Glendale Water and Power

141 North Glendale Ave, 4th Floor • Glendale, CA 91206

Experimental Design and Operations Plan for Hexavalent Chromium Removal using Weak-Base Anion Exchange Resin:

A Demonstration-Scale Study

October 5, 2007
Draft

Report Prepared By:

Malcolm Pirnie, Inc.

1821 Wilshire Blvd.
Suite 302
Santa Monica, CA 90403
310-829-1441

5337004

Contents

List of Tables

List of Figures

Appendices

A. Preliminary Design Report
B. Quality Assurance Project Plan
C. Pump Curve Evaluation
D. Corrosivity Evaluation of the Treated WBA Water

1. Introduction

1.1. Project Background

The City of Glendale's groundwater supplies in the San Fernando Valley have been contaminated with a wide variety of chemicals, including hexavalent chromium [Cr(VI)], trichloroethylene (TCE), perchloroethylene (PCE), 1,2,3-trichloropropane (TCP), and others, mainly as a result of the improper disposal of industrial waste products. Volatile organic compounds (VOCs) are treated with air stripping and granular activated carbon (GAC), and the treated water is served to customers. Although Cr(VI) was also found in the groundwater supplies when VOC treatment was installed, Cr(VI) levels were below the maximum contaminant level (MCL) and Cr(VI) treatment was not included with the VOC treatment facilities.

Until June 2007, the health effects of Cr(VI) in drinking water were uncertain; Cr(VI) was a proven carcinogen by inhalation but little evidence existed to demonstrate the impact of Cr(VI) by ingestion. However, a recent study conducted by the National Toxicology Program (NTP) showed that Cr(VI) is a carcinogen by ingestion in animal studies (NTP 2007). Even prior to this study, the governor of California mandated that the California Department of Public Health (DPH) establish a Cr(VI) MCL. First, the Office of Environmental Health Hazard Assessment (OEHHA) must set a public health goal (PHG), which will likely be based on the new NTP findings. In Glendale, public concern about Cr(VI) in the groundwater supply caused the city to embark on a multi-phase study to identify and install Cr(VI) treatment in anticipation of a Cr(VI) MCL lower than the current total Cr [i.e., Cr(VI) plus Cr(III)] MCL in California.

In the year 2000, the City of Glendale, along with the Cities of Los Angeles, Burbank, and San Fernando, initiated a testing program to develop a full-scale Cr(VI) treatment system capable of removing Cr(VI) to low parts-per-billion levels. The **Phase I Bench-scale study** was conducted to improve our understanding of fundamental chromium chemistry and to screen promising technologies for their ability to treat and remove Cr(VI) to very low levels. The Phase I study is complete and the final report was published by AwwaRF (Brandhuber et al. 2004). The **Phase II Pilot-scale study** was initiated in the summer of 2003 to further test the promising Cr(VI) removal technologies at the pilot scale (i.e., several gallons-per-minute flows) using Glendale groundwater. A final report on the Phase II pilot-scale study was completed in 2005 (MEC 2005). Selected results were also published in peer-reviewed scientific journals (Qin et al. 2005, McGuire et al. 2006).

The **Phase III Demonstration-scale study** will finalize the treatment evaluation, residuals assessment, and cost estimate development by implementing one or more Cr(VI) removal technologies at flows of 500 to 1,000 gpm. The initial part of the Phase III effort was designated as the Phase III Bridge project, which included additional studies to finalize testing of weak-base anion exchange resins for Cr(VI) treatment, refinement of treatment technology cost estimates based on Phase III Bridge project results, and assembly of an expert panel to recommend the one or more treatment processes for demonstration-scale testing. The Phase III Bridge project was completed in early 2007. The second part of the Phase III study, the Demonstration-scale study, is the focus of this document and will be discussed in the following sections. **Phase IV** is the construction of a full capacity system to treat all of Glendale's impacted groundwater supplies.

1.2. Project Description

The Phase III Demonstration-scale study will test Cr(VI) removal using weak-base anion exchange resin (WBA) to treat a 425 gpm well. Depending on additional funding availability, the City of Glendale may also construct a reduction/coagulation/filtration (RCF) treatment system on one or more other wells. Treated product water will have reduced Cr(VI) concentrations and will be used for human consumption after blending.

This document is intended to provide the experimental design for the WBA system, which includes the WBA process description (Chapter 2), study objectives (Chapter 3), data collection and sampling protocol (Chapter 4), and operations evaluation (Chapter 5).

The experimental plan of the RCF system is not included in this document. A separate RCF experimental plan will be developed as an additional document at a later time.

2. WBA Process Description

2.1. General

Cr(VI) removal by WBA resin is a novel application of ion exchange for drinking water treatment. Originally, WBA resin was believed to behave similarly to strong-base anion exchange (SBA) resins in terms of removal mechanism, except that the WBA resins are only useful in the acidic pH range where the functional groups are protonated and thus have positively charged exchange sites to attract Cr(VI) as chromate or bichromate anions. However, the WBA resin tested in the Phase II Pilot-scale study (Duolite A7, now called PWA7, resin provided by Rohm & Haas) showed a 20 times higher Cr(VI) removal capacity compared with five SBA resins tested (McGuire et al. 2006). Other observations, such as leakage of trivalent chromium [Cr(III)] during periods in which pH values were lower than 5.5, indicated that an ion exchange mechanism alone was not likely responsible for all of the Cr(VI) removal by WBA resin.

As part of the Phase III Bridge project, five WBA resins were tested to evaluate Cr(VI) capacity. In addition, the impact of pH on the capacity of the top performers was assessed to minimize acid addition requirements. Duolite A7 resin again showed a high Cr(VI) capacity along with another WBA resin (ResinTech SIR-700, which did not perform quite as well as the Duolite A7 initially but improved over time). Testing confirmed that more than 95% of the Cr(VI) retained on both resins was in the form of Cr(III), as observed directly by x-ray absorption spectroscopy. The true mechanism of Cr(VI) removal and retention by the WBA resins is understood to involve ion exchange followed by reduction.

To date, WBA resin has only been tested in bench- and pilot-scale studies for drinking water applications. The proposed demonstration-scale WBA system will be the first installation of this technology in drinking water treatment.

Addition design details not shown in this Experimental Plan are contained within the “Preliminary Design Report: Well GS-3 WBA Chromium 6 Removal Facility” (Malcolm Pirnie, 2007a; Appendix A) or the Detailed Design Drawings.

2.2. Location of the WBA System

The WBA system is proposed to be located at the Glendale South Operable Unit well site GS-3 adjacent to Goodwin Street in the City of Los Angeles. The well site area is a paved truck parking area that is part of a large Ralph’s Grocery Distribution Center. The City of Glendale has an easement within the Ralph’s property. The area is paved with asphalt concrete and is relatively flat. Well GS-3 has a capacity of 425 gpm and is one of the high Cr(VI) concentration wells, with a current Cr(VI) concentration of approximately 35 µg/L. The zoning in the area is manufacturing/commercial. Figure 2-1 shows an aerial photo of the GS-3 well site. Figure 2-2 shows the proposed WBA facility site layout with the property easement boundaries.

The GS-3 site was selected for the WBA system demonstration-scale study for the following reasons: (1) the GS-3 well is one of the high Cr(VI) wells, with a current Cr(VI) concentration of approximately 35 µg/L; (2) a pair of unused GAC vessels at the GS-3 well site can be retrofitted for WBA resin, thus minimizing the capital costs for ion exchange vessels.

Figure 2-1: Aerial photo of the GS-3 well site

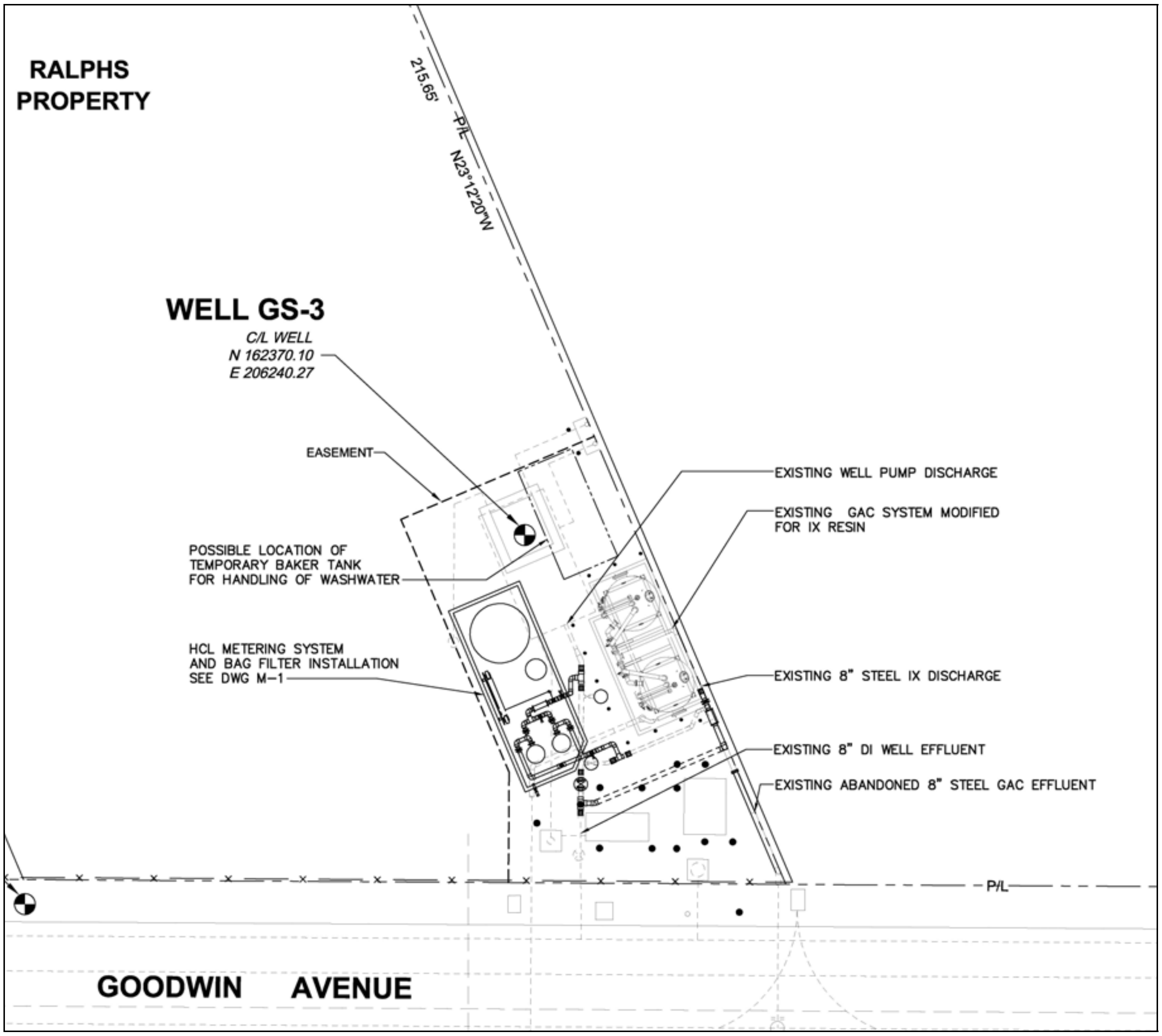


Figure 2-2: WBA facility site layout with property easement boundaries

2.3. WBA Process Components

Figure 2-3 provides a process flow schematic for the WBA system. The system will consist of a pair of lead/lag vessels with upstream acid addition. Due to its high capacity and difficulty in regeneration, WBA resin will be used as a once-through, non-regenerable media.

The major components of the WBA system are briefly described in the following sections. Note that the WBA system design parameters presented below are conceptual only. The construction of the WBA system should follow the detailed design report prepared by the selected contractor.

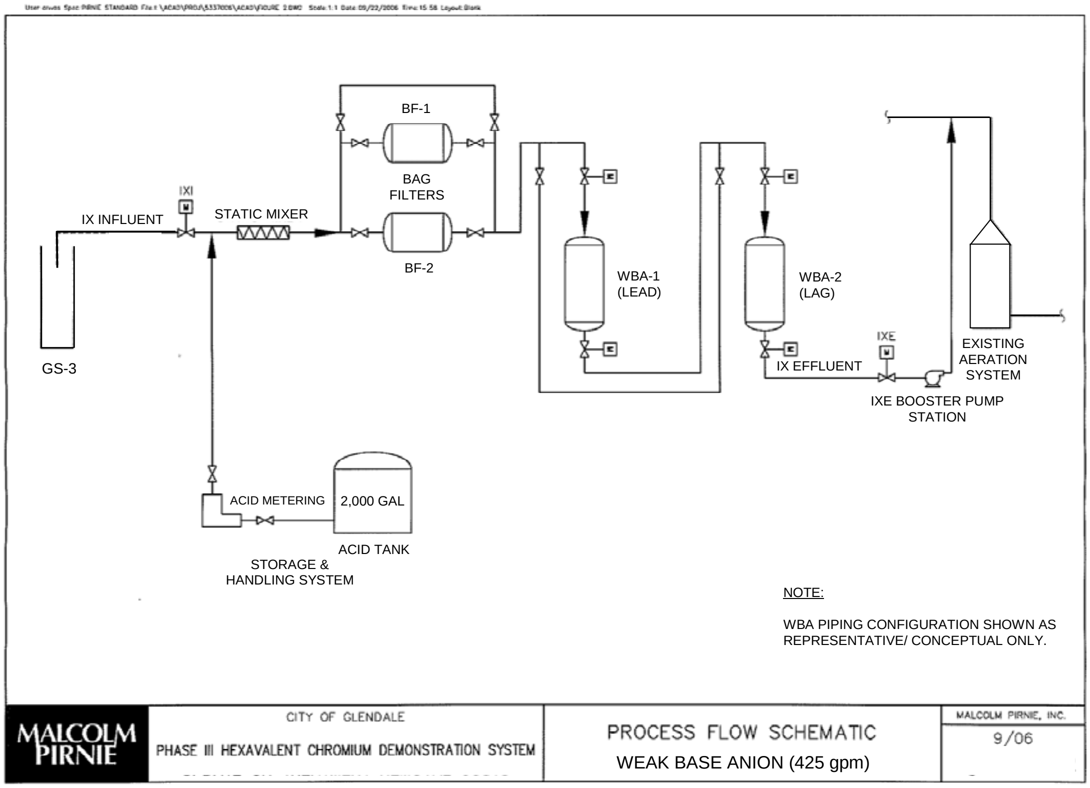


Figure 2-3: Process flow schematic of the WBA system

2.3.1. Ion Exchange (IX) Vessels

The City of Glendale installed two steel vessels adjacent to the Well GS-3 site several years ago for granular activated carbon (GAC) treatment of VOCs. This system was never used for several reasons, including a short-term program to reduce pumping from Well GS-3 and other high Cr(VI) wells and increase pumping from the low Cr(VI) wells. This operational strategy, however, was allowed only temporarily under an agreement with the EPA.

For the demonstration-scale study, the two 8-ft. diameter vessels will be retrofitted to support resin material for Cr(VI) removal. The retrofitted IX vessels will have sample ports to accommodate sampling at the 50% bed depths and on effluent piping of each vessel.

Siemens (formerly US Filter) and Rohm & Haas recommend a volumetric design flow rate for the WBA resin of approximately 2.5 gpm per cubic feet and bed volumes of 185 cubic feet for the 8-ft diameter vessel.

2.3.2. Acid Feed and Control System

The acid feed and control system will be used to inject hydrochloric acid (HCl) into the GS-3 well water to obtain a pH of 6.0. The operating pH of 6.0 was determined to be effective for Cr(VI) removal during the Phase III Bridge project. Major components of the acid feed and control system include an acid storage tank, chemical feed pump(s), an online pH probe, and programmable logic controller (PLC).

Acid requirements for pH depression to 6.0 are approximately 69 mg/L of 36% HCl per gallon of water treated. The daily acid usage for the 425 gpm design flow rate is therefore approximately 100 gallons per day (gpd).

The acid storage tank will have a capacity of 2,000 gallons, with secondary containment and a scrubber system for acid vapor. This volume will provide at least a two week supply of acid.

Two variable speed metering pumps (one operating and one standby) will be located adjacent to the acid storage tank to pump HCl into the raw well water. The chemical pump speed will be flow paced.

2.3.3. WBA Backwash System

The WBA vessels will have the capability for backwashing the resin. Backwash supply water will be provided from the common GS wells' transmission line. Once the headloss across the media bed exceeds a pre-defined value (TBD), backwashing will be initiated. Waste backwash water from the WBA vessels will flow to a temporary roll-off containment tank and then slowly into the sewer.

3. Study Objectives

The objectives of the Phase III Demonstration-scale WBA study include the following:

- Evaluate Cr(VI) removal capacity of WBA resin at the demonstration-scale (approximately 425 gpm) and the ability to scale-up bench and pilot results;
- Quantify demonstration treatment performance with respect to Cr(VI) removal over extended periods of time (i.e., at least one year);
- Assess the impact of WBA resin treatment on finished water quality, including any leaching of nitrosamines, and develop mitigation strategies;
- Optimize day-to-day operations of the WBA treatment system and develop a comprehensive operations and maintenance manual;
- Assess the reliability of the demonstration-scale WBA technology during a year of operations and identify necessary backwashing or fluffing frequency;
- Confirm residuals optimization and disposal strategies identified in the Phase III Bridge project;
- Verify unit cost information developed in the pilot study with actual treatment costs; and
- Publicly disseminate project plans and findings to a wide audience, including water agencies also concerned with Cr(VI) in water supplies, California DPH, the USEPA, and consumers.

4. Data Collection and Study Protocol

Evaluation of WBA exchange resin for Cr(VI) removal at the demonstration scale will focus on the measurement of key chemical and process parameters to fully test the utility of the treatment process. Of critical importance, Cr(VI) and total Cr concentrations in influent, 50% bed depth, lead vessel effluent, and lag vessel effluent water samples will be monitored. In addition, other process-related parameters and water quality constituents described below will be measured to assess operational effectiveness of the WBA technology and its impact on water quality.

The sections below provide an overview of the data collection and study protocol for the WBA system, which includes monitoring parameters, locations, frequency, and analytical approach. The comprehensive data collection and management plan is contained within the document entitled “The Treatment of Hexavalent Chromium in the City of Glendale Ground Water Supply: Phase III Demonstration-Scale WBA Resin Treatment Technology Evaluation – Quality Assurance Project Plan” (QAPP, Malcolm Pirnie 2007b). The QAPP is provided as Appendix B in this Experimental Design document.

4.1. Monitoring Parameters

4.1.1. Water Quality Parameters

Critical water quality parameters for the demonstration-scale WBA system include Cr(VI), total Cr, and pH. Pilot testing highlighted the importance of pH depression and constant pH control for the effective operation of WBA resin.

Other chemical and physical parameters, including temperature, conductivity, turbidity, and alkalinity, will be routinely measured. Anions that may impact ion exchange, such as sulfate, nitrate, and silicate, will be monitored. Nitrosamines, which have been found to leach from ion exchange resins, will be monitored during WBA facility startup to determine the amount of time necessary to flush the resins.

Table 4-1 summarizes the proposed sampling parameters for the Phase III WBA Demonstration-scale study.

4.1.2. Process Parameters

In addition to chemical and physical water quality analyses, process-related parameters will be recorded to evaluate the operations of the WBA system. The process-related parameters include flow rate, system pressure, headloss through the bag filters and resin vessels (both lead and lag vessels), backwash frequency, empty bed contact time (EBCT), numbers of bed volumes to breakthrough (> 5µg/L), numbers of bed volumes to 50% saturation of the lead vessel, and HCl feed rate and volume use rate.

4.1.3. Treatment Residuals

Treatment residuals, including exhausted ion exchange resin and backwash water, will also be assessed to confirm disposal options using the Toxicity Characteristic Leaching Procedure (TCLP, EPA Method 1311 as mandated by 40 CFR 261) and the California Waste Extraction Test (CWET). Pilot-scale testing indicated that the spent WBA resins would likely be classified a hazardous waste in the State of California based on total chromium concentrations leached during the California WET test. Uranium accumulated on the spent WBA resin will also be determined throughout the testing; PWA7 resin may need to be replaced prior to 50% resin breakthrough to avoid uranium concentrations exceeding 500 mg/kg (i.e., the threshold above which the waste could be classified a low-level radioactive waste). Table 4-1 also lists the required measurements for the treatment residuals

Table 4-1.
Analytical measurements for the WBA demonstration-scale study, identified as Critical (C) and non-critical (N/C) measurements

Sampling Types and Locations	Cr(VI)	Total Cr	pH	Temp.	SO_4^{2-}	NO_3^-	PO_4^{3-}	SiO_2	Alk-alinity	Cond-uctivity	Turb-idity	Nitros-amines	TCLP, WET tests	Ura-nium
Raw water (before pH adjustment)			N/C											
Influent (after pH adjustment)	C	C	C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	C		
Lead Vessel 50% bed depth	N/C	N/C												
Lead Vessel Effluent	C	C	C	N/C										
Lag Vessel 50% bed depth	N/C	N/C												
Lag Vessel Effluent	C	C	C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	C		
Residuals (spent resin)													C	C
Residuals (backwash water)		C												

4.2. Monitoring Locations

All the samples collected for analysis will be obtained from the demonstration-scale study site at GS-3. Figure 4-1 shows a schematic of the WBA system with sampling ports for water quality parameters highlighted. Table 4-1 also lists the sampling locations.

Sampling locations for the WBA treatment system include raw water (before acid addition, designated as Sample Port 1, or SP-1), WBA influent (after acid addition, SP-2), lead vessel 50% bed depth (SP-3), lead vessel effluent (SP-4), lag vessel 50% bed depth (SP-5), and lag vessel effluent (SP-6).

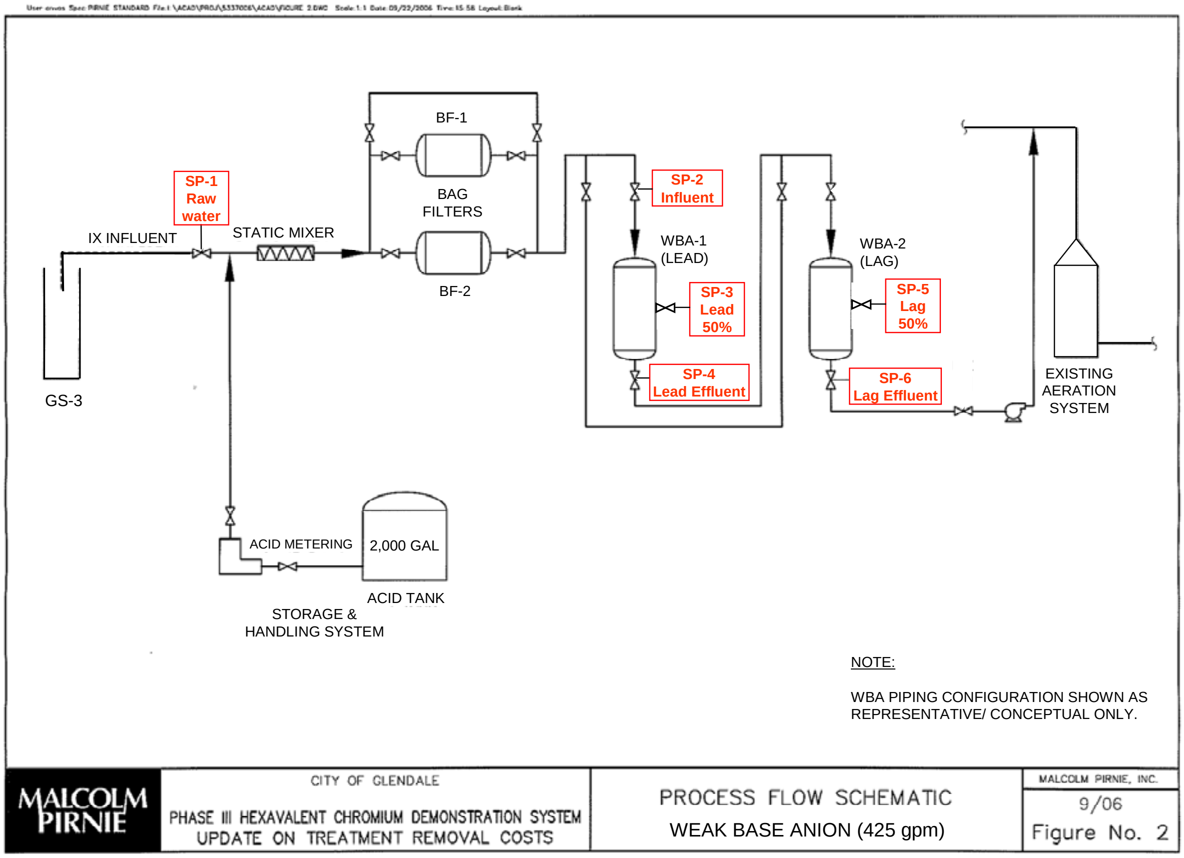


Figure 4-1: Sampling locations for water quality parameters (highlighted in red)

4.3. Monitoring Frequency

4.3.1. Water Quality Parameters

The planned sampling frequency for chemical and physical parameters, shown in Table 4-2, is based on treatment process design and the expected duration of testing (approximately one year for the demonstration-scale study). Samples will be collected at a sufficient frequency to provide enough information to achieve the project's stated objectives. For a predicted bed life of 207 days (based on maximum uranium accumulation), the chromium sampling frequency will capture a 29-point breakthrough curve.

The weekly Cr(VI) and total Cr sampling frequency will be established for the following key sampling points:

- WBA influent
- Lead vessel 50% bed depth
- Lead vessel effluent
- Lag vessel effluent

Once breakthrough occurs such that the lead bed effluent Cr concentration exceeds 5 μg/L, the lag vessel 50% depth location will be added to the list of sampling points monitored weekly and the lead vessel 50% depth curtailed (until the next bed is installed and the lead and lag vessel order is changed).

pH, which is a critical parameter due to its impact on WBA resin treatment, will be measured continuously at a point near the influent sampling point. Note that sufficient mixing is necessary to enable capture of stable pH values representative of the influent to the WBA resin; thus, acid will be added upstream of the bag filters and samples collected after the bag filters and before the lead vessel inlet. pH of lead and lag vessel effluent will be monitored on a weekly basis to evaluate the corrosion potential of the treated effluent on the transmission pipes.

Nitrosamines will be measured during the first week of startup according to California DPH permit requirements.
Non-critical parameters, including temperature, sulfate, nitrate, phosphate, silicate, alkalinity, conductivity, and turbidity, will be measured monthly at the following sampling points:

- Influent
- Lag vessel effluent

The proposed sampling frequencies for the water quality parameters are summarized in Table 4-2.

4.3.2. Process Parameters

Process-related parameters of the WBA system, such as flow rate and head loss, will be measured on a daily basis to determine the initiation of backwash and replacement of bag filters.

4.3.3. Treatment Residuals

The analyses of resin residuals will be performed each time resin changeout is required. Backwash water will be analyzed periodically as specified in the discharge permit.

Table 4-2.
Monitoring locations and frequencies for water quality parameters

Analytical Measurements	**Monitoring Locations and Frequency**					
	SP-1: Raw water (before acid addition)	**SP-2:** WBA Influent (after acid addition)	**SP-3:** Lead vessel 50% bed depth	**SP-4:** Lead vessel effluent	**SP-5:** Lag vessel 50% bed depth	**SP-6:** Lag vessel effluent
Cr(VI)	Monthly	Weekly	Weekly	Weekly	Weekly*	Weekly
Total Cr	Monthly	Weekly	Weekly	Weekly	Weekly*	Weekly
pH	/	Continuously	/	Weekly	/	Weekly
Temperature	/	Continuously	/	Weekly	/	Weekly
SO_4^{2-}	/	Monthly	/	/	/	Monthly
NO_3^-	/	Monthly	/	/	/	Monthly
PO_4^{3-}	/	Monthly	/	/	/	Monthly
SiO_2	/	Monthly	/	/	/	Monthly
Alkalinity	/	Monthly	/	/	/	Monthly
Conductivity	/	Monthly	/	/	/	Monthly
Turbidity	/	Monthly	/	/	/	Monthly
Nitrosamines	/	Start of test[a]	/	Start of test	/	Start of test

[a] Nitrosamines will be analyzed at a frequency required by the DPH permit

* Samples collected only when the lead vessel effluent exceeds 5 μg/L.

4.4. Analytical Approach

The analytical methods for the water quality parameters and treatment residuals will conform to EPA guidelines and recommended test methods, including those in *Standard Methods for the Examination of Water and Wastewater* (APHA 1999). This section briefly describes the analytical approach used in the demonstration-scale study. More detailed information can be found in the QAPP mentioned above.

Chemical and physical analytes will be measured in this demonstration-scale study either in the field or in a laboratory. Laboratory analytical measurements will be sent to one of three labs:

- Truesdail Laboratories, Inc. – for Cr(VI), total Cr, and nitrate
- Montgomery Watson Harza Laboratories – for nitrosamines

- Severn Trent – for TCLP, CWET, and uranium in residuals

The laboratory analyses of total chromium (a California DPH regulated constituent) will be performed by ICP-MS (EPA Method 200.8). Cr(VI) will be analyzed using EPA Method 218.6, which is an ion chromatography method. Nitrate will be analyzed using Method 300.0. Nitrosamines will likely be measured with EPA Method 521 (depending on method availability). Treatment residuals from the WBA treatment process will be analyzed for TCLP (metals), CWET (metals), and uranium analyses prior to disposal. All other parameters will be analyzed using the methods shown in Table 4-3.

Table 4-3.
Analytical methods and locations of analyses for the demonstration-scale study

Sample Analysis	Analytical Method	Analysis Location
Cr(VI)	EPA 218.6 (IC)	ELAP-certified Lab
Total Cr (contract lab for compliance)	EPA 200.8 (ICP-MS)	ELAP-certified Lab
SO_4^{2-}	Hach 8051 (Colorimetric)	Field
NO_3^-	EPA 300.0 (IC)	ELAP-certified Lab
PO_4^{3-}	Hach 8048 (Colorimetric)	Field
SiO_2	Hach 8185 (Colorimetric)	Field
Alkalinity	Hach 8203 (Titration)	Field
Conductivity	SM 2510B (Conductance)	Field
pH	SM 4500H+ B (Electrometric)	Field
Temperature	SM 2550 (Thermometric)	Field
Turbidity	SM 2130 B	Field
Nitrosamines	EPA 521	ELAP-certified Lab
Residuals – TCLP	EPA 1311	ELAP-certified Lab
Residuals – CWET	CWET Test (Title 22)	ELAP-certified Lab
Residuals: Uranium	ASTM5174-91 (KPA method)	ELAP-certified Lab

5. Operations Evaluation

In addition to the water quality issues, ongoing operations and maintenance (O&M) of the demonstration-scale WBA system will be constantly evaluated to optimize the system performance, minimize the negative impact on the distribution system, and reduce the O&M cost of the WBA system.

5.1. O&M Manual

As part of the demonstration study, a draft O&M manual will be prepared along with the experimental plan. The O&M manual will serve as a resource in the operation and maintenance of the demonstration-scale WBA system for the facility operators. In order to achieve optimized system performance, the manual will be updated regularly during the demonstration study to reflect the changes in operational conditions and maintenance schedules. A final O&M manual will be prepared after the demonstration study based on lessons learned.

Components of the O&M manual for the WBA system include, but are not limited to, the following:

- Background on the goals and objectives of the demonstration study
- Description of the WBA technology, including all process components
- Process and instrumentation diagrams (P&IDs)
- Maintenance schedule for all process components
- Replacement schedule or triggers for replacing all process components with a limited life
- Training documents for operations staff, including duties, responsibilities, chain-of-command, and health and safety plan
- Standard Operating Procedures (SOPs), including site inspection sheets, calculations for determining dose rates of acid, procedures for chemical deliveries, procedures for waste handling and disposal, spill control actions, safety information on chemicals, and staffing and emergency call-out procedures
- Notification procedures in case of a chemical feed problem, and
- Reference to QAPP, which contains field and laboratory analytical and sampling procedures and record keeping requirements

5.2. Facility Operation Evaluation

5.2.1. Pump Evaluation

One operational issue associated with the installation of a demonstration-scale WBA system at the GS-3 site will be the pump hydraulics (i.e., projected pumping capacity). As part of the preliminary design of the GS-3 WBA treatment system, we evaluated the hydraulics of the current pump in GS-3 and the system losses expected from the new facilities to determine the projected pumping capacity.

Figure 5-1 shows the current GS-3 pump curve from a test performed in June 2007 by CDM (dark blue line). To bracket the range, two roughness coefficients (C=130 and 100) and two main pressures (45 and 55 psi) were used in the pump curve evaluation. According to the figure, the GS-3 pump has an estimated operating range of between 550 to 600 gpm at 100% pump speed.

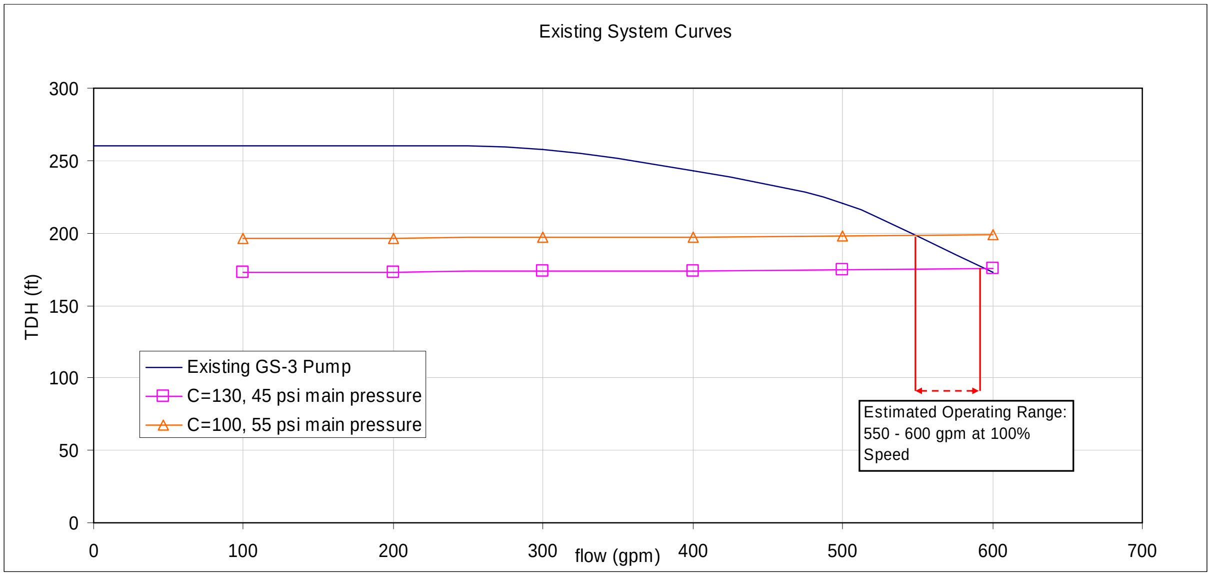


Figure 5-1: Existing system curves for the GS-3 pump without the WBA facility

The addition of a WBA treatment system between the well and the main will introduce pressure losses, due to the bag filters, ion exchange resin beds, and additional piping. For example, the bag filters are estimated to have a 2 psi drop across the filter housing when the filters are clean, and up to a 10 psi drop for dirty filters (i.e., the point at which filter change-out is recommended by the vendor). Figure 5-2 shows the intersection of the actual GS-3 pump curve (dark blue line) and manufacturer provided pump curve (light blue line) with the upper and lower range for the system curves. The upper range is based on clean bag filters (2 psi differential) and the estimated best-case main pressure (45 psi) and C factor (130). The lower range is based on dirty bag filters (10 psi differential) and the estimated worst case main pressure (55 psi) and C factor (100). The estimated operating range for the pump is between 250 and 480 gpm at 100% pump speed.

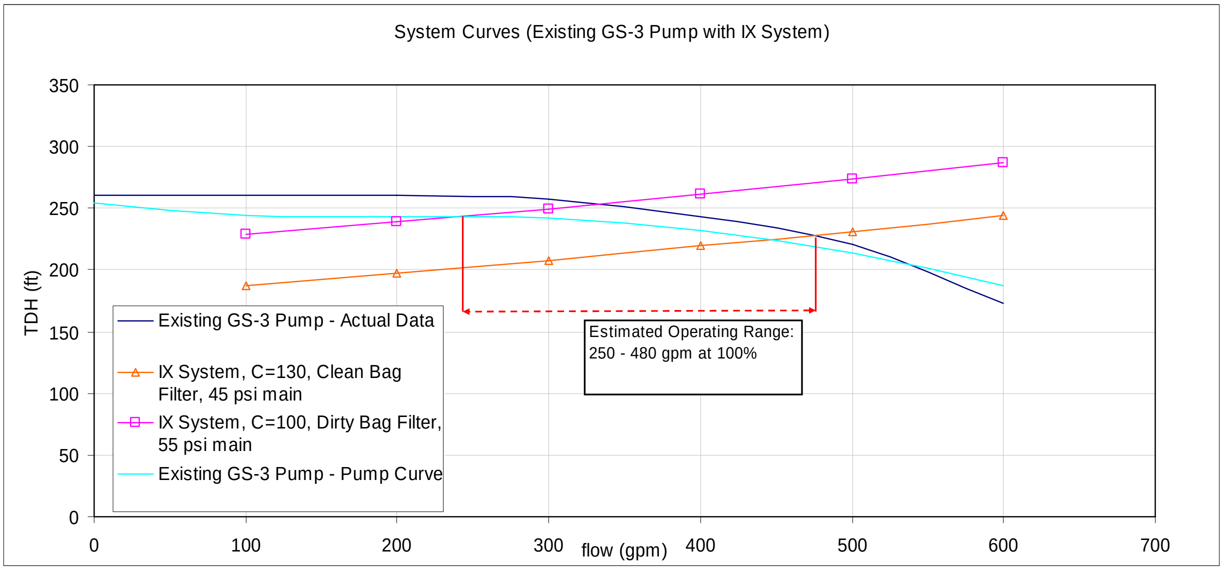


Figure 5-2: Predicted system curves for the GS-3 pump with the WBA facility

Although the pressure losses in the WBA facility will limit the flow compared with the current possible flow capacity of the existing GS-3 pump, Glendale decided to proceed with the preliminary design of the WBA system using the existing GS-3 pump of the existing GS-3 pump. It was noted that pressure losses in the WBA facility will limit the flow compared with the current possible flow capacity of the existing GS-3 pump. However, flow limitations might be overcome during the demonstration-scale study by replacing bag filters on a more frequent basis. The reasons behind that recommendation can be found in a technical memorandum entitled “Pump Curve Evaluation and Decision” submitted to Glendale (Malcolm Pirnie 2007c, Appendix C).

To evaluate the pump hydraulics in the demonstration study, pressure drops and flow rate readings will be recorded on a daily basis.

5.2.2. Backwash and Bag Filter Change Frequency

The frequencies of resin bed backwash and bag filter change are related to the pump hydraulics as described above. For example, flow limitations might be overcome during the demonstration-scale study by replacing bag filters on a more frequent basis (i.e., replacing the dirty filters once 5 psi pressure drop is observed instead of 10 psi). More frequent backwash of the resin bed is also expected to improve the system production capacity. One task of the operational evaluation will then focus on finding the necessary bag filter replacement frequency to maximize treated water flow. The frequencies bag filter changes and any necessary backwashing will be recorded as a part of the operations evaluation.

5.2.3. Corrosivity of the WBA Treated Effluent

The WBA resin was found to require pH reduction for effective use; a pH of 6.0 was shown to both remove Cr(VI) to levels below the treatment goal of 5 μg/L and to maximize Cr(VI) capacity of the resin. In the demonstration study, hydrochloric acid will be injected into the GS-3 well water (originally at a pH of approximately 6.8) upstream of the IX vessels to maintain a constant pH of 6.0. As shown in pilot testing, the pH does not change significantly as the water passes through the IX beds; consequently, the WBA treated water will have a pH of approximately 6.0. The potential for increased corrosivity (due to reduced pH) of this water was another operational concern of the demonstration-scale system.

Based on a technical memorandum prepared by Malcolm Pirnie (2007d, Appendix D), the raw GS-3 well water was already corrosive with respect to calcium carbonate under ambient groundwater conditions [Langelier Saturation Index (LSI) of -0.43 and Calcium Carbonate Precipitation Potential (CCPP) of -34 mg/L]. The addition of WBA treatment, including pH adjustment, will increase the magnitude of the negative LSI and CCPP values to -1.51 and -162 mg/L, respectively (and -1.05 LSI and -101 mg/L CCPP for GS-3 water blended with GS-4 water). However, the impact of this change on the corrosivity of the water toward the cement-mortar lined transmission line is uncertain. This analysis indicated that even raising the pH of the WBA-treated water back to the ambient groundwater pH level of 6.8 would result in original conditions that were corrosive to the mortar lining of the pipes.

Visual inspection of the pipeline condition before and after the demonstration-scale study is strongly recommended to evaluate the impact of WBA treated effluent on the pipeline and the necessity of pH adjustment after treatment.

5.3. Facility Cost Evaluation

The proposed demonstration study breaks new ground by testing the first treatment technology for Cr(VI) removal to low levels in drinking water. Actual cost information from the demonstration-scale study will be valuable to other water utilities requiring Cr(VI) treatment and to the California DPH, who will be charged with setting an MCL for Cr(VI).

During the demonstration study year of operations, the following cost components will be tracked carefully and compiled at the end of the study to provide detailed cost information associated with the demonstration-scale WBA system.

5.3.1. Capital Costs

The capital costs for the demonstration-scale WBA system will be tracked using various tools. Copies of all contracts and invoices (e.g., invoice for WBA resin) will be stored in a single place and managed by dedicated personnel.

5.3.2. O&M Costs

5.3.2.1. Staffing Requirements

Glendale operations staff (mostly sub-contracted to CDM) will record the time spent on routine O&M of the WBA system on a daily basis. In case of an emergency related to the WBA system (e.g., acid feed problem), the operators will also record the time spent to resume the system operation.

5.3.2.2. Acid Dosage

Acid dosage required for the WBA system operation will be tracked along with the volumes used. The volume of acid transferred to the acid storage tank will be recorded each time the acid is delivered to the GS-3 site. In addition, the Glendale operating staff will record the level in the acid storage tank on a daily basis.

5.3.2.3. Resin Changeout Frequency

Based on the pilot testing results, the WBA resin will be changed out approximately every 207 days. In the demonstration study, Glendale staff will record the date and time of each resin changeout event and confirm the amount of resin loaded to the ion exchange vessels.

5.3.2.4. Backwash Water Quantity

Resin backwash may be necessary to reduce any pressure buildup in the vessels. In order to quantify the costs associated with the backwash process, the following information will be recorded for each backwash event: backwash date and time, duration, flow rate, and total volume of water used.

6. References

APHA, AWWA, and WEF. 1995. Standard Methods for the Examination of Water and Wastewater, 19th ed. American Public Health Association, Washington, DC, 1995.

Brandhuber, P.; Frey, M.; McGuire, M.J.; Chao, P.; Seidel, C.; Amy, G.; Yoon, J.; McNeill, L.; Banerjee, K. 2004. Treatment Options for Low-Level Hexavalent Chromium Removal Tested at Bench Scale. Denver, Colo.: AwwaRF.

EPA. 1993. Method 300: Determination of Inorganic Anions in Drinking Water by Ion Chromatography. EPA-600/R-93-100.

EPA. 1994. Method 200.8: Determination of Trace Elements in Waters and Wastes by Inductively Coupled Plasma – Mass Spectrometry. EPA-600/R-94/111.

EPA. 1994. Method 218.6: Determination of Dissolved Hexavalent Chromium in Drinking Water, Groundwater, and Industrial Wastewater Effluents by Ion Chromatography.

Malcolm Pirnie, Inc. 2007a. Preliminary Design Report: Well GS-3 WBA Chromium 6 Removal Facility. Technical memorandum submitted to the City of Glendale on October 2, 2007.

Malcolm Pirnie, Inc. 2007b. Quality Assurance Project Plan: Phase III Demonstration-Scale WBA Resin Treatment Technology Evaluation. Submitted to the EPA on September 18, 2007.

Malcolm Pirnie, Inc. 2007c. Pump Curve Evaluation and Decision. Technical memorandum submitted to the City of Glendale on July 2, 2007.

Malcolm Pirnie, Inc. 2007d. Corrosivity of the Proposed WBA Resin Treated Effluent due to Acid Addition. Technical memorandum submitted to the City of Glendale on September 24, 2007.

McGuire, M.J.; Blute, N.K.; Seidel, C.; Qin, G.; Fong, L. 2006. Pilot-Scale Studies of Hexavalent Chromium Removal from Drinking Water. *Jour. AWWA.* 98(2):134-143.

McGuire, M.J., Blute, N.K., Qin, G., Kavounas, P., Froelich, D., Fong, L. 2007. Hexavalent Chromium Removal from Drinking Water Using Weak- and Strong-Base Ion Exchange and Reduction/Coagulation/Filtration. Denver, Colo.: AwwaRF.

McGuire Environmental Consultants, Inc. (MEC) 2005. The Treatment of Hexavalent Chromium (Cr(VI)) in the City of Glendale Groundwater Supply: Phase II Demonstration of Pilot-Scale Treatment Technologies. Final report submitted to the City of Glendale. Glendale, CA.

National Toxicology Program (NTP), 2007. Technical Report on the Toxicology and Carcinogenesis Studies of Sodium Dichromate Dihydrate in F344/N Rats and B6C3F1 Mice. Draft.

Qin, G.; McGuire, M.J.; Blute, N.K.; Seidel, C.J.; Fong, L. 2005. Hexavalent Chromium Removal by Reduction with Ferrous Sulfate, Coagulation, and Filtration: A Pilot-Scale Study. *Environ. Sci. Technol.* 39(16):6321-6327.

Appendix A – Preliminary Design Report

City of Glendale Water and Power
141 N. Glendale Ave. • Level 4 • Glendale, CA 91206

Preliminary Design Report: Well GS-3 WBA Chromium 6 Removal Facility

Final
October 2, 2007

Report Prepared By:

Malcolm Pirnie, Inc.

1821 Wishire Blvd.
Suite 302
Santa Monica, CA 90403
310-829-1441

5337008

Table of Contents

List of Figures

List of Tables

Appendices

1. Civil Site Plan
2. Mechanical Plan
3. Instrumentation and Control Process Flow Diagram
4. Rohm & Haas PWA7 Product Data Sheet

1. Introduction

The City of Glendale's groundwater supply in the San Fernando Valley has been contaminated with a wide variety of chemicals, including hexavalent chromium [Cr(VI)], trichloroethylene (TCE), perchloroethylene (PCE), 1,2,3-trichloropropane (TCP), and others, mainly as a result of the improper disposal of industrial waste products.

A recent study conducted by the National Toxicology Program (NTP)[1] showed that Cr(VI) is a carcinogen by ingestion in animal studies, and recent legislation in California has mandated that the California Department of Public Health establish a Cr(VI) Maximum Contaminant Level (MCL). In Glendale and other cities such as Los Angeles and Burbank in the San Fernando Valley, public concern about Cr(VI) in the groundwater supply led the city to embark on a multi-phase study to identify and install Cr(VI) treatment in anticipation of a Cr(VI) MCL lower than the current total Cr MCL in California.

In the year 2000, the City of Glendale, along with the Cities of Los Angeles, Burbank, and San Fernando, initiated a testing program to develop a full-scale Cr(VI) treatment system capable of removing Cr(VI) to low parts-per-billion levels. The **Phase I Bench-scale study** was conducted to improve our understanding of fundamental chromium chemistry and to screen promising technologies for their ability to treat and remove Cr(VI) to very low levels. The Phase I study is complete and the final report was published by AwwaRF.[2] The **Phase II Pilot-scale study** was initiated in the summer of 2003 to further test the promising Cr(VI) removal technologies at the pilot scale (i.e., several gallons-per-minute flows) using Glendale groundwater. A final report on the Phase II pilot-scale study was completed in 2005.[3] Selected results were also published in peer-reviewed scientific journals.[4,5]

The **Phase III Demonstration-scale study** will finalize the treatment evaluation, residuals assessment, and cost estimate development by implementing one or more Cr(VI) removal technologies at flows of approximately 500 to 1,000 gpm. The initial part of the Phase III effort was designated the Phase III Bridge Project, which included additional studies to finalize testing of weak-base anion exchange resins for Cr(VI) treatment, refinement of treatment technology cost estimates based on Phase III Bridge Project results, and assembly of an Expert Panel that recommended to Glendale construct a demonstration-scale reduction-coagulation-filtration (RCF) treatment system and further evaluate weak-base anion exchange. The Phase III Bridge Project was completed in early 2007.

The City selected the construction of the test weak-base anion (WBA) exchange system at Well Site GS-3 using an existing 400-500 gpm well and the RCF system adjacent to the existing Glendale Water Treatment Plant. The purpose of this report is to identify the design criteria that will be used for the facility that will demonstrate the effectiveness of WBA resin in removing Cr(VI) to low parts-per-billion levels. Treated water will be put to beneficial use by serving Glendale's consumers. Treatment cost information developed in the Phase II Pilot-scale and Phase III Bridge studies will be updated as a result of this effort, and this information intended to be of use to other utilities requiring Cr(VI) treatment and to the state of California in setting a Cr(VI) MCL.

To date, WBA has only been tested in bench- and pilot-scale studies. The proposed demonstration-scale WBA system will be the first installation of this technology in a drinking water treatment application.

The WBA system that will be constructed and tested in the Phase III Demonstration-scale study will consist of the following major components:

- Modification of existing Vessels for ion exchange treatment (two 8-ft. diameter vessels each containing WBA resin)
- Bag filters (two parallel filter housings containing 10-micron filters),
- Hydrochloric acid storage tank, and
- Acid feed and control system

The system will consist of a pair of lead/lag vessels installed in series with upstream acid addition. Based on pilot studies, the pH of the raw water must be lowered to approximately a pH of 6.0. Due to its high capacity and difficulty in regeneration, WBA resin will be used as a once-through, non-regenerable media.

The WBA system will be located at the GS-3 well site adjacent to Goodwin Street in the City of Los Angeles. The GS-3 well was selected for testing the WBA demonstration-scale system for two primary reasons: (1) GS-3 is one of the high Cr(VI) wells, with a current Cr(VI) concentration of approximately 35 μg/L; and (2) a pair of unused GAC vessels exist at the GS-3 well site and can be retrofitted for WBA resin, thus minimizing capital costs for ion exchange (IX) vessels.

---

[1] National Toxicology Program (NTP), 2007. Technical Report on the Toxicology and Carcinogenesis Studies of Sodium Dichromate Dihydrate in F344/N Rats and B6C3F1 Mice. Draft.

[2] Brandhuber, P.; Frey, M.; McGuire, M.J.; Chao, P.; Seidel, C.; Amy, G.; Yoon, J.; McNeill, L.; Banerjee, K. 2004. Treatment Options for Low-Level Hexavalent Chromium Removal Tested at Bench Scale. Denver, Colo.: AwwaRF.

[3] McGuire Environmental Consultants, Inc. (MEC) 2005. The Treatment of Hexavalent Chromium (Cr(VI)) in the City of Glendale Groundwater Supply: Phase II Demonstration of Pilot-Scale Treatment Technologies. Final report submitted to the City of Glendale. Glendale, CA.

[4] Qin, G.; McGuire, M.J.; Blute, N.K.; Seidel, C.J.; Fong, L. 2005. Hexavalent Chromium Removal by Reduction with Ferrous Sulfate, Coagulation, and Filtration: A Pilot-Scale Study. *Environ. Sci. Technol.* 39(16):6321-6327.

[5] McGuire, M.J.; Blute, N.K.; Seidel, C.; Qin, G.; Fong, L. 2006. Pilot-Scale Studies of Hexavalent Chromium Removal from Drinking Water. *Jour. AWWA.* 98(2):134-143.

2. Design Parameters

The treatment concept for the Glendale WBA treatment facility is based on retrofitting existing GAC vessels with WBA IX resin for removal of Chromium 6. The facility will consist of the following:

- Existing GAC vessels retrofitted with IX resin
- Bag filters for particulate removal
- Hydrochloric acid (HCl) feed facilities for pH adjustment.

IX Vessels

Two existing GAC vessels will be operated in series in a lead and lag configuration. The facility will initially be sized for the design flow with facility storage and pipes sized to accommodate the ultimate design flow. The system is designed as a demonstration scale facility that will have a limited operating period. It is not expected that the facility will need to be in operation for 30 or more years, so the construction material choices are based on a limited life cycle demonstration facility. The design criteria for the IX vessels are based on the criteria in Table 2-1.

Table 2-1.

Design Criteria for Retrofitted IX Vessels

Parameter	IX Vessel (each)
Ultimate Design Flow	600 gpm
Design Flow	425 gpm
IX Loading Rate	2.5 gpm/cf
Required Usable IX Volume at Ultimate Design Flow	240 cf
Required Usable IX Volume at Design Flow	170 cf
Vessel Diameter	8 ft.
Vessel Total Straight Shell Height	7 ft.
Vessel Rounded Bottom Height	2 ft.
Unusable Volume From Bottom of Vessel to Top of Nozzle	1 ft.
Unusable Resin Below Nozzle	15 cf
Total IX Resin Required at Ultimate Design Flow	255 cf
Total IX Resin Required at Design Flow	185 cf

Parameter	IX Vessel (each)
Straight Shell Depth of Resin at Ultimate Design Flow	4.08 ft.
Available Bed Expansion at Ultimate Design Flow	42%
Straight Shell Depth of Resin at Design Flow	2.68 ft.
Available Bed Expansion at Design Flow.	62%
Minimum Required Backwash Rate for 60% Bed Expansion	3.5 gpm/sf (176 gpm)
Backwash Supply	Existing 8" Water Main
IX Resin	Rohm & Haas PWA7 or ResinTech SIR-700[i]
IX Resin Particle Size	0.3 – 1.2 mm
Underdrain Lateral Screen Size	0.25 mm (60 mesh)

The vessels will initially be filled with IX resin based on the design flow. If the output of the facility is increased to the ultimate design flow, additional IX resin should be added.

Backwash Procedures

The size of the vessels will allow for 62% expansion at the design flow and 42% at the ultimate design flow. The backwash water will be provided from the common 8" water transmission line from the other well sites, which will back feed the IX vessels for the washwater supply. The backwash rate will need to be carefully controlled to limit losing any resin during backwashing. It is not anticipated to have to backwash the IX resin often with bag filters in front of the vessels. The backwash frequency will be developed based on operational experience. The rate of pressure loss through the IX vessels will be observed and the backwash frequency will be established. It is anticipated that backwashing will be an every other week or monthly event. It is anticipated that the maximum backwash duration would be 10 minutes. The pressure loss through the vessel will be observed to ensure the backwash duration was sufficient.

Provisions for Backwash Equalization

The backwash water will be discharge either directly to the existing 6" DIP sewer line or to a temporary roll-off containment tank that can be procured and brought to the site during backwashing and discharged at a lower rate to the sewer. A connection will be provided to connect a hose to the backwash waste line to supply the temporary roll-off containment tank. The anticipated size of the roll-off containment tank is a 17 cubic yard (3,400 gallon) roll-off tank. This will accommodate a 19 – 20 minute backwash.

---

[i] Currently, SIR-700 is not NSF certified. Use of this resin would require that certification. PWA7 is already NSF certified.

Bag Filters

Prior to the IX vessels, bag filters will be provided for particulate matter removal. The design criteria for the bag filters are provided in Table 2-2.

Table 2-2.
Bag Filter Design Criteria

Parameter	Design Criteria
Bag Filter Size	10 micron
Number of Bag Filter Assemblies	2 (1 duty + 1 standby)
Filter Bags per Assembly	6
Design Flow	600 gpm
Maximum Clean Headloss at Design Flow	2 psi
Bag Filter Housing Material	Painted Carbon Steel

HCl Facilities

Hydrochloric acid feed facilities will be provided prior to the IX vessels for pH adjustment to pH 6.0. The design criteria for the HCl feed facilities are provided in Table 2-3.

Table 2-3.
HCl Facilities Design Criteria

Parameter	Design Criteria
Ultimate Design Flow	600 gpm
Design Flow	425 gpm
Average HCl Dose	69 mg/L
Maximum HCl Dose(1)	76 mg/L
Design Solution Strength	36% HCl (22 baume)
Maximum Usage at Ultimate Design Flow (Maximum Dose)	155 gpd of 36%
Average Usage at Design Flow (Average Dose)	100 gpd of 36%
Total Storage Volume(2)	2,000 gallons
Total Usable Storage Volume	1,800 gallons
Days of Storage at Design Flow (Average Dose)	18 days at 36%
Days of Storage at Ultimate Design Flow (Maximum Dose)	11.6 days at 36%
Type of Storage Tank	Double Wall
Material	High Density Cross Linked Polyethylene (XLPE)
Scrubber Type	Passive Scrubber
Scrubber Tank Size	200 gallons
Pipe and Valve Materials	CPVC
Gaskets and Elastomeric Materials	Viton

(1) Based on applying a 10% Safety Factor to the design dose. Average dose was determined based on field data.

(2) Based on discussions between the Los Angeles Fire Department and the City of Glendale Water and Power, storage capacity will be limited at the site to 2,000 gallons, requiring more frequent filling of the HCl storage tank than a typical 20 to 30 day frequency.

The HCl storage facilities will be provided with a scrubber system to prevent release of vapors into the atmosphere. Scrubber systems can consist of re-circulating scrubbers or passive scrubber systems. Commonly, re-circulating scrubbers consist of a pump and eductor system that draws vapors from the storage tank into a water stream. By comparison, passive systems are typically designed to feed water into the top of a packed column with the off-gas discharge fed into the bottom of the column. Some chemical suppliers have also utilized passive systems based on routing the outlet vent so the vent is submerged below the surface of water in a separate scrubber tank to dissolve the vapors into solution. The preliminary design is based on routing the vent from the bulk tank to a simplified scrubber tank arrangement. The final configuration of the scrubber system will be determined during final design.

The HCl facilities with be installed in a double contained tank and will also be provided with a containment area to handle any nuisance spills. The containment area will not be sized for full containment since a double contained tank is provided. The containment area will be coated with a corrosion resistant coating.

A single double walled storage tank will be provided and a duty and standby metering pump will be provided based on the dosage ranges identified in Table 2-3. The metering pumps will have speed control only and will be controlled locally or remotely from SCADA.

3. Facility Layout

The hydrochloric acid facilities and the bag filters will be added to the existing GS-3 well site as shown in Appendix 1. The facilities will be installed on the western edge of the existing easement as shown. The site piping will be reconfigured so that the lag IX vessel will discharge into the existing 8” Ductile Iron Pipe (DIP) well effluent as shown in Appendices 2 and 3. The existing 8” connection to the 30” reclaimed water line will be abandoned. Valving will be provided so that either the bag filter assembly or the IX vessels can be bypassed. The effluent from the IX vessels will discharge to same location as the existing GS-3 pump, i.e., through the existing 8” well effluent line.

The site piping materials will be Schedule 80 PVC. The velocities in the piping will be maintained below 5 ft/s to protect against surge for the PVC. Exposed valves will be PVC Butterfly valves. Buried valves will be ductile iron gate valves installed in traffic rated valve cans with the valve operators below grade. The piping materials for the HCl system will be CPVC with CPVC ball valves.

4. Hydraulics

The hydraulics of the current pump in GS-3 and the losses expected from the new facilities were evaluated to determine the projected pumping capacity. Figure 4-1 shows that current GS-3 pump curve from a test performed in June 2007 by CDM (dark blue line). To bracket the range the following assumptions were utilized:

- Best-case C factor: 130
- Worst Case C factor: 100
- Highest Main Pressure: 55 psi
- Lowest Main Pressure: 45 psi

Based on field data from the pump test and the calculated system curves using the assumptions above, the GS-3 pump currently has an estimated operating range of between 550 to 600 gpm at 100% pump speed.

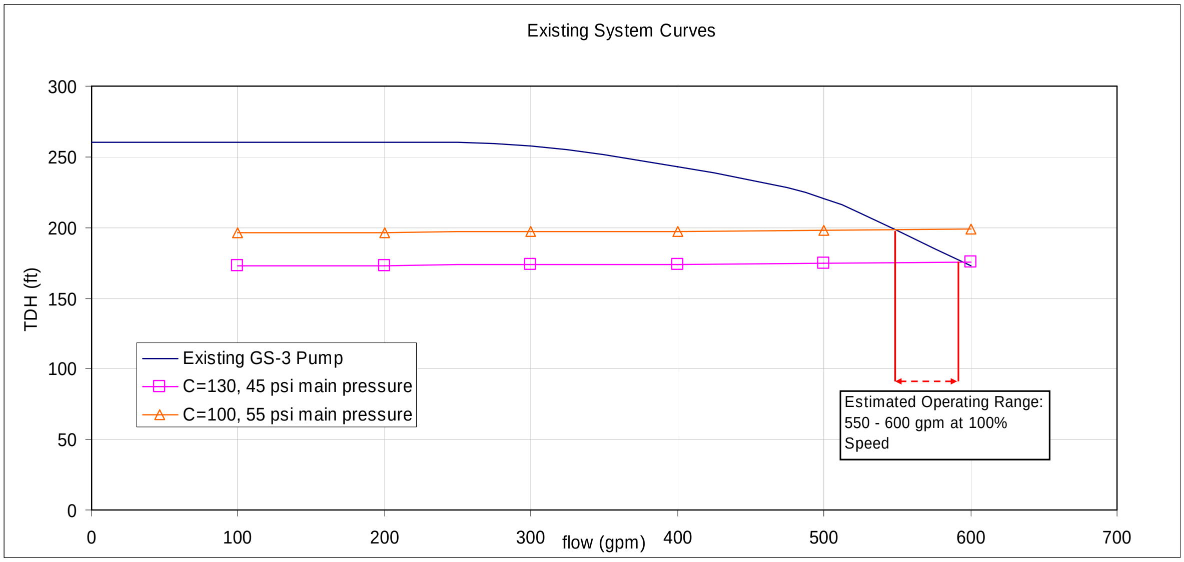


Figure 4-1: Existing System Curves for the GS-3 Pump without the WBA Facility

The addition of a WBA treatment system between the well and the main will introduce pressure losses due to the bag filters, ion exchange resin beds, and additional piping. For example, the bag filters are estimated to have a 2 psi drop across the filter housing when the filters are clean, and up to a 10 psi drop when dirty (i.e., the point at which filter change-out is recommended by the vendor). The IX system losses were calculated based on pressure loss curves provided by the manufacturers (Appendix 4). Figure 4-2 shows the intersection of the actual GS-3 pump curve (dark blue line) and manufacturer provided pump curve (light blue line) with the upper and lower range for the system curves. The upper range is based on clean bag filters (2 psi differential) and the estimated best-case main pressure (45 psi) and C factor (130). The lower range is based on dirty bag filters (10 psi differential) and the estimated worst case main pressure (55 psi) and C factor (100). The estimated operating range for the pump is between 250 and 480 gpm at 100% pump speed.

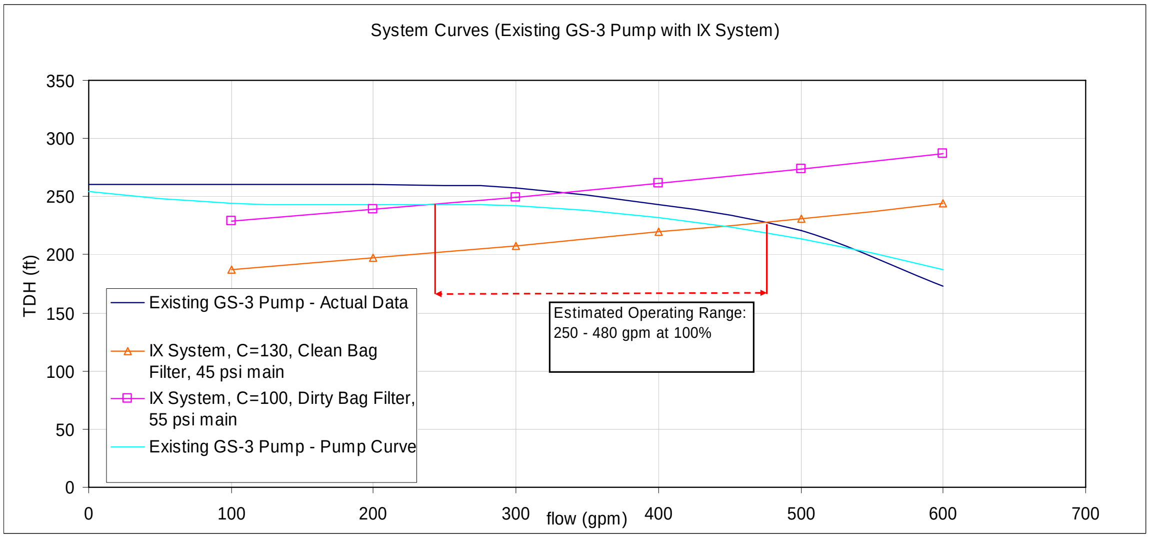


Figure 4-2: Predicted System Curves for the GS-3 Pump with the WBA Facility

Two possibilities exist to achieve an output closer to the desired 425 gpm design capacity for the WBA treatment system. First, the existing GS-3 pump could be used and the bag filters replaced more frequently than when 10 psi pressure loss occurs. Second, the GS-3 pump could be replaced with one capable of achieving a higher operating flow. To achieve the ultimate design flow of 600 gpm, the GS-3 pump will need to be replaced.

Glendale has an unused high head pump that was purchased with the GAC vessels, so the hydraulics were evaluated to determine if the existing high head pump could be used to achieve a higher flow. Figure 4-3 shows the pump curves for 100%, 80%, and 50% pump speeds, along with the system curves for a range of ion exchange system conditions. The analysis indicated that the high head pump could achieve an operating capacity of approximately 410 to 475 gpm at 80% speed. However, operation of the pump at 80% speed would not optimize the capital costs associated with installing a larger 75 HP pump at the facility, and the upper end of the flow operating range would not be improved over the existing GS-3 pump, so the ultimate design flow of 600 gpm would not be met with this pump. Based on this evaluation, it is recommended that Glendale purchase and install a different pump optimized for the ultimate design flow if this expansion in capacity is required.

Other issues that may cause complications with well pump replacement include clearance in the GS-3 vault and the potential costs of a new pump, such as system upgrades to accommodate a larger motor. Exchanging the existing pump with a larger horsepower motor may not be simple due to space constraints. Significant costs may also arise if a new pump is purchased and if modifications to the vault are necessary for the larger motor.

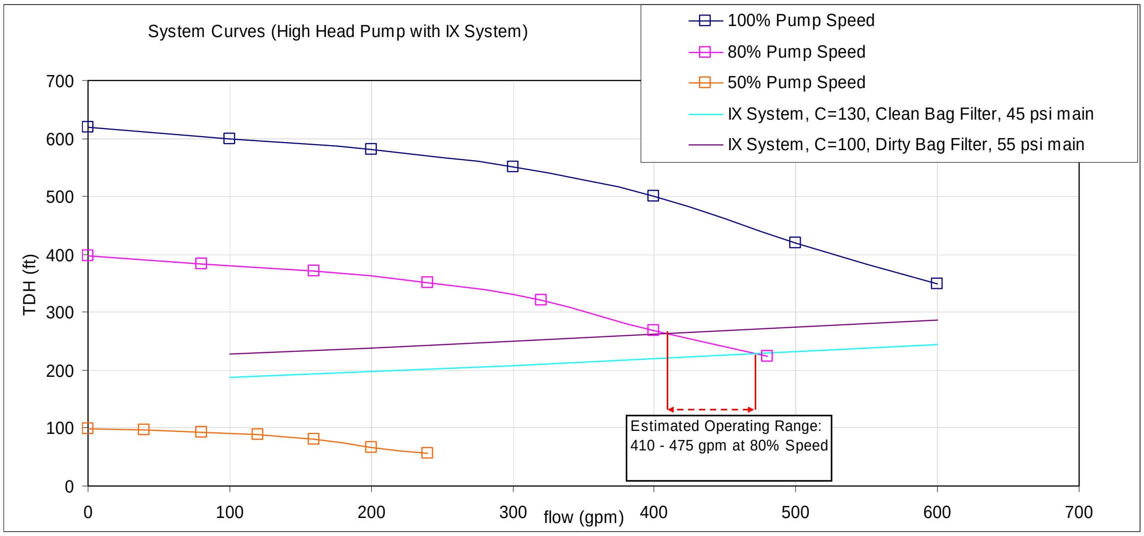


Figure 4-3: High Head Pump Operation with WBA Facility

Based on this hydraulic analysis, Glendale elected to proceed with the design using the existing GS-3 pump with the understanding that pressure losses in the WBA facility will limit the flow compared with the current possible flow capacity of the existing GS-3 pump. The flow output of the demonstration-scale study will be maximized by replacing bag filters on a more frequent basis. If the output of the pump with the new IX system is not sufficient, then the pump will be replaced.

The operation of the demonstration-scale study using the existing pump will also provide useful hydraulic information on head losses through the WBA treatment facility including the rate of pressure loss development through the bag filters. If Glendale decides that the flow is not sufficient with the existing pump, this information will be useful to optimize selection of a more optimal pump based on the actual operating data from the system.

5. Facility Operation

The process schematic for the Chromium 6 removal facilities is shown in Appendix 3. The Chromium 6 treatment facilities for well GS-3 include two bag filters, two IX vessels (existing GAC vessels modified to support WBA IX resin) and an acid feed system including an HCl storage tank and two HCl metering pumps.

The control descriptions for each component are identified below:

- The flow through the IX facilities will be monitored by the existing well effluent meter
- Provisions for local and remote automatic controls are included for the acid metering pumps

5.1. Control Descriptions

<u>IX Vessels</u>

1. Overview:

The two IX vessels will be operated in series in a lead/lag configuration with the effluent from one vessel feeding the inlet of the other. Effluent from the second vessel will be discharged to the existing 8” water transmission main.

2. Monitoring and Control:

The majority of the operational changes for the IX system will be manually initiated. Flow through the IX vessels will be controlled by the well pump speed and losses through the system. It is anticipated that the pump will operate at full speed; thus, no flow control or throttling valves will be used to control flow through the IX vessels.

Backwashing of the IX vessels will be manually initiated. The pump will be shut down and the IX vessel influent and effluent valves will be closed. The common backwash discharge valve will then be opened. The backwash discharge valve on the vessel to be backwashed will be opened and the throttling valve on the backwash effluent will be throttled down to the set position. The effluent valve on this vessel will be opened and the backwash will be initiated. The flow will be monitored on the effluent meter to ensure the backwash rate does not exceed the recommended rate. Once the backwashing period for each vessel is complete, the IX vessels and pump will be placed back in service.

Field instruments used for controlling the IX vessels include:

- Existing flow meter on well pump outlet
- Existing pressure transmitters on the IX vessel influent and effluent piping
- Common flow meter on the IX effluent/backwash supply line

3. Local Display/Control:

The common flow meter will display at the meter and SCADA. The backwash rate will be controlled by manually throttling the valve.

4. Remote Manual Control:

Not applicable (N/A)

5. Remote Auto Control:

N/A

6. Interlocks:

N/A

7. HMI generated alarms and indications:

- High Backwash Flow
- Low Flow

Bag Filters

The control description below is typical for Bag Filter 1 and Bag Filter 2.

1. Overview:

Bag filters will be used to remove particulates from well water prior to ion exchange treatment.

2. Monitoring and Control:

Pressure drops across on the bag filters will be monitored by a differential pressure switch. An alarm will be annunciated remotely on SCADA based on a high differential pressure setpoint. The setpoint will initially be set at 5 psig and will be adjusted based on a evaluation of the rate of particle accumulation and associated impacts on the well pump output during operation.

3. Local Display/Control:

The local display will include a differential pressure reading between bag filters' inlet and outlet at the instrument.

4. Remote Manual Control:

N/A

5. Remote Auto Control:

N/A

6. Interlocks

N/A

7. HMI generated alarms and indications

- High differential pressure

HCl Storage Tank

1. Overview:

A 2,000 gallon tank will be provided for HCl storage. Two HCl feed pumps will be connected directly to this tank**.**

2. Monitoring and Control:

An ultrasonic level transmitter will be installed on the tank to measure the tank level. A 4-20mA signal will be sent to the PLC, and the continuous level signal will be displayed on the SCADA. The 4-20mA signal will also be utilized to develop three separate setpoints through software switches in the PLC (High, Low and Low-Low). High and Low level switches will be used for alarm annunciation, and the Low-Low level switch will be used for acid feed pump shut down. The levels will be determined during final design based on final HCl storage tank selection.

3. Local Display/Control:

Local display: Continuous level signal

4. Remote Manual Control:

N/A

5. Remote Auto Control:

N/A

6. Interlocks

N/A

7. HMI generated alarms and indications

- Storage Tank Level High
- Storage Tank Level Low

HCl Feed Pumps

1. Overview:

Two HCl feed pumps will be used as main/standby pumps to feed the acid from the storage tank to the static mixer.

2. Monitoring and Control:

Field instruments used for controlling the feed pump will include:
- Existing flow meter on well pump's outlet
- pH analyzer on bag filters' outlet
- Pressure switch on the feed pump's outlet
- Level transmitter on the acid storage tank

In remote auto mode, the pump speed control (dosing rate) shall be flow paced based on main water flow rate measured by the existing flow meter on the well pump's outlet.

In manual mode (local or remote), the pump speed will be adjusted by the operator.
The pH analyzer will have four separate setpoints (Low-Low, Low, High and High-High). The Low and High setpoints will initiate an alarm at SCADA. The Low setpoint will initially be set at 5.8 and the High will initially be set at 6.2 to ensure the tragte pH of 6.0 is maintained within a narrow range. The Low-Low and High-High setpoints will stop the well pump and acid feed pump. The Low-Low setpoint will be set at 5.5 and the High-High setpoint will be set at 6.4 to protect the materials of the piping and vessel and to prevent any breakthrough of Chromium 6 through the resin. The acid feed will also be stopped on a Low-Low level signal from the storage tank or on a High pressure signal from the feed pump discharge to protect the feed pump.

3. Local Display/Control:

Local/Remote mode will be locally selected by the operator. In local mode, the operator will adjust the feed pump speed.

4. Remote Manual Control:

In remote mode, the operator can select auto or manual mode in SCADA. In remote manual mode, the operator sets the target flow rate, which would be converted to speed by PLC and sent to the pump. The operator can also set Pump 1 or 2 as Main or Standby.

5. Remote Auto Control:

The following signals will be sent from each pump to the PLC:

- Remote mode selected
- Speed
- Fault
- Running

The following commands will be sent to the pump in remote mode:

- Start/stop
- Dosing rate

When the operator selects auto in remote mode, the dosing rate command (which is flow paced based on main water flow rate) will be sent to the main feed pump. If the main pump has stopped due to any failure, the Standby pump will be started and speed control resumed.

6. Interlocks

- Shutdown on Low-Low or High-High from the pH analyzer or High feed pump discharge pressure or Low-Low level from the storage tank.

7. HMI generated alarms and indications

- Main / Standby Pump running
- Main / Standby Pump failure
- Main / Standby Pump Speed
- Main / Standby Pump in Remote/Local
- Main / Standby Pump in Auto/Manual
- pH High-High
- pH High

- pH Low
- pH Low-Low
- Pumps’ Outlet Pressure High

6. Electrical and Instrumentation

6.1. I&C Requirement

Existing facilities are controlled by a PLC based control system installed into the CP-3 control panel. The well pump speed is controlled by the VFD installed in the CP-3 VFD panel.

The Chromium 6 treatment facilities will include two bag filters, two IX vessels, an HCl storage tank, and acid feed pumps. The following drives and field instruments need to be added to the existing control system:

Drives

- Acid Feed Pump No.1
- Acid Feed Pump No.2

Each feed pump will have following I/O points:

1. Remote selected (Digital Input: DI)
2. Running (DI)
3. Fault (DI)
4. Start/Stop (DO)
5. Speed (Analog Input: AI)
6. Dosing Rate (AO)

Field Instruments

- DPSH-1: Differential Pressure Switch on Bag Filter No.1 (DI)
- DPSH-2: Differential Pressure Switch on Bag Filter No.2 (DI)
- PSH: Pressure Switch on Feed Pumps' Outlet: DI
- LSH: Leak Detection Switch in Containment Area (Level Switch High): DI
- LIT: Level Transmitter on Acid Storage Tank: AI
- AIT: pH Analyzer on Bag Filters' Outlet: AI
- FIT: Flow Meter on IX Vessel Effluent/Backwash Supply: AI

Based on above listing, additions to the existing control system will include 10 Digital inputs, 2 Digital Outputs, 5 Analog Inputs and 2 Analog outputs.

The existing control panel CP-3 includes a Modicon Micro PLC model (110 CPU 612 00), which has 16 Digital Inputs, 12 Digital Outputs, 4 Analog Inputs and 2 Analog

Outputs in a single housing. The panel has only one digital input spare, one analog input spare, and one analog output spare. Consequently, I/O expansion is necessary for the new drives and instrumentation.

Expanding the system capacity can be achieved in two ways; by simply linking another Micro PLC, configured as "Child", to the existing Micro PLC as "Parent" over a single cable, high speed I/O Expansion Link, or by utilizing A120 Series I/O. Since the CPU model is old, selecting the expansion method will depend on market availability. The most cost-effective approach for expansion will be determined during detailed design.

6.2. Electrical Requirements

The power supply requirements for two acid feed pumps, ultrasonic level transmitter, high level switch in containment area, flow meter and pH analyzer are 120 VAC and can be provided from existing local control panel (CP-3- VFD panel). Lighting, security and fire alarm system are not required. All electrical & control conduits will be exposed and shall have seal fittings in accordance with the NEC. Drain sealing fittings shall be installed in all vertical conduit runs and at low points in conduit systems to provide continuous, automatic drainage of condensate.

7. Acronym List

AI	analog input
AIT	Analyzer indicating transmitter (pH meter)
AO	analog output
AwwaRF	American Water Works Association Research Foundation
cf	cubic feet
CPVC	chlorinated poly vinyl chloride
CML&C	cement-mortar lined and coated
CPU	central processing unit
Cr(VI)	Chromium 6 or hexavalent chromium
DHS	California Department of Health Services; now Department of Public Health
DPSH	differential pressure switch high
DI	digital input
DIP	ductile iron pipe
DO	digital output
FIT	Flow indicating transmitter (Magnetic Flowmeter)
FRP	fiberglass reinforced plastic
ft	foot
GAC	granular activated carbon
gpd	gallons per day
gpm	gallons per minute
gpm/cf	gallons per minute per cubic feet
gpm/sf	gallons per minute per square feet
GWP	Glendale Water and Power
GWTP	Glendale Water Treatment Plant
HCl	hydrochloric acid
HP	horsepower
I&C	instrumentation and control
I/O	input/output
IX	ion exchange
LIH	level indicator high
LSH	level switch high

MCL	maximum contaminant level
MEC	McGuire Environmental Consultants, Inc.
µg/L	micrograms per liter, or parts per billion (ppb)
mg/L	milligrams per liter, or parts per million (ppm)
mm	millimeter
NEC	National Electric Code
NTP	National Toxicology Program
PCE	perchloroethylene
PI	pressure indicator
PLC	programmable logic controller
PSH	pressure switch high
PVC	poly vinyl chloride
SCADA	supervisory control and data acquisition
TCE	trichloroethylene
TCP	tricholoropropane
VAC	volts alternating current
VFD	variable frequency drive
WBA	weak base anion exchange

8. Appendices

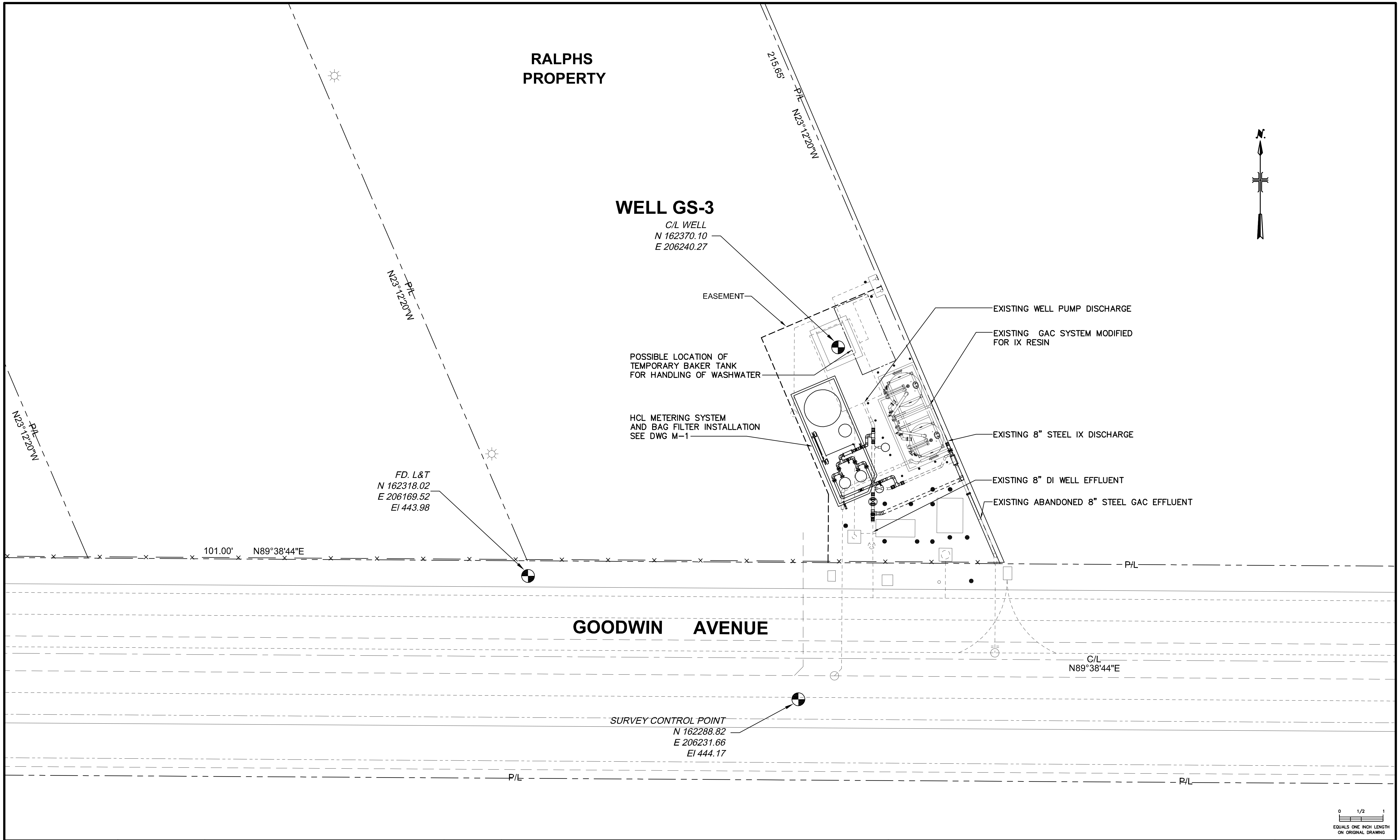
Appendix 1 - Civil Site Plan

Appendix 2 - Mechanical Plan

Appendix 3 - Instrumentation and Control Process Flow Diagram

Appendix 4 - Rohm & Haas PWA7 Product Data Sheet

8.1. Appendix 1 – Civil Site Plan



MALCOLM PIRNIE

REVISIONS			
NO.	BY	DATE	REMARKS

DES JB
DWN PAL
CKD ___

CITY OF GLENDALE WATER AND POWER
GLENDALE CALIFORNIA

CHROMIUM 6 TREATMENT
FOR WELL GS-3

CIVIL
FIGURE 1
SITE PLAN
SCALE: 1" = 10'

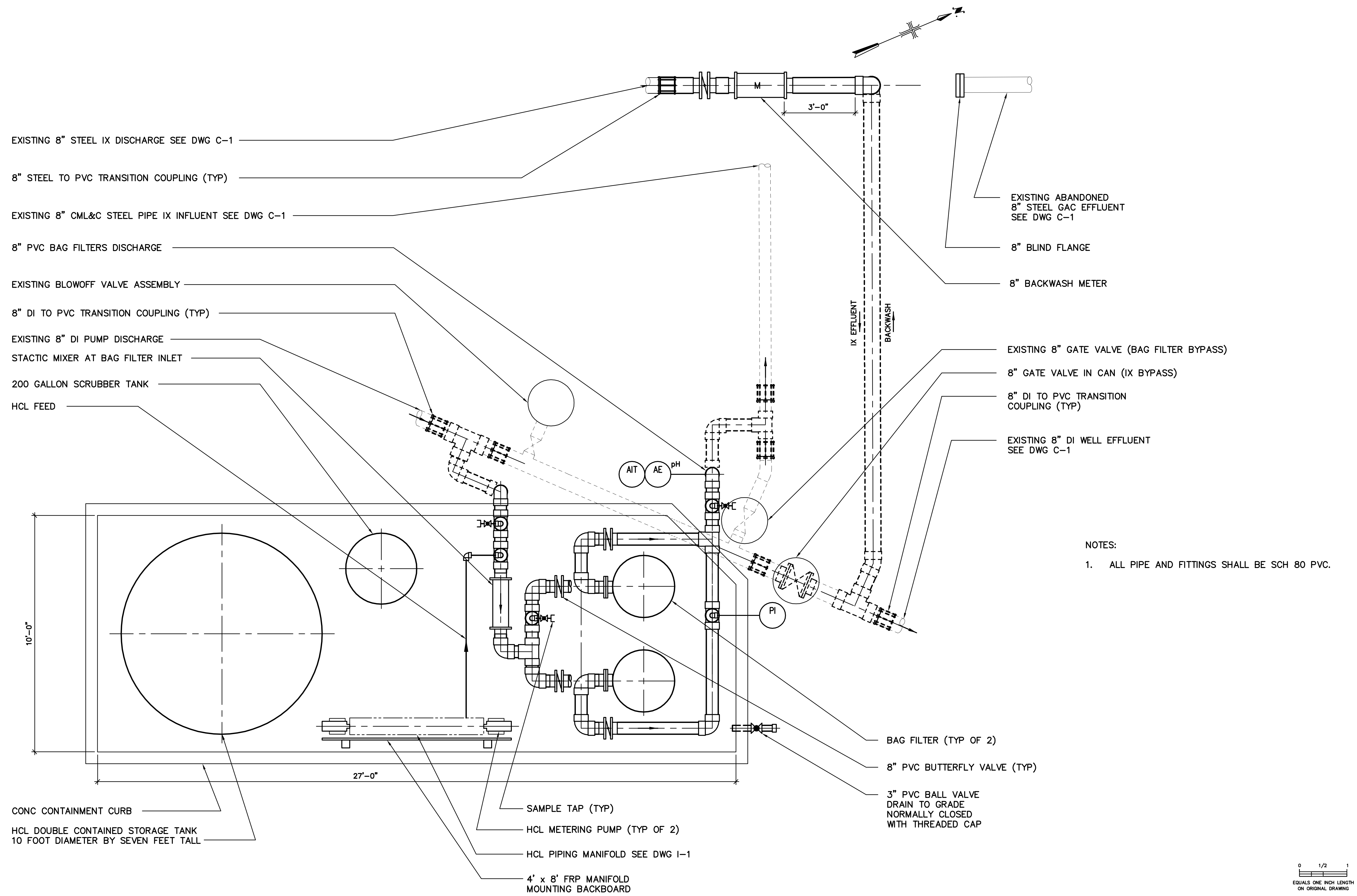
DATE JULY 2007

C-1 SHEET ___ OF ___

CAD REF. NO. 5337003 C-1

XREFS: 5337003 BM1.dwg 5337003 TBLK.dwg 5337003 BC1.dwg IMAGES: None
User: LARSON Spec: PIRNIE STANDARD File: P:\5337\003\acad\5337003 C-1.DWG Scale: 1:1 Date: 08/01/2007 Time: 13:55 Layout: C-1

8.2. Appendix 2 – Mechanical Plan



NOTES:

1. ALL PIPE AND FITTINGS SHALL BE SCH 80 PVC.

MALCOLM PIRNIE

REVISIONS			
NO.	BY	DATE	REMARKS

DES JB
DWN PAL
CKD ——

CITY OF GLENDALE WATER AND POWER
GLENDALE CALIFORNIA

CHROMIUM 6 TREATMENT
FOR WELL GS–3

MECHANICAL

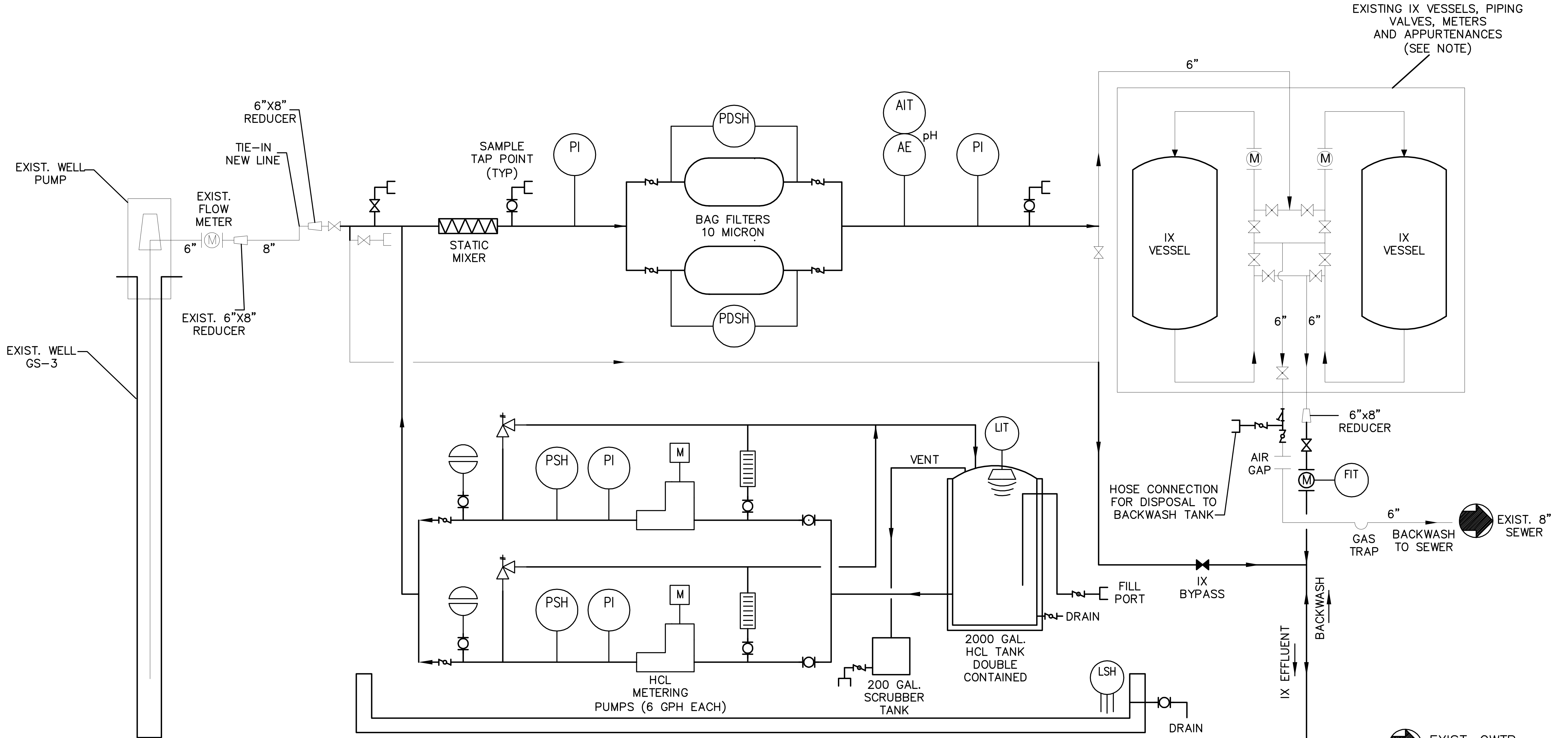
FIGURE 2
PLAN

SCALE: 1/2" = 1'–0"

DATE JULY 2007
M–1 SHEET — OF —
CAD REF. NO. 5337003 M–1

XREFS: 5337003 BM1.dwg 5337003 TBLK.dwg IMAGES: None
User: LARSON Spec: PIRNIE STANDARD File: P:\5337\003\acad\5337003 M–1.DWG Scale: 1:1 Date: 08/01/2007 Time: 10:20 Layout: M–1

8.3. Appendix 3 – Instrumentation and Control Process Flow Diagram



NOTES:

REPLACE EXIST SCREENS ON LATERALS (26 PER VESSEL)
WITH 316 SS 60 MESH SCREENS.
INSTALL 185 CUBIC FEET OF IX RESIN IN EACH VESSEL.

0 1/2 1
EQUALS ONE INCH LENGTH ON ORIGINAL DRAWING

MALCOLM PIRNIE

REVISIONS			
NO.	BY	DATE	REMARKS

DES SZ
DWN SZ
CKD --

CITY OF GLENDALE WATER AND POWER
GLENDALE CALIFORNIA

CHROMIUM 6 TREATMENT
FOR WELL GS-3

INSTRUMENTATION AND CONTROL

PROCESS FLOW DIAGRAM
FIGURE 3
NTS

DATE JULY 2007
I-1 SHEET – OF –
CAD REF. NO. 5337003 I-1

XREFS: P:\I&C\0. Projects\5337003 - GS-3\PDR\Starting Data\acad\5337003 TBLK.dwg IMAGES: None
User: LARSON Spec: PIRNIE STANDARD File: P:\5337\003\acad\5337003 I-1.DWG Scale: 1:1 Date: 08/27/2007 Time: 10:14 Layout: I-1

8.4. Appendix 4 – Rohm & Haas PWA7 Product Data Sheet

Appendix B – Quality Assurance Project Plan

The Treatment of Hexavalent Chromium (Cr(VI)) in the City of Glendale, California Ground Water Supply:

Phase III
Demonstration-Scale
WBA Resin
Treatment Technology Evaluation

QUALITY ASSURANCE PROJECT PLAN

September 18, 2007

City of Glendale Water & Power
Reliable • Competitive • Trusted

Utah State University

University of Colorado • 1876 •

UCLA

Table of Contents

0. Approval by Project Participants

Bruce Macler, Ph.D, USEPA	Date
Eugenia McNaughton, Ph.D, USEPA	Date
Peter Kavounas, City of Glendale	Date
Michael McGuire, Ph.D., P.E., MMP	Date
Laurie McNeill, Ph.D., Utah State University	Date
Gary Amy, Ph.D., UNESCO	Date
Mel Suffet, Ph.D., UCLA	Date

Distribution List of Principal Project Participants

Each organization included in this project is to receive and retain a copy of this QAPP.

Names of Individuals	Contact Information
Bruce Macler, Ph.D. EPA Region 9	**US EPA Water Management Divsion** 75 Hawthorne Street (W-6-1) San Francisco, CA 94105-3901 Phone: (415) 972-3569; Email: macler.bruce@epa.gov
Eugenia McNaughton, Ph.D. EPA Region 9	**US EPA Quality Assurance Office, MTS-3** 75 Hawthorne Street San Francisco, CA 94105
Peter Kavounas, P.E. City of Glendale	**City of Glendale Water and Power** 141 North Glendale Ave. Level 4 Glendale, CA 91206-4496 Phone: (818) 548-2137; Email: pkavounas@ci.glendale.ca.us
Michael McGuire, Ph.D. McGuire Malcolm Pirnie	**McGuire Malcolm Pirnie** 1821 Wilshire Blvd, Suite 302 Santa Monica, CA 90403 Phone: (310) 829-1441; Email: mmcguire@pirnie.com
Laurie McNeill, Ph.D. Utah State University	**Utah State University** 1855 Blake Street, Suite 101 Denver, CO 80202-1288 Phone: (303) 623-0122; Email: Lmcneill@cc.usu.edu
Gary Amy, Ph.D. UNESCO (formerly University of Colorado at Boulder)	**UNESCO-IHE Institute for Water Education** Westvelt 7, 2601 DA Delft, Netherlands Phone: +31-15-215-1782; Email: g.amy@unesco-ihe.org
Mel Suffet, Ph.D. UCLA	**University of California, Los Angeles** Environmental Science & Engineering Program 46-081 Capitol CHS, 10833 Le Conte Avenue Los Angeles, CA 90024 Phone: (310) 206-8230; Email: msuffet@ucla.edu

1. Project Description and Objectives

The City of Glendale's groundwater supply in the San Fernando Valley has been contaminated with a wide variety of chemicals, including hexavalent chromium [Cr(VI)], trichloroethylene (TCE), perchloroethylene (PCE), 1,2,3-trichloropropane (TCP), and others, mainly as a result of the improper disposal of industrial waste products. Extraction and treatment of volatile organic compounds (VOCs) is underway in the San Fernando Valley using air stripping and granular activated carbon (GAC), and the treated water is served to customers. Although Cr(VI) was also found in the groundwater supplies, levels were below the maximum contaminant level (MCL) and no Cr(VI) treatment was included with the VOC facilities at the time they were constructed.

Until June 2007, the health effects of Cr(VI) in drinking water were uncertain; Cr(VI) was a proven carcinogen by inhalation but little evidence existed to demonstrate the impact of Cr(VI) by ingestion. However, a recent study conducted by the National Toxicology Program (NTP) showed that Cr(VI) is a carcinogen by ingestion in animal studies (NTP 2007). Even prior to this study, the Legislature of California mandated that the California Department of Public Health (DPH) establish a Cr(VI) MCL. First, the Office of Environmental Health Hazard Assessment (OEHHA) must set a public health goal (PHG), which will likely be based on the new NTP findings. In Glendale, public concern about Cr(VI) in the groundwater supply led the city to embark on a multi-phase study to identify and install Cr(VI) treatment in anticipation of a Cr(VI) MCL lower than the current total Cr MCL in California.

In the year 2000, the City of Glendale, along with the Cities of Los Angeles, Burbank, and San Fernando, initiated a testing program to develop a full-scale Cr(VI) treatment system capable of removing Cr(VI) to low parts-per-billion levels. The **Phase I Bench-scale study** was conducted to improve our understanding of fundamental chromium chemistry and to screen promising technologies for their ability to treat and remove Cr(VI) to very low levels. The Phase I study is complete and the final report was published by AwwaRF (Brandhuber et al. 2004). The **Phase II Pilot-scale study** was initiated in the summer of 2003 to further test the promising Cr(VI) removal technologies at the pilot scale (i.e., several gallons-per-minute flows) using Glendale groundwater. A final report on the Phase II pilot-scale study was completed in 2005 (MEC 2005). Selected results were also published in peer-reviewed scientific journals (Qin et al. 2005, McGuire et al. 2006).

The **Phase III Demonstration-scale study** will finalize the treatment evaluation, residuals assessment, and cost estimate development by implementing one or more Cr(VI) removal technologies at flows of 500 to 1,000 gpm. The initial part of the Phase III effort was designated as the Phase III Bridge Project, which included additional studies to finalize testing of weak-base anion exchange resins for Cr(VI) treatment, refinement of treatment technology cost estimates based on Phase III Bridge Project results, and assembly of an expert panel to recommend one or more treatment processes for demonstration-scale testing. The Phase III Bridge Project was completed in early 2007.

The Phase III Demonstration-scale study will test weak-base anion (WBA) exchange using a 425 gpm well. Depending on additional funding availability, the City of Glendale may also construct a reduction-coagulation-filtration (RCF) treatment system on one or more other wells. This

QAPP covers only the WBA treatment system, which is funded in part by the USEPA State and Tribal Assistance Grant (STAG).

The purpose of this project is to demonstrate the effectiveness of WBA resin in removing Cr(VI) to low part-per-billion levels. The system will be operated for one year under the STAG grant, and treated water will be put to beneficial use by serving Glendale's consumers. Treatment cost information developed in the Phase II Pilot-scale and Phase III Bridge studies will be updated as a result of this effort. This information intended to be of use to other utilities requiring Cr(VI) treatment and to the state of California in setting a Cr(VI) MCL.

1.1 Treatment System Description

Cr(VI) removal by WBA resin is a novel application of ion exchange for drinking water treatment. Originally, WBA resin was believed to behave similarly to strong-base anion exchange (SBA) resins in terms of removal mechanism, except that the WBA resins are only useful in the acidic pH range where the functional groups are protonated and thus have positively charged exchange sites to attract Cr(VI) as chromate or bichromate ion. However, the WBA resin tested in the Phase II pilot study (Duolite A7, now called PWA7, resin provided by Rohm & Haas) showed a 20 times higher Cr(VI) removal capacity compared with five SBA resins tested. Other observations, such as leakage of Cr(III) during periods in which pH values were lower than 5.5, indicated that an ion exchange mechanism alone was not likely responsible for all of the Cr(VI) removal by WBA resin.

As part of the Phase III Bridge study, five other WBA resins were tested to evaluate Cr(VI) capacity. In addition, the impact of pH on the capacity of the top performers was assessed to minimize acid addition requirements. PWA7 resin again showed a high Cr(VI) capacity along with another WBA resin (ResinTech SIR-700, which did not perform as well as the PWA7 initially but improved over time). Testing confirmed that more than 95% of the Cr(VI) retained on both resins was in the form of Cr(III), as observed directly by x-ray absorption spectroscopy. The true mechanism of Cr(VI) removal and retention by the WBA resins is hypothesized to first involve adsorption followed by reduction and retention perhaps by the resin backbone (SenGupta and Sarkar, 2007).

To date, WBA has only been tested in bench- and pilot-scale studies. The proposed demonstration-scale WBA system will be the first installation of this technology in a drinking water treatment application.

The WBA system that will be constructed and tested in the Phase III Demonstration-scale study will consist of the following major components:

- Ion exchange vessels (two 8-ft. diameter vessels each containing 200 cubic feet of WBA resin)
- Bag filters (two parallel filter housings containing 10-micron filters),
- Hydrochloric acid storage tank (2,000 gallons, with secondary containment), and
- Acid feed and control system (metering pumps capable of up to 288 gallons per day).

Figure 1-1 provides a process flow schematic for the WBA system. The system will consist of a pair of lead/lag vessels with upstream acid addition. Due to the resin's high capacity and difficulty in regeneration, WBA resin will be used as a once-through, non-regenerable media.

The WBA system will be located at the GS-3 well site adjacent to Goodwin Street in the City of Los Angeles. The GS-3 well was selected for testing the WBA demonstration-scale system for two primary reasons: (1) GS-3 is one of the high Cr(VI) wells, with a current Cr(VI) concentration of approximately 35 μg/L; and (2) a pair of unused GAC vessels exist at the GS-3 well site and can be retrofitted for WBA resin, thus minimizing capital costs for ion exchange vessels.

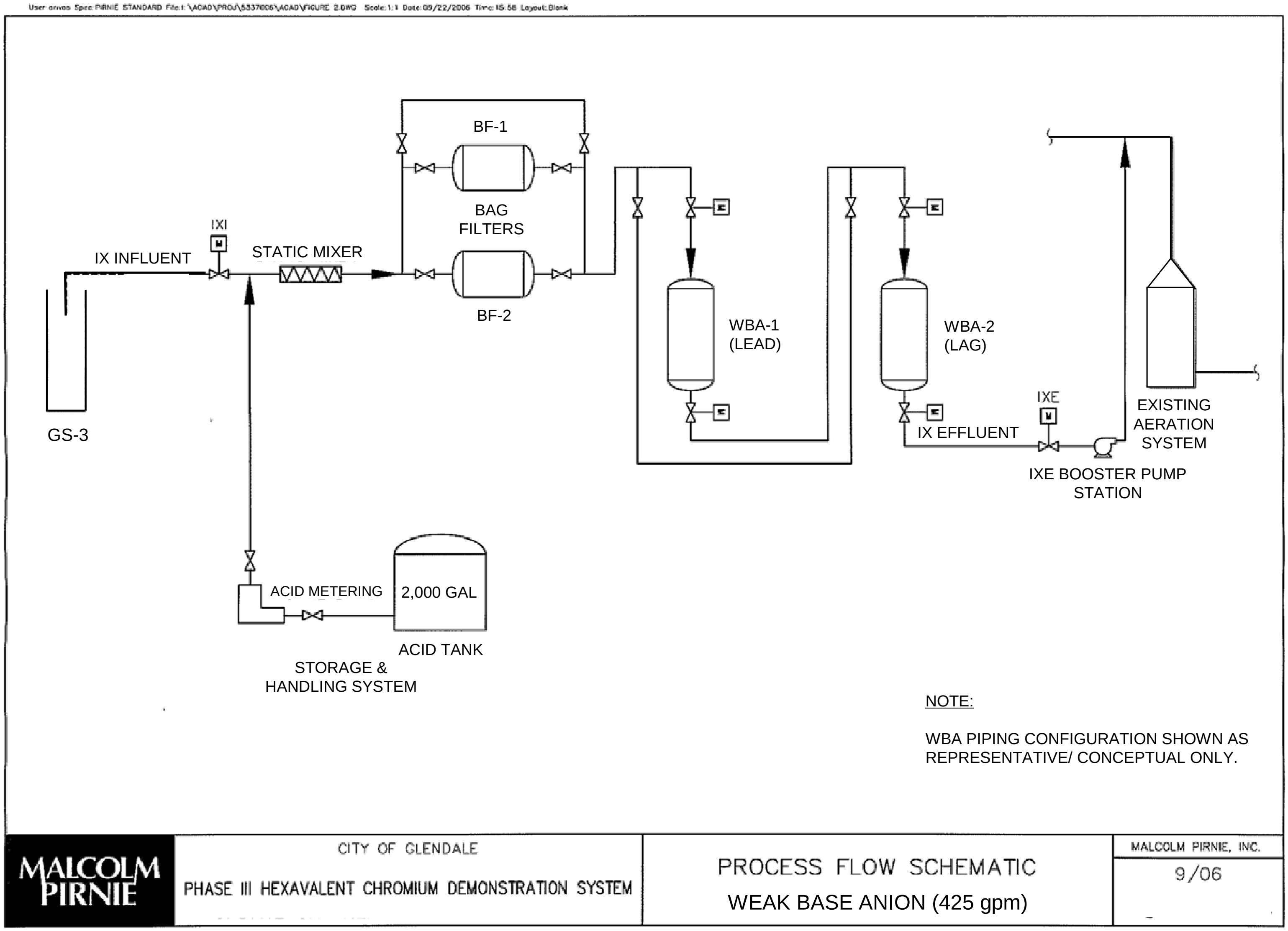


Figure 1-1. Process flow schematic of the WBA ion exchange system

1.2 Project Objectives

The objectives of the Phase III Demonstration-scale study include the following:

- Evaluate Cr(VI) removal capacity of WBA resin at the demonstration-scale (approximately 425 gpm) and the ability to scale-up bench and pilot results;
- Quantify demonstration treatment performance with respect to Cr(VI) removal over extended periods of time (i.e., at least one year);
- Assess the impact of WBA resin treatment on finished water quality, including any leaching of nitrosamines, and develop mitigation strategies;
- Optimize day-to-day operations of the WBA treatment system and develop a comprehensive operations and maintenance manual;
- Assess the reliability of the demonstration-scale WBA technology during a year of operations and identify necessary backwashing or fluffing frequency;
- Confirm residuals optimization and disposal strategies identified in the Phase III Bridge project;
- Verify unit cost information developed in the pilot study with actual treatment costs; and
- Publicly disseminate project plans and findings to a wide audience, including water agencies also concerned with Cr(VI) in water supplies, California DPH, the USEPA, and consumers.

2. Project Organization

2.1 Key Points of Contact

Refer to the above Distribution List of Principal Project Participants for the key points of contact at each organization.

2.2 QA Managers

The QAPP dictates procedures that will be used by two primary organizations: McGuire Malcolm Pirnie and the ELAP-certified laboratory (Truesdail Laboratories, Inc.). With respect to data quality assurance, Malcolm Pirnie is charged with the tasks of sample collection, handling, field analysis of selected parameters, data management, data reduction, and data validation. McGuire Malcolm Pirnie's QA Manager will be Dr. Michael MacPhee. He is independent of Project Management and his only role in the project is as QA Manager. The QA Manager at Truesdail will be Dr. Pat Iyer, Director of Quality Assurance.

2.3 Responsibilities of Project Participants

Each project participant responsible for critical components in this project is listed in Table 2-1. Team members' affiliations and overall project involvement are also listed. Project involvement roles specified here include: Planning, Coordination, Sample Collection, Sample Custody, Measurements (Analytical, Physical, and Process), Data Reduction, Data Validation, and Report Preparation. The project team organization is illustrated in Figure 2-1.

2.4 Laboratory Certification Requirements

All of the laboratories that will be used are certified by the California Department of Public Health under the State's Environmental Laboratory Accreditation Program (ELAP). Each laboratory's QA and Project Managers will be responsible for ensuring that the laboratory staff are appropriately trained and qualified to conduct the analyses.

Table 2-1.
Project Participant Roles

Team Member	Title and Organization	Overall Project Involvement	Specific Involvement
Peter Kavounas, PE	City of Glendale	Glendale Principal Investigator	Planning Coordination
Don Froelich, PE	City of Glendale	Glendale Project Management	Planning Coordination
Leighton Fong, PE	City of Glendale	Glendale Project Management	Coordination
Michael McGuire, PhD, PE	Vice President, McGuire Malcolm Pirnie	McGuire Malcolm Pirnie Project Manager	Experimental Design Report Preparation
Michael MacPhee, PhD	Vice President, McGuire Malcolm Pirnie	Technical Advisor	McGuire Malcolm Pirnie QA Manager
Nicole Blute, PhD	Project Engineer, McGuire Malcolm Pirnie	McGuire Malcolm Pirnie Deputy Project Manager	Planning Coordination Data Reduction and Validation Report Preparation
Danny Qin, D.Env.	Engineer, McGuire Malcolm Pirnie	Study Field Testing	Study Operations Sample Collection Sample Custody Field Measurements (analytical, physical, process) Data Management
Xuan Dang	Project Manager, Truesdail Laboratories	Analytical Support	Coordination of Analytical Laboratory Measurements
Gary Amy, PhD	Professor, UNESCO	Technical Advisor	Experimental Design
Laurie McNeill, PhD	Associate Professor, USU	Technical Advisor	Experimental Design
Mel Suffet, PhD	Professor, UCLA	Technical Advisor	Experimental Design
To Be Determined	To Be Determined	To Be Determined	Construction

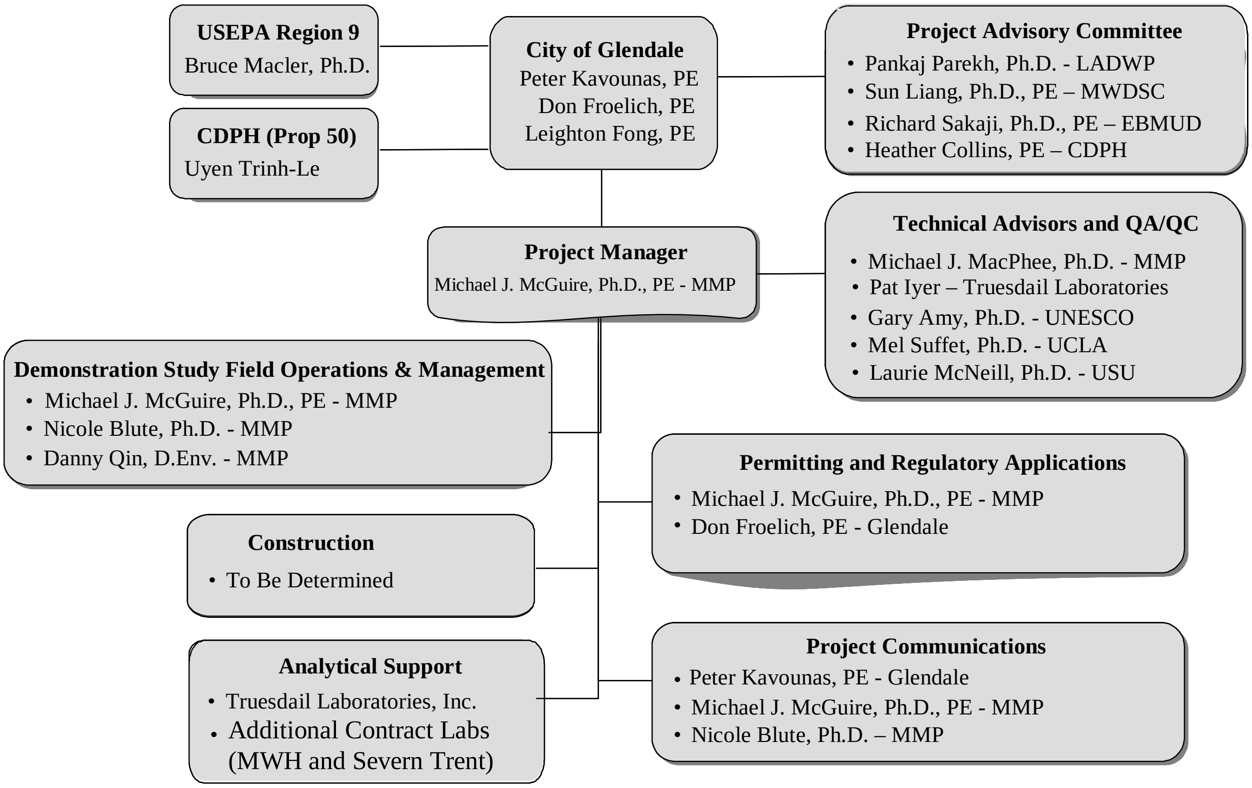


Figure 2-1. Demonstration Study Team Organization and Lines of Communication

3. Experimental Approach

3.1 General Approach and Test Conditions

Evaluation of WBA resin for Cr(VI) removal at the demonstration scale will focus on the measurement of key chemical and process parameters described in this section. Of critical importance, the project team will closely monitor Cr(VI) and total Cr concentrations in influent, mid-treatment train, and effluent water samples. In addition, other process-related parameters and water quality constituents described below will be measured to assess operational effectiveness and the impact of the WBA technology on water quality.

3.2 Sampling Strategy

Table 3-1 lists the proposed sampling parameters for the WBA demonstration-scale testing. In addition to chemical and physical analytical measurements, process-related parameters listed in Table 3-2 will be assessed.

Critical sampling parameters in the demonstration study include Cr(VI), total Cr [ie., Cr(VI) plus Cr(III)], and pH. Other chemical and physical parameters, including temperature, conductivity, turbidity, and alkalinity will be routinely measured. Anions such as sulfate, nitrate, phosphate, and silicate may impact ion exchange treatment; consequently periodic measurements of these parameters will also be obtained. Nitrosamines, which have been found to leach from ion exchange resins, will be monitored in the start-up period of the demonstration-scale study to identify strategies to mitigate initial releases (e.g., flushing the resin for a specified period of time).

Treatment residuals, including exhausted ion exchange resin and backwash water, will also be assessed to confirm disposal options using the Toxicity Characteristic Leaching Procedure (TCLP, EPA Method 1311 as mandated by 40 CFR 261) and the California Waste Extraction Test (CWET). Pilot-scale testing indicated that the spent WBA resins would be classified a hazardous waste in the State of California based on total chromium concentrations leached during the California WET test. Uranium accumulated on the spent WBA resin will also be determined throughout the testing; PWA7 resin may need to be replaced prior to 50% resin breakthrough to avoid uranium concentrations exceeding 500 mg/kg (i.e., the threshold above which the waste could be classified a low-level radioactive waste).

3.3 Sampling/Monitoring Locations

All of the samples collected for analysis will be obtained from the demonstration-scale study site at GS-3. Samples will be collected from sample ports shown in Figure 3-1. Sample types collected at each of these locations are highlighted in Table 3-1.

For the WBA treatment systems, sampling locations include the raw GS-3 well water (pre-acid addition), influent water to the lead ion exchange vessel (post-acid addition and bag filtration), lead vessel midpoint (50% depth), lead vessel effluent, lag vessel midpoint (50% depth), and lag vessel effluent.

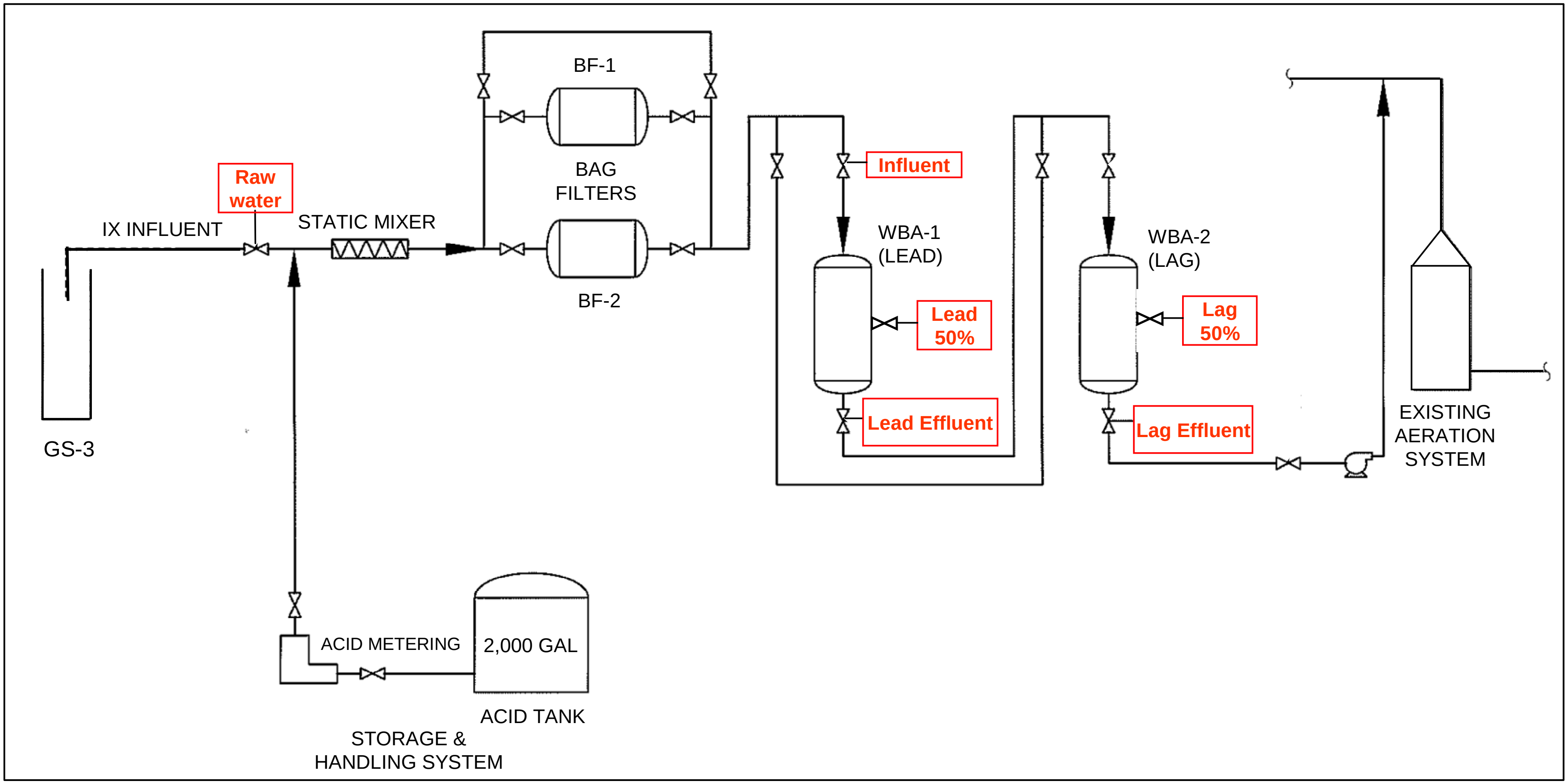


Figure 2-1. Sampling locations for Chemical and Process Parameters (highlighted in red)

Table 3-1. Analytical Measurements for the WBA Demonstration-Scale Study, Identified as Critical (C) and Non-Critical (N/C) Measurements

Sampling Types and Locations	Cr(VI)	Total Cr	pH	Temp.	SO_4^{2-}	NO_3^-	PO_4^{3-}	SiO_2	Alk-alinity	Cond-uctivity	Turb-idity	Nitros-amines	TCLP, WET tests	Ura-nium
Raw water (before pH adjustment)			N/C											
Influent (after pH adjustment)	C	C	C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	C		
Lead Vessel 50% bed depth	N/C	N/C												
Lead Vessel Effluent	C	C	C	N/C										
Lag Vessel 50% bed depth	N/C	N/C												
Lag Vessel Effluent	C	C	C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	N/C	C		
Residuals (spent resin)													C	C
Residuals (backwash water)		C												

Table 3-2. Process-Related Measurements

	Flow Rates	Pressure loss through the lead vessel	Pressure loss through the lag vessel	Backwash frequency	Backwash frequency	EBCT	# Bed volumes to breakthrough (> 5 μg/L)	# Bed volumes to 50% saturation of the lead vessel	HCl feed rate and volume use rate
WBA	C	C	C	C	C	C	C	C	C

3.4 Sampling/Monitoring Frequency

The planned sampling frequency for chemical and physical parameters, shown in Table 4-3, is based on treatment process design and the expected duration of testing (one year for the demonstration-scale study). Samples will be collected at a sufficient frequency to provide enough information to achieve the project's stated objectives. For a predicted bed life of 207 days (based on maximum uranium accumulation), the weekly chromium sampling frequency will capture an approximately 29-point breakthrough curve. Process-related parameters, such as flow rate and pressure loss, will be taken on a daily basis to determine when bag filters should be changed and backwash initiated. Other chemical and physical analyses of influent and treated water will be collected at least monthly or more frequently as deemed necessary.

The weekly Cr(VI) and total Cr sampling frequency will be established for the following key sampling points:

- Influent
- Lead vessel 50% depth
- Lead vessel effluent
- Lag vessel effluent

Once breakthrough occurs such that the lead bed effluent Cr concentration exceeds 5 μg/L, the lag vessel 50% depth location will be added to the list of sampling points monitored weekly and the lead vessel 50% depth curtailed (until the next bed is installed and the lead and lag vessel order is changed).

pH, which is a critical parameter due to its impact on WBA resin treatment, will be measured continuously at a point near the influent sampling point. Note that sufficient mixing is necessary to enable capture of stable pH values representative of the influent to the WBA resin; thus, acid will be added upstream of the bag filters and samples collected after the bag filters and before the lead vessel inlet.

Nitrosamines will be measured during the first week of startup according to California DPH permit requirements.

Non-critical parameters, including temperature, sulfate, nitrate, phosphate, silicate, alkalinity, conductivity, and turbidity, will be measured monthly at the following sampling points:

- Influent
- Lag vessel effluent.

3.5 Identification of Measurements

Tables 3-1 and 3-2 identify analytical and process-related measurements and specify whether they are critical (C) or non-critical (N/C) analytes.

3.6 Evaluation of Project Objectives

Treatment technology success will primarily be judged by the effectiveness of the process for removing Cr(VI) and total Cr from the water supply. This objective will be assessed by calculating the difference between influent and effluent chromium concentrations during the demonstration-scale study. Efficiency of removal will be calculated as follows:

$$\text{Removal (\%)} = (1- [\text{Cr}_{\text{effluent}}]/[\text{Cr}_{\text{influent}}])*100\%.$$

Effluent Cr(VI) and total Cr will be measured and plotted as a function of time to determine when breakthrough occurs. Number of bed volumes (i.e., volume of water treated per volume of the resin bed) of water treated will be calculated at breakthrough of the lead vessel (i.e., defined as Cr concentrations of greater than 5 μg/L) and also 50% saturation.

Operations and maintenance (O&M) issues associated with the WBA resin will be assessed, as listed in Table 3-2. For example, pressure drop through the beds and resultant backwashing frequency for the resin will be determined in the demonstration-scale study.

The Phase III Bridge study indicated that the spent WBA resin was classified as hazardous in the state of California due to the California Waste Extraction test (WET -- CCR Title 22 §66261.24) but not in states governed only by the federal Toxicity Characteristic Leaching Procedure (TCLP – EPA Method 1311 as mandated by 40 CFR 261). Subsamples of disposable spent media from the demonstration test will be analyzed to verify the hazardous nature of the residuals and, subsequently, the disposal options.

A broader purpose of the demonstration testing is to develop a technology that can be applied in other water utilities needing Cr(VI) treatment. Glendale’s demonstration study will therefore foster a better understanding of the WBA treatment technology for Cr(VI) removal from groundwater.

4. Sampling Procedures

4.1 Methods to Establish Steady-State Conditions

Achievement of steady-state conditions will be determined on the basis of process operating parameters rather than water quality. For WBA resin, dynamic water quality conditions will occur during operation, whereby the treated water quality will change over time as the media becomes exhausted. Therefore, sampling conditions that reflect steady-state operations will be based on the consistency of flows and chemical feed conditions (in particular, a stable pH within plus or minus 0.2 pH units).

4.2 Known Site-Specific Factors Affecting Sampling and Monitoring Procedures

The GS-3 well site will have dedicated space, power, and water from the GS-3 well. The effluent will be pumped into the transmission line leading to the Glendale Water Treatment Plant for VOC treatment. The ion exchange vessels and piping will be designed with sampling ports to enable appropriate sampling for technology performance assessment as detailed in Section 3.

Limited hours of site accessibility (approximately 8 hours per day) will affect the possible time on site. However, the system will be tied into the existing SCADA system and will be alarmed. Operators are available around the clock in case the system experiences problems. The WBA resin is expected to last for at least 6 months prior to reaching 50% breakthrough on the lead vessel, which supports a weekly sampling periodicity.

4.3 Site Preparation Prior to Sampling

The demonstration-scale facility will be located at the GS-3 well site, as shown in Figure 4-1. The City of Glendale has an easement within the Ralph’s Grocery warehouse property located in the City of Los Angeles. The GS-3 well site is located on the Ralph’s property just off of Goodwin Street.

Site preparations that will be conducted before the demonstration-scale study commences include the following tasks:

- retrofitting the existing GAC vessels with different screens to support ion exchange media,
- construction of a concrete pad and an acid feed system with secondary containment,
- preparation of necessary electrical power supplies,
- integration of the treatment system with the existing SCADA,
- piping of the raw GS-3 well water to the treatment system,
- piping of the ion exchange treated water to the transmission pipeline serving the GWTP, and
- connection of the ion exchange vessel effluent to the sewer discharge line.

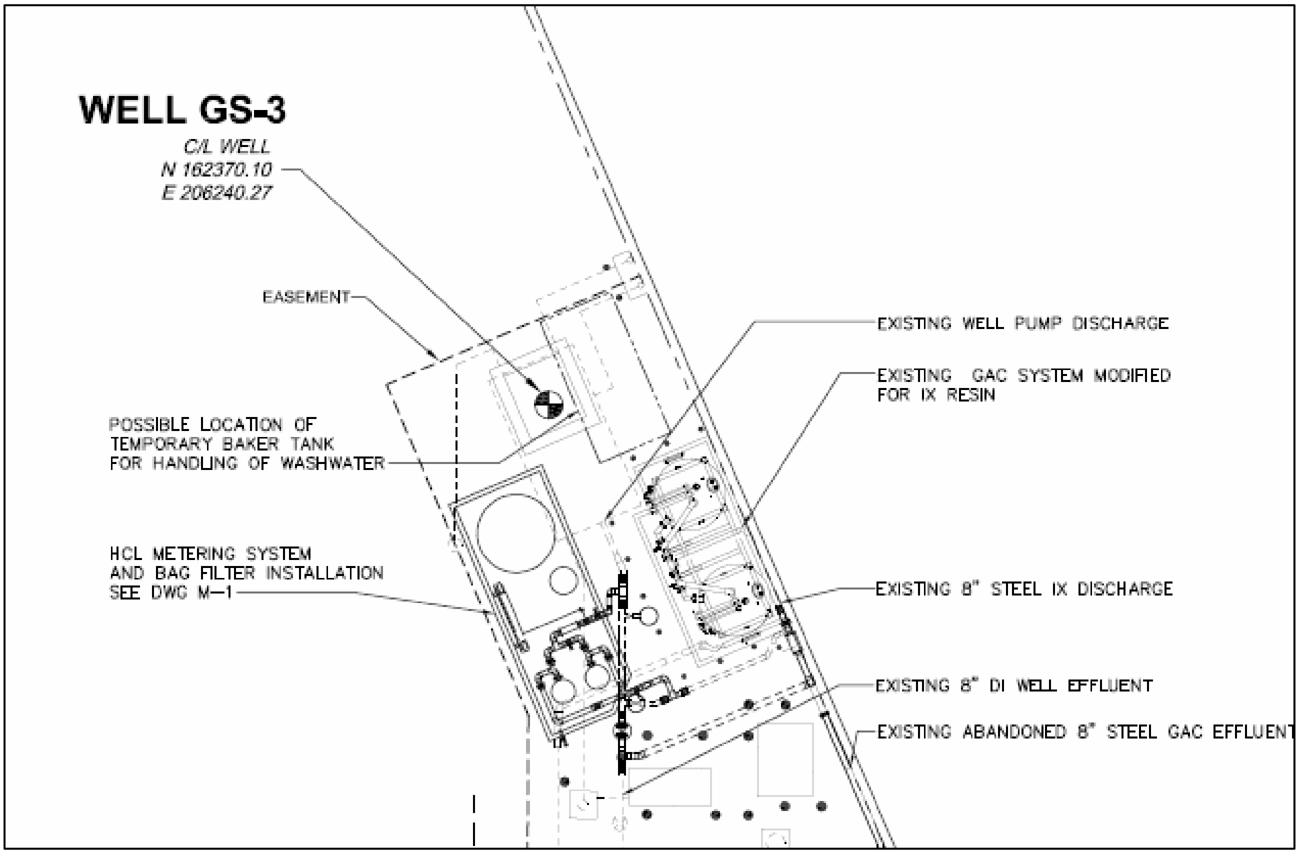


Figure 4-1. GS-3 well site and property easement boundaries

4.4 Sampling/Monitoring Methods

Chemical and physical analytes will be measured in this demonstration-scale study either in the field or in a laboratory. The analytical methods and locations of analyses are shown in Table 4-3.

Laboratory analytical measurements will be sent to one of three labs:

- Truesdail Laboratories, Inc. – for Cr(VI), total Cr, and nitrate
- Montgomery Watson Harza Laboratories – for nitrosamines
- Severn Trent – for TCLP, CWET, and uranium in residuals

The laboratory analyses of total chromium (a California DPH regulated constituent) will be performed by ICP-MS (EPA Method 200.8). Cr(VI) will be analyzed using EPA Method 218.6, which is an ion chromatography method. Nitrate will be analyzed using Method 300.0. Nitrosamines will likely be measured with EPA Method 521 (depending on method availability). Treatment residuals from the WBA treatment process will be analyzed for TCLP (metals), CWET (metals), and uranium analyses prior to disposal. All other parameters will be analyzed using the methods shown in Table 4-3.

Quality assurance sampling includes field-collected duplicate samples and field blanks (refer to Section 6.1 for full details). Generally, field-collected duplicate samples will be collected for at least 10% of all samples. These duplicates will not be identified as QA samples when sent to the laboratory.

Blanks that will be analyzed include: metal-free water added to a sample bottle in the field and shipped to the laboratory for analysis (testing field sample handling, transport, and storage), preservative reagents added to metal-free water, and deionized water used for diluting field samples for measurement. Blanks submitted to the laboratory for analysis will not be identified as QA samples.

Samples will not be composited to amplify sample volume or average samples over time. Sufficient sample volume will be available for the required analyses. To achieve the project objective of evaluating Cr(VI) removal efficiency as a function of time, sample compositing is not desirable.

In addition to chemical and physical analytical measurements, process measurements listed in Table 3-2 will be recorded daily. Flow rate and pressure drop across the vessels will be monitored throughout the demonstration-scale testing to determine when backwashing is needed. Empty bed contact time (EBCT) will be calculated by dividing the media volume in a vessel by the flow rate. The number of bed volumes of water treated will then be calculated as the volume of treated water divided by the resin bed volume.

4.5 Split Sampling for QA/QC Sampling

Split samples (i.e., samples split into two or more subsamples) will be used to verify analytical precision. Additional details in Section 6.1 describe precision testing with split samples. In addition to split samples, field-collected duplicate samples will be collected at the frequency shown in Table 6-1 to test analytical accuracy.

Table 4-3.
Sampling Frequency, Analytical Methods, & Analytical Location

Sample Analysis	Analytical Method	Analysis Location	Sampling Frequency
Cr(VI)	EPA 218.6 (IC)	Truesdail Labs	Weekly
Total Cr	EPA 200.8 (ICP-MS)	Truesdail Labs	Weekly
Sulfate	Hach 8051 (Colorimetric)	Field	Monthly
Nitrate	EPA 300.0 (IC)	Truesdail Labs	Monthly
Phosphate	Hach 8048 (Colorimetric)	Field	Monthly
Silicate	Hach 8185 (Colorimetric)	Field	Monthly
Alkalinity	Hach 8203 (Titration)	Field	Weekly
Conductivity	SM 2510B (Conductance)	Field	Weekly
pH	SM 4500H+ B (Electrometric)	Field	Continuous online monitoring
Temperature	SM 2550 (Thermometric)	Field	Weekly
Turbidity	SM 2130 B	Field	Weekly
Nitrosamines	EPA 521	MWH Labs	Start of test[a]
Residuals – TCLP	EPA 1311	Severn Trent Labs	End of test
Residuals – CWET	CWET Test (Title 22)	Severn Trent Labs	End of test
Residuals: Uranium	ASTM5174-91 (KPA method)	Severn Trent Labs	Monthly on lead vessel

[a] Nitrosamines will be analyzed at a frequency required by the DPH permit

4.6 Calibration of Sampling/Monitoring Equipment

Field equipment calibration will be performed in accordance with manufacturer specifications for each instrument. Certified standard solutions will be used to test the functionality and accuracy of each instrument within the range of measurements and at a frequency specified by the manufacturer, or at least once per month.

Process instruments, such as flow meters and pumps, will be calibrated before the demonstration-scale treatment unit is brought online, at one intermediate time during operations (minimally), and at the conclusion of the test. Calibration results and date and time of calibration will be recorded in the Field Sample Log Book.

Trained operators will determine whether the calibrations are acceptable based on the allowed drift specified by the manufacturer. If an instrument is not functioning properly (e.g. calibration attempts are unsuccessful or the standard curve is unacceptable), the operator will obtain a calibrated back-up instrument for interim use and will send the malfunctioning instrument for repair.

4.7 Avoidance of Cross-Contamination

Sample contamination will be avoided by practicing clean sampling techniques. Water samples will be collected from dedicated sampling ports by directly filling pre-cleaned sample bottles Sample collections staff will avoid contact with the interior surfaces of the bottles. Hosing from the sampling ports will initially be acid-cleaned to remove any contaminants. Between collected samples, the ends of the hoses will be covered with clean polyethylene coverings to prevent contamination. Prior to sample collection, the sampling port and hose will be flushed for at least 1 minute to clean out the lines.

California DPH recommends *not* filtering drinking water samples to avoid potential sorption of Cr(VI) on the filter membranes and cross-contamination (CA DHS, 2001). Cr(VI) samples will therefore remain unfiltered in the field.

4.8 Selection of Representative Samples

Samples collected in this demonstration-scale study will be representative of the whole study based on consistent sampling at established sampling locations indicated in Table 3-1 and sampling frequencies shown Table 4-3.

4.9 Sample Amounts Required for Analysis

Table 4-4 lists the sample analysis methods, sample amounts required for analysis according to each method (including QA aliquots except duplicates), preservatives, and maximum holding times. The same amounts will be required for each analysis at each sampling location. Field-collected duplicate sample quantities discussed in Section 4.4 will be in addition to the bottles below.

To determine if spent media will be classified as a hazardous waste, TCLP and WET tests will be performed on the media. The Federal TCLP test requires a minimum of two 100-gram samples: one sample to determine percent solids, and one sample on which the extractions will be performed. California WET mandates a 50 gram sample for analysis.

4.10 Sample Containers

All samples will be collected using containers pre-cleaned and approved by the USEPA for the analytes of interest. Samples for the critical Cr(VI) and total Cr analyses will be collected in pre-cleaned plastic bottles provided by the laboratory or, for field testing, those shown to be clean of contamination in the Phase II testing. Bottle types for other analyses of interest may be plastic or glass (EPA 1997), although plastic will be used to eliminate breakage during shipping (refer to Table 4-4). Empty containers will be stored in the original packaging until use. Once collected, samples will be shipped to the laboratories for analysis according to the protocol for sample custody.

4.11 Sample Identification

Samples will be identified using a standardized code that imparts sampling information to each party. Each sample location will be assigned a numerical ID. Next, the appropriate sample type (e.g. raw water, lead bed effluent) will be recorded. The date and time will then be recorded using the convention of military time. The analyte(s) to be measured in that sample will be recorded on the label, as will the preservative used. Finally, the field sample collector’s initials will be added.

An example identification label is as follows:

Sample Location ID ___________________
Sample Type ___________________
Date and Time ___________________
Analyte(s) ___________________
Preservative, if any ___________________
Field Sampler Initials ___________________

Table 4-4.
Sample Handling Requirements

Sample Analysis	Sample Size Required, including QC Aliquots	Container Material	Preservative	Maximum Holding Time
Cr(VI)	250 mL	P[1]	None[*]	24 hours[*]
Total Cr	250 mL	P	HNO_3 to pH <2	6 months
Sulfate	60 mL	P, G[2]	4ºC	28 days
Nitrate	50 mL	P	None	48 hours
Phosphate	60 mL	P	4ºC	48 hours
Silicate	60 mL	P	4ºC	28 days
Alkalinity	200 mL	P, G	4ºC	14 days
Conductivity	500 mL[3]	P, G	4ºC	28 days
pH	500 mL[3]	P, G	None	Analyze Immediately
Temperature	500 mL[3]	P, G	None	Analyze Immediately
Turbidity	500 mL[3]	P, G	None	Analyze Immediately
Nitrosamines	2 L	Amber glass	None	7 days
Residuals: TCLP	200 g	P	4ºC	None specified
Residuals: CWET test	50 g	P	4ºC	None specified
Residuals: Uranium	100 g	P	4ºC	None specified

[1] P = Plastic. [2] G = Glass. [3] Combined 500 mL bottle for conductivity, pH, temperature, and turbidity.
[*] Note that if 24-hour turnaround time is not possible even though it is standard practice for Truesdail Laboratories, samples can be preserved with ammonium sulfate/ammonium hydroxide buffer and held for up to 28 days.

4.12 Sample Preservation Methods

Table 4-4 lists the preservation requirements for each of the methods that will be used in the demonstration study. Details of sample preservation include whether the sample needs to be chilled at 4°C, if an acid or base is required (and if so, what dosage), the type of container required for sample collection and storage, and the maximum holding time.

As the critical analytes, more details for Cr(VI) and total Cr are provided here. Samples for total Cr will be preserved with 2% nitric acid (HNO_3). It is intended that Cr(VI) samples will be analyzed within 24 hours of sample collection, thereby avoiding the need for preservative. If this is not possible, samples will be preserved with ammonium sulfate/ ammonium hydroxide buffer, and analyzed within 28 days.

4.13 Sample Holding Time Requirements

Maximum holding times for each of the analytes are shown in Table 4-4.

4.14 Sample Shipment

Samples will be shipped by courier from the site of collection (GS-3) to the appropriate contract laboratory using a reputable shipping company. Shipping containers will consist of coolers with ice packs to chill samples and bubble wrap to protect the bottles during transit.

4.15 Sample Chain-of-Custody

Samples will be considered “in custody” when they are in someone’s physical possession or view, locked up, or stored in a secure area accessible only by authorized personnel. A minimal number of persons participating in sample handling and custody is desirable.

Samples collected for analyses will be recorded in a sampling field log using waterproof, permanent ink. The log will contain the following information: Sample ID (as described in Section 4.11), results of field measurements, and descriptions of incidents that may have affected operations.

After samples have been collected for laboratory measurements, the field staff person will complete the Sample Chain-of-Custody form in ink (Appendix A), affix and sign Custody Seals, and surrender the samples to the ELAP-certified lab courier or the authorized shipper for shipment. Upon arrival at the contract laboratory, laboratory personnel will immediately log the samples in on the Chain-of-Custody form, inspect for damage and sample integrity, and store the samples as appropriate until analysis. Problems encountered during sample shipping will be reported to the analytical manager.

4.16 Sample Archives

Samples will be stored at 4°C after analysis until personnel at the laboratory and McGuire Malcolm Pirnie review sample data and associated quality control analyses. In general, samples are kept by Truesdail Laboratories for two years. Unless directed otherwise, samples will then be disposed of in accordance with appropriate environmental health and safety regulations for hazardous chemical waste.

5. Testing and Measurement Protocols

5.1 Measurement Methods

The analytical methods for the water quality parameters and treatment residuals will conform to EPA guidelines and recommended test methods, including those in *Standard Methods for the Examination of Water and Wastewater* (APHA 1999). Standard Operating Procedures (SOPs) will be used for all measurements according to the methods shown in Table 4-4.

At Truesdail Laboratories, total chromium analyses will be performed using the ICP-MS method (EPA Method 200.8). Ion chromatography (EPA Method 218.6) will be used to analyze Cr(VI). Nitrate will be measured using EPA Method 300.0 (IC).

Nitrosamines will be measured in at MWH Labs using EPA Method 521 (depending on method availability). Treatment residuals from each process will be shipped to a certified laboratory (e.g., Severn Trent Labs) for TCLP, California WET, and uranium analyses prior to disposal.

Other water quality parameters will be measured in the field by trained operators (as discussed in Section 4.6).

5.2 Verification of Unproven Methods

No unproven laboratory methods will be used in this project.

5.3 Calibration Procedures

For Cr(VI) analysis, the ion chromatograph at Truesdail Laboratories will be calibrated each analysis day using a 5-point calibration curve ranging from 0.2 to 40 ppb. The method detection limit (MDL) at the laboratory is reported to be 0.026 ppb. However, the practical quantitation level (PQL) is 0.2 ppb based on the low end of the calibration curve. External laboratory control samples (LCS) and laboratory control sample duplicates (LCSD) will be analyzed for every batch of 20 samples. In addition, a mid-range calibration verification sample (MRCVS) will be run every 10 samples. The acceptance range for the LCS, LCSD, and MRCVS samples is within 90-110%.

Total Cr samples will be analyzed by ICP-MS, which includes daily calibration using an 8-point calibration curve ranging from 1 to 500 ppb. The laboratory-report MDL for total Cr is 0.143 ppb, and the PQL is 1 ppb. External LCS, LCSD, and mid-range continuous calibration standards (MRCCS) will be analyzed for every batch of 20 samples. In addition, an MRCVS will be run every 10 samples. The acceptance range for the LCS, LCSD, and MRCVS samples is within 90-110%.

If the laboratory calibration check criteria are not met, the analysis run will be stopped and the instrument recalibrated. The blank should be less than 2.2 times the MDL, and the standard should be within 90 – 110% of the calibrated value. If these criteria are not met, the samples analyzed after the anomalous blank/standard will be rerun.

Other analyses run at the ELAP-certified laboratories will conform to established calibration procedures that are part of the standard drinking water measurement protocols. Standard calibration curves run on the field instrument will be sufficient to ensure that the instrument is operational and large deviations in concentrations are real phenomena.

6. QA/QC Checks

6.1 Quantitative Acceptance Criteria for Data

QA/QC sampling, which includes field-collected duplicate samples, replicate analyses, matrix spikes, and field blanks, will be used to verify consistency in sample collection and handling, in addition to providing replicates of samples for analytical accuracy checks. Field-collected duplicate samples will be obtained for at least 10% of all samples collected, and the duplicates will not be identified as QA/QC samples when sent to the laboratory. Matrix spike analyses will be performed for at least 5% of all samples analyzed in the laboratory (i.e., one sample for every batch of twenty), or at least once per sample run. Field blank samples will be prepared by filling distilled water in the sample bottles provided by the lab (with added preservatives if necessary); these samples will be sent for analysis to test any possible contamination during sampling handling, transport, and storage. At least one field blank sample per method will be prepared for each shipment. The routine frequency for the field blanks will be approximately one in ten samples to be shipped (i.e., 10% field blanks). Field blanks submitted to the laboratory for analysis will not be identified as QA/QC samples. The proposed QA/QC sampling and analysis frequency is listed in Table 6-1.

As the critical parameters in evaluating the success of the project, total Cr and Cr(VI) concentration data quality will be subject to rigorous quantitative acceptance criteria. Paired samples for Cr(VI) and total Cr will be analyzed at Truesdail Labs.

As reported above, the MDLs for Cr(VI) and total Cr are 0.026 μg/L (using IC) and 0.143 μg/L (using ICP-MS), respectively. Samples found to be less than these values will be reported as “below detection limit”, or “<MDL.” Samples that are measured as higher than the highest calibration standard will be diluted and re-run. For values falling below the lowest calibration standard and above the MDL, samples will be reported by the laboratory as less than the method reporting limit (MRL). The % Relative Standard Deviation (RSD) on samples should generally be less than 10% (except for blanks).

Accuracy (a combination of random and systematic error) in Cr(VI) and total Cr analyses will be evaluated by determining percent recoveries in spiked samples. A matrix spike will be performed on 5% of samples (or at least one sample per run), chosen at random. Spike recoveries should be between 75 and 125% of the expected value. Accuracy will also be tested throughout the runs by sampling a mid-range calibration verification standard (MRCVS) every 10 samples and a mid-range continuous calibration standard (MRCCS) every 20 samples.

Precision (random error) will be investigated by performing repeat analyses on the same analytical instruments. For every batch of twenty samples, a laboratory control sample (LCS) and laboratory control sample duplicate (LCSD) will be run. The relative percent deviation (RPD) for these samples should be between 90 and 110%.

For field-measured chemical parameters (sulfate, phosphate, silicate), accuracy and precision acceptance criteria will be based on manufacturer specifications, which will be tested further using standards prepared in the water matrices. In general, acceptance criteria for these analytes will be less than 20% precision and accuracy for field-collected duplicate samples compared with standard curves.

Table 6-1.
Sampling Quality Assurance Frequency

Sample Analysis	Sampling QA/QC Frequency			
	Sample Frequency	**Field-Collected Duplicates**	**Matrix Spikes**	**Field Blanks**
Cr(VI)	Weekly	10% of samples	5% of samples	1/week
Total Cr	Weekly	10% of samples	5% of samples	1/week
Sulfate	Monthly	10% of samples	None	1/month
Nitrate	Monthly	10% of samples	None	1/month
Phosphate	Monthly	10% of samples	None	1/month
Silicate	Monthly	10% of samples	None	1/month
Alkalinity	Weekly	10% of samples	None	None
Conductivity	Weekly	10% of samples	None	None
pH	Continuous online monitoring	Weekly	None	None
Temperature	Weekly	10% of samples	None	None
Turbidity	Weekly	10% of samples	None	None
Nitrosamines	Start of test[a]	10% of samples	N/A	1/sample shipment
Residuals: TCLP	End of resin bed life	10% of samples	5% of samples	None
Residuals: CWET	End of resin bed life	10% of samples	5% of samples	None
Residuals: Uranium	Monthly on lead vessel	10% of samples	5% of samples	None

[a] Nitrosamines will be analyzed at a frequency required by the DPH permit

6.2 Additional Project-Specific Quality Assurance Objectives

In addition to the primary objective of evaluating the effectiveness of Cr(VI) removal from water using the WBA resin, this demonstration-scale study will test the operations and maintenance (O&M) requirements for this technology. Table 3-2 highlights the critical process-related measurements that will be obtained during testing. To ensure quality data are collected to evaluate these objectives, flow rates and pressures will be measured and assessed within the acceptance criteria set forth by manufacturer specifications for the instrumentation.

6.3 Procedures to Assess QA Objectives

Quality assurance objectives will be assessed as detailed throughout this QAPP. Field measurements will be tested for accuracy by frequent calibration of equipment, for precision by obtaining replicate analyses of parameters, and for any contamination that may occur during sample handling and transfer by analyzing blanks and collecting duplicate samples.

Laboratory analyses, including critical chromium measurements, will be subjected to numerous procedures to assess quality assurance objectives. Sample accuracy will be tested by comparing sample concentrations to spiked matrix concentrations and laboratory control samples. Relative standard deviations on duplicate samples will be used to determine instrumental precision. The examination of QA parameters including accuracy, precision, and sample contamination will enable us to have confidence in data and trends observed throughout the demonstration-scale study.

7. Data Reporting, Data Reduction, & Data Validation

7.1 Data Reporting Requirements

Table 7-1 details the reporting requirements (units, MDL, and MRL) for each of the analyses to be performed. All of the analyses in Table 7-1 for water samples are expressed in mg/L or µg/L. Data reporting requirements for residuals analyses are also listed in Table 7-1.

The total Cr concentration for each sample will be reported as the average concentration with a standard deviation (based on three replicate analyses for each sample), in units of µg/L. Cr(VI) analysis by IC is a single measurement, so the standard deviation will be calculated from split samples rather than replicate analyses of the same sample.

7.2 Field and Data Deliverables

Field data to be collected includes pH, temperature, conductivity, turbidity, alkalinity, sulfate, phosphate, and silicate. Measurements will be recorded in a field log book and entered into Microsoft Excel.

Laboratory data for Cr(VI), total Cr, nitrate, and nitrosamines will also be reported to McGuire Malcolm Pirnie by the contract laboratories. The data will be stored in the project data management system as well as at the contract laboratory. Routine analytical QC data will also be stored electronically.

McGuire Malcolm Pirnie will gather all data and prepare summary tables and graphics to characterize the findings from the demonstration-scale study. Quality assurance procedures (refer to Section 7.4) will be used to validate and confirm the data.

7.3 Data Reduction Procedures

In the laboratory and in the field, analytical measurements will be converted to concentrations by running appropriate calibration curves (on the same instrument) and interpolating the sample values. Data from the ICP-MS and IC at the contract laboratory will be output to a printer. Within the data file, sample concentrations will be separated from QC sample results, and each will be put into an electronic file for reporting purposes.

Sample and QC concentrations received from the labs will be entered manually into a Microsoft Excel spreadsheet, from which efficiencies of Cr(VI) removal can be calculated. Replicate measurements will be compared and averaged to generate standard deviation statistics to reflect sampling and analytical error.

Table 6.
Measurement Data Reporting

Sample Analysis	Analytical Method	Units	Method Detection Level (MDL)	Method Reporting Level (MRL)*
Cr(VI)	EPA 218.6	µg/L	0.026	0.2
Total Cr	EPA 200.8 (ICP-MS)	µg/L	0.143	1
Nitrate	300.0 (IC)	mg/L	0.2	0.2
Sulfate	Hach 8051 (Colorimetric)	mg/L	5	5
Phosphate	Hach 8048 (Colorimetric)	mg/L	0.5	0.5
Silicate	Hach 8185 (Colorimetric)	mg/L	1	1
Alkalinity	Hach 8203 (Titration)	mg/L (as $CaCO_3$)	N/A	N/A
Conductivity	SM 2510B (Conductance)	µmho/cm	N/A	N/A
pH	SM 4500H+ B (Electrometric)	pH units	N/A	N/A
Temperature	SM 2550 (Thermometric)	ºC	N/A	N/A
Turbidity	SM 2130 B	NTU	0.02	0.02
Nitrosamines	EPA 521	ng/L	2	2
Residuals: TCLP	EPA 1311 (TCLP) EPA 200.8 (ICP-MS): Total Cr	mg/L	N/A	N/A
Residuals: STLC	CA WET Test (Title 22:§66261.126) Cr(VI) compounds Cr and/or Cr(III) compounds	mg/L mg/L	N/A N/A	N/A N/A
Residuals: TTLC	CA WET Test (Title 22:§66261.126) Cr(VI) compounds Cr and/or Cr(III) compounds	mg/kg (wet wt) mg/kg (wet wt)	N/A N/A	N/A N/A
Residuals: Uranium	ASTM 5174-91 (KPA method)	mg/kg (wet wt)	N/A	N/A

* MRL as defined in this table is the laboratory or field method PQL.

7.4 Data Validation Procedures

Depending on the analytical measurement, the types of QA/QC samples may include the following:

- Laboratory matrix spike samples that are used to assess the accuracy of laboratory procedures in at least 5% of the samples;
- Laboratory blank samples that are used to determine the PQL of the analytical procedure and to detect potential problems in the sample collection and preservation methods;
- Laboratory control samples that are subjected to multiple analyses to determine laboratory precision in at least 5% of the samples; and
- Field-collected duplicate samples to assess how representative samples are and the degree to which the samples reflect actual field conditions.

Operational data will be routinely collected onsite using standardized log sheets. Log sheets will contain information about operational conditions and water quality parameters and will be transferred into Microsoft Excel each week.

At the contract laboratory, a person other than the analyst will compare ten percent of all spreadsheet data to original hard-copy printouts. The analyst will ensure that all QC criteria are met, and the analysis manager will review all QC data monthly. Truesdail Laboratories also conducts an annual performance evaluation for all methods.

Field data entered manually will be validated internally by qualified McGuire Malcolm Pirnie personnel. Calculations performed in a spreadsheet will be carefully examined to ensure the accuracy of the formulas, data input, and results. After data have been validated and reduced, the QA Manager will review the files to ensure that the data are not suspicious. Any quality control data that do not meet the acceptance criteria, either in the field or in the laboratory, will be flagged and either reported with an explanatory note or excluded from the data reduction.

7.5 Data Storage Requirements

Project data will be generated and duplicated in several locations. Operational data and water quality data generated on site will be recorded on standardized log sheets. Water quality samples collected will be identified on standardized log sheets to ensure correct identification of sample results returned from off-site laboratories. The standardized log sheets for water quality samples will include: sample identification number, name of person who collected the sample, date, time, sample volume, and sample preservation method.

Electronic and hard copies of data will be sent to McGuire Malcolm Pirnie by the contract labs. Project data on standardized log sheets and off-site laboratory reports will be entered into and will reside in the main project data files. The project data files will serve many purposes, including validation of data entry, central storage of all project data, and routine reduction and reporting of operational and water quality data. In addition, Truesdail will keep the electronic data for at least 5 years.

The main project data files will be hosted on the data server at the McGuire Malcolm Pirnie-Santa Monica office. This data server is routinely backed up on daily, weekly, and monthly schedules, with weekly off-site backups. The server is protected with hardware firewall, and the data files are protected from viruses with reputable anti-virus software.

7.6 Final Project Documentation

The product documents from this project include an operations and maintenance manual and a final report.

8. Assessments

8.1 Audit Schedule

Internal audits are not scheduled for this project. However, the Quality Assurance managers at McGuire Malcolm Pirnie and the contract laboratory will review all QC data monthly to ensure that QC objectives are being met.

8.2 Corrective Action Procedures

The need for corrective action may be identified by assessing standard QC procedures. The essential steps in the corrective action system are detailed below.

Identification and definition of the problem
Corrective action will be required if analytical data are determined to be out-of-control. An analytical batch will be considered to be out-of-control when replicate samples, matrix spiked samples, calibration blanks, the standard curve, calibration check samples, or external reference samples fail to meet the QC criteria.

Investigation and determination of the cause of the problem
When an analysis is determined to be out-of-control, steps will be taken to determine the cause. First, it must be determined whether a calculation error has occurred. Then the instrument used in the analysis will be checked against performance specifications. The indicators of being out-of-control will be a clue to the problem. For example, wrong readings of laboratory control samples may indicate the instrument is not properly set-up or standards are bad; if replicates are not within precision limits, contamination may be a problem; if spike recovery is outside acceptable limits, matrix interferences may be expected; or if blanks are too high, contamination has probably occurred.

Determination of a corrective action to eliminate the problem

- Calibration check samples
  If results of the daily calibration sample check are out-of-control, as indicated by flagged values, causes may include instrument malfunction or improper set-up, bad standards, or operator error. The first step will be to check instrument performance. The instrument will be restarted. If this does not bring the system back into control, then standards will be re-made and analyzed. If the problem is operator error, the analyst will be re-trained and put through a rigorous QC check before he/she can continue with the sample analyses.

- Accuracy

  When a result is out-of-control as indicated by flagged values for spiked samples, the following steps will be taken to determine the cause. First, calculations will be checked. Then the instrument will be checked for proper set-up. The sample(s) will be reanalyzed. If these steps do not bring the analysis under control, then the spiked sample will be prepared again and analyzed. It may be necessary at this time to prepare fresh standards. If all of the above procedures do not bring the analysis into control, analysis will be performed by standard addition. All samples analyzed in the batch containing the out-of-control sample will be re-analyzed by the procedure used to bring the analysis back into control.

- Precision

  When a result for duplicate analysis is out-of-control, as indicated by flagged values, steps will be taken to determine the cause. First calculations will be checked. Then instrument performance will be evaluated. The samples will be reanalyzed. If these procedures do not bring the samples back into control, then all samples in the analytical batch will be prepared again and analyzed.

- Blank contamination

  If the reagent blank shows contamination (i.e. concentrations greater than the MRL) during analysis, materials and reagents used to make that blank will be replaced before additional samples are prepared. Also glassware and sample preparation will be re-evaluated to ensure that contamination is not occurring during these processes. Standards prepared with contaminated reagents will be discarded, and samples will be reprocessed.

- External reference sample analysis

  The inability of the laboratory to accurately analyze an external reference sample is indicative of analytical problems related to sample preparation procedures, instrument operation, or calibration. If the calibration check sample within the same analytical batch analysis is also out-of-control, a problem with the instrument or operator performance is indicated. Corrective action will be taken as described earlier. If the calibration check sample is within the control limits, the problem may be with the sample preparation procedure. At this point the calibration standards will be prepared again and analyzed. If this fails to bring the measurement back into control, the procedure will be reevaluated to determine if there are points within the procedure likely to be the source of contamination or loss of the analyte. All samples analyzed in the batch with the out-of-control sample will be re-analyzed by the procedure used to bring the check samples back into control.

8.3 Implementation of Corrective Action

The analyst at the contract laboratories will have the authority to implement corrective action (described in Section 8.2 Investigation and Determination of the Cause of the Problem) during an analysis run if quality control samples are determined to be out-of-control. The Quality Assurance managers and Project Managers at McGuire Malcolm Pirnie and the contract laboratory will review QC logs monthly and will consult with the analyst if further corrective action is identified as necessary. Following any corrective action, the primary investigators will ensure that the analysis is truly back in control, as indicated by consistently meeting quality control criteria.

9. References

APHA, AWWA, and WEF. 1995. Standard methods for the examination of water and wastewater, 19th ed. American Public Health Association, Washington, DC, 1995.

Brandhuber, P.; Frey, M.; McGuire, M.J.; Chao, P.; Seidel, C.; Amy, G.; Yoon, J.; McNeill, L.; Banerjee, K. 2004. Treatment Options for Low-Level Hexavalent Chromium Removal Tested at Bench Scale. Denver, Colo.: AwwaRF.

California DHS, 2001, Chromium-6 (Hexavalent Chromium) in Drinking Water: Sampling and Analysis. http://www.dhs.ca.gov/ps/ddwem/chemicals/Chromium6/Cr+6labs.htm# Recommendations for Sample Collection

EPA. 1993. Method 300: Determination of Inorganic Anions in Drinking Water by Ion Chromatography. 600/R-93-100.

EPA. 1994. Method 200.8: Determination of Trace Elements in Waters and Wastes by Inductively Coupled Plasma – Mass Spectrometry. EPA-600/R-94/111.

EPA. 1996. Method 1636: Determination of Hexavalent Chromium by Ion Chromatography. EPA-821/R-96/003.

EPA. 1997. Manual for the Certification of Laboratories Analyzing Drinking Water: Criteria and Procedures Quality Assurance. EPA-815/B-97/001.

Lee, G.; Hering, J.G. 2003. Removal of chromium(VI) from drinking water by redox-assisted coagulation with iron(II). *J. Wat. Supply: Res. & Technol. – Aqua, 52*, 319-332.

McGuire, M.J.; Blute, N.K.; Seidel, C.; Qin, G.; Fong, L. 2006. Pilot-Scale Studies of Hexavalent Chromium Removal from Drinking Water. *Jour. AWWA.* 98(2):134-143.

McGuire Environmental Consultants, Inc. (MEC) 2005. The Treatment of Hexavalent Chromium (Cr(VI)) in the City of Glendale Groundwater Supply: Phase II Demonstration of Pilot-Scale Treatment Technologies. Final report submitted to the City of Glendale. Glendale, CA.

National Toxicology Program (NTP), 2007. Technical Report on the Toxicology and Carcinogenesis Studies of Sodium Dichromate Dihydrate in F344/N Rats and B6C3F1 Mice. Draft.

Qin, G.; McGuire, M.J.; Blute, N.K.; Seidel, C.J.; Fong, L. 2005. Hexavalent Chromium Removal by Reduction with Ferrous Sulfate, Coagulation, and Filtration: A Pilot-Scale Study. *Environ. Sci. Technol.* 39(16):6321-6327.

Sengupta, A.; Sarkar, S. 2007. Trace Cr(VI) Removal by Weak Base Duolite A-7 and SIR-700 from Groundwater in Glendale, CA: Underlying Mechanism. *Report to the City of Glendale, CA.*

Chain of Custody: Page 1 of 1

Date:

Sent from:

McGuire/Malcolm Pirnie, Inc.
1821 Wilshire Blvd. Suite 302
Santa Monica, CA 90403
310-829-1441

Received by:

Project Name: ______________________

Sampler Names: ______________________

Contact Phone: ______________________

Special Instructions: ______________________

	Date	Time	Sample ID	Qty of bottles	Analyses Required	Comments
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
16						
17						
18						
19						
20						

	Name	Date			Name	Date
Relinquished by:				Received by:		
Relinquished by:				Received by:		
Relinquished by:				Received by:		

Appendix C – Pump Curve Evaluation

MALCOLM PIRNIE

Technical Memorandum

Date: July 2, 2007

To: Don Froelich and Peter Kavounas

From: Michael McGuire, Jack Bebee, and Nicole Blute

Subject: Pump Curve Evaluation and Decision

Pump Curve Evaluation

As part of the preliminary design of the GS-3 WBA treatment system, we evaluated the hydraulics of the current pump in GS-3 and the system losses expected from the new facilities to determine the projected pumping capacity. Figure 1 shows that current GS-3 pump curve from a test performed in June 2007 by CDM (dark blue line). To bracket the range, two roughness coefficients (C=130 and 100) and two main pressures (45 and 55 psi) were used in the pump curve evaluation. According to the figure, the GS-3 pump currently has an estimated operating range of between 550 to 600 gpm at 100% pump speed.

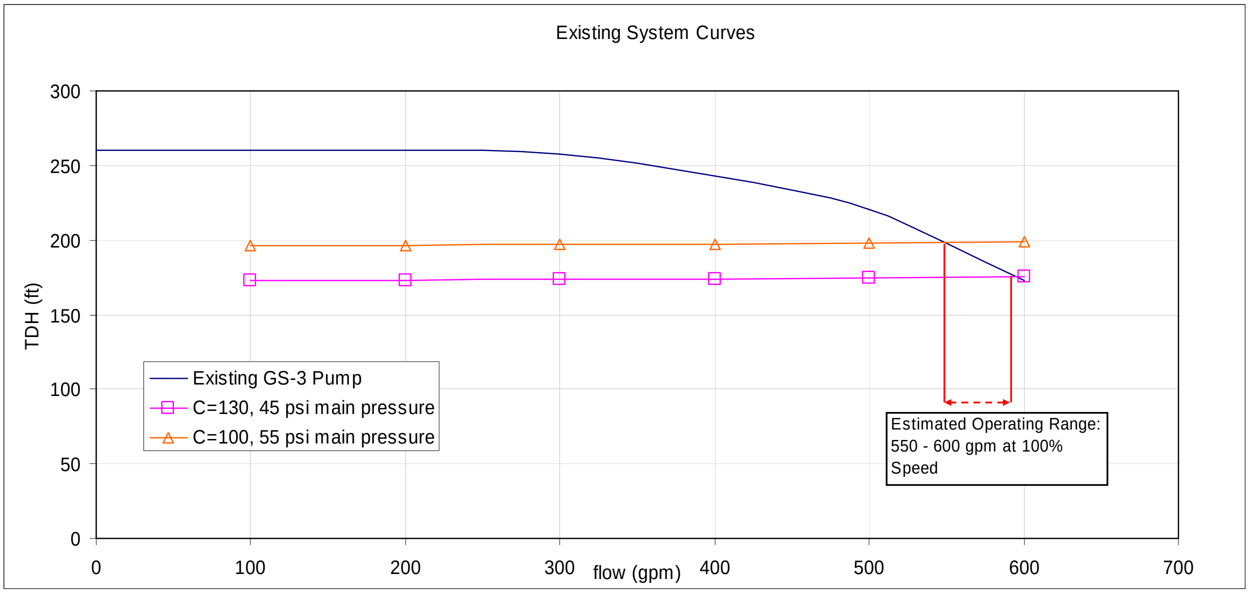


Figure 1. Existing System Curves for the GS-3 Pump without the WBA Facility

The addition of a WBA treatment system between the well and the main will introduce pressure losses, due to the bag filters, ion exchange resin beds, and additional piping. For example, the bag filters are estimated to have a 2 psi drop across the filter housing when the filters are clean, and up to a 10 psi drop for dirty filters (i.e., the point at which filter change-out is recommended by the vendor). Figure 2 shows the intersection of the actual GS-3 pump curve (dark blue line) and manufacturer provided pump curve (light blue line) with the upper and lower range for the system curves. The upper range is based on clean bag filters (2 psi differential) and the estimated best-case main pressure (45 psi) and C factor (130). The lower range is based on dirty bag filters (10 psi differential) and the estimated worst case main pressure (55 psi) and C factor (100). The estimated operating range for the pump is between 250 and 480 gpm at 100% pump speed.

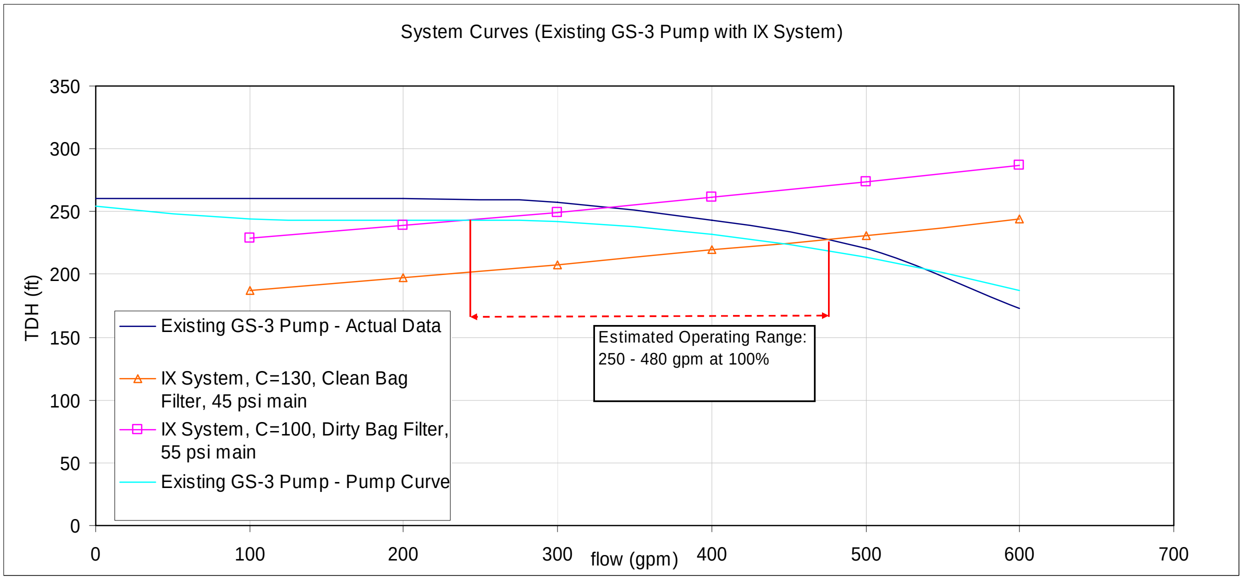


Figure 2. Predicted System Curves for the GS-3 Pump with the WBA Facility

Two possibilities exist to achieve the desired 425 gpm design capacity for the WBA treatment system. First, the existing GS-3 pump could be used and the bag filters replaced on more frequently than when 10 psi pressure loss occurs. Second, the GS-3 pump could be replaced with one capable of achieving a higher operating flow.

Glendale has an unused high head pump purchased with the GAC vessels, so the hydraulics were evaluated to determine if option is possible using the existing equipment. Figure 3 shows the pump curves for 100%, 80%, and 50% pump speeds, along with the system curves for a range of ion exchange system conditions. The analysis indicated that the high head pump could achieve an operating capacity of approximately 410 to 475 gpm at 80% speed. However, operation of the pump at 80% speed would not optimize the capital costs associated with installing a larger 75 HP pump at the facility, and the upper end of the flow operating range would not be improved over the existing GS-3 pump. Based on this evaluation, purchasing and installing a new pump optimized for the system would likely be preferable compared with using the existing high head pump.

Other issues that may cause complications with well pump replacement include clearance in the GS-3 vault and the potential costs of a new pump and system upgrades to accommodate a larger motor. Exchanging the existing pump with a larger horsepower motor may not be simple due to space constraints. Significant costs may also arise if a new pump is purchased and electrical modifications are necessary for the larger motor.

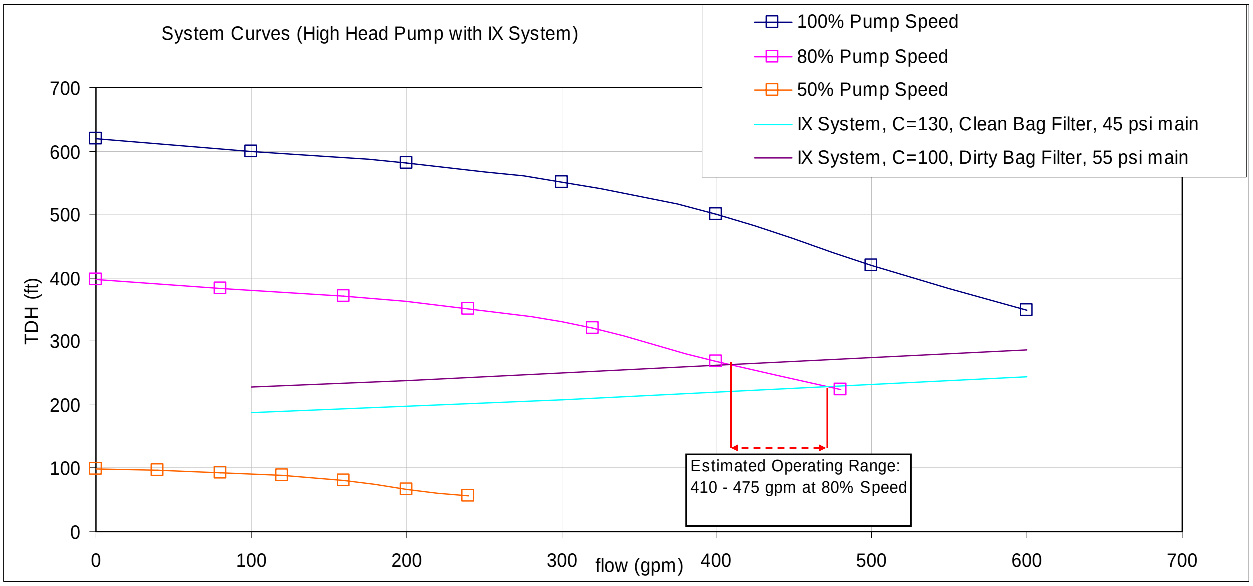


Figure 3. High Head Pump Predicted System Curves with the WBA Facility

Recommendations

Based on this hydraulic analysis, we recommend that Glendale proceed with the preliminary design using the existing GS-3 pump. It should be noted that pressure losses in the WBA facility will limit the flow compared with the current possible flow capacity of the existing GS-3 pump. However, flow limitations might be overcome during the demonstration-scale study by replacing bag filters on a more frequent basis.

Operation of the demonstration-scale study using the existing pump will also provide useful hydraulic information on head losses through the WBA treatment facility including the rate of development of pressure loss through the bag filters. If Glendale decides that the flow is not sufficient with the existing pump, this information will be useful to optimize selection of a more optimal pump based on the actual operating data from the system.

Appendix D – Corrosivity Evaluation of the Treated WBA Water

MALCOLM PIRNIE

Technical Memorandum

Date: September 24, 2007

To: Don Froelich

From: Danny Qin, Nicole Blute, and Michael McGuire

Subject: Corrosivity of the proposed WBA resin treated effluent due to acid addition

In an effort to remove hexavalent chromium (Cr(VI)) from its contaminated groundwater supplies, the City of Glendale is proposing to test two Cr(VI) treatment processes at demonstration scale: weak-base anion exchange (WBA) and reduction-coagulation-filtration (RCF). The RCF process was recommended by an Expert Panel that reviewed the pilot testing results in the Phase II Pilot Study[1] and the Phase III Bridge Project[2]. The WBA process is being carried forward to demonstration scale as a result of a decision by Glendale and additional testing at Lehigh University recommended by the Expert Panel. The two demonstration-scale systems (with capacity of 425 gpm for WBA and either 567 or 1,134 gpm for RCF) will be constructed to treat Cr(VI) contaminated water from high-Cr wells of the Glendale Operable Unit. Treated water (i.e., chromium levels less than 5 μg/L) will be used for human consumption after blending with lower chromium wells at the Glendale Water Treatment Plant.

Final design of the WBA system is currently in progress, while pre-design of the RCF system is scheduled in several months. This memorandum is intended to address an outstanding water quality issue for the WBA process: the corrosion potential of the WBA treatment process effluent, which may be of concern due to the pH reduction necessary for WBA resin use. The potential impact of integrating the WBA treated water (with lower pH) into the existing Glendale SOU transmission system is assessed in this technical memo.

Proposed WBA process

Cr(VI) removal using WBA resin is a novel treatment technology application for drinking water. During the Phase II Pilot Study and Phase III Bridge Project, WBA resin (Duolite A7 resin manufactured by Rohm & Haas; since renamed PWA7) consistently demonstrated an exceptional Cr(VI) removal capacity. Another WBA resin, ResinTech SIR-700, showed a high capacity but mixed results in consistently achieving the treatment goal of 5 μg/L. As determined in the Phase III Bridge Project, the mechanism

---

[1] McGuire Environmental Consultants, Inc. (MEC) 2005. The Treatment of Hexavalent Chromium (Cr(VI)) in the City of Glendale Groundwater Supply: Phase II Demonstration of Pilot-Scale Treatment Technologies. Final report submitted to the City of Glendale. Glendale, CA.

[2] McGuire, M.J., Blute, N.K., Qin, G., Kavounas, P., Froelich, D., Fong, L. 2007. Hexavalent Chromium Removal from Drinking Water Using Weak- and Strong-Base Ion Exchange and Reduction/Coagulation/Filtration. Denver, Colo.: AwwaRF.

of Cr(VI) removal and/or retention by WBA resin involves a reduction process in which Cr(VI) is reduced to Cr(III).

The WBA demonstration-scale system will be located at Glendale South Operable Unit (SOU) well site GS-3 adjacent to Goodwin Street in the City of Los Angeles. The system will consist of two ion exchange (IX) vessels operated in series (lead-lag) with upstream hydrochloric acid addition for pH depression. Figure 1 provides a process flow schematic for the treatment system. Due to its high capacity and difficulty in regeneration, the WBA will be used as a once-through, disposable media.

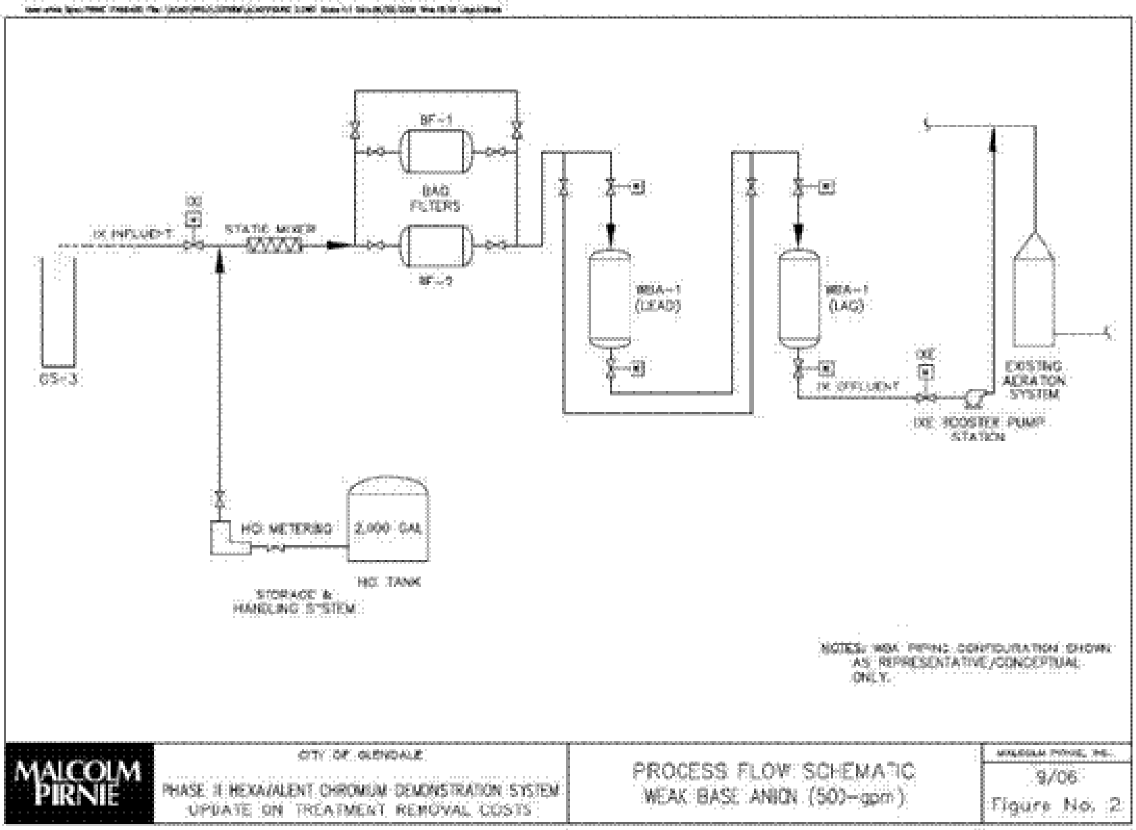


Figure 1: Process flow schematic of the WBA system

The WBA resin was found to require pH reduction for effective use; a pH of 6.0 was shown to both remove Cr(VI) to levels below the treatment goal of 5 µg/L and to maximize Cr(VI) capacity of the resin. Hydrochloric acid will be injected into the GS-3 well water upstream of the IX vessels to maintain a constant pH of 6.0. As shown in pilot testing, the pH does not change significantly as the water passes through the IX beds; consequently, the WBA treated water will have a pH of approximately 6.0. The potential for increased corrosivity of this water was therefore considered in this preliminary design phase technical memo.

Methodology

Water utility operators have relied on precipitation of calcium carbonate ($CaCO_3$) for many years to control corrosion of distribution system materials. Several indices are available to describe the potential for precipitation of $CaCO_3$ including: Langelier Saturation Index (LSI), Aggressiveness Index, Ryznar Index, Driving Force Index and Calcium Carbonate Precipitation Potential (CCPP)[3]. Among them, LSI and CCPP are the most commonly used indices by researchers and utility managers.

In this assessment, LSI and CCPP values were calculated using a model developed by Rothberg, Tamburini, and Winsor (RTW Model for Corrosion Chemistry and Water Process, Version 4.0). Water quality parameters input into the RTW Model included pH, temperature, alkalinity, total dissolved solids (TDS), calcium (Ca^{2+}), chloride (Cl^-), and sulfate (SO_4^{2-}).

Water quality data for pH, temperature, and alkalinity from all four Glendale SOU wells (GS-1, GS-2, GS-3, and GS-4) were obtained from field analysis conducted on June 11, 2007. pH and temperature were measured using a Hach SensION1® meter with a specialized sampling apparatus developed for this testing (see Figure 2 for details). The purpose of the sampling apparatus was to minimize the release of supersaturated carbon dioxide (CO_2) from the groundwater to ensure the accuracy of pH measurement. Previous testing in the Phase III Bridge Project indicated that off gassing of CO_2 led to rapid increases in the Glendale groundwater pH. In addition to pH measurements, alkalinity was determined immediately in the field using Hach Method 8203.

Ca^{2+}, Cl^-, SO_4^{2-} and TDS are monitored approximately every three years in the Glendale GS wells; historical data (up through 2007) provided by CDM were used in the RTW modeling.

---

[3] Rossum, J.R., and Merrill, D.T., "An Evaluation of the Calcium Carbonate Saturation Indexes," Jour. AWWA, 75:2, February 1983.

Figure 2: pH and temperature measurement with the specialized sampling apparatus developed to minimize CO_2 off gassing (pH probe shown in the center of the apparatus)

Results

Table 1 lists the field analysis results of pH, temperature, and alkalinity from all four GS wells. The pH values in all GS wells were quite similar – approximately 7.0 using the sampling apparatus. Unfortunately, carbon dioxide degassing was not fully eliminated during pH sampling even with the apparatus, as evidenced by the bubbles inside in the sampling line (Figure 3). The measured pH was expected to be a little higher than the actual groundwater pH due to this off gassing. In Phase III Bridge Project testing, the pH in GS-3 well was determined to be 6.8 using an in-line pH probe under pressure (i.e., without CO_2 degassing). Since all other wells showed similar pH values to the GS-3 well in this testing on June 11th, a pH of 6.8 was found to be a good estimate for all of the GS wells; this value was consequently used in the RTW Model. Field temperature data from each well were also used as the model input.

Table 1: Water quality results from GS wells on June 11, 2007

	Well ID			
Field Measurements	**GS-1**	**GS-2**	**GS-3**	**GS-4**
pH	7.01	7.02	7.05	6.97
Temperature (^oC)	21.6	22.1	22.9	23.6
Alkalinity (mg/L as $CaCO_3$)	162	156	154	141

Figure 3: Release of some supersaturated CO_2 in the sampling line

Table 2 lists the historical Ca^{2+}, Cl^-, SO_4^{2-}, TDS, and alkalinity data from the four GS wells from 1998 to 2007. Table 2 shows that water quality in all four GS wells was generally similar and did not change much over a 9 year period.

Table 2: Historical water quality data ranges for the GS wells sampled between 1998 and 2007

	Well ID			
Lab Measurements	**GS-1**	**GS-2**	**GS-3**	**GS-4**
Ca^{2+} (mg/L)	87 - 98	80 - 86	79 - 90	82 - 90
Cl^- (mg/L)	65 - 88	53 - 58	59 – 68	63 – 70
SO_4^{2-} (mg/L)	140 - 160	96 - 110	96 - 110	112 – 130
TDS (mg/L)	540 - 630	440 - 530	450 - 530	480 – 540
Alkalinity (mg/L as $CaCO_3$)	223 - 251	205 - 244	176 - 220	163 – 187

* Note: Ca^{2+}, Cl^-, SO_4^{2-}, and TDS were measured five times between 1998 and 2007.

As seen in Tables 1 and 2, alkalinity measured in the field was lower than the historical data. The reason for this difference is not clear. Consequently, two sets of LSI and CCPP values were determined using both the field data and the historical data.

Table 3 summarizes the ranges in LSI and CCPP of the RTW Model output using datasets from 1998, 1999, 2000, 2002, 2004, and 2007. Regardless of the alkalinity input in the model, all GS well water had negative LSI values between -0.22 and -0.50 and

CCPP values in the -27 to -37 mg/L $CaCO_3$ range, indicating that the water is corrosive in the existing Glendale SOU transmission system.

Table 3: Summary of RTW Model output

	Well ID			
	GS-1	GS-2	GS-3	GS-4
LSI				
Field alkalinity data[a]	-0.40 to -0.45	-0.46 to -0.48	-0.43 to -0.48	-0.46 to -0.50
Historical alkalinity data[b]	-0.22 to -0.31	-0.27 to -0.36	-0.28 to -0.42	-0.35 to -0.43
CCPP (mg/L as $CaCO_3$)				
Field alkalinity data[a]	-33 to -37	-36 to -37	-34 to -37	-33 to -35
Historical alkalinity data[b]	-27 to -34	-31 to -36	-30 to -37	-32 to -35

Note:

a. Calculated with field alkalinity data as shown in Table 1
b. Calculated with historical alkalinity data as shown in Table 2

According to RTW modeling, the planned change in pH for using the WBA resins (from the ambient groundwater pH of 6.8 to pH 6.0) will reduce the LSI Index and CCPP corrosion indices as shown in Table 4. The LSI and CCPP values of WBA treated water were calculated as -1.51 and -162 mg/L, respectively, indicating the water would be more aggressive than the raw GS-3 water (LSI of -0.43 and CCPP of -34 mg/L).

Table 4: Summary of water quality and RTW Model output data for raw GS-3 water and the WBA treated water

	Raw GS-3 water	WBA treated GS-3 water (pH 6.0)
Water Characteristics		
pH	6.8	6.0
Temperature (ºC)	22.9	22.9
Alkalinity (mg/L as $CaCO_3$)	154[a]	82[b]
Ca^{2+} (mg/L)	89[c]	89[d]
Cl^- (mg/L)	68[c]	128[e]
SO_4^{2-} (mg/L)	110[c]	110[d]
TDS (mg/L)	466[c]	526[e]
Calculated Values		
LSI	-0.43	-1.51
CCPP (mg/L)	-34	-162

Notes:

a. Field alkalinity data as shown in Table 1
b. Average alkalinity of WBA resin (PWA7) treated effluent as measured during Phase III Bridge Project
c. Data from 5/16/2007
d. Assumed to be equivalent to raw GS-3 water
e. HCl addition is expected to increase the Cl^- and TDS concentrations in WBA treated water by approximately 60 mg/L

Under normal operation (i.e., all GS wells operating), the WBA treated water will first blended with GS-4 well water in the transmission pipeline. Assuming both GS-3 and GS-4 wells were running at design capacity (425 gpm), LSI and CCPP values were determined using the RTW Model (Table 5).

Table 5: Summary of water quality and RTW Model output data of blending the WBA treated water (pH 6.0) and raw GS-4 well water

	WBA treated GS-3 water (pH 6.0)	**Raw GS-4 water**
Water Characteristics		
pH	6.0	6.8
Temperature (ºC)	22.9	23.6
Alkalinity (mg/L as $CaCO_3$)	82	141[a]
Ca^{2+} (mg/L)	89	90[b]
Cl^- (mg/L)	128	70[b]
SO_4^{2-} (mg/L)	110	130[b]
TDS (mg/L)	526	510[b]
Design flow rate (gpm)	425	425
Calculated Values	**Blended water**	
pH	6.33	
Temperature (ºC)	23.3	
Alkalinity (mg/L as $CaCO_3$)	112	
Ca^{2+} (mg/L)	90	
Cl^- (mg/L)	99	
SO_4^{2-} (mg/L)	120	
TDS (mg/L)	520	
LSI	**-1.04**	
CCPP (mg/L)	**-101**	

Note:

a. Field alkalinity data as shown in Table 1
b. Data from 5/16/2007

Summary and Recommendations

The results of this investigation indicated that the well water was already corrosive with respect to calcium carbonate under ambient groundwater conditions. The addition of WBA treatment, including pH adjustment to 6.0, will increase the magnitude of the negative LSI and CCPP values. However, the impact of this change (i.e., from -0.44 to -1.05 for LI and -34 to -101 for CCPP) on corrosivity of the cement-mortar lined piping is uncertain since the water is corrosive to begin with. Visual inspection of the pipeline condition before and after the demonstration-scale study is strongly recommended to evaluate the impact of WBA treated effluent on the pipeline and the necessity of pH adjustment after treatment.