewatered Sludge Disposal (Hazardous Landfill)	$2000/ton, or $50/cu-ft	Based on ACWA Report on Residuals Disposal from Cr(VI) Treatment Plants
	F.4	Spent Resin Disposal as TENORM	$326/cu-ft	Based on ACWA Report on Residuals Disposal from Cr(VI) Treatment Plants
	F.7	Total Waste Disposal	Sum of D.1 through D.4.	
E. Maintenance	G.1	Maintenance	1.5% of Construction Cost (less media cost)	
F. Annual Cost	H.1	Total Annual Cost	Sum of A.4, B.4, C.4, D.1, E.1, F.7, and G.1	

5.0 ESTIMATES OF PROBABLE CAPITAL AND O&M COSTS

Based on the cost assumptions detailed in Section 4, probable capital and annual O&M costs were developed for treating Well 20 water to various potential Cr(VI) MCL values using each of the three treatment technologies (SBA, WBA, and RCF). *At this planning stage, all probable cost estimates have a confidence range between –30% and +50%.*

Table 8 lists capacity of Well 20 and its utilization rate. Also listed in Table 8 are the average values of key water quality parameters for the well. As discussed in Section 3.0, the quality of the water being treated impacts the cost of each technology. For example, the pH and alkalinity of water impact the CO_2 or acid doses required to lower the pH to 6.0 for the WBA treatment system.

Table 8 – Average Quality of the City's Well 20 Water

Parameter	Unit	Value
Flowrate	gpm	1,100
Utilization Rate	%	40%
pH	--	8.2
Total Alkalinity	mg/L $CaCO_3$	438
Conductivity	µS/cm	952
Nitrate	mg/L NO_3	40
Uranium	µg/L	2.8
Sulfate	mg/L	39
Total Cr	µg/L	42
Cr(VI)	µg/L	41

Cost estimates were developed for four treatment configurations to meet potential Cr(VI) MCL values of 2, 5, 10, 15, and 20 µg/L. In developing the costs, only part of the flow was treated and the remaining flow was by-passed around the treatment system. The size of the treatment flow was determined by assuming that the effluent of each treatment system contains approximately 1.5 µg/L Cr, and that the blended water Cr level should be no greater than 80% of the MCL.

Table 9 lists the treatment capacities required to meet the various potential MCL values, which range from a low of 698 gpm to meet an MCL of 20 µg/L to a high of 1,100 gpm to meet an MCL of 2 µg/L. This range is quite narrow, and is driven by the high Cr concentration in the raw water.

Table 9 – Treatment Capacities Required to Treat Well 20 to Various Cr(VI) MCL Levels

MCL	Treatment Capacity, gpm	By-Pass Capacity, gpm
2	1,100	0
5	1,032	68
10	923	177
15	815	285
20	706	394

The following four treatment systems were evaluated for Cr(VI) removal from Well 20 water:

1. **SBA treatment** with full waste brine treatment to separate the Cr from the brine, hauling of the clarified brine for off-site disposal, dewatering of the settled sludge, and disposal of the dewatered solids as California non-RCRA hazardous waste.
2. **RCF treatment** with direct discharge of the untreated waste backwash water to the sewer.
3. **RCF treatment** with full waste backwash water treatment to separate the Cr from the water, return of the clarified water to the head of the plant, dewatering of the settled sludge, and disposal of the dewatered solids as California non-RCRA hazardous waste.
4. **WBA treatment** with CO_2 for pH suppression and air-stripping for pH adjustment of the treated water.

The probable capital and O&M costs for treating Well 20 water to the various MCLs are presented in Figures 8.A through 8.E. The top two figures (8.A and 8.B) present the capital and annual O&M costs, respectively. The middle two figures (8.C and 8.D) present the O&M water cost expressed in $/AF of water produced and $/kgal of water produced, respectively. The bottom two figures (8.E and 8.F) present the total water cost expressed in $/AF of water produced and $/kgal of water produced, respectively. The legend in each figure includes the same sequence of conditions, which are also numbered 1 through 4, to help with reading the graphs. The sequence from left to right is as follows:

1. *SBA with clarified waste brine hauled off-site for disposal*
2. *RCF with waste backwash water discharged to the sewer*
3. *RCF with clarified waste washwater returned to head of the plant*
4. *WBA with CO_2 and air stripping for pH adjustment*

Figure 8.A shows that the capital cost of the SBA process is significantly lower than those of the RCF and WBA processes under all potential MCL options. The SBA capital cost ranges from $1.9M for meeting an MCL of 20 µg/L, to $2.5M for meeting an MCL of 2 µg/L. On the other hand, the probable capital cost for RCF treatment with sewer disposal of the waste backwash water ranges from a low of $2.9M for an MCL of 20 µg/L to a high of $4.6M for an MCL of 2 µg/L. If the waste backwash water needs to be treated for Cr removal and then recycled to the head of the plant, the probable capital cost is projected to range from $3.5M for a potential MCL of 20 µg/L to $5.2M for a potential MCL of 2 µg/L. Finally, the WBA system costs are the highest, ranging from a low of $4.6M for a potential MCL of 20 µg/L to a high of $6.3M for a potential MCL of 2 µg/L.

Figure 8.B shows that the probable annual O&M costs for the four treatment options considered. The RCF process with sewer disposal of the waste backwash water has the lowest O&M cost, ranging from a low of $100,000/yr for a potential MCL of 20 µg/L to a high of $132,000/yr for a potential MCL of 2 µg/L. The highest annual O&M costs are incurred by the WBA process, with probable costs ranging from $360,000/yr for a potential MCL of 20 µg/L to $530,000/yr for a potential MCL of 2 µg/L. The annual O&M costs are also manifested in the O&M water costs shown in Figures 8.C and 8.D. For the RCF process with sewer disposal, the probable O&M water cost ranges from $141/AF to $186/AF ($0.43/kgal to $0.57/kgal). However, for the WBA process, the cost ranges from $507/AF to $747/AF ($1.6/kgal to $2.3/kgal).

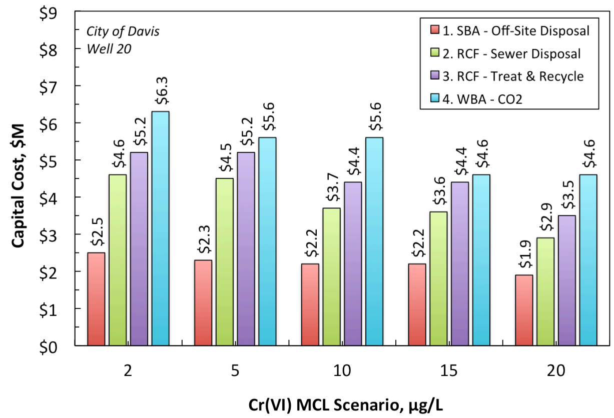

Figure 8.A – Probable Capital Cost for Cr(VI) Removal from Well 20 Water to Meet Various MCL Values

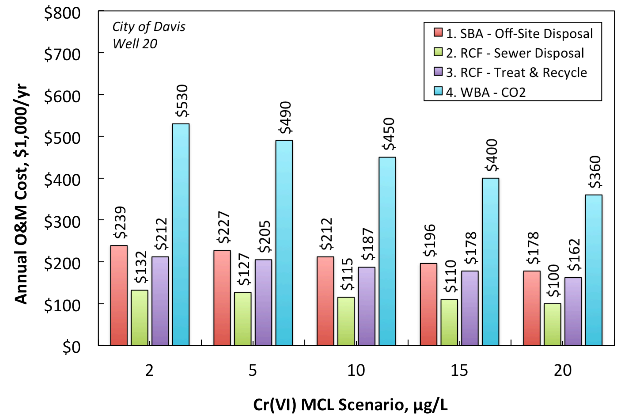

Figure 8.B – Probable Annual O&M Cost for Cr(VI) Removal from Well 20 Water to Meet Various MCL Values

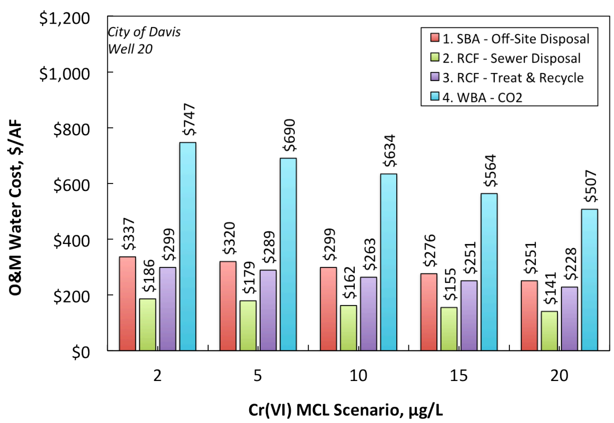

Figure 8.C – Probable O&M Water Cost, $/AF, for Cr(VI) Removal from Well 20 Water to Meet Various MCL Values

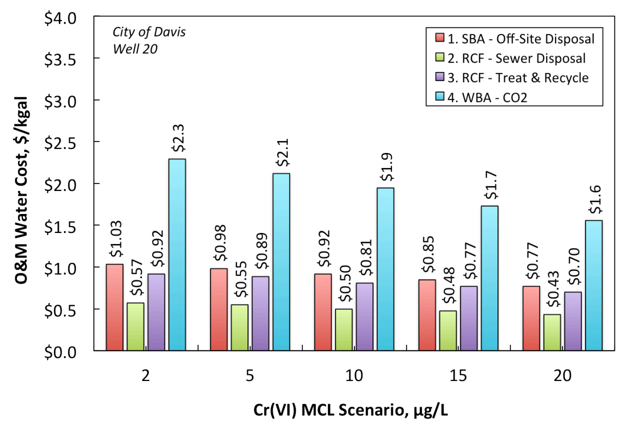

Figure 8.D – Probable O&M Water Cost, $/kgal, for Cr(VI) Removal from Well 20 Water to Meet Various MCL Values

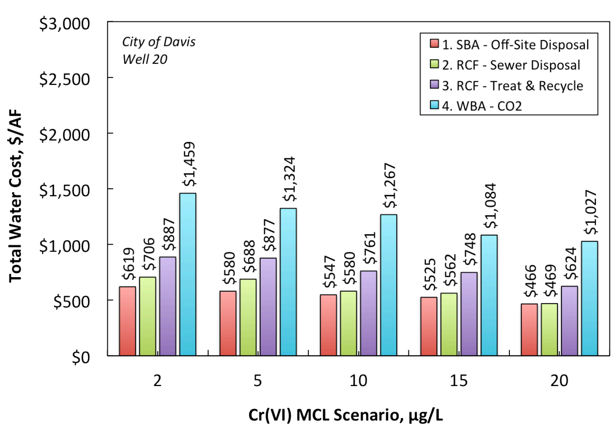

Figure 8.E – Probable Total Water Cost, $/AF, for Cr(VI) Removal from Well 20 Water to Meet Various MCL Values

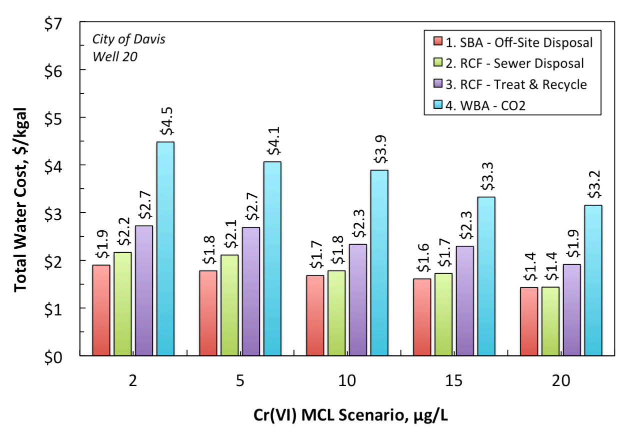

Figure 8.F – Probable Total Water Cost, $/kgal, for Cr(VI) Removal from Well 20 Water to Meet Various MCL Values

Figures 8.E and 8.F show the total water cost in $/AF and $/kgal, respectively. The total water cost is determined by calculating the sum of the amortized capital cost and the annual O&M cost, and then dividing it by the total annual water volume produced in either AF or kgal. While the RCF process with sewer disposal had a significantly lower annual cost compared to the SBA process, its higher capital cost resulted in the two processes having similar total water costs ranging from $466/AF ($1.4/kgal) for a potential MCL of 20 μg/L to $706/AF ($2.2/kgal) for a potential MCL of 2 μg/L. For the RCF process with waste backwash treatment and recycling, the total water cost ranges from a low of $624/AF ($1.9/kgal) for a potential MCL of 20 μg/L to a high of $887/AF ($2.7/kgal) for a potential MCL of 2 μg/L. With the highest capital and O&M costs, the WBA process was determined to have the highest total water cost ranging from $1,027/AF ($3.2/kgal) for a potential MCL of 20 μg/L to $1,459/AF ($4.5/kgal) for a potential MCL of 2 μg/L.

While SBA and RCF with sewer disposal emerged as the two alternatives with the lowest overall costs, some of their non-financial factors should be taken into consideration. Factors impacting each of these processes are presented in Figures 9 and 10. Figure 9 shows a plot of the number of days between bulk truck pickups of the clarified waste brine from the SBA process. The analysis shows that one bulk truck will have to come to the site every 3.4 days for a potential MCL of 20 μg/L and every 2.2 days for a potential MCL of 2 μg/L. These translate into a truck traffic volume between 3 and 4 trucks each week. This is a relatively high traffic volume that could be prohibitive depending on the location of the well and the neighborhood conditions. Figure 10 shows the anticipated average flowrate into the sewer under the first RCF option in which the waste backwash water is discharged directly to the sewer without treatment. For a potential MCL of 20 μg/L, the sewer discharge rate is projected at about 19 gpm, which increases to 29 gpm at a potential MCL of 2 μg/L. It is important to determine that the onsite sewer can handle these flowrates before this treatment approach can be implemented at the well.

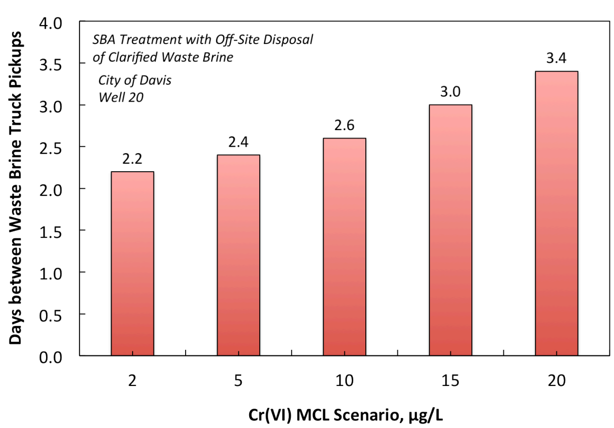

Figure 9 – Projected Days between Truck Pickups of the Clarified Waste Brine from the SBA Process

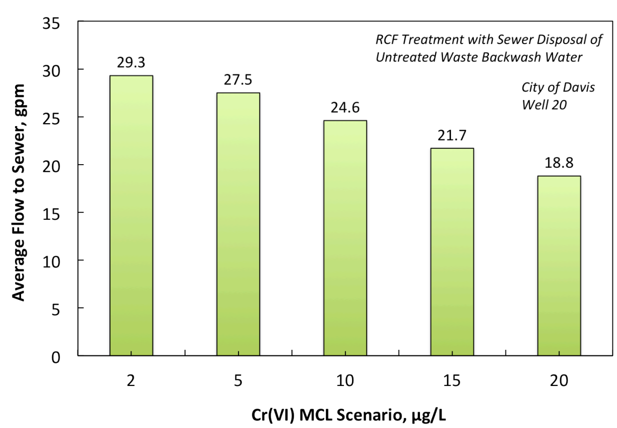

Figure 10 – Projected Average Sewer Discharge Rate of the Untreated Waste Backwash Water from the RCF Process

6.0 SUMMARY & CONCLUSIONS

The costs of four treatment alternatives for Cr(VI) removal from Well 20 water to comply with various potential MCL scenarios were evaluated. The four alternatives were as follows:

Alternative 1 – Strong Base Anion (SBA) Exchange treatment with onsite treatment of the waste brine to remove the Cr from the waste brine, and then off-site disposal of the treated waste brine. The sludge containing the Cr removed from the waste brine is dewatered and disposed as California non-RCRA hazardous waste.

Alternative 2 – Reduction, Coagulation, and Filtration (RCF) treatment with onsite sewer disposal of the untreated waste backwash water.

Alternative 3 – RCF treatment with onsite treatment of the waste backwash water to remove the Cr and return the treated backwash water to the head of the treatment system. The sludge containing the removed Cr is then dewatered and disposed as a California non-RCRA hazardous waste.

Alternative 4 – Weak Base Anion (WBA) Exchange treatment using CO_2 for pH suppression and air-stripping for raising the water pH after treatment.

The size of the treatment system required for Well 20 was different for each MCL scenario based on the assumption that each treatment system can reliably achieve a treated-water Cr(VI) level of 1.5 µg/L. Therefore, a blending strategy was implemented to minimize the size of the treatment system while maintaining the final blended-water Cr level at no more than 80% of the MCL evaluated. With a total well capacity of 1,100 gpm, the treatment system size ranged from 706 gpm for an MCL of 20 µg/L to 1,100 gpm for an MCL of 2 µg/L.

From a capital cost perspective, Alternative 1 (SBA treatment) is projected to have the lowest capital cost ranging from $1.9M for an MCL of 20 µg/L to $2.5M for an MCL of 2 µg/L. However, from an annual O&M cost perspective, Alternative 2 (RCF with sewer discharge) is projected to have the lowest annual cost ranging from $100,000/yr for an MCL of 20 µg/L to $132,000/yr for an MCL of 2 µg/L. This range translates into an annual O&M water cost ranging from $141/AF ($0.43/kgal) for an MCL of 20 µg/L to $186/AF ($0.57/kgal) for an MCL of 2 µg/L.

From a total water cost perspective, Alternatives 1 and 2 are projected to have relatively similar water costs ranging from $466/AF ($1.4/kgal) for an MCL of 20 µg/L to $706/AF ($2.2/kgal) for an MCL of 2 µg/L. However, while these two alternatives are cost effective, they have specific non-financial factors that impact their viability. Specifically, the implementation of Alternative 1 at Well 20 will require 3 to 4 bulk trucks each week to pick up the clarified waste brine, while the implementation of Alternative 2 requires the availability of an on-site sewer capacity ranging from 19 gpm to 29 gpm for the range of MCLs evaluated.

If neither off-site disposal of the waste brine under Alternative 1 nor sewer disposal of the waste backwash water under Alternative 2 is available, then Alternative 3 (RCF with recycling of waste backwash water) becomes the least costly alternative as it has a lower capital and O&M cost compared to Alternative 4 (WBA treatment). Under all conditions evaluated, WBA treatment had the highest capital and annual O&M costs.

It should be emphasized that none of the treatment alternatives evaluated herein will result in significant removal of nitrate, which approaches the MCL of 10 mg/L as N in Well 20 water.

While SBA resins (Alternative 1) do remove ammonia from water, operating them for the projected 3,500 BVs between regenerations means that the nitrate removal will be minimal. If the City is interested in the combined removal of nitrate and Cr(VI), WQTS recommends the evaluation of Biological Denitrification (BDN) as the technology of choice. While more costly than SBA treatment, BDN treatment achieves high removals of both nitrate and Cr(VI). Its only limitation is that it generates a waste backwash water that requires sewer disposal.

APPENDIX A –

PROJECTED DESIGN CRITERIA, PROBABLE CAPITAL COST, & PROBABLE ANNUAL O&M COST OF THE Cr(VI) TREATMENT SYSTEMS AT WELL 20

Cost of Cr(VI) Removal with SBA Resin

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Enter Values in Yellow Cells Only

WQTS Water Quality & Treatment Solutions, Inc. An environmental engineering and science consulting company

General Information:

Water Agency:	City of Davis	
Well Name:	Well 20	
Well Capacity =	1,100	gpm
Well % Utilization =	40	%
Raw Water Cr(VI) =	42	µg/L
Potential Cr(VI) MCL =	2	µg/L
Target % of MCL =	80	%
Anticipated Treated Cr(VI) =	1.5	µg/L
Design EBCT =	3.0	minutes
Projected Bed Volumes btwn Regenerations =	3,500	BVs
(Leave Above Blank if Runtime is to be obtained from SO4 & NO3 Data)		
Raw Water Sulfate =	38	mg/L
Raw Water Nitrate =	40	mg/L as NO3
Estimated BVs to Regeneration =	3,500	BVs
Untreated Waste Brine to Sewer (Y/N)?	no	
Clarified Waste Brine to Sewer (Yes/No)?	no	
Select Dewatered Sludge Disposal Option➔	Hazardous Waste	
Amortization Period =	20	years
Interest Rate =	5	%

Treatment System Capacity:

Treatment System Capacity =	1,097 gpm
By-Pass Capacity =	3 gpm
Number of Vessels =	2
Vessel Diameter =	10 ft
Volume of Resin per Vessel =	236 ft^3
Volume of Resin =	471 ft^3
Annual Average Flowrate =	439 gpm

Space Requirements:

Indoor Area Required =	332 ft^2
Outdoor Area Required =	1,848 ft^2
Days between Bulk Salt Deliveries =	44 days
Days between Ferrous Truck Deliveries =	79 days
Days between Waste Brine Truck Pickups =	2.2 days
Annual Discharge to Sewer =	NA kgal/year
Average Flow to Sewer During Operation =	NA gpm
Estimated Cr in Waste Discharge =	31.5 mg/L

Probable Capital Cost (2012):

Equipment =	$	537,000
Installation =	$	161,000
Building Cost =	$	142,000
Construction Activities =	$	991,000
Total Construction Cost =	$	1,831,000
Professional Services =	$	624,000
Sewer Connection Fee =	$	-
Mid-Range Total Capital Cost =	$	2,500,000
Probable Range of Capital Cost =		$1,800,000 – $3,800,000

Probable Annual Operation Cost (2012):

Labor =	$	55,000	/year
Chemicals =	$	36,000	/year
Liquid Waste Disposal =	$	68,100	/year
Dewatered Sludge Disposal =	$	56,000	/year
Energy =	$	3,000	/year
Analytical Cost =	$	10,000	/year
Maintenance =	$	11,000	/year
Mid-Range Total Annual Cost =	$	239,000	/year
Probable Range of Annual Cost =		$167,000/yr – $359,000/yr	

Probable Mid-Range Annualized & Water Cost:

Amortized Capital =	$201,000/yr		
Annual O&M Cost =	$239,000/yr		
Total Annualized Cost =	$440,000/yr		
Water Cost from Capital =	$284/AF	=	$0.87/kgal
Water Cost from O&M =	$338/AF	=	$1.04/kgal
Totallized Water Cost =	$622/AF	=	$1.91/kgal

Cost of Cr(VI) Removal with SBA Resin

Developed by WQTS, Inc. www.WQTS.com

Enter Values in Yellow Cells Only

WQTS Water Quality & Treatment Solutions, Inc. An environmental engineering and science consulting company

General Information:

Water Agency:	City of Davis	
Well Name:	Well 20	
Well Capacity =	1,100	gpm
Well % Utilization =	40	%
Raw Water Cr(VI) =	42	µg/L
Potential Cr(VI) MCL =	5	µg/L
Target % of MCL =	80	%
Anticipated Treated Cr(VI) =	1.5	µg/L
Design EBCT =	3.0	minutes
Projected Bed Volumes btwn Regenerations =	3,500	BVs
(Leave Above Blank if Runtime is to be obtained from SO4 & NO3 Data)		
Raw Water Sulfate =	38	mg/L
Raw Water Nitrate =	40	mg/L as NO3
Estimated BVs to Regeneration =	3,500	BVs
Untreated Waste Brine to Sewer (Y/N)?	no	
Clarified Waste Brine to Sewer (Yes/No)?	no	
Select Dewatered Sludge Disposal Option→	Hazardous Waste	
Amortization Period =	20	years
Interest Rate =	5	%

Treatment System Capacity:

Treatment System Capacity =	1,032	gpm
By-Pass Capacity =	68	gpm
Number of Vessels =	2	
Vessel Diameter =	10	ft
Volume of Resin per Vessel =	236	ft^3
Volume of Resin =	471	ft^3
Annual Average Flowrate =	413	gpm

Space Requirements:

Indoor Area Required =	306	ft^2
Outdoor Area Required =	1,848	ft^2
Days between Bulk Salt Deliveries =	47	days
Days between Ferrous Truck Deliveries =	84	days
Days between Waste Brine Truck Pickups =	2.4	days
Annual Discharge to Sewer =	NA	kgal/year
Average Flow to Sewer During Operation =	NA	gpm
Estimated Cr in Waste Discharge =	31.5	mg/L

Probable Capital Cost (2012):

Equipment =	$	507,000
Installation =	$	152,000
Building Cost =	$	138,000
Construction Activities =	$	945,000
Total Construction Cost =	$	1,742,000
Professional Services =	$	593,000
Sewer Connection Fee =	$	-
Mid-Range Total Capital Cost =	$	2,300,000
Probable Range of Capital Cost =		$1,600,000 – $3,500,000

Probable Annual Operation Cost (2012):

Labor =	$	55,000	/year
Chemicals =	$	34,000	/year
Liquid Waste Disposal =	$	64,100	/year
Dewatered Sludge Disposal =	$	52,000	/year
Energy =	$	2,000	/year
Analytical Cost =	$	10,000	/year
Maintenance =	$	10,000	/year
Mid-Range Total Annual Cost =	$	227,000	/year
Probable Range of Annual Cost =		$159,000/yr – $341,000/yr	

Probable Mid-Range Annualized & Water Cost:

Amortized Capital =	$185,000/yr		
Annual O&M Cost =	$227,000/yr		
Total Annualized Cost =	$412,000/yr		
Water Cost from Capital =	$261/AF	=	$0.80/kgal
Water Cost from O&M =	$321/AF	=	$0.98/kgal
Totallized Water Cost =	$582/AF	=	$1.79/kgal

Cost of Cr(VI) Removal with SBA Resin

Developed by WQTS, Inc. www.WQTS.com

Enter Values in Yellow Cells Only

WQTS Water Quality & Treatment Solutions, Inc. An environmental engineering and science consulting company

General Information:

Water Agency:	City of Davis	
Well Name:	Well 20	
Well Capacity =	1,100	gpm
Well % Utilization =	40	%
Raw Water Cr(VI) =	42	µg/L
Potential Cr(VI) MCL =	10	µg/L
Target % of MCL =	80	%
Anticipated Treated Cr(VI) =	1.5	µg/L
Design EBCT =	3.0	minutes
Projected Bed Volumes btwn Regenerations =	3,500	BVs
(Leave Above Blank if Runtime is to be obtained from SO4 & NO3 Data)		
Raw Water Sulfate =	38	mg/L
Raw Water Nitrate =	40	mg/L as NO3
Estimated BVs to Regeneration =	3,500	BVs
Untreated Waste Brine to Sewer (Y/N)?	no	
Clarified Waste Brine to Sewer (Yes/No)?	no	
Select Dewatered Sludge Disposal Option→	Hazardous Waste	
Amortization Period =	20	years
Interest Rate =	5	%

Treatment System Capacity:

Treatment System Capacity =	923	gpm
By-Pass Capacity =	177	gpm
Number of Vessels =	2	
Vessel Diameter =	10	ft
Volume of Resin per Vessel =	236	ft^3
Volume of Resin =	471	ft^3
Annual Average Flowrate =	369	gpm

Space Requirements:

Indoor Area Required =	296	ft^2
Outdoor Area Required =	1,848	ft^2
Days between Bulk Salt Deliveries =	53	days
Days between Ferrous Truck Deliveries =	94	days
Days between Waste Brine Truck Pickups =	2.6	days
Annual Discharge to Sewer =	NA	kgal/year
Average Flow to Sewer During Operation =	NA	gpm
Estimated Cr in Waste Discharge =	31.5	mg/L

Probable Capital Cost (2012):

Equipment =	$	484,000
Installation =	$	145,000
Building Cost =	$	137,000
Construction Activities =	$	911,000
Total Construction Cost =	$	1,677,000
Professional Services =	$	569,000
Sewer Connection Fee =	$	-
Mid-Range Total Capital Cost =	$	2,200,000
Probable Range of Capital Cost =		$1,500,000 – $3,300,000

Probable Annual Operation Cost (2012):

Labor =	$	55,000	/year
Chemicals =	$	31,000	/year
Liquid Waste Disposal =	$	57,300	/year
Dewatered Sludge Disposal =	$	47,000	/year
Energy =	$	2,000	/year
Analytical Cost =	$	10,000	/year
Maintenance =	$	10,000	/year
Mid-Range Total Annual Cost =	$	212,000	/year
Probable Range of Annual Cost =		$148,000/yr – $318,000/yr	

Probable Mid-Range Annualized & Water Cost:

Amortized Capital =	$177,000/yr		
Annual O&M Cost =	$212,000/yr		
Total Annualized Cost =	$389,000/yr		
Water Cost from Capital =	$250/AF	=	$0.77/kgal
Water Cost from O&M =	$300/AF	=	$0.92/kgal
Totallized Water Cost =	$550/AF	=	$1.69/kgal

Cost of Cr(VI) Removal with SBA Resin

 www.WQTS.com

Enter Values in Yellow Cells Only

WQTS Water Quality & Treatment Solutions, Inc. An environmental engineering and science consulting company

General Information:

Water Agency:	City of Davis	
Well Name:	Well 20	
Well Capacity =	1,100	gpm
Well % Utilization =	40	%
Raw Water Cr(VI) =	42	µg/L
Potential Cr(VI) MCL =	15	µg/L
Target % of MCL =	80	%
Anticipated Treated Cr(VI) =	1.5	µg/L
Design EBCT =	3.0	minutes
Projected Bed Volumes btwn Regenerations =	3,500	BVs
(Leave Above Blank if Runtime is to be obtained from SO4 & NO3 Data)		
Raw Water Sulfate =	38	mg/L
Raw Water Nitrate =	40	mg/L as NO3
Estimated BVs to Regeneration =	3,500	BVs
Untreated Waste Brine to Sewer (Y/N)?	no	
Clarified Waste Brine to Sewer (Yes/No)?	no	
Select Dewatered Sludge Disposal Option➔	Hazardous Waste	
Amortization Period =	20	years
Interest Rate =	5	%

Treatment System Capacity:

Treatment System Capacity =	815	gpm
By-Pass Capacity =	285	gpm
Number of Vessels =	2	
Vessel Diameter =	10	ft
Volume of Resin per Vessel =	236	ft^3
Volume of Resin =	471	ft^3
Annual Average Flowrate =	326	gpm

Space Requirements:

Indoor Area Required =	296	ft^2
Outdoor Area Required =	1,848	ft^2
Days between Bulk Salt Deliveries =	60	days
Days between Ferrous Truck Deliveries =	106	days
Days between Waste Brine Truck Pickups =	3.0	days
Annual Discharge to Sewer =	NA	kgal/year
Average Flow to Sewer During Operation =	NA	gpm
Estimated Cr in Waste Discharge =	31.5	mg/L

Probable Capital Cost (2012):

Equipment =	$	484,000
Installation =	$	145,000
Building Cost =	$	137,000
Construction Activities =	$	911,000
Total Construction Cost =	$	1,677,000
Professional Services =	$	569,000
Sewer Connection Fee =	$	-
Mid-Range Total Capital Cost =	$	2,200,000
Probable Range of Capital Cost =		$1,500,000 – $3,300,000

Probable Annual Operation Cost (2012):

Labor =	$	55,000	/year
Chemicals =	$	27,000	/year
Liquid Waste Disposal =	$	50,600	/year
Dewatered Sludge Disposal =	$	41,000	/year
Energy =	$	2,000	/year
Analytical Cost =	$	10,000	/year
Maintenance =	$	10,000	/year
Mid-Range Total Annual Cost =	$	196,000	/year
Probable Range of Annual Cost =		$137,000/yr – $294,000/yr	

Probable Mid-Range Annualized & Water Cost:

Amortized Capital =	$177,000/yr		
Annual O&M Cost =	$196,000/yr		
Total Annualized Cost =	$373,000/yr		
Water Cost from Capital =	$250/AF	=	$0.77/kgal
Water Cost from O&M =	$277/AF	=	$0.85/kgal
Totallized Water Cost =	$527/AF	=	$1.62/kgal

Cost of Cr(VI) Removal with SBA Resin

 www.WQTS.com

Enter Values in Yellow Cells Only

WQTS Water Quality & Treatment Solutions, Inc. An environmental engineering and science consulting company

General Information:

Water Agency:	City of Davis	
Well Name:	Well 20	
Well Capacity =	1,100	gpm
Well % Utilization =	40	%
Raw Water Cr(VI) =	42	µg/L
Potential Cr(VI) MCL =	20	µg/L
Target % of MCL =	80	%
Anticipated Treated Cr(VI) =	1.5	µg/L
Design EBCT =	3.0	minutes
Projected Bed Volumes btwn Regenerations =	3,500	BVs
(Leave Above Blank if Runtime is to be obtained from SO4 & NO3 Data)		
Raw Water Sulfate =	38	mg/L
Raw Water Nitrate =	40	mg/L as NO3
Estimated BVs to Regeneration =	3,500	BVs
Untreated Waste Brine to Sewer (Y/N)?	no	
Clarified Waste Brine to Sewer (Yes/No)?	no	
Select Dewatered Sludge Disposal Option➔	Hazardous Waste	
Amortization Period =	20	years
Interest Rate =	5	%

Treatment System Capacity:

Treatment System Capacity =	706	gpm
By-Pass Capacity =	394	gpm
Number of Vessels =	2	
Vessel Diameter =	8	ft
Volume of Resin per Vessel =	151	ft^3
Volume of Resin =	302	ft^3
Annual Average Flowrate =	282	gpm

Space Requirements:

Indoor Area Required =	296	ft^2
Outdoor Area Required =	1,689	ft^2
Days between Bulk Salt Deliveries =	34	days
Days between Ferrous Truck Deliveries =	122	days
Days between Waste Brine Truck Pickups =	3.4	days
Annual Discharge to Sewer =	NA	kgal/year
Average Flow to Sewer During Operation =	NA	gpm
Estimated Cr in Waste Discharge =	31.5	mg/L

Probable Capital Cost (2012):

Equipment =	$	404,000	
Installation =	$	121,000	
Building Cost =	$	129,000	
Construction Activities =	$	760,000	
Total Construction Cost =	$	1,414,000	
Professional Services =	$	485,000	
Sewer Connection Fee =	$	-	
Mid-Range Total Capital Cost =	$	1,900,000	
Probable Range of Capital Cost =		$1,300,000 – $2,900,000	

Probable Annual Operation Cost (2012):

Labor =	$	55,000	/year
Chemicals =	$	23,000	/year
Liquid Waste Disposal =	$	43,800	/year
Dewatered Sludge Disposal =	$	36,000	/year
Energy =	$	2,000	/year
Analytical Cost =	$	10,000	/year
Maintenance =	$	8,000	/year
Mid-Range Total Annual Cost =	$	178,000	/year
Probable Range of Annual Cost =		$125,000/yr – $267,000/yr	

Probable Mid-Range Annualized & Water Cost:

Amortized Capital =	$152,000/yr		
Annual O&M Cost =	$178,000/yr		
Total Annualized Cost =	$330,000/yr		
Water Cost from Capital =	$215/AF	=	$0.66/kgal
Water Cost from O&M =	$252/AF	=	$0.77/kgal
Totallized Water Cost =	$466/AF	=	$1.43/kgal

Cost of Cr(VI) Removal with the RCF Process

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WQTS Water Quality & Treatment Solutions, Inc. An environmental engineering and science consulting company

Enter Values in Yellow Cells Only

General Information:

Water Agency:	City of Davis	
Well Name:	Well 20	
Well Capacity =	1,100	gpm
Well % Utilization =	40	%
Raw Water Cr(VI) =	42	µg/L
Potential Cr(VI) MCL =	2	µg/L
Target % of MCL =	80	%
Anticipated Treated Cr(VI) =	1.5	µg/L
Reduction Contact Time =	10	minutes
Ferrous Iron Dose =	3.0	mg/L
Design Surface Loading Rate =	3.0	gpm/sf
Anticipated Unit Filter Run Volume =	7,500	gal/sf
Anticipated Unit Filter Backwash Volume =	200	gal/sf
Percent Efficiency =	97%	
Untreated Backwash Water to Sewer (Y/N)?	yes	
Leave This Cell Blank -->		
Select Dewatered Sludge Disposal Option➔	Hazardous Waste	

Capital Financing Terms:

Amortization Period =	20	years
Interest Rate =	5.0	%

System Components:

Treatment System Capacity =	1,097	gpm
By-Pass Capacity =	3	gpm
Number of Pre-Treatment Contactors =	1	
Contactor Diameter =	10	ft
Contactor Length =	20	ft
Type of Filter Vessels =	Vertical	
Number of Vessels =	4	
Vessel Diameter =	12	ft
Days between Ferrous Truck Deliveries =	29.4	days
Annual Discharge to Sewer =	6.2	MG/year
Average Flow to Sewer During Operation =	29.3	gpm
Indoor Area Required =	25	ft^2
Outdoor Area Required =	2,914	ft^2
Estimated Cr in Waste Backwash Water =	1,575	µg/L

Probable Capital Cost (2012):

Equipment =	$953,000		
Installation =	$286,000		
Building Cost =	$149,000		
Construction Activities =	$1,536,000		
Total Construction Cost =	$2,925,000		
Professional Services =	$1,031,000		
Sewer Connection Fee =	$597,000		
Mid-Range Total Capital Cost =	$4,600,000		
Probable Range of Capital Cost =	$ 3,220,000	–	$ 6,900,000

Probable Annual Operation Cost (2012):

Labor =	$35,000	/year	
Chemicals =	$49,000	/year	
Liquid Waste Disposal =	$7,000	/year	
Dewatered Sludge Disposal =	$0	/year	
Energy =	$3,000	/year	
Analytical Costs =	$14,000	/year	
Maintenance =	$24,000	/year	
Mid-Range Total Annual Cost =	$132,000	/year	
Probable Range of Annual Cost =	$92,400/yr	–	$198,000/yr

Probable Mid-Range Annualized & Water Costs:

Amoritized Capital =	$365,395	/year	
Annual O&M Cost =	$132,000	/year	
Total Annualized Cost =	$497,000	/year	
Water Cost from Capital =	$516/AF	=	$1.58/kgal
Water Cost from O&M =	$187/AF	=	$0.57/kgal
Totallized Water Cost =	$702/AF	=	$2.16/kgal

Cost of Cr(VI) Removal with the RCF Process

 www.WQTS.com

WQTS Water Quality & Treatment Solutions, Inc. An environmental engineering and science consulting company

Enter Values in Yellow Cells Only

General Information:

Water Agency:	City of Davis	
Well Name:	Well 20	
Well Capacity =	1,100	gpm
Well % Utilization =	40	%
Raw Water Cr(VI) =	42	µg/L
Potential Cr(VI) MCL =	5	µg/L
Target % of MCL =	80	%
Anticipated Treated Cr(VI) =	1.5	µg/L
Reduction Contact Time =	10	minutes
Ferrous Iron Dose =	3.0	mg/L
Design Surface Loading Rate =	3.0	gpm/sf
Anticipated Unit Filter Run Volume =	7,500	gal/sf
Anticipated Unit Filter Backwash Volume =	200	gal/sf
Percent Efficiency =	97%	
Untreated Backwash Water to Sewer (Y/N)?	yes	
Leave This Cell Blank -->		
Select Dewatered Sludge Disposal Option➔	Hazardous Waste	

Capital Financing Terms:

Amortization Period =	20	years
Interest Rate =	5.0	%

System Components:

Treatment System Capacity =	1,032	gpm
By-Pass Capacity =	68	gpm
Number of Pre-Treatment Contactors =	1	
Contactor Diameter =	10	ft
Contactor Length =	20	ft
Type of Filter Vessels =	Vertical	
Number of Vessels =	4	
Vessel Diameter =	12	ft
Days between Ferrous Truck Deliveries =	31.2	days
Annual Discharge to Sewer =	5.8	MG/year
Average Flow to Sewer During Operation =	27.5	gpm
Indoor Area Required =	25	ft^2
Outdoor Area Required =	2,914	ft^2
Estimated Cr in Waste Backwash Water =	1,575	µg/L

Probable Capital Cost (2012):

Equipment =	$953,000		
Installation =	$286,000		
Building Cost =	$149,000		
Construction Activities =	$1,536,000		
Total Construction Cost =	$2,925,000		
Professional Services =	$1,031,000		
Sewer Connection Fee =	$562,000		
Mid-Range Total Capital Cost =	$4,500,000		
Probable Range of Capital Cost =	$ 3,150,000	– $	6,750,000

Probable Annual Operation Cost (2012):

Labor =	$35,000	/year	
Chemicals =	$46,000	/year	
Liquid Waste Disposal =	$6,000	/year	
Dewatered Sludge Disposal =	$0	/year	
Energy =	$2,000	/year	
Analytical Costs =	$14,000	/year	
Maintenance =	$24,000	/year	
Mid-Range Total Annual Cost =	$127,000	/year	
Probable Range of Annual Cost =	$88,900/yr	–	$190,500/yr

Probable Mid-Range Annualized & Water Costs:

Amoritized Capital =	$362,548	/year	
Annual O&M Cost =	$127,000	/year	
Total Annualized Cost =	$490,000	/year	
Water Cost from Capital =	$512/AF	=	$1.57/kgal
Water Cost from O&M =	$179/AF	=	$0.55/kgal
Totallized Water Cost =	$693/AF	=	$2.13/kgal

Cost of Cr(VI) Removal with the RCF Process

Developed by WQTS, Inc. www.WQTS.com

WQTS Water Quality & Treatment Solutions, Inc. An environmental engineering and science consulting company

Enter Values in Yellow Cells Only

General Information:

Water Agency:	City of Davis	
Well Name:	Well 20	
Well Capacity =	1,100	gpm
Well % Utilization =	40	%
Raw Water Cr(VI) =	42	µg/L
Potential Cr(VI) MCL =	10	µg/L
Target % of MCL =	80	%
Anticipated Treated Cr(VI) =	1.5	µg/L
Reduction Contact Time =	10	minutes
Ferrous Iron Dose =	3.0	mg/L
Design Surface Loading Rate =	3.0	gpm/sf
Anticipated Unit Filter Run Volume =	7,500	gal/sf
Anticipated Unit Filter Backwash Volume =	200	gal/sf
Percent Efficiency =	97%	
Untreated Backwash Water to Sewer (Y/N)?	yes	
Leave This Cell Blank -->		
Select Dewatered Sludge Disposal Option➔	Hazardous Waste	

Capital Financing Terms:

Amortization Period =	20	years
Interest Rate =	5.0	%

System Components:

Treatment System Capacity =	923	gpm
By-Pass Capacity =	177	gpm
Number of Pre-Treatment Contactors =	1	
Contactor Diameter =	10	ft
Contactor Length =	20	ft
Type of Filter Vessels =	Vertical	
Number of Vessels =	3	
Vessel Diameter =	12	ft
Days between Ferrous Truck Deliveries =	34.9	days
Annual Discharge to Sewer =	5.2	MG/year
Average Flow to Sewer During Operation =	24.6	gpm
Indoor Area Required =	25	ft^2
Outdoor Area Required =	2,086	ft^2
Estimated Cr in Waste Backwash Water =	1,575	µg/L

Probable Capital Cost (2012):

Equipment =	$781,000		
Installation =	$234,000		
Building Cost =	$108,000		
Construction Activities =	$1,240,000		
Total Construction Cost =	$2,364,000		
Professional Services =	$834,000		
Sewer Connection Fee =	$503,000		
Mid-Range Total Capital Cost =	$3,700,000		
Probable Range of Capital Cost =	$ 2,590,000	–	$ 5,550,000

Probable Annual Operation Cost (2012):

Labor =	$35,000	/year	
Chemicals =	$41,000	/year	
Liquid Waste Disposal =	$6,000	/year	
Dewatered Sludge Disposal =	$0	/year	
Energy =	$2,000	/year	
Analytical Costs =	$12,000	/year	
Maintenance =	$19,000	/year	
Mid-Range Total Annual Cost =	$115,000	/year	
Probable Range of Annual Cost =	$80,500/yr	–	$172,500/yr

Probable Mid-Range Annualized & Water Costs:

Amoritized Capital =	$296,912	/year	
Annual O&M Cost =	$115,000	/year	
Total Annualized Cost =	$412,000	/year	
Water Cost from Capital =	$420/AF	=	$1.29/kgal
Water Cost from O&M =	$163/AF	=	$0.50/kgal
Totallized Water Cost =	$582/AF	=	$1.79/kgal

Cost of Cr(VI) Removal with the RCF Process

Developed by WQTS, Inc. www.WQTS.com

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Water Quality & Treatment Solutions, Inc.
An environmental engineering and science consulting company

Enter Values in Yellow Cells Only

General Information:		
Water Agency:	City of Davis	
Well Name:	Well 20	
Well Capacity =	1,100	gpm
Well % Utilization =	40	%
Raw Water Cr(VI) =	42	µg/L
Potential Cr(VI) MCL =	15	µg/L
Target % of MCL =	80	%
Anticipated Treated Cr(VI) =	1.5	µg/L
Reduction Contact Time =	10	minutes
Ferrous Iron Dose =	3.0	mg/L
Design Surface Loading Rate =	3.0	gpm/sf
Anticipated Unit Filter Run Volume =	7,500	gal/sf
Anticipated Unit Filter Backwash Volume =	200	gal/sf
Percent Efficiency =	97%	
Untreated Backwash Water to Sewer (Y/N)?	yes	
Leave This Cell Blank -->		
Select Dewatered Sludge Disposal Option➔	Hazardous Waste	
Capital Financing Terms:		
Amortization Period =	20	years
Interest Rate =	5.0	%

System Components:		
Treatment System Capacity =	815	gpm
By-Pass Capacity =	285	gpm
Number of Pre-Treatment Contactors =	1	
Contactor Diameter =	10	ft
Contactor Length =	20	ft
Type of Filter Vessels =	Vertical	
Number of Vessels =	3	
Vessel Diameter =	12	ft
Days between Ferrous Truck Deliveries =	39.5	days
Annual Discharge to Sewer =	4.6	MG/year
Average Flow to Sewer During Operation =	21.7	gpm
Indoor Area Required =	25	ft^2
Outdoor Area Required =	2,086	ft^2
Estimated Cr in Waste Backwash Water =	1,575	µg/L

Probable Capital Cost (2012):			
Equipment =	$781,000		
Installation =	$234,000		
Building Cost =	$108,000		
Construction Activities =	$1,240,000		
Total Construction Cost =	$2,364,000		
Professional Services =	$834,000		
Sewer Connection Fee =	$443,000		
Mid-Range Total Capital Cost =	$3,600,000		
Probable Range of Capital Cost =	$ 2,520,000	– $	5,400,000
Probable Annual Operation Cost (2012):			
Labor =	$35,000	/year	
Chemicals =	$37,000	/year	
Liquid Waste Disposal =	$5,000	/year	
Dewatered Sludge Disposal =	$0	/year	
Energy =	$2,000	/year	
Analytical Costs =	$12,000	/year	
Maintenance =	$19,000	/year	
Mid-Range Total Annual Cost =	$110,000	/year	
Probable Range of Annual Cost =	$77,000/yr	–	$165,000/yr
Probable Mid-Range Annualized & Water Costs:			
Amoritized Capital =	$292,167	/year	
Annual O&M Cost =	$110,000	/year	
Total Annualized Cost =	$402,000	/year	
Water Cost from Capital =	$413/AF	=	$1.27/kgal
Water Cost from O&M =	$155/AF	=	$0.48/kgal
Totallized Water Cost =	$568/AF	=	$1.74/kgal

Cost of Cr(VI) Removal with the RCF Process

 www.WQTS.com

Water Quality & Treatment Solutions, Inc.
An environmental engineering and science consulting company

Enter Values in Yellow Cells Only

General Information:

Water Agency:	City of Davis	
Well Name:	Well 20	
Well Capacity =	1,100	gpm
Well % Utilization =	40	%
Raw Water Cr(VI) =	42	µg/L
Potential Cr(VI) MCL =	20	µg/L
Target % of MCL =	80	%
Anticipated Treated Cr(VI) =	1.5	µg/L
Reduction Contact Time =	10	minutes
Ferrous Iron Dose =	3.0	mg/L
Design Surface Loading Rate =	3.0	gpm/sf
Anticipated Unit Filter Run Volume =	7,500	gal/sf
Anticipated Unit Filter Backwash Volume =	200	gal/sf
Percent Efficiency =	97%	
Untreated Backwash Water to Sewer (Y/N)?	yes	
Leave This Cell Blank -->		
Select Dewatered Sludge Disposal Option➔	Hazardous Waste	

Capital Financing Terms:

Amortization Period =	20	years
Interest Rate =	5.0	%

System Components:

Treatment System Capacity =	706 gpm
By-Pass Capacity =	394 gpm
Number of Pre-Treatment Contactors =	1
Contactor Diameter =	8 ft
Contactor Length =	20 ft
Type of Filter Vessels =	Vertical
Number of Vessels =	3
Vessel Diameter =	10 ft
Days between Ferrous Truck Deliveries =	45.6 days
Annual Discharge to Sewer =	4.0 MG/year
Average Flow to Sewer During Operation =	18.8 gpm
Indoor Area Required =	25 ft^2
Outdoor Area Required =	1,650 ft^2
Estimated Cr in Waste Backwash Water =	1,575 µg/L

Probable Capital Cost (2012):

Equipment =	$618,000		
Installation =	$185,000		
Building Cost =	$86,000		
Construction Activities =	$980,000		
Total Construction Cost =	$1,869,000		
Professional Services =	$660,000		
Sewer Connection Fee =	$384,000		
Mid-Range Total Capital Cost =	$2,900,000		
Probable Range of Capital Cost =	$ 2,030,000	–	$ 4,350,000
Probable Annual Operation Cost (2012):			
Labor =	$35,000	/year	
Chemicals =	$32,000	/year	
Liquid Waste Disposal =	$4,000	/year	
Dewatered Sludge Disposal =	$0	/year	
Energy =	$2,000	/year	
Analytical Costs =	$12,000	/year	
Maintenance =	$15,000	/year	
Mid-Range Total Annual Cost =	$100,000	/year	
Probable Range of Annual Cost =	$70,000/yr	–	$150,000/yr
Probable Mid-Range Annualized & Water Costs:			
Amoritized Capital =	$233,783	/year	
Annual O&M Cost =	$100,000	/year	
Total Annualized Cost =	$334,000	/year	
Water Cost from Capital =	$330/AF	=	$1.01/kgal
Water Cost from O&M =	$141/AF	=	$0.43/kgal
Totallized Water Cost =	$472/AF	=	$1.45/kgal

Cost of Cr(VI) Removal with the RCF Process

 www.WQTS.com

Enter Values in Yellow Cells Only

WQTS Water Quality & Treatment Solutions, Inc. An environmental engineering and science consulting company

General Information:

Water Agency:	City of Davis	
Well Name:	Well 20	
Well Capacity =	1,100	gpm
Well % Utilization =	40	%
Raw Water Cr(VI) =	42	μg/L
Potential Cr(VI) MCL =	2	μg/L
Target % of MCL =	80	%
Anticipated Treated Cr(VI) =	1.5	μg/L
Reduction Contact Time =	10	minutes
Ferrous Iron Dose =	3.0	mg/L
Design Surface Loading Rate =	3.0	gpm/sf
Anticipated Unit Filter Run Volume =	7,500	gal/sf
Anticipated Unit Filter Backwash Volume =	200	gal/sf
Percent Efficiency =	97%	
Untreated Backwash Water to Sewer (Y/N)?	no	
Clarified Backwash Water to Sewer (Yes/No)?	no	
Select Dewatered Sludge Disposal Option➔	Hazardous Waste	

Capital Financing Terms:

Amortization Period =	20	years
Interest Rate =	5.0	%

System Components:

Treatment System Capacity =	1,097	gpm
By-Pass Capacity =	3	gpm
Number of Pre-Treatment Contactors =	1	
Contactor Diameter =	10	ft
Contactor Length =	20	ft
Type of Filter Vessels =	Vertical	
Number of Vessels =	4	
Vessel Diameter =	12	ft
Days between Ferrous Truck Deliveries =	29.4	days
Annual Discharge to Sewer =	NA	MG/year
Average Flow to Sewer During Operation =	NA	gpm
Indoor Area Required =	329	ft^2
Outdoor Area Required =	3,686	ft^2
Estimated Cr in Waste Backwash Water =	1,575	μg/L

Probable Capital Cost (2012):

Equipment =	$1,226,000		
Installation =	$368,000		
Building Cost =	$234,000		
Construction Activities =	$2,012,000		
Total Construction Cost =	$3,839,000		
Professional Services =	$1,357,000		
Sewer Connection Fee =	$0		
Mid-Range Total Capital Cost =	$5,200,000		
Probable Range of Capital Cost =	$ 3,640,000	– $	7,800,000

Probable Annual Operation Cost (2012):

Labor =	$55,000	/year	
Chemicals =	$49,000	/year	
Liquid Waste Disposal =	$0	/year	
Dewatered Sludge Disposal =	$55,000	/year	
Energy =	$3,000	/year	
Analytical Costs =	$19,000	/year	
Maintenance =	$31,000	/year	
Mid-Range Total Annual Cost =	$212,000	/year	
Probable Range of Annual Cost =	$148,400/yr	–	$318,000/yr

Probable Mid-Range Annualized & Water Costs:

Amoritized Capital =	$416,884	/year	
Annual O&M Cost =	$212,000	/year	
Total Annualized Cost =	$629,000	/year	
Water Cost from Capital =	$589/AF	=	$1.81/kgal
Water Cost from O&M =	$300/AF	=	$0.92/kgal
Totallized Water Cost =	$889/AF	=	$2.73/kgal

Cost of Cr(VI) Removal with the RCF Process

Developed by WQTS, Inc. www.WQTS.com

Enter Values in Yellow Cells Only

WQTS Water Quality & Treatment Solutions, Inc. An environmental engineering and science consulting company

General Information:		
Water Agency:	City of Davis	
Well Name:	Well 20	
Well Capacity =	1,100	gpm
Well % Utilization =	40	%
Raw Water Cr(VI) =	42	µg/L
Potential Cr(VI) MCL =	5	µg/L
Target % of MCL =	80	%
Anticipated Treated Cr(VI) =	1.5	µg/L
Reduction Contact Time =	10	minutes
Ferrous Iron Dose =	3.0	mg/L
Design Surface Loading Rate =	3.0	gpm/sf
Anticipated Unit Filter Run Volume =	7,500	gal/sf
Anticipated Unit Filter Backwash Volume =	200	gal/sf
Percent Efficiency =	97%	
Untreated Backwash Water to Sewer (Y/N)?	no	
Clarified Backwash Water to Sewer (Yes/No)?	no	
Select Dewatered Sludge Disposal Option➔	Hazardous Waste	
Capital Financing Terms:		
Amortization Period =	20	years
Interest Rate =	5.0	%

System Components:		
Treatment System Capacity =	1,032	gpm
By-Pass Capacity =	68	gpm
Number of Pre-Treatment Contactors =	1	
Contactor Diameter =	10	ft
Contactor Length =	20	ft
Type of Filter Vessels =	Vertical	
Number of Vessels =	4	
Vessel Diameter =	12	ft
Days between Ferrous Truck Deliveries =	31.2	days
Annual Discharge to Sewer =	NA	MG/year
Average Flow to Sewer During Operation =	NA	gpm
Indoor Area Required =	329	ft^2
Outdoor Area Required =	3,686	ft^2
Estimated Cr in Waste Backwash Water =	1,575	µg/L

Probable Capital Cost (2012):				
Equipment =	$1,226,000			
Installation =	$368,000			
Building Cost =	$234,000			
Construction Activities =	$2,012,000			
Total Construction Cost =	$3,839,000			
Professional Services =	$1,357,000			
Sewer Connection Fee =	$0			
Mid-Range Total Capital Cost =	$5,200,000			
Probable Range of Capital Cost =	$ 3,640,000	–	$	7,800,000
Probable Annual Operation Cost (2012):				
Labor =	$55,000	/year		
Chemicals =	$46,000	/year		
Liquid Waste Disposal =	$0	/year		
Dewatered Sludge Disposal =	$52,000	/year		
Energy =	$2,000	/year		
Analytical Costs =	$19,000	/year		
Maintenance =	$31,000	/year		
Mid-Range Total Annual Cost =	$205,000	/year		
Probable Range of Annual Cost =	$143,500/yr	–		$307,500/yr
Probable Mid-Range Annualized & Water Costs:				
Amoritized Capital =	$416,884	/year		
Annual O&M Cost =	$205,000	/year		
Total Annualized Cost =	$622,000	/year		
Water Cost from Capital =	$589/AF	=		$1.81/kgal
Water Cost from O&M =	$290/AF	=		$0.89/kgal
Totallized Water Cost =	$879/AF	=		$2.70/kgal

Cost of Cr(VI) Removal with the RCF Process

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WQTS Water Quality & Treatment Solutions, Inc. An environmental engineering and science consulting company

Enter Values in Yellow Cells Only

General Information:

Water Agency:	City of Davis	
Well Name:	Well 20	
Well Capacity =	1,100	gpm
Well % Utilization =	40	%
Raw Water Cr(VI) =	42	µg/L
Potential Cr(VI) MCL =	10	µg/L
Target % of MCL =	80	%
Anticipated Treated Cr(VI) =	1.5	µg/L
Reduction Contact Time =	10	minutes
Ferrous Iron Dose =	3.0	mg/L
Design Surface Loading Rate =	3.0	gpm/sf
Anticipated Unit Filter Run Volume =	7,500	gal/sf
Anticipated Unit Filter Backwash Volume =	200	gal/sf
Percent Efficiency =	97%	
Untreated Backwash Water to Sewer (Y/N)?	no	
Clarified Backwash Water to Sewer (Yes/No)?	no	
Select Dewatered Sludge Disposal Option➔	Hazardous Waste	

Capital Financing Terms:

Amortization Period =	20	years
Interest Rate =	5.0	%

System Components:

Treatment System Capacity =	923	gpm
By-Pass Capacity =	177	gpm
Number of Pre-Treatment Contactors =	1	
Contactor Diameter =	10	ft
Contactor Length =	20	ft
Type of Filter Vessels =	Vertical	
Number of Vessels =	3	
Vessel Diameter =	12	ft
Days between Ferrous Truck Deliveries =	34.9	days
Annual Discharge to Sewer =	NA	MG/year
Average Flow to Sewer During Operation =	NA	gpm
Indoor Area Required =	329	ft^2
Outdoor Area Required =	2,858	ft^2
Estimated Cr in Waste Backwash Water =	1,575	µg/L

Probable Capital Cost (2012):

Equipment =	$1,053,000		
Installation =	$316,000		
Building Cost =	$192,000		
Construction Activities =	$1,716,000		
Total Construction Cost =	$3,277,000		
Professional Services =	$1,159,000		
Sewer Connection Fee =	$0		
Mid-Range Total Capital Cost =	$4,400,000		
Probable Range of Capital Cost =	$ 3,080,000	–	$ 6,600,000

Probable Annual Operation Cost (2012):

Labor =	$55,000	/year	
Chemicals =	$41,000	/year	
Liquid Waste Disposal =	$0	/year	
Dewatered Sludge Disposal =	$46,000	/year	
Energy =	$2,000	/year	
Analytical Costs =	$17,000	/year	
Maintenance =	$26,000	/year	
Mid-Range Total Annual Cost =	$187,000	/year	
Probable Range of Annual Cost =	$130,900/yr	–	$280,500/yr

Probable Mid-Range Annualized & Water Costs:

Amoritized Capital =	$355,992	/year	
Annual O&M Cost =	$187,000	/year	
Total Annualized Cost =	$543,000	/year	
Water Cost from Capital =	$503/AF	=	$1.54/kgal
Water Cost from O&M =	$264/AF	=	$0.81/kgal
Totallized Water Cost =	$767/AF	=	$2.36/kgal

Cost of Cr(VI) Removal with the RCF Process

Developed by WQTS, Inc. www.WQTS.com

WQTS Water Quality & Treatment Solutions, Inc. An environmental engineering and science consulting company

Enter Values in Yellow Cells Only

General Information:

Water Agency:	City of Davis	
Well Name:	Well 20	
Well Capacity =	1,100	gpm
Well % Utilization =	40	%
Raw Water Cr(VI) =	42	µg/L
Potential Cr(VI) MCL =	15	µg/L
Target % of MCL =	80	%
Anticipated Treated Cr(VI) =	1.5	µg/L
Reduction Contact Time =	10	minutes
Ferrous Iron Dose =	3.0	mg/L
Design Surface Loading Rate =	3.0	gpm/sf
Anticipated Unit Filter Run Volume =	7,500	gal/sf
Anticipated Unit Filter Backwash Volume =	200	gal/sf
Percent Efficiency =	97%	
Untreated Backwash Water to Sewer (Y/N)?	no	
Clarified Backwash Water to Sewer (Yes/No)?	no	
Select Dewatered Sludge Disposal Option➔	Hazardous Waste	

Capital Financing Terms:

Amortization Period =	20	years
Interest Rate =	5.0	%

System Components:

Treatment System Capacity =	815	gpm
By-Pass Capacity =	285	gpm
Number of Pre-Treatment Contactors =	1	
Contactor Diameter =	10	ft
Contactor Length =	20	ft
Type of Filter Vessels =	Vertical	
Number of Vessels =	3	
Vessel Diameter =	12	ft
Days between Ferrous Truck Deliveries =	39.5	days
Annual Discharge to Sewer =	NA	MG/year
Average Flow to Sewer During Operation =	NA	gpm
Indoor Area Required =	329	ft^2
Outdoor Area Required =	2,806	ft^2
Estimated Cr in Waste Backwash Water =	1,575	µg/L

Probable Capital Cost (2012):

Equipment =	$1,046,000		
Installation =	$314,000		
Building Cost =	$190,000		
Construction Activities =	$1,703,000		
Total Construction Cost =	$3,253,000		
Professional Services =	$1,151,000		
Sewer Connection Fee =	$0		
Mid-Range Total Capital Cost =	$4,400,000		
Probable Range of Capital Cost =	$ 3,080,000	–	$ 6,600,000

Probable Annual Operation Cost (2012):

Labor =	$55,000	/year	
Chemicals =	$37,000	/year	
Liquid Waste Disposal =	$0	/year	
Dewatered Sludge Disposal =	$41,000	/year	
Energy =	$2,000	/year	
Analytical Costs =	$17,000	/year	
Maintenance =	$26,000	/year	
Mid-Range Total Annual Cost =	$178,000	/year	
Probable Range of Annual Cost =	$124,600/yr	–	$267,000/yr

Probable Mid-Range Annualized & Water Costs:

Amoritized Capital =	$353,367	/year	
Annual O&M Cost =	$178,000	/year	
Total Annualized Cost =	$531,000	/year	
Water Cost from Capital =	$499/AF	=	$1.53/kgal
Water Cost from O&M =	$252/AF	=	$0.77/kgal
Totallized Water Cost =	$750/AF	=	$2.30/kgal

Cost of Cr(VI) Removal with the RCF Process

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WQTS Water Quality & Treatment Solutions, Inc. An environmental engineering and science consulting company

Enter Values in Yellow Cells Only

General Information:

Water Agency:	City of Davis	
Well Name:	Well 20	
Well Capacity =	1,100	gpm
Well % Utilization =	40	%
Raw Water Cr(VI) =	42	µg/L
Potential Cr(VI) MCL =	20	µg/L
Target % of MCL =	80	%
Anticipated Treated Cr(VI) =	1.5	µg/L
Reduction Contact Time =	10	minutes
Ferrous Iron Dose =	3.0	mg/L
Design Surface Loading Rate =	3.0	gpm/sf
Anticipated Unit Filter Run Volume =	7,500	gal/sf
Anticipated Unit Filter Backwash Volume =	200	gal/sf
Percent Efficiency =	97%	
Untreated Backwash Water to Sewer (Y/N)?	no	
Clarified Backwash Water to Sewer (Yes/No)?	no	
Select Dewatered Sludge Disposal Option➔	Hazardous Waste	

Capital Financing Terms:

Amortization Period =	20	years
Interest Rate =	5.0	%

System Components:

Treatment System Capacity =	706	gpm
By-Pass Capacity =	394	gpm
Number of Pre-Treatment Contactors =	1	
Contactor Diameter =	8	ft
Contactor Length =	20	ft
Type of Filter Vessels =	Vertical	
Number of Vessels =	3	
Vessel Diameter =	10	ft
Days between Ferrous Truck Deliveries =	45.6	days
Annual Discharge to Sewer =	NA	MG/year
Average Flow to Sewer During Operation =	NA	gpm
Indoor Area Required =	304	ft^2
Outdoor Area Required =	2,175	ft^2
Estimated Cr in Waste Backwash Water =	1,575	µg/L

Probable Capital Cost (2012):

Equipment =	$829,000			
Installation =	$249,000			
Building Cost =	$154,000			
Construction Activities =	$1,352,000			
Total Construction Cost =	$2,584,000			
Professional Services =	$915,000			
Sewer Connection Fee =	$0			
Mid-Range Total Capital Cost =	$3,500,000			
Probable Range of Capital Cost =	$ 2,450,000	–	$	5,250,000

Probable Annual Operation Cost (2012):

Labor =	$55,000	/year	
Chemicals =	$32,000	/year	
Liquid Waste Disposal =	$0	/year	
Dewatered Sludge Disposal =	$35,000	/year	
Energy =	$2,000	/year	
Analytical Costs =	$17,000	/year	
Maintenance =	$21,000	/year	
Mid-Range Total Annual Cost =	$162,000	/year	
Probable Range of Annual Cost =	$113,400/yr	–	$243,000/yr

Probable Mid-Range Annualized & Water Costs:

Amoritized Capital =	$280,785	/year	
Annual O&M Cost =	$162,000	/year	
Total Annualized Cost =	$443,000	/year	
Water Cost from Capital =	$397/AF	=	$1.22/kgal
Water Cost from O&M =	$229/AF	=	$0.70/kgal
Totallized Water Cost =	$626/AF	=	$1.92/kgal

Cost of Cr(VI) Removal with WBA Resin

WQTS Water Quality & Treatment Solutions, Inc. An environmental engineering and science consulting company

Enter Values in Yellow Cells Only

Enter Known Information:

Water Agency:	City of Davis	
Well Name:	Well 20	
Well Capacity =	1,100	gpm
Well % Utilization =	40	%
Raw Water Cr(VI) =	42	μg/L
Potential Cr(VI) MCL =	2	μg/L
Target % of MCL =	80	%
Anticipated Treated Cr(VI) =	1.5	μg/L
Raw Water pH =	8.2	
Raw Water Alkalinity =	438	mg/L $CaCO_3$
Raw Water Conductivity =	952	μS/cm
Raw Water TDS =	638	mg/L
Raw Water Temp. =	20	°C
Raw Water Uranium =	2.8	μg/L
Design EBCT (Lead-Lag) =	6.0	minutes
BVs to Resin Replacement =	90,000	BVs
(if you don't know the above value, leave it blank)		
Projected BVs to Resin Replacement =	90,000	BVs
Select Waste Resin Disposal Option ➔	TENORM Waste	
Select pH Adjustment Method ➔	CO2, then Air-stripping	
Target Water pH at WBA Inlet =	6.0	
Target Adjusted pH =	8.0	
Target Effluent Pressure =	50	psi
Capital Amortization Period =	20	years
Capital Amortization Interest Rate =	5	%

System Components:

Treatment System Capacity =	1,097	gpm
By-Pass Capacity =	3	gpm
CO2 Dose =	801	mg/L
CO2 Max. Usage Rate =	10,559	ppd
Days bewteen CO2 Truck Deliveries =	4.2	days
Booster Pump & Blower HP =	128	HP
Days between NaOH Truck Deliveries =	NA	days
Number of Vessels =	4	
Vessel Configuration =	Vertical	
Vessel Diameter =	10	ft
Horizontal Vessel Length =	NA	ft
Total Volume of Resin =	942	ft^3
Annual Average Flowrate =	439	gpm
Months between Resin Changeout =	33	months
Resin Replaced/year =	338	ft^3
Uranium Load on Spent Resin =	0.042%	
Indoor Area Required =	1,103	ft^2
Outdoor Area Required =	3,257	ft^2

Probable Capital Cost (2012):

Equipment =	$	1,305,000		
Installation =	$	392,000		
Building Cost =	$	328,000		
Construction Activities =	$	2,726,000		
Total Construction Cost =	$	4,751,000		
Professional Services =	$	1,504,000		
Mid-Range Total Capital Cost =	$	6,300,000		
Probable Range of Capital Cost =		$4,400,000	–	$9,500,000

Probable Annual Operation Cost (2012):

Labor =	$	35,000	/yr	
Chemicals =	$	92,000	/yr	
Resin Replacement =	$	199,000	/yr	
Resin Disposal =	$	110,000	/yr	
Energy =	$	53,000	/yr	
Analytical Costs =	$	11,000	/yr	
Maintenance =	$	29,000	/yr	
Mid-Range Total Annual Cost =	$	530,000	/yr	
Probable Range of Annual Cost =		$370,000/yr	–	$800,000/yr

Probable Mid-Range Annualized & Water Costs:

Amoritized Capital =	$	506,000	/yr			
Annual O&M Cost =	$	530,000	/yr			
Total Annualized Cost =	$	1,036,000	/yr			
Water Cost from Capital =	$	715	/AF	=	$	2.19 /kgal
Water Cost from O&M =	$	749	/AF	=	$	2.30 /kgal
Totallized Water Cost =	$	1,464	/AF	=	$	4.49 /kgal

Cost of Cr(VI) Removal with WBA Resin

 www.WQTS.com

Enter Values in Yellow Cells Only

Enter Known Information:

Water Agency:	City of Davis	
Well Name:	Well 20	
Well Capacity =	1,100	gpm
Well % Utilization =	40	%
Raw Water Cr(VI) =	42	μg/L
Potential Cr(VI) MCL =	5	μg/L
Target % of MCL =	80	%
Anticipated Treated Cr(VI) =	1.5	μg/L
Raw Water pH =	8.2	
Raw Water Alkalinity =	438	mg/L $CaCO_3$
Raw Water Conductivity =	952	μS/cm
Raw Water TDS =	638	mg/L
Raw Water Temp. =	20	°C
Raw Water Uranium =	2.8	μg/L
Design EBCT (Lead-Lag) =	6.0	minutes
BVs to Resin Replacement =	90,000	BVs
(if you don't know the above value, leave it blank)		
Projected BVs to Resin Replacement =	90,000	BVs
Select Waste Resin Disposal Option ➔	TENORM Waste	
Select pH Adjustment Method ➔	CO2, then Air-stripping	
Target Water pH at WBA Inlet =	6.0	
Target Adjusted pH =	8.0	
Target Effluent Pressure =	50	psi
Capital Amortization Period =	20	years
Capital Amortization Interest Rate =	5	%

System Components:

Treatment System Capacity =	1,032	gpm
By-Pass Capacity =	68	gpm
CO2 Dose =	801	mg/L
CO2 Max. Usage Rate =	9,931	ppd
Days bewteen CO2 Truck Deliveries =	4.4	days
Booster Pump & Blower HP =	86	HP
Days between NaOH Truck Deliveries =	NA	days
Number of Vessels =	4	
Vessel Configuration =	Vertical	
Vessel Diameter =	10	ft
Horizontal Vessel Length =	NA	ft
Total Volume of Resin =	942	ft^3
Annual Average Flowrate =	413	gpm
Months between Resin Changeout =	36	months
Resin Replaced/year =	318	ft^3
Uranium Load on Spent Resin =	0.042%	
Indoor Area Required =	603	ft^2
Outdoor Area Required =	3,257	ft^2

Probable Capital Cost (2012):

Equipment =	$	1,185,000		
Installation =	$	355,000		
Building Cost =	$	253,000		
Construction Activities =	$	2,475,000		
Total Construction Cost =	$	4,268,000		
Professional Services =	$	1,332,000		
Mid-Range Total Capital Cost =	$	5,600,000		
Probable Range of Capital Cost =		$3,900,000	–	$8,400,000

Probable Annual Operation Cost (2012):

Labor =	$	35,000	/yr	
Chemicals =	$	87,000	/yr	
Resin Replacement =	$	187,000	/yr	
Resin Disposal =	$	104,000	/yr	
Energy =	$	36,000	/yr	
Analytical Costs =	$	11,000	/yr	
Maintenance =	$	26,000	/yr	
Mid-Range Total Annual Cost =	$	490,000	/yr	
Probable Range of Annual Cost =		$340,000/yr	–	$740,000/yr

Probable Mid-Range Annualized & Water Costs:

Amoritized Capital =	$	449,000	/yr			
Annual O&M Cost =	$	490,000	/yr			
Total Annualized Cost =	$	939,000	/yr			
Water Cost from Capital =	$	635	/AF	=	$	1.95 /kgal
Water Cost from O&M =	$	693	/AF	=	$	2.13 /kgal
Totallized Water Cost =	$	1,327	/AF	=	$	4.07 /kgal

Cost of Cr(VI) Removal with WBA Resin

WQTS Water Quality & Treatment Solutions, Inc. An environmental engineering and science consulting company

Enter Values in Yellow Cells Only

Enter Known Information:

Water Agency:	City of Davis	
Well Name:	Well 20	
Well Capacity =	1,100	gpm
Well % Utilization =	40	%
Raw Water Cr(VI) =	42	µg/L
Potential Cr(VI) MCL =	10	µg/L
Target % of MCL =	80	%
Anticipated Treated Cr(VI) =	1.5	µg/L
Raw Water pH =	8.2	
Raw Water Alkalinity =	438	mg/L $CaCO_3$
Raw Water Conductivity =	952	µS/cm
Raw Water TDS =	638	mg/L
Raw Water Temp. =	20	°C
Raw Water Uranium =	2.8	µg/L
Design EBCT (Lead-Lag) =	6.0	minutes
BVs to Resin Replacement =	90,000	BVs
(if you don't know the above value, leave it blank)		
Projected BVs to Resin Replacement =	90,000	BVs
Select Waste Resin Disposal Option →	TENORM Waste	
Select pH Adjustment Method →	CO2, then Air-stripping	
Target Water pH at WBA Inlet =	6.0	
Target Adjusted pH =	8.0	
Target Effluent Pressure =	50	psi
Capital Amortization Period =	20	years
Capital Amortization Interest Rate =	5	%

System Components:

Treatment System Capacity =	923	gpm
By-Pass Capacity =	177	gpm
CO2 Dose =	801	mg/L
CO2 Max. Usage Rate =	8,886	ppd
Days bewteen CO2 Truck Deliveries =	5.0	days
Booster Pump & Blower HP =	86	HP
Days between NaOH Truck Deliveries =	NA	days
Number of Vessels =	4	
Vessel Configuration =	Vertical	
Vessel Diameter =	10	ft
Horizontal Vessel Length =	NA	ft
Total Volume of Resin =	942	ft^3
Annual Average Flowrate =	369	gpm
Months between Resin Changeout =	40	months
Resin Replaced/year =	284	ft^3
Uranium Load on Spent Resin =	0.042%	
Indoor Area Required =	593	ft^2
Outdoor Area Required =	3,257	ft^2

Probable Capital Cost (2012):

Equipment =	$	1,173,000		
Installation =	$	352,000		
Building Cost =	$	252,000		
Construction Activities =	$	2,457,000		
Total Construction Cost =	$	4,234,000		
Professional Services =	$	1,320,000		
Mid-Range Total Capital Cost =	$	5,600,000		
Probable Range of Capital Cost =		$3,900,000	–	$8,400,000

Probable Annual Operation Cost (2012):

Labor =	$	35,000	/yr	
Chemicals =	$	78,000	/yr	
Resin Replacement =	$	167,000	/yr	
Resin Disposal =	$	93,000	/yr	
Energy =	$	36,000	/yr	
Analytical Costs =	$	11,000	/yr	
Maintenance =	$	25,000	/yr	
Mid-Range Total Annual Cost =	$	450,000	/yr	
Probable Range of Annual Cost =		$320,000/yr	–	$680,000/yr

Probable Mid-Range Annualized & Water Costs:

Amoritized Capital =	$	449,000	/yr			
Annual O&M Cost =	$	450,000	/yr			
Total Annualized Cost =	$	899,000	/yr			
Water Cost from Capital =	$	635	/AF	=	$	1.95 /kgal
Water Cost from O&M =	$	636	/AF	=	$	1.95 /kgal
Totallized Water Cost =	$	1,271	/AF	=	$	3.90 /kgal

Cost of Cr(VI) Removal with WBA Resin

 www.WQTS.com

WQTS Water Quality & Treatment Solutions, Inc. An environmental engineering and science consulting company

Enter Values in Yellow Cells Only

Enter Known Information:

Water Agency:	City of Davis	
Well Name:	Well 20	
Well Capacity =	1,100	gpm
Well % Utilization =	40	%
Raw Water Cr(VI) =	42	µg/L
Potential Cr(VI) MCL =	15	µg/L
Target % of MCL =	80	%
Anticipated Treated Cr(VI) =	1.5	µg/L
Raw Water pH =	8.2	
Raw Water Alkalinity =	438	mg/L $CaCO_3$
Raw Water Conductivity =	952	µS/cm
Raw Water TDS =	638	mg/L
Raw Water Temp. =	20	°C
Raw Water Uranium =	2.8	µg/L
Design EBCT (Lead-Lag) =	6.0	minutes
BVs to Resin Replacement =	90,000	BVs
(if you don't know the above value, leave it blank)		
Projected BVs to Resin Replacement =	90,000	BVs
Select Waste Resin Disposal Option →	TENORM Waste	
Select pH Adjustment Method →	CO2, then Air-stripping	
Target Water pH at WBA Inlet =	6.0	
Target Adjusted pH =	8.0	
Target Effluent Pressure =	50	psi
Capital Amortization Period =	20	years
Capital Amortization Interest Rate =	5	%

System Components:

Treatment System Capacity =	815	gpm
By-Pass Capacity =	285	gpm
CO2 Dose =	801	mg/L
CO2 Max. Usage Rate =	7,841	ppd
Days bewteen CO2 Truck Deliveries =	5.6	days
Booster Pump & Blower HP =	86	HP
Days between NaOH Truck Deliveries =	NA	days
Number of Vessels =	2	
Vessel Configuration =	Vertical	
Vessel Diameter =	12	ft
Horizontal Vessel Length =	NA	ft
Total Volume of Resin =	679	ft^3
Annual Average Flowrate =	326	gpm
Months between Resin Changeout =	32	months
Resin Replaced/year =	251	ft^3
Uranium Load on Spent Resin =	0.042%	
Indoor Area Required =	593	ft^2
Outdoor Area Required =	2,445	ft^2

Probable Capital Cost (2012):

Equipment =	$	978,000				
Installation =	$	293,000				
Building Cost =	$	211,000				
Construction Activities =	$	1,988,000				
Total Construction Cost =	$	3,470,000				
Professional Services =	$	1,100,000				
Mid-Range Total Capital Cost =	$	4,600,000				
Probable Range of Capital Cost =		$3,200,000	–	$6,900,000		
Probable Annual Operation Cost (2012):						
Labor =	$	35,000	/yr			
Chemicals =	$	69,000	/yr			
Resin Replacement =	$	147,000	/yr			
Resin Disposal =	$	82,000	/yr			
Energy =	$	35,000	/yr			
Analytical Costs =	$	10,000	/yr			
Maintenance =	$	21,000	/yr			
Mid-Range Total Annual Cost =	$	400,000	/yr			
Probable Range of Annual Cost =		$280,000/yr	–	$600,000/yr		
Probable Mid-Range Annualized & Water Costs:						
Amoritized Capital =	$	369,000	/yr			
Annual O&M Cost =	$	400,000	/yr			
Total Annualized Cost =	$	769,000	/yr			
Water Cost from Capital =	$	522 /AF	=	$	1.60	/kgal
Water Cost from O&M =	$	565 /AF	=	$	1.73	/kgal
Totallized Water Cost =	$	1,087 /AF	=	$	3.34	/kgal

Cost of Cr(VI) Removal with WBA Resin

WQTS Water Quality & Treatment Solutions, Inc. An environmental engineering and science consulting company

Enter Values in Yellow Cells Only

Enter Known Information:

Water Agency:	City of Davis	
Well Name:	Well 20	
Well Capacity =	1,100	gpm
Well % Utilization =	40	%
Raw Water Cr(VI) =	42	µg/L
Potential Cr(VI) MCL =	20	µg/L
Target % of MCL =	80	%
Anticipated Treated Cr(VI) =	1.5	µg/L
Raw Water pH =	8.2	
Raw Water Alkalinity =	438	mg/L $CaCO_3$
Raw Water Conductivity =	952	µS/cm
Raw Water TDS =	638	mg/L
Raw Water Temp. =	20	°C
Raw Water Uranium =	2.8	µg/L
Design EBCT (Lead-Lag) =	6.0	minutes
BVs to Resin Replacement =	90,000	BVs
(if you don't know the above value, leave it blank)		
Projected BVs to Resin Replacement =	90,000	BVs
Select Waste Resin Disposal Option →	TENORM Waste	
Select pH Adjustment Method →	CO2, then Air-stripping	
Target Water pH at WBA Inlet =	6.0	
Target Adjusted pH =	8.0	
Target Effluent Pressure =	50	psi
Capital Amortization Period =	20	years
Capital Amortization Interest Rate =	5	%

System Components:

Treatment System Capacity =	706	gpm
By-Pass Capacity =	394	gpm
CO2 Dose =	801	mg/L
CO2 Max. Usage Rate =	6,795	ppd
Days bewteen CO2 Truck Deliveries =	6.5	days
Booster Pump & Blower HP =	86	HP
Days between NaOH Truck Deliveries =	NA	days
Number of Vessels =	2	
Vessel Configuration =	Vertical	
Vessel Diameter =	12	ft
Horizontal Vessel Length =	NA	ft
Total Volume of Resin =	679	ft^3
Annual Average Flowrate =	282	gpm
Months between Resin Changeout =	37	months
Resin Replaced/year =	218	ft^3
Uranium Load on Spent Resin =	0.042%	
Indoor Area Required =	593	ft^2
Outdoor Area Required =	2,445	ft^2

Probable Capital Cost (2012):

Equipment =	$	978,000		
Installation =	$	293,000		
Building Cost =	$	211,000		
Construction Activities =	$	1,988,000		
Total Construction Cost =	$	3,470,000		
Professional Services =	$	1,100,000		
Mid-Range Total Capital Cost =	$	4,600,000		
Probable Range of Capital Cost =		$3,200,000	–	$6,900,000

Probable Annual Operation Cost (2012):

Labor =	$	35,000	/yr	
Chemicals =	$	60,000	/yr	
Resin Replacement =	$	128,000	/yr	
Resin Disposal =	$	71,000	/yr	
Energy =	$	35,000	/yr	
Analytical Costs =	$	10,000	/yr	
Maintenance =	$	21,000	/yr	
Mid-Range Total Annual Cost =	$	360,000	/yr	
Probable Range of Annual Cost =		$250,000/yr	–	$540,000/yr

Probable Mid-Range Annualized & Water Costs:

Amoritized Capital =	$	369,000	/yr		
Annual O&M Cost =	$	360,000	/yr		
Total Annualized Cost =	$	729,000	/yr		
Water Cost from Capital =	$	522 /AF	=	$	1.60 /kgal
Water Cost from O&M =	$	509 /AF	=	$	1.56 /kgal
Totallized Water Cost =	$	1,030 /AF	=	$	3.16 /kgal

Appendix XIII

Association of California Water Agencies Newsletter,
Volume 41, No. 4, April 19, 2013

Association of California Water Agencies
Since 1910
ACWA
Leadership • Advocacy
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ACWA NEWS

ACWA's • Member • Newsletter

VOLUME 41 | NO. 4
APRIL 19, 2013

Save Our Water Adds New Tools and Programs for 2013

Michelle Latin of Grover Beach enjoys the colors and diversity of her water-wise garden. Latin is one of several real Californians featured in the Save Our Water program's "Real People, Real Savings" campaign in 2013. The effort is designed to showcase how Californians all over the state are saving water outdoors while still enjoying a beautiful landscape. With warmer weather approaching on the heels of a dry winter, Save Our Water is gearing up for an active year in 2013. See story on page 10 for more.

Photo credit: DWR

ACWA Outlines Priorities for 2014 Water Bond

ACWA's Board of Directors has identified guidelines for modifying the 2014 water bond to protect key priority areas and aid its passage next year.

The ACWA Board, already on record in support of the $11.14 billion water bond currently set for the November 2014 ballot, has provided direction to staff to support some reductions to the bond while prioritizing funding for elements that have statewide significance, including water storage, ecosystem restoration, substantial support for local resources development, and funding for disadvantaged communities and rural areas.

The concepts, discussed by the ACWA Board at its March 29 meeting in Sacramento, stem from a statewide California Water Finance Task Force convened by ACWA this year to explore options for improving the bond's viability in 2014. The task force includes a diverse cross-section of ACWA members representing urban and agricultural water agencies around the state.

"ACWA strongly believes that public funding through a water bond is an appropriate way to finance the public benefits of investing in our water system. We recognize, however, that significant changes, including reduc-

WATER BOND Continued on page 15

Key Water Policy Leaders Set to Headline ACWA's 2013 Spring Conference & Exhibition

Several California water policy leaders — including the new chair of the State Water Resources Control Board and the director of the California Department of Water Resources — will speak at ACWA's 2013 Spring Conference & Exhibition, set for May 7-10 in Sacramento.

The speakers will address conferees at ACWA's four-day conference themed "Rethinking California Water" to be held at the Sacramento Convention Center and surrounding hotels. The conference is aimed at providing a fresh perspective to California's current water policy discussions and will feature a host of state, local and federal speakers in various settings, including town hall-style forums and luncheon speeches.

ACWA CONFERENCE Continued on page 4

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Friant Dam, which forms Millerton Reservoir, the source of Friant Division contractors' water supply. Photo courtesy of U.S. Bureau of Reclamation

Reclamation Announces Further Reductions in 2013 Water Allocations For Friant Division

Responding to continuing dry conditions in California, the U.S. Bureau of Reclamation on April 5 announced further 2013 water allocation reductions, with water service contractors in the Friant Division receiving the latest cuts.

Reclamation announced a decrease to the Friant Division water supply allocation of 10%, lowering the allocation from 65% to 55% of Class 1 water rights. Class 2 water remains at 0% allocation. Friant Division contractors' water supply is delivered from Millerton Reservoir on the Upper San Joaquin River. The first 800,000 acre-feet of water supply is considered Class 1 and the next 1.4 million acre-feet is considered Class 2.

The water cutbacks announced April 5 are the latest made this year by the Bureau and the California Department of Water Resources. Last month, DWR announced it had reduced its delivery allocation estimate from 40% to 35% of requested SWP water. In a separate announcement, Reclamation said Central Valley Project (CVP) allocations would be reduced for agricultural water service contractors south of the Delta from 25% to 20% of their contract supply.

Allocations for CVP municipal and industrial water service contractors south of the Delta also were decreased from 75% to 70% of historical use.

The start to the water year was relatively wet in November and December of 2012, but the period from January through March was among the driest on record, resulting in a critical classification for both the Sacramento and San Joaquin river basins.

Officials from DWR and Reclamation have linked the allocation cutbacks to dry conditions in the first months of 2013 as well as pumping restrictions in the Sacramento-San Joaquin Delta to protect endangered fish.

DWR reports that snowpack and precipitation in the Sierra Nevada are below normal. Snow water content readings taken in late March show California's snowpack is at only 52% of normal. DWR's manual readings taken March 28 near Echo Summit found 12.3 inches of water content (37% of normal) at Alpha; 6.1 in. (32%) at Phillips Station; 14.1 in. (45%) at Lyons Creek; and 14.7 in. (54%) at Tamarack Flat.

Senate Passes Measure On Irrigation District Boards of Directors

ACWA-opposed legislation that would eliminate the landownership requirement for serving on the elected boards of irrigation districts cleared the Senate April 8 and is now awaiting action in the Assembly.

SB 614 (Wolk) passed the Senate Governance and Finance Committee on a 4-2 vote on April 3.

The bill's proponents assert that the landownership requirement is antiquated and inequitable, and that the right to hold elective office within an irrigation district should be open to all residents in the district. The bill is supported by the California Teamsters Public Affairs Council, the California Labor Federation, the Community Water Center and others.

Opponents, including several ACWA members and agricultural organizations, say the ownership requirement remains appropriate for irrigation districts that provide *only* irrigation and drainage services. Irrigation districts that provide other services within their territory, including residential drinking water and wastewater treatment services, have eliminated the landownership requirement in response to legislation enacted in 2000 and 2006.

The Legislature has recognized that irrigation districts that provide only irrigation or drainage services to land should continue to retain landownership requirements for their directors, opponents said in a coalition letter on the bill.

Opponents note there is a strong legal foundation for such a requirement with the holding of the U.S. Supreme Court in *Salyer Land Co. et al v. Tulare Lake Basin Water Storage District* (410 U.S. 719, 93 S. Ct. 1224) and no compelling reason to change the current law. Retaining the landownership requirement for irrigation districts that provide only irrigation and drainage services is an appropriate safeguard for the capital investments made by landowners in the irrigation infrastructure within districts, opponents say.

"Persons who have no connection to the land or farming — persons who have not paid for infrastructure and who do not pay irrigation and drainage assessments — would be able to govern irrigation districts," opponents said in a coalition letter.

ACWA Takes Part in Stakeholder Process on Drinking Water Bill

ACWA is participating in a stakeholder process convened by Assembly Member Henry Perea (D-Fresno) to discuss concerns with a bill that would transfer responsibility for the state's drinking water programs from the Department of Public Health to a new division of the State Water Resources Control Board.

ACWA has taken an "oppose unless amended" position on AB 145 (Perea), which would vest authority, responsibility and jurisdiction for the state's drinking water program with a new Division of Drinking Water Quality at the State Board. The existing Division of Drinking Water and Environmental Health housed within the Department of Public Health would become the Division of Drinking Water Quality within the State Board.

The bill cleared the Assembly Water, Parks and Wildlife Committee on a 9-2 vote April 2. It is awaiting action in the Assembly Environmental Safety and Toxic Materials Committee.

According to the author, the bill is aimed at creating a more comprehensive strategy for ensuring safe drinking water for California residents by consolidating all water quality programs into the state agency primarily responsible for water quality.

ACWA and its members, however, are concerned that moving the entire drinking water program could jeopardize elements of the drinking water program that work well while failing to address challenges facing some communities. More targeted actions should be tried first to resolve core problems and impediments facing communities that seek assistance with drinking water issues, the association contends.

In its letter to the author, ACWA notes that the "SWRCB is skilled in environmental and resource protection (e.g., the regulation of wastewater discharges) — but the SWRCB is *not* a public health agency. In addition, moving the Drinking Water Program to the SWRCB runs the risk of taking the SWRCB's focus away from a very full plate of critical programs and complex issues." ACWA's letter on AB 145 can be found at www.acwa.com.

As a result of concerns raised by ACWA and coalition partners such as the Health Officers Association of California, the California Municipal Utilities Association, the California Water Association and others, the bill's author committed to a stakeholder process to discuss the issues and potential alternative approaches.

Some concepts suggested for further discussion include moving the management of the Safe Drinking Water Revolving Fund (SRF) to the State Board, creating a new Office of Drinking Water at the California Envornmental Protection Agency, assigning DPH staff to assist small water systems in navigating the SRF program and making potential changes to accelerate funding through the SRF.

AB 145 is one of several bills moving through the Legislature this year related to drinking water and issues associated with contaminated groundwater sources in some disadvantaged communities in the state.

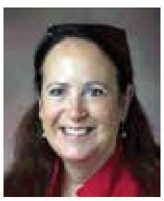
The Brown Administration has not yet signaled a position on AB 145 but is expected to include some recommendations as part of the May revise of the governor's proposed state budget.

ACWA members should direct questions on AB 145 to ACWA's Deputy Executive Director for Government Relations, Cindy Tuck, at cindyt@acwa.com or 916-441-4545.

ACWA CONFERENCE Continued from page 1

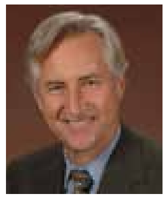
Senate President Pro Tem **Darrell Steinberg** (D-Sacramento) will kick off the opening day of the conference with a keynote address at the breakfast May 8. Steinberg played a critical role in the legislative negotiations that resulted in the 2009 water package and will discuss his thoughts on the potential for reopening the water bond currently set for the November 2014 ballot, the political ramifications of the two-thirds majority and priorities for his last two years in the term-limited Legislature.

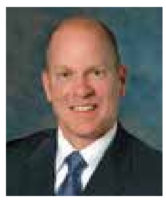
Sacramento Mayor Kevin Johnson also is scheduled to deliver opening remarks at the breakfast.



Later that day, State Water Resources Control Board Chair **Felicia Marcus** is scheduled to speak at the luncheon. Marcus will talk about leadership during times of multiple water priorities and coequal goals.

Marcus, who became board chair this month following the retirement of former State Board Chair Charlie Hoppin, will share her perspective on balancing the competing interests in the Bay-Delta planning process and the multiple priorities currently before the Board.





The following day, **Mark Cowin**, director of the California Department of Water Resources (DWR), and **Charlton "Chuck" Bonham**, director of the California Department of Fish and Wildlife, will keynote the luncheon program. Cowin and Bonham, two leaders with pivotal roles in the Bay Delta Conservation Plan, will discuss how the BDCP will move forward and share perspectives on decisions and policy implications related to the long-term planning effort.

Cowin was appointed director of DWR by Governor Jerry Brown in April 2012 and has worked over 30 years at DWR. Prior to his appointment as director, Cowin served as Deputy Director of Integrated Water Management for DWR.

Bonham was appointed Director of the California Department of Fish and Wildlife in September 2011. Prior to his appointment, he served in a number of roles for Trout Unlimited over 10 years, including as its California director since 2004. Bonham also served on the Board of Directors of the Delta Conservancy.

Bonham and Cowin's remarks will follow a panel discussion earlier that day featuring BDCP stakeholders discussing their views on the specific Delta conveyance facilities that will be considered as part of the plan.

Conference Town Hall to Focus on 2014 Water Bond, Potential Changes

ACWA members can get the latest on the 2014 water bond and potential changes under consideration at a town hall on Thursday, May 9, at the ACWA 2013 Spring Conference & Exhibition.

ACWA's Board of Directors supports the 2014 water bond as an appropriate and much-needed mechanism to fund the public benefits of investing in the state's water system. The Board recognizes, however, that significant changes are needed to aid its passage.

The ACWA Board recently identified guidelines for potential changes such as reducing the size of the bond and avoiding earmarks. The guidelines stemmed from the work of the Water Finance Task Force convened by the board this year to explore options for modifying the bond and how potential reductions could be backfilled.

The town hall, titled **"Changing the Water Bond for Success in 2014,"** is set for 1:45 p.m. Thursday, May 9, and will provide an opportunity for ACWA members to hear about the guidelines and ask questions about ACWA's efforts on the 2014 water bond.

The session will be moderated by ACWA Vice President John Coleman, co-chair of the Water Finance Task Force.

Other speakers will include Thad Bettner, general manager of the Glenn-Colusa Irrigation District; Gary Breaux, assistant general manager and chief finance officer for Metropolitan Water District of Southern California; Paul Jones (invited), general manager, Eastern Municipal Water District; and Dave Orth, general manager, Kings River Conservation District.

For more on the water bond discussion, please see the story on page 1 of this issue.

Water Storage, BDCP and Headwaters Focus of Conference Issue Forums

Issues ranging from new Delta water conveyance facilities to protection of California's headwaters and planning for adequate water storage will be explored in statewide issue forums at ACWA's Spring Conference & Exhibition in May.

The conference, themed "Rethinking California Water," will delve into several contemporary water issues facing water planners in California. The forums will bring together experts to distill some of the complex water issues facing the state.

Statewide Issue Forums

"Water Storage: New Strategies for a New Era," 10 a.m. Wednesday, May 8

ACWA Executive Director Timothy Quinn will moderate this panel featuring Thad Bettner, general manager of the Glenn-Colusa Irrigation District; Jerry Brown, general manager of the Contra Costa Water District; Ron Jacobsina, general manager of Friant Water Authority; and Randy Fiorini, vice chair of the Delta Stewardship Council.

The forum will examine the importance of water storage in California, highlight some proposed projects and discuss how storage strategies are changing to meet this generation's challenges.

"BDCP – How Big is Big Enough?," 10 a.m. Thursday, May 9

Quinn will moderate this forum exploring all angles of the Bay Delta Conservation Plan. Debate simmers over the size and scope of the $14 billion project to improve water conveyance with the state's proposal for a 9,000 cfs facility. Another plan advanced by some environmental groups calls for a smaller 3,000 cfs facility.

Panelists include: Jeffrey Kightlinger, general manager, Metropolitan Water District of Southern California; Greg Gartrell, assistant general manager for water resources, Contra Costa Water District; Jason Peltier, chief deputy general manager, Westlands Water District; and Kate Poole, senior attorney and litigation director, Natural Resources Defense Council.

Water Industry Trends Programs

"Water Conservation Rate Structures and BMP 1.4," 10 a.m. Wednesday, May 8

This forum, moderated by Cindy Paulson, executive director of the California Urban Water Agencies, will focus on water pricing policy. Panelists will look at influences on water agency rate-setting as agencies face a variety of challenges. Panelists are: Chris Brown, executive director, California Urban Water Conservation Council; Heather Cooley, co-director of the Water Program, Pacific Institute; David Shank, financial planning manager, San Diego County Water Authority; and Walter Wadlow, general manager, Alameda County Water District.

"Recycled Water: Promising Developments on the Legislative and Policy Fronts," 1:30 p.m. Wednesday, May 8

This program will examine initiatives gathering momentum to advance the cause of potable uses of recycled water. The panel, moderated by Richard Nagel, general manager of West Basin Municipal Water District, also will focus on case studies on recycled water. Panelists are: Sean Bothwell, staff attorney, California Coastkeeper Alliance; Jim Fiedler, chief operating officer, Santa Clara Valley Water District; and David Smith, managing director, WateReuse California.

"Improving Management of California's Headwaters," 3 p.m. Wednesday, May 8

This panel will address some of the policy principles recently adopted by the ACWA Board of Directors regarding how the management of headwaters can be improved. Jim Branham, executive officer of the Sierra Nevada Conservancy, is one of the panelists. ACWA Region 3 Chair Bob Dean, who co-headed the ACWA workgroup that developed the principles, is invited as moderator.

"Outside the Box: Drinking Water Solutions for Disadvantaged Communities," 9:30 a.m. Thursday, May 9

Experts will discuss various solutions available for small and disadvantaged communities facing water quality challenges. The panel, moderated by ACWA Deputy Executive Director for Government Relations Cindy Tuck, includes Laurel Firestone, co-executive director of the Community Water Center, and Chris Kapheim, general manager of Alta Irrigation District.

ACWA Regional Forums to Highlight IRWM, Project Financing

Project financing in the 21st century and Integrated Regional Water Management (IRWM) will be the focus of separate region forums at ACWA's conference in May in Sacramento.

On Wednesday afternoon, ACWA's regions 6 and 7 will host the program, **"Perspectives on Integrated Regional Water Management in the San Joaquin Valley."** The forum will examine IRWM, which is a collaborative effort among multiple agencies and stakeholders to arrive at mutually beneficial solutions to manage regional water resources. Moderated by David Orth, general manager of Kings River Conservation District, the program will outline the differing perspectives on IRWM in the San Joaquin Valley. Among the overarching questions probed will be how to keep IRWM sustainable and whether agencies should prepare to fund projects regionally without IRWM grants.

Panelists are: Gary Bardini, deputy director of integrated water management at the California Department of Water Resources; Gary Serrato, general manager, Fresno Irrigation District; William A. Taube, Wheeler Ridge-Maricopa Water Storage District; and Christopher White, general manager, Central California Irrigation District.

On Thursday afternoon, Region 10 will host the program – "**Innovative Project Financing in the 21st Century."** The program will encourage water agency officials to think beyond traditional funding structures for water projects in the future. It will delve into the unique public-private financing structure implemented by the San Diego County Water Authority for the Carlsbad Desalination Project. Panelists will discuss the benefits and potential challenges of this financing structure and how it can be applied to other types of water projects.

The program will be moderated by Sandra Kerl, deputy general manager of San Diego County Water Authority. Panelists are: Jamison Feheley, managing director, J.P. Morgan; Daniel Hentschke, general counsel, San Diego County Water Authority; and David Moore, managing director of Clean Energy Capital.

Seismic Expert to Headline Rebranded Friday Breakfast Forum

U.S. Geological Survey seismologist **Lucy Jones** will be the keynote speaker at ACWA's Hans Doe Past Presidents' Breakfast in Partnership with ACWA/JPIA on Friday, May 10, at the 2013 Spring Conference & Exhibition.

Jones, an expert on earthquake science and advocate for earthquake safety in California, will discuss the impact of earthquakes on the Delta and water systems across the state.

She has been a seismologist with USGS and a visiting research associate at the Seismological Laboratory of Caltech since 1983. She currently serves as the Science Advisor for Risk Reduction for the Natural Hazards Mission of USGS, leading the long-term science planning for natural hazards research. She has authored over 90 papers on research seismology with primary interest in the physics of earthquakes, foreshocks and earthquake hazard assessment, especially in southern California.

She serves on the California Earthquake Prediction Evaluation Council and was a member of the California Seismic Safety Commission from 2002 to 2009.

The breakfast program, newly rebranded to reflect ACWA's exclusive partnership with ACWA/JPIA and to recognize the many inspiring leaders who have contributed to the association and the water community at large, is set for 8:30 a.m. at the Hyatt Hotel.

Hans Doe was president of ACWA from 1961-1964 and established the Friday breakfast in 1963 as a forum for the most interesting, education and sometimes controversial programs during the conference. In the 1970s, the breakfast was named the Hans Doe Forum Breakfast and a decades-long tradition was born.

Since Doe's time, many individuals have capably led ACWA as president. To pay tribute to those leaders and celebrate a new exclusive partnership with ACWA/JPIA, the breakfast is being rebranded this year as the ACWA Hans Doe Past Presidents' Breakfast in Partnership with ACWA/JPIA.

JPIA ASSOCIATION OF CALIFORNIA WATER AGENCIES JOINT POWERS INSURANCE AUTHORITY

ACWA Association of California Water Agencies Since 1910 Leadership • Advocacy • Information • Service

Conference Schedule of Exhibitor Technical Presentations

Wednesday, May 8 (10:00 – 11:30 a.m.)

- Dudek – Environmental and regulatory considerations for developing seawater desalination in California
- California Department of Water Resources – BDCP proposed facilities and benefits

Wednesday, May 8 (1:30 – 2:30 p.m.)

- Pumping Efficiency Testing Services – Utility pump efficiency programs, pump testing and incentives

Wednesday, May 8 (3:00 - 4:00 p.m.)

- Badger Meter – Ten things to consider when writing an AMI (Advance Metering Infrastructure) Request For Proposal

Thursday, May 9 (9:30 – 11:00am)

- UPC Quagga Inspection Services – Aquatic nuisance species and compliant recreation practices
- Contractor Compliance & Monitoring – Proposition 84, CMU and Prevailing Wage — What is REALLY Going on

Thursday, May 9, 2013 – (1:45 – 2:45 p.m.)

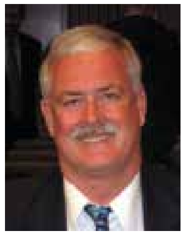
- WSO (Water Systems Optimization) – Using the latest technologies in AMI and cloud computing to implement a comprehensive water loss control program — a California case study

Thursday, May 9 (3:00 – 4:00 p.m.)

- HomeServe USA – Aging infrastructure of the California water market: A method to bridge the gap through a customer conservation and education program

Program to Discuss How Water Agencies Contribute to California's Electricity Grid

By Lon House, President, Water and Energy Consulting



California's electric grid faces many challenges in the coming years. The majority of power plants are approaching 50 years old. The San Onofre Nuclear Generating Station (SONGS) has been offline since January 2012. Renewable generation is playing an ever-increasing role in our power supply (33% of electricity generated by 2020), but increased reliance on intermittent sources like wind and solar makes it more difficult to keep supply and demand balanced on the grid.

Water agencies are a critical component of the grid response, being the single largest provider of on-peak demand reduction and demand response in California. On a daily basis during the summer, California's water agencies collectively reduce their demand by 400 to 600 megawatts (MW).

Fifty water agencies are providing 100 MW of additional demand response from approximately 150 sites through EnerNoc and Constellation, two demand response providers designated as ACWA Preferred Providers. In a demand response program, a water agency reduces its electricity demand by turning off pumps or other electricity consuming processes in response to an emergency call from a utility. Participating in demand response programs helped water agencies recoup approximately $5 million last year.

Here are four ways that a water district can help improve the overall efficiency and reliability of the state's power grid:

1.) Work with water/energy nexus specialists to develop predictive models

APP
ACWA Preferred Provider

on water consumption, allocations and associated energy use so you can better plan for operational resources and scheduled maintenance. Sophisticated tools are available to help you better anticipate and manage your energy consumed when pumping, based on snowpack, expected temperature and historical energy consumption patterns.

2.) Adjust electricity use in response to grid conditions by participating in demand response programs or peak-day pricing rates. These programs are ways to benefit financially from flexibility in your operations.

3.) Engage energy efficiency experts to help you identify and eliminate hidden energy waste. Not only will you save money each month, but in many cases usage incentive programs can help offset upfront investments for professional services, technology tools and equipment retrofits.

4.) Implement or enhance automated controls for your most energy-intensive equipment. Monitoring and quickly adjusting your energy consumption will drive cost savings and create opportunities to capture value.

An Energy Committee program called Water Agency Demand Response — Critical to California and Your Bottom Line is scheduled for the ACWA Spring Conference & Exhibition on May 9 from 9:30-11 a.m.

U.S. Senate Confirms Sally Jewell as Interior Secretary

EPA nominee McCarthy testifies at Senate hearing.

The U.S. Senate on April 10 confirmed **Sally Jewell**, chief executive officer of outdoor gear retailer REI, as Secretary of the Interior.

Jewell, 57, replaces outgoing Interior Secretary Ken Salazar, who announced his departure in January. The Senate voted to confirm Jewell's nomination on an 87-11 vote. President Barack Obama nominated Jewell in February.

Jewell has been the CEO of outdoor gear retailer REI since 2005. An outdoor enthusiast from Seattle, she previously worked as a petroleum engineer and banker. Jewell has served on the board of the National Parks Conservation Association and is a graduate of the University of Washington. She is married with two adult children.

Jewell was a key contributor to the Obama administration's Great Outdoors Initiative. Launched in 2010, the initiative aims to reconnect Americans to the natural world.

In a separate April 11 nomination hearing, the Senate Committee on Environment and Public Works took testimony from **Gina McCarthy**, President Obama's pick to succeed Lisa Jackson as administrator of the Environmental Protection Agency.

It's expected McCarthy will be tasked with enacting and enforcing regulations that combat climate change, an issue Obama has repeatedly pledged to work on during the next four years. Since 2009, it's been McCarthy who has been writing rules for coal-fired power plants and other energy producers that emit greenhouse gases.

In all, the Massachusetts native has 30 years of experience working on environmental regulations at the state and federal levels. McCarthy led the Connecticut Department of Environmental Protection (2004-'09) and the Massachusetts Executive Office of Environmental Affairs (1999-2003). During those two stops, Obama said McCarthy helped design programs to expand energy efficiency and promote renewable energy. ▮▮▮

House Passes Bill to Ease Reclamation Hydropower Development

A bill that would streamline the regulatory process for construction of small-scale hydropower projects on existing Bureau of Reclamation water "conduits" passed the House April 10.

Sponsored by U.S. Rep. Scott Tipton (R-Colo.), the Bureau of Reclamation Small Conduit Hydropower Development and Rural Jobs Act (H.R. 678) passed by a 416-7 vote. The legislation's backers say the bill would cut red tape and reduce administrative costs for lessees that develop small hydropower projects (those of 5 megawatts or less) along Reclamation canals, ditches and similar small conduits.

H.R. 678 passed with bipartisan support after Tipton amended the bill to remove a National Environmental Policy Act (NEPA) waiver for the affected hydropower projects and replaced it with a "categorical exclusion."

"By advancing these projects under the Bureau's categorical exclusion process, we ensure that all of the elements in that process are retained, including agency discretion for examining extraordinary circumstances. In addition, the amendment specifically mentions codifying the categorical exclusion process for small conduit hydropower," Tipton said.

Rep. Grace F. Napolitano (D-32) was among the Democrats in the California delegation voting for the bill. She called H.R. 678 "far from perfect," but said that striking the NEPA waiver was key to reaching a bipartisan solution.

ACWA is joined in support of H.R. 678 with the National Hydropower Association, National Water Resources Association, the American Public Power Association, and others.

A Department of Interior report last year found that there are hundreds of reclamation-owned sites in the U.S. that are candidates for small hydropower development.

In February the House passed a similar hydropower bill (H.R. 267) ACWA also supports that would eliminate federal licensing for some hydropower installations built at manmade conduits not owned by the federal government. That bill would allow some hydropower projects with less than 10 megawatts of installed capacity to be exempted from time-consuming licensing and permitting procedures.

The Senate Energy and Natural Resources Committee is expected to consider the two hydropower bills during an April 23 hearing. ▮▮▮

President Obama Releases $3.77 trillion Budget Proposal for 2014

President Obama released his $3.77 trillion budget proposal for fiscal year 2014 on April 10. Total discretionary spending is set at $1.058 trillion in accordance with the cap established in the Budget Control Act (BCA) of 2011. The proposal includes nearly $1.8 trillion in additional deficit reduction over the next 10 years, and under the terms of the BCA, this reduction replaces the need for sequestration.

A financing mechanism used by ACWA members to help build infrastructure projects would be impacted by the 2014 budget proposal. In order to help achieve the savings required by the BCA, the President proposes reducing the tax exemption for municipal bonds. Under the 2014 budget proposal, municipal bonds would no longer be tax-exempt for individuals in the top three tax brackets: 33%, 35% and 39.6%. As a result, an investor in the 39.6% tax bracket would pay 11.6% in taxes on municipal bond interest income. This change could greatly impact the market for municipal bonds and ACWA will work with other associations to preserve water agencies' ability to use municipal bonds.

Below is a summary of the budget items of interest to ACWA members.

Army Corps of Engineers Department of Civil Works: The President repeated his FY 2013 proposal to reduce the Army Corps budget by 5.5% from 2012, lowering total spending from $5 billion to $4.7 billion. The Construction fund would receive $1.35 billion and the Operations and Maintenance fund would receive $2.58 billion.

Bureau of Reclamation: The proposed Reclamation budget for FY 2014 is $996.3 million, similar to the 2012 enacted budget of $995 million and down slightly from the $1.0 billion that Reclamation received in the 2013 continuing resolutions. The budget proposes decreasing CALFED funding by $3 million, from $40 million under the continuing resolution to $37 million. Larger decreases were proposed for the water recycling program, Title XVI, and the WaterSMART program. The budget requests $14 million for Title XVI, a decrease of $10 million from FY 2012, and $12 million for WaterSMART grants run by Reclamation, down from a high of $24.5 million in the continuing resolutions.

Department of Agriculture: The programs of interest to ACWA members are funded through the Farm Bill and aren't subject to the normal appropriations process. As governed by the bill, the Environmental Quality Incentives Program is set to receive $1.4 billion. However, the President expressed a desire to reduce this amount to $1.35 billion. The Agriculture Watershed Enhancement Program, as in years past, is set to receive $60 million.

Environmental Protection Agency: President Obama proposed significant cuts to EPA's State Revolving Loan fund, reducing them by a combined $472 million. The Clean Water SRF's proposed funding level is $1.10 billion compared to $1.47 billion in 2012. The Drinking Water SRF proposal is for $817 million compared to $918 million in 2012. The Administration states that it strongly supports the SRF program and would like it to "target assistance to small and underserved communities with a limited ability to repay loans, while maintaining state program integrity." Green infrastructure continues to remain a priority of the Obama Administration, and the budget proposal stipulates that 20% of the Clean Water SRF and 10% of the Drinking Water SRF must be used to fund green projects.

National Oceanic and Atmospheric Administration: The President continued his quest to increase the NOAA budget, proposing an 8% increase from 2012 to $5.4 billion. The National Marine Fisheries Service budget is proposed to increase by $49 million from 2013 to $847 million. The Pacific Coastal Salmon Recovery Fund would be reduced by $15 million to $50 million.

U.S. Geological Survey: The overall USGS budget proposal for FY 2014 is up by $115 million to $1.2 billion. President Obama proposes increasing USGS's WaterSMART program by $8 million to $22.5 million. Additionally, an extra $7.2 million is proposed for the program that funds streamgages in order to bring the total number of streamgages operated by USGS to 400. The FY 2014 budget proposal also includes $3 million for the USGS to conduct ecosystem restoration projects in the Bay-Delta.

Amid Dry Conditions, Save Our Water Gears Up for Busy 2013

After an extremely wet December, California experienced one of the driest January–March periods on record. News that the Sierra snowpack had dipped to just 52% of average at the end of March brought announcements of cutbacks in state and federal water deliveries, and a reminder that California can never take water for granted.

Save Our Water, the statewide water conservation public education program created by ACWA and DWR, is rolling out new partnerships, tools and seasonal programs in 2013 to help water agencies encourage their customers to use water wisely this year.

Partnerships

In March, the Save Our Water team and the California Urban Water Conservation Council (CUWCC) announced a new partnership that will expand the reach of both organizations' water conservation education efforts. CUWCC developed a new webpage at www.cuwcc.org that explains the benefits of the Save Our Water program and provides information on how to take advantage of the program's benefits and services. Look for more information on this exciting new partnership in the months to come.

Kim Mayman's yard in Palo Alto features a variety of water-wise plants.

Save Our Water continues its sponsorship of Sunset Magazine's Plant Finder, the most popular element of the Sunset website, in 2013. Additionally, the Save Our Water logo will be prominently featured on the water-wise plants in Sunset's new line of plants: the Sunset Western Garden Collection, which debuted in 2012. More can be found at www.sunsetwesterngardencollection.com.

Tools for Members

ACWA members should check out the new online toolbox on the Save Our Water website at www.saveourh2o.org. This handy one-stop shop includes helpful links, videos, photos and printed materials.

Public Education

To increase the public's knowledge and awareness about water-efficient irrigation equipment and techniques, Save Our Water is creating a new section on its website, Sprinklers 101, which will provide homeowners and landscape professionals with helpful information and a host of online resources. This new web portal will be launched at the beginning of May.

Save Our Water kicked off a new spring and fall campaign, "Change Your Clock, Check Your Sprinklers," to remind Californians to check their sprinkler systems and settings when they change their clock. The program put out a news release and used social media and the program's website to urge people to check their sprinkler timer and sprinkler system the weekend of Sunday, March 10. Californians will be reminded again to check their sprinklers in November when it is time to turn clocks back.

The Real People, Real Savings program again will add new faces to the program this year. The program will travel to the regions of El Dorado/Placer County, Redding/Chico and Orange County/Inland Empire to photograph homeowners who have made significant changes to their landscaping to save water.

Connect with Save Our Water

Stop by the Save Our Water exhibit at ACWA's 2013 Spring Conference & Exhibition to talk with team members and to learn more about the many ways Save Our Water can support your agency's water conservation public education program.

Save Our Water also will have an exhibit this summer at the California State Fair. Visitors will be able to visit the program's permanent water-wise garden, as well as learn about ways to save water outdoors through exhibits and workshops on plant selection, drip irrigation and smart controllers.

Finally, Save Our Water's successful social media program will continue to connect with Californians through Facebook, Twitter, Pinterest, the "Words to Save By" blog and other new media tools. If your agency is interested in submitting a guest blog, please contact Jennifer Nelson at jennifer-nelson@pacbell.net.

What Do You Think?

The Save Our Water team would love to hear your feedback and/or ideas on ways the program can support local water agencies' water conservation education efforts. ▮▮▮

Imperial Irrigation District delivers water to approximately 5,500 fields covering half a million acres of cultivated land. *Photos courtesy of IID*

Imperial Irrigation District Prepares for Water Apportionment Plan

Q&A with Tina Shields, IID's Colorado River resources manager

When farmers in the Imperial Valley have needed water, they have simply called and placed an order — and the Imperial Irrigation District has delivered it. This relatively simple method has prevailed for more than 100 years, buoyed by IID's right to 3.1 million acre-feet of Colorado River water as prescribed by the Quantification Settlement Agreement.

But times could be changing in a matter of weeks. On April 23, the IID Board of Directors will consider revising an "apportionment plan" that will give all growers in the IID's service area — encompassing a half million acres of farmed land — the same amount of water each year (5.45 acre-feet per acre), regardless of what kind of crop they grow.

Tina Shields, the IID's Colorado River resources manager, said the new policy will help manage IID's 3.1 million acre-feet cap and assist in its obligation to pay back significant overruns — 90,000 acre-feet in 2011 and 150,000 acre-feet in 2012. Shields discussed the details of the new policy that could start May 1.

Why is now the right time to implement water apportionment?

When we had those two back-to-back overrun years in 2011 and 2012, it was an epiphany for the IID and our water users. Seeing the drought conditions on the Colorado River continuing and getting worse, we knew we couldn't continue as we had. We have to pay that water back, and it's really easy to overuse, but it's not so easy to go on a diet and conserve water to give it back to the river. We dusted off an apportionment plan our board adopted in 2007, and are revising it to accommodate an annual apportionment system that will give our farmers a water budget that will enable them to make their planting and planning decisions in advance.

How have the community and your customers reacted to the proposed change?

My family and I have been involved with agriculture most of our lives, and just as in any other private business, if you put 10 farmers in a room, you'll get 10 different opinions on how best to do things. There are strong feelings about water in the Imperial Valley, but I think our growers understand the circumstances. Our board gave clear directions that we should modify the existing policy with input from our water users, because they're going to have to live with these rules, so they should help design them. IID recently began a series of meetings with water users to look at what revisions needed to be made.

It's largely going to be a mindset change. We know it's going to be a difficult year and we know there will probably be kinks in the implementation, but we feel it's important to get started May 1 and make changes as we go along. As we run into issues, we'll fix them with input from our growers.

What else needs to be done?

What's crucial to making the straight-line apportionment work is having a district water exchange or "clearinghouse" that would facilitate the movement of water between the high-use and low-use farmland. Growers have to get the hang of working with their neighbors and IID to better manage and move that water, on paper, between the different farm units. Our committee of water users hasn't developed those rules yet, but that will happen shortly. We also need to prorate our remaining water supply under the apportionment plan for the balance of 2013. On May 1, everyone would have the same size 'bucket' of water to manage. It's not going to matter what was used on a field-by-field basis the first four months of the year.

How do you think those outside the IID will view this big change?

I do think the other Colorado River water contractors are appreciative of where IID is headed. I think they understand that IID is going in a direction that it has never gone before. We have never had to be on a water budget. We have a relatively new board, and the implementation of an annual apportionment will give them an opportunity to show their decisions can change perceptions about IID. We're hopeful the board will take action later this month when we bring them the policy to enact these changes. ■

Glendale Water and Power Releases Final Report on Chromium 6

The City of Glendale Water & Power (GWP) recently released its final project report to the California Department of Public Health (CDPH) identifying water treatment technologies that can be used to remove hexavalent chromium (chromium 6) from drinking water supplies.

The Glendale City Council took on this significant research effort more than a decade ago to identify ways to minimize the presence of the contaminant in its local water supplies. This information on technical feasibility and cost for various treatment technologies will assist Glendale and also will be used by CDPH as the department develops the draft maximum contaminant level (MCL) for chromium 6. The draft MCL is expected to be released in July 2013. The Office of Environmental Health Hazard Assessment (OEHHA) set the public health goal at 20 parts per trillion (ppt).

With the cooperation of many partners and a robust advisory committee, Glendale began work in 2002 under then-Assistant General Manager of Water Peter Kavounas with bench testing at the University of Colorado at Boulder to screen a large array of potential treatment technologies for removing chromium 6. Once that was completed, Glendale began pilot testing of seven treatment technologies in order to assess treatability under flow-through conditions. Three technologies emerged at leading candidates for achieving single parts per billion (ppb) treated water concentrations: weal-base anion exchange (WBA), strong-base anion exchange (SBA) and reduction/coagulation/filtration (RCF). Demonstration studies provided additional information on the advantages and disadvantages of each technology.

The multiple phases of the project cost nearly $9 million and were funded in large part by sources outside of Glendale, such as Los Angeles Department of Water and Power, City of Burbank, City of San Fernando, California Water Service Company, San Fernando Valley Industry, Water Research Foundation, Metropolitan Water District of Southern California, California Department of Public Health, United States Environmental Protection Agency, U.S. Bureau of Reclamation, California Department of Water Resources, National Water Resource Institute, and the Association of California Water Agencies.

ACWA funded a portion of the project in which the research team reviewed the cost implications for residuals handling and disposal utilizing the RCF treatment option. In addition, ACWA member Los Angeles DWP managed Phase I, the bench scale testing for the project.

Photo caption: Demonstration facilities tested the potential of reduction/coagulation/filtration (RCF) water treatment technology for removal of hexavalent chromium.

"We were so pleased that so many other organizations throughout the country assisted in funding the research activities to make this a premier research effort and recognizing its nationwide significance," stated Don Froelich, project manager for Glendale Water & Power. As part of the research, GWP constructed two state-of-the-art water demonstration treatment facilities that received nationwide attention for their capability to remove chromium to exceptionally low levels in drinking water.

The Project Advisory Committee included Eugene Leung, CDPH; Dr. Bruce Macler, USEPA Region 9; Dr. Sun Liang, MWD; Dr. Rick Sakaji, East Bay MUD; and Dr. Pankaj Parekh, LADWP and member of ACWA's Board of Directors.

The research at GWP is currently under the direction of Ramon Abueg, chief assistant general manager, Glendale Water and Power.

To read the full report and learn more about the different treatment technologies and how the costs of a chromium 6 MCL may affect your agency, please visit GWP's website www.GlendaleWaterAndPower.com. Glendale Water & Power has provided copies of its report to statewide and national water quality agencies as well as local legislators and state and federal water quality agencies. Although intended to be the final project report, there are a few ongoing research activities which should be completed this summer, and their results included in a supplemental report which will be issued by the end of this year.

If you have questions about chromium 6, please contact Danielle Blacet, ACWA senior regulatory advocate at 916-441-4545 or danielleb@acwa.com.

Davis Tests Biofiltration Method for Removing Chromium 6

By City of Davis Public Works

The City of Davis held an open house Feb. 26 to share information about its four-month-long pilot study on co-removal of hexavalent chromium (chromium 6) using a biological filtration treatment technology. The study was initiated in response to state legislation requiring the establishment of a new chromium 6 drinking water standard. The current standard is 50 mg/l for total chromium. It's anticipated that the California Department of Public Health will set a maximum contaminant level (MCL) for chromium 6 in the 1.0 to 25 mg/l range. The draft MCL is expected to be released in July.

Chromium 6 levels are relatively high — above the expected MCL — in wells throughout California, especially in service areas reliant on groundwater such as Davis and Woodland as well as other water agencies in the greater Sacramento area. These communities are anticipating compliance issues with the new proposed chromium 6 MCL range. The city of Davis has concentrations of chromium 6 greater than 10 mg/l in 13 of its 21 municipal groundwater wells. Finding appropriate and affordable treatment technologies to meet the anticipated chromium 6 standards will be similar to the response that occurred when arsenic standards were made more stringent. All of the current solutions potentially available to meet this future regulation are expensive to construct and operate, and will add complexity to community well systems that currently have no treatment in place.

Davis funded the study regionally by collaborating with the Water Resources Association of Yolo County, Sacramento Groundwater Authority, and State Water Resources Control Board to fund a novel Chromium 6 Treatment Pilot Study project evaluating an alternative sustainable treatment technology — biological filtration.

Pilot Objectives

The city of Davis, Kennedy/Jenks Consultants, Envirogen Technologies, and BSK have been conducting the pilot study of a biological treatment system since October. The bench scale pilot unit (20 to 80 mL/min flow rate — see photo right) has been co-removing chromium 6, nitrates and selenium — three constituents of concern within the city's intermediate wells. The source water was the city of Davis Well 20, located in the western half of the city. The biological treatment process will reduce chromium 6 to chromium 3, a more benign form of chromium and a required human nutrient, which would then be removed by filtration.

Biological treatment is a sustainable drinking water treatment process that can reduce levels of other contaminants, such as perchlorate, nitrates and organics. The biological treatment process being utilized in this study is the NSF 61-approved fluidized bed bioreactor (FBR) technology (which requires any equipment coming in contact with drinking water be NSF 61 approved per the California Waterworks Standards). The FBR is an active, fixed-film bioreactor that fosters the growth of microorganisms on a hydraulically fluidized bed of fine media. The small, fluidized media provides an extremely large active surface area upon which microorganisms can grow. An electron donor (i.e., NSF 60-approved acetic acid) is provided to the FBR, where it is used by the microbes in the denitrification/chrome reduction process. The end products are nitrogen gas, reduced chrome, carbon dioxide, water and biomass.

Information from this chromium 6 pilot study is being shared with the California Department of Public Health to support development of an MCL. This study will consolidate results from Water Research Foundation Project 4450 (Impact of Water Quality on Hexavalent Chromium Removal Efficiency and Costs) that the city of Davis also is participating in. The Research Foundation study is treating City Well 20 water using the reduction/coagulation/filtration and anion exchange processes that are currently being evaluated by other projects. Compliance costs will be developed and included in the final study.

Davis also is participating in the CA-NV American Water Works Association Chromium 6 Technical Advisory Group that is meeting on a regular basis to develop factual information about chromium 6 compliance efforts and issues. The group also is engaging with the California Department of Public Health on the establishment of the chromium 6 MCL.

The field pilot work is complete and the report will be completed by June 2013. A special thanks goes to the Davis water operations staff for a job well done in facilitating the pilot project work.

For more information, contact Tim Williams with Kennedy/Jenks Consultants at timwilliams@kennedyjenks.com or Jacques DeBra with the City of Davis at jdebra@cityofdavis.org.

No Rate Hikes for East Valley District in Foreseeable Future

East Valley Water District customers received good news in March – there will be no need for rate increases in 2013 and possibly even 2014. The district's financial plan update presented at the regular board meeting revealed that East Valley is operating at healthy levels, due to streamlined operations and continuing high levels of efficiency.

"East Valley Water District strives to meet the day-to-day needs of our customers, while also maintaining the underground pipeline and critical distribution system that typically goes unseen," said Board President Matt LeVesque.

Currently, East Valley Water District has $5.7 million in the water reserve fund beyond the required $7.3 million minimum needed for bond payments. Reserves are generally used for funding specific projects, such as the new surface water treatment facility, or to complete emergency system repairs.

The district's conservative budgeting approach, paired with the improving local economy, is resulting in revenues above initial estimates, and operational adjustment savings have expenses below budgeted amounts. These financial results allow the district the opportunity to defer a rate study while various outside economic factors adjust, paving the way for a reliable 10-year financial plan to be presented in fall 2014.

"There are so many unknowns for us over the next year, so that any rate study we did now could be outdated before it is completed," said General Manager/CEO John Mura. "We are committed to providing water and sewer services as affordably as possible, and want to make sure that when we prepare a long-term financial plan that it is with the most accurate and consistent outlook information available."

Geocaching Craze Has Caught on in Mojave Desert

A real-life treasure hunt known as geocaching is now on in the desert, thanks to the Mojave Water Agency (MWA). All you need is a GPS system and a taste for adventure. Popular around the world, the goal of this game is to find a small cache container hidden from plain sight and stocked with a log book to record the treasure finders. MWA currently has two geocaching sites, with plans to add more.

Caches are found with little trinkets inside and the person who finds it can take the contents, but must replenish it with new trinkets of equal value. These can be anything from a keychain to a book or a small toy.

The GPS locations of all the hidden geocaching containers in the world are listed on www.geocaching.com. The coordinates listed on the site will only get the hunter within 10 feet at most of the exact location of the hidden container; a searcher must rely on sharp sight to find the cache.

"We want everyone to have fun with this, but be sure to respect the plant and animal life while hunting. Don't trespass on private property and enjoy the hunt," said MWA Board President Kimberly Cox.

Facility Upgrades Complete at Monte Vista Water District

Monte Vista Water District recently opened its customer service lobby doors to the public after an eight-month construction project. The facility improvements include the installation of an elevator in its two-story main office building, a remodeled entrance, an enhanced customer service counter, and newly installed landscaping.

The installation of an elevator provides improved public access to the district's main office upstairs facilities, including the district board room. Improvements also were made to the customer service counter and lobby area, including the installation of safety glass to enhance the security of district personnel.

"The board and I are very pleased with the new upgrades to the district facilities and are thrilled to offer our customers easier access to the board room," said Board President Sandra Rose. "The main office building looks beautiful, both inside and out, and gives our customers and staff a sense of pride in the district."

In addition to the indoor upgrades, the district installed water-efficient landscaping around the entire exterior of the main office. A variety of low-water use plants were installed, including yarrow, manzanita and kangaroo paw, which are all drip-irrigated to reduce runoff and evaporation. Moreover, the new landscaping serves as a water-collecting

system, distributing storm water to cobble and gravel bioswales that naturally recycle water back into the ground.

Threatened Russian River Salmon Monitored by Traps

In March, the Sonoma County Water Agency installed two downstream salmon monitoring traps in the Russian River near Forestville. The traps are used to monitor endangered coho, and threatened Chinook and steelhead as they begin their migration from the Russian River to the Pacific Ocean. The monitoring is required under the National Marine Fisheries Service's 2008 Russian River Biological Opinion, a federally mandated 15-year blueprint to help save the endangered and threatened fish.

These "rotary screw" monitoring traps — known for their rotating cone positioned between two pontoons — are a common tool used to capture migrating juvenile salmon. Fishery technicians use hand nets to scoop out captured fish for biological data collection before release. This data is used to estimate abundance, survival, size distribution, mortality between life stages, and behavior of wild and hatchery salmons.

The traps are positioned along each bank of the river approximately a half mile downstream from the Wohler Bridge. As a safety precaution, the Water Agency has restricted all kayaks, canoes, and flotation devices around the equipment.

WATER BOND Continued from page 1

ing the overall size of the existing bond and addressing the perception that the bond contains too much 'pork,' will be required to secure the passage of a water bond in 2014," ACWA Executive Director Timothy Quinn said. "As a statewide organization, ACWA intends to prioritize funding for bond elements of true statewide importance so we can advance solutions that work for our members throughout the state."

The ACWA Board acknowledged that the bond will need to be downsized and voiced support for several guidelines for potential changes to the current bond, including:

- Avoiding "earmarks" that allocate funds for specific projects without a competitive process;
- Protecting bond funding for the public benefits of water storage projects, ecosystem restoration beyond mitigation obligations, and support for local resources development projects, including those in disadvantaged communities and rural areas;
- Rejecting statewide fees on water to pay for statewide public benefits;
- Supporting substantial investment in local resources development and looking for ways to maximize funding at the regional level.

"We want this bond to be successful so we can move forward with critical investments in these areas. It is up to us to discipline ourselves as we reshape it for success in 2014," Quinn said.

Legislative leaders have indicated that modifications to the bond may be taken up later this year after passage of the state budget. ACWA will continue to play a leadership role in water bond discussions over the coming months.

ACWA has scheduled a Town Hall on the water bond and potential modifications at the upcoming ACWA 2013 Spring Conference & Exhibition in Sacramento. The session is set for 1:45 p.m. to 2:45 p.m. on Thursday, May 9.

For questions, contact ACWA Deputy Executive Director, Government Relations Cindy Tuck at 916-441-4545 or cindyt@acwa.com.

Study: 1 in 5 Californians Live in a Floodplain

California must take action now with "unprecedented cooperation" to address the 7 million people and $580 billion of property residing in areas at risk of flooding, according to a public draft of a new report.

Compiled by the Department of Water Resources and the U.S. Army Corps of Engineers, "California's Flood Future: Recommendations for Managing California's Flood Risk," takes a first-of-its-kind, comprehensive look at flooding in the state and makes seven recommendations for improving flood management. The study combines data from 142 local agencies, and state and federal agencies.

The study, complied over the past three years, determined that there is "catastrophic risk" of flooding in California and that all 58 counties have declared a flood emergency during the past 20 years. Potential losses from a major flood event, the report said, likely would exceed the $110 billion spent in the aftermath of Hurricane Katrina recovery, or the $60 billion appropriated for Superstorm Sandy.

The report's researchers assessed that there's an immediate need for $50 billion to complete flood management improvements and projects, and room for an additional $100 billion in capital investment. Flood agencies in California have invested a total of $11 billion in flood management during the past 10 years, predominantly through Proposition 1E and Proposition 84 funds.

A $150 billion investment is pricey, but the cost of Katrina and Sandy recovery shows that inaction — if California was devastated by a similar regional event — would be more expensive in the long run, said Keith Swanson, chief of the DWR's Division of Flood Management.

Swanson said the new report shows the need for better governance and coordination among the more than 1,300 agencies in California that are responsible for

flood control and management. It will take a lot of effort and leadership at the local, state and federal levels to integrate planning and to identify how to fund projects, but there's an urgent need, he added.

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7 Recommendations for California's Flood Future

California's Flood Future report's seven recommendations are:

1) **Conduct regional flood risk assessments to better understand statewide flood risk.**

   Identifying flood risk is an important first step toward reducing risk and prioritizing flood management infrastructure needs in California; however, few detailed risk assessments have been completed.

2) **Increase public and policymaker awareness about flood risks to facilitate informed decisions.**

   Policymakers and the public have varying levels of understanding about the risks and consequences of flooding. This can lead to decisions that put people and property at increased risk.

3) **Increase support for flood emergency preparedness, response and recovery programs to reduce flood impacts.**

   Flood emergency programs are a cost-effective, non-structural tool to reduce flood risk.

4) **Encourage land use planning practices that reduce the consequences of flooding.**

   Development in California has increased in areas that are at risk for flooding. Some local land use agencies experience pressure to approve developments in floodplains.

5) **Implement flood management from regional, systemwide and statewide perspectives to provide multiple benefits.**

   Historically, flood management projects have been developed on a site-by-site basis. This approach does not consider regional solutions or California's complex regulatory, permitting and water management environment.

6) **Increase collaboration among public agencies to improve flood management planning, policies and investments.**

   California has more than 1,300 agencies overseeing operation, maintenance and improvement of vital infrastructure facilities within agency boundaries. This complex governance situation makes agency coordination and alignment fragmented and difficult.

7) **Establish sufficient and stable funding mechanisms to reduce flood risk.**

   The backlog of identified flood management projects is primarily due to lack of funding. Prioritizing and communicating flood management investment needs will help generate support for increased funding.

Coachella Valley Water District Celebrates 50 Years as State Water Project Contractor

March 29 marked the 50th anniversary of the Coachella Valley Water District (CVWD) signing on as a contractor for State Water Project (SWP) water, an agreement that has been a significant factor in the efficient management of the region's water supply portfolio.

"The ability to replenish the aquifer with State Water Project water enables us to combat overdraft. This, in turn, helps us protect water quality and minimize land subsidence caused by the permanent, long-term removal of groundwater," said CVWD General Manager Jim Barrett. "Without this valuable resource, groundwater levels would be at historic lows in portions of the Coachella Valley."

Contractors for the State Water Project are entitled to what are known as Table A allotments. The SWP delivers water from supply and storage facilities in Northern California to service areas as far north as Plumas County and as far south as the border with Mexico, representing more than 25 million residents and 750,000 acres of agricultural land.

A direct connection from the California Aqueduct to Coachella Valley was not constructed in 1963 because it came with a $150 million price tag ($1.75 billion in 2012 dollars). Instead, CVWD and the Desert Water Agency (DWA), also a SWP contractor, negotiated an agreement with the Metropolitan Water District (MWD) of Southern California for a "bucket-for-bucket" exchange of SWP water for Colorado River water. Exchange water is delivered to the Whitewater River and Mission Creek groundwater replenishment facilities via turnouts off the Colorado River Aqueduct, which traverses the Coachella Valley.

The exchange accord was amended to enable MWD to deposit Colorado River water in the valley's aquifer during years of above average precipitation and make withdrawals (MWD takes the SWP water and does not deliver Colorado River water to the valley) in years of drought. This arrangement benefits the valley since the storage of additional groundwater aids in overdraft reduction.

"This agreement has been extremely beneficial for everyone involved," said Barrett. "There have been many years where we replenished amounts of water that far exceeded our annual legal allotments." ▮▮▮

Pebble Beach Water Storage Tank Project Nears Completion

Coming in at 800,000 gallons, the Huckleberry Hill Water Storage Tank is the last project in Pebble Beach Community Services District's 20-year capital improvement program for fire protection. Located next to the existing 800,000-gallon water storage tank located on Sunset Lane, this $2.5 million project will be completed at the end of April 2013 and provide additional storage to ensure water availability for firefighting in areas that have had a deficiency. ▮▮▮

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"This report gives us a better realization that [flood risk] is a statewide problem," Swanson said.

Terri Wegener, program manager of DWR's Statewide Flood Management Planning Program, said the California's Flood Future report is a first step in a multi-phase process of work and collaboration. She said she is hopeful that the report's findings will get the public's attention and start communication among agencies about the challenges.

DWR hosted an Integrated Water Management Summit in early April in Sacramento. The use of integrated water management is one strategy identified in the report.

Comments on the draft report can be presented in person at a series of nine California's Flood Future statewide meetings scheduled for April and May. The schedule is posted on the DWR website. Comments also may be submitted in writing via sfmp@water.gov or at any of the scheduled regional workshops through May 20. The California's Flood Future report can be downloaded at http://www.water.ca.gov/SFMP/resources.cfm#floodreport. ▮▮▮

Public Member Agencies

Santa Margarita Water District

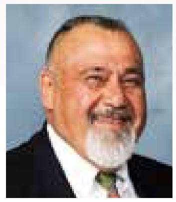
David Cordero, government affairs manager far the Municipal Water District of Orange County (MWDOC), recently left the district to become chief of staff to Irvine Mayor Pro-Tem Jeff Lalloway. Cordero will serve as Councilman Lalloway's strategic adviser in support of Lalloway's roles as city council member, Orange County Transportation Authority board member and Orange County Fire Authority board member, and as chairman of the board of the Orange County Great Park.

Vallecitos Water District

Vallecitos Water District Board Director Betty Evans is the district's new representative to the San Diego County Water Authority Board, which assists in setting policy and strategy for meeting water supply demands of the region's residents.

Evans, a San Marcos resident who represents the water district's Division 1, is a former City of San Marcos council member with experience serving many local government organizations. She has worked as an elementary school teacher.

West Valley Water District



Anthony "Butch" Araiza, the longtime general manager of West Valley Water District, will reach his 50th year as an employee of the water district in June.

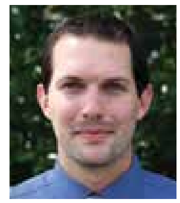
Araiza began his career with the water district in 1963. His first job with West Valley was in field maintenance, digging trenches and maintaining landscaping. Later he became a water service operator in charge of irrigation for the citrus groves within the district's boundaries. In 1971 he was promoted to assistant water superintendent, and in 1975 became the water superintendent responsible for operating the entire water system. In 1981, he became the assistant GM. In 1995, the West Valley Water District Board of Directors appointed Araiza to become the water district's general manager — a position he has held for the past 18 years.

He has been a resident of the City of Rialto for 63 years, and has no immediate plans to retire, according to the water district.

During his long career, Araiza has headed the Inland Empire Perchlorate Task Force and secured federal and state grants for new technologies to treat contaminated drinking water. Araiza also has been involved in ACWA, the Inland Counties Water Association and several other municipal organizations in the Rialto area.

Araiza's 50 years of service will be recognized at the West Valley Water District Board meeting on June 6.

Valley of the Moon Water District



Daniel Muelrath is taking over as general manager of Valley of the Moon Water District effective April 24. Muelrath was the City of Santa Rosa's Water Resources Sustainability Manager and had been with the city since 2005.

Muelrath has served as water efficiency chairman of the California/Nevada Section of the American Water Works Association and also is a member of the California Urban Water Conservation Council Board. Concurrently he has been a lecturer at Santa Rosa Junior College in water management and computer application classes.

Muelrath is replacing Krishna Kumar, who left late last year to become Marin Municipal Water District's general manager.

San Diego's Water Source Diversification Called a 'Smart Path Forward'

San Diego County Water Authority's continuing efforts to diversify the region's water supply is a model for other communities in the West, according to a report released March 26 by Carpe Diem West, a nonprofit network of water managers, scientists and conservationists.

The Bay Area group's report — New Visions, Smart Choices: Western Water Security in a Changing Climate — spotlights the measures that 10 regions are taking to ensure a reliable water supply in the future.

As recently as 20 years ago, 95% of San Diego County's water supply came from Metropolitan Water District of Southern California (MWD). The Water Authority plans for only 30% of its water supply to be imported by 2020.

San Diego County Water Authority is completing a $3.6 billion capital improvement program, which includes the nation's tallest dam raise — at San Vicente Dam — and the Twin Oaks Valley Water Treatment Plant in north San Diego County. Last fall the Water Authority signed a 30-year contract with Poseidon Resources that launched construction in Carlsbad of the largest seawater desalination plant in the Western Hemisphere. It's expected to produce water in 2016.

"San Diego's experience demonstrates that for communities reliant on imported water from vulnerable ecosystems, diversifying their supply portfolios with an emphasis on local sustainability is the smart path forward," said the Carpe Diem report.

The other nine communities profiled in the report are Salt Lake City; San Antonio; Tualatin River Valley, Ore.; the Rocky Mountain Front Range; Hayman Watershed, Colo.; Yampa River, Colo.; Santa Fe, N.M.; McKenzie Watershed, Ore. and Upper Clark Fork Basin, Mon.

CALENDAR

ACWA EVENTS   OTHER EVENTS

MAY

7 – 10 **ACWA's 2013 Spring Conference & Exhibition** is **May 7 – 10** at the Sacramento Convention Center and surrounding hotels. For more information, contact ACWA's Member Services and Events Department at events@acwa.com or 916.441.4545.

16 – 17 **Water & Agriculture: Investment Summit** is scheduled for **May 16 – 17** at the Terranea Resort, Palos Verdes. This event focuses on investment in water and agriculture-related real assets. For more information go to www.agwaterinvest.com.

22 – 23 Groundwater Resources Association, ReNUWIt and ACWA present the first symposium, **"Managed Aquifer Recharge in the Urban Environment: Technical and Policy Challenges,"** in a series on Groundwater Management on **May 22 – 23** in the Crowne Plaza San Francisco International Airport Hotel. Register at http://www.grac.org/marreg. For more information go to http://grac.org/aquiferrecharge.asp.

JUNE

17 **ACWA Region 3 / Mountain Counties Water Resources Association** will hold a joint meeting Monday, **June 17** at El Dorado Irrigation District, Placerville. For more information visit http://mountaincountieswater.com/meeting-schedule/upcoming-meetings/ or contact Executive Director John Kingsbury at johnkingsbury.mcwra@gmail.com.

25 **California Extreme Precipitation Symposium** is scheduled for **June 25** at University of California, Davis. The symposium's preliminary theme is "improving precipitation and runoff forecasts and implications for reservoir operations." Registration opens April 25. For more information, go to http://cepsym.info/.

AUGUST

14 **ACWA 2013 Regulatory Summit** is **Aug. 14** at the Embassy Suites Mandalay Beach, Oxnard. The program focus will be groundwater. For more information, contact ACWA's Member Services and Events Department at events@acwa.com or 916.441.4545.

SEPTEMBER

13 **ACWA Region 3 / Mountain Counties Water Resources Association** will hold a joint meeting Friday, **Sept. 13** at The Ridge Golf Golf Club and Events Center, Auburn. For more information visit http://mountaincountieswater.com/meeting-schedule/upcoming-meetings/ or contact Executive Director John Kingsbury at johnkingsbury.mcwra@gmail.com.

OCTOBER

3 – 4 **ACWA's 2013 Continuing Legal Education Workshop (CLE)** is **Oct. 3 – 4** in the Hyatt Regency Newport Beach. For more information, contact ACWA's Member Services and Events Department at events@acwa.com or 916.441.4545.

8 – 9 **29th Biennial Groundwater Conference & Groundwater Resources Association Annual Meeting** is scheduled for **Oct. 8 – 9** in Sacramento. For more information visit www.grac.com.

DECEMBER

3 – 6 **ACWA's 2013 Fall Conference & Exhibition** is **Dec. 3 – 6** at the JW Marriott LA Live, Los Angeles. For more information, contact ACWA's Member Services and Events Department at events@acwa.com or 916.441.4545.

Vallecitos Water District Presents Award-Winning Bus Tour

Vallecitos Water District's Academy bus tour has become a must-see attraction – garnering the California WateReuse's prestigious 2013 Recycled Water Community/Public Education Program of the Year. Geared toward enlightening customers about the complexities of maintaining reliable water and sewer services, the tour begins with a presentation and then a first-hand look at the district's 33-million and 40-million gallon capacity Twin Oaks reservoirs at the upgraded Meadowlark Water Reclamation facility in Carlsbad.

Acknowledging many worthy public agency competitors, Vallecitos Board President Jim Hernandez accepted the award at the WateReuse Association's 2013 annual conference in Monterey on March 18. WateReuse is a nonprofit trade association whose mission is to advance the beneficial uses of high-quality, locally produced, sustainable water sources for the betterment of society and the environment.

For more information or to take the tour, contact the Vallecitos Water District at (760) 744-0460.

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Positions Open

Water Resources Engineer

Merced Irrigation District

Salary DOQ ($75,527.00 to $113,291.00 annually)

The Merced Irrigation District (MID), located in California's agriculturally-rich Central Valley, is the leading provider of clean, affordable irrigation water for its 2,200 growers. The District is also the 25th largest public utility in the State, supplying electric service to commercial, industrial and residential customers in Eastern Merced County. The District also owns Lake McClure and Lake McSwain and operates five recreation areas adjacent to these facilities. Lake McClure, on the Merced River, is formed by New Exchequer Dam, a rock filled dam with a reinforced concrete face. At the base of the dam is a hydroelectric generation facility with a capacity of 94.5 MW of power. MID is within two hours of San Francisco, Sacramento, Monterey and Yosemite.

Under general direction of the Deputy General Manager, Water Resources, the Water Resources Engineer performs complex, professional engineering work related to all phases of MID water operations, including design, construction and maintenance of water storage, control, pumping and distribution systems. Represents MID in local, regional and state wide activities including coordination, planning and management of such activities. Perform work related to water balance plans, water management plans and administer reports related to water rights, consumption and water quality. Design and utilize computer models for reservoir operations and downstream flow regulation and scheduling. Participate in coordinating and reporting reservoir releases within the District and with local, state and federal agencies. Manage all aspects of engineering studies and capital projects, including the preparation and monitoring of feasibility studies, technical studies, project budgets and management of staff, consultants and vendors.

Qualifications include a minimum of 8 years of increasingly responsible experience as a professional engineer, including management and supervision of employees with a background in water resources related activities, such as reservoir operations, water balance calculations, water management plans, etc. Experience in effectively participating in or leading local and regional water resources related groups and experience with data management systems. Graduation from an accredited four-year college or university with major course work in civil engineering, agricultural engineering or related field. Master's degree is desirable.

The Merced Irrigation District is a public agency offering a competitive benefit program along with participation in California Public Employees Retirement program.

An employment application and the job description may be obtained on-line at www.mercedid.org or at 744 W. 20th St in Merced. To apply, send a complete employment application, resume, cover letter and list of four references to PO Box 2288, Merced, CA 95344 or apply@mercedid.org. Applications will be accepted until the position is filled.

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